Energy & Nutrient Optimization of North North Carolina wastewater treatment plants: "Wastewater Excellence"

Webinar for North Carolina Wastewater Operators
April 29, 2021
10:00 - 11:45 AM

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Webinar Housekeeping

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Energy & Nutrient Optimization
of NC Municipal Wastewater Treatment Plants

Biological Nitrogen Removal, Parts 1&2

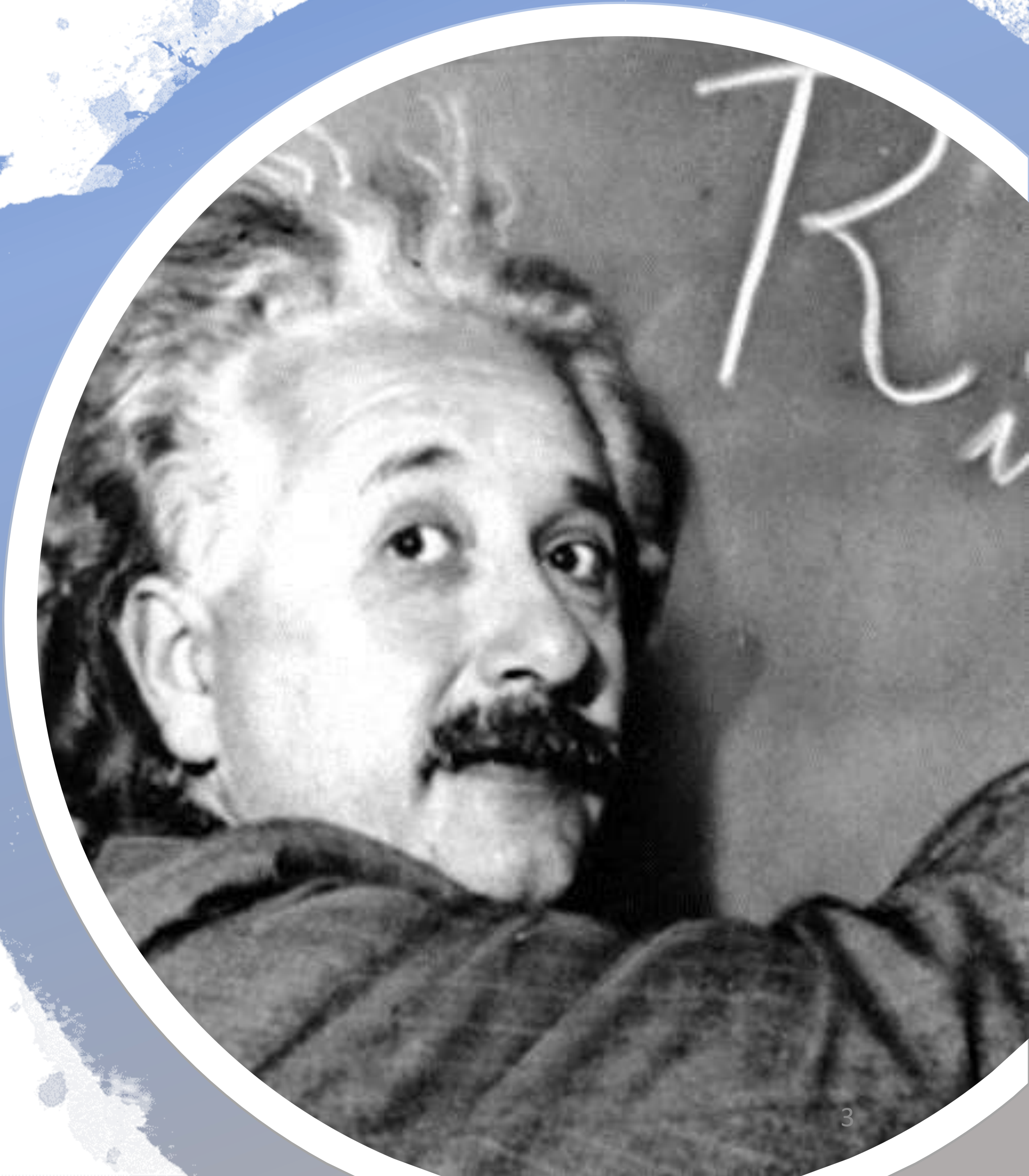
Activated Sludge, Parts 1&2

Biological Phosphorus Review, Parts 1&2

North Carolina Case Studies, Parts 1&2

Energy Management, Parts 1&2

Today: Wastewater Excellence in North Carolina - an Overview



Introducing a new way of thinking:

Facility upgrades aren't the only way to get nutrient removal…

Empowered operators achieve amazing results!

Lessons Learned

Biological Nitrogen Removal: 10 mg/L at many (most) activated sludge wwtps

Biological Phosphorus Removal: 1.0 mg/L at many (most) activated sludge wwtps

Many (most) wwtps can reduce their electric bill

Tools are available:

- Bio-Tiger Model
- Nutrient and Energy Assessment Tool
- Nutrient Removal Study Guides
- Course website
- …and much more

It takes knowledge and courage to transition from PERMIT COMPLIANCE to WASTEWATER EXCELLENCE

7

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Nitrogen

Biological Nitrogen Removal:

Convert LIQUID to GAS …

BOD and TSS Removal:

Convert LIQUID to SOLID …

Step 1: Convert Ammonia (NH_4) to Nitrate (NO_3)

Oxygen-rich Aerobic Process
Don’t need BOD for bacteria to grow
Bacteria are sensitive to pH and temperature

Step 2: Convert Nitrate (NO_3) to Nitrogen Gas (N_2)

Oxygen-poor Anoxic Process
Do need BOD for bacteria to grow
Bacteria are hardy

Phosphorus

15

P

30.974

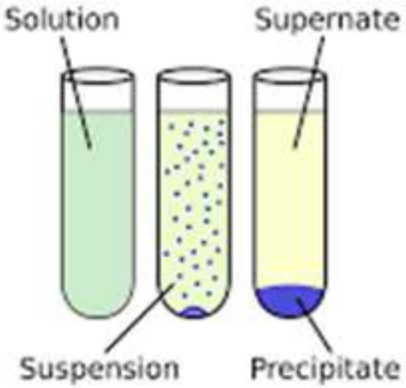
Phosphorus Removal:
What an Operator needs to know

ONE. Convert soluble phosphorus to TSS (total suspended solids)…

Biologically

Chemically

TWO. Remove TSS



Biological Phosphorus Removal

Step 1: prepare "dinner"

VFA (volatile fatty acids) production in anaerobic/fermentive conditions

Step 2: "eat"

Bio-P bugs (PAOs, "phosphate accumulating organisms") eat VFAs in anaerobic/fermentive conditions … temporarily releasing more P into the water

