Removal of Nutrients from IRL Dredged Muck Residuals Utilizing High-Valence Iron (FeO_4^{2-}) Technology

-An Estuary in Peril-

T.D. Waite PhD PE

President & Founder

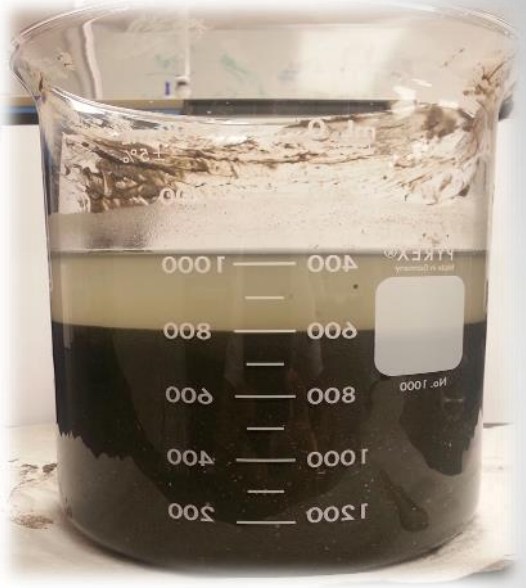
IRL National Estuaries Program

August 10, 2021

Muck vs. "Dredged Muck"

Muck Sediment

Dredged Muck



Settled Dredged Muck

-Muck Settling Kinetics-

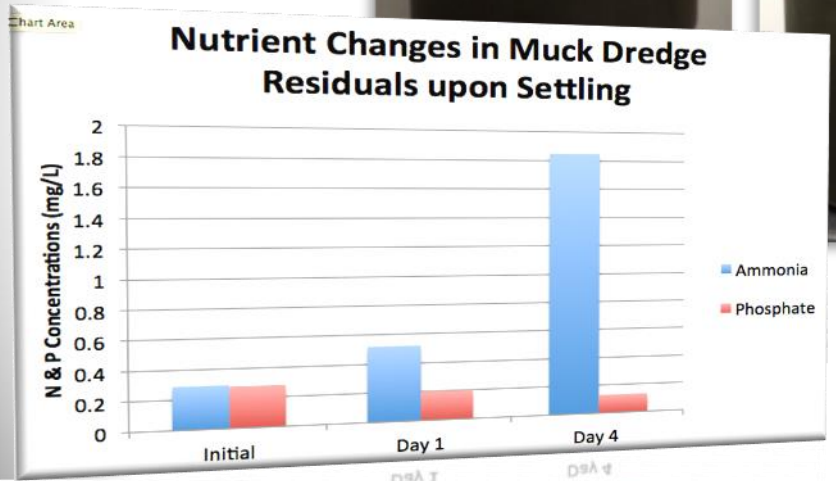
t = 0 min.

t = 1 min.

t = 2 min.

t = 5 min.

t = 10 min.



What is Ferrate(VI) $(FeO_4)^{2-}$?

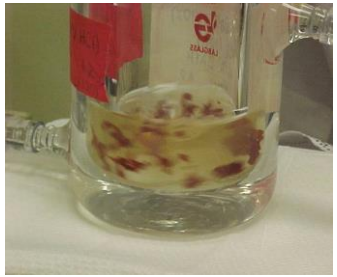
- **Oxyanion of iron in +6 oxidation state – better known as Ferrate(VI).**
- **More powerful than ozone, chlorine dioxide, hydrogen peroxide, permanganate, hypochlorite, and chlorine.**
- **Multiple effects from a single dose. As Ferrate(IV) reacts to form ferric hydroxide (Fe^{3+}), it accomplishes superior oxidation, disinfection, coagulation, precipitation, dewatering, and deodorization.**
- **Easy to synthesize, but difficult (expensive) to purify and stabilize long enough to be a "commercial" chemical.**

