Nutrient Removal in Oxidation Ditches

Webinar for Tennessee Wastewater Treatment Plant Operators
February 24, 2021

Grant Weaver, PE & wastewater operator
President
CleanWaterOps
G.Weaver@CleanWaterOps.com

Strategies for Optimizing Nutrient Removal

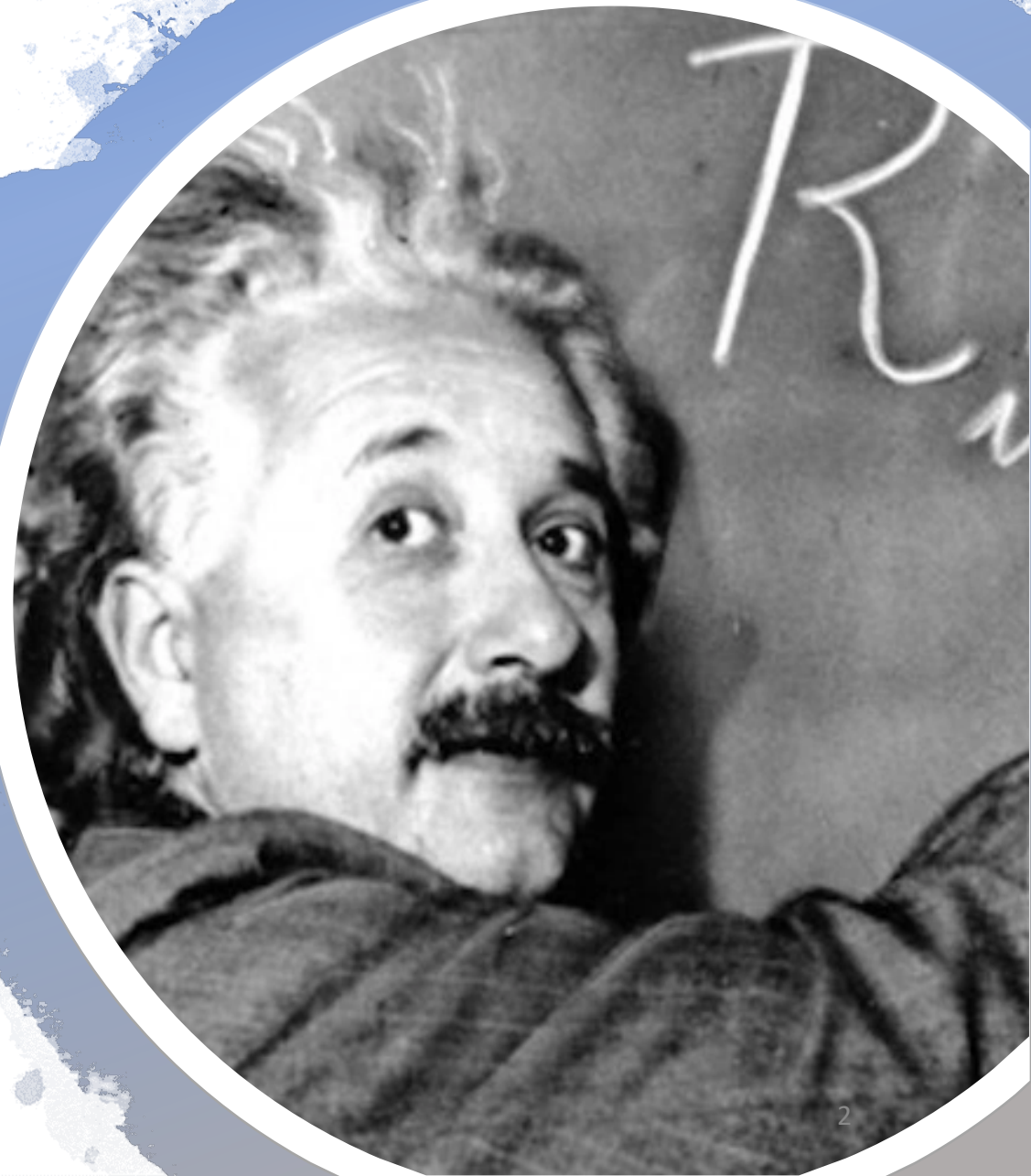
Week 1: Nitrogen Removal
Week 2: Phosphorus Removal
Week 3: N&P Review and Case Studies

Today: Nitrogen & Phosphorus Removal in Oxidation Ditch wwtps

Mar 3: N&P Removal in SBRs

Mar 10: N&P Removal in Conventional Activated Sludge

Mar 17: Brainstorming N&P Removal Opportunities for Tennessee Wastewater Treatment Plants




REVIEW

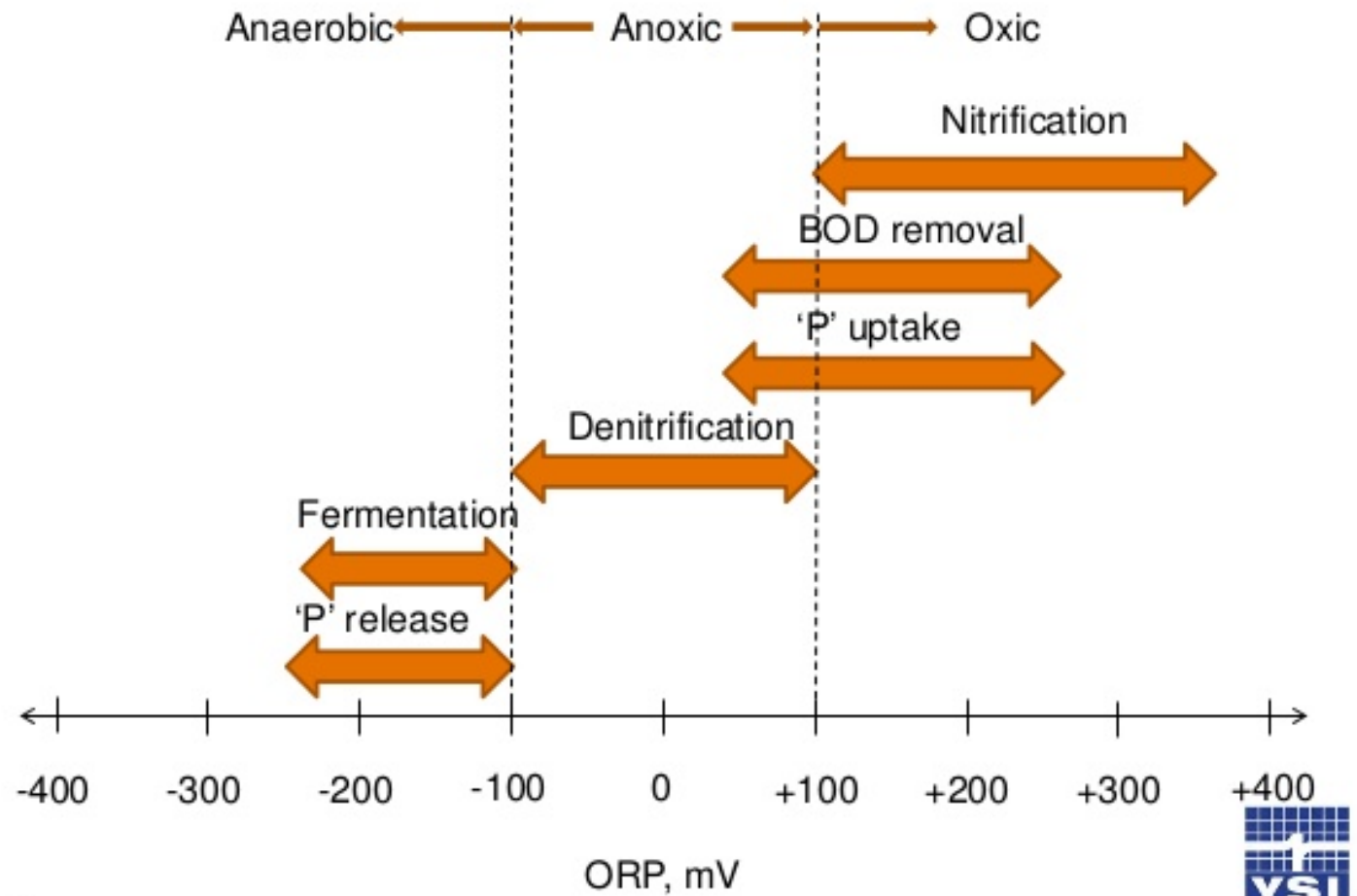

Science

Wastewater Science

DO (Dissolved Oxygen)

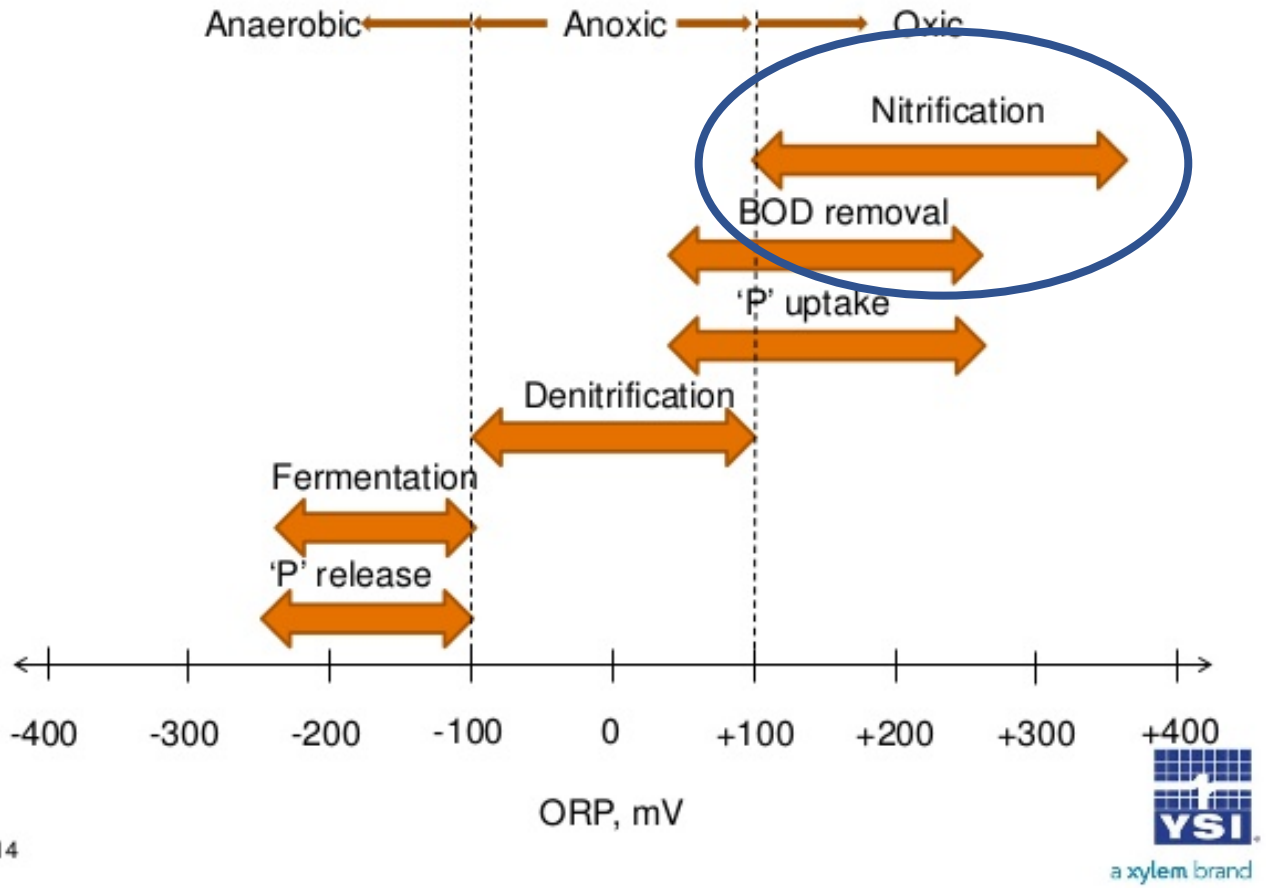
ORP (Oxidation Reduction Potential)

What Does ORP Tell Us About Our Process?



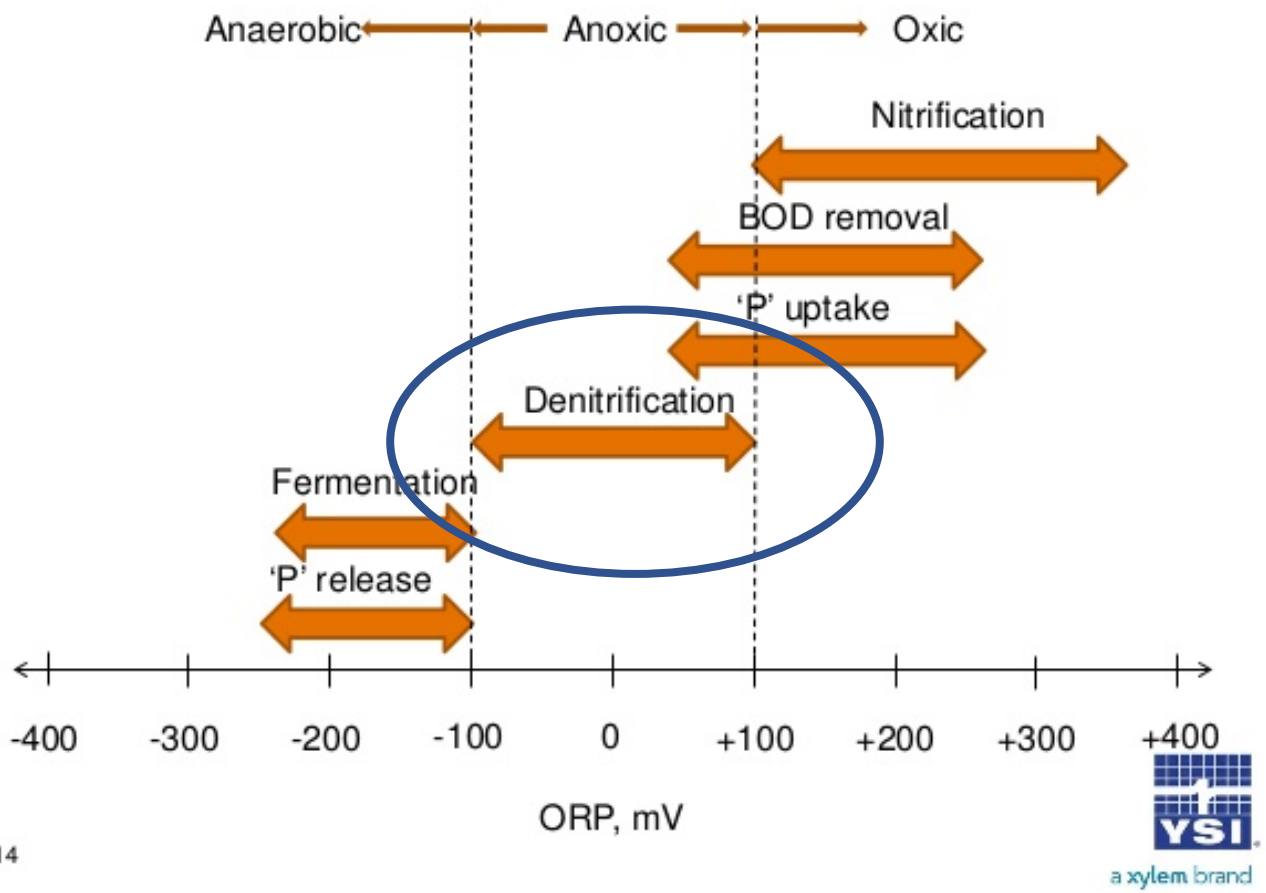
YSI
a xylem brand

What Does ORP Tell Us About Our Process?