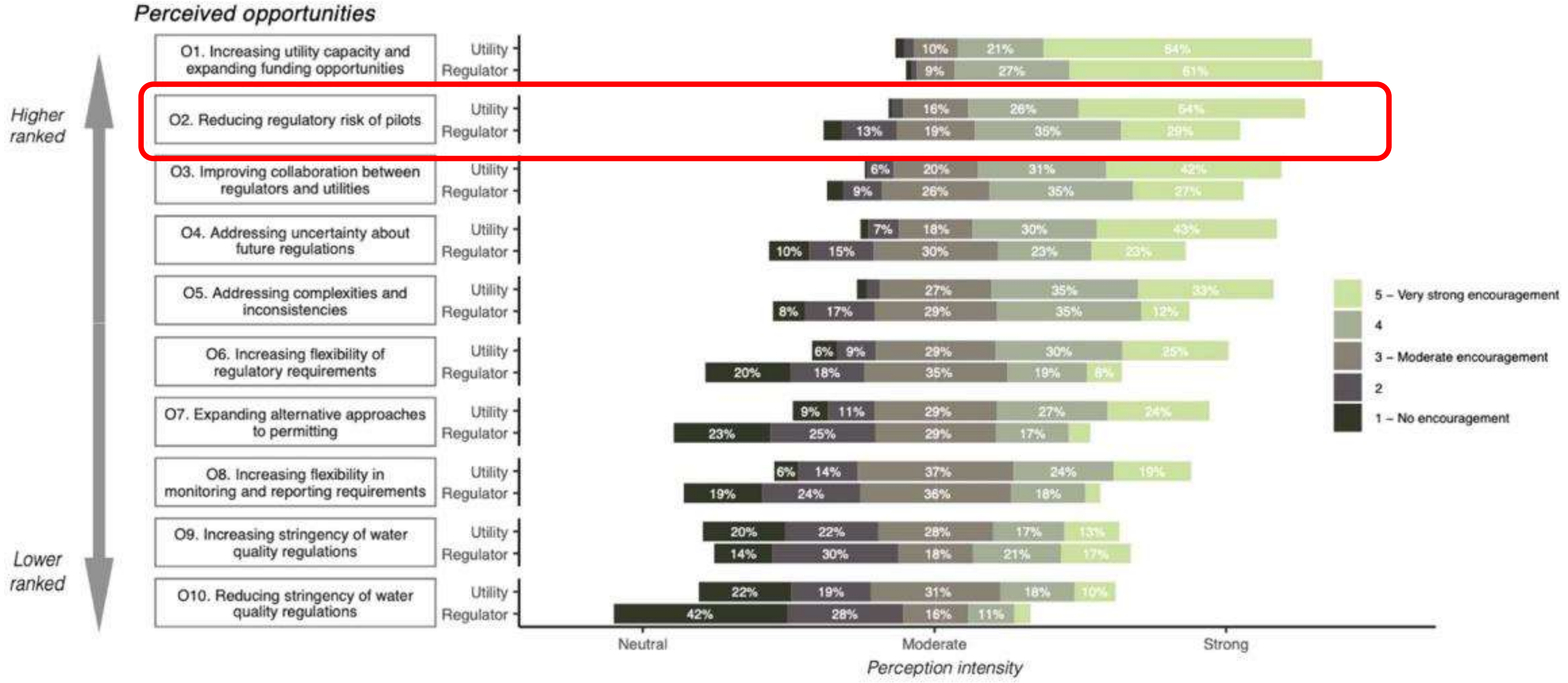
Step 3: "breathe" and grow

Bio-P bugs (PAOs) take in almost all of the soluble P in aerobic conditions as they grow and reproduce

First steps for nutrient optimization

- Expand your toolkit for process control sampling
  - Test strips (ammonia, nitrite/nitrate, alkalinity)
  - Spectrophotometer (ammonia, nitrite/nitrate, orthophosphate)
  - Portable DO / ORP meters
  - In-line DO meter
  - Additional in-line instruments (ammonia, orthophosphate …)
- Manage Regulatory Risk
  - Communication
  - Documentation
  - Ask for help

More on Regulatory Risk…



From Cantor, et al (2021), “Regulators and Utility Managers Agree about Barriers and Opportunities for Innovation in the Municipal Wastewater Sector”

The landscape is changing…

- Some states are requiring optimization as an intermediate step toward nutrient limits
- Other states are offering "safe harbor" letters of support after review of optimization plans, outside of the permitting process
- Any state will require advance communication and strong documentation throughout

Energy Management at Municipal WWTPs

Session Topics:

Organize an Energy Management Program

Energy Vocabulary Literacy

Utility Billing – Understanding your billing

Baseline Data & Tracking (at utility billing level)

Benchmarking

Plant Survey & Evaluations:

Common BMPs for Energy Management

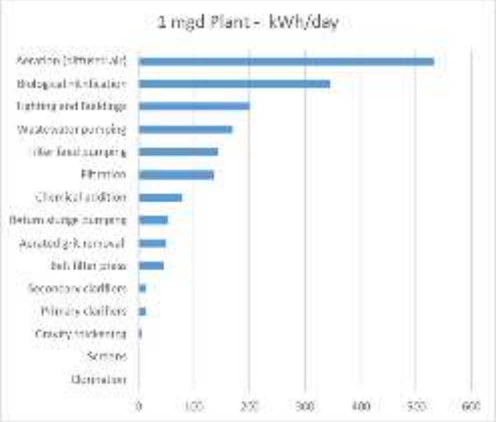
Renewables

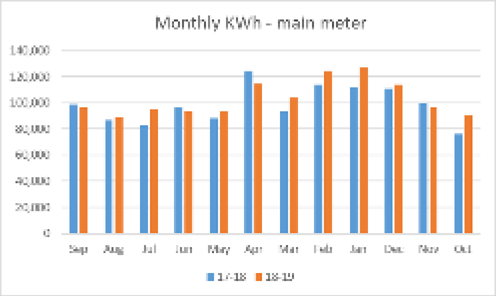
OWASA: Energy Management Case Example – Mary Tiger

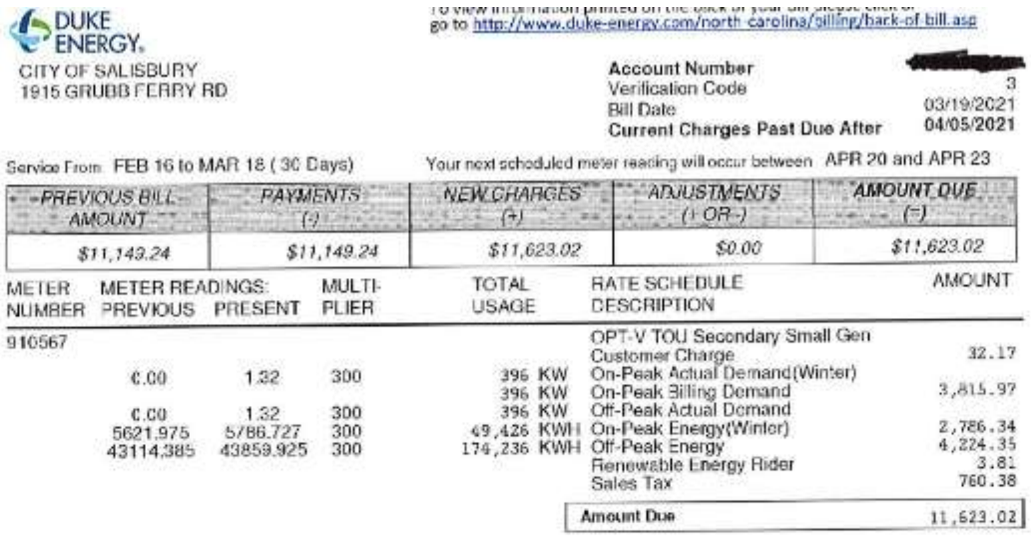
Resources for Taking the Next Step

Key Takeaways

- Get Familiar with Utility Billing
- Start Tracking Energy Use and Cost Monthly – Make this a KPI!
- Conduct a Plant Assessment for an Energy Balance
- Reach out to Available Resources for Help: Utility, WRP, RWA, Others
- ID Energy Saving Opportunities – Start with no & low cost
- Make your plan!







