Energy & Nutrient Optimization
of NC Municipal Wastewater Treatment Plants

Nitrogen Removal: Part 2 of 2

February 18, 2021
10:00 - 11:45 AM

Grant Weaver
CleanWaterOps

Energy & Nutrient Optimization
of NC Municipal Wastewater Treatment Plants

Today: Biological Nitrogen Removal, Part 2

Last week: Introductions & Nitrogen Removal, Part 1

Feb 25: Activated Sludge, Part 1 - Oxygen Demand and Supply

Mar 4: Activated Sludge, Part 2 - Bio-Tiger Model

Mar 11: Biological Phosphorus Removal, Part 1

Mar 18: Biological Phosphorus Review, Part 2

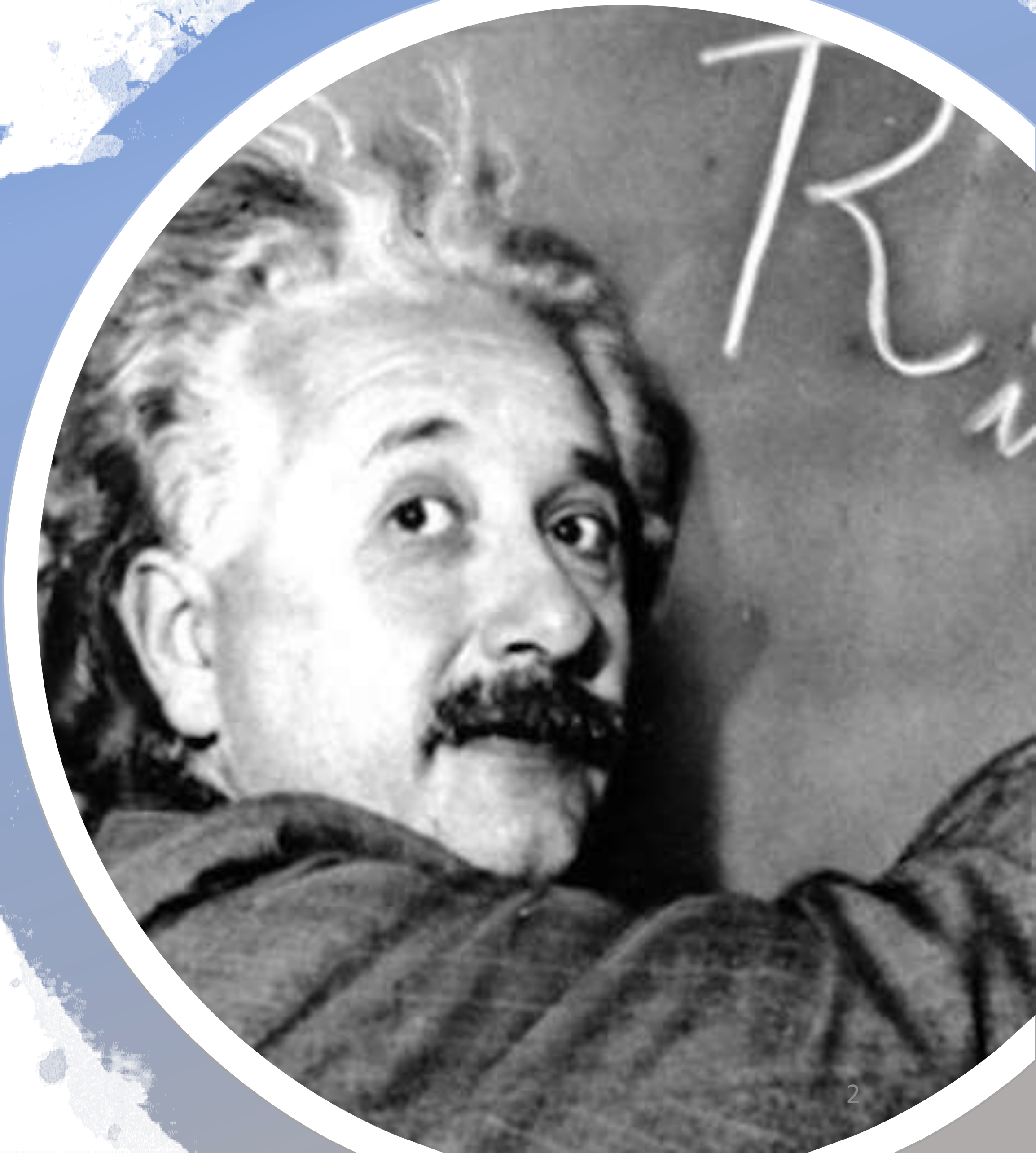
Mar 25: North Carolina Case Studies, Part 1 (your plants!)

