Marco Island, Florida

Water Quality

Hypoxia Investigation

8.25.21

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Waterways Advisory Committee
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Summary

- *Dissolved Oxygen (DO) deficiency* has been observed within the Rookery Bay estuary, centered on Marco Island - threat to aquatic life
- *DO "pit" and pH "dome" have formed* over Marco (only) since 2020
- *Marco "flirting" with hypoxia* - DO and pH trends variable & negative
- *Hypothesis*: Nutrients feed Harmful Algal Blooms (HAB) which deplete oxygen leading to seagrass die-off and manatee mortality
- *Reuse water TN and TP* appear to be nutrient "food" sources for HAB which depletes DO and spikes pH
- Marco impaired for TN - If current trends persist, anticipate DO impairment in 2023
- Basins 1,2 and 4 are impaired for DO; Swallow location (Cape Marco Point) is now hypoxic
- Basin 5 is healthy; Basin 5 gets NO reuse water

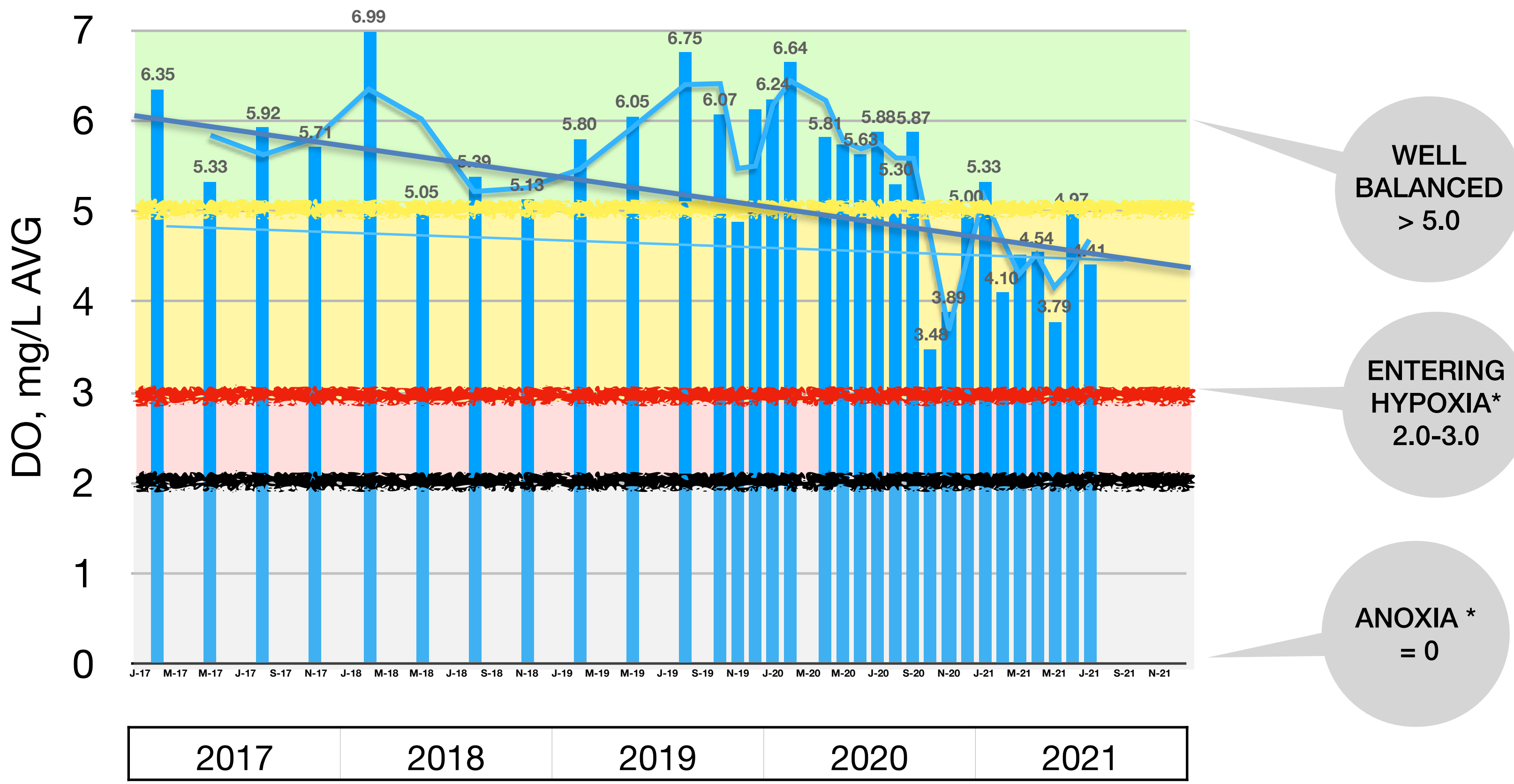
Marco Island waterways are impaired for dissolved oxygen

Background

- Water quality on Marco has been a concern for many years - Highlights:
  - 10/9/13: Nancie Ritchie - “Our Canals Need Care & Conservation”
  - 9/14/14: Phares Hindl - Memo on need for Waterway Management Plan
  - 01/4/17: Dr. W.D. Trotter - White paper recommends monthly water testing
  - Circa 2018: Position Paper by Sam Young
  - 4/29/19: City Council Convenes 2nd Water Quality Workshop
  - 8/22/19: FDEP issues TN impairment letter
- Much has been done:
  - 2006-2012 STRP - Septic Tank Replacement Program
  - 2016 Fertilizer Ordinance
  - 2019 50% Reduction of TN in reuse water by WWTP
- These efforts have not resolved the issue

Water quality on Marco Island continues to deteriorate

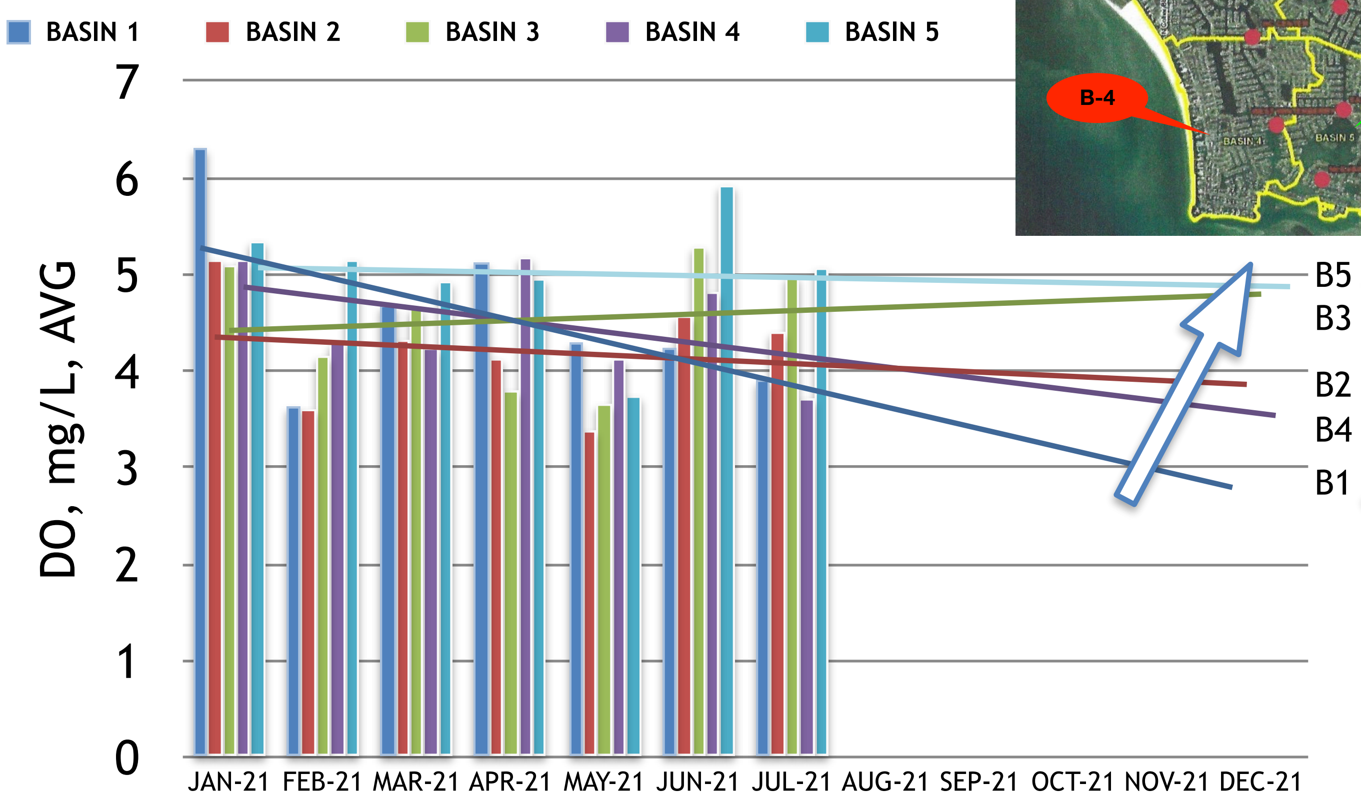
DO Trend - MARCO 2017-2021

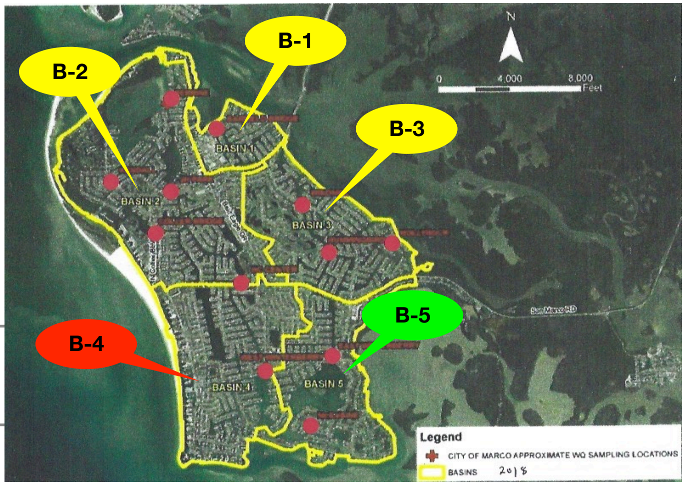


* Source: Assessment of Hypoxia in U.S. Coastal Waters, 2010
* Source: City of Marco Island Water Quality Sampling Reports

Marco is “flirting” with hypoxia
If trend continues - anticipate Marco DO impairment in 2023

DO - by Basin 2021





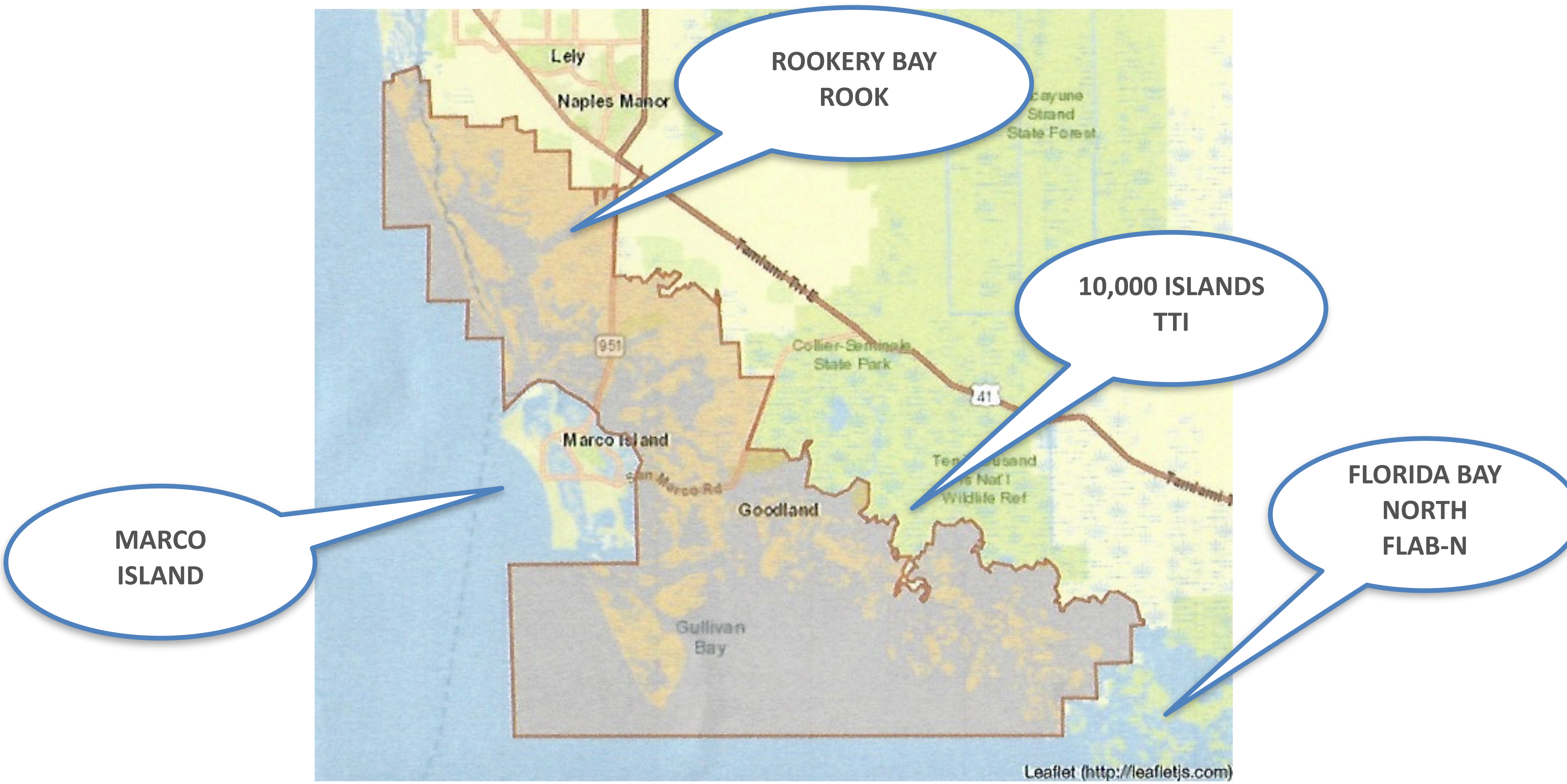
B5 GETS ZERO REUSE

B1 HAS WWTP

HOW MUCH REUSE FLOWS INTO EACH BASIN?