DUKE ENERGY.

go to http://www.duke-energy.com/north carolina/billing/back-of bill.asp

CITY OF SALISBURY
1915 GRUBB FERRY RD

Account Number [redacted]
Verification Code 3
Bill Date 03/19/2021
Current Charges Past Due After 04/05/2021

Service From FEB 16 to MAR 18 (30 Days)   Your next scheduled meter reading will occur between APR 20 and APR 23

PREVIOUS BILL AMOUNT	PAYMENTS (-)	NEW CHARGES (+)	ADJUSTMENTS (+ OR -)	AMOUNT DUE (=)
$11,143.24	$11,149.24	$11,623.02	$0.00	$11,623.02

METER NUMBER	METER READINGS: PREVIOUS	PRESENT	MULTIPLIER	TOTAL USAGE	RATE SCHEDULE DESCRIPTION	AMOUNT
910567					OPT-V TOU Secondary Small Gen	
					Customer Charge	32.17
	0.00	1.32	300	396 KW	On-Peak Actual Demand(Winter)	
				396 KW	On-Peak Billing Demand	3,815.97
	0.00	1.32	300	396 KW	Off-Peak Actual Demand	
	5621.975	5786.727	300	49,426 KWH	On-Peak Energy(Winter)	2,786.34
	43114.385	43859.925	300	174,236 KWH	Off-Peak Energy	4,224.35
					Renewable Energy Rider	3.81
					Sales Tax	760.38

Amount Due 11,623.02

Resources to take the next step

- Duke Energy: Business Energy Advisors and Large Account Reps
- Dominion Energy: RNG Projects (Lee McElrath, Dominion Energy, NC 828-230-7118)
- Your Local COOP/Municipal Utility Reps
- Your Peer Networks: PWOC-WEF
- Your Consulting Engineers
- State Clean Water Grant Sources: Green Project Reserve
- Advanced Energy: Kitt Butler, kbutler@advancedenergy.org
- Energy Efficiency Assessment Providers:
  - Waste Reduction Partners (serving all of NC)
    - Russ Jordan, Energy Manager, rjordan@wrpnc.org, (828) 251-7477
  - NC Rural Water Association (serving populations <10,000)
    - Natalie Narron, Energy Efficiency Circuit Rider, natalienarron@ncrwa.org, (336) 887-0741
- EPA: Brendan Held & Team Held.Brendan@EPA.gov

Waste Reduction Partners – Energy Assessments

- *Land of Sky's WRP program provides no-cost energy efficiency and waste assessments.*
- *<u>Clients:</u> Any water/wastewater plant, business or institution in NC.*
- *<u>The Team</u>: 40 staff and volunteer engineers (statewide)*
- *Past energy work with: Asheville Water Resources Department, Town of Salisbury, Town of Boone, Cape Fear Public Utility Authority, Kerr Lake, and others*
- *<u>Results:</u> –past 5 years: 275 clients served, $16.4 million in utility cost savings, 130,000 MWh saved*
- *<u>Initiate a Project</u>: WasteReductionPartners.org or Russ Jordan rjordan@wrpnc.org*

LAND OF SKY REGIONAL COUNCIL

WRP Waste Reduction Partners

Pilot Plant Updates

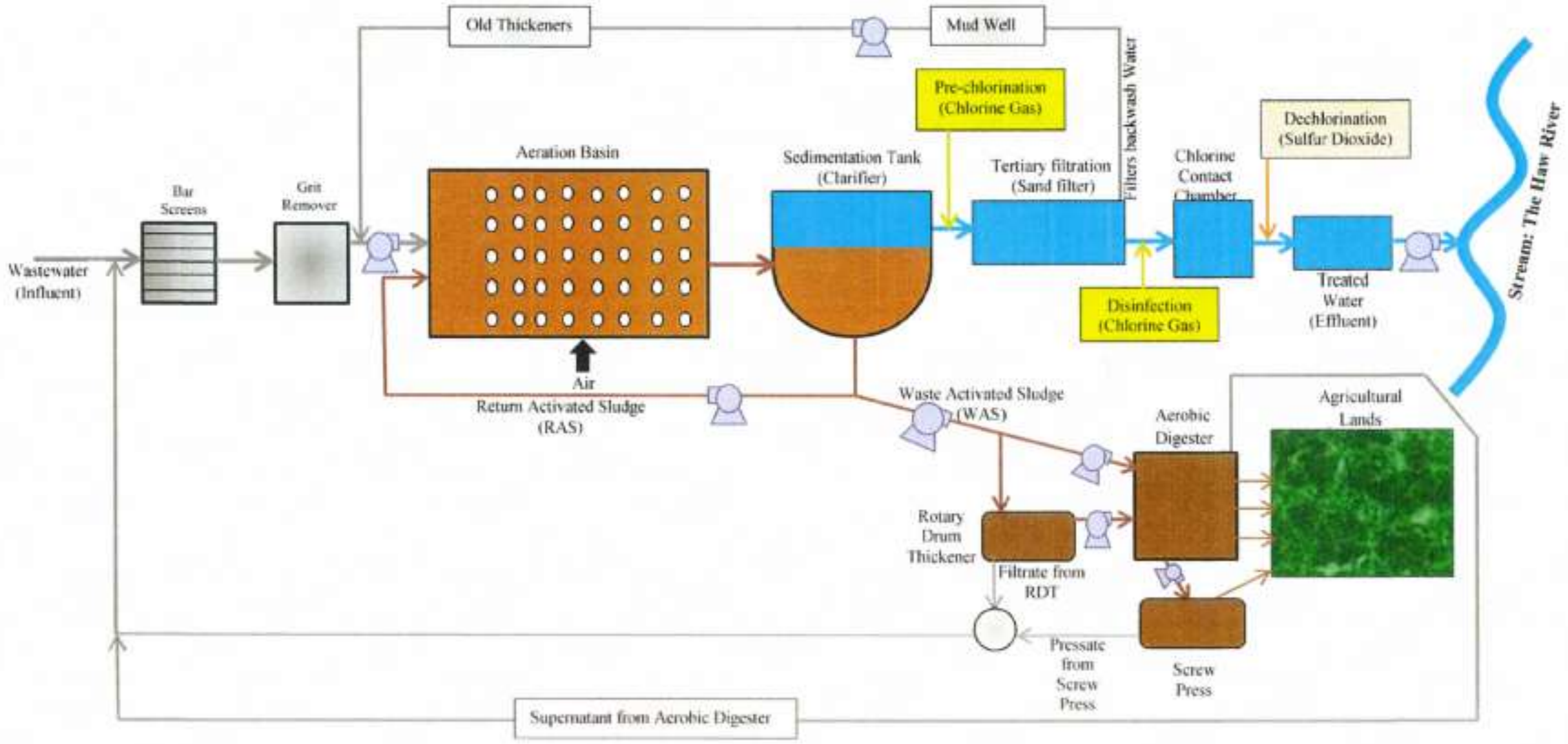
Eden
Reidsville
Yanceyville
Norlina
Warrenton
Roanoke Rapids
Gatesville
Elizabeth City
Southern Shores
Kill Devil Hills
Manteo
Boone
Winston-Salem
Kernersville
Greensboro
Durham
Hertford
Edenton
Hot Springs
Marshall
Lenoir
Morganton
Statesville
Newton
Asheboro
Carrboro
Cary
Raleigh
Wake Forest
Rocky Mount
Tarboro
Windsor
Plymouth
Asheville
Maggie Valley
Waynesville
Mooresville
Kannapolis
Concord
Albemarle
Sanford
Smithfield
Garner
Apex
Wilson
Greenville
Belhaven
Sylva
Brevard
Franklin
Andrews
Murphy
Highlands
Shelby
Gastonia
Charlotte
Matthews
Monroe
Southern Pines
Fayetteville
Mount Olive
Kinston
Vanceboro
Bayboro
New Bern
Clinton
Roseboro
Pink Hill
Kenansville
Richlands
Havelock
Jacksonville
Beaufort
Morehead City
Laurinburg
Lumberton
Rowland
McDonald
Boardman
Atkinson
Clarkton
Wallace
Rose Hill
Whiteville
Emerald Isle
Holly Ridge
Surf City
Wilmington
Wrightsville Beach
Tabor City
Shallotte
Carolina Beach
US Highways
Interstate Highways
0
50 KM
50 Miles
© geology.com