YSI
a xylem brand

What Does ORP Tell Us About Our Process?



YSI
a xylem brand

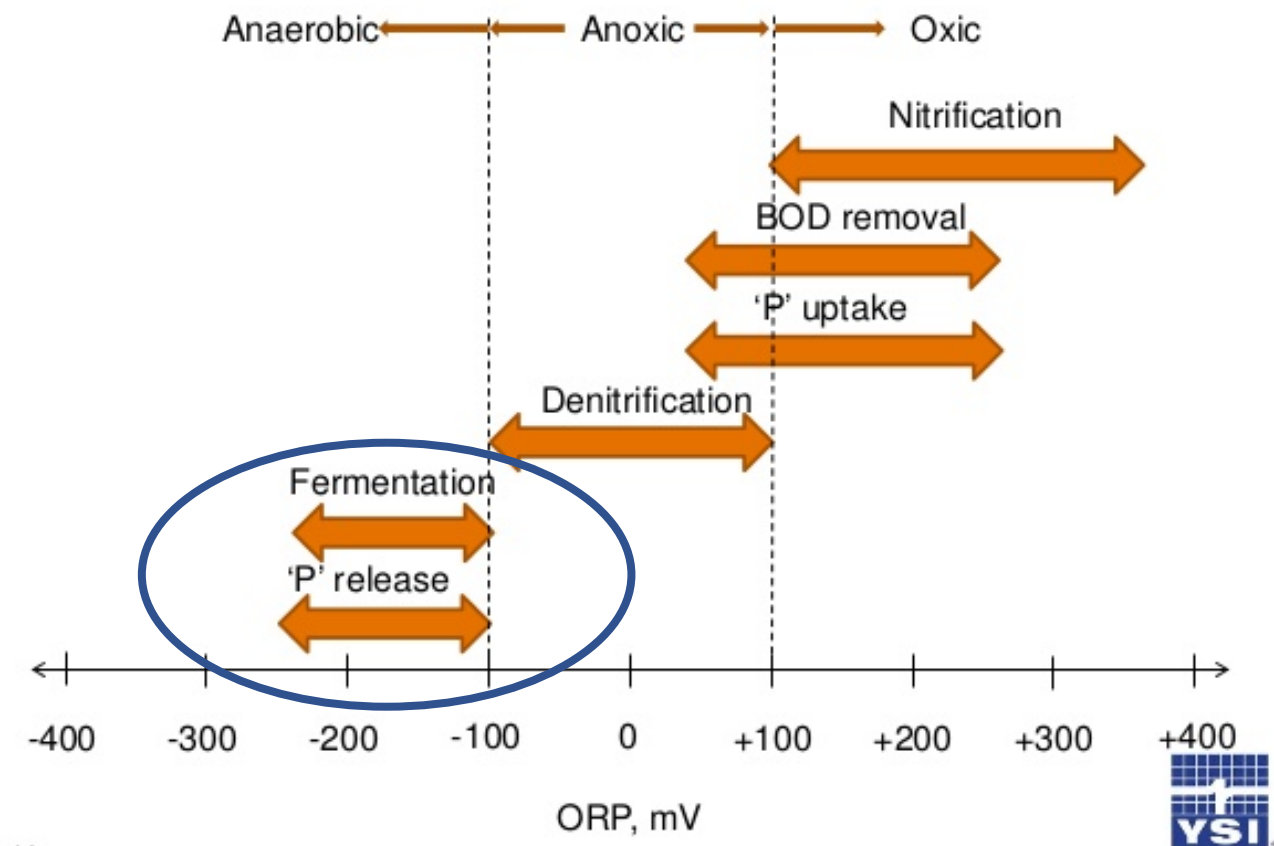
Phosphorus

15

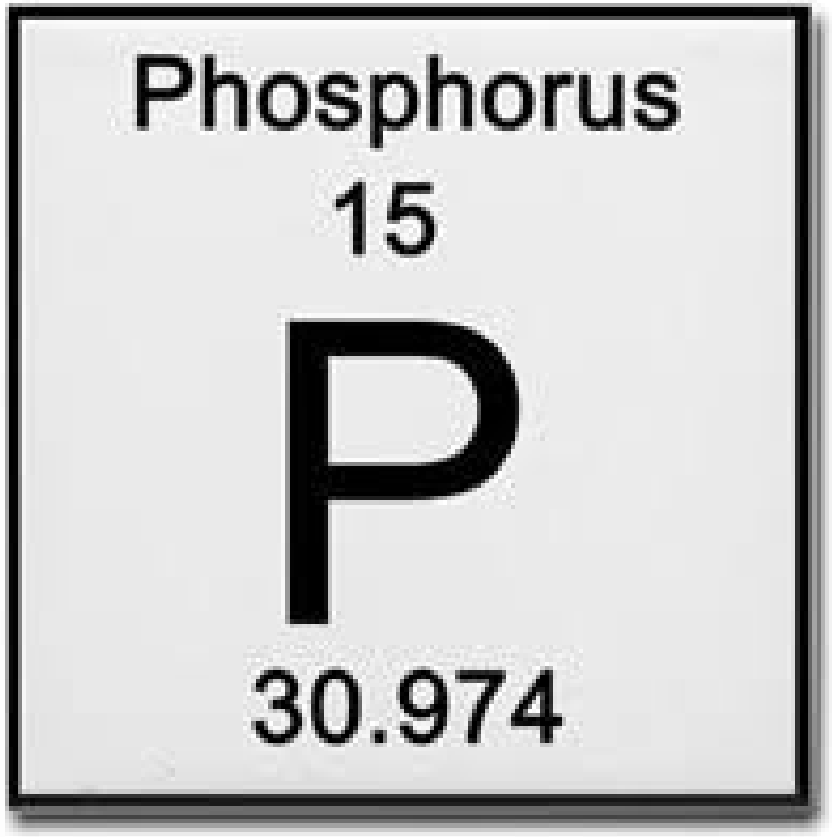
P

30.974

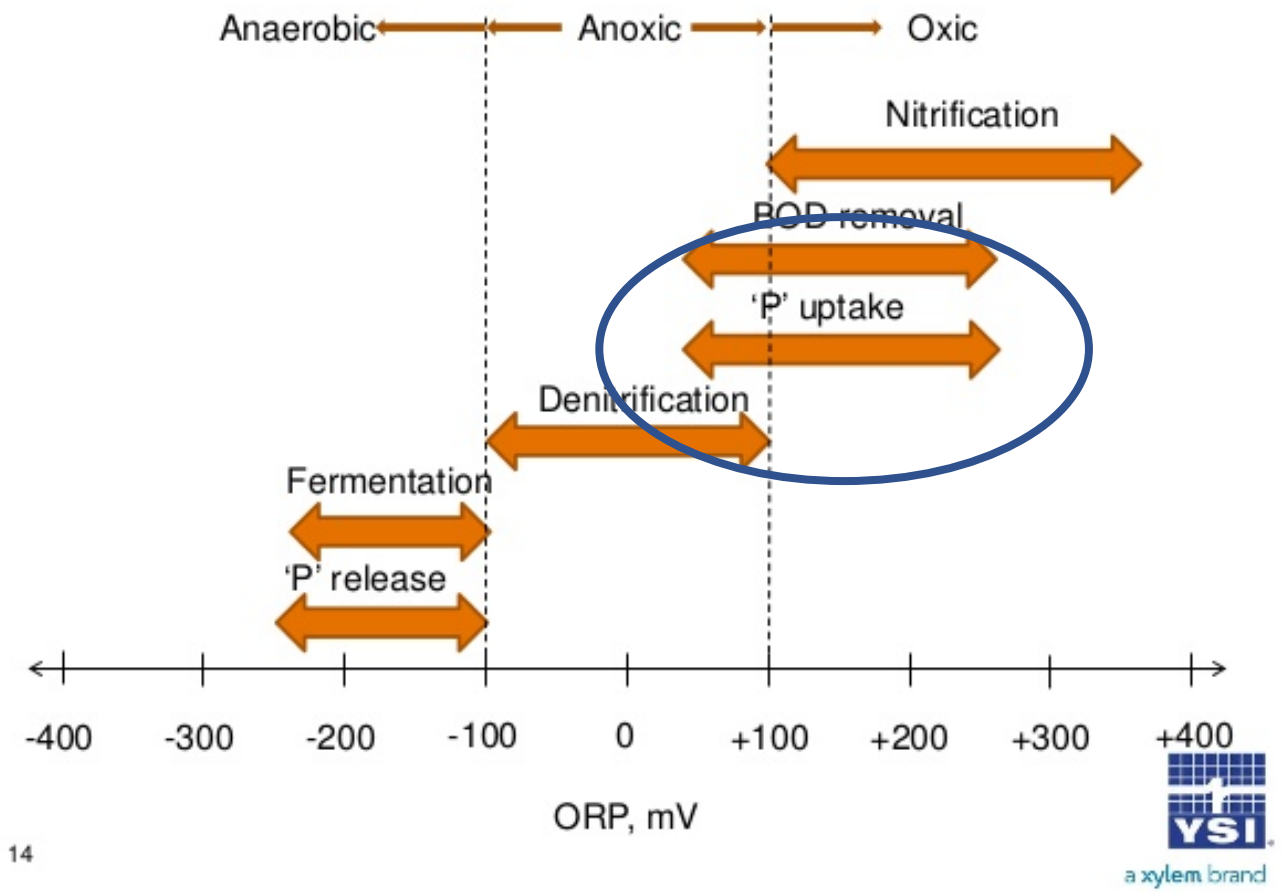
What Does ORP Tell Us About Our Process?



YSI a xylem brand



What Does ORP Tell Us About Our Process?



YSI
a xylem brand

Grant Weaver
g.weaver@cleanwaterops.com

Oxidation Ditch Knowledge


7
N
Nitrogen

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

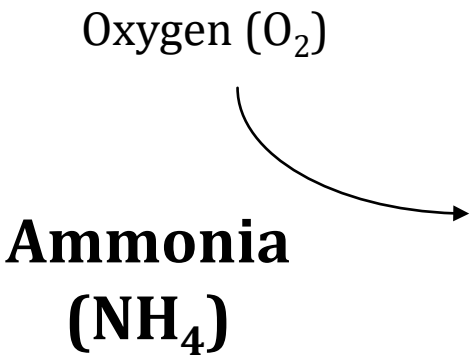
Ammonia Removal - 1st Step of N Removal

Ammonia Removal

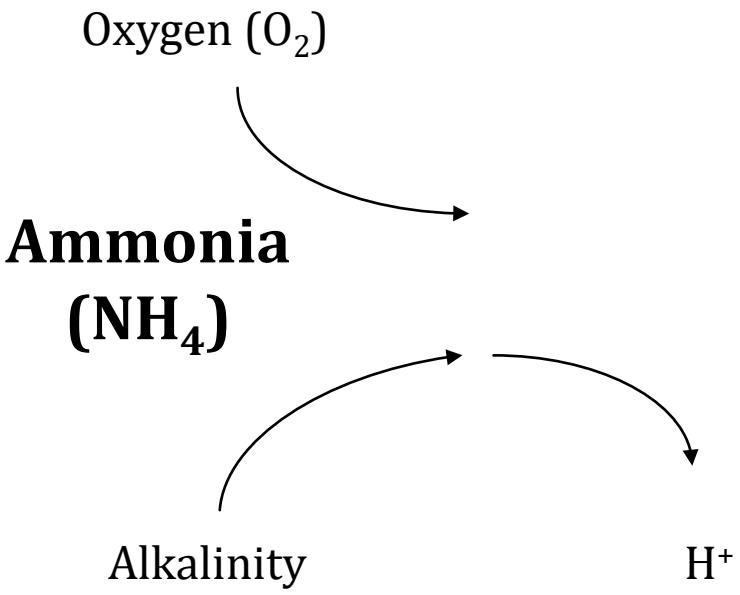
Ammonia (NH_4) is converted to Nitrate (NO_3)

Ammonia
(NH_4)