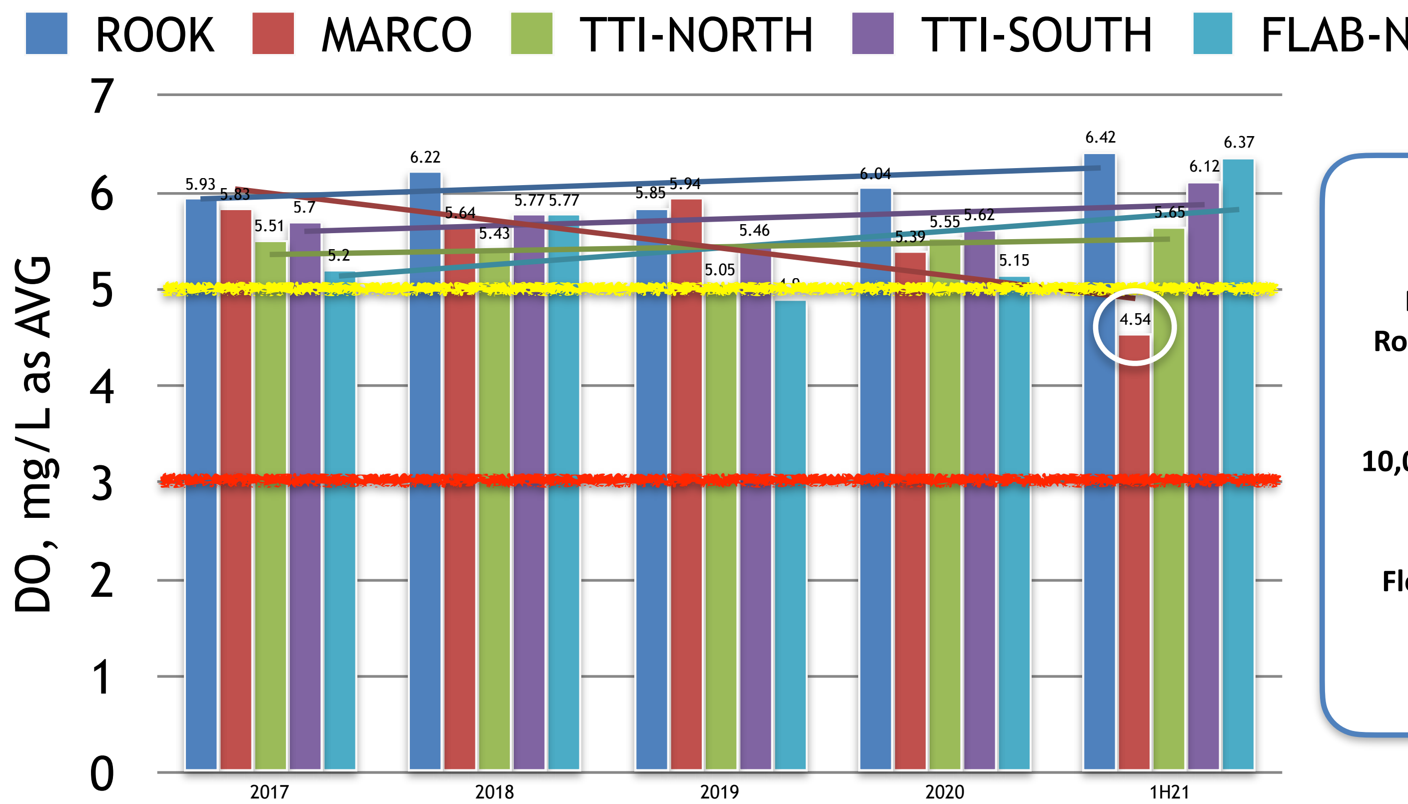
DO trends are variable & negative across all basins
Basin 1 fastest downward trend; Basin 4 entering hypoxia

Rookery Bay Estuary



Marco is in the middle of an estuarine eco-system

Estuary Dissolved Oxygen (DO)



ROOK =
Rookery Bay

TTI =
10,000 Islands

FLAB =
Florida Bay

Source: Marco (2018-2021) City of Marco Island Water Quality Sampling Reports
Source: Marco (2017) WIN
Source: Rook & TTI - DBHYDRO

Estuary DO improving - Marco DO declining!

Estuary Dissolved Oxygen - 1H21

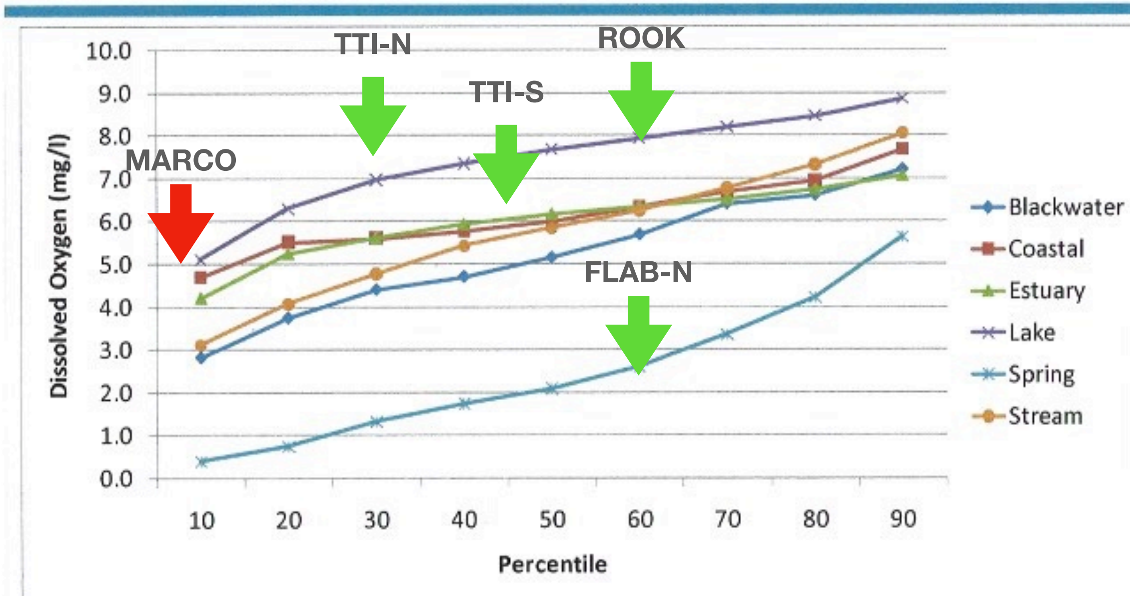
Oxygen, Dissolved (DO)
Milligrams per liter (mg/L)

Dissolved oxygen (DO), which is the amount of free (not chemically combined) oxygen dissolved in water or wastewater, is an essential component in the aquatic environment. The most important and commonly used measurement of water quality, it indicates a waterbody's state of health—that is, the ability to support desirable aquatic life. A vast array of aquatic organisms depends on the presence of adequate levels of DO for survival. DO concentrations in a waterbody vary seasonally.[3]

Generally, waters with DO concentrations of 5.0 mg/L or higher can support a well-balanced, healthy biological community. However, some species cannot tolerate even slight depletion, and when DO concentrations fall below natural levels, the result is often a complete alteration of the community structure. The consequences of these changes often have both ecological and economic significance.

Some systems with "good" water quality exhibit naturally low DO concentrations (e.g., swamps). Also, daytime and mean measurements of DO have limited significance, since nocturnal respiration and other episodic instances of low oxygen can significantly affect aquatic life. Diurnal DO studies are important to understanding the oxygen cycle in a particular waterbody.

Source: NALMS



Percentile	Blackwater	Coastal	Estuary	Lake	Spring	Stream
10	2.8	4.7	4.2	5.1	0.4	3.1
20	3.7	5.5	5.2	6.3	0.7	4.1
30	4.4	5.6	5.6	7.0	1.3	4.8
40	4.7	5.8	5.9	7.4	1.7	5.4
50	5.1	6.0	6.2	7.7	2.1	5.8
60	5.7	6.3	6.4	7.9	2.6	6.2
70	6.4	6.7	6.5	8.2	3.3	6.8
80	6.6	6.9	6.7	8.4	4.2	7.3
90	7.2	7.7	7.1	8.9	5.6	8.0
# of waterbodies	56	92	448	833	100	1394

Marco DO lower than 95% of Florida estuaries

Marco DO Measurements 2017

< 3 mg/L

< 5 mg/L

MO-YR	BARF	OLDE	B-1	JHPA	KEND	COLL	HCCE	B-2	HOLL	HUMM	WIND	B-3	LAND	SWAL	WWIN	B-4	EWIN	MCIL	B-5	MARCO
Jan-17																				
Feb-17	6.82		6.82	6.51	5.82	6.12	6.89	6.34	6.08	6.25	6.10	6.14			6.47	6.47	6.44		6.44	6.35
Mar-17																				
Apr-17																				
May-17	5.44		5.44	5.48	5.36	5.07	4.55	5.12	5.26	5.53	4.75	5.18			6.03	6.03	5.79		5.79	5.33
Jun-17																				
Jul-17																				
Aug-17	5.75		5.75	5.83	5.87	6.22	6.16	6.02	5.67	6.24	5.40	5.77			6.11	6.11	5.97		5.97	5.92
Sep-17																				
Oct-17																				
Nov-17	6.07		6.07	5.78	5.52	5.87	5.29	5.62	5.61		6.16	5.89			5.47	5.47	5.62		5.62	5.71
Dec-17																				
AVG	6.02		6.02	5.90	5.64	5.82	5.72	5.77	5.66	6.01	5.60	5.74			6.02	6.02	5.96		5.96	5.83

2 “impaired” readings; 4% of all observations

Marco DO Measurements 2018

< 3 mg/L

< 5 mg/L

MO-YR	BARF	OLDE	B-1	JHPA	KEND	COLL	HCCE	B-2	HOLL	HUMM	WIND	B-3	LAND	SWAL	WWIN	B-4	EWIN	MCIL	B-5	MARCO
Jan-18																				
Feb-18	6.88		6.88	6.94	7.52	7.37	7.44	7.32	5.87		6.69	6.28			7.05	7.05	7.30	6.83	7.07	6.99
Mar-18																				
Apr-18																				
May-18	5.16		5.16	4.86	4.56	4.87	5.51	4.95	3.97	4.54	4.72	4.41			6.73	6.73	5.20	5.45	5.33	5.05
Jun-18																				
Jul-18																				
Aug-18	6.67		6.67	5.13	4.98	4.64	5.03	4.95	4.69	4.89	5.81	5.13			5.92	5.92	5.80	5.74	5.77	5.39
Sep-18																				
Oct-18																				
Nov-18	5.65		5.65	4.71	5.00	5.73	5.86	5.33	4.20	4.88	5.29	4.79			5.30	5.30	4.73	5.09	4.91	5.13
Dec-18																				
AVG	6.09		6.09	5.41	5.52	5.65	5.96	5.63	4.68	4.77	5.63	5.15			6.25	6.25	5.76		5.77	5.64

13 “impaired” readings; 24% of all observations

Marco DO Measurements 2019

< 3 mg/L   < 5 mg/L

MO-YR	BARF	OLDE	B-1	JHPA	KEND	COLL	HCCE	B-2	HOLL	HUMM	WIND	B-3	LAND	SWAL	WWIN	B-4	EWIN	MCIL	B-5	MARCO
Jan-19																				
Feb-19	6.23		6.23	5.50	5.15	5.77	6.58	5.75	5.08	6.22	5.97	5.76			5.78	5.78	5.50	5.98	5.74	5.80
Mar-19																				
Apr-19																				
May-19	6.09		6.09	5.70	5.48	7.04	6.18	6.10	5.45	6.37	5.60	5.81			6.44	6.44	6.12	6.06	6.09	6.05
Jun-19																				
Jul-19																				
Aug-19	6.09		6.09	7.32	6.72	9.23	10.36	8.41	4.97	5.55	4.74	5.09			6.83	6.83	6.13	6.28	6.21	6.75
Sep-19																				
Oct-19	6.64	4.73	5.69	6.05	5.14	6.18	7.94	6.33	4.34	6.79	5.57	5.57	5.03	7.52	5.69	6.08	6.68	6.70	6.69	6.07
Nov-19	6.05	5.12	5.59	4.58	4.19	4.25	5.67	4.67	4.90	4.30	5.94	5.05	4.12	3.80	4.74	4.22	5.43	5.29	5.36	4.88
Dec-19	6.53	6.92	6.73	5.53	4.88	5.92	6.73	5.77	5.16	5.35	6.96	5.82	6.89	6.33	6.63	6.62	5.85	5.93	5.89	6.12
AVG	6.27	5.59	6.07	5.78	5.26	6.40	7.24	6.17	4.98	5.76	5.80	5.51	5.35	5.88	6.02	5.99	5.95	6.04	6.00	5.94

13 “impaired” readings; 17% of all observations

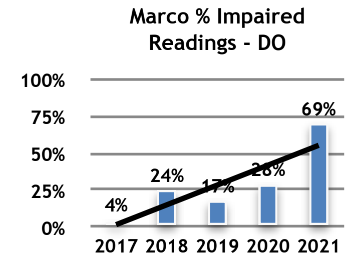
Marco DO Measurements 2020

< 3 mg/L (red) | < 5 mg/L (yellow)