Reidsville

Reidsville, North Carolina Population: 14,000 7.5 MGD design flow

Google

Section 2: Treatment Process Flow Diagram



Reidsville's Action Plan

Phosphorus:

- Already achieving excellent removal, often < 1.0 mg/L
- No additional steps at this time

Nitrogen:

- Effluent currently ~10 mg/L
- After diffuser repairs, consider turning off blowers for 1 hour each morning
- Monitor NH_3 and NO_3
- Consider additional 1 hour off cycle in the afternoon
- Continue monitoring performance
- Consider additional off cycles up to four 90-min cycles per day

Scott Bryan
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Eden Mebane Bridge
CleanB
bcrinc.com
866-724-9145
BCR
Solid Solutions
CAC

Eden, North Carolina Population: 15,000 13.5 MGD design flow

Eden's Action Plan

Phosphorus:

- Already achieving excellent removal, partially due to alum sludge from WTP
- No additional steps at this time

Nitrogen:

- Effluent currently ~10-12 mg/L
- Continuing cycling off 6 of 12 aerators during peak billing hours
- Increase # of "off" aerators to 9, starting 1 hr/d, increase weekly
- Process control sampling for effluent NH_3 and NO_3
- Goal is 8 mg/L TN or less

BioTiger Modeling (Summer months)

Assumptions:

- Alum sludge from WTP means higher than normal inert solids
- Average DO concentration throughout basin is less than DO measured at effluent
- Oxygen supply:
  - 12 x 20 HP aerators running for 16.25 hrs/d
  - 6 x 20 HP aerators running for 7.75 hrs/d
  - This is 4830 HP-hr of aeration per day, so, 201 HP over 24 hrs.
- Plant is fully nitrifying, partially denitrifying
- WAS TSS = RAS TSS

BioTiger Modeling (Summer months)

- Assumption:
  - Alum sludge from WTP means higher than normal inert solids

Activated Sludge Input Data	
Temperature (°C)	25
S_O (mg/L)	160
V (mil gal)	7
Q (mgd)	3.5
Inert VSS (mg/L)	30
Oxidizable N (mg/L)	20
biomass (VSS/TSS)	0.85
Influent TSS (mg/L)	200
Inert Inorg TSS (mg/L)	40
Effluent TSS (mg/L)	4
RAS TSS (mg/L)	4500

BioTiger Modeling (Summer months)

- Assumptions:
  - Average DO concentration throughout basin is less than DO measured at effluent
  - Oxygen supply:
    - 12 x 20 HP aerators running for 16.25 hrs/d
    - 6 x 20 HP aerators running for 7.75 hrs/d
    - This is 4830 HP-hr of aeration per day, so, 201 HP over 24 hrs.

Aerator Performance Data	
Operating DO concentration (mg/L)	1.5
alpha	0.84
beta	0.92
SOTR, lb O2 / hp-hr	2.7
Temperature (°C)	25
Aeration (hp) being operated	201
Elevation (ft)	600
Aerators operating time (hr/day)	24
Type of aerators (1, 2, or 3)	1
Speed of aerators (%)	100
Energy cost unit ($/kWh)	0.05

BioTiger Modeling (Summer months)

Assumptions:

- Plant is fully nitrifying, partially denitrifying
- WAS TSS = RAS TSS

Analysis:

- O2 supply is within range
- Projected NO3 (w/o any nitrification) is higher than actual NO3
- Will not likely reduce NO3 to 4 mg/L; lower bound of O2 demand unrealistic
- WAS Q ~50% lower than expected – needs further review

Approximate Operating Conditions	
Total average daily flow rate (mgd)	3.50
Aeration volume in service (mil gal)	7.00
Influent BOD5 concentration (mg/L)	160
Influent BOD5 mass loading (lb/day)	4,670
Sec ww Oxid N load (lb/day)	584
Sec ww TSS load (lb/day)	5,838
F/M ratio	0.066
Solids Retention Time (day)	46.0
MLSS (mg/L)	2,219
MLVSS (mg/L)	1,208
TSS Sludge Production (lb/day)	2,700
TSS in activated sludge effluent (lb/day)	116.8
Total Oxygen Requirements (lb/day)	8,313
Total Oxygen Req'd W/Denit. (lb/day)	7,448
Total oxygen supplied (lb/day)	8,003
Mixing intensity in the reactor (hp/mil gal)	29
RAS flow rate (mgd)	3.41
RAS recycle percentage (%)	97.3
WAS flow rate (mgd)	0.072
RAS TSS concentration (mg/L)	4,500
Total sludge production (lb/day)	2,816
Reactor Detention Time (hr)	48.0
VOLR (lb BOD/(thou cu ft-day))	4.99
Effluent CBOD5 (mg/L)	2.3
Effluent TSS (mg/L)	4.0
Effluent Ammonia-N (mg/L)	0.02
Effluent NO3-N (mg/L)	14.8
Effluent NO3-N W/denit (mg/L)	4.4

BioTiger Modeling (Summer months)

Assumptions:

- WWTP uses ~50% of total electric bill, shared w/ DW Plant

Analysis:

- Aerator electricity use = ~26% of bill, or about 50% of total WWTP
- This seems low for this facility - no aerobic digesters UV disinfection or effluent pumping

Field OTR (lb O2 / hp-hr)	1.66
Aerator energy use (kWh/month)	94,068
Energy cost ($/month)	4,703

	Dec 2020
Energy Used	351,286 kWh
Days in billing period	30
Average kWh per day	11,710 kWh
Average cost per day	$506.54

Questions?
Comments?

Melinda Ward
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Newton Clark Creek

Newton, North Carolina Population: 13,000 MGD design flow


Aeration Basin #3
Aeration Basin #4
Lime Grit Building
Primary Clarifier #1
Reactor Building
Aeration Basin #1
Primary Clarifier #2
Thickener Basins
#4
#3
#2
#1
Aeration Basin #2
Dewatering Building
Administration Building
Transfer Building
Switchgears
Generator
Chlorine Feed
Filter Building
Shop Building
Effluent Contact Basin
Backwash Basin
Recycle Building

Newton’s Action Plan

Phosphorus:

- Already achieving excellent removal (<1.0 mg/L avg)
- No additional steps recommended at this time

Nitrogen:

- Effluent TN currently ~25 mg/L with low NH_3
- Evaluate VFDs and SCADA upgrade to allow routine on/off cycling of aerators.
- Start with 90 min off/6 hrs on. Monitor NH_3 and NO_3, and use ORP to fine tune off cycle
- <u>Rough</u> estimate of cost savings: $40,000/year

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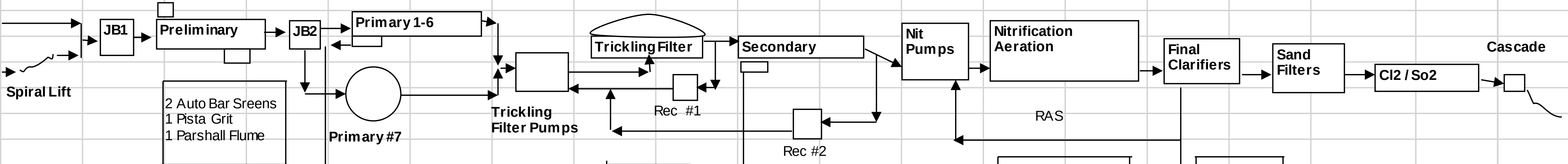
Stacy Rowe
srowe@newtonnc.gov