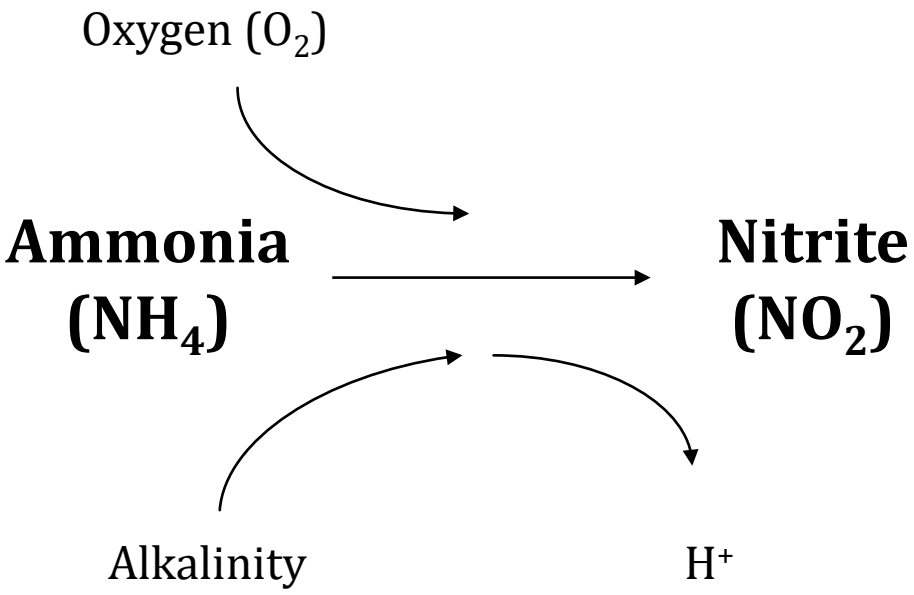
Ammonia Removal



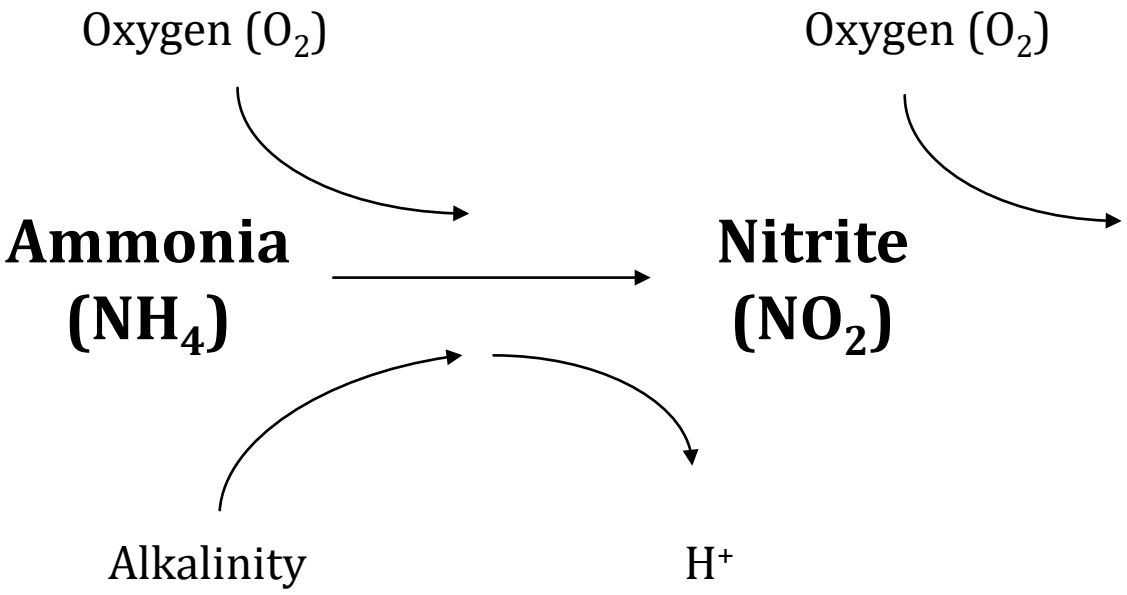
Ammonia Removal



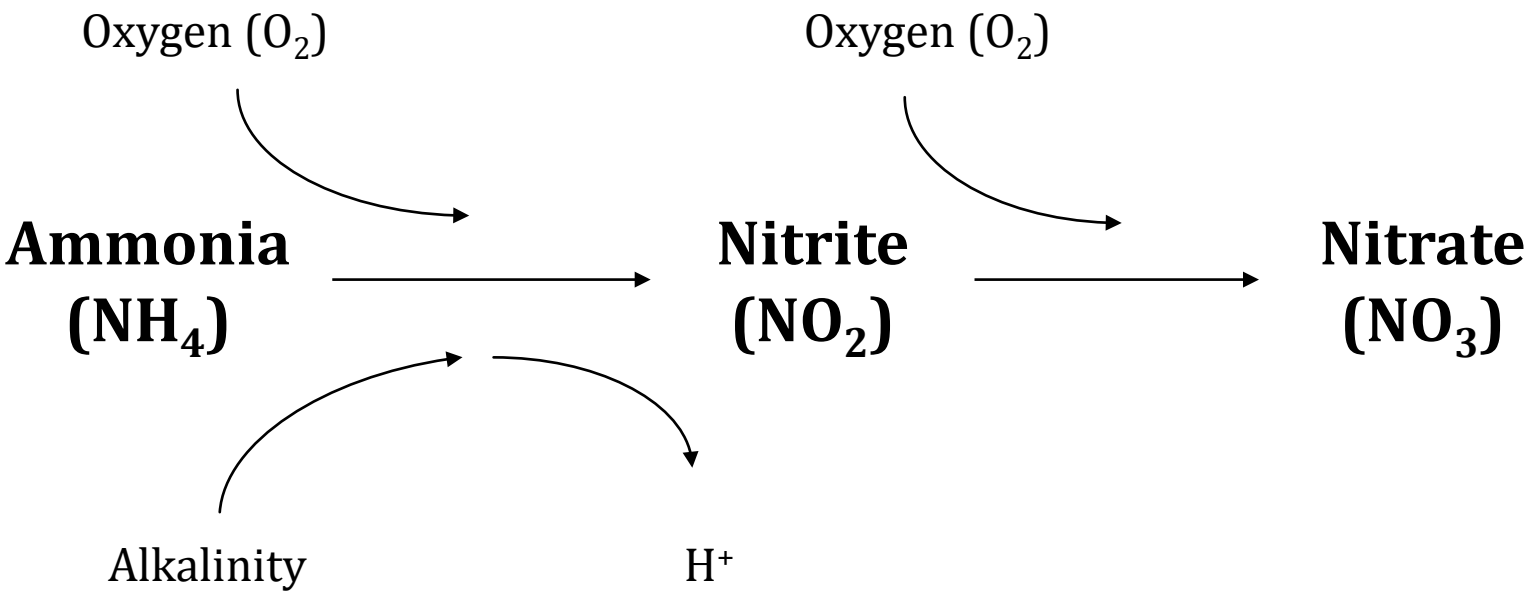
Ammonia Removal



Ammonia Removal



Ammonia Removal

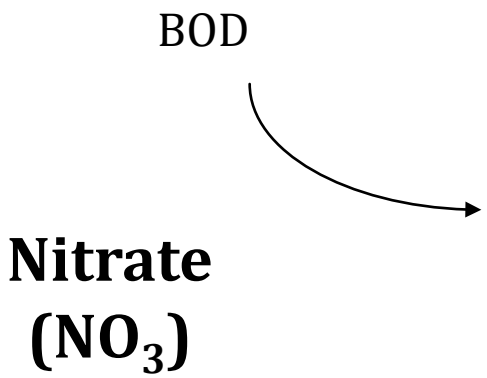


Nitrate Removal - 2nd Step of N removal

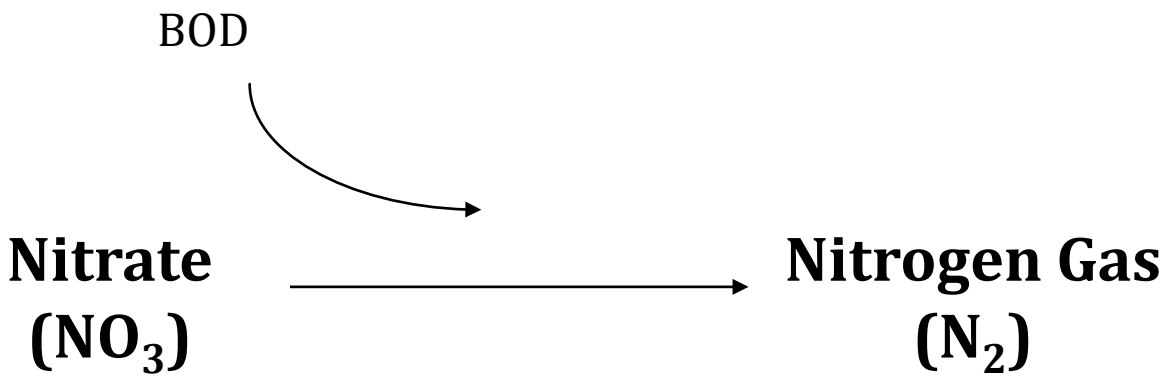
Nitrate Removal

Nitrate
(NO_3)

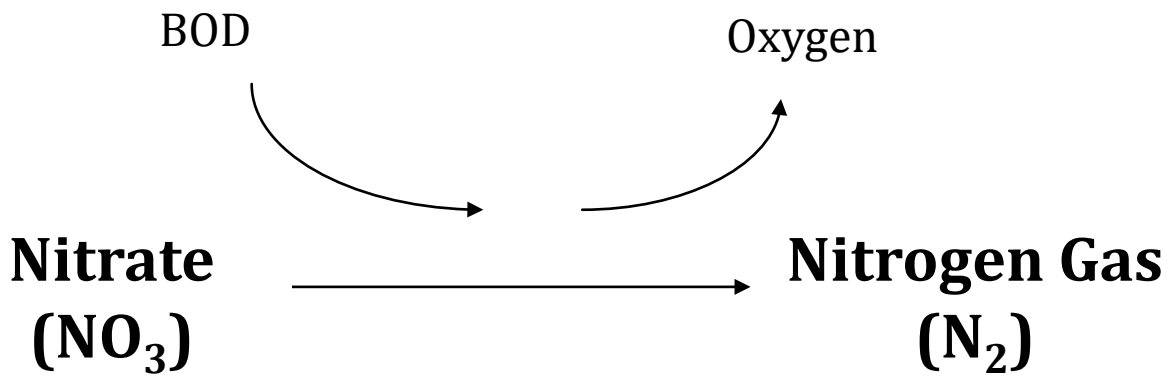
Nitrate Removal



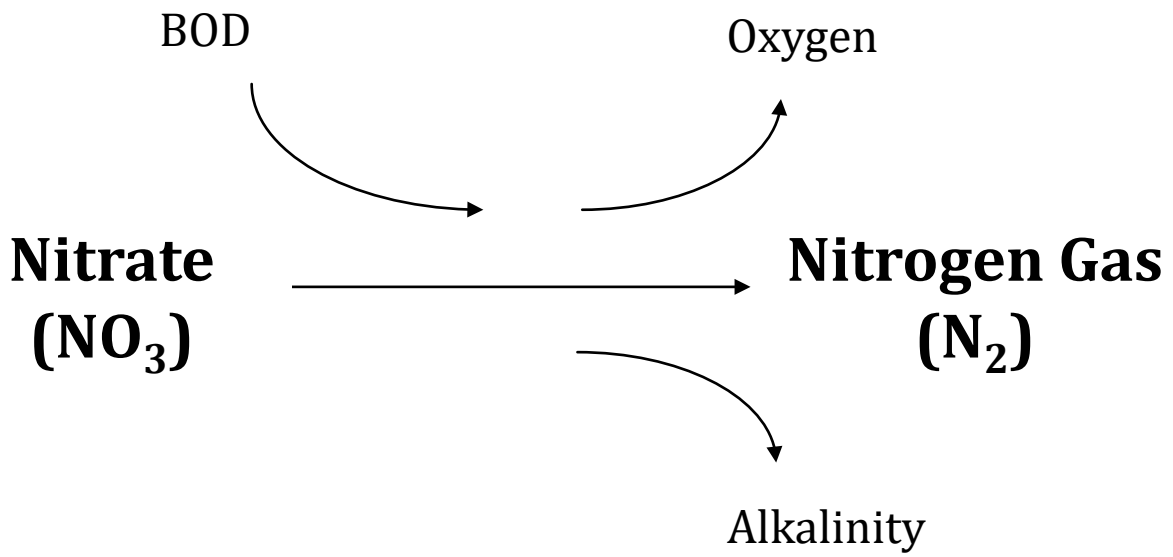
Nitrate Removal



Nitrate Removal



Nitrate Removal



Adds DO (dissolved oxygen)

Consumes BOD … Denitrifiers out compete bio-P bugs for VFAs!

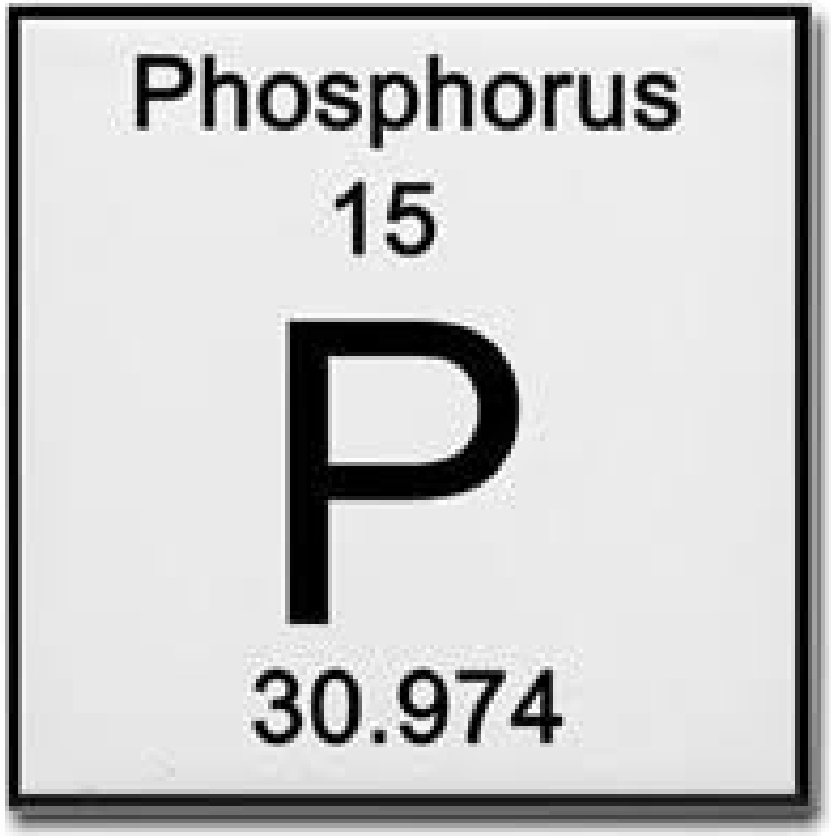
Gives back alkalinity … beneficially raises pH