Apr 8: North Carolina Case Studies, Part 2 (your plants!)

Apr 15: Energy Management, Part 1

Apr 22: Energy Management, Part 2

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




REVIEW

7

N

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

Ammonia Removal - 1st Step of N Removal

Ammonia Removal

Ammonia (NH_4) is converted to Nitrate (NO_3)

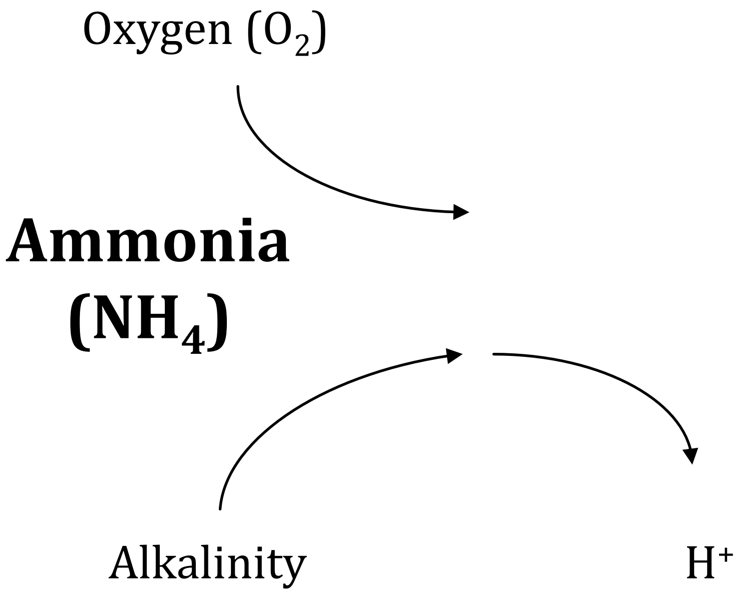
Ammonia
(NH_4)

Ammonia Removal

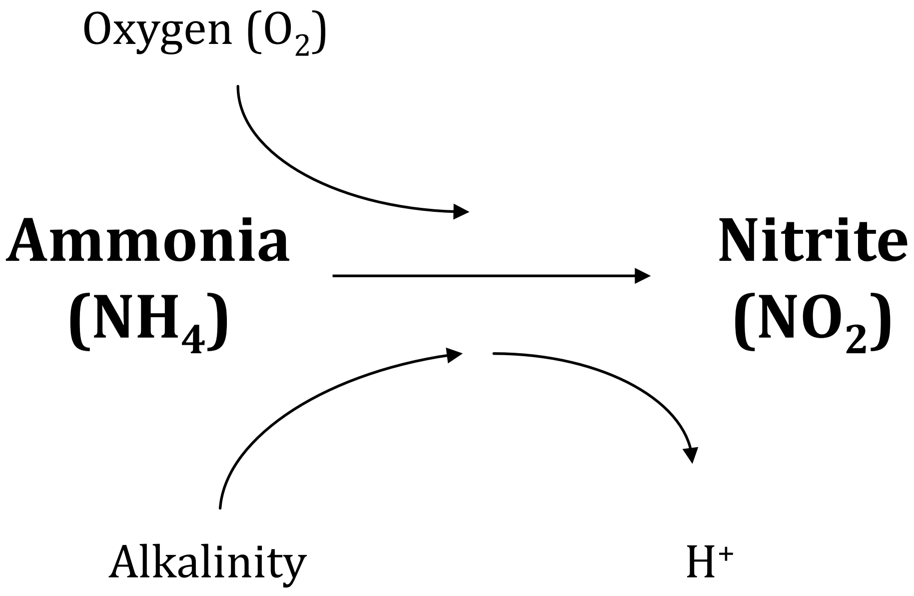
Oxygen (O_2)

Ammonia (NH_4)