MO-YR	BARF	OLDE	B-1	JHPA	KEND	COLL	HCCE	B-2	HOLL	HUMM	WIND	B-3	LAND	SWAL	WWIN	B-4	EWIN	MCIL	B-5	MARCO
Jan-20	6.30	6.13	6.22	6.26	6.26	6.71	6.26	6.37	5.36	6.33	6.27	5.99	6.93	5.52	6.22	6.22	6.79	6.04	6.42	6.24
Feb-20	6.57	7.30	6.94	6.52	6.63	7.59	6.64	6.85	5.32	6.77	6.52	6.20	7.72	5.42	6.38	6.51	6.37	7.20	6.79	6.64
Mar-20																				
Apr-20	6.43	5.50	5.97	5.23	5.39	4.52	4.81	4.99	5.73	5.37	5.34	5.48	6.42	6.58	5.55	6.18	6.05	5.55	5.80	5.61
May-20	6.17	6.13	6.15	6.13	5.55	5.27	5.50	5.61	5.42	5.94	5.79	5.72	5.22	5.52	5.78	5.51	5.76	6.25	6.01	5.75
Jun-20	5.81	5.08	5.45	5.27	4.88	5.26	5.29	5.18	6.03	6.87	7.47	6.79	6.66	1.65	6.39	4.90	6.23	5.86	6.05	5.63
Jul-20	5.24	4.79	5.02	5.51	5.13	5.65	6.41	5.68	4.90	6.17	5.64	5.57	7.59	6.20	7.06	6.95	6.16	5.92	6.04	5.88
Aug-20	5.92	5.20	5.56	5.09	4.99	4.26	4.33	4.67	4.99	4.71	5.32	5.01	6.52	6.31	5.33	6.05	5.48	5.75	5.62	5.30
Sep-20	6.00	5.69	5.85	5.66	6.01	5.75	5.57	5.75	5.75	6.29	6.50	6.18	5.83	5.59	5.90	5.77	6.17	5.40	5.79	5.87
Oct-20	3.80	3.63	3.72	3.99	3.66	3.54	2.90	3.52	3.80	3.00	3.50	3.43	2.46	3.75	4.63	3.61	2.82	3.18	3.00	3.48
Nov-20	4.80	3.75	4.28	4.44	3.60	3.67	4.48	4.05	3.47	3.60	3.90	3.66	3.68	2.76	4.13	3.52	4.20	3.97	4.09	3.89
Dec-20	5.72	5.43	5.58	6.21	4.97	4.82	5.16	5.29	5.17	4.91	4.72	4.93	3.30	3.69	5.20	4.06	5.45	5.21	5.33	5.00
AVG	5.71	5.33	5.52	5.48	5.19	5.19	5.21	5.27	5.09	5.45	5.54	5.36	5.67	4.82	5.69	5.39	5.59	5.48	5.54	5.39

44 "impaired" readings; 28% of all observations

Marco DO Measurements 2021



< 3 mg/L   < 5 mg/L

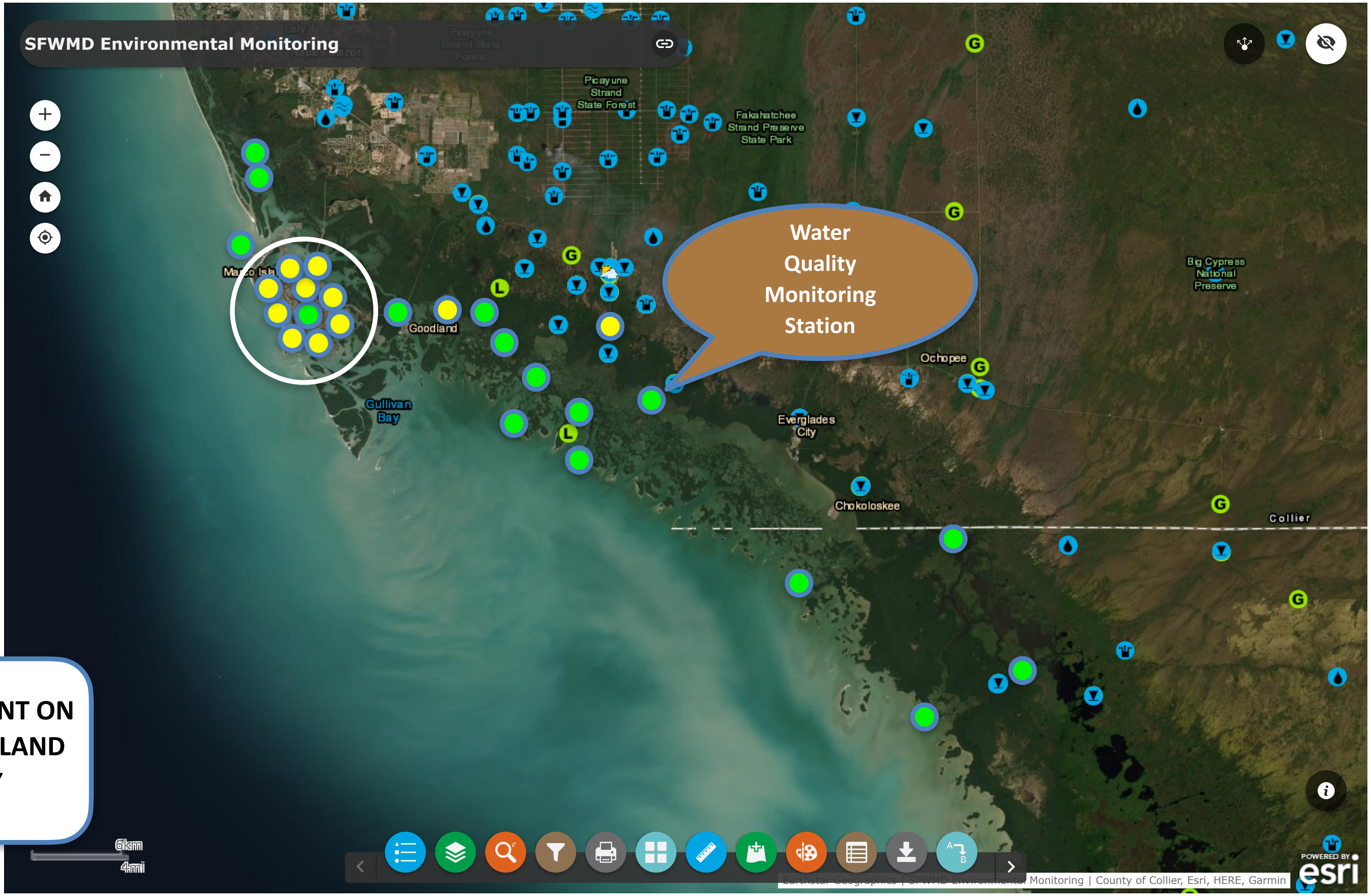
MO-YR	BARF	OLDE	B-1	JHPA	KEND	COLL	HCCE	B-2	HOLL	HUMM	WIND	B-3	LAND	SWAL	WWIN	B-4	EWIN	MCIL	B-5	MARCO
Jan-21	6.74	5.90	6.32	6.26	4.44	4.91	4.95	5.14	4.77	5.35	5.17	5.10	4.72	4.84	5.92	5.16	5.71	4.99	5.35	5.33
Feb-21	3.60	3.64	3.62	3.68	3.88	3.29	3.57	3.61	4.36	3.67	4.43	4.15	5.90	2.75	4.24	4.30	5.47	4.85	5.16	4.10
Mar-21	5.45	3.91	4.68	5.16	4.73	3.27	4.06	4.31	4.73	4.44	4.80	4.66	5.05	3.58	4.06	4.23	4.90	4.96	4.93	4.51
Apr-21	5.00	5.21	5.11	4.31	4.42	3.94	3.85	4.13	3.70	3.39	4.31	3.80	5.69	4.29	5.58	5.19	4.81	5.09	4.95	4.54
May-21	4.52	4.08	4.30	3.85	3.49	3.17	3.01	3.38	3.68	3.27	4.05	3.67	3.72	3.69	5.01	4.14	3.70	3.78	3.74	3.79
Jun-21		4.25	4.25	5.12	3.87	4.19	5.07	4.56	5.25	5.99	4.63	5.29	6.13	2.66	5.70	4.83	6.74	5.07	5.91	4.97
Jul-21	4.10	3.74	3.92	4.97	3.95	4.47	4.21	4.40	4.82	5.28	4.87	4.99	4.47	1.84	4.81	3.71	5.15	5.01	5.08	4.41
Aug-21																				
Sep-21																				
Oct-21																				
Nov-21																				
Dec-21																				
AVG	4.90	4.39	4.60	4.76	4.11	3.89	4.10	4.22	4.47	4.48	4.61	4.52	5.10	3.38	5.05	4.51	5.21	4.82	5.02	4.52

68 "impaired" readings; 69% of all observations
Swallow sampling location (Cape Marco Point) Hypoxic

Estuary DO Status MAY-21

< 5 mg/L

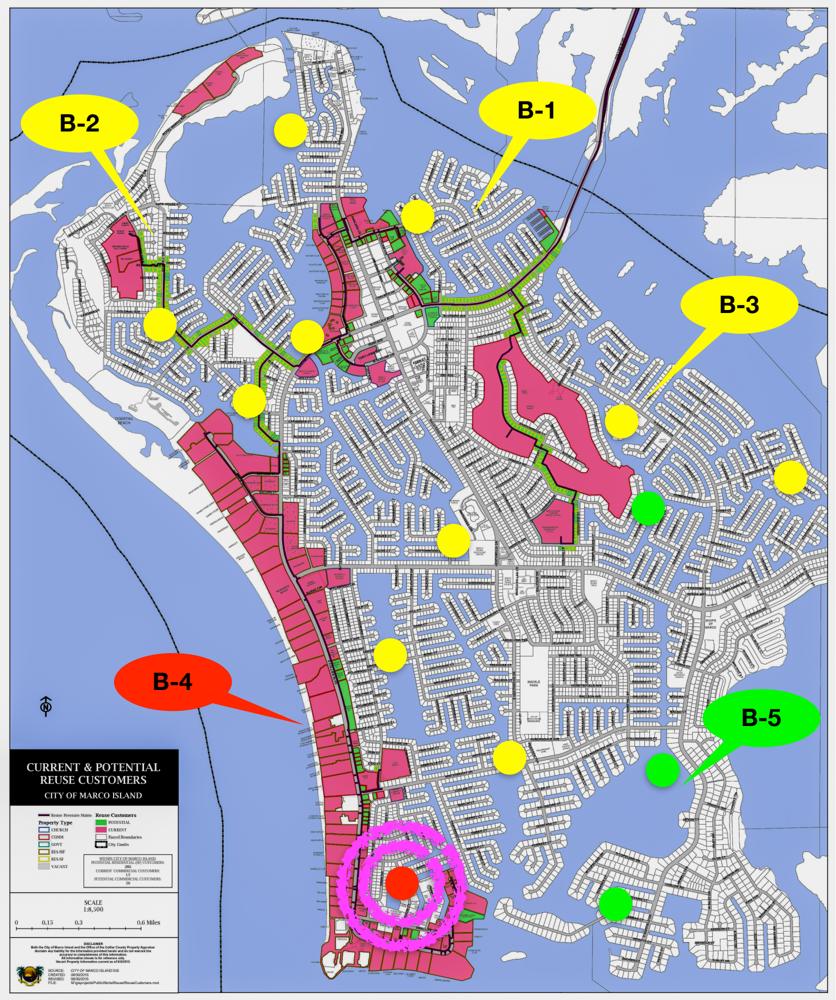
> 5 mg/L



IMPAIRMENT ON MARCO ISLAND ONLY

DO "pit" has formed only over Marco Island

MARCO DO Status JUL-21



Swallow location surrounded on three sides by reuse irrigation = IMPAIRED

Basin 5 gets NO Reuse water = NOT IMPAIRED

B4 IMPAIRED & B5 HEALTHY > REUSE IS SOURCE

< 3 mg/L | < 5 mg/L | > 5 mg/L

11 locations Impaired; Swallow location Hypoxic

Monitoring Estuaries, NOAA

- “Oxygen depletion may occur in estuaries when many plants die and decompose, or when **wastewater** with large amounts of organic material enters the estuary”
    - *99% of the TN in Marco waterways is organic (99% TKN - JUN-21)*
- “In some estuaries, **large nutrient inputs**, typically from sewage, **stimulate algal blooms**”
    - *100% of the reuse water TN is organic (84% NO3; 16% TKN - JUN-21)*
- “When the **algae die**, they begin to **decompose**”
- “The process of decomposition **depletes** the surrounding water of **oxygen** and, in severe cases, leads to **hypoxic** (very low oxygen) conditions that kill aquatic animals”

Marco has large amounts of organic material in the waterways

Root Cause - Nutrients Feed Algal Blooms

- "Much of the resulting nitrogen and phosphorus that feeds algal blooms comes from fertilizer runoff and sewage leaks" *Naples News*, *7/12/21*

- "Blooms kill seagrass - manatee's main food source - by robbing the water of oxygen and sunlight the grass needs to grow" *Naples News 7/12/21*

- Sources of Nutrients on Marco Island:
  - TN: Reuse water, fertilizer, stormwater
  - TP: Reuse water - the only source on the island?

Nutrients feed algal blooms, which consume oxygen and block sunlight, killing seagrass and leading to manatee mortality

"Nitrogen and Phosphorus in Reuse and Potable Water", *2018* - position paper by Sam Young

• Annual nitrogen load from reuse and potable water	88,564 #
• Annual phosphorus load from reuse and potable water (2)	36,783 #
• Nitrogen load equivalent annual 20# bags of fertilizer	42,782
• Daily 20# bags of nitrogen fertilizer equivalent into Marco waterbody (3)	171

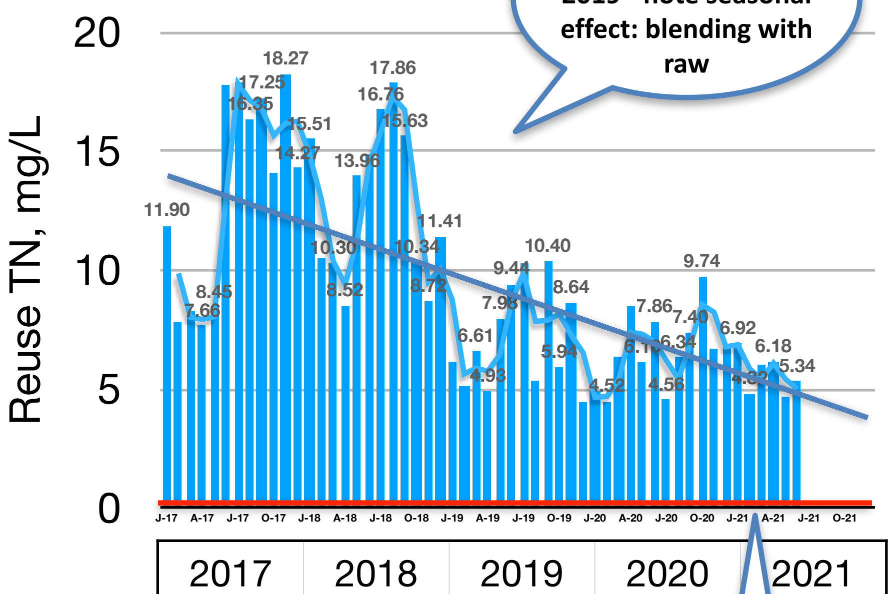
(1) Logistics: Hire 2-3 full-time employees; buy 2 barges; build a dock, build fertilizer warehouse; maintain 30 day inventory (4,000 bags)
(2) We do not allow ANY TP in our fertilizer - yet we spread 1.5 tons PURE TP each month with reuse water
(3) 5 days per week; 50 weeks per year