FERRATE SOLUTIONS

Synthesis of FeO_4^{2-} is Now Simple …

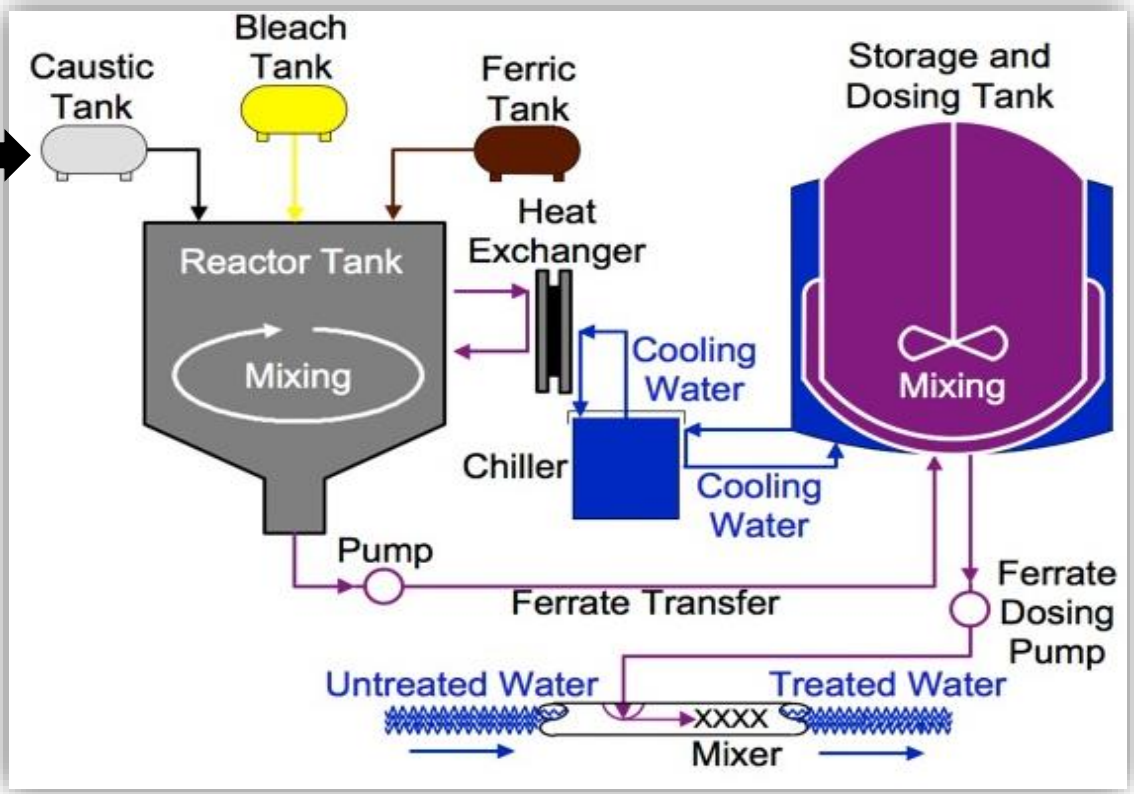
Iron + Bleach + Caustic --> Ferrate + Salt +Water

$$2FeCl_3 + 3NaOCl + 10NaOH = 2Na_2FeO_4 + 9NaCl + 5H_2O$$



Ferrate Synthesis Process

Common Feedstock Chemicals – Available Everywhere in the World



Typical Process Skid

Synthesizer can make 150 GPH Ferrate solution – Treat 60 MGD @ 1 mg/L dose

Currently operating at muck dredging site (4,000 GPM), Florida

Reaction of FeO_4^{2-} with Water

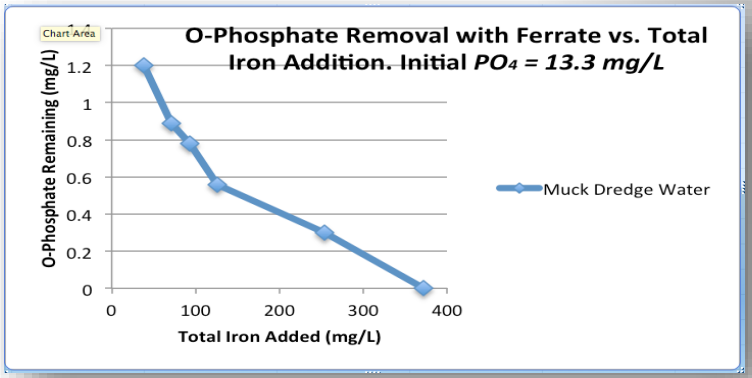
$$(OH)^*FeO_4^{2-} + H_2O \rightarrow FeO_4^{3-} + FeO_3^{2-} \rightarrow Fe(OH)_3$$