Nitrogen Removal

	Step 1: Nitrification (Ammonia Removal)	**Step 1: Denitrification** (Nitrate Removal)
DO: Dissolved Oxygen	1 mg/L or more	Less than 0.2 mg/L
ORP: Oxygen Reduction Potential	+100 mV or more +	Less than -100 mV
MLSS: Mixed Liquor Suspended Solids	2500 mg/L or more	Same
HRT: Hydraulic Retention Time	6 or more hours	1 or more hours
BOD: Biochemical Oxygen Demand	less than 20 mg/L	**100 mg/L or more … VFAs preferred!**
Alkalinity	60 mg/L or more	
	Alkalinity is lost	***Alkalinity is gained***

Note: All numbers are approximations, “rules of thumb”

Grant Weaver
g.weaver@cleanwaterops.com


Phosphorus
15
P
30.974

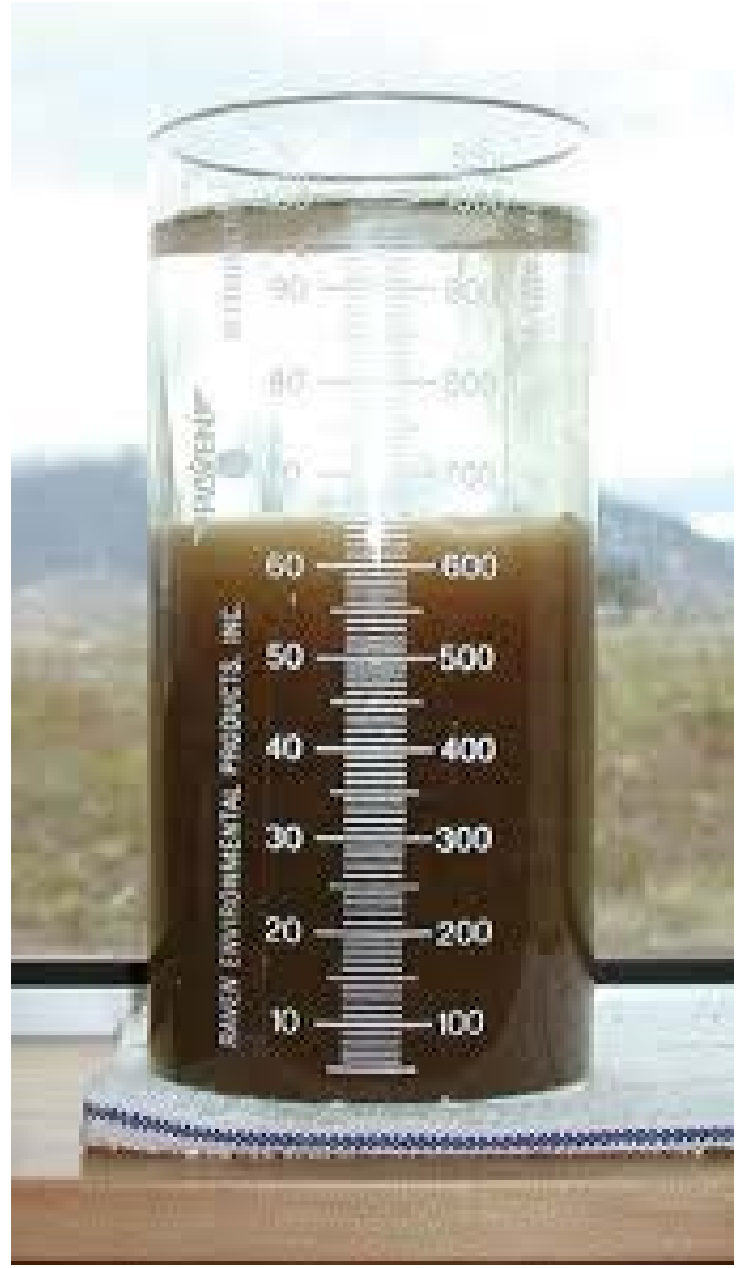
Phosphorus Removal:
What an Operator needs to know

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

Optimizing Bio-P Removal: Mainstream or Sidestream Fermentation

Anaerobic Tank

2 hour HRT (hydraulic retention time)*
ORP of -200 mV*
25 times as much BOD as influent ortho-P*
Ortho-P release (3 times influent ortho-P)*

Aeration Tank

DO of 2.0 mg/L
ORP of +150 mV
pH of 7.0+*
Ortho-P concentration of 0.05 mg/L*

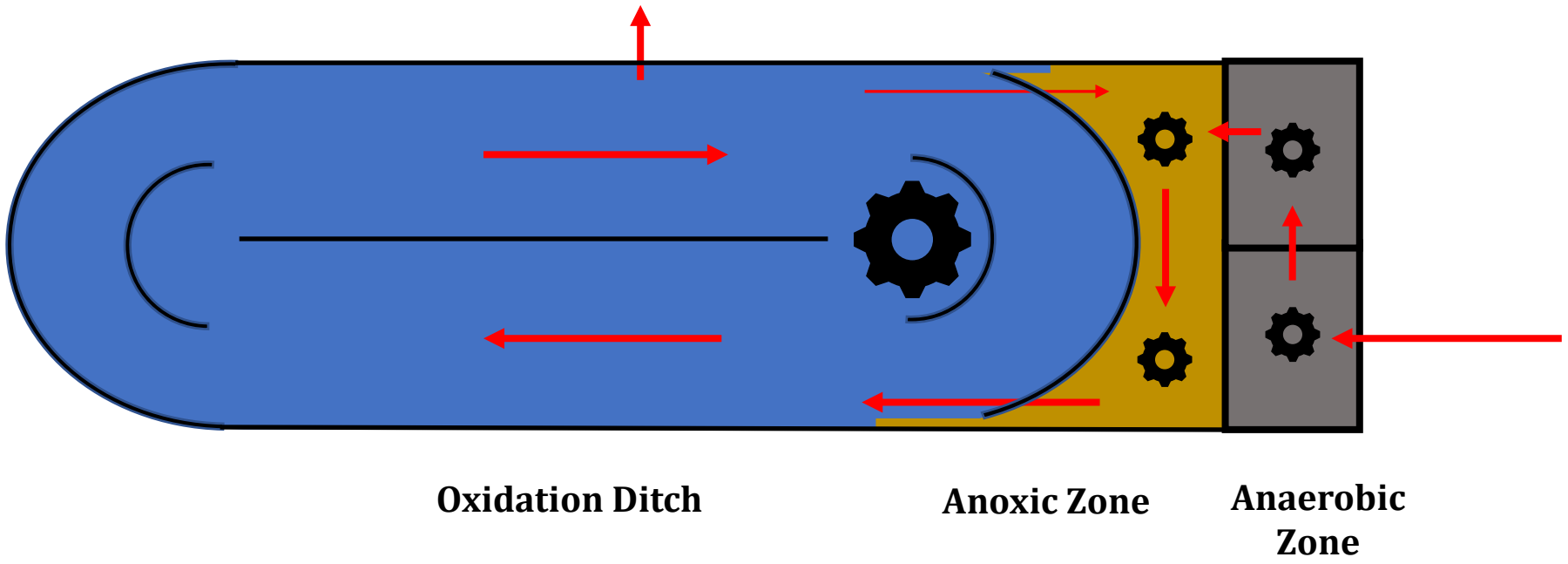
*Approximate: Every Plant is Different

Grant Weaver
g.weaver@cleanwaterops.com

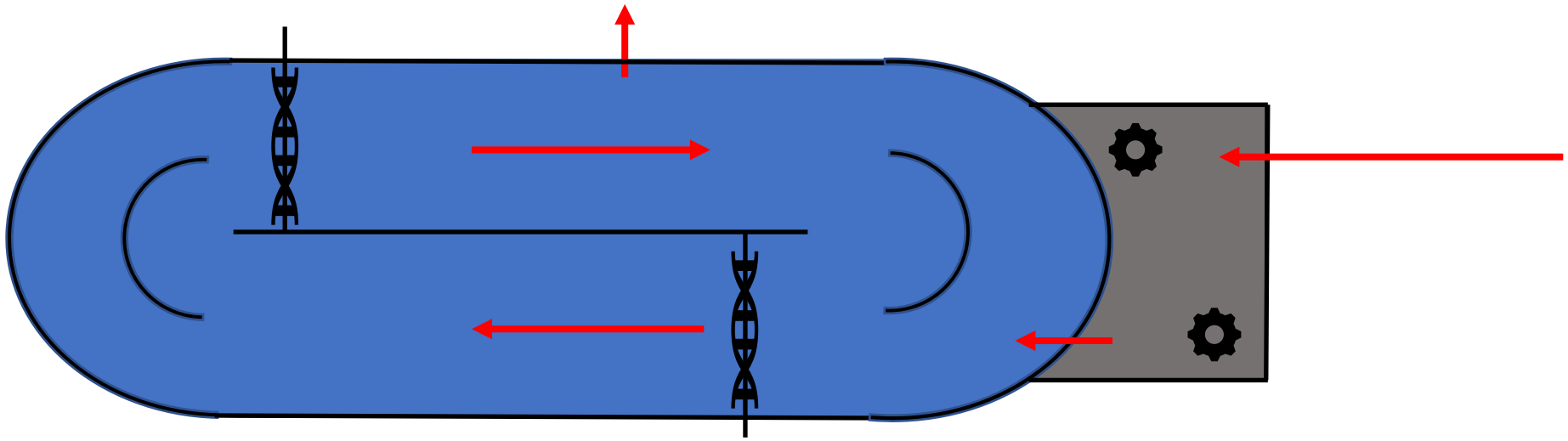
Survey Question (soon):
Which Oxidation Ditch is yours?

Orbal Oxidation Ditch

Oxidation Ditch with Anaerobic and Anoxic Zone

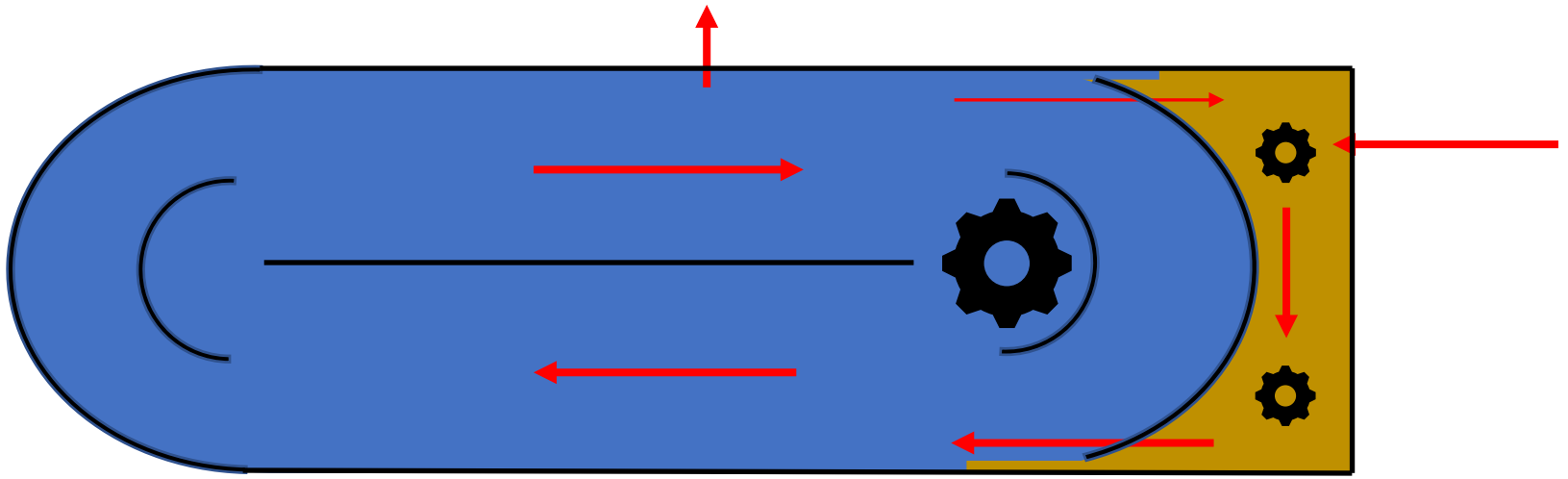


Oxidation Ditch with Anaerobic Zone



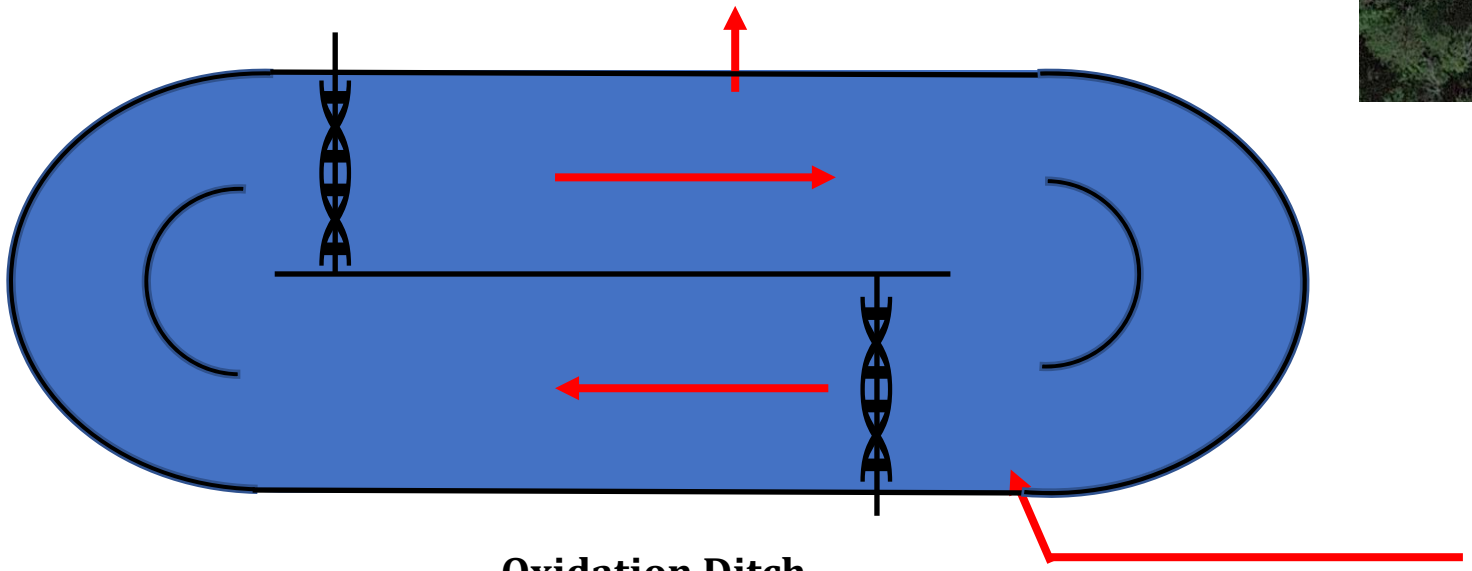
Oxidation Ditch **Anaerobic Zone**

Oxidation Ditch with Anoxic Zone



Oxidation Ditch **Anoxic Zone**

Oxidation Ditch with no Anoxic Zone and no Anaerobic Zone



Oxidation Ditch


Which Oxidation Ditch is Yours?


