Brainstorming Nutrient Removal at Four North Carolina wastewater treatment plants

Webinar for North Carolina Wastewater Operators
April 7, 2021
10:00 - 11:45 AM

Grant Weaver, PE & wastewater operator
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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, Part 1

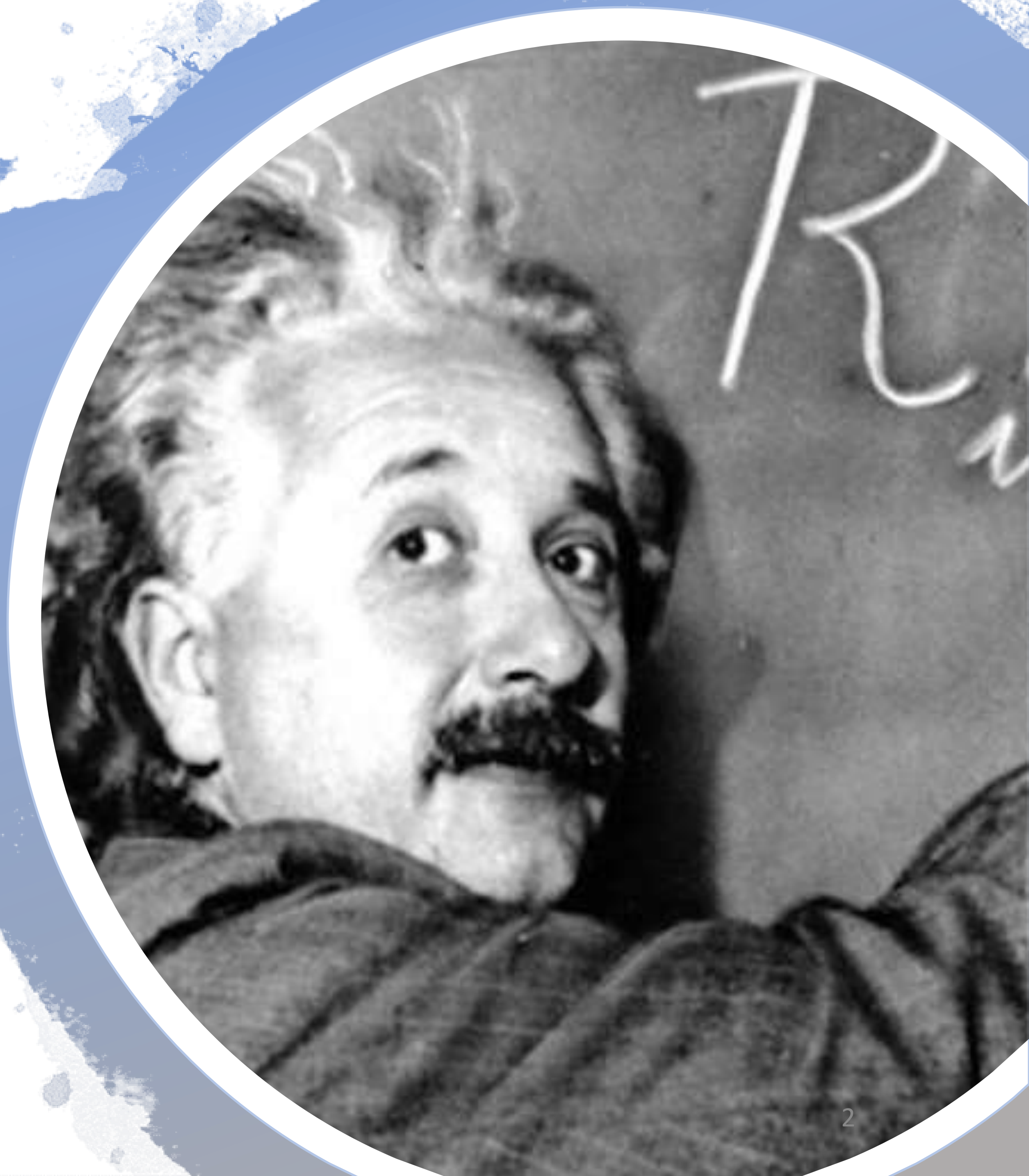
Today: Following up on North Carolina site visits:

Asheboro, Eden-Mebane Bridge, Newton-Clark Creek & Reidsville

Apr 15: Energy Management, Part 1

Apr 22: Energy Management, Part 2

Apr 29: North Carolina Case Studies, Part 3 (your plants!)




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

Eden Mebane Bridge

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

MEBANE BRIDGE WASTEWATER FACILITY

CITY OF EDEN

204 Mebane Bridge Road Eden, North Carolina 27288 Permit # NC0025071

The City of Eden's Wastewater Facility is responsible for handling and treating up to 13.5 million gallons of wastewater from the local citizens, businesses, and industries in a day's time. On average, the plant only has to handle approximately 2.5 – 4.5 MGD. All of the wastewater is collected in lines throughout the city and either pumped from the city's pump stations or gravity fed to the wastewater facility.

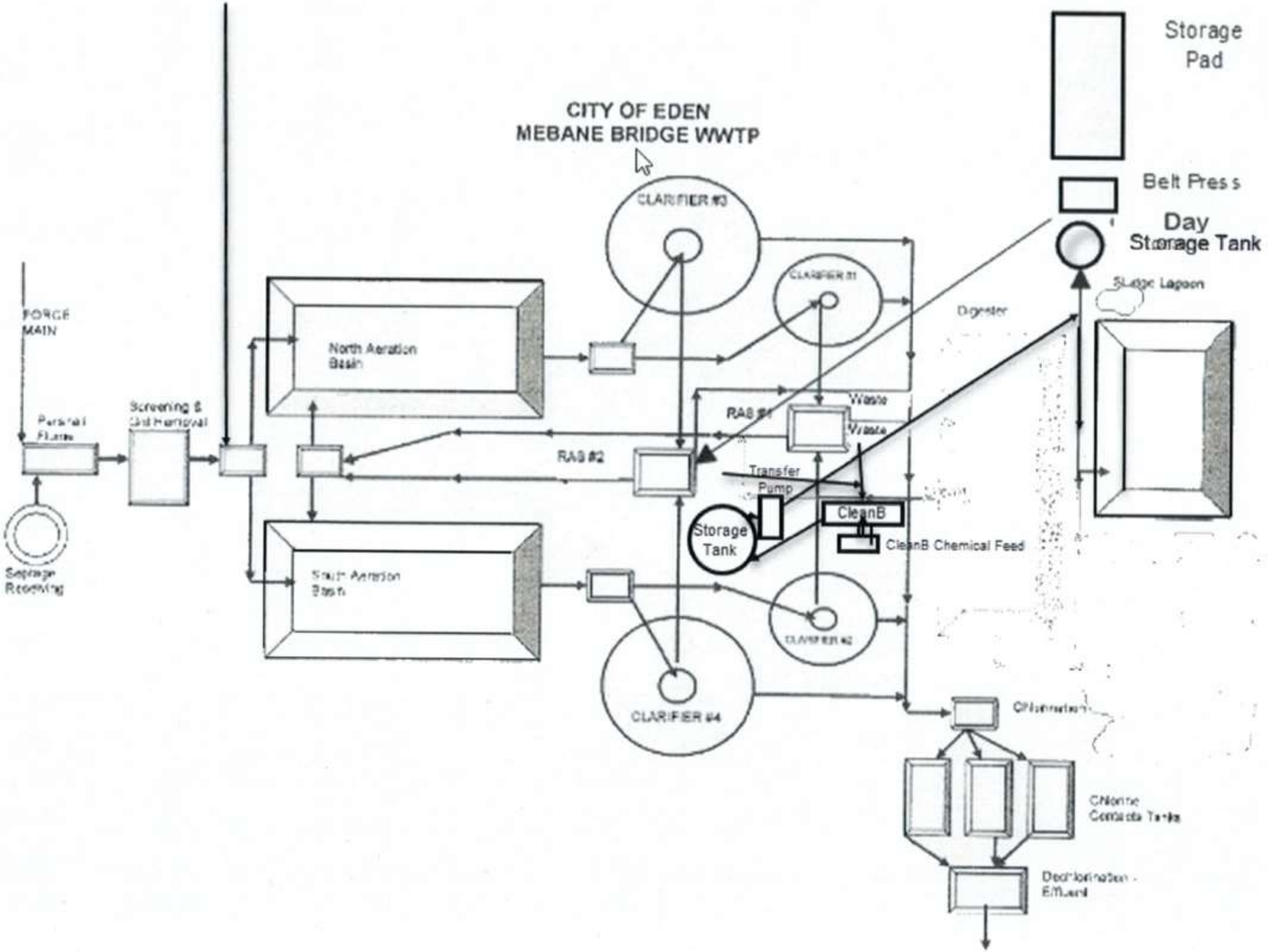
Once inside the plant, the wastewater goes through a preliminary treatment system. First, it must pass through one of two mechanical bar screens in order to remove larger inert material, such as rags or sticks. Next, it passes through an aerated grit channel to freshen up the wastewater and remove smaller inert material, such as sand or egg shells. The removal of this material helps to protect the equipment in the plant from extra wear. The collected material is then sent to the nearest landfill after it is dried out.

After preliminary treatment, the wastewater is divided between two, seven million gallon aeration basins. Each basin contains 12 brush aerators that keep the liquid mixed and the dissolved oxygen above a 2.0 mg/l. This mixed liquor contains "bugs" that feed off of the solids in the wastewater, which helps the solids to settle out in later treatment units. This is what makes the whole process a biological treatment system. Extra settled solids are sent back into these basins to make sure that there are enough "bugs" to feed on the solids, and periodically, part of the older settled solids are wasted into a digester for further treatment so that the "bugs" do not get over populated.