Asheboro

AVERAGES FOR 2020



6 Rectangle 1 Round Based on 9MGD 2.40 Hrs DT 756 gpd/sf overflow	4 Pumps 6 Mgd Each	3 TF Tanks 140 ft Dia	4 Sec Tanks 2.5 hrs DT 500 gpd/sf Overflow

4 Nit Pumps 7 MGD Each	2 Nit Basins 10 hr DT 6 40 hp Blow ers 2 300 hp Blow ers 1 85 hp Blow er	3 Final Clar. 5 Hr DT 400 gpd/sf Overflow	32 Top Feed Deep Bed Sand Filters

Influent

Flow Cap	**9 MGD**
Actual	4.583812

Construction Dates

Start	1962	3 MGD
Upgrade	1975	
Upgrade	1986	6 MGD
Upgrade	1996	9 MGD

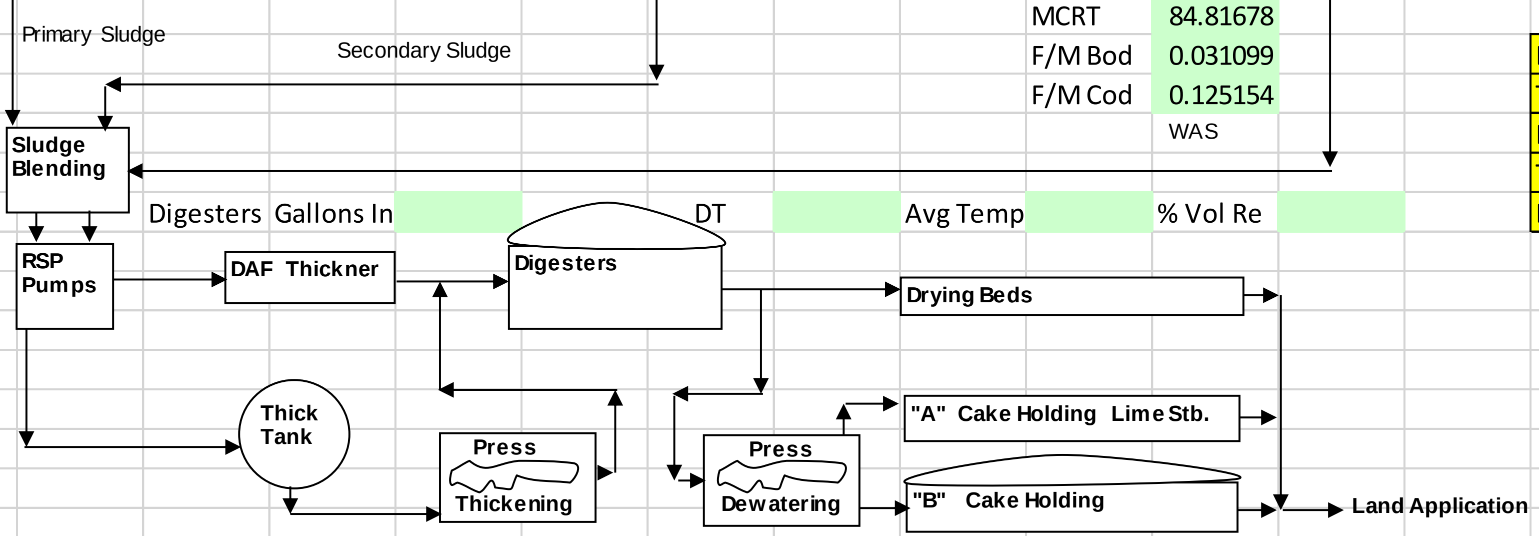
Sec SS	41.83472
Sec BOD	42.37137
Sec COD	170.3114

MLSS	2237.056
MLVSS	1673.289
RAS	7076.608
SA	58.75032
MCRT	84.81678
F/M Bod	0.031099
F/M Cod	0.125154

Eff Flow	4.223598
Eff SS	5.289267
Eff BOD	2.797907
Eff Nh3	0.169685

	INF	EFF
BOD	400 mg/l	2.80 mg/l
TKN	31.5 mg/l	1.75 mg/l
NO3+NO2	2.6 mg/l	11.1 mg/l
TP	5.5 mg/l	.34 mg/l
DO in Aeratio	1.8 mg/l	

Sludge Handling System
3 RSP Pumps 200 gpm
4 TSP Pumps 200 gpm
2 DSP Pumps 200 gpm
2 SFP Pumps 400 GPM
1 DAF 600 sf
2 Digesters 400,000 gal
1 Piston Pump 300 gpm
2 Ashebrook 1.5 Meter
Presses
16 Drying Beds
1 Covered Storage Bldg
1 Uncovered Storage
Land Application Permitt
1200 Dry Tons / Year



Digesters Gallons In		DT		Avg Temp		% Vol Re	

Gallons		Gallons	
% Poly		%Poly	
% Thick		% Cake	

TRUCK LOADS

TOTAL CUBIC YARDS PRESS= 0

Previous Optimization Efforts

- Successfully proved we can BNR, more work to do to meet expected permit limits
- Air on for only 12 hrs instead of 24 hrs, huge savings
- Saving in pH adjusting chemical costs because denitrification process recovers pH and alkalinity
- We know what is happening in real time and can react accordingly

Asheboro’s Action Plan

Phosphorus:

- Already achieving excellent removal (<1.0 mg/L avg)
- No additional steps recommended at this time
- Long term, consider using intermediate clarifier as side stream fermented

Nitrogen:

- Managing good TN removal using sugar water supplied by cereal manufacturer
- “Reach” goals include routine flooding of trickling filters to eliminate need for off-site carbon
- Consider using intermediate clarifier as side stream fermenter for additional Bio-P