WWTP has since dropped TN by 50%; TP remains about the same

Imagine if city staff had to spread this much fertilizer - a lot of work! (1)

Marco Island WWTP - Reuse TN

WWTP
Reduced TN 50% in 2019 - note seasonal effect: blending with raw



NNC = Narrative Nutrient Criterion

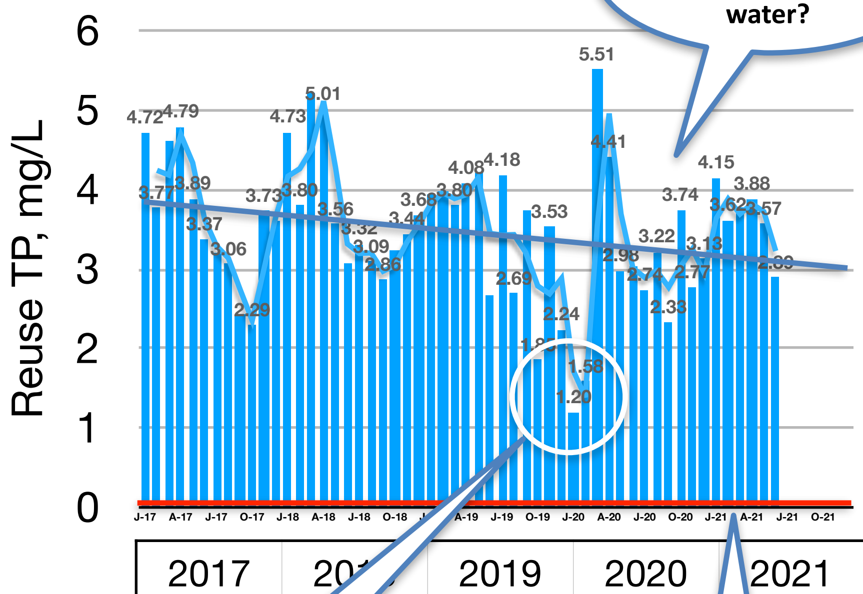
Marco NNC
TN Limit
0.3 mg/L

"The major sources of excessive amounts of nitrogen in surface water are the effluent from municipal treatment plants and runoff from agricultural sites. When nutrient concentrations consistently exceed natural levels, the resulting nutrient imbalance can cause undesirable changes in a waterbody's biological community and increase the rate of eutrophication (or aging) in an aquatic system. Usually, the eutrophication process is observed as a change in the structure of the algal community and includes severe algal blooms that may cover large areas of a waterbody for extended periods. Large blooms are generally followed by a depletion in dissolved oxygen concentrations as a result of algal decomposition"

FDEP

At the 2017 peak, TN level was 61X the NNC - now only 18X

Marco Island WWTP - Reuse TP



Note seasonal effect: blending with raw water?

Extreme Low TP - Can WWTP sustain this?

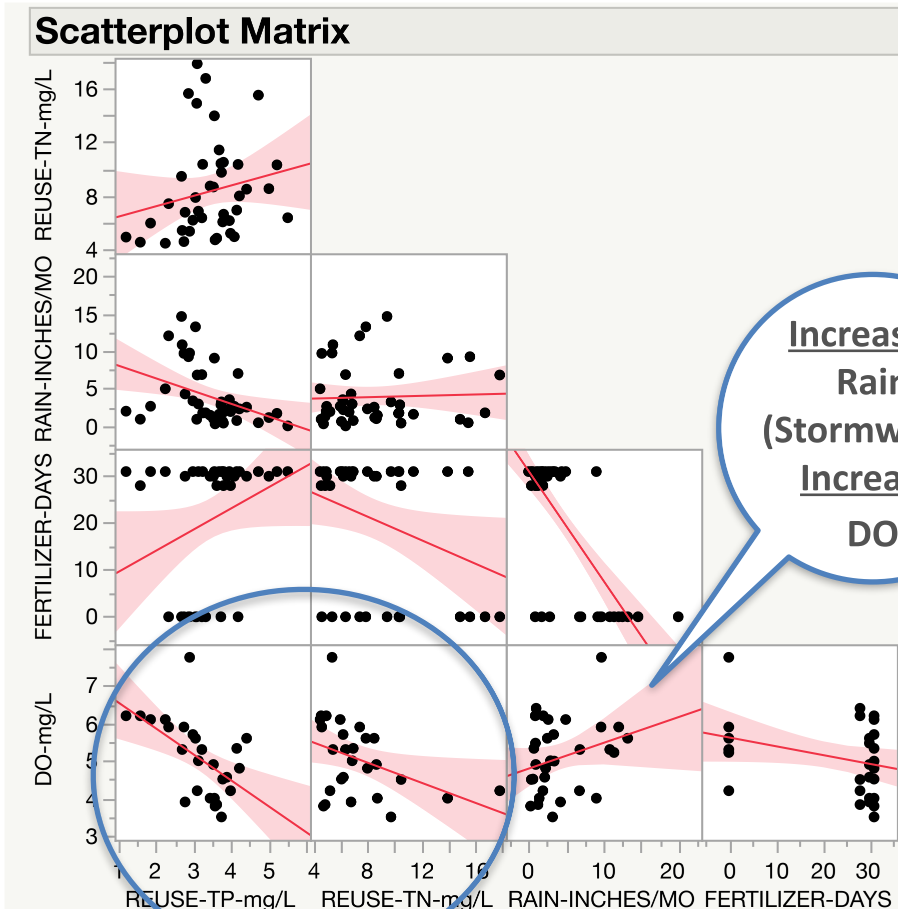
Marco NNC TP Limit 0.046 mg/L

"High phosphorus concentrations are frequently responsible for accelerating the process of eutrophication (or aging) of a waterbody. Once phosphorus and other important nutrients enter the ecosystem, they are extremely difficult to remove because they are taken up by plants or deposited in sediments. Nutrients, particularly phosphates, deposited in sediments generally are redistributed into the water. This type of cycling compounds the difficulty of halting the eutrophication process"

FDEP

At the 2020 peak, TP level was 120X the NNC - now only 63X

Marco Water Quality Database: 5 YR by MO



Increasing Rain (Stormwater) Increases DO 👍

Decreasing Fertilizer Increases DO 👍

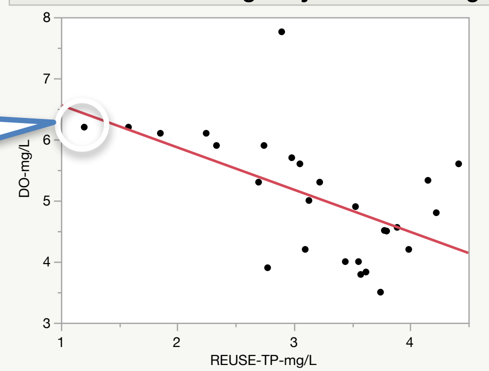
Decreasing Reuse TP & TN Increases DO 👍

DO By Reuse-TP & Reuse-TN

Extreme **low** Reuse TP corresponds to **high** DO - low variation suggests that reuse TP is the main driver of DO impairments

Linear Fit suggests that if Reuse TP = 0 mg/L then DO = 7.25 mg/L

Bivariate Fit of DO-mg/L By REUSE-TP-mg/L



Linear Fit

DO-mg/L = 7.2507932 - 0.6909095*REUSE-TP-mg/L

Summary of Fit

RSquare	0.309403
RSquare Adj	0.28178
Root Mean Square Error	0.85136
Mean of Response	5.062222
Observations (or Sum Wgts)	27

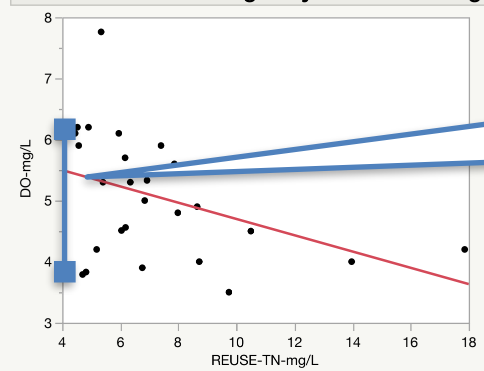
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	8.118335	8.11833	11.2006
Error	25	18.120332	0.72481	Prob > F
C. Total	26	26.238667		0.0026*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	7.2507932	0.674157	10.76	<.0001*
REUSE-TP-mg/L	-0.690909	0.206443	-3.35	0.0026*

Bivariate Fit of DO-mg/L By REUSE-TN-mg/L



Linear Fit

DO-mg/L = 6.0302749 - 0.1331914*REUSE-TN-mg/L

Summary of Fit

RSquare	0.161941
RSquare Adj	0.128419
Root Mean Square Error	0.93786
Mean of Response	5.062222
Observations (or Sum Wgts)	27

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	4.249128	4.24913	4.8309
Error	25	21.989539	0.87958	Prob > F
C. Total	26	26.238667		0.0374*

Parameter Estimates

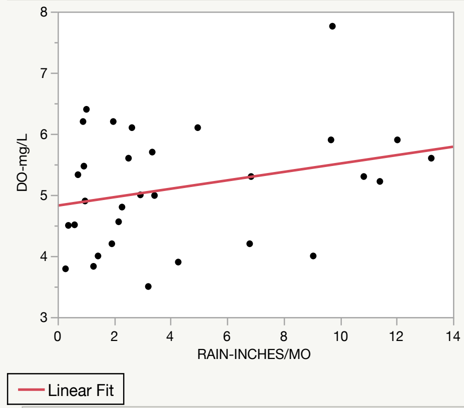
Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	6.0302749	0.475988	12.67	<.0001*
REUSE-TN-mg/L	-0.133191	0.060599	-2.20	0.0374*

Extreme **low** Reuse TN corresponds to **high** DO - high variation suggests other drivers at work

Decreasing Reuse TP & TN increases DO - reducing TP is the next *MAJOR* hurdle for Marco WWTP

DO By Rain & Fertilizer Days

Bivariate Fit of DO-mg/L By RAIN-INCHES/MO



Linear Fit

DO-mg/L = 4.8245152 + 0.0687904*RAIN-INCHES/MO

Summary of Fit

RSquare	0.080396
RSquare Adj	0.048685
Root Mean Square Error	0.94424
Mean of Response	5.12129
Observations (or Sum Wgts)	31

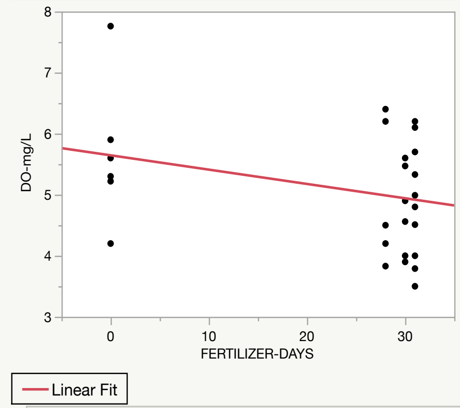
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	2.260448	2.26045	2.5353
Error	29	25.856101	0.89159	Prob > F
C. Total	30	28.116548		0.1222

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	4.8245152	0.251993	19.15	<.0001*
RAIN-INCHES/MO	0.0687904	0.043203	1.59	0.1222

Bivariate Fit of DO-mg/L By FERTILIZER-DAYS



Linear Fit

DO-mg/L = 5.6448827 - 0.0234557*FERTILIZER-DAYS

Summary of Fit

RSquare	0.105758
RSquare Adj	0.074922
Root Mean Square Error	0.931128
Mean of Response	5.12129
Observations (or Sum Wgts)	31

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	2.973550	2.97355	3.4297
Error	29	25.142998	0.86700	Prob > F
C. Total	30	28.116548		0.0742

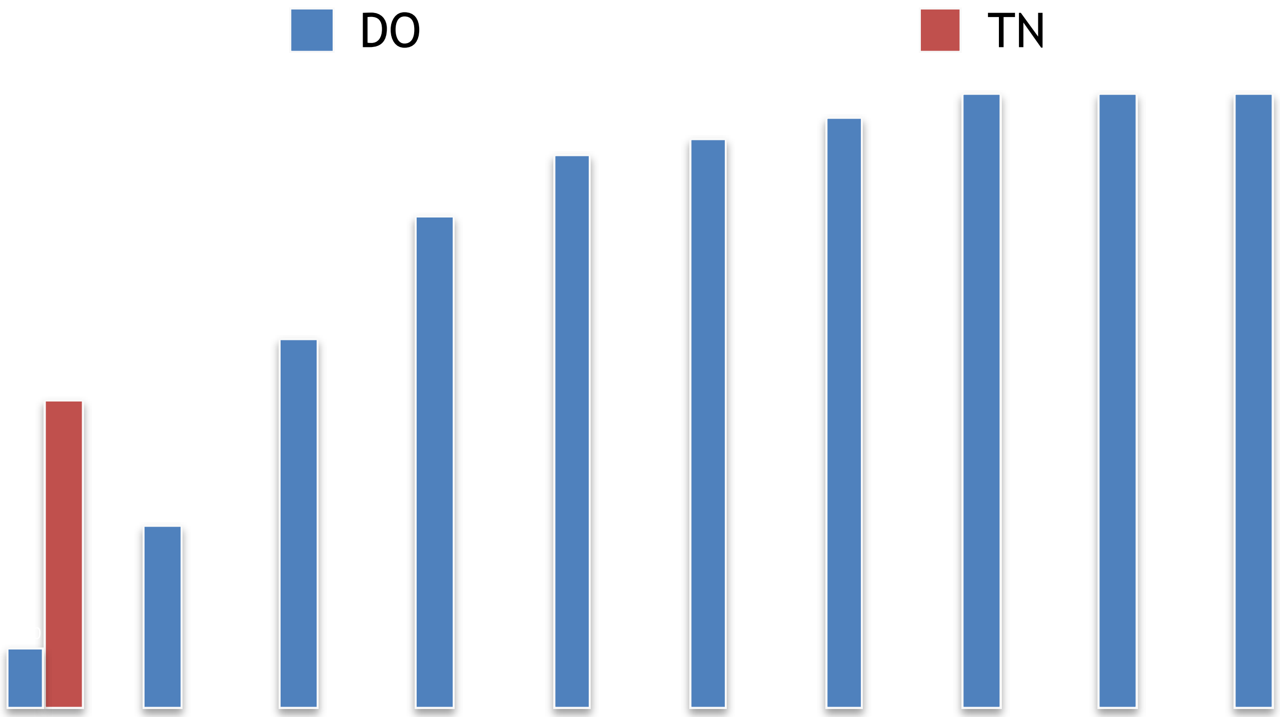
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	5.6448827	0.328484	17.18	<.0001*
FERTILIZER-DAYS	-0.023456	0.012665	-1.85	0.0742