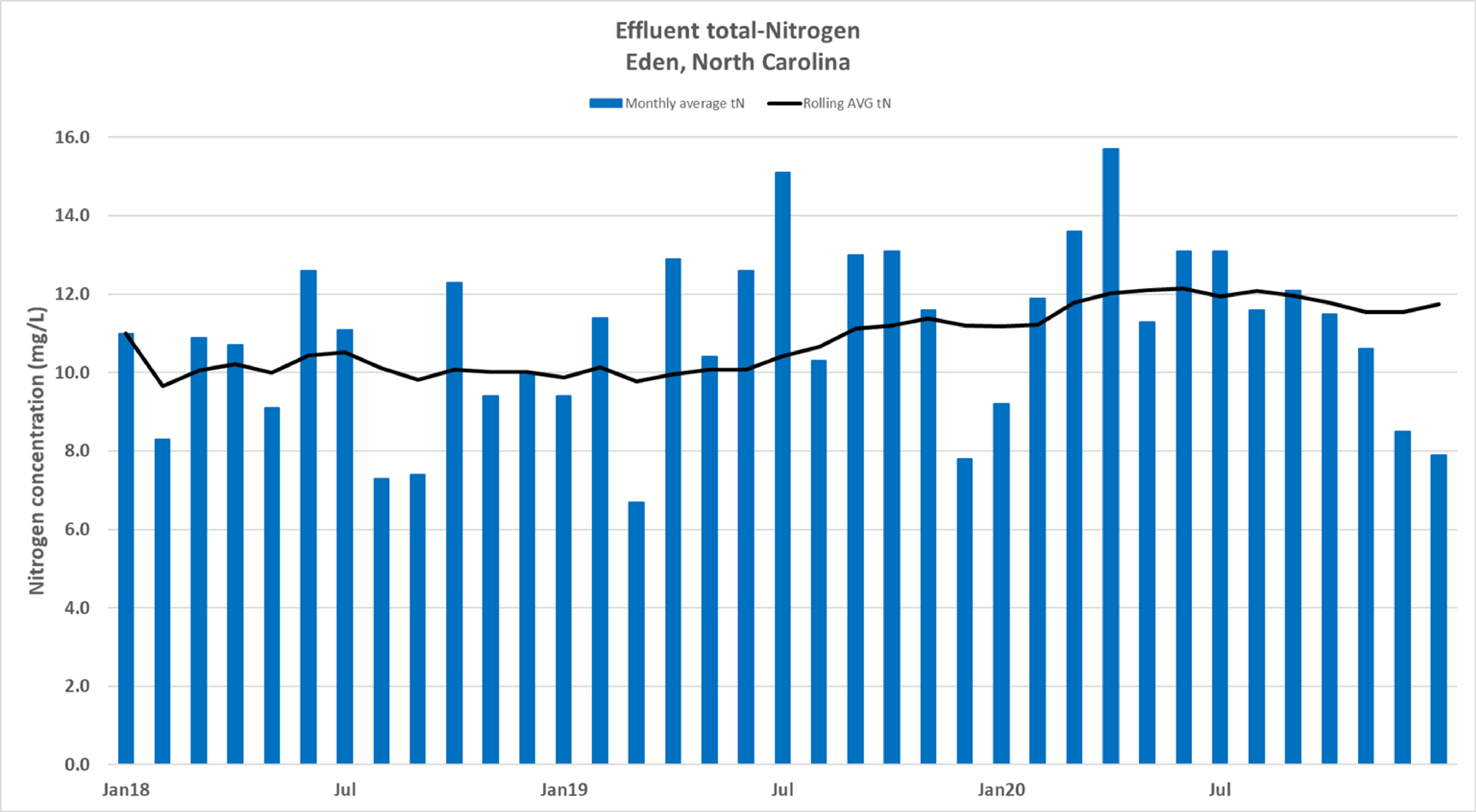
From here, the wastewater is divided into four secondary clarifiers. There are two 90 feet diameter clarifiers and two 130 feet diameter clarifiers on this site. In this secondary treatment, the solids in the mixed liquor from the aeration basins are given time to settle out in the bottom of the tanks. The clear water then goes into the final stage of treatment.

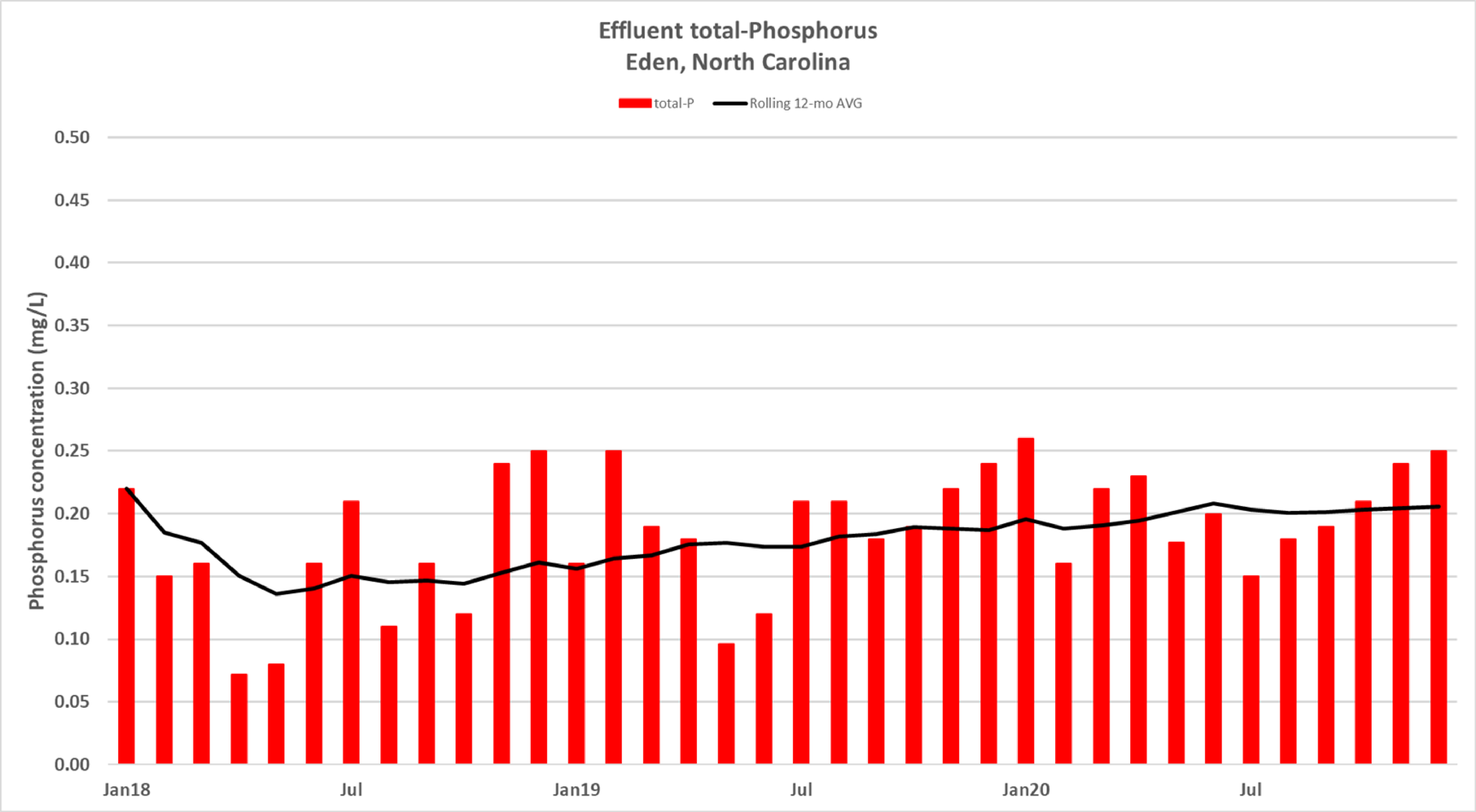
Solids wasted from the secondary process are sent to a CleanB system for chemical treatment and then stored on site and dewatered. Once ready, it is dewatered on a belt press into a cake form, stored on a storage pad as needed, and then land applied on farm land. This is a beneficial use for farmers, reducing the amount of chemicals that they might need to produce healthy crops.

This final stage of treatment consists of three chlorine contact basins. All of the water from all four of the clarifiers comes together at one point where chlorine gas in injected. The chlorine contact basins are designed in a serpentine pattern to allow proper contact time for the chlorine to disinfect the water. The contact time for each basin is between 30 and 45 minutes. At the end of the three basins, sodium bisulfite is added to the wastewater to neutralize the chlorine since too much chlorine can be harmful to the aquatic life in the river. At this point, the effluent is released to the Dan River clean and safe.


CITY OF EDEN
MEBANE BRIDGE WWTP
Storage
Pad
Belt Press
Day
Storage Tank
Sludge Lagoon
CLARIFIER #3
CLARIFIER #1
Digester
FORCE
MAIN
North Aeration
Basin
Screening &
Grit Removal
RAS #1
Waste
Waste
RAS #2
Transfer
Pump
Storage
Tank
CleanB
CleanB Chemical Feed
South Aeration
Basin
CLARIFIER #2
CLARIFIER #4
Chlorine
Contacts Tanks


Mebane Bridge Rd
Mebane Bridge Rd
Tyner Pl
Mebane Bridge Rd
Mebane Bridge Rd
Mebane Bridge Rd
Google
Imagery ©2021 Commonwealth of Virginia, Maxar Technologies, U.S. Geolog


Effluent total-Nitrogen
Eden, North Carolina
Monthly average tN
Rolling AVG tN
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Nitrogen concentration (mg/L)
Jan18
Jul
Jan19
Jul
Jan20
Jul



Effluent total-Phosphorus
Eden, North Carolina
total-P
Rolling 12-mo AVG
Phosphorus concentration (mg/L)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Jan18
Jul
Jan19
Jul
Jan20
Jul