Fe^6 Fe^5 Fe^4 Fe^3

Disinfection + Oxidation → Coagulation

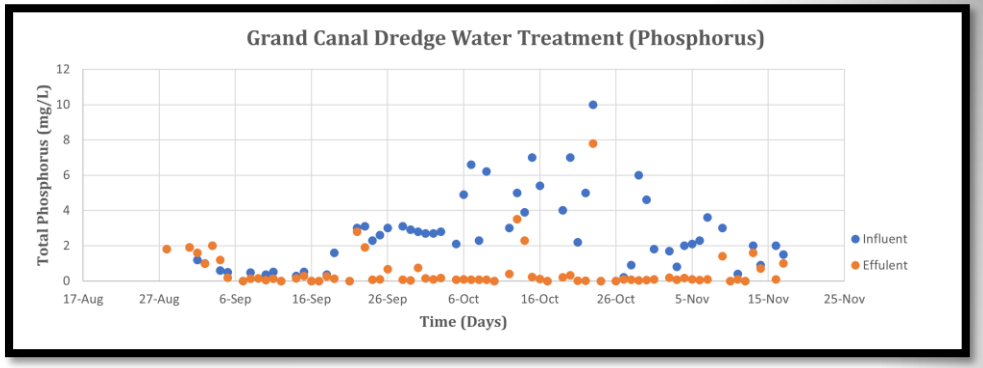
-Demonstrate Unique Chemistry-

- **Studies in FIT laboratories using this chemistry to treat dredge spoil water have shown very high treatment efficiencies for nutrient & contaminant removal from dredge water.**

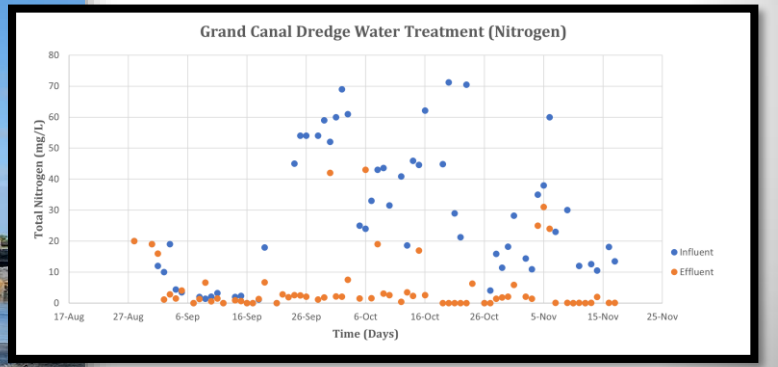


Muck Dredge Water	pH	NH_4-N (mg/L)	NO_2-N (mg/L)	NO_3-N (mg/L)	PO_4-P (mg/L)	TSS (mg/L)	Total N+P	Total N+P+TSS
Control	7.5	2.03	0.03	0.36	1.2	185.4		
Treated	7.0	0.16	0.006	0.35	0.4	8.5		
Chemical Cost ($/lb.)	-----	$30.00	-----	-----	$69.0	$0.3	$21.0	$0.3