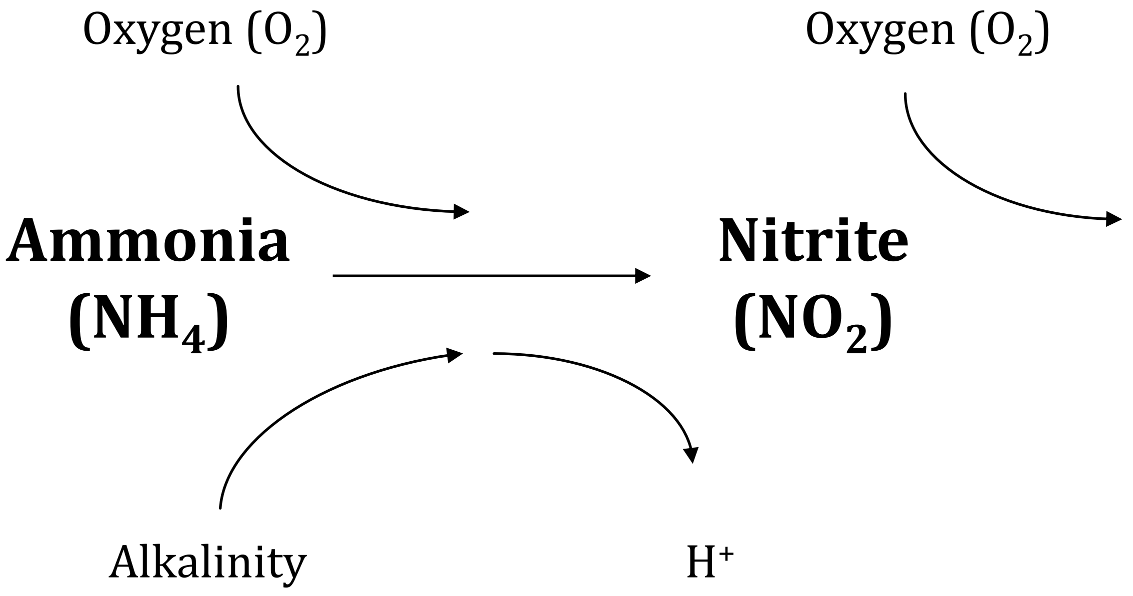
Ammonia Removal



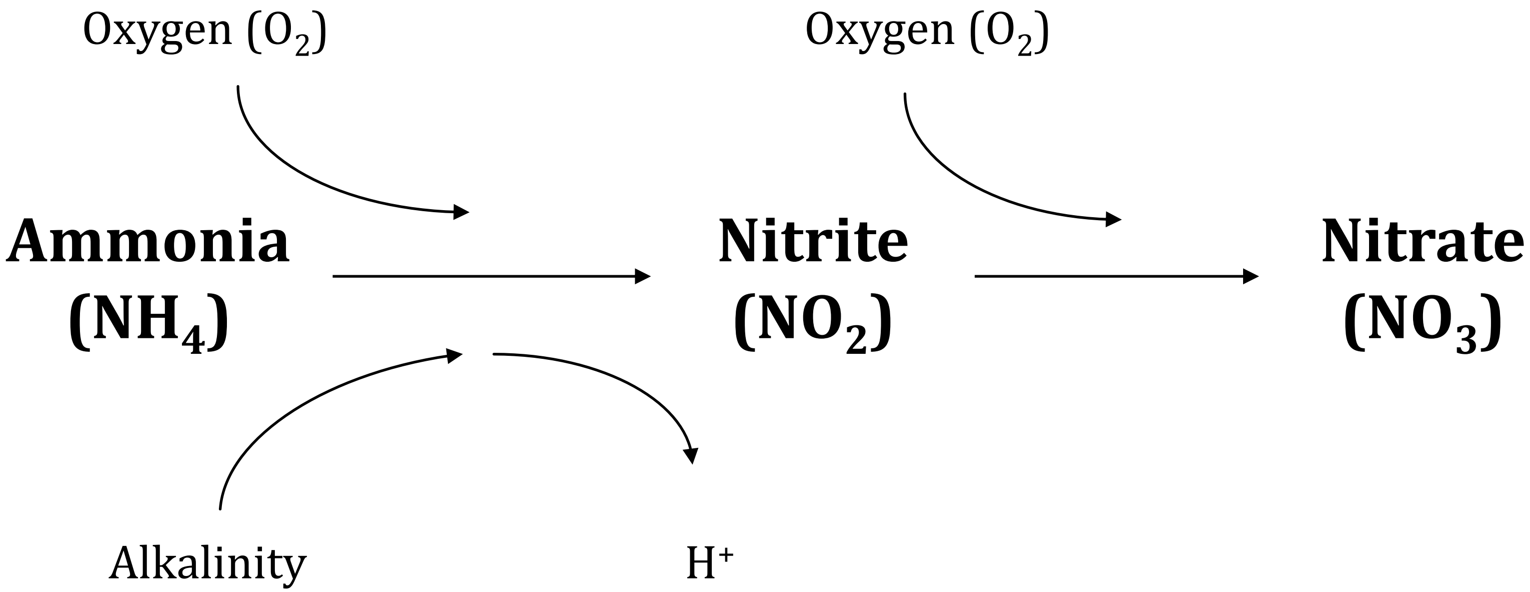
Ammonia Removal



Ammonia Removal



Ammonia Removal



Nitrification:
Ammonia (NH_4) is converted to Nitrate (NO_3)

Oxygen Rich Habitat

MLSS* of 2500+ mg/L (High Sludge Age / MCRT / low F:M)

ORP* of +100 to +150 mV (High DO)

Time* (high HRT … 24 hr, 12 hr, 6 hr)