Melinda Ward
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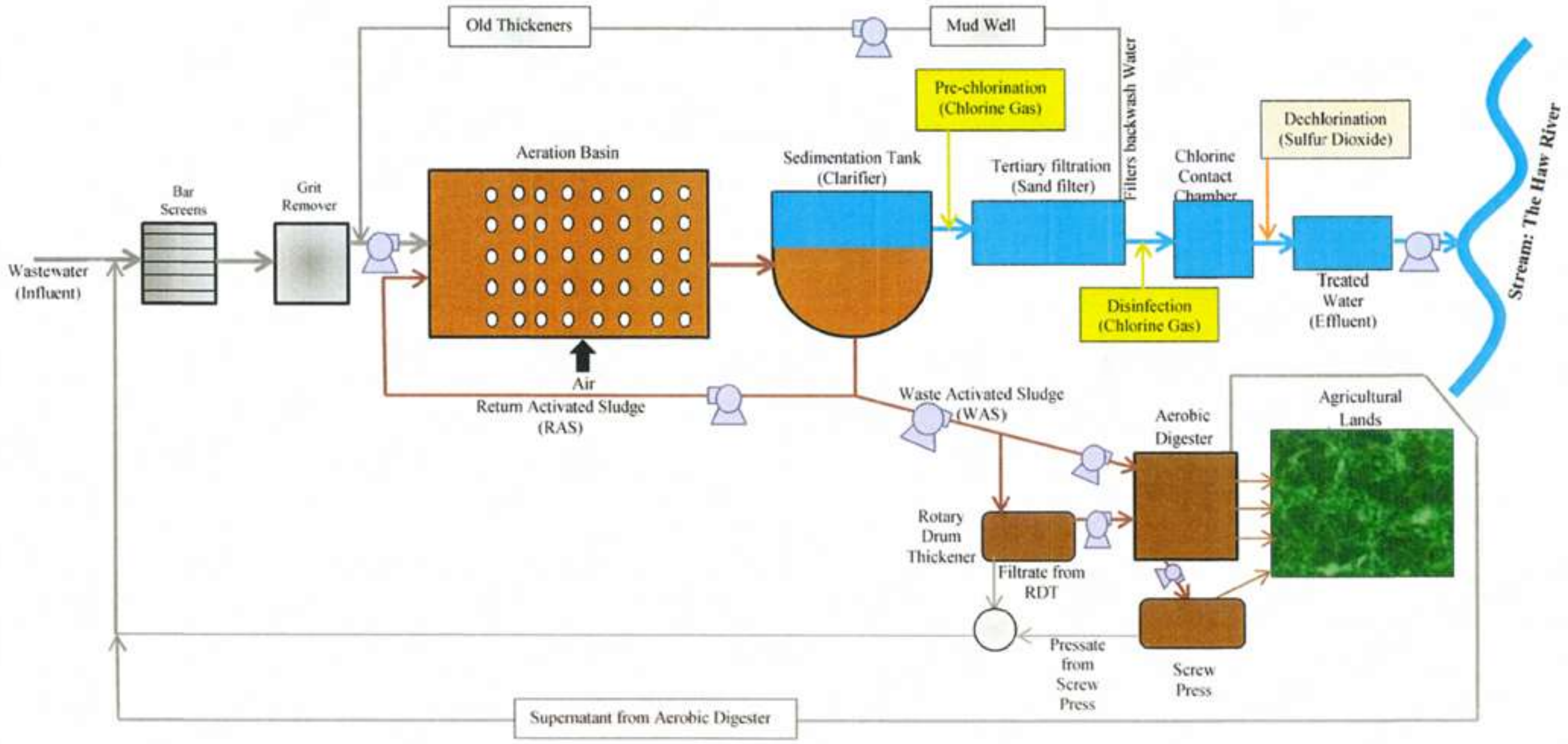
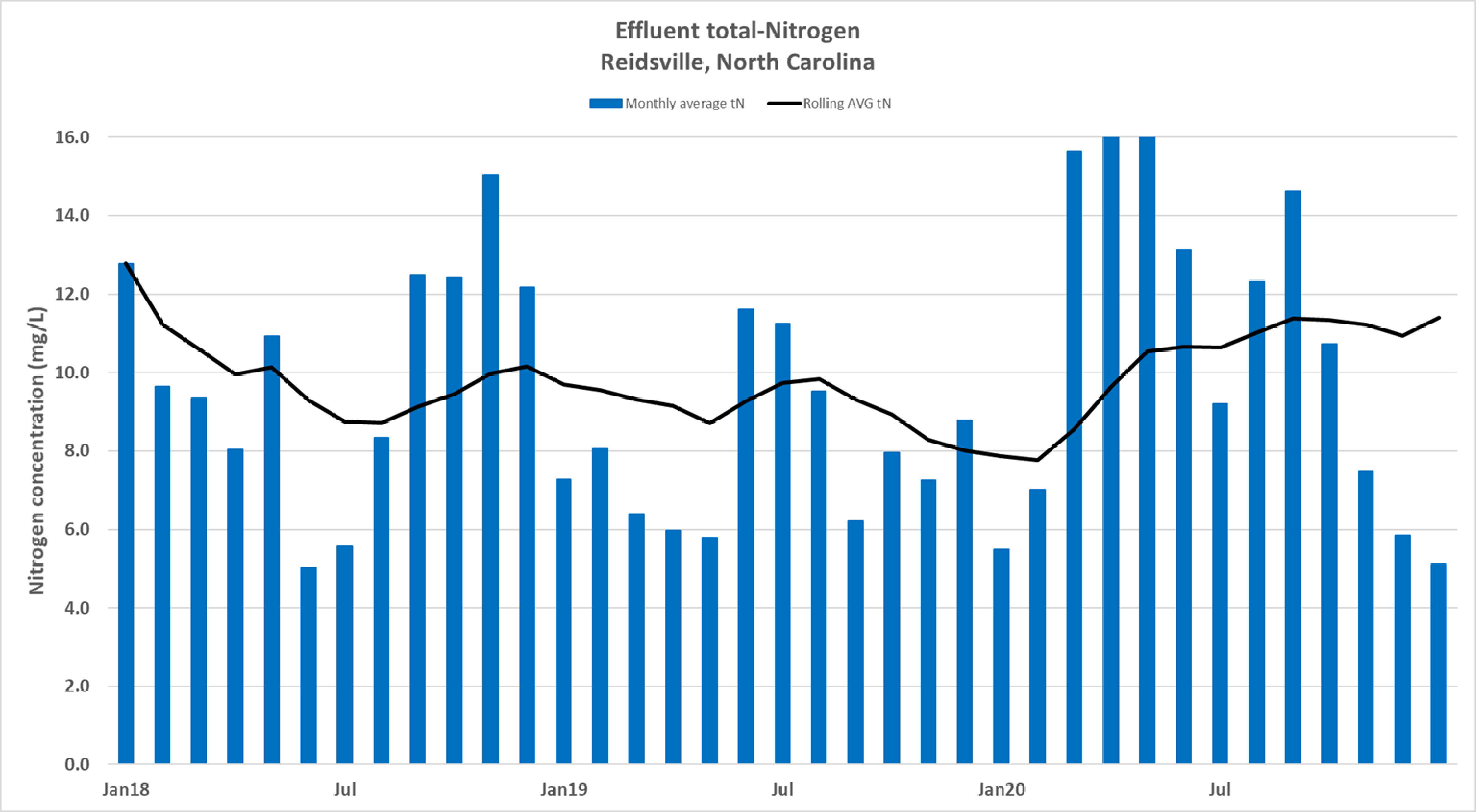
Reidsville

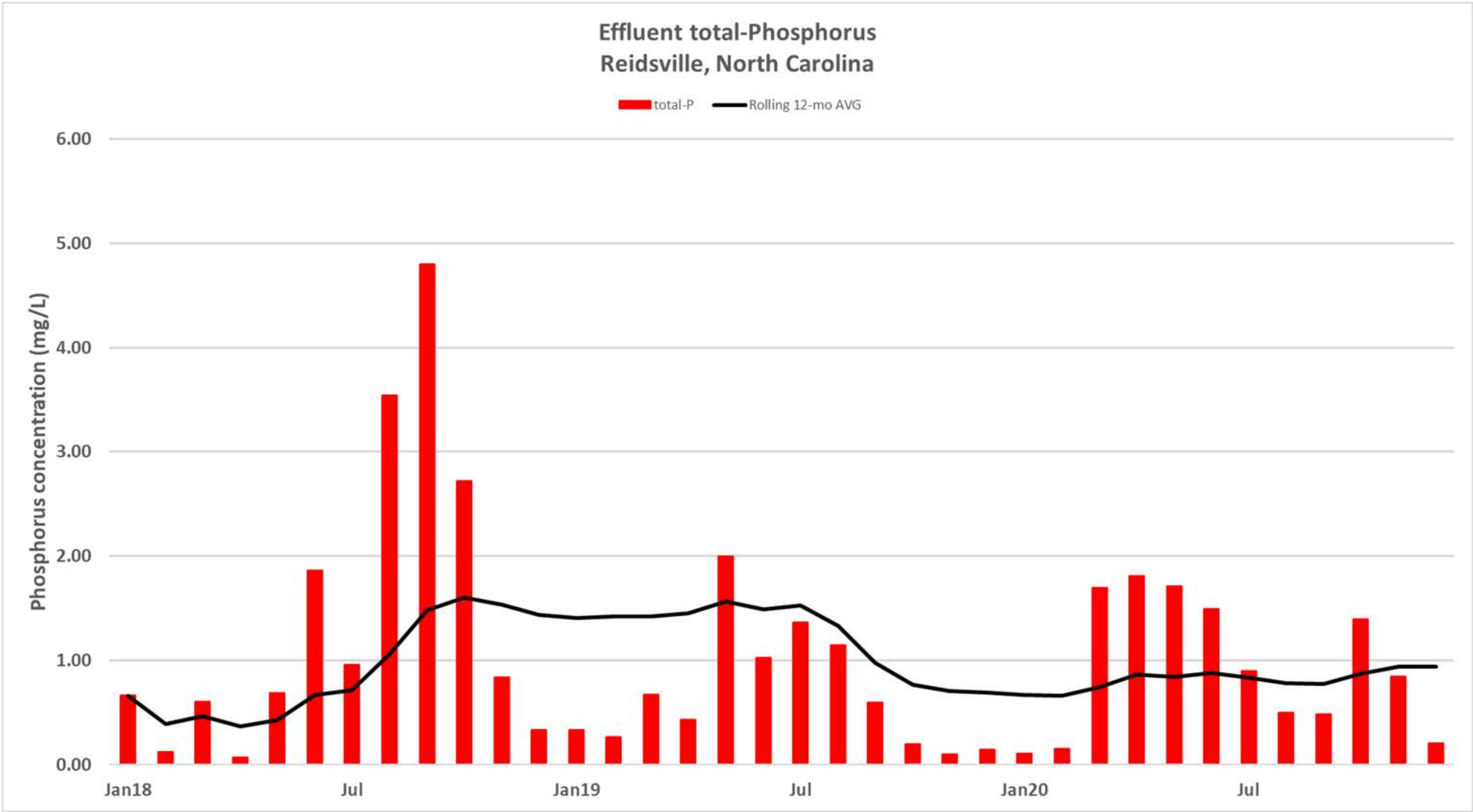
Reidsville, North Carolina Population: 14,000 7.5 MGD design flow

Section 2: Treatment Process Flow Diagram




Broad St
Reidsville Wastewater Treatment
Little Troublesome Creek
Google
Photos


Effluent total-Nitrogen
Reidsville, North Carolina
Monthly average tN
Rolling AVG tN
Nitrogen concentration (mg/L)
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Jan18
Jul
Jan19
Jul
Jan20
Jul