HOW
AND
WHY

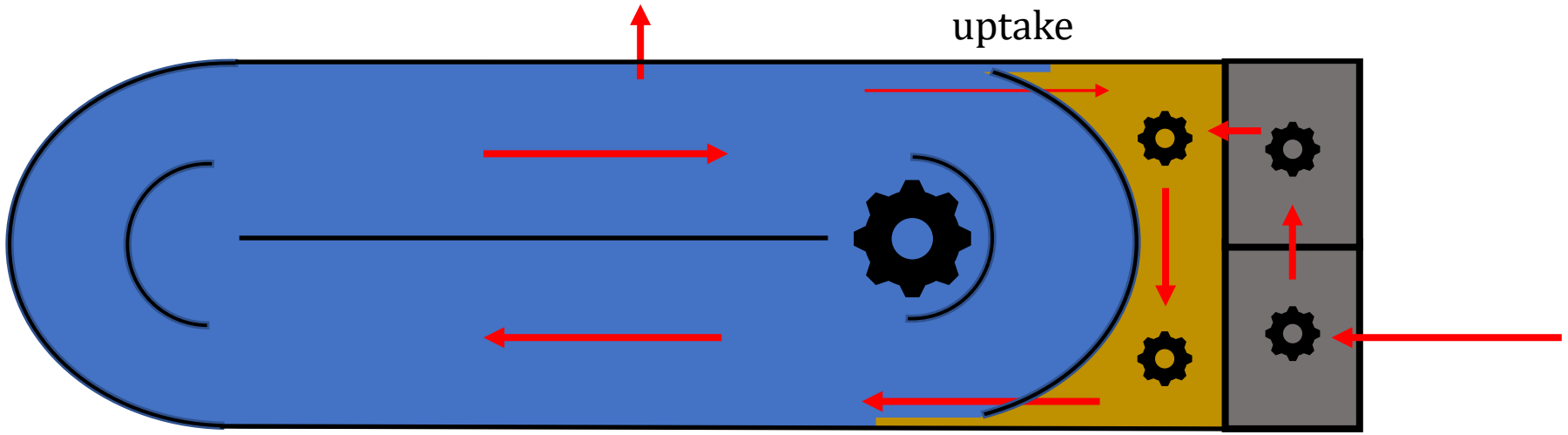
Anaerobic Zone:
VFA production / VFA uptake / Phosphorus release

Oxidation Ditch with Anaerobic and Anoxic Zones

Anoxic Zone:
Nitrate removal (Denitrification)

Designed for Nitrogen and Phosphorus Removal

Oxidation Ditch:
Ammonia removal (Nitrification) / Phosphorus uptake



Anoxic Zone **Anaerobic Zone**

Optimizing Nutrient Removal **Oxidation Ditch**

Anaerobic zone: VFA production & uptake

Anoxic zone: Nitrate → Nitrogen Gas

Aerobic zone: Ammonia → Nitrate / Phosphorus uptake

Grant Weaver
g.weaver@cleanwaterops.com

Oxidation Ditch with Anaerobic and Anoxic Zones

Lansing, KS

Choteau, MT
Garden Plains, KS
Rose Hill, KS

Lansing, Kansas Population: 12,000 3.2 MGD design flow


Lansing, KS

Lansing, KS
Nitrogen Removal

Lansing, KS
Nitrogen Removal

Lansing, KS
Phosphorus Removal


Lansing, KS
Phosphorus Removal

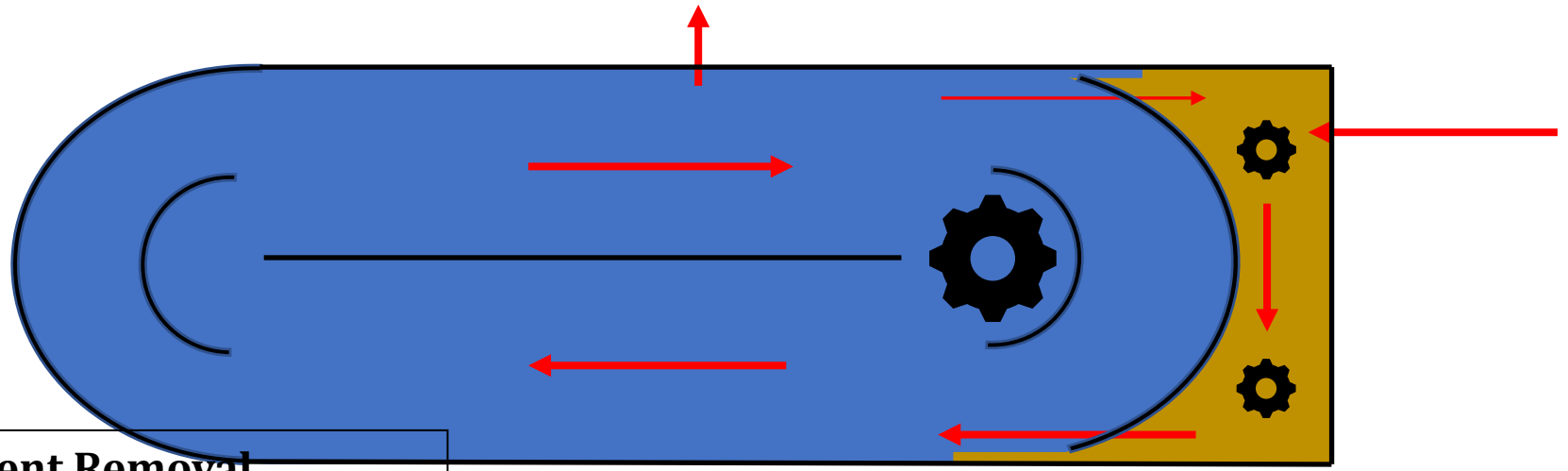
Grant Weaver
g.weaver@cleanwaterops.com

Oxidation Ditch with Anoxic Zone

NOT designed for Phosphorus Removal

Anoxic Zone:
Nitrate removal (Denitrification)

Oxidation Ditch:
BOD and Ammonia removal (Nitrification)



Oxidation Ditch **Anoxic Zone**

Optimizing Nutrient Removal

Plan A. Nitrify <u>and</u> Denitrify in Ditch
Make Anoxic Zone anaerobic

Plan B. 3D/4D ferment in ditch

Plan C. Sidestream fermenter

Grant Weaver
g.weaver@cleanwaterops.com

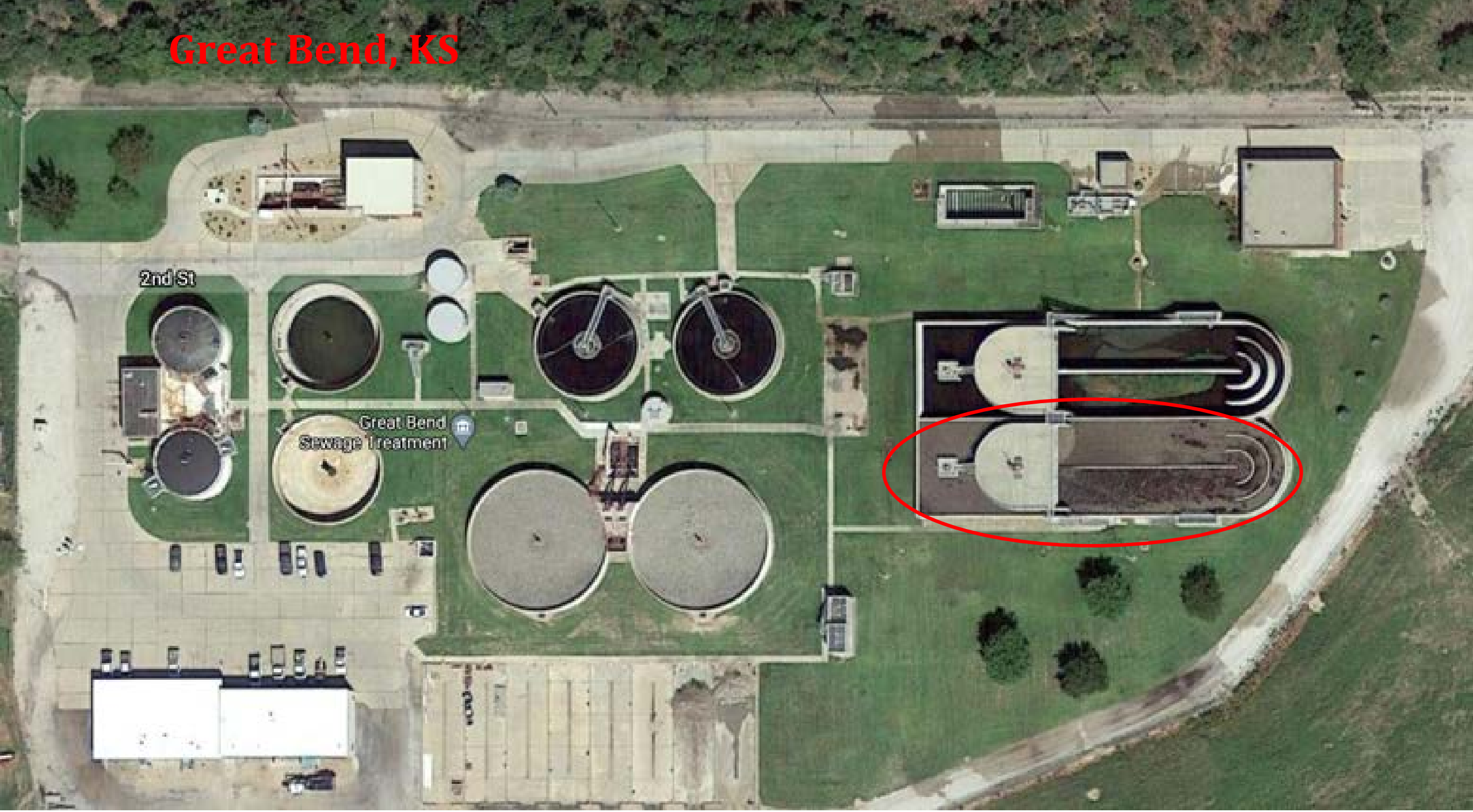
Oxidation Ditch with Anoxic Zone

Great Bend, KS

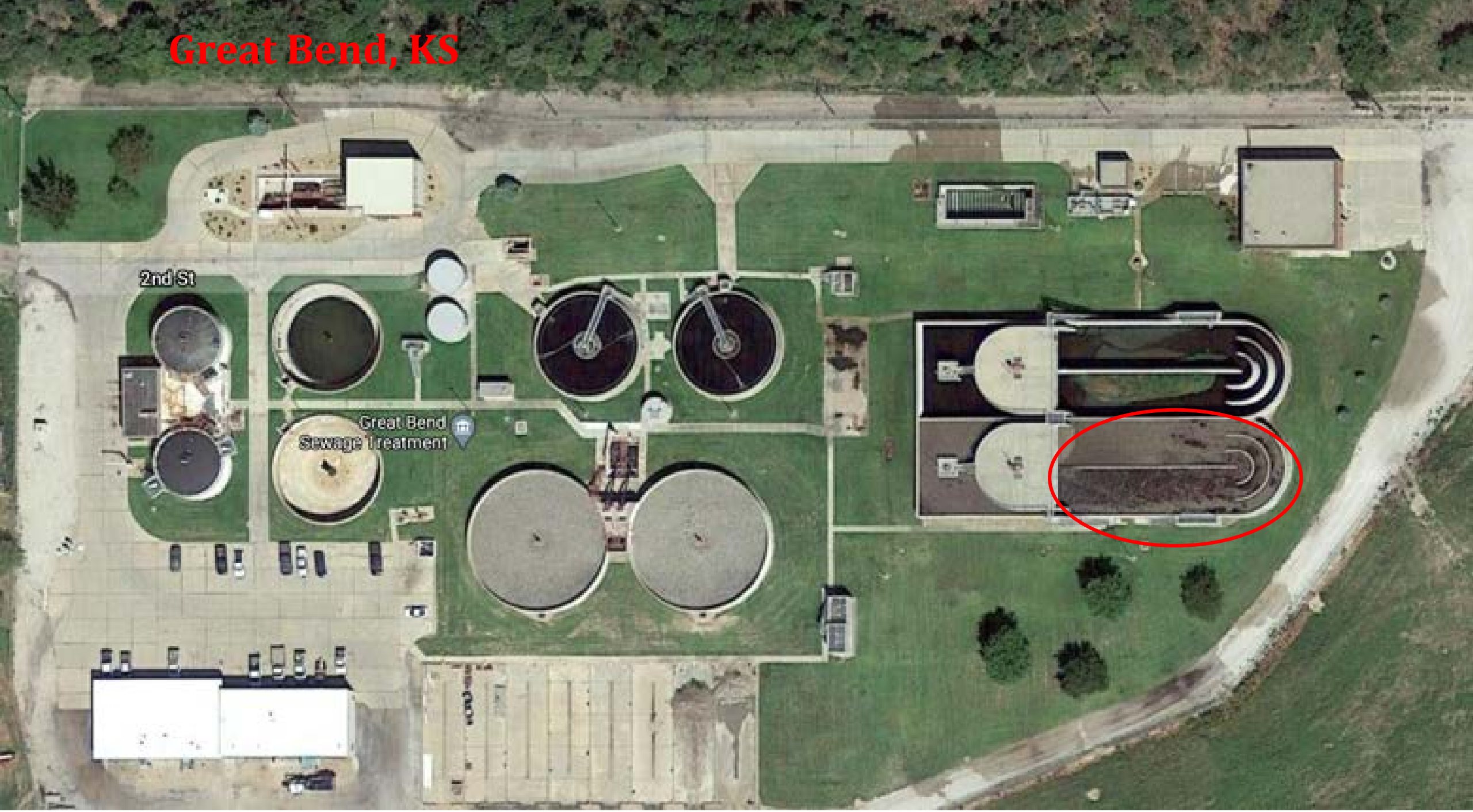
Collierville, TN
Derby, KS
Great Bend, KS
Hamilton, MT
Kingman, KS
LaFollette, TN