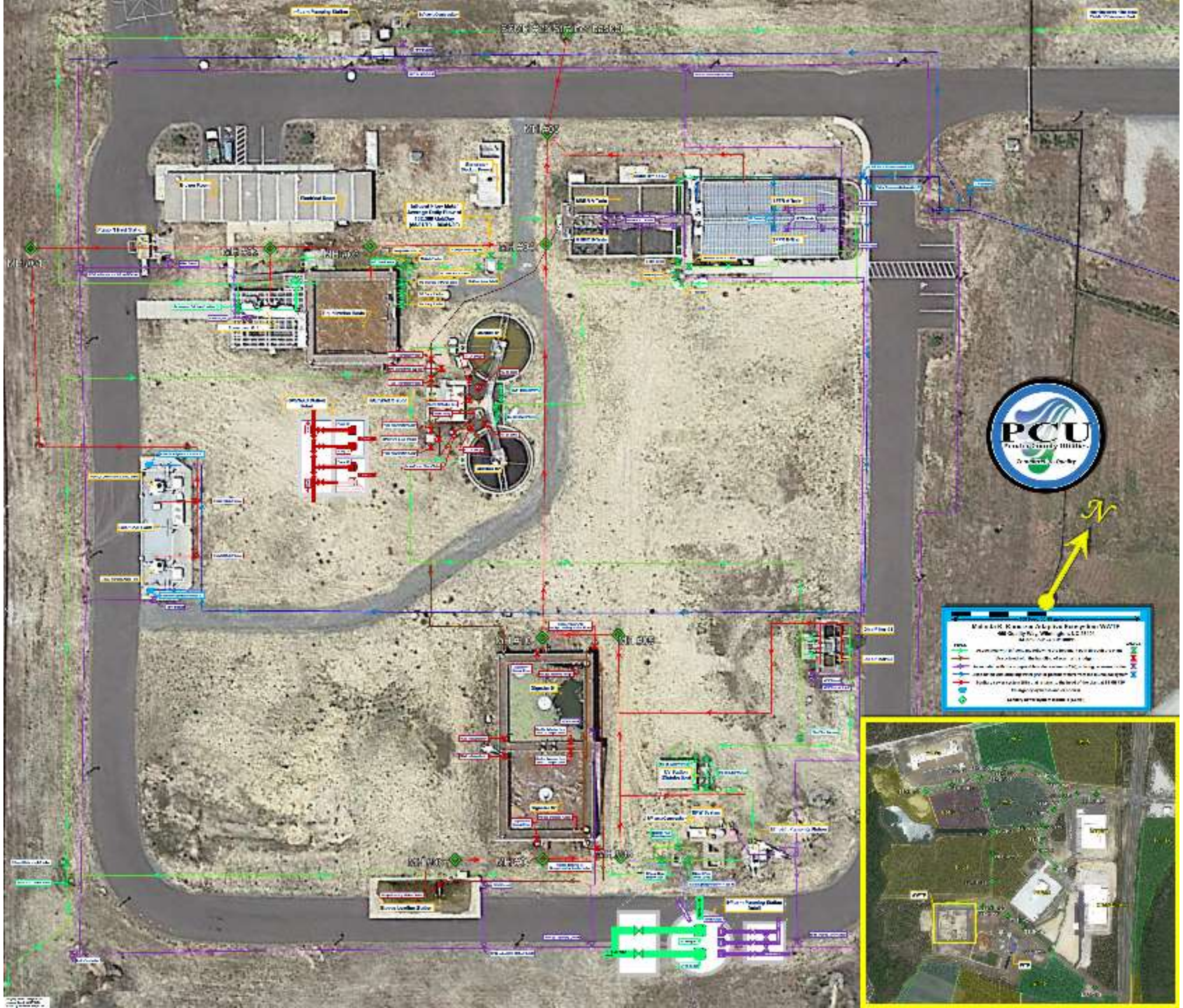
Mike Wiseman
mwiseman@ci.Asheboro.nc.us

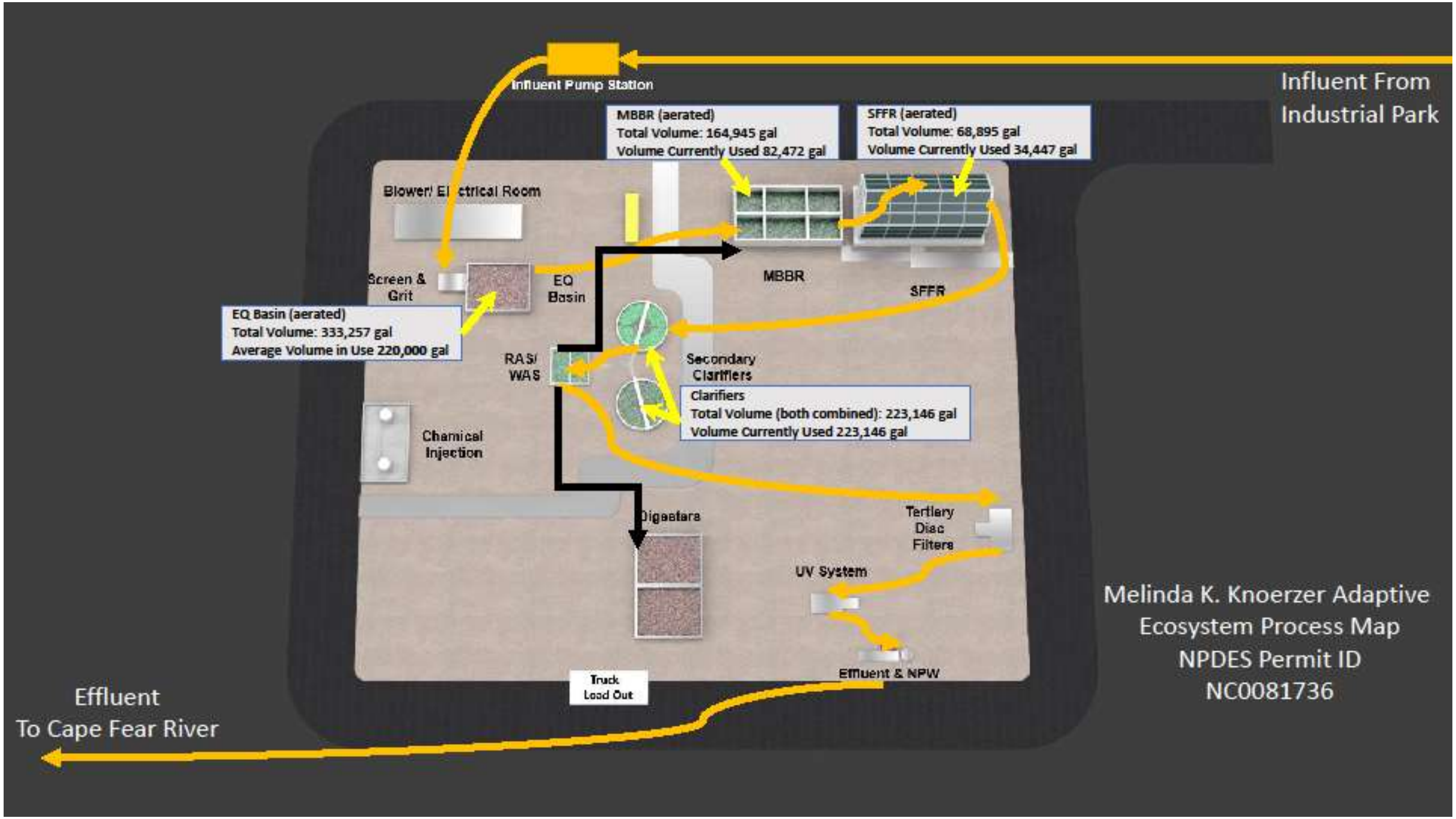

BREAK TIME

Pender County, North Carolina

0.5 MGD design flow

Date	M3 MLSS	MLVSS	INF BOD (mg/l)	INF Flow (MGD)	F/M Ratio	HRT	Aeration Basin DO	INF Ammonia (mg/L)	INF Tphos (mg/L)	INF COD (mg/L)	EFF COD (mg/L)	EFF TSS (mg/L)
12/8/20	3500	1883	454	0.09	0.07	82	3.9	8.97	21.25	2886	43	8
12/9/20	3400	2360	999	0.12	0.16	62	5.1					8
12/10/20	3000	2075	957	0.14	0.21	53	4.3	4.21	10.75	2100	46	8
12/15/20	1650	1075	981	0.13	0.38	57	7.5	7.85	20	2114	91	24
12/16/20	1660	1220	1020	0.13	0.35	57	7.2					17
12/17/20	2040	1500	705	0.11	0.17	67	6.4	4.16	11.5	2078	82	14
12/21/20	3360	2400	234	0.09	0.03	82	4.8					4
12/22/20	3720	2540	595	0.13	0.10	57	4.1	6.34	46.25	1196	102	3
12/23/20	3800	2380	660	0.14	0.13	53	4.5					5
12/30/20	4420	2860	729	0.15	0.12	49	6.4					7
12/31/20	4075	2800	1110	0.15	0.19	49	4.7					2.5
1/5/21	2760	1660	451	0.18	0.16	41	5.3	4.14	16.5	1140	31	3
1/6/21	2540	1600	775	0.18	0.28	41	6.9					2.5
1/7/21	2680	1780	576	0.15	0.16	49	5.9	3.97	10.75	1316	49	2.5
1/12/21	3360	2120	320	0.17	0.08	44	7	3.65	47.25	1348	39	3
1/13/21	4140	2240	395	0.18	0.10	41	4.8					5
1/14/21	4340	2580	332	0.18	0.07	41	6.4	2.95	46.5	1498	48	4
1/19/21	2920	1680	350	0.17	0.11	44	7.5					4
1/20/21	1800	980	405	0.17	0.23	44	5.6					5
1/21/21	1580	4400???	533	0.18	0.07	41	6.7					4
1/26/21	1840	1220	750	0.22	0.44	34	7.1	4.75	63.25	1914	57	2.5
1/27/21	2200	1380	406	0.22	0.21	34	5.2					3
1/28/21	2120	1100	479	0.23	0.32	32	7.2	3.01	6.5	2550	39	3
2/2/21	2700	1340	897	0.22	0.48	34	6.7	10.3	100.25	4050	61	6
2/3/21	3040	1540	721	0.21	0.32	35	6					8
2/4/21	2100	1140	649	0.20	0.37	37	6.5	2.24	9.25	1282	37	4
2/9/21	3820	2300	183	0.19	0.05	39	5.3	2.83	22.75	874	18	2.5
2/10/21	3180	1920	277	0.20	0.09	37	5.9					2.5
2/11/21	2160	1380	290	0.20	0.14	37	6.3	1.46	5.25	784	25	2.5
2/16/21	1320	960	487	0.23	0.38	32	6.4	1.88	7	1018	24	2.5
2/17/21	1920	1260	334	0.23	0.20	32	6.7					2.5
2/18/21	1540	1020		0.22		34	6.1	3.5		1096	26	2.5
Averages	2771	1751	582	0.17	0.20	46	6.0	4.48	27.8	1720	48	5.5