Increasing Rain increases DO

Decreasing Fertilizer increases DO

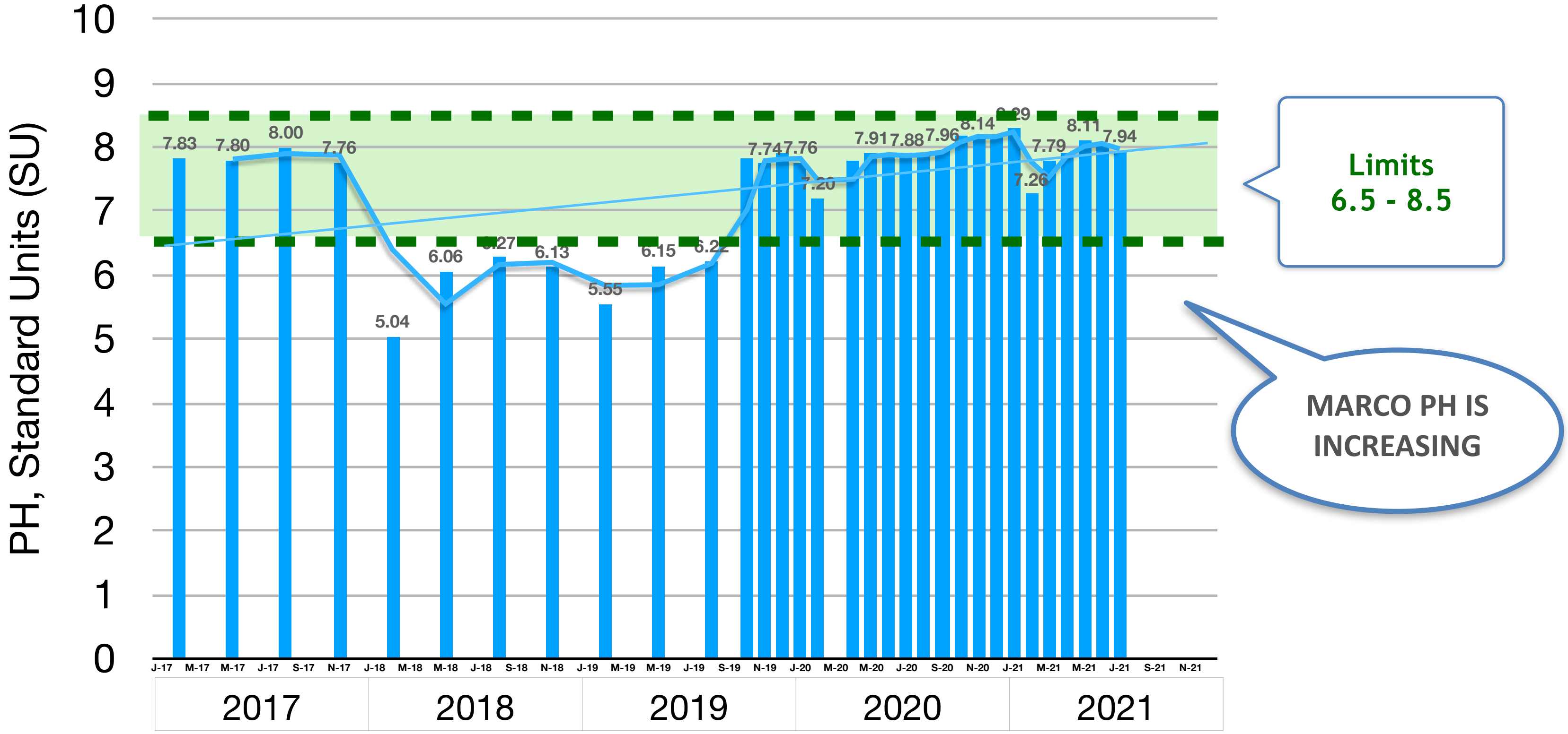
First Flush Hypothesis - Stormwater



Is first flush TN supplanted by oxygen from rainwater?

Marco Waterways NEED this source of oxygen

pH Trend - More Evidence



“An overabundance of algae (called an algal bloom) may cause pH levels in an estuary to rise significantly, and this can be lethal to aquatic animals” NOAA

Estuary pH - 1H21

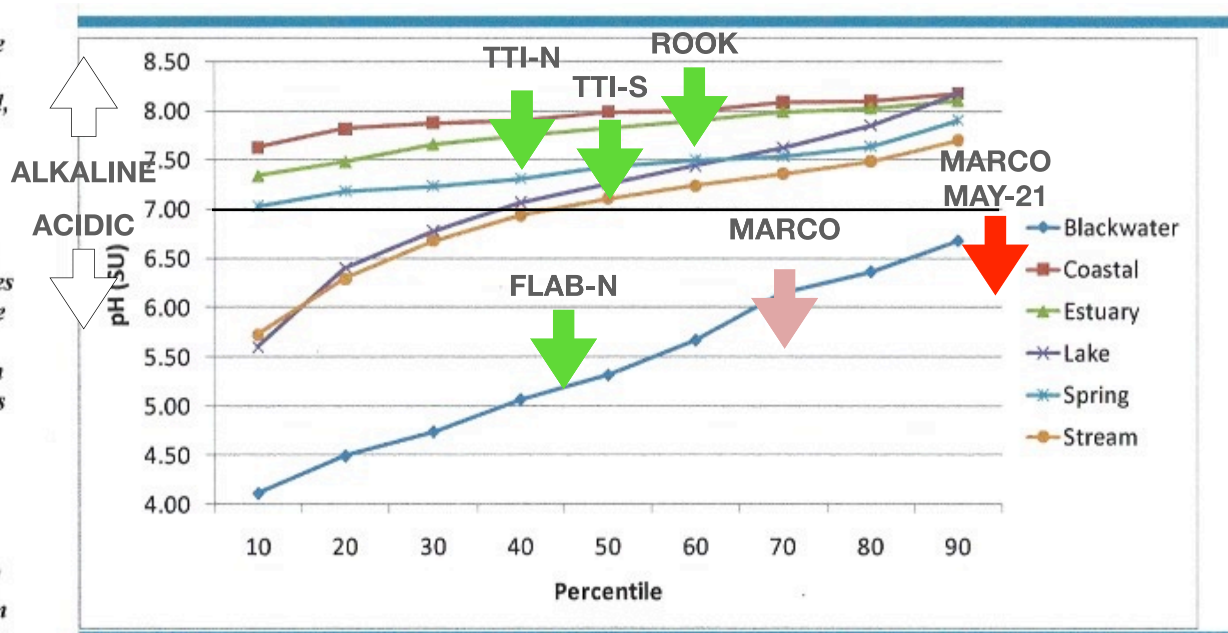
pH (PH)
Standard units (SU)

The pH of a body of water denotes its hydrogen ion activity, based on the negative logarithm of hydrogen ion concentrations. A pH of 1 to 7 is acidic, a pH of 7 is neutral, and a pH of 7 to 14 is alkaline.

pH significantly affects chemical and biological interactions in the aquatic environment. This is of particular concern in considering the effects of toxic substances on aquatic organisms, especially the release of metals from sediments. At certain pH levels, a particular toxicant may increase in toxicity or become more soluble, and thus is more likely to affect aquatic organisms.

The problems of acidic deposition and the acidification of lakes and streams have gained widespread attention. However, certain biological communities are adapted to acidic conditions (e.g., blackwater stream systems, where pH ranges from 4 to 5) or to slightly alkaline conditions (e.g., spring runs, where pH values of 8 are not unusual) and are endangered only when the natural conditions are altered.

Source: FDEP



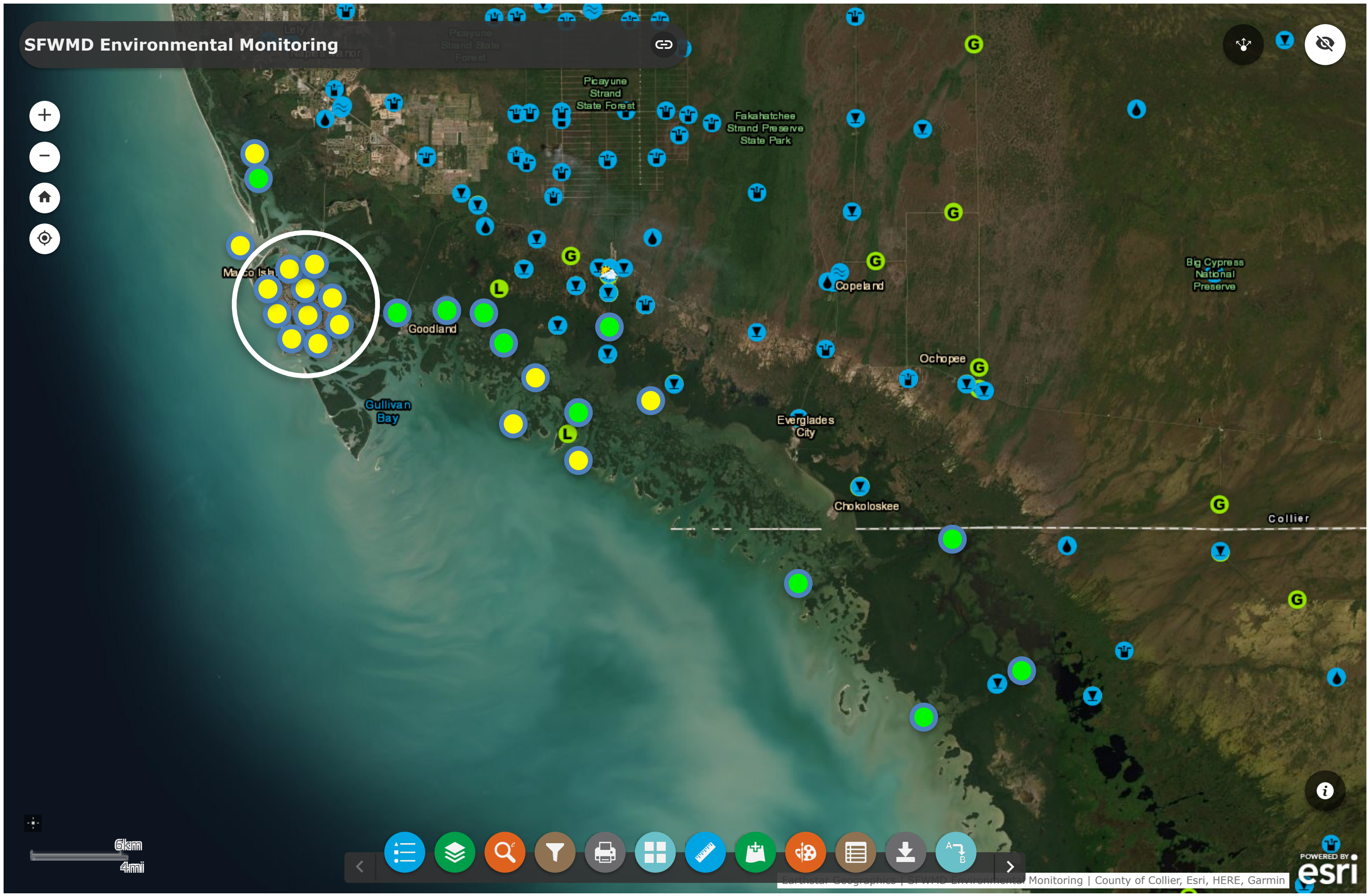
Percentile	Blackwater	Coastal	Estuary	Lake	Spring	Stream
10	4.12	7.63	7.34	5.60	7.04	5.73
20	4.50	7.82	7.48	6.40	7.19	6.30
30	4.74	7.88	7.66	6.78	7.24	6.68
40	5.07	7.90	7.75	7.07	7.31	6.94
50	5.32	7.99	7.83	7.26	7.43	7.11
60	5.67	8.00	7.90	7.44	7.50	7.24
70	6.16	8.09	7.99	7.63	7.54	7.37
80	6.37	8.10	8.03	7.86	7.64	7.49
90	6.68	8.18	8.10	8.18	7.90	7.70
# of waterbodies	56	81	447	836	100	1397

1H21 Marco pH was higher than 70% of Florida estuaries
May-21 Marco pH was higher than 95% of Florida estuaries