Effluent total-Phosphorus
Reidsville, North Carolina
total-P
Rolling 12-mo AVG
Phosphorus concentration (mg/L)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Jan18
Jul
Jan19
Jul
Jan20
Jul

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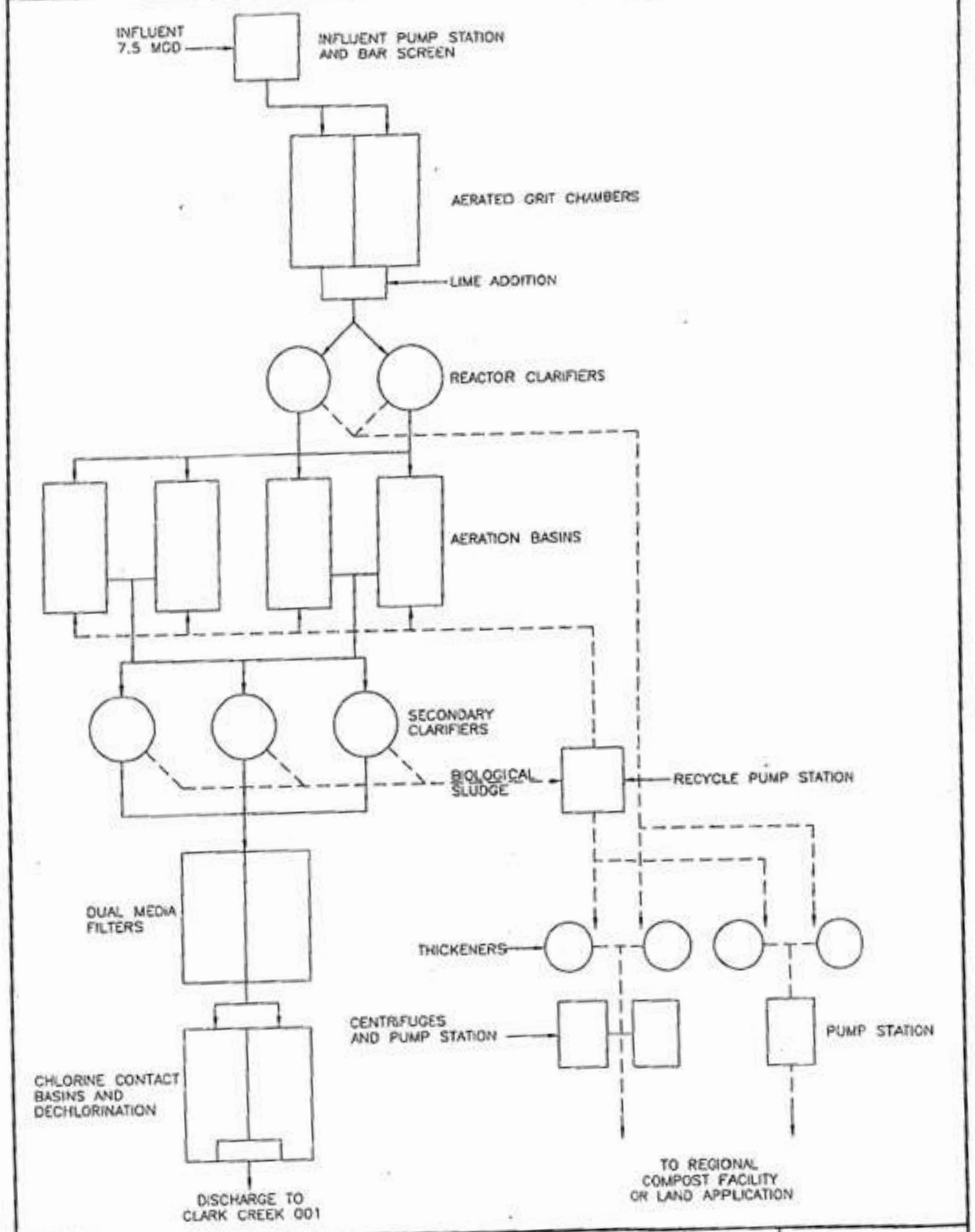
BREAK TIME