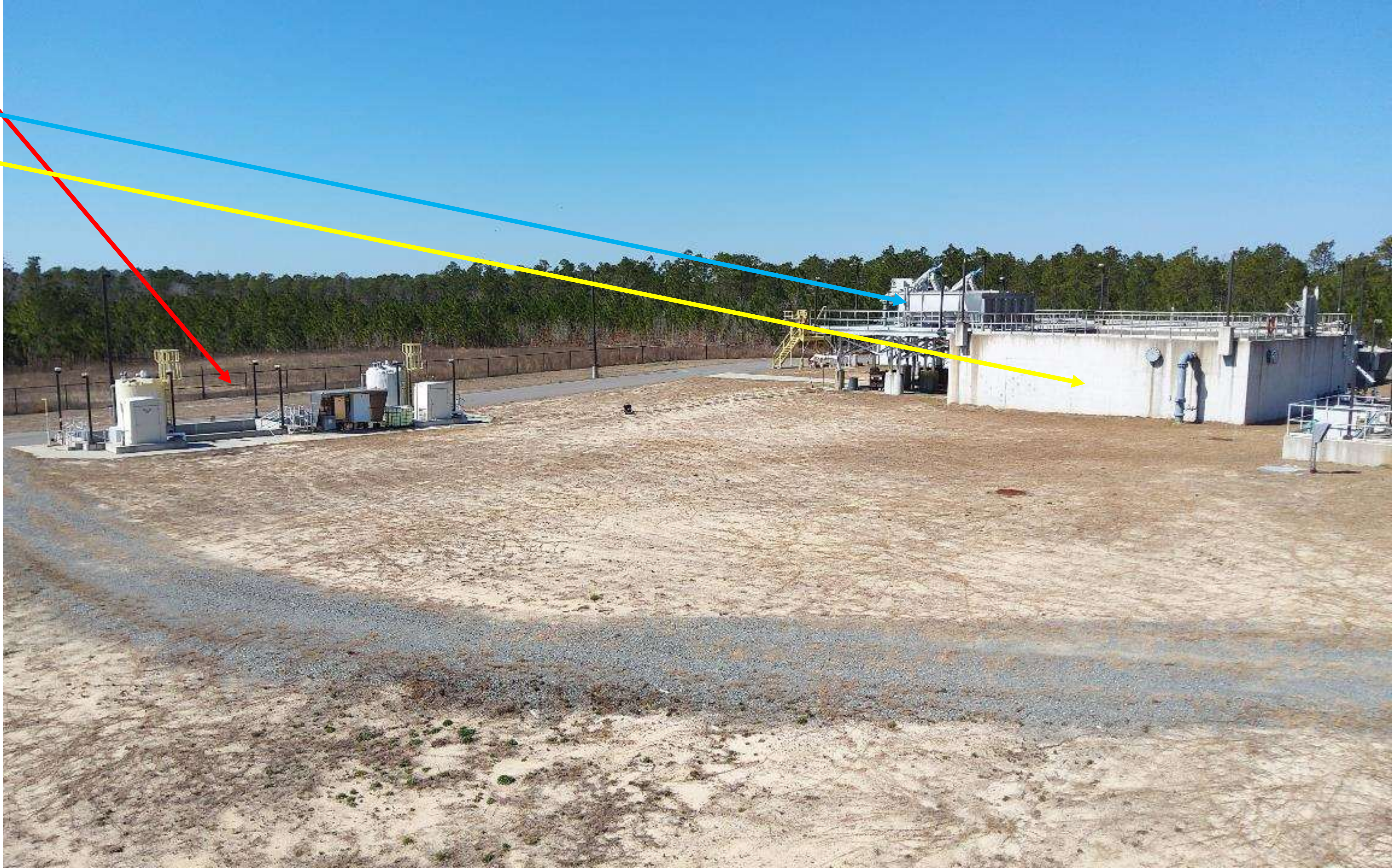



Influent Pump Station
Influent From
Industrial Park
MBBR (aerated)
Total Volume: 164,945 gal
Volume Currently Used 82,472 gal
SFFR (aerated)
Total Volume: 68,895 gal
Volume Currently Used 34,447 gal
Blower/ El ctrical Room
Screen &
Grit
EQ
Basin
MBBR
SFFR
EQ Basin (aerated)
Total Volume: 333,257 gal
Average Volume in Use 220,000 gal
RAS/
WAS
Secondary
Clarifiers
Clarifiers
Total Volume (both combined): 223,146 gal
Volume Currently Used 223,146 gal
Chemical
Injection
Digesters
Tertiary
Disc
Filters
UV System
Effluent & NPW
Truck
Load Out
Effluent
To Cape Fear River
Melinda K. Knoerzer Adaptive
Ecosystem Process Map
NPDES Permit ID
NC0081736

A View of the greenhouse and the office and lab inside the greenhouse.

A View of the influent pumping station

A View of the chemical farm, screen and grit station, and the EQ basin.



A View of the Screen and grit station. EQ basin is off camera to the right.

A View of the EQ basin from the screen and grit station (off camera behind).

A View of the MBBR with the EQ basin and the secondary clarifiers in the background. Note the black bio-media in the water. These “bio-balls” provide the surface area for additional bacterial growth. Media pictured below.

Left to right: EQ basin, secondary clarifiers, RAS/WAS station, MBBR, lab/office, greenhouse/ SFFR.

A View of the interior of the greenhouse / SFFR

A View of the secondary clarifiers with the digesters background left. And RAS/WAS station behind, and to the right of the clarifiers.

A View of secondary clarifier 2.