Low BOD

Consumes Oxygen

Adds acid - Consumes 7 mg/L alkalinity per mg/L of $NH_4 \rightarrow NO_3$

*Approximate, each facility is different.

Nitrate Removal - 2nd Step of N removal

Nitrate Removal

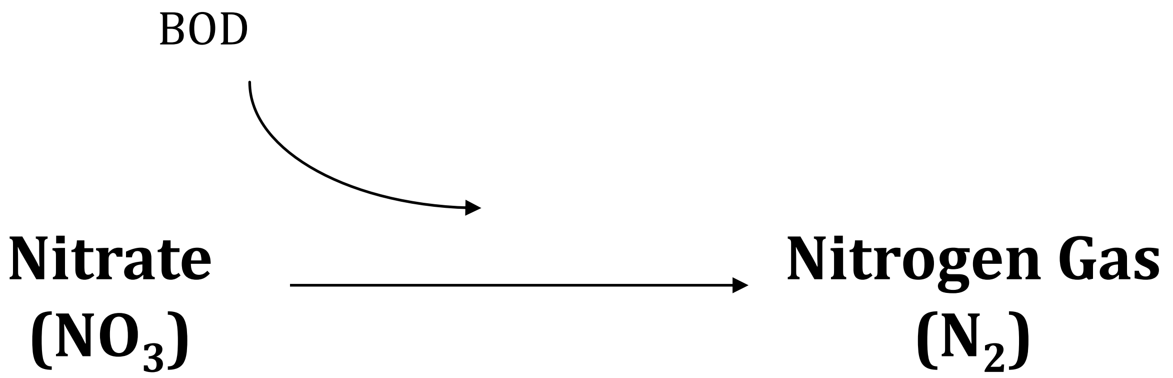
Nitrate
(NO_3)

Nitrate Removal

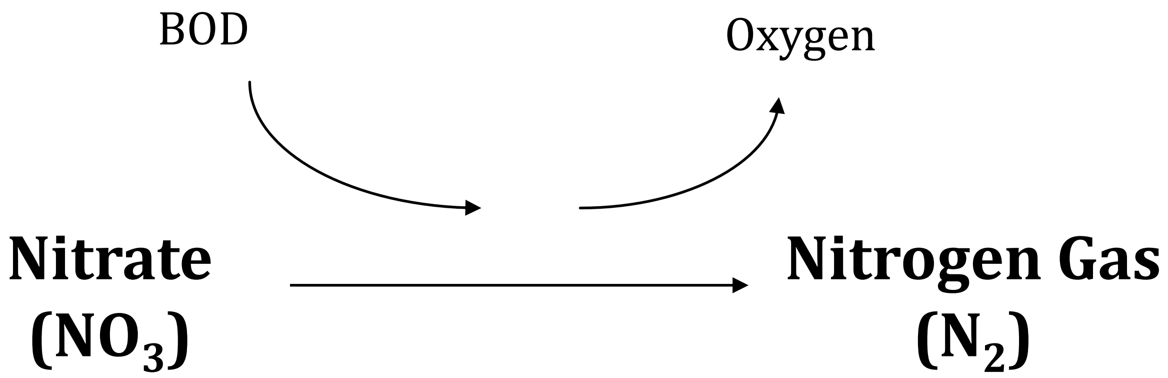
BOD

Nitrate
(NO_3)