Estuary pH Status MAY-21

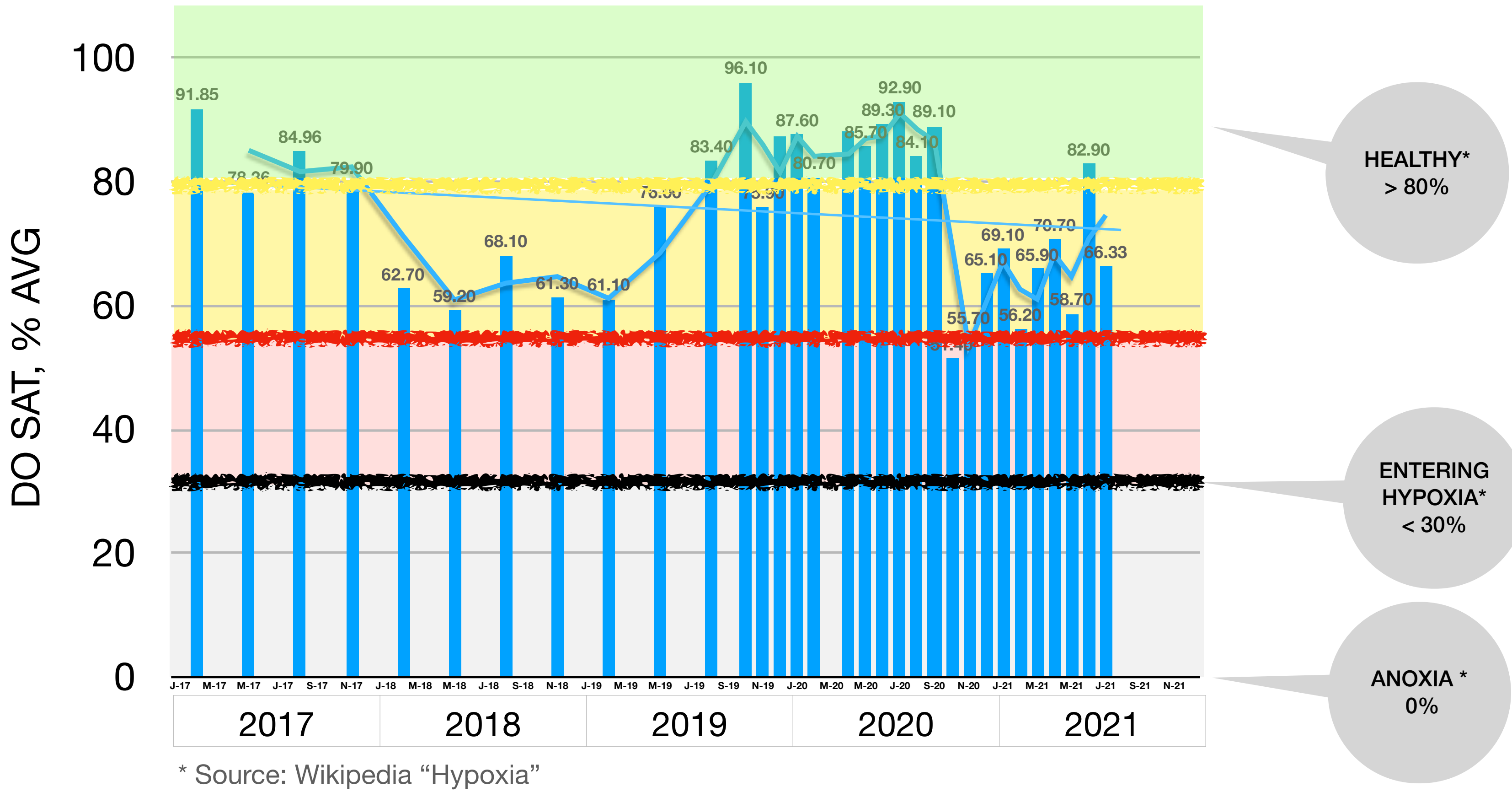
< 8.0

=> 8.0



pH “dome” has formed only over Marco Island

DOSAT % Trend - even more evidence



* Source: Wikipedia “Hypoxia”

Marco DOSAT trending to Hypoxia - other parameters may indicate Hypoxia as well

Impact on Manatee - *Naples Daily News 7/12/21*

- "More manatees have died in 2021 than any other year"
- "841 manatees have died in Florida waters, mostly in Brevard County"
- No real manatee death on Marco? Maybe they just do not come here anymore? They can find other food sources in the estuary
- Brevard County the manatee may have nowhere to go and die of starvation

Can we track the manatee population like we do dolphin?
When was the last time the water looked like this photo on Marco?

Hypoxia (environmental)

Causes of Hypoxia

"Oxygen depletion can result from a number of natural factors, but is most often a concern as a consequence of pollution and eutrophication in which plant nutrients enter a river, lake, or ocean, and phytoplankton blooms are encouraged"

"As phytoplankton break down, free phosphorus and nitrogen become available in the environment, which also fosters hypoxic conditions"

Solutions

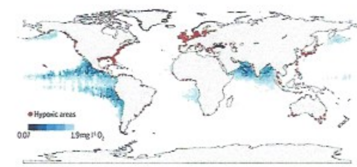
"To combat hypoxia, it is essential to reduce the amount of land-derived nutrients reaching rivers in runoff. This can be done by improving sewage treatment and by reducing the amount of fertilizers leaching into the rivers"

"Other natural habitat-based solutions include restoration of shellfish populations, such as oysters"

WIKIPEDIA

Hypoxia (environmental)

Hypoxia refers to low oxygen conditions. Normally, 20.9% of the gas in the atmosphere is oxygen. The partial pressure of oxygen in the atmosphere is 20.9% of the total barometric pressure.[3] In water, oxygen levels are much lower, approximately 7 ppm 0.0007% in good quality water, and fluctuate locally depending on the presence of photosynthetic organisms and relative distance to the surface (if there is more oxygen in the air, it will diffuse across the partial pressure gradient).[4]



Global areas of ocean hypoxia 2009

Global map of low and declining oxygen levels in the open ocean and coastal waters.[1] The map indicates coastal sites where anthropogenic nutrients have exacerbated or caused oxygen declines to <2 mg/l (<63 μmol/l) (red dots), as well as ocean oxygen minimum zones at 300 m (blue shaded regions).[2]

Contents

Atmospheric hypoxia

Atmospheric hypoxia occurs naturally at high altitudes. Total atmospheric pressure decreases as altitude increases, causing a lower partial pressure of oxygen which is defined as hypobaric hypoxia. Oxygen remains at 20.9% of the total gas mixture, differing from hypoxic hypoxia, where the percentage of oxygen in the air (or blood) is decreased. This is common in the sealed burrows of some subterranean animals, such as blesmols.[5] Atmospheric hypoxia is also the basis of altitude training which is a standard part of training for elite athletes. Several companies mimic hypoxia using normobaric artificial atmosphere.

Hypoxia appears to be a self-sustaining, accelerating process

Managed Nutrient Reduction

"The Rhode Island Department of Environmental Management (RI DEM) implemented nitrogen reductions in waste water treatment facilities (WWTF) beginning in 2005"

(RI DEM, 2005)

"By summer 2012 the overall goal of a 50% reduction of the WWTP effluent DIN load was achieved in Narragansett Bay"

(Liberti, A. 2014 RI DEM. personal communication)

"Management regulations have mandated tertiary treatment at WWTP year round …"

DIN = Dissolved Inorganic Nitrogen

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Managed nutrient reduction impacts on nutrient concentrations, water clarity, primary production, and hypoxia in a north temperate estuary

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Hypoxia

A B S T R A C T

Except for the Providence River and side embayments like Greenwich Bay, Narragansett Bay can no longer be considered eutrophic. In summer 2012 managed nitrogen treatment in Narragansett Bay achieved a goal of reducing effluent dissolved inorganic nitrogen inputs by over 50%. Narragansett Bay represents a small northeast US estuary that had been heavily loaded with sewage effluent nutrients since the late 1800s. The input reduction was reflected in standing stock nutrients resulting in a statistically significant 60% reduction in concentration. In the Providence River estuary, total nitrogen decreased from 100 μm to about 40 μm, for example. We tested four environmental changes that might be associated with the nitrogen reduction. System apparent production was significantly decreased by 31% and 45% in the upper and mid Bay. Nutrient reductions resulted in statistically improved water clarity in the mid and upper Bay and in a 34% reduction in summer hypoxia. Nitrogen reduction also reduced the winter spring diatom bloom; winter chlorophyll levels after nutrient reduction have been significantly lower than before the reduction. The impact on the Bay will continue to evolve over the next few years and be a natural experiment for other temperate estuaries that will be experiencing nitrogen reduction. To provide perspective we review factors effecting hypoxia in other estuaries with managed nutrient reduction and conclude that, as in Narragansett Bay, physical factors can be as important as nutrients. On a positive note managed nutrient reduction has mitigated further deterioration in most estuaries.

1. Introduction

As the expensive engineering efforts reduce nutrients in coastal systems, the documentation toward restoration becomes increasingly relevant to justify. Some systems fail to follow a simple trajectory from degradation to restoration (Duarte et al., 2009; Conley, 2012). In large stratified Chesapeake Bay, inorganic nutrients were a primary driver of hypoxia through growth, sinking and decomposition of algal cells, but the removal of bivalve filter feeders, climate change and changing physical factors have continued to contribute to hypoxia (Kemp et al., 2009). However, other systems indicate improvement with reduced chlorophyll levels, improved water clarity and in some cases the re-growth of seagrass beds (Staehr et al., 2017; Taylor et al., 2011; Greening and Janicki, 2006). Here, we offer one more case where the effort may be evaluated.

In the late 1990s and early 2000s, studies in Narragansett Bay

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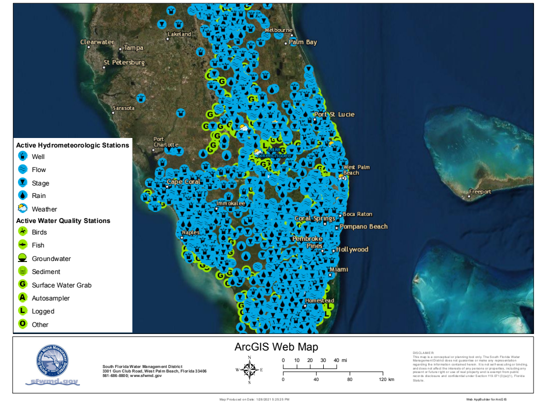
https://doi.org/10.1016/j.ecss.2017.09.026

Could the City commission a study like this for the Marco waterways?

Next Steps



1. Continue research into the Root-Cause of variation in Marco waterbody chemistry: DO, TN, TP, CHLA, pH; produce quarterly reports; examine variation across the estuary for all 17 parameters that are measured
2. Investigate cost of Tertiary Treatment of reuse water to lower the reuse TN & TP levels to NNC standards: TN = 0.3 mg/L; TP = 0.046 mg/L <or> to sustainable levels, known as "Managed Nutrient Reduction"
3. Evaluate possibility of getting Marco WQ data into DBHYDRO for ease of data analysis - current data in WIN CANNOT be accessed
4. Evaluate cost of continuous-automatic Data Loggers for Marco Island and nearby waterbodies: Data logged each 30 minutes - Depth, Salinity, DO, Turbidity, pH - critical eutrophication parameters; "Mirror" the NOAA SWMP System
5. Investigate "Developing and Implementing an Estuarine Water Quality Monitoring, Assessment, and Outreach Program" - The MYSound Project (See City Council Water Quality Workshop 4/29/19)

Solution: Clean up the reuse water

Motions for consideration: WAC 8.19.21

1. Post the documents from today's agenda on the WAC web page for public access:
   A. **"Marco Hypoxia Investigation"**
   B. **"Managed Nutrient Reduction", Estuarine, Coastal and Shelf Science**
   C. **"Hypoxia (environmental)", Wikipedia**

2. **Investigate the cost of tertiary treatment of reuse water to lower the reuse TN & TP levels to NNC standards: TN = 0.3 mg/L; TP = 0.046 mg/L or to sustainable levels, known as "Managed Nutrient Reduction".**

3. **Evaluate the possibility of getting Marco WQ data into DBHYDRO for ease of data analysis.**

4. **Assess the cost of continuous-automatic data loggers for Marco Island and nearby waterbodies: Data logged each 30 minutes - Depth, Salinity, DO, Turbidity, pH - critical eutrophication parameters; "Mirror" the NOAA SWMP system.**

5. **Investigate "Developing and Implementing an Estuarine Water Quality Monitoring, Assessment, and Outreach Program" - The MYSound Project (See City Council Water Quality Workshop 4/29/19).**

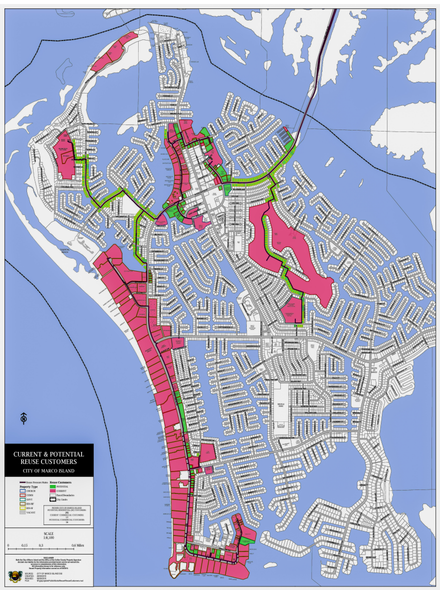
6. **Commission a study that investigates restoration of the Marco waterbody shellfish and seagrass populations with recommendations and implementation plans.**

7. **Implement a demonstration project for the installation of (1) compressed air injection system at the Swallow water quality sampling station to determine the effectiveness of this technology in increasing DO in the waterway.**

8. **Commission a study (See "Managed Nutrient Reduction") to understand the effects of any actions taken to resolve the hypoxic conditions in the Marco Island waterways.**

Motions not voted

Questions?