Currently Operating in IRL

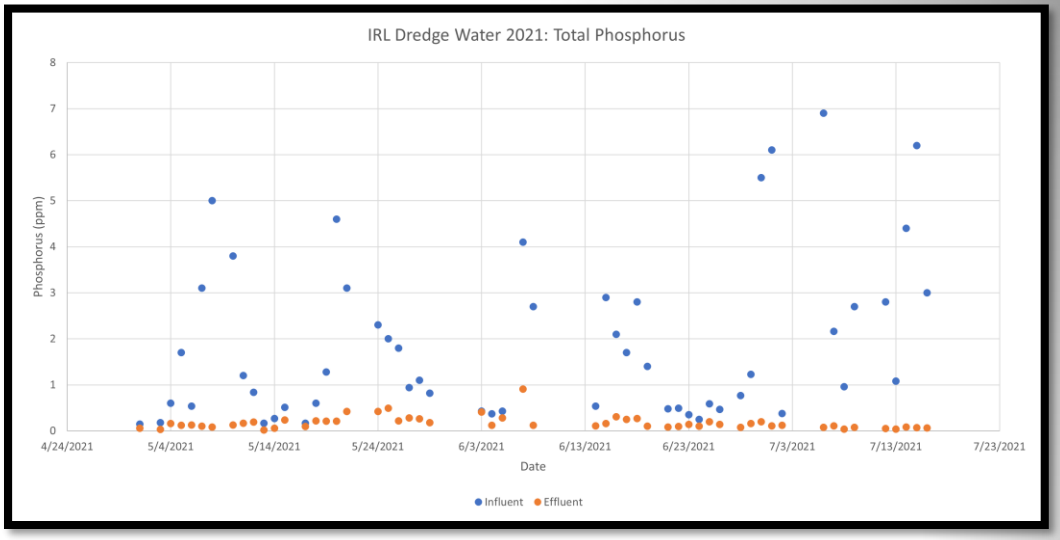


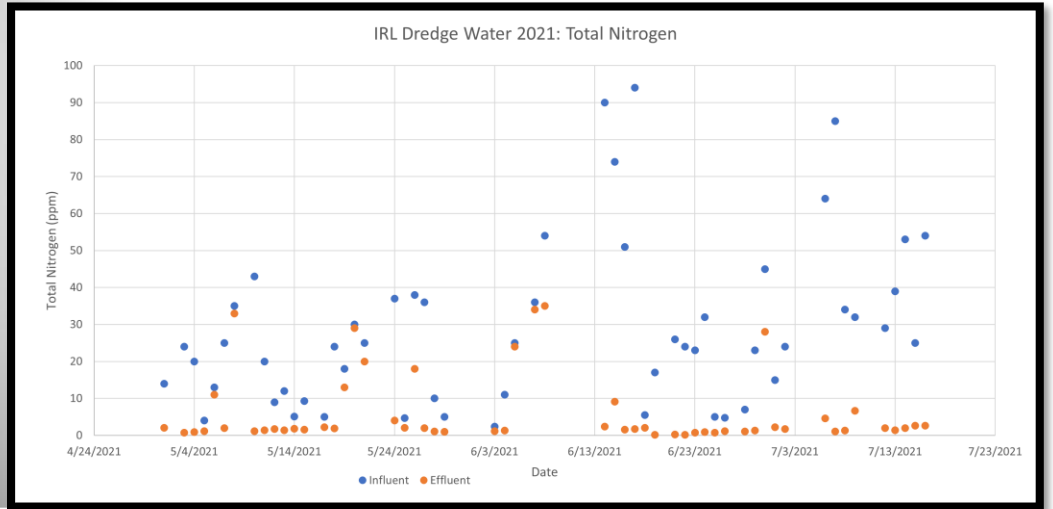
Estimated to remove 10,000 lbs. N per mth.



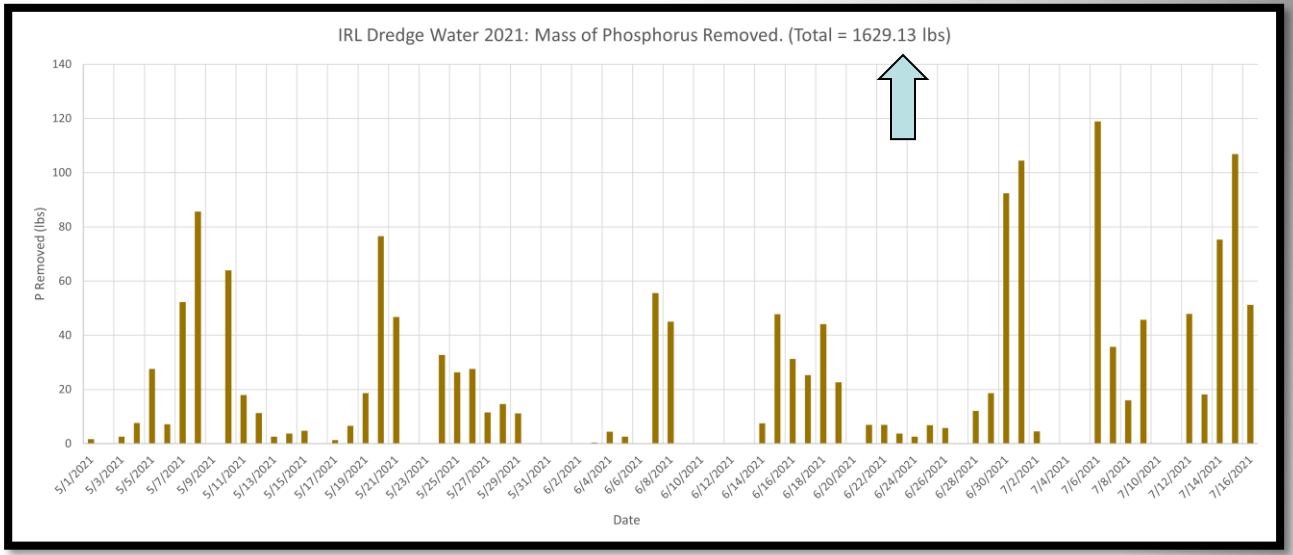
N & P in Dredge Water Before and After Treatment with Ferrate