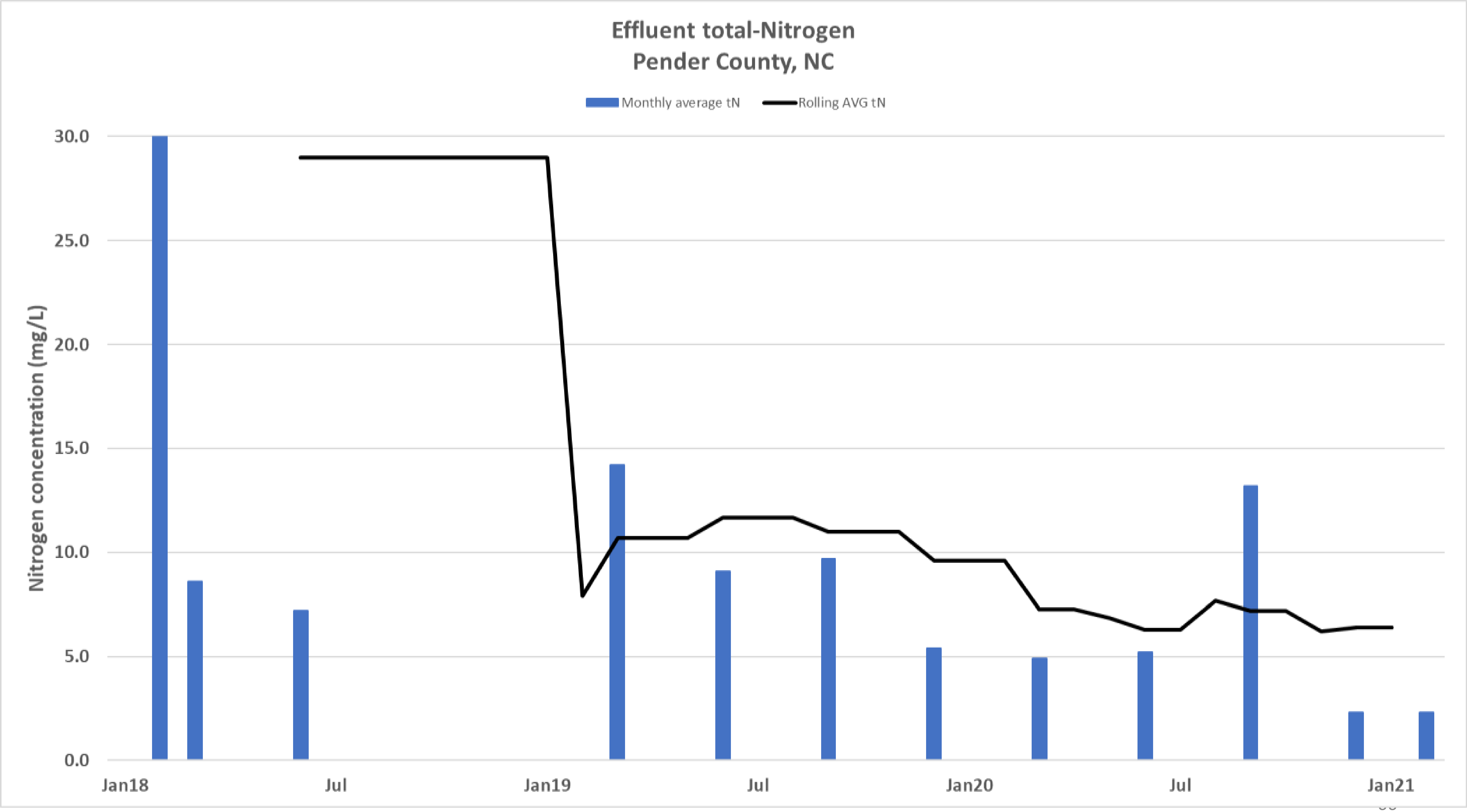
A View of secondary clarifier 1 with the MBBR in the background (right).

A View of the Tertiary filters (left) and the UV disinfecting units (right) with the effluent pump and non-potable water stations behind the UV.

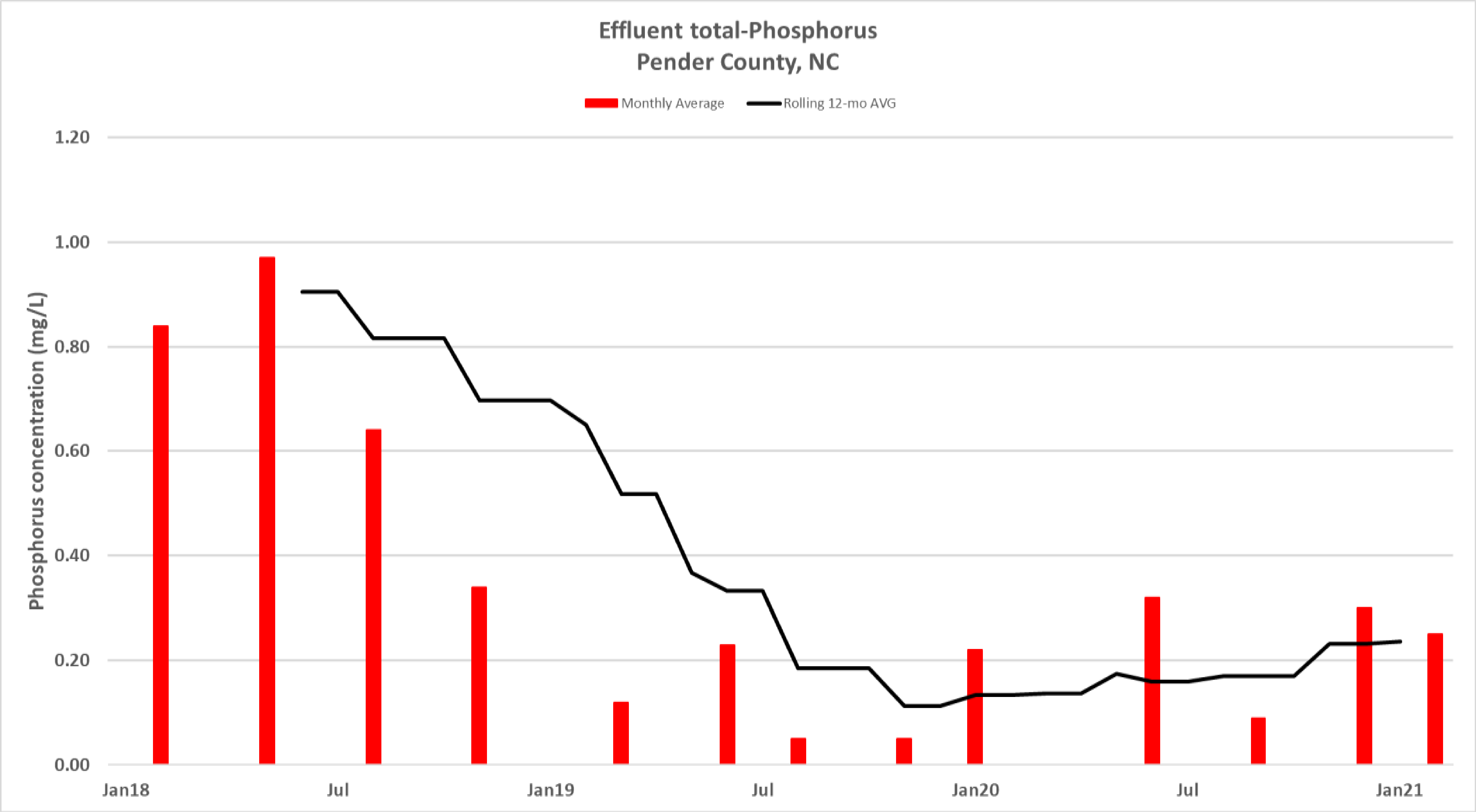
A View of the UV station (left), the tertiary filters (background center), the effluent pumping station and NPW system (right)

A View of the aerobic digesters.

A fairly clean overhead view, north is straight up.



Effluent total-Nitrogen
Pender County, NC
Monthly average tN
Rolling AVG tN
Nitrogen concentration (mg/L)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Jan18
Jul
Jan19
Jul
Jan20
Jul
Jan21



Effluent total-Phosphorus
Pender County, NC
Monthly Average
Rolling 12-mo AVG
Phosphorus concentration (mg/L)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Jan18
Jul
Jan19
Jul
Jan20
Jul
Jan21

Questions? Comments?

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Questions
Comments
Discussion

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