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



willis ENGINEERS

CITY OF NEWTON

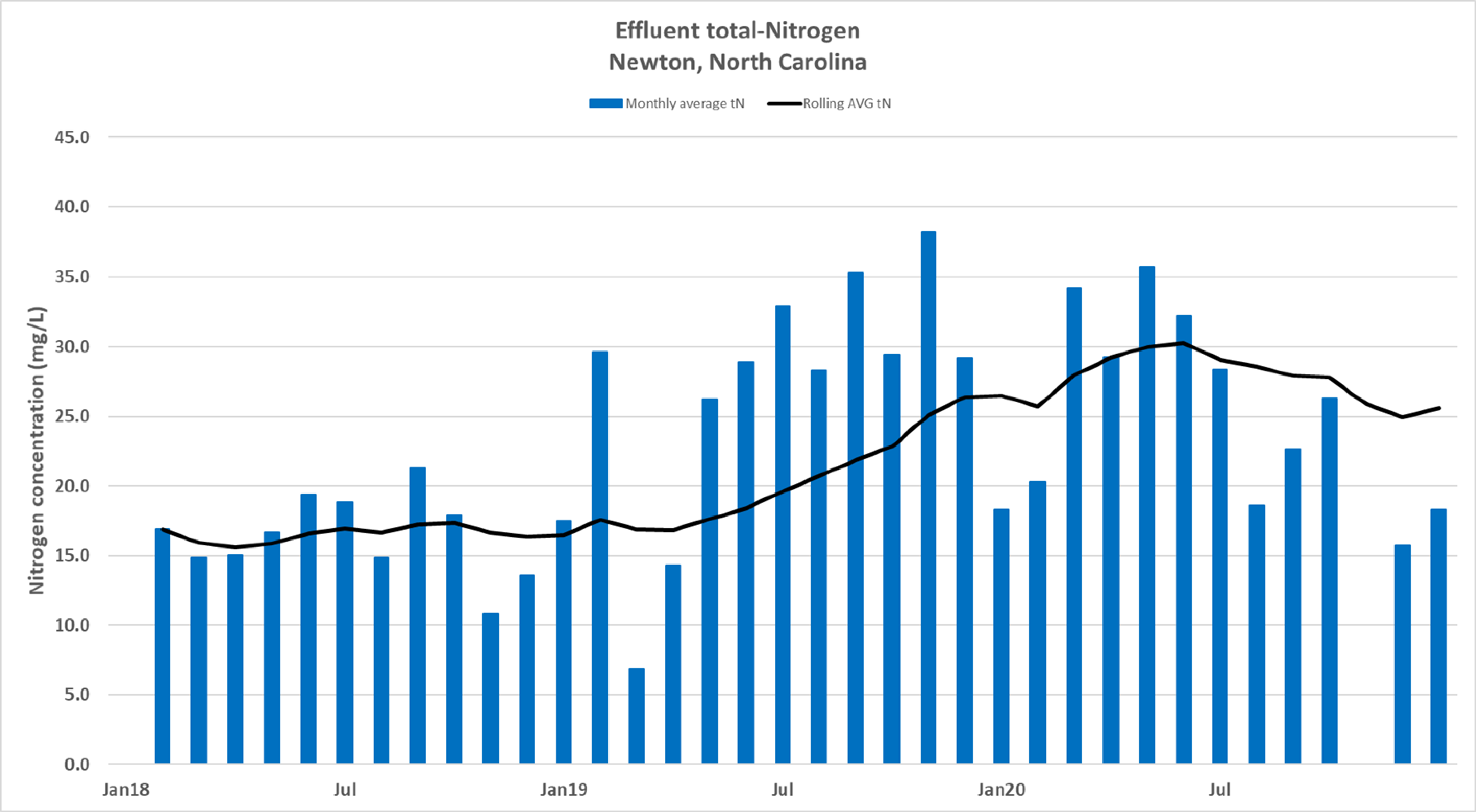
CLARK CREEK WWTP

FLOW SCHEMATIC

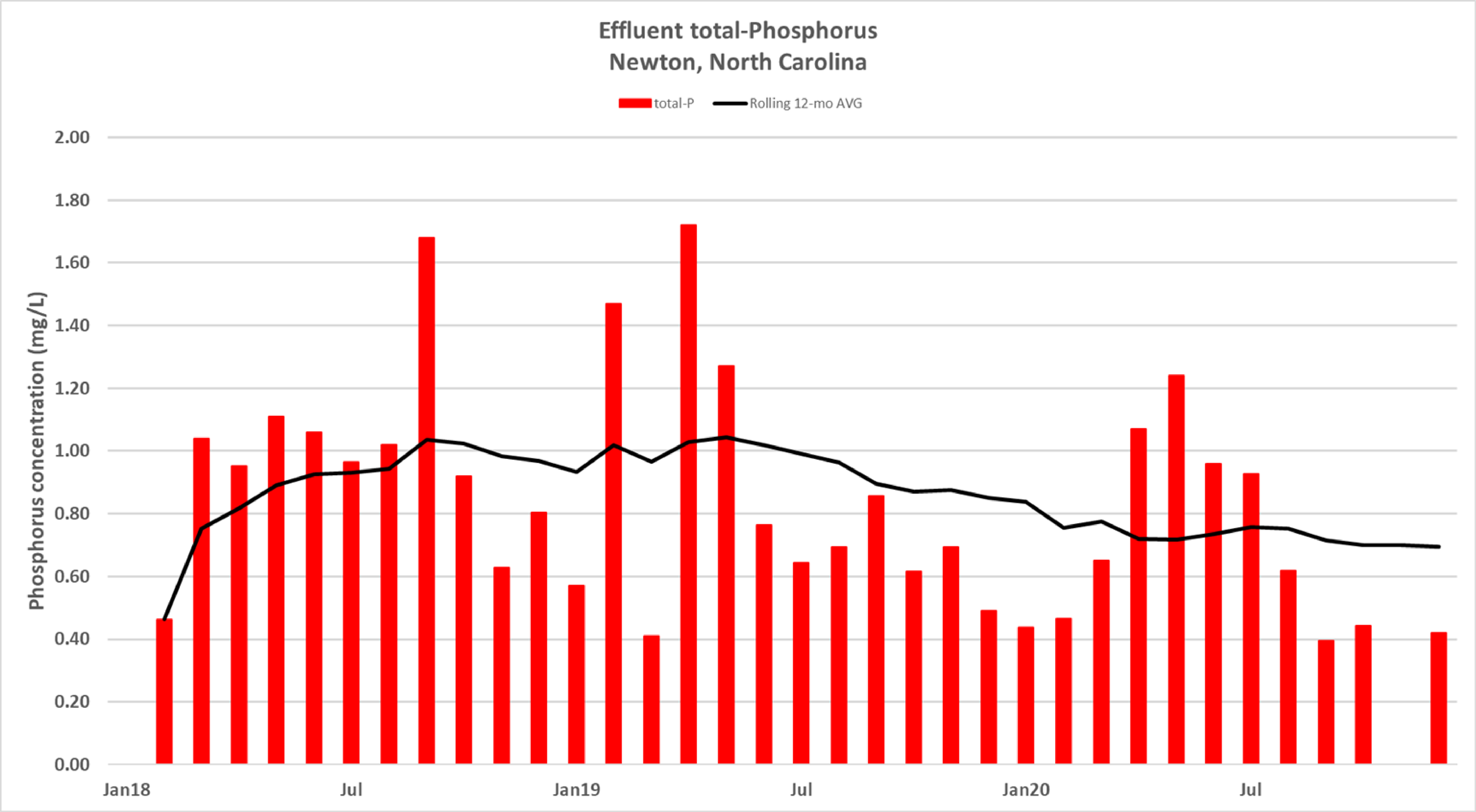
JANUARY 2005

NO	949.037
SCALE	1


Clark Creek



Effluent total-Nitrogen
Newton, North Carolina
Monthly average tN
Rolling AVG tN
Nitrogen concentration (mg/L)
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Jan18
Jul
Jan19
Jul
Jan20
Jul


Effluent total-Phosphorus
Newton, North Carolina
total-P
Rolling 12-mo AVG
Phosphorus concentration (mg/L)
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Jan18
Jul
Jan19
Jul
Jan20
Jul

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Stacy Rowe
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Asheboro

Asheboro, North Carolina Population: 26,000 9.0 MGD design flow

Asheboro WWTP

- Rated for 9 MGD
- Extended aeration (Schreiber System)
- BOD limit 5mg/l : 10mg/l
- NH_3 limit 2mg/l : 4mg/l
- Monitor only for Total Nitrogen and Total Phosphorus

Changes Affecting Asheboro

From 2005 to Present

- Major industrial users shut down
- Went from 70% industrial to 90% domestic
- Lost 3 MGD in daily average flow
- Press Filtrate disrupting aeration basins
- Permit Renewal in 2016 is still pending
- Detention Time too long through plant
- Diurnal Flow
- Shrinking Budgets!!!

Why Look at BNR?

- Permit requirements?
- Good Stewards of the Environment
- Potential Money SAVINGS!!

What we found out

- Our existing equipment is capable of removing total N and Total P
- It has to have some help
- Current system performs Nitrification only ($NH_3 \rightarrow NO_2 \longrightarrow NO_3$)
- Now we need to perform Denitrification ($NO_3 \rightarrow N\uparrow$)
- In order to do this we found that we have to turn the air off and add a carbon source
- If you leave air off an additional 30 minutes, phosphorus will also be consumed(luxury uptake)

What we did

- We obtained a carbon source from a local cereal manufacturer (sugar water)
- Air on for 2 hrs/ air off for 2 hrs
- Before Eff Total N avg was 20mg/l, After it is 12mg/l
- Before Eff Total P avg was 1.0mg/l, After it is 0.3mg/l
- Lowest Eff Total N 1.93mg/l, Total P .07mg/l

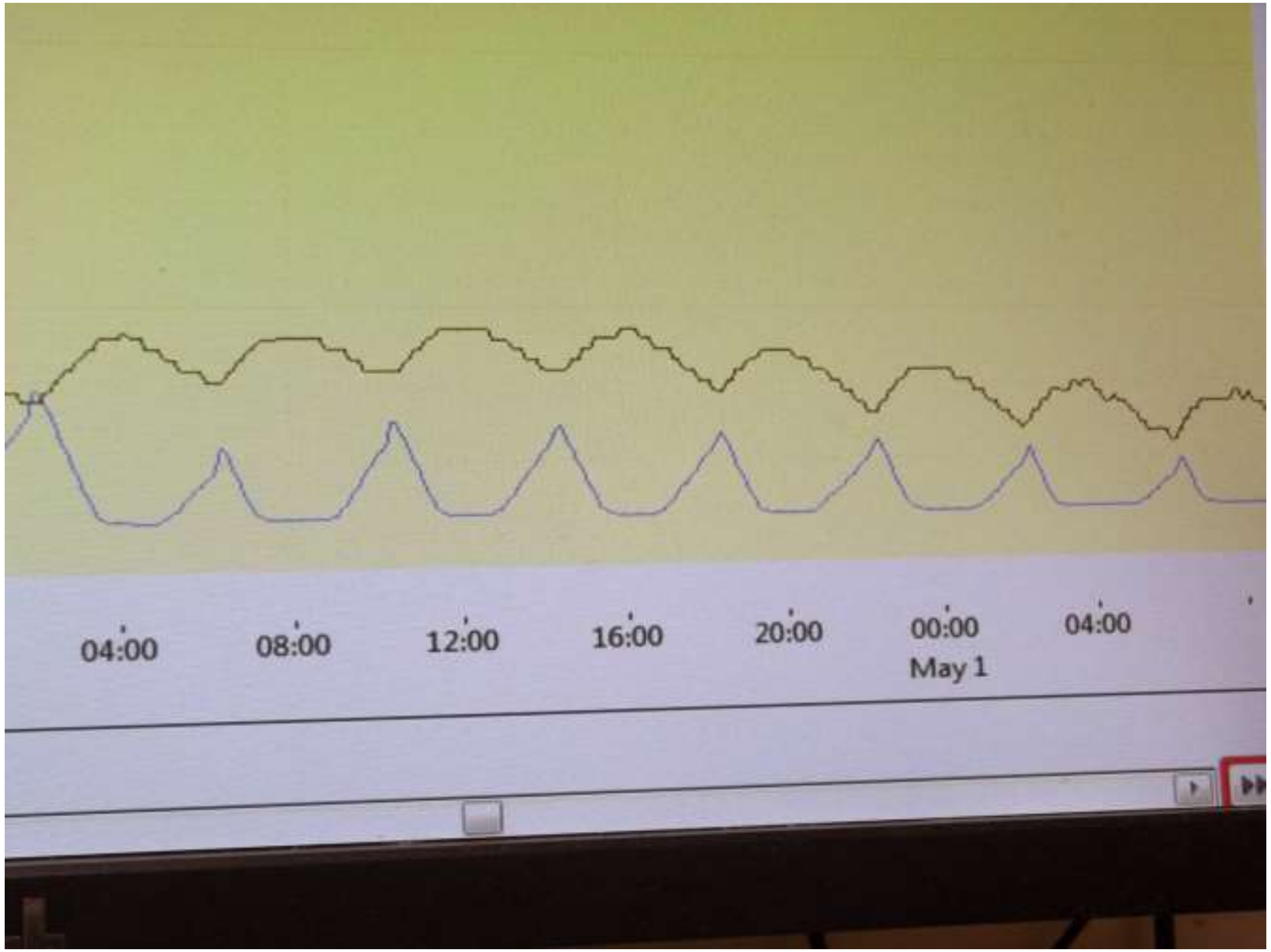
Costs Associated with BNR Changes

- Purchased a 12,000 gallon tank, 2 tanker trailers, feed pump, coriolis flow meter, nitrate sensor, and ammonium sensor.
- Added a new card and programming to PLC , updated SCADA to reflect changes
- Total Investment of $100,000

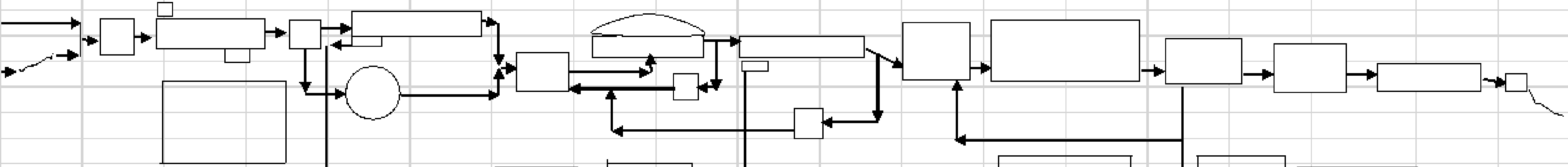
Results

- 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

Historical Trending-NO3 & NH4



AVERAGES FOR 2020



Influent

Flow Cap	**9 MGD**
Actual	4.583812

Construction Dates

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

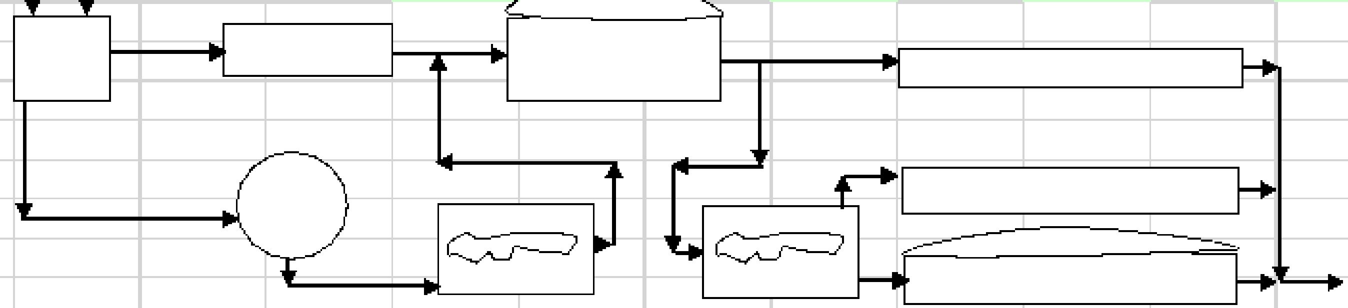
Sec SS	41.83472
Sec BOD	42.37137
Sec COD	170.3114