TREATED SEWAGE

>

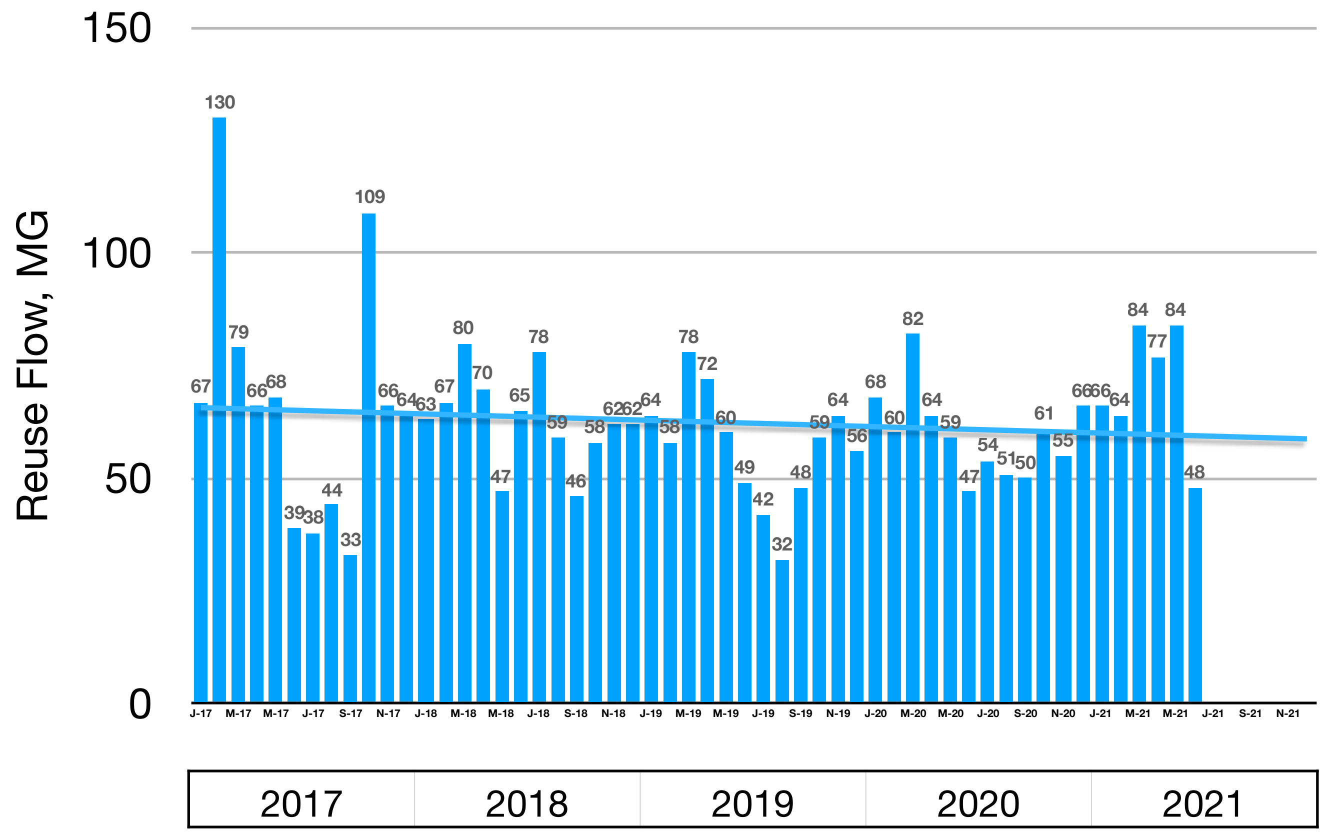
GREEN GRASS

>

HAB

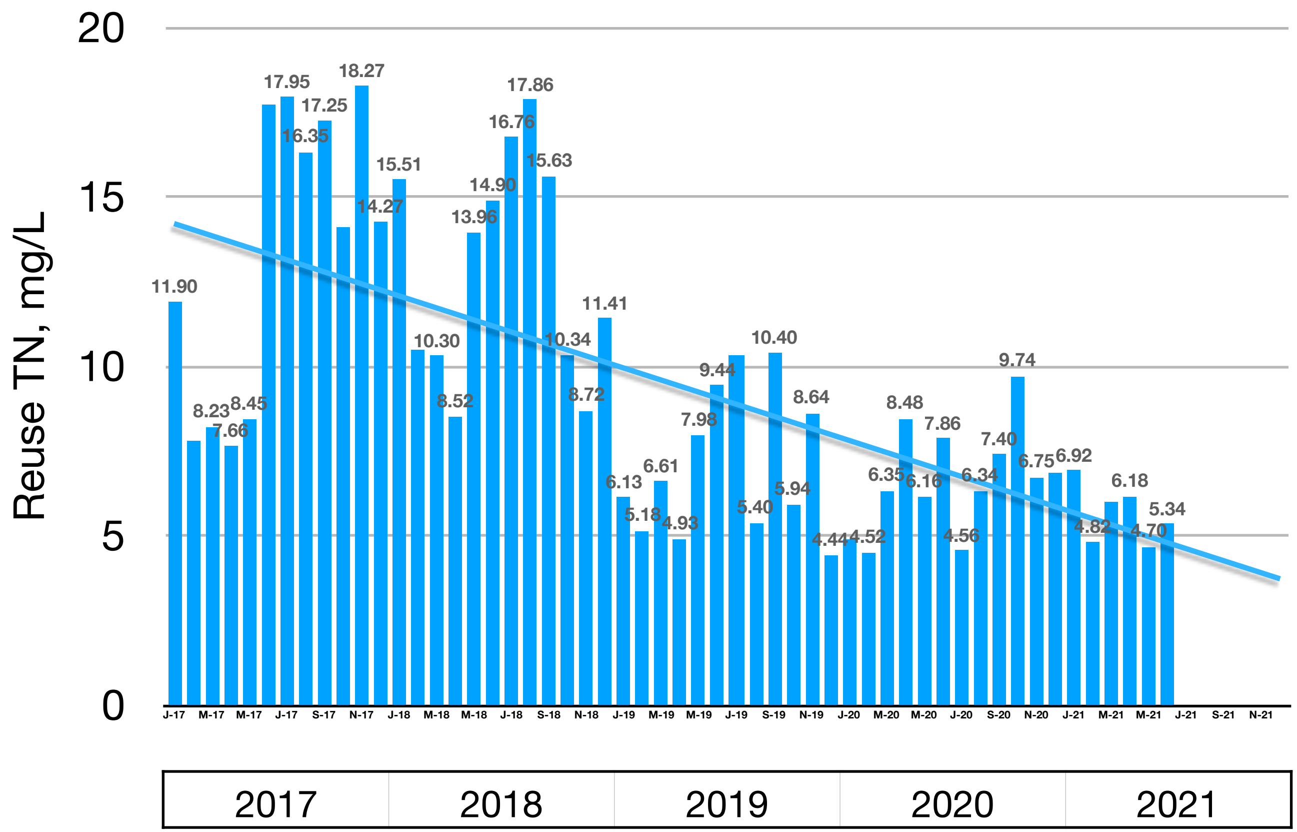
Appendix

Marco Island WWTP - Reuse Flow



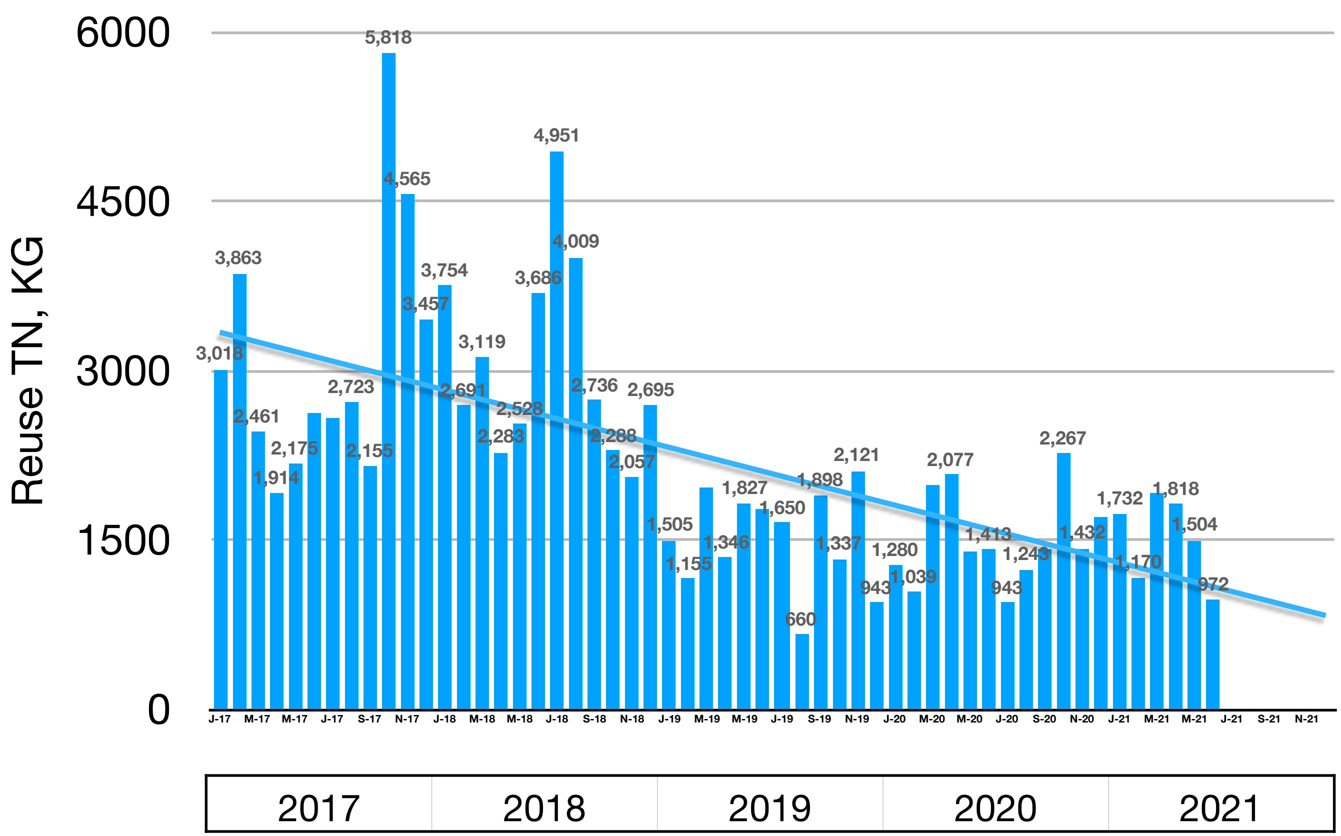
Reuse flow is seasonal - dropping during the off-season

Marco Island WWTP - Reuse TN



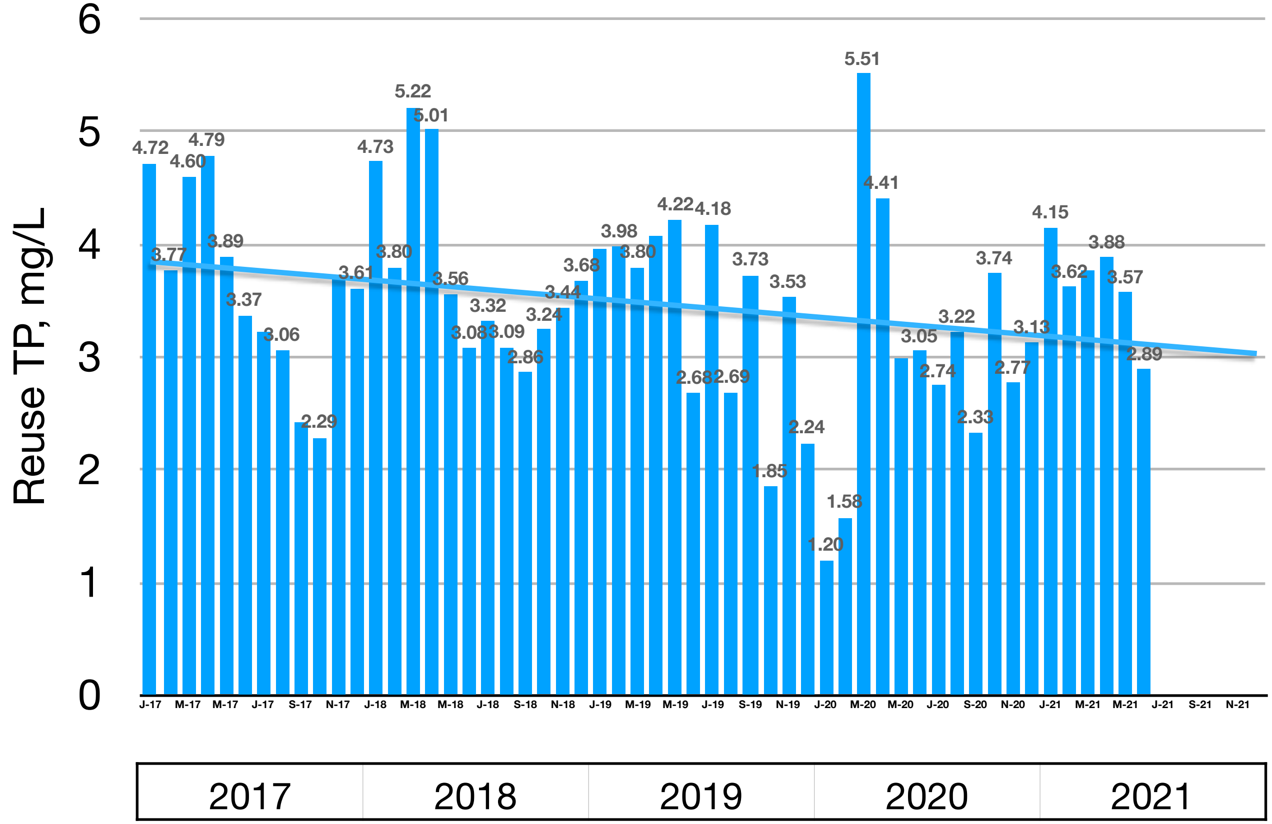
Reuse TN was reduced by 50% in early 2019 - 1H21 Average = 5.66 mg/L

Marco Island WWTP - Reuse TN Load



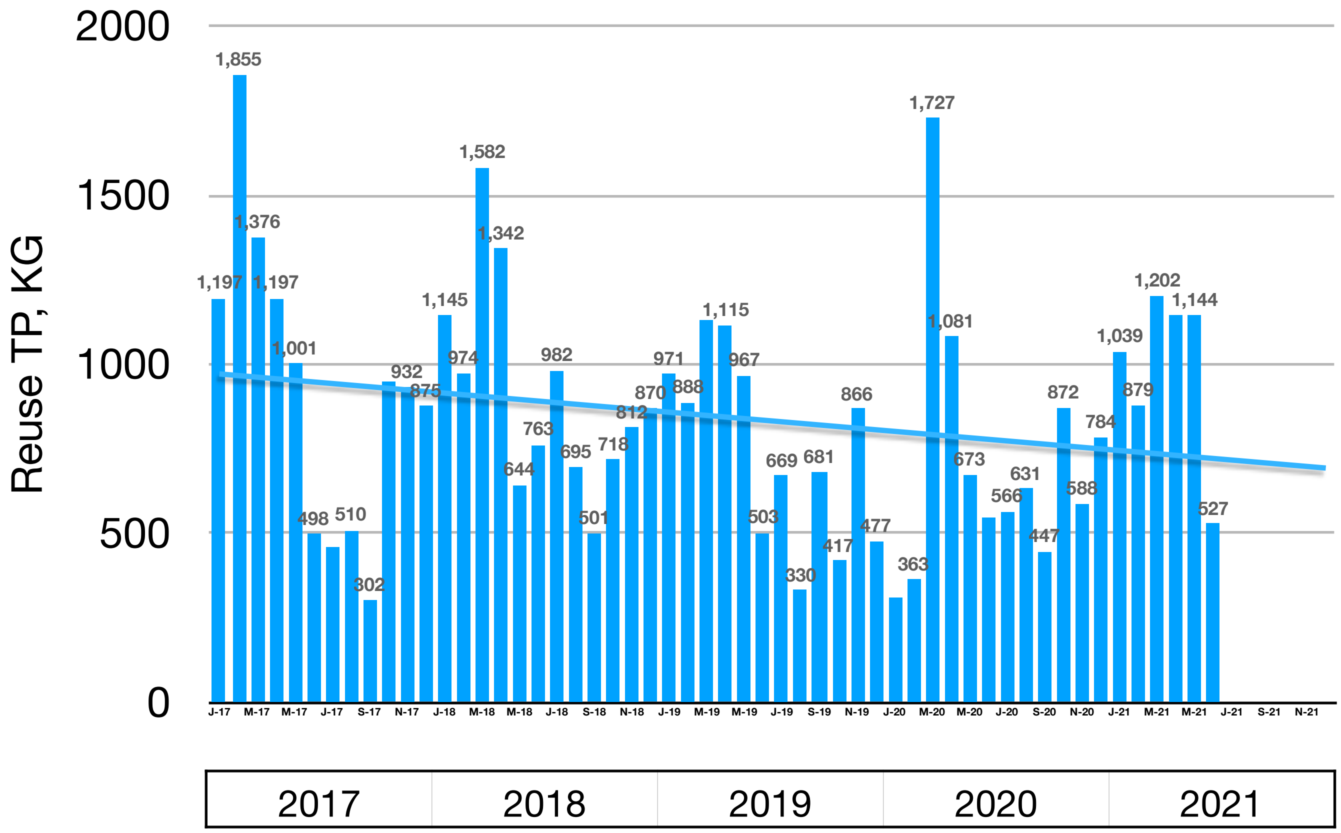
Reuse TN load reduced significantly in early 2019