Great Bend, Kansas Population: 13,400 3.6 MGD design flow

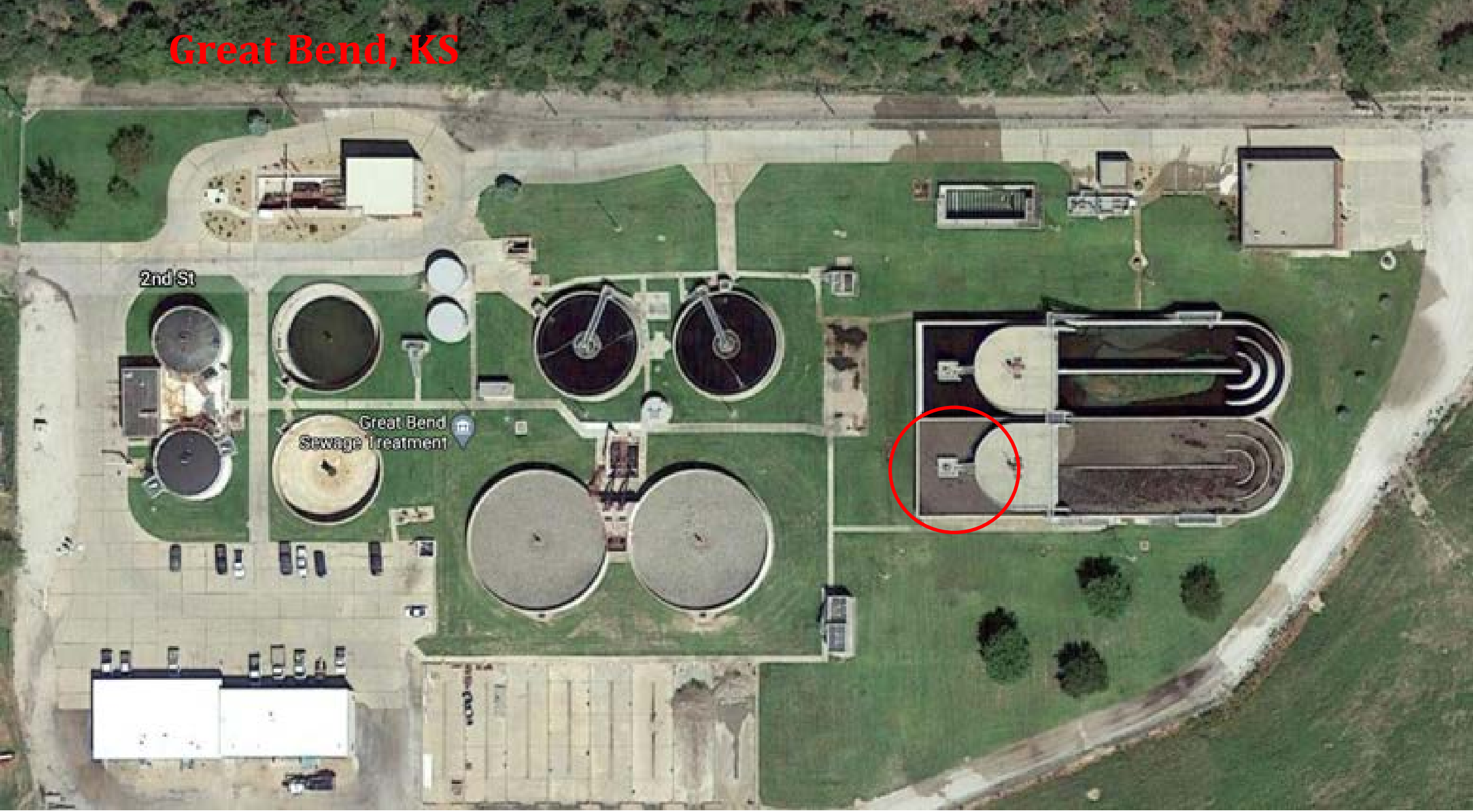
Great Bend, KS



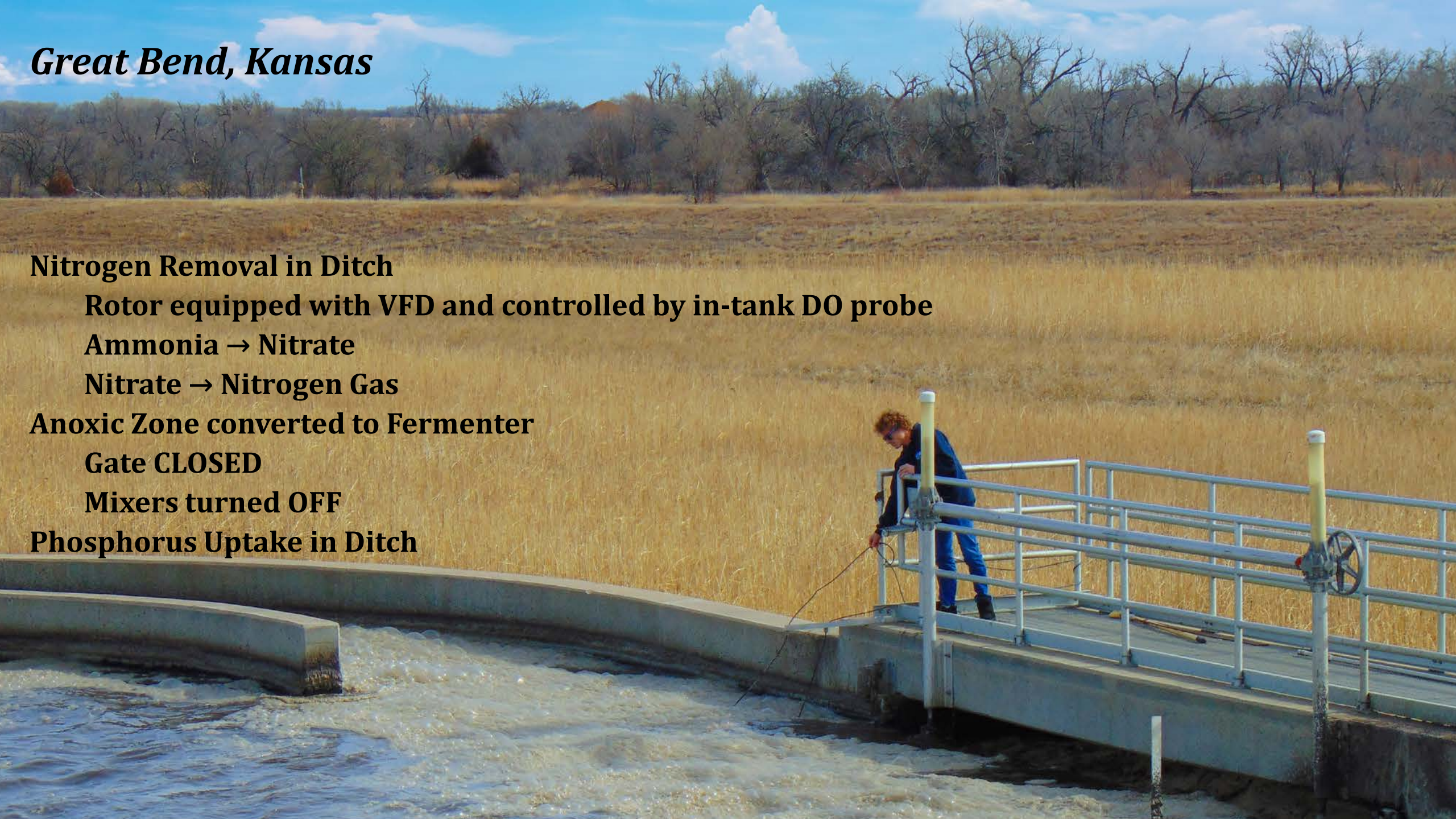
Great Bend, KS



Great Bend, KS



Great Bend, Kansas



Nitrogen Removal in Ditch

- **Rotor equipped with VFD and controlled by in-tank DO probe**
- **Ammonia → Nitrate**
- **Nitrate → Nitrogen Gas**

Anoxic Zone converted to Fermenter

- **Gate CLOSED**
- **Mixers turned OFF**

Phosphorus Uptake in Ditch

Grant Weaver
g.weaver@cleanwaterops.com


BREAK TIME
memegenerator.net

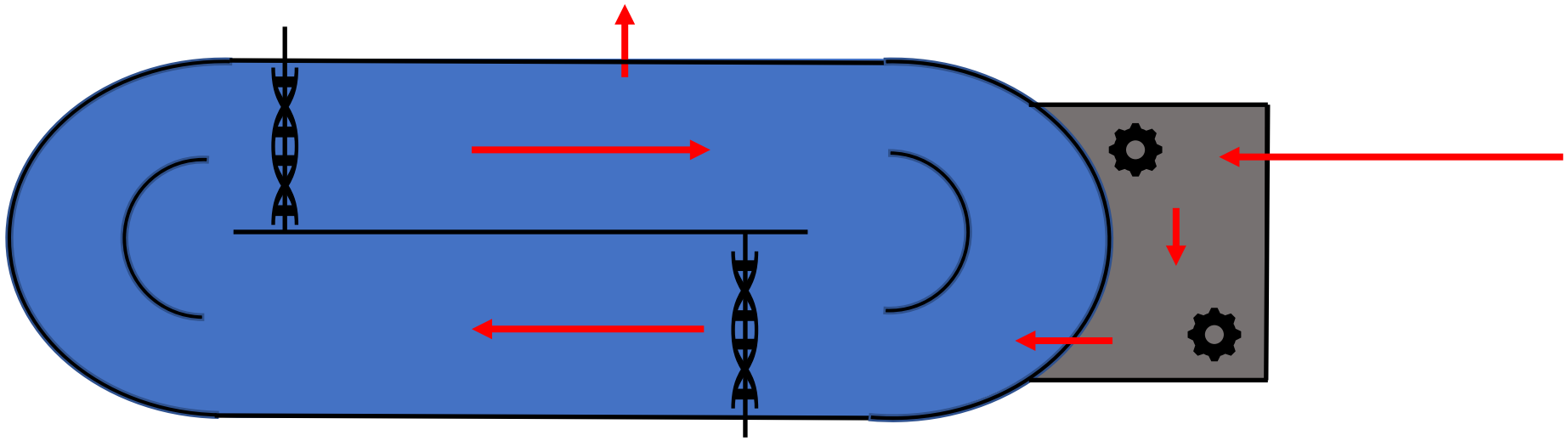
Oxidation Ditch with Anaerobic Zone

Designed for Ammonia Removal but NOT total-Nitrogen Removal

Anaerobic Zone:
VFA production / VFA uptake / ortho-P release

Oxidation Ditch:
BOD and Ammonia removal (Nitrification)

Oxidation Ditch



Optimizing Nutrient Removal

Nitrogen: Nitrify and Denitrify in Ditch: 1 rotor and/or cycle rotor(s) on & off

Phosphorus: Strengthen Anaerobic Zone by cycling mixer(s) off & on

Grant Weaver
g.weaver@cleanwaterops.com

Oxidation Ditch with Anaerobic Zone

LaFollette, TN

LaFollette, Tennessee Population: 6,800 1.87 MGD design flow


LaFollette, TN
La Follette
Wastewater Plant


LaFollette, TN
La Follette
Wastewater Plant

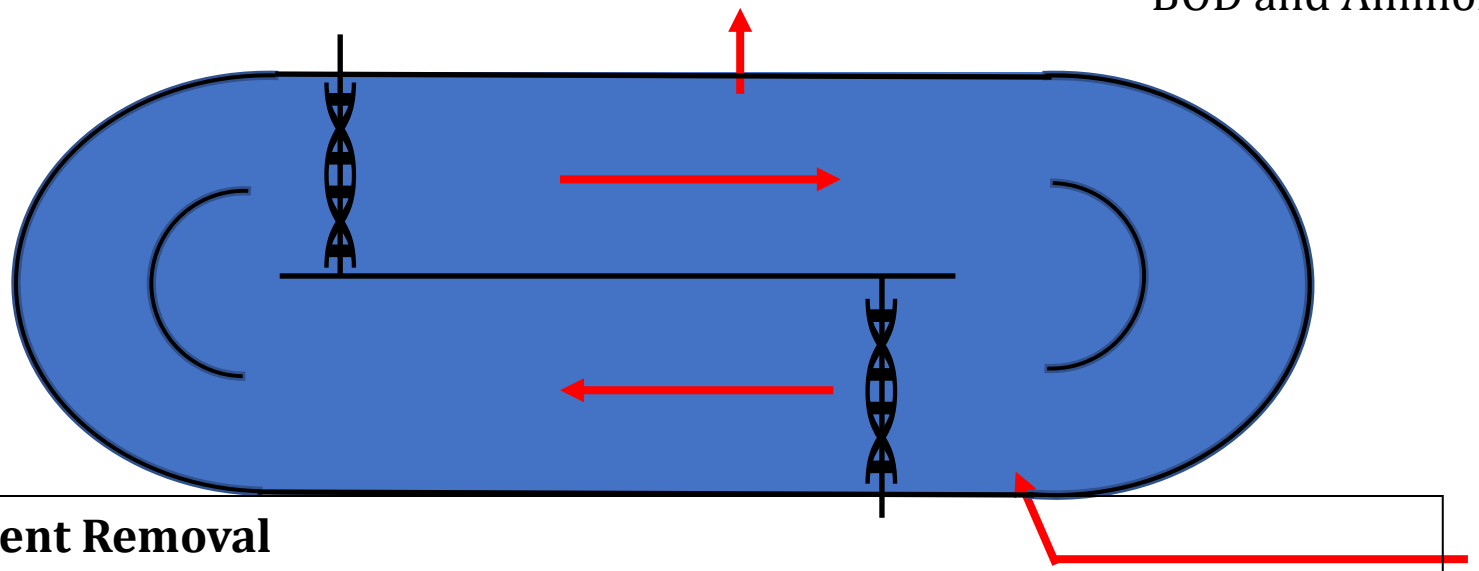

LaFollette, TN
La Follette Wastewater Plant

Grant Weaver
g.weaver@cleanwaterops.com

Oxidation Ditch with no Anoxic Zone and no Anaerobic Zone

Designed for Ammonia Removal but
NOT designed for total-Nitrogen or Phosphorus Removal