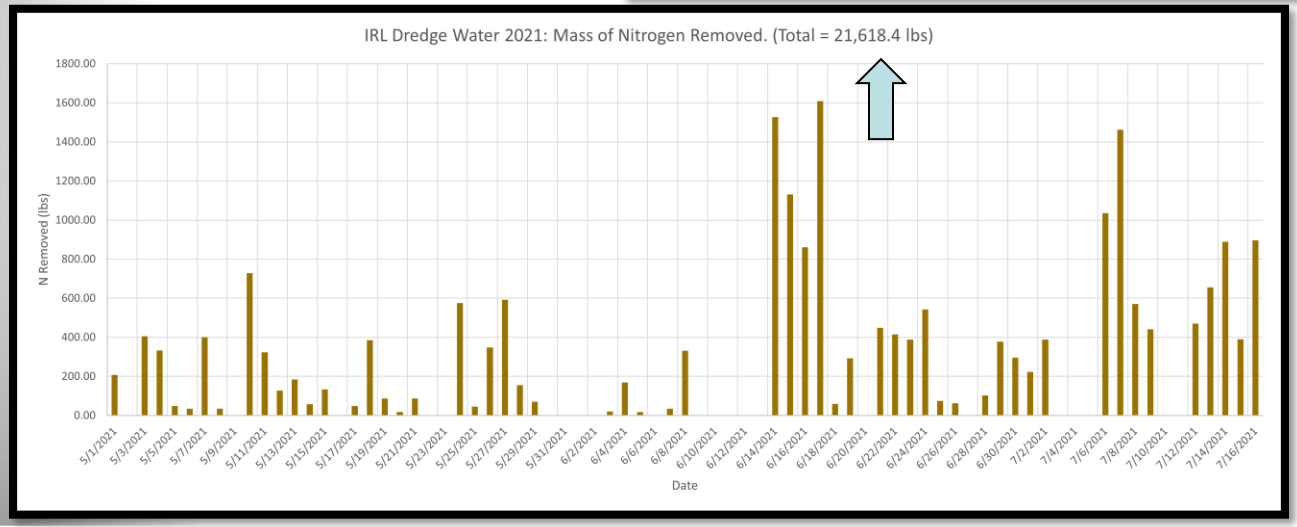
-Recent Data-





Mass of N & P Removed in 2.5 Months





Speaking of Nutrient Removal

Table 1 - Amounts and Costs ($/lb) of Nutrients (N & P) Removed from the Indian River Lagoon Environment by Different Approaches. (*From: The Save the Lagoon Plan, prepared by Tetra Tech Inc. & CloseWaters LLC, for Brevard County, FL)*

Plan Activity	*Pounds of P Removed / yr*	*Removal Cost $/Pound P*	*Pounds of N Removed / yr*	*Removal Cost $/Pound N*
Fertilizer Management & Public Ed.	813	$769	6,123	$102
Muck Removal	----------	----------	491,300	$401
Stormwater Management Projects	17,026	$612	118,440	$88
Constructed Oyster Reef & Living Shores	7,181	$1,393	21,120	$473
Sewage Trt Plant Upgrades	----------	----------	40,778	$214
Septic Tank Removals	----------	----------	56,509	$852
Septic Tank Upgrades	----------	----------	27,659	$802

What-Where-why-How Much ??