Marco Island WWTP - Reuse TP



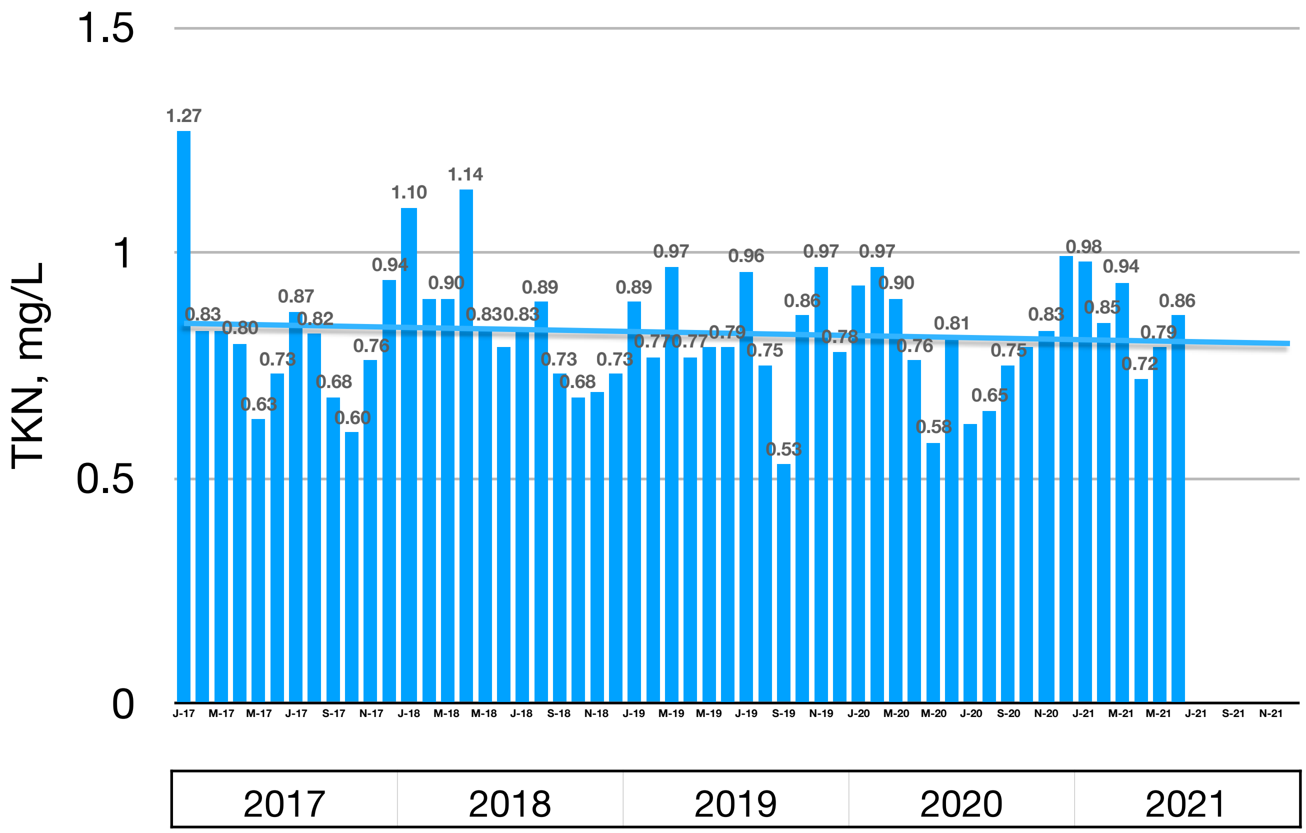
TP highly variable - 1H21 Average = 3.64 mg/L

Marco Island WWTP - Reuse TP Load



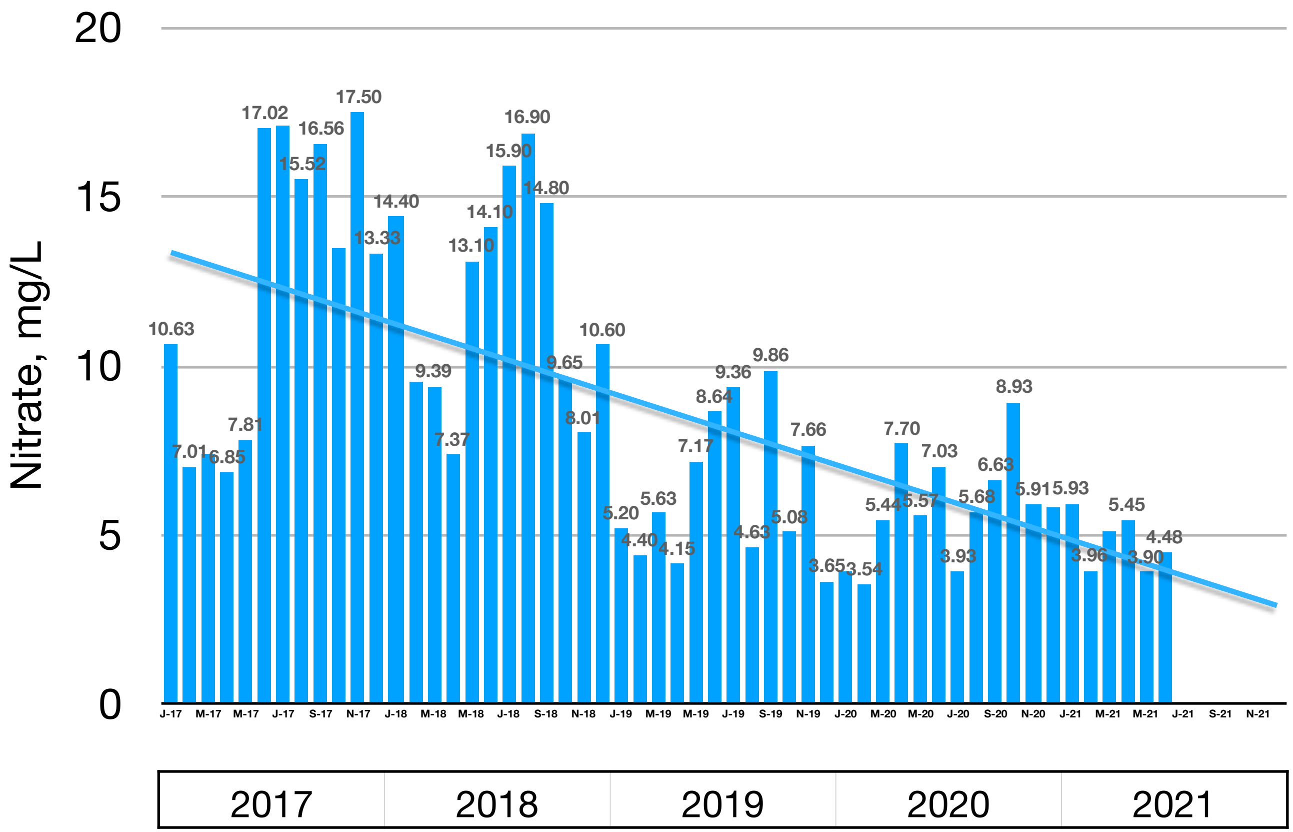
TP load highly variable - seasonal effect & process effect combined

Marco Island WWTP - Reuse TKN



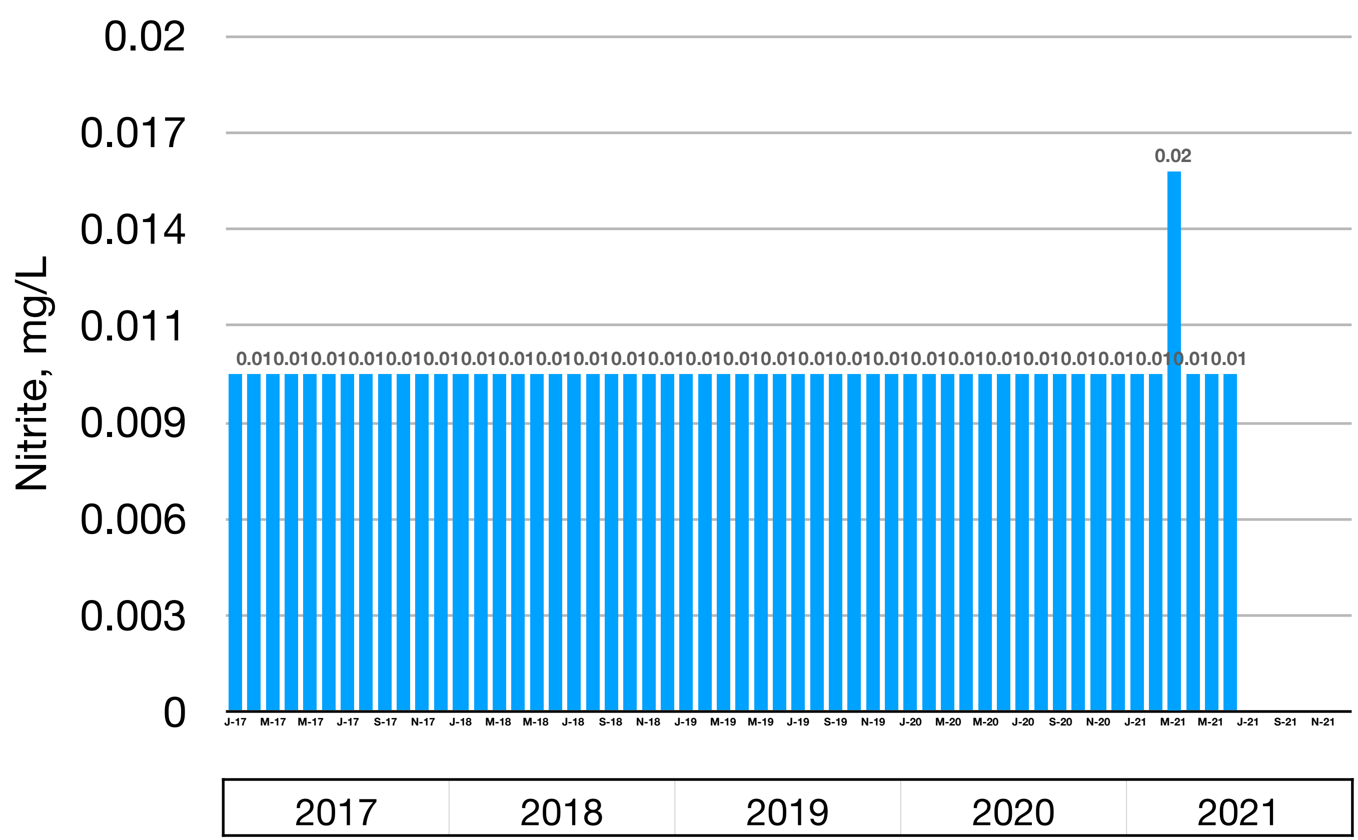
TKN variable and stable

Marco Island WWTP - Reuse Nitrate (NO3)



Nitrate reduced significantly beginning early 2019

Marco Island WWTP - Reuse Nitrite (NO2)



Nitrate can not be detected

Aquatic Hypoxia

Oxygen depletion is a phenomenon that occurs in aquatic environments as dissolved oxygen (DO; molecular oxygen dissolved in the water) becomes reduced in concentration to a point where it becomes detrimental to aquatic organisms living in the system. Dissolved oxygen is typically expressed as a percentage of the oxygen that would dissolve in the water at the prevailing temperature and salinity (both of which affect the solubility of oxygen in water; see oxygen saturation and underwater). An aquatic system lacking dissolved oxygen (0% saturation) is termed anaerobic, reducing, or anoxic; a system with low concentration—in the range between 1 and 30% saturation—is called hypoxic or dysoxic. Most fish cannot live below 30% saturation. Hypoxia leads to impaired reproduction of remaining fish via endocrine disruption. A "healthy" aquatic environment should seldom experience less than 80%. The exaerobic zone is found at the boundary of anoxic and hypoxic zones.

Oxygen depletion can result from a number of natural factors, but is most often a concern as a consequence of pollution and eutrophication in which plant nutrients enter a river, lake, or ocean, and phytoplankton blooms are encouraged. While phytoplankton, through photosynthesis, will raise DO saturation during daylight hours, the dense population of a bloom reduces DO saturation during the night by respiration. When phytoplankton cells die, they sink towards the bottom and are decomposed by bacteria, a process that further reduces DO in the water column. If oxygen depletion progresses to hypoxia, fish kills can occur and invertebrates like worms and clams on the bottom may be killed as well.

To combat hypoxia, it is essential to reduce the amount of land-derived nutrients reaching rivers in runoff. This can be done by *improving sewage treatment* and by reducing the amount of fertilizers leaching into the rivers. Alternately, this can be done by restoring natural environments along a river; marshes are particularly effective in reducing the amount of phosphorus and nitrogen (nutrients) in water. Other natural habitat-based solutions include restoration of shellfish populations, such as oysters. Oyster reefs remove nitrogen from the water column and filter out suspended solids, subsequently reducing the likelihood or extent of harmful algal blooms or anoxic conditions. Foundational work toward the idea of improving marine water quality through shellfish cultivation was conducted by Odd Lindahl et al., using mussels in Sweden. More involved than single-species shellfish cultivation, integrated multi-trophic aquaculture mimics natural marine ecosystems, relying on polyculture to improve marine water quality.

Source: Wikipedia