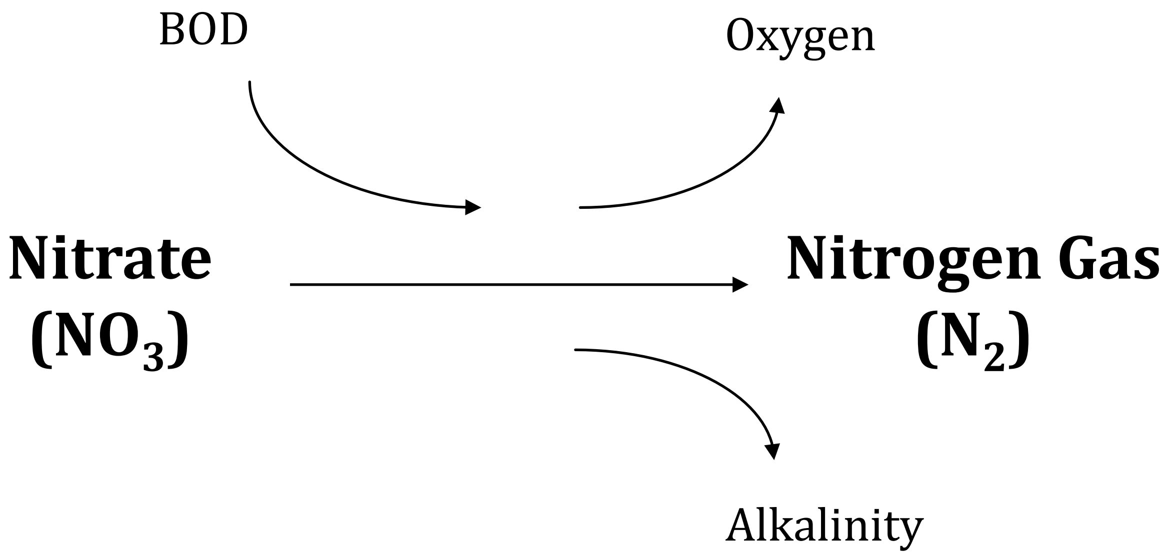
Nitrate Removal



Nitrate Removal



Nitrate Removal



Adds DO (dissolved oxygen)

Consumes BOD

Gives back alkalinity … beneficially raises pH

Denitrification:
Nitrate (NO_3) is converted to Nitrogen Gas (N_2)

Oxygen Poor Habitat

ORP* of -100 mV or less (DO less than 0.3 mg/L)
Surplus BOD* (100-250 mg/L: 5-10 times as much as NO_3)
Retention Time* of 1-2 hours

Gives back Oxygen
Gives back Alkalinity (3.5 mg/L per mg/L of $NO_3 \rightarrow N_2$)

*Approximate, each facility is different.

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**
Alkalinity	60 mg/L or more	
	Alkalinity is lost	***Alkalinity is gained***