Oxidation Ditch:
BOD and Ammonia removal (Nitrification)



Optimizing Nutrient Removal

Nitrogen Removal: Nitrify and Denitrify in Ditch: 1 rotor and/or cycle rotor(s) on & off

Phosphorus Removal:

A. Create anaerobic sludge blankets in ditch / resuspend MLSS

B. Create sidestream fermenter and recycle sludge into ditch

Grant Weaver
g.weaver@cleanwaterops.com

Oxidation Ditch w/o Anoxic or Anaerobic Zones

Harriman, TN
Cookeville, TN

Athens Mouse Creek, TN
Bartlett, TN
Chinook, MT
Colstrip, MT
Cowan, TN
Forsyth, MT
Halstead, KS

Hardin, MT
Pratt, KS
Lewistown, MT
Libby, MT
Lyons, KS
Miles City, MT
Millington, TN

Harriman, Tennessee Population: 6,200 1.5 MGD design flow

Harriman, Tennessee

Actual Flow	Effluent Nitrogen (mg/L)		Effluent Phosphorus (mg/L)	
(MGD)	Historical Average	After Optimization	Historical Average	After Optimization
1.2	21.5	2.3	2.9	1.4

Harriman - As Designed


Harriman - As Operated
Emory River
Emory River
Bullard Ford Rd

Harriman - As Operated


Harriman - As Operated
Emory River
Bullard Ford Rd
Bullard Ford Rd
Emory River


Harriman - As Operated
Emory River
Emory River
Bullard Ford Rd
llard Ford Rd


Harriman - As Operated
Emory River
Emory River
Bullard Ford Rd
llard Ford Rd


Harriman - As Operated
Emory River
Bullard Ford Rd
Emory River
llard Ford Rd

Grant Weaver
g.weaver@cleanwaterops.com

Oxidation Ditch w/o Anoxic or Anaerobic Zones

Harriman, TN
Cookeville, TN

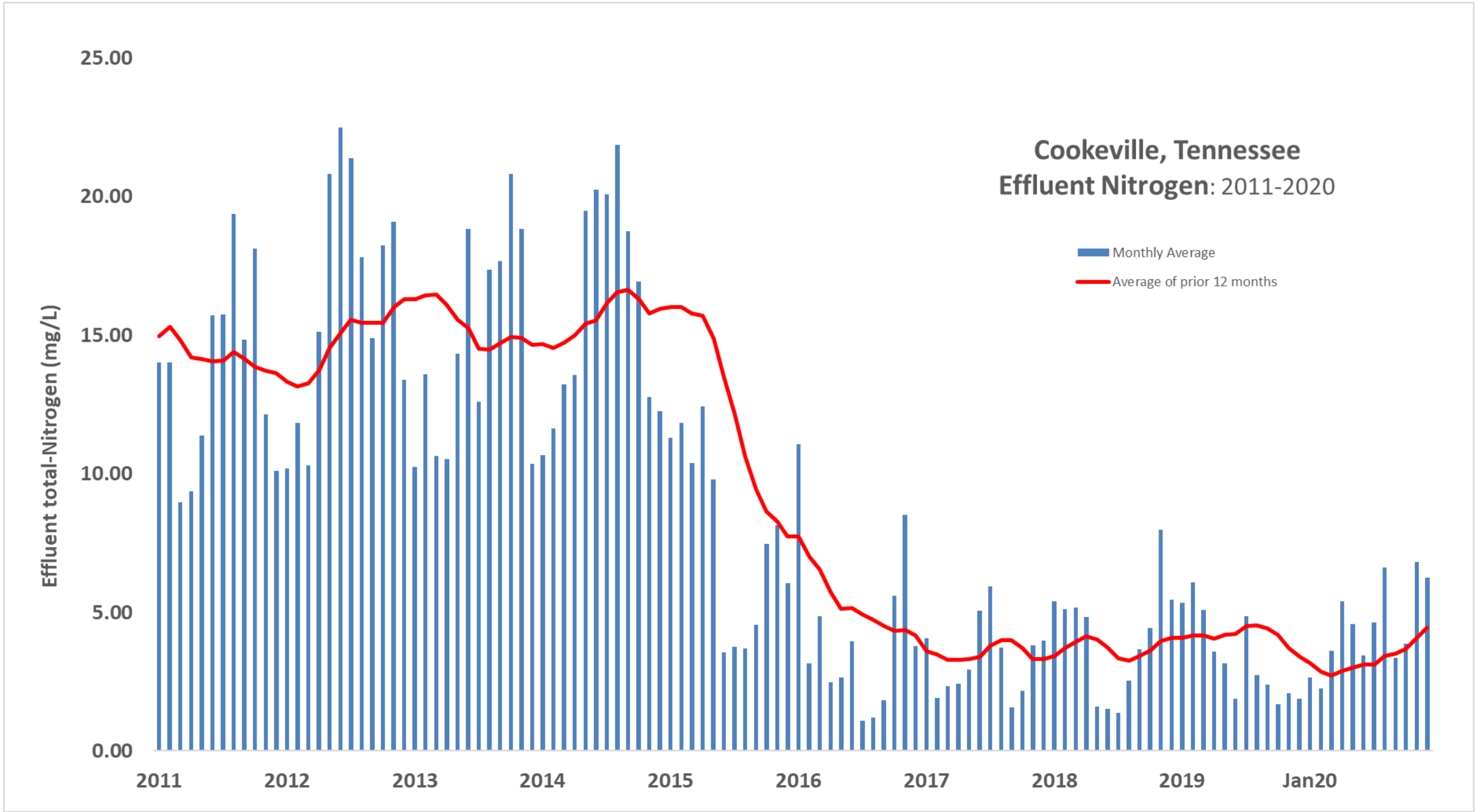
Athens Mouse Creek, TN
Bartlett, TN
Chinook, MT
Colstrip, MT
Cowan, TN
Forsyth, MT
Halstead, KS

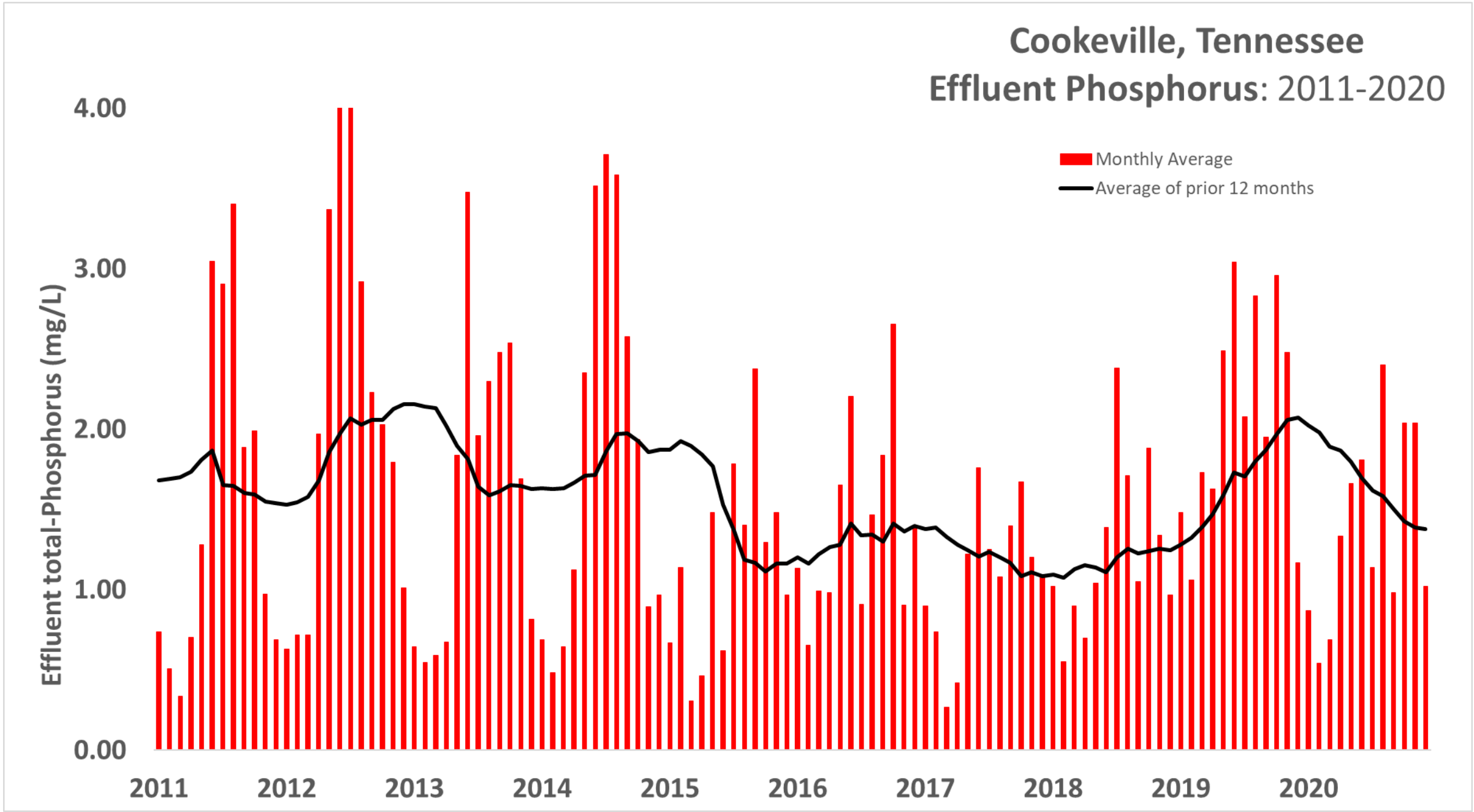
Hardin, MT
Pratt, KS
Lewistown, MT
Libby, MT
Lyons, KS
Miles City, MT
Millington, TN

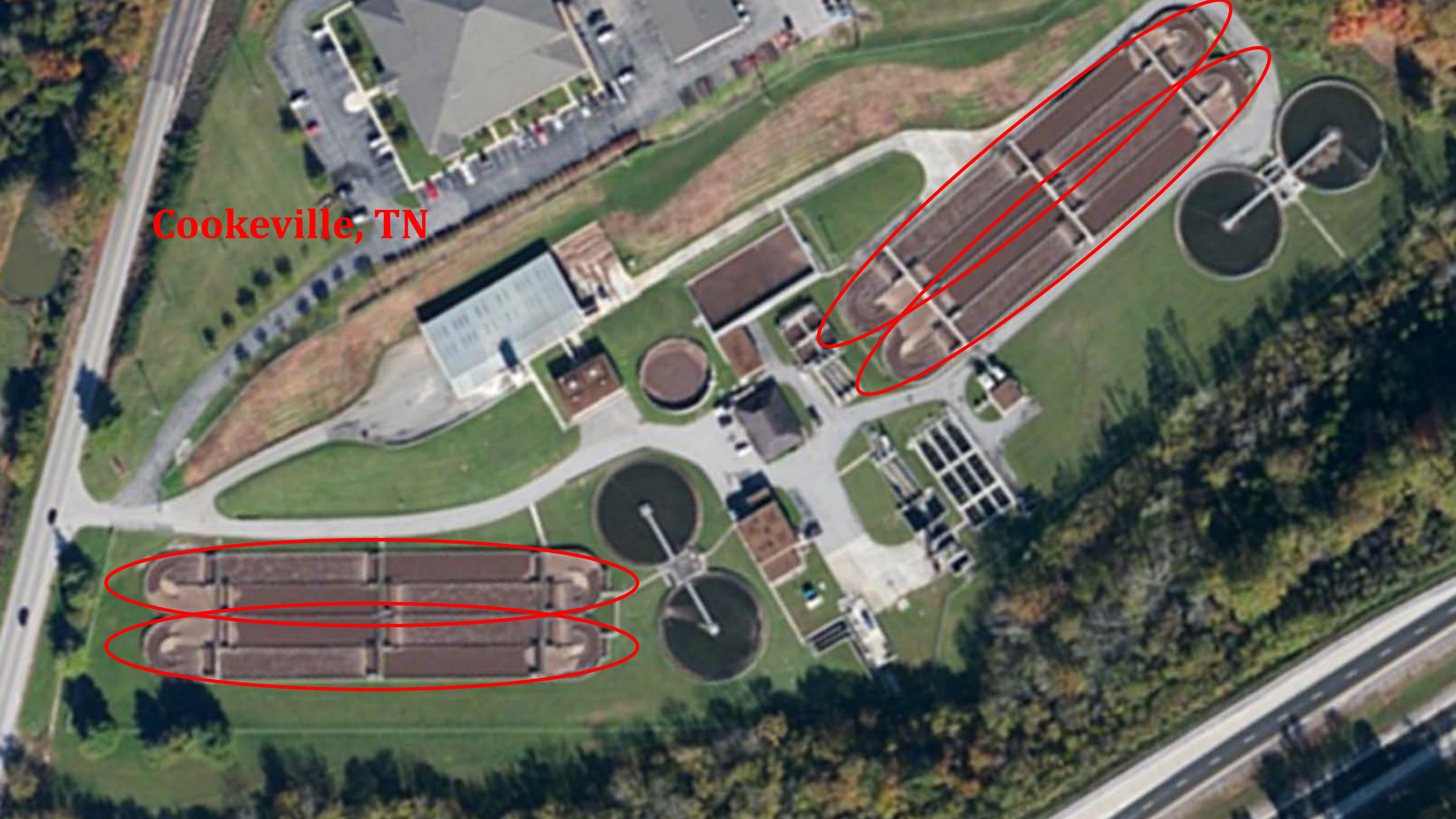
Cookeville, Tennessee Population: 33,500 15 MGD design flow