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 Aerati	1.8 mg/l	

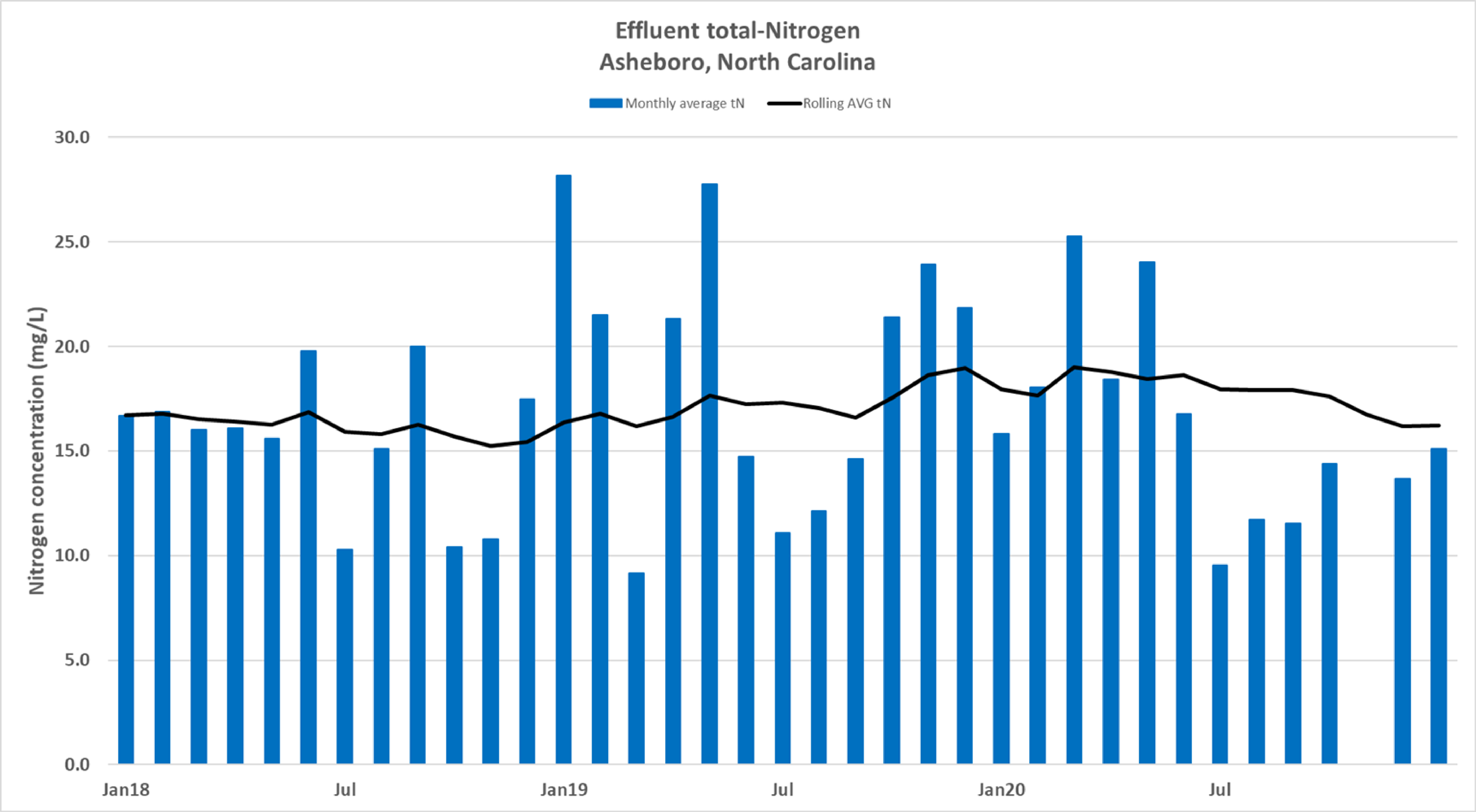
Digesters Gallons In | DT | Avg Temp | % Vol Re



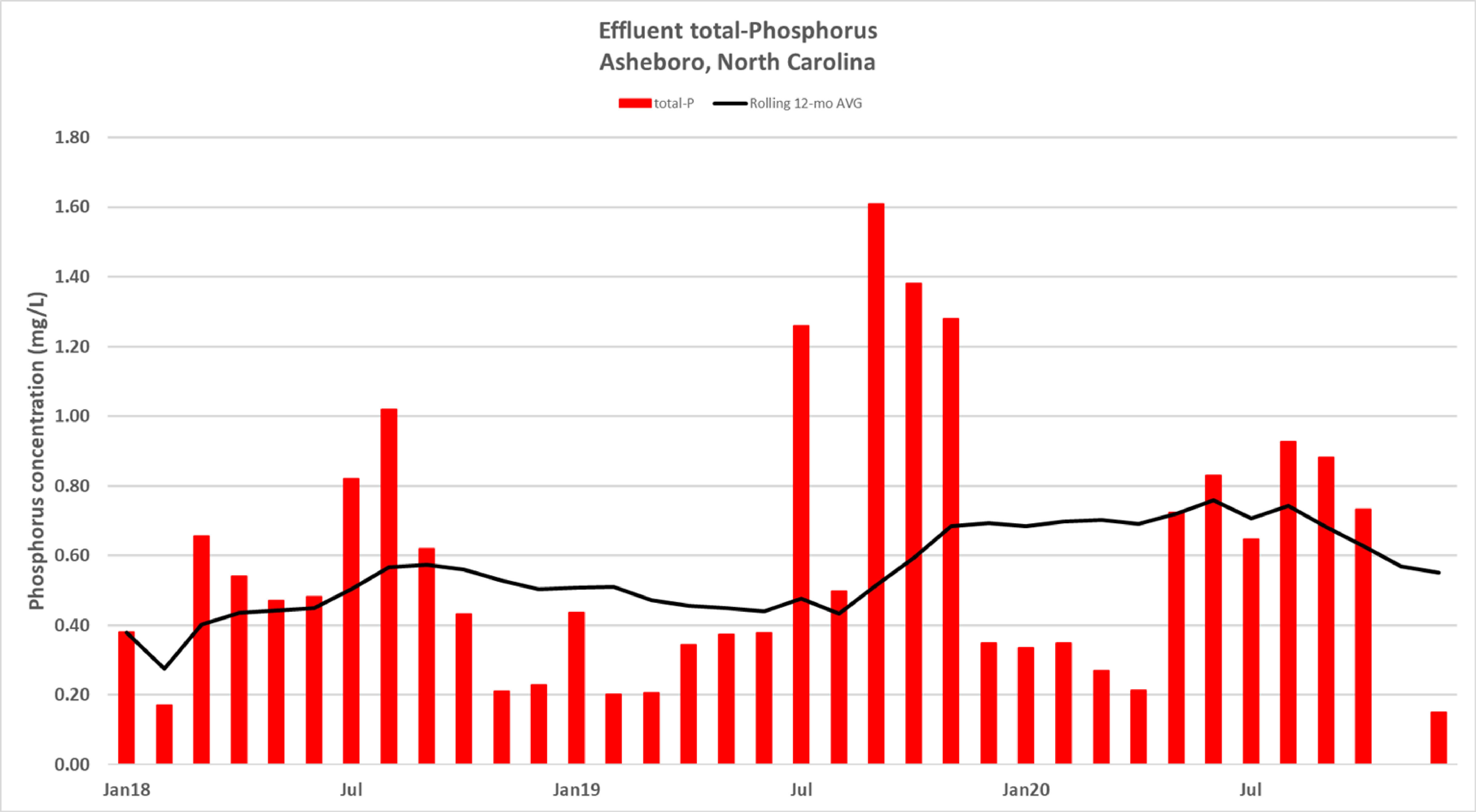
Gallons		Gallons	
% Poly		%Poly	
% Thick		% Cake	

TRUCK LOADS

TOTAL CUBIC YARDS PRESS= 0



Effluent total-Nitrogen
Asheboro, North Carolina
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



Effluent total-Phosphorus
Asheboro, North Carolina
total-P
Rolling 12-mo AVG
Phosphorus concentration (mg/L)
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Jan18
Jul
Jan19
Jul
Jan20
Jul

Questions or Comments?

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Acknowledgements

US EPA
Brendan Held & Craig Hesterlee

NC DEQ
Terry Albrecht, Corey Basinger & Ron Haynes

U MEMPHIS
Larry Moore, PhD

ASHEBORO
Mike Wiseman

EDEN
Melinda Ward

NEWTON
Eric Jones

REIDSVILLE
Scott Bryan

… and many more!

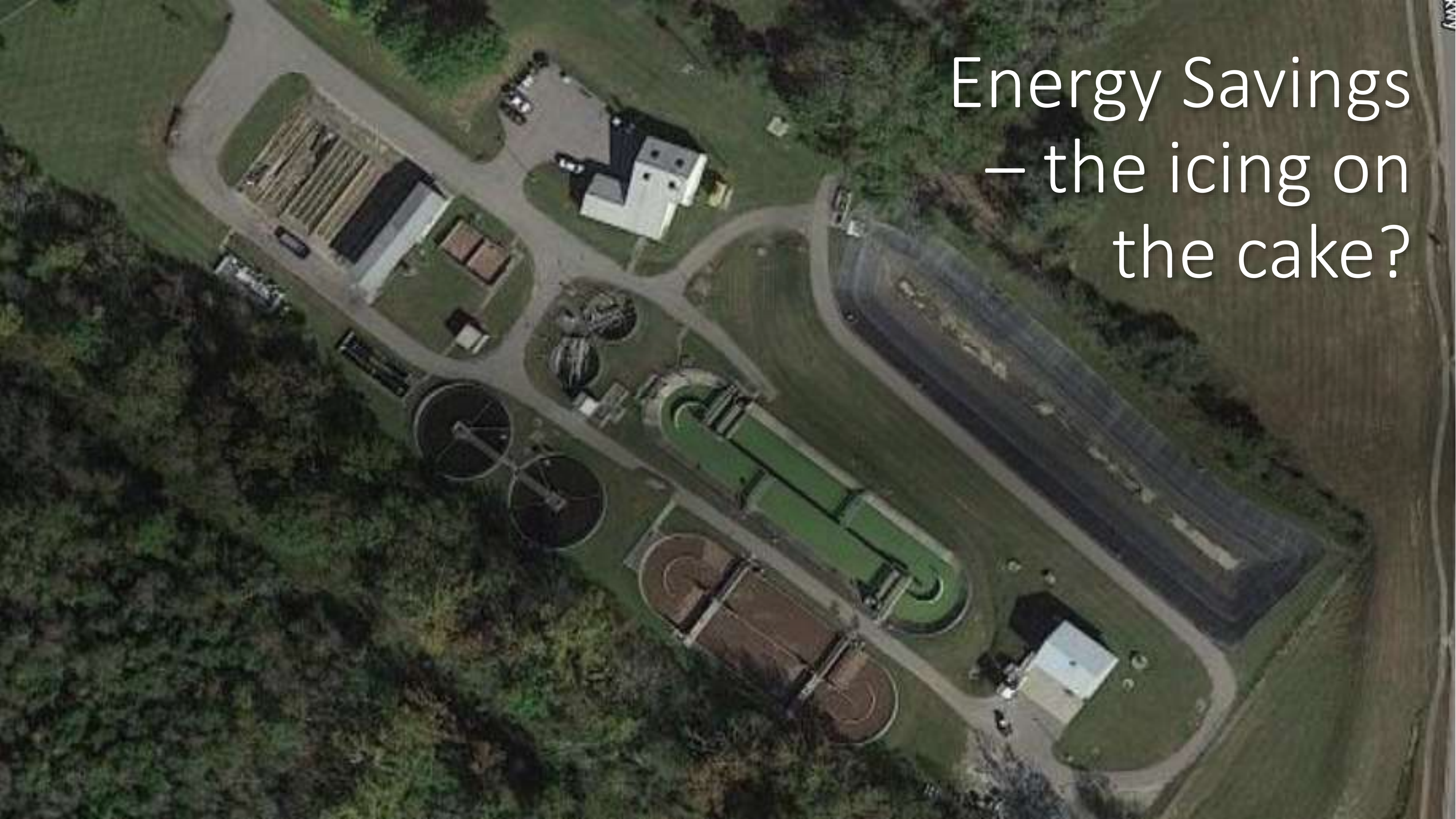
Next Webinar:
North Carolina Case Studies: part 2