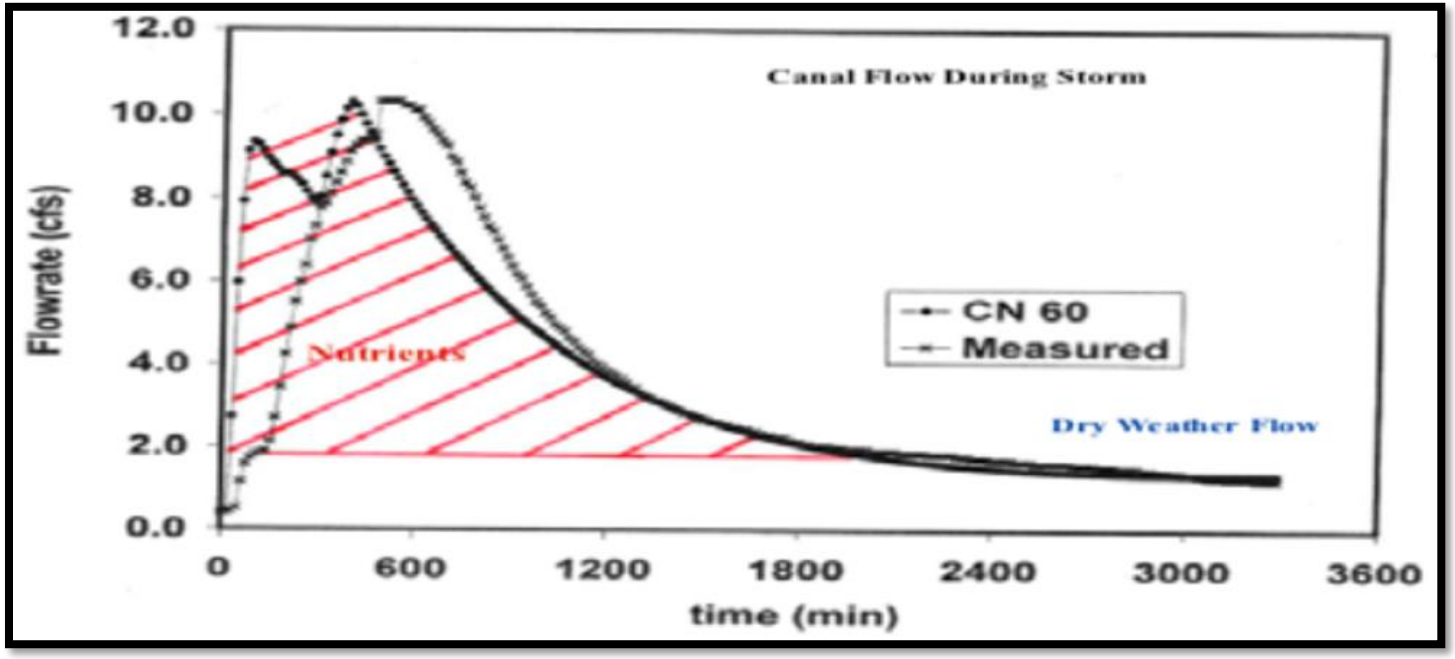
Impacts of Environmental Muck Dredging at Florida Institute of Technology 2017-2018, Final Report, December 2019

Mean annual inputs of total N and P (2016, 2017) from the four major tributaries were within 25% of estimated benthic fluxes of N (300 tons) and P (45 tons) from muck sediments in the North IRL (north of Melbourne Causeway, State Road 192). Very high PO_4^{3-} fluxes, concurrent with low N+N and NH_4^+ fluxes, were observed in the St. Sebastian River (South Prong) during large rain events when pH was < 7; this observation is likely due to remobilization of phosphate minerals. In most cases, >70% of the TN and TP were delivered to the IRL during above-median flow that occurred on ~120 days per year. These results confirm the importance of continuing a fertilizer ban during the June- improve estimates of continuous water flow

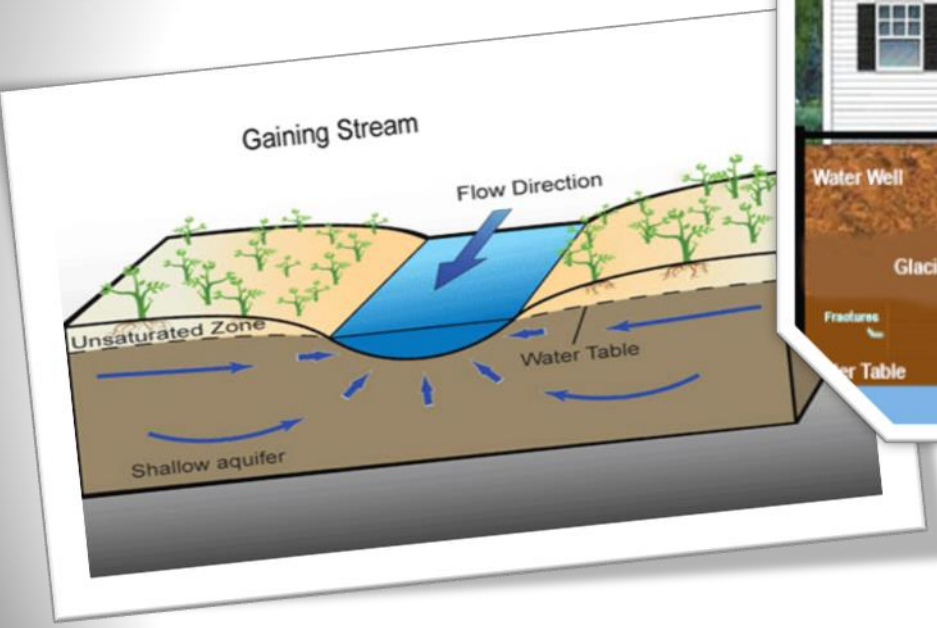
Table ES1. Fluxes of total nitrogen (N) and total phosphorus (P) from major tributaries of the Indian River Lagoon.