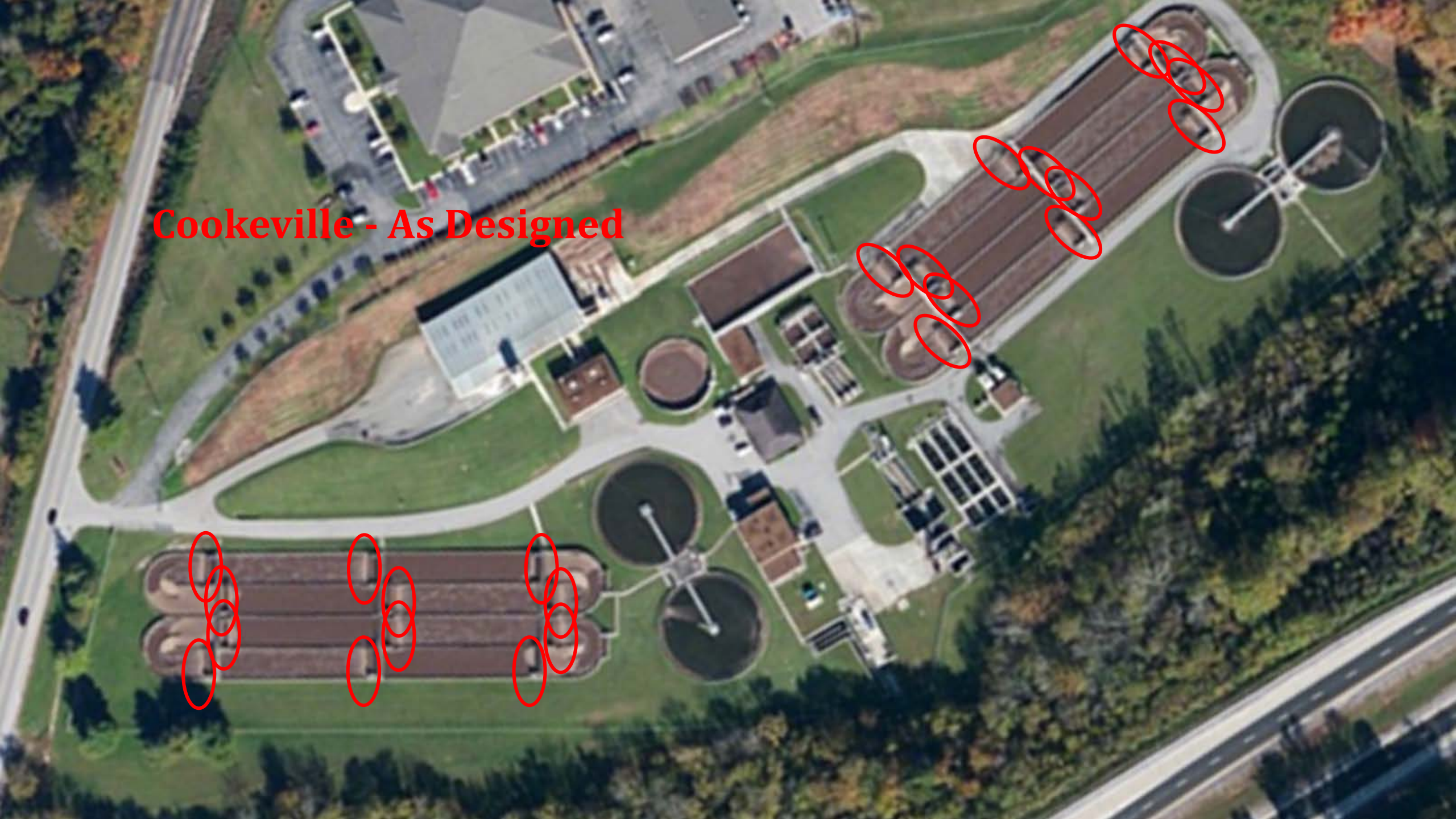

Cookeville


TREATMENT PLANT OPERATOR
tpo
LET'S BE CLEAR:
Are you a technophobe? | 6
IN MY WORDS:
Treatment innovations for small communities | 22
TECH TALK:
A new approach to flood protection | 14
From Learner to Mentor
MICHELE HIGDON SAYS THANKS FOR HER SUCCESS BY GIVING BACK AS A VOLUNTEER | 10
SPECIAL FEATURE:
PLANT PROFICIENCIES


Cookeville, Tennessee
Effluent Nitrogen: 2011-2020
Monthly Average
Average of prior 12 months
Effluent total-Nitrogen (mg/L)
25.00
20.00
15.00
10.00
5.00
0.00
2011
2012
2013
2014
2015
2016
2017
2018
2019
Jan20


Cookeville, Tennessee
Effluent Phosphorus: 2011-2020
Monthly Average
Average of prior 12 months
Effluent total-Phosphorus (mg/L)
4.00
3.00
2.00
1.00
0.00
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020


Cookeville, TN


Cookeville - As Designed


Cookeville - As Now Operated


Cookeville - As Now Operated

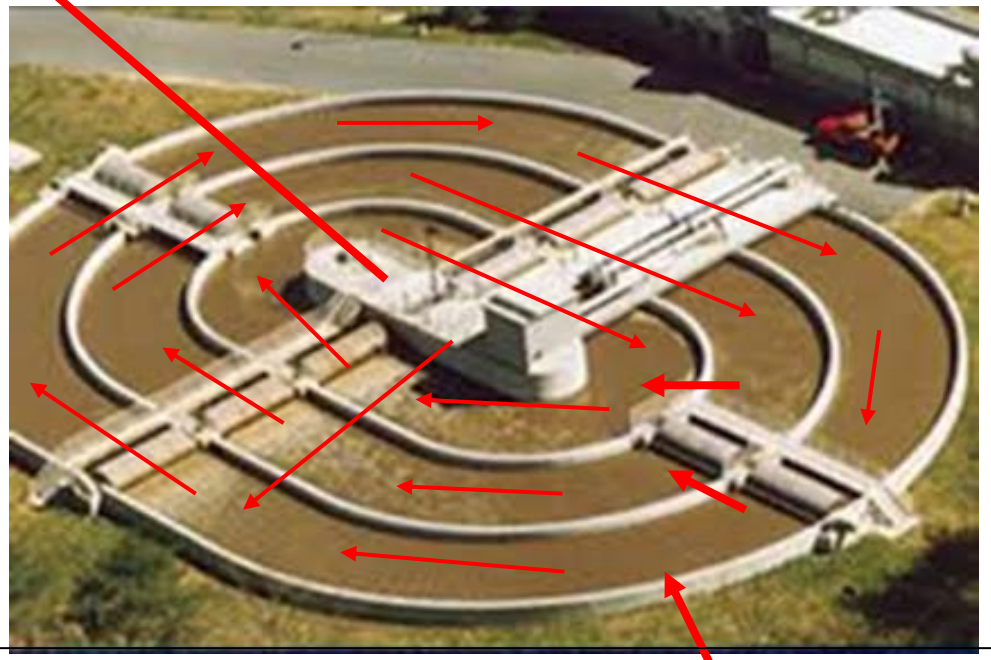

Cookeville - As Now Operated


Cookeville - As Now Operated

Grant Weaver
g.weaver@cleanwaterops.com

Orbal Oxidation Ditch

Designed for Nitrogen Removal … often for Phosphorus Removal too



Outermost Ring:
Anoxic (Denitrification)
Oftentimes, Anaerobic (VFA production)

Middle Ring:
Simultaneous Nitrification / Denitrification

Innermost Ring:
Aerobic (Nitrification)

Opportunities for enhancing nutrient removal
Nitrogen Removal: Aerobic & Anoxic zones
Phosphorus Removal:
A. Optimize ditch … maybe bypass portion of influent around two outer rings
B. Sidestream fermenter

Grant Weaver
g.weaver@cleanwaterops.com

Orbal System

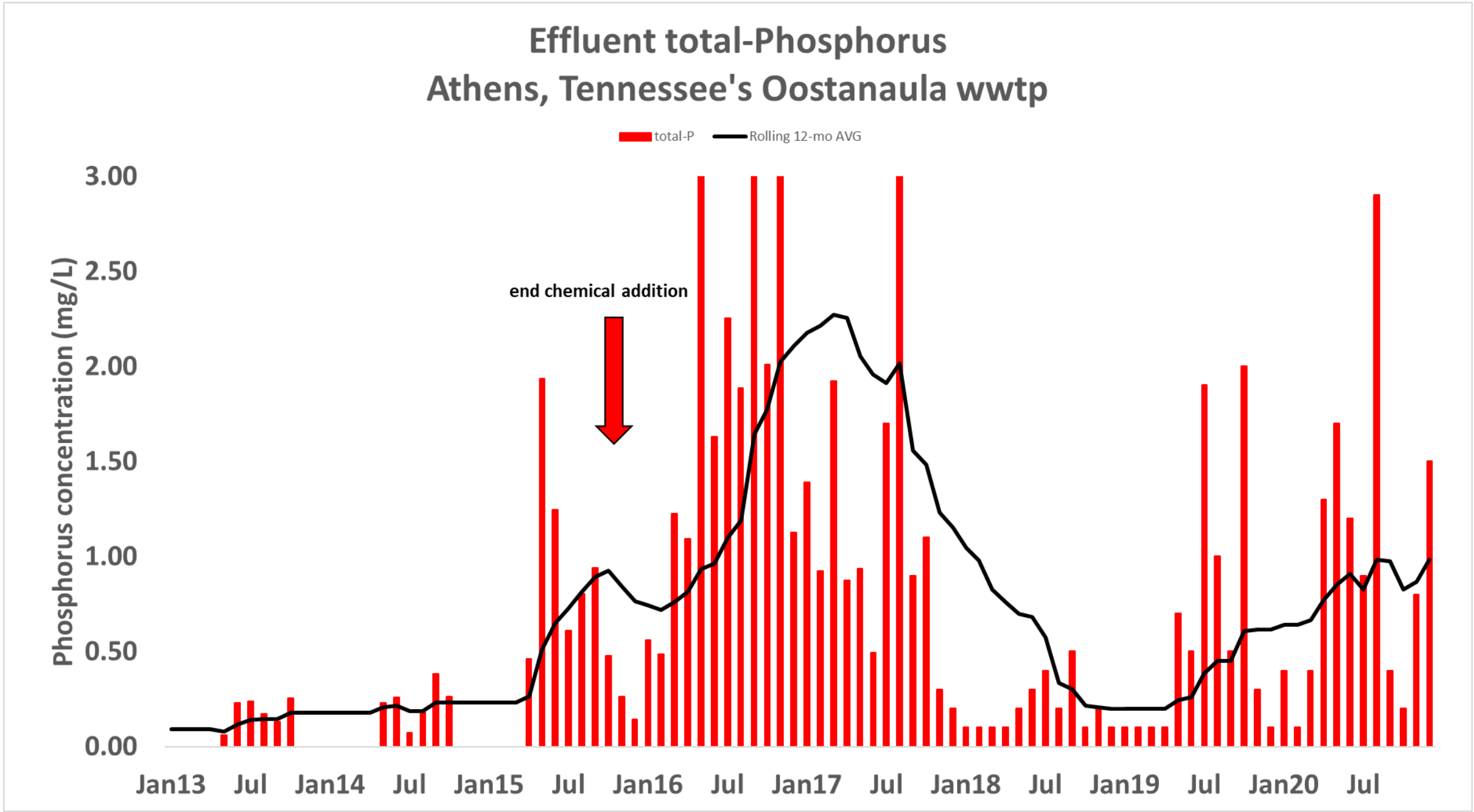
Athens, TN Oostanaula wwtp

Athens, Tennessee Population: 13,850 6.0 MGD design flow


Athens Oostanaula (TN)


Athens Oostanaula (TN)


Athens Oostanaula (TN)


Effluent total-Phosphorus
Athens, Tennessee's Oostanaula wwtp
total-P
Rolling 12-mo AVG
Phosphorus concentration (mg/L)
3.00
2.50
2.00
1.50
1.00
0.50
0.00
end chemical addition
Jan13
Jul
Jan14
Jul
Jan15
Jul
Jan16
Jul
Jan17
Jul
Jan18
Jul
Jan19
Jul
Jan20
Jul

Grant Weaver
g.weaver@cleanwaterops.com

Acknowledgements, Part 1

TENNESSEE DEPARTMENT OF ENVIRONMENT & CONSERVATION (TDEC)
Karina Bynum, Sherry Wang, George Garden, Jenny Dodd, Jason Benton, Eddie Bouzied, Bryan Carter, David Duhl, Jordan Fey, Oakley Hall, Michael Murphy, Steve Owens, Rob Ramsey, Sherwin Smith, Robert Tipton, Sandra Vance, John West, Ariel Wessel-Fuss, Tim Hill, Brianne Begley & Alle Crampton

ATHENS
Greg Hayes, Russell Coleman & John Sullivan

COOKEVILLE
Ronnie Kelly, Tom Graham & John Buford

HARRIMAN
Ray Freeman

LAFOLLETTE
Nick Cowan

NASHVILLE
Johnnie MacDonald & David Tucker

NORRIS
Tony Wilkerson & Doug Snelson

Acknowledgements, continued

TENNESSEE, continued Brett Ward (**UT-MTAS**), Dewayne Culpepper (**TAUD**), Larry Gamblin (**Bartlett**), Danny Neely (**Baileyton**), David Harrison (**Collierville**), Nic Willis (**Cowan**), Darryl Green (**Henderson**), Jack Hauskins & Rocky Hudson (**Lafayette**)

KANSAS Tom Stiles, Rod Geisler (retired), Shelly Shores-Miller, Nick Reams & Ryan Eldredge (**KDHE**), Jason Cauley, Reuben Martin, April Batts & James Gaunt (**Great Bend**), Tony Zell, Gordon Cunning & Kris Bennetts (**Lansing**), Jamie Belden & Becky Lewis (**Wichita**)

MONTANA Paul LaVigne (retired), Pete Boettcher, Josh Viall, Ryan Weiss, Bill Bahr (retired), Dave Frickey (retired) & Mike Abrahamson (**DEQ**), Drue Newfield (**Havre**), Curt Konecky (retired), Del Phipps & Aaron Losing (**Kalispell**), Grant Burroughs (**Big Sky**), Gene Connell (**Missoula**), Eric Miller & Cory Fox (**Chinook**), Keith Thaut (**Conrad**), Mark Fitzwater & entire staff (**Helena**)

EPA Paul Shriner & Tony Tripp (**HQ**), Tina Laidlaw (**R8**), Brendon Held & Craig Hesterlee (**R4**), Sydney Weiss (**R5**)

… and, many more!


Oxidation Ditch Knowledge

Nutrient Removal in SBRs (Sequencing Batch Reactors) with Case Studies

Wednesday, March 3

10:00 - 11:45 AM Eastern Time

March 10: Nutrient Removal in Conventional and Extended Aeration Activated Sludge wwtps

March 17: Brainstorming Nutrient Removal Opportunities for <u>Your</u> Plants

Comments & Questions

Grant Weaver
g.weaver@cleanwaterops.com