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

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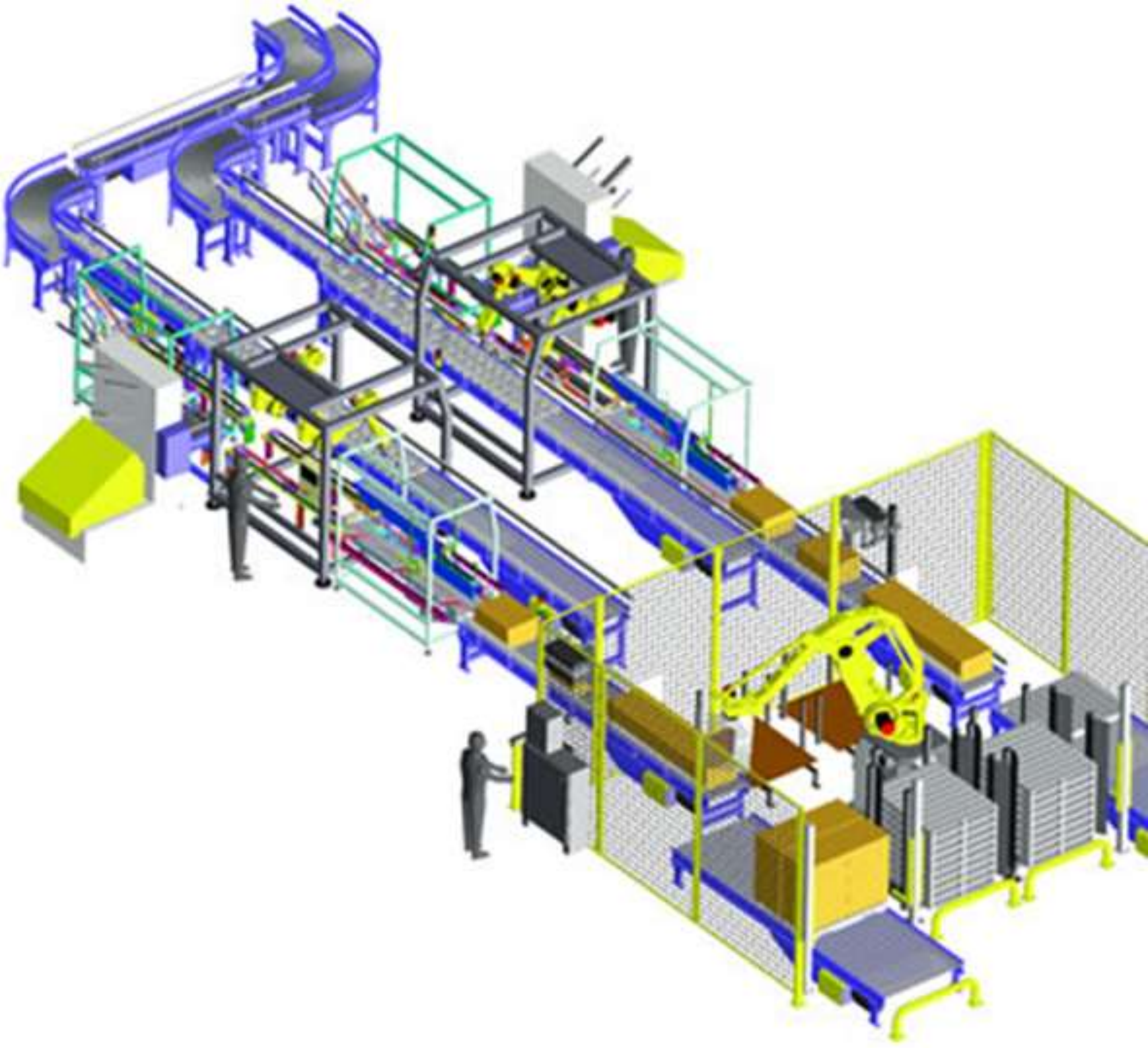
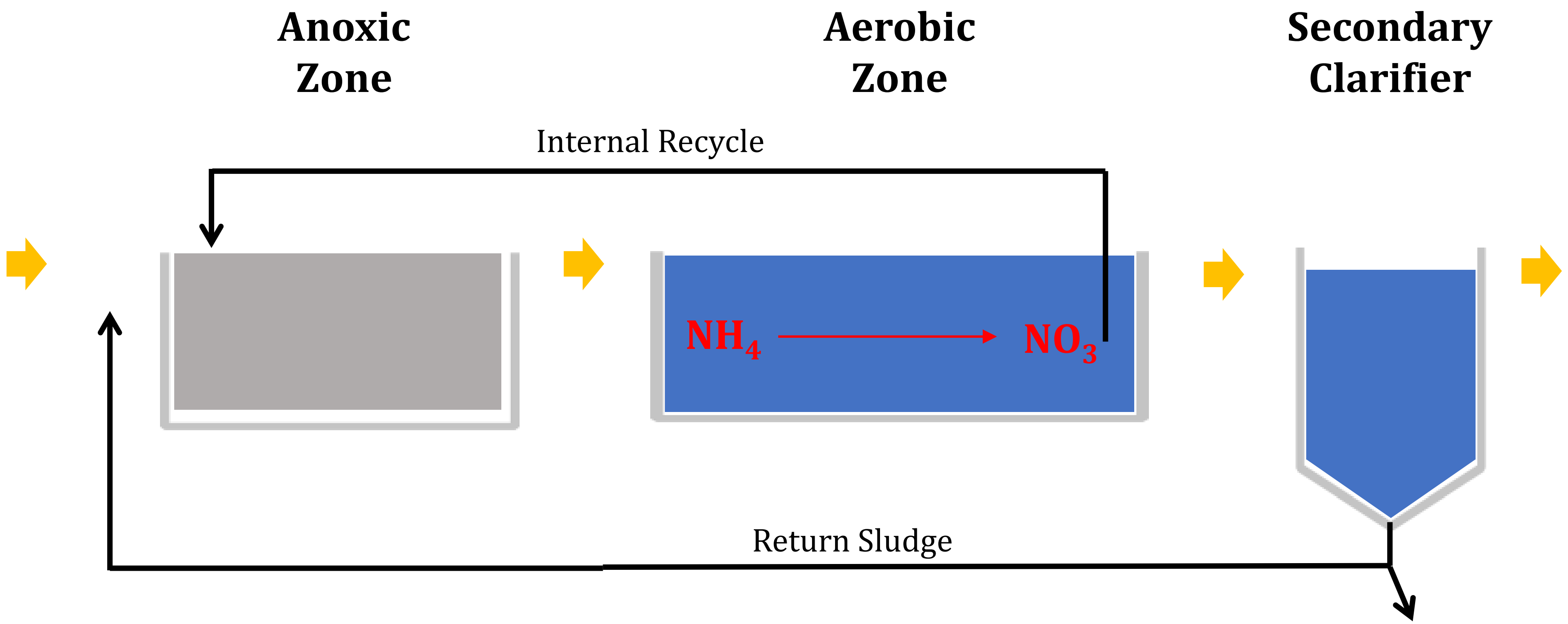
What might I say about Nitrogen Removal?