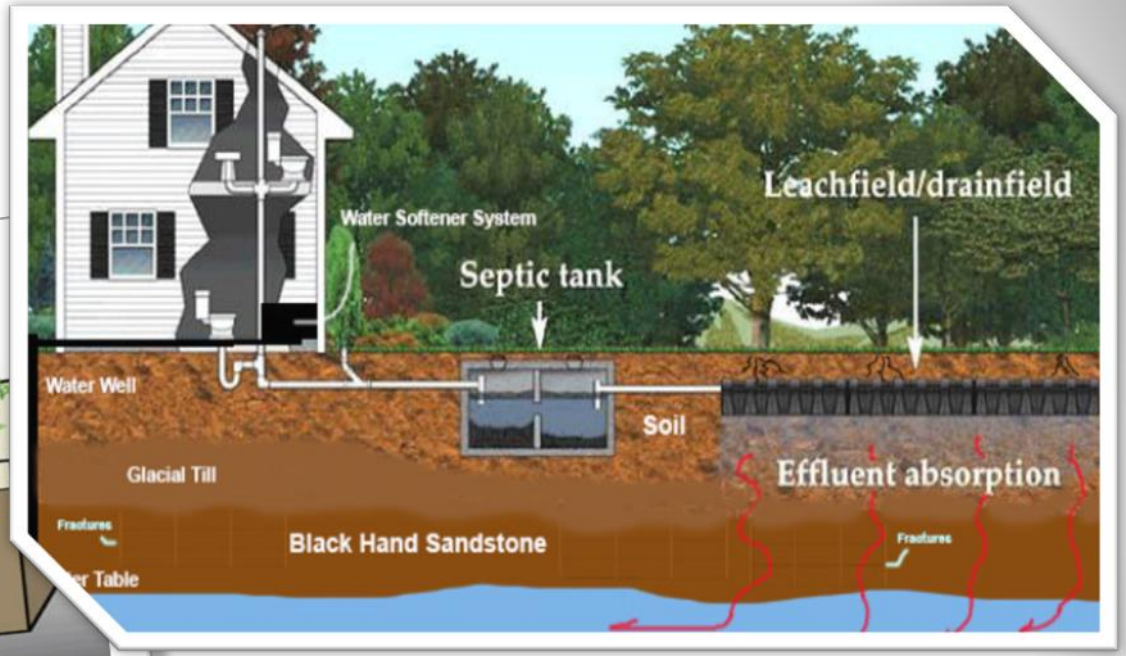
Tributary	Total N (tons/y)		Total P (tons/y)		Mean Flow (CFS)		Drainage Area (km^2)
	2016	2017	2016	2017	2016	2017	
Eau Gallie River (EG)	10	14	2.5	3.7	11	17	24
Crane Creek (CC)	24	27	3.4	3.8	32	35	48
Turkey Creek (TC)	164	162	11	11	211	210	254
St. Sebastian River So. Prong (SR)	108	184	19	57	111	165	91
Total	306	387	36	76	365	427	417

Nutrients & Contaminates are Concentrated in the STR Event up to 10X, but low Concentrations are Present in Dry-Weather flow.



Septic Tanks Leach to Groundwater, then to Canals





Removal of Nutrients and SS from Canals During Storm Events to Prevent Muck Formation in the IRL

Sludge from Ferrate Treated Muck Dredge Water Tested as Soil Conditioner / Fertilizer

Thank You

td@ferrate-solutions.com