Thursday, April 8
10:00 - 11:45 AM

Energy Management *(4/15 & 4/22)*
NC DEQ's Ron Haynes

NC Case Studies *(4/29)*

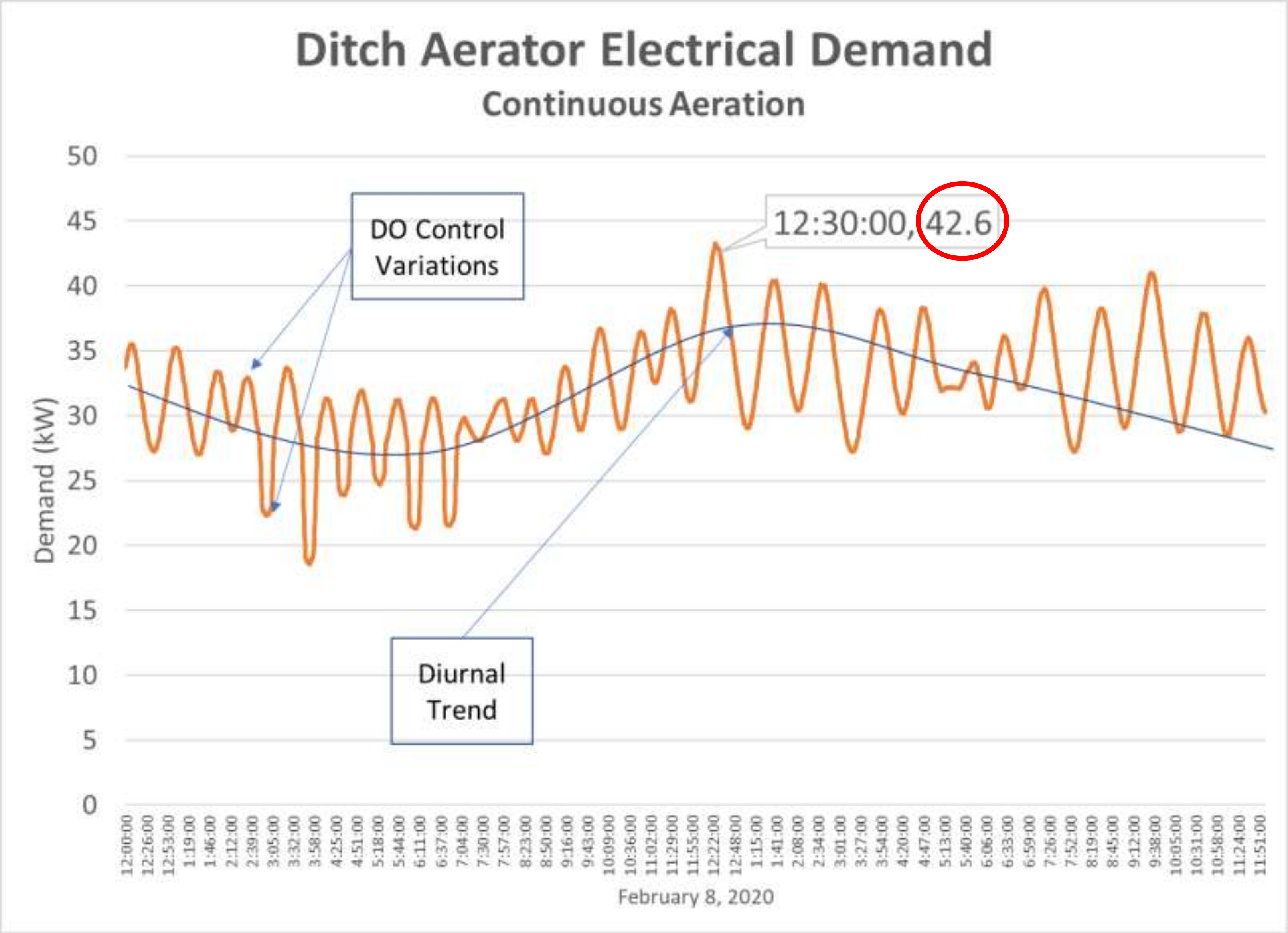
Energy Savings – the icing on the cake?