Technology!

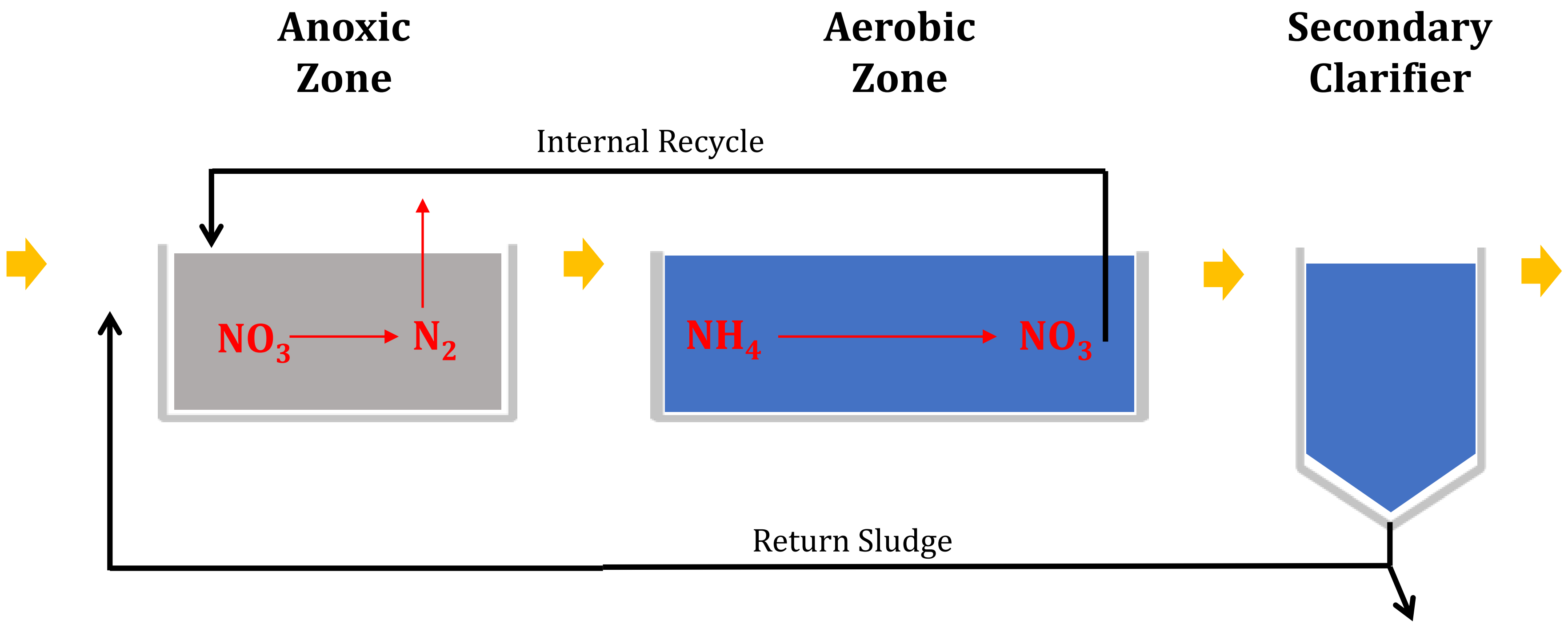


MLE Process
(Modified Ludzack-Ettinger)