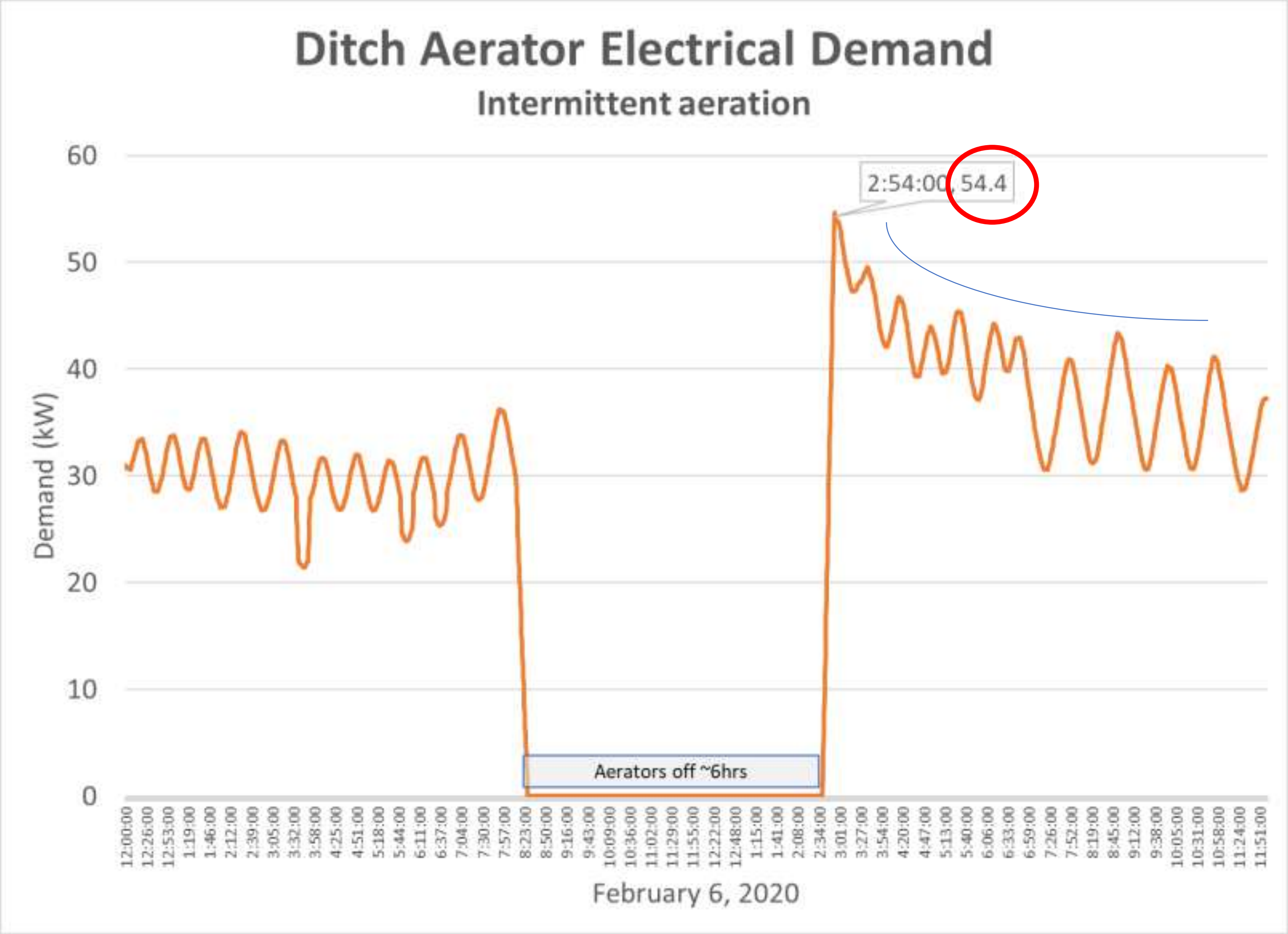


Facility Characteristics

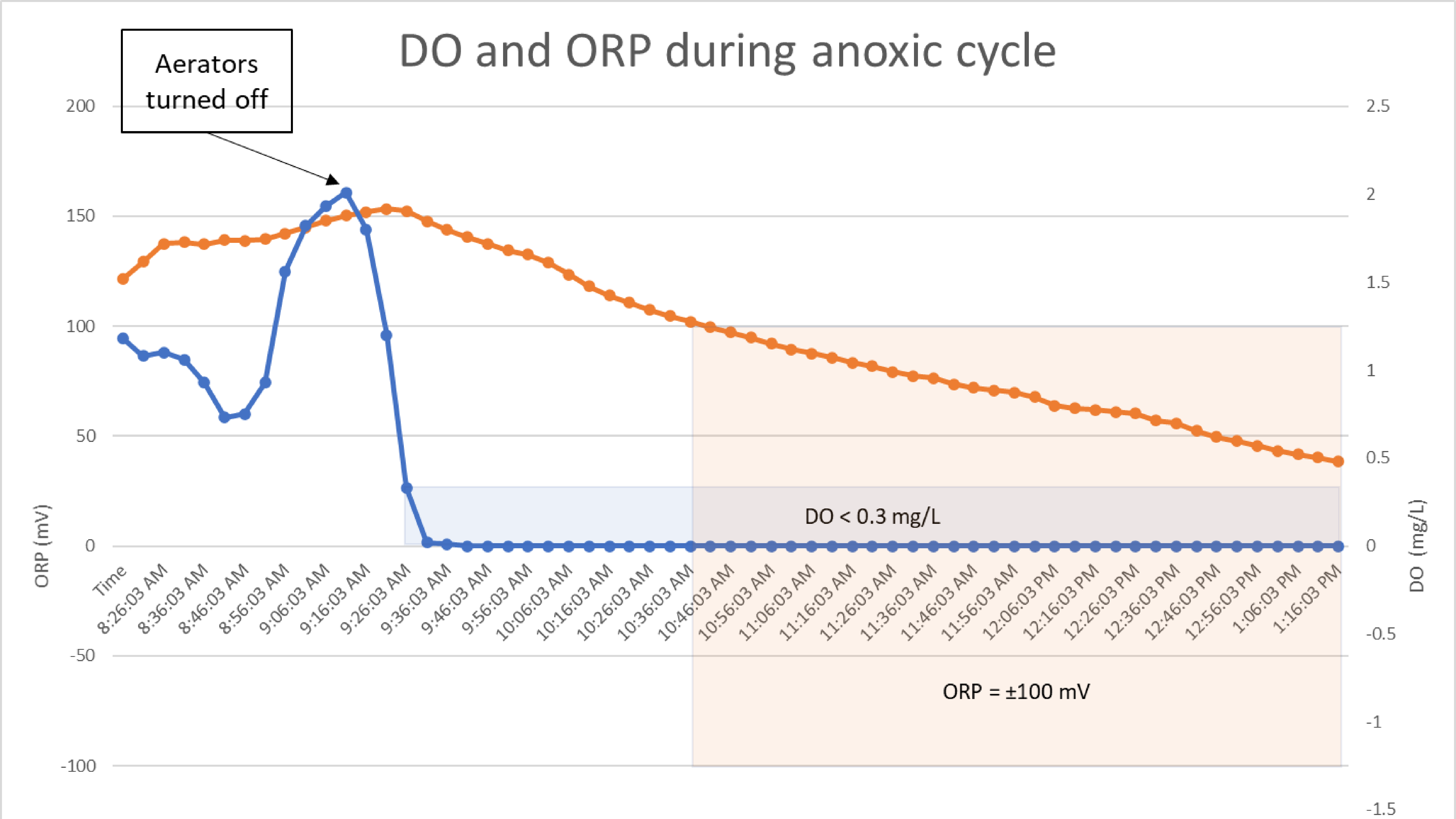
- Medium-strength influent. No large industry, septage, or leachate.
- Underloaded hydraulically, but operating 50% of available aeration volume
- Aeration controls have VFDs with DO set point (1.5 mg/L)
- Operator had already been shutting off aerators intermittently w/ goal of denitrifying
- Controls do not allow automated shut off & start up of aerators. Shut off only when operator has time.

Parameter	Influent Avg	Effluent Avg	Limit
Flow (MGD)	0.96	0.96	1.9 (design)
CBOD-5 (mg/L)	280	4.3	8
TSS (mg/L)	290	12	30
NH_3 (mg/L)	-	0.2	3.0-10.5 seasonal, most stringent May-Oct
TN (mg/L)	-	20.5	Report only
TP (mg/L)	-	0.7	1.0


Ditch Aerator Electrical Demand
Continuous Aeration
DO Control Variations
12:30:00, 42.6
Diurnal Trend
Demand (kW)
February 8, 2020



Ditch Aerator Electrical Demand
Intermittent aeration
Demand (kW)
2:54:00, 54.4
Aerators off ~6hrs
February 6, 2020


DO and ORP during anoxic cycle
Aerators turned off
DO < 0.3 mg/L
ORP = ±100 mV
ORP (mV)
DO (mg/L)
200
150
100
50
0
-50
-100
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
Time
8:26:03 AM
8:36:03 AM
8:46:03 AM
8:56:03 AM
9:06:03 AM
9:16:03 AM
9:26:03 AM
9:36:03 AM
9:46:03 AM
9:56:03 AM
10:06:03 AM
10:16:03 AM
10:26:03 AM
10:36:03 AM
10:46:03 AM
10:56:03 AM
11:06:03 AM
11:16:03 AM
11:26:03 AM
11:36:03 AM
11:46:03 AM
11:56:03 AM
12:06:03 PM
12:16:03 PM
12:26:03 PM
12:36:03 PM
12:46:03 PM
12:56:03 PM
1:06:03 PM
1:16:03 PM

But what about the savings?

Continuous Aeration

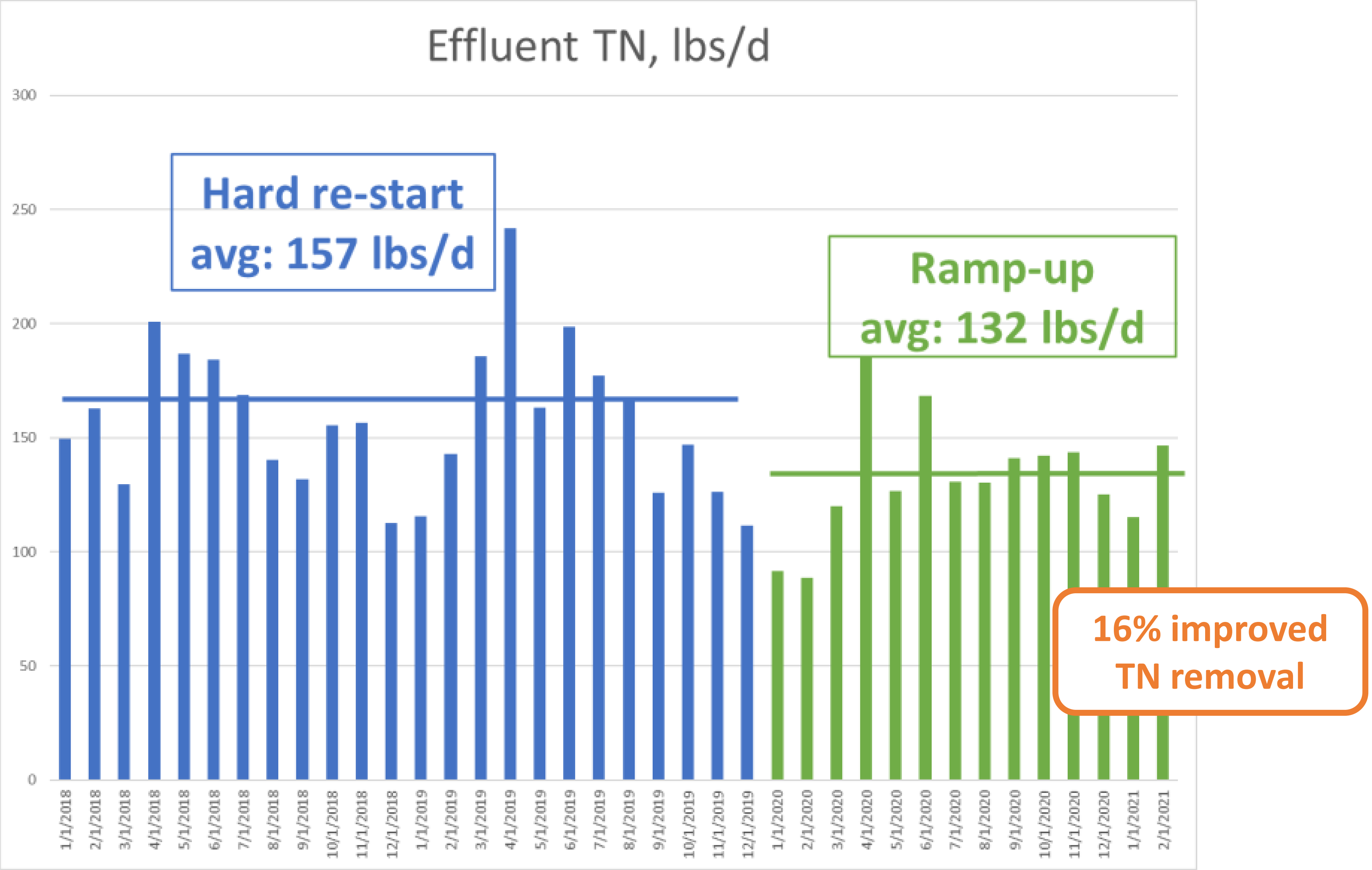
Billing Component	Quantity	Monthly Cost
kWh consumed	32 kW x 3 aerators x 6 hrs = **17,280 kWh**	17,280 kWh x $0.034 x 30d = **$588/mo**
"Surge" demand	N/A	**$0/mo**
Total cost to leave aerators running:		**$588/mo**

Intermittent Aeration w/ hard restart

Billing Component	Quantity	Cost
kWh consumed	0 kWh, some days	**$0/mo**
"Surge" demand	12 kW/aerator x 3 aerators = 36 kW	36 kW x $21/kW = **$756/mo**
Total cost of hard restart:		**$756/mo**

Increased electrical costs over $2000 per year!

…need to ramp up DO setpoint gradually



Effluent TN, lbs/d
300
250
200
150
100
50
0
Hard re-start
avg: 157 lbs/d
Ramp-up
avg: 132 lbs/d
16% improved
TN removal
1/1/2018
2/1/2018
3/1/2018
4/1/2018
5/1/2018
6/1/2018
7/1/2018
8/1/2018
9/1/2018
10/1/2018
11/1/2018
12/1/2018
1/1/2019
2/1/2019
3/1/2019
4/1/2019
5/1/2019
6/1/2019
7/1/2019
8/1/2019
9/1/2019
10/1/2019
11/1/2019
12/1/2019
1/1/2020
2/1/2020
3/1/2020
4/1/2020
5/1/2020
6/1/2020
7/1/2020
8/1/2020
9/1/2020
10/1/2020
11/1/2020
12/1/2020
1/1/2021
2/1/2021

Obviously, this is a special case. But:

- Saving energy does not always mean saving money
- Understanding the electric billing structure is critical

More on energy management is coming over the next couple weeks!