MLE (Modified Ludzack-Ettinger) Process



MLE (Modified Ludzack-Ettinger) Process



MLE Process Control:

Proper Internal Recycle Rate; not too much / not too little.
ORP of +100 mV in Aerobic Zone for Ammonia (NH_4) Removal.
ORP of -75 to -150 mV in Anoxic Zone for Nitrate (NO_3) Removal.
Enough BOD to support Nitrate (NO_3) Removal.

Questions?
Comments?

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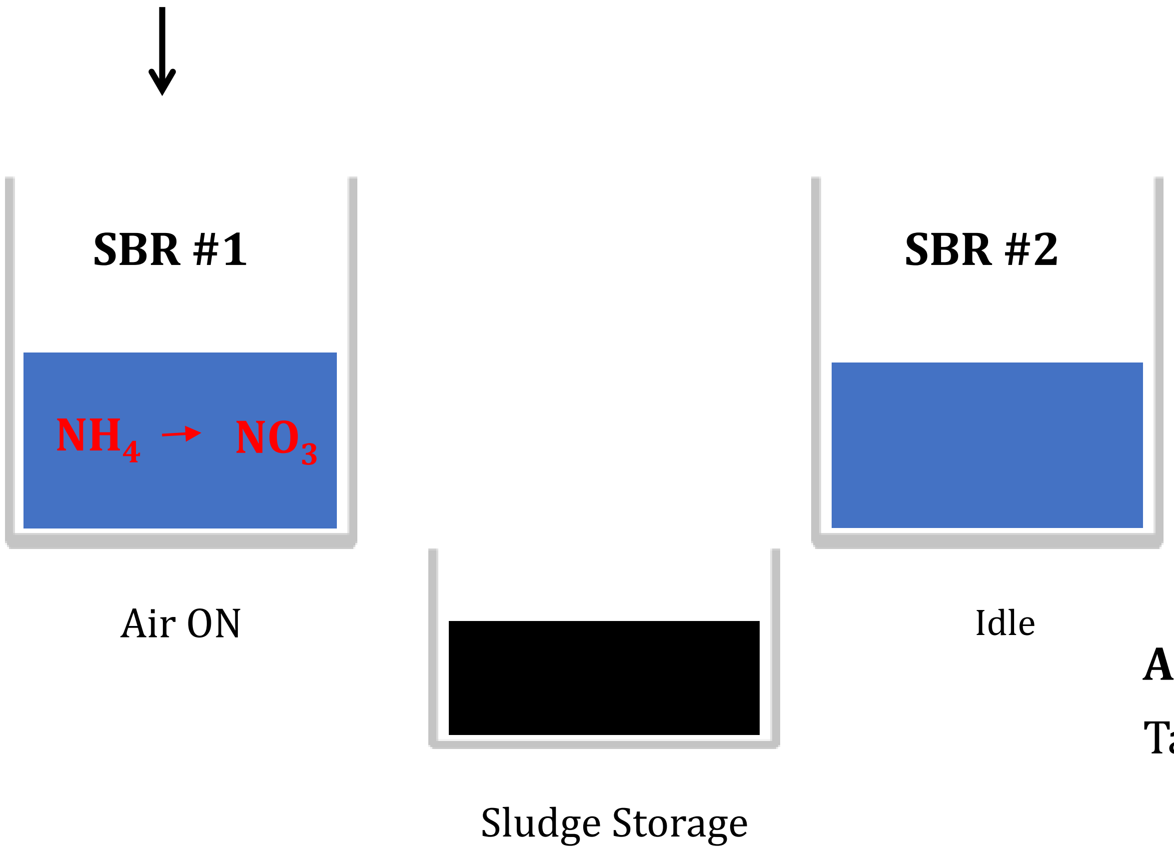
MOVING FORWARD

Sequencing Batch Reactor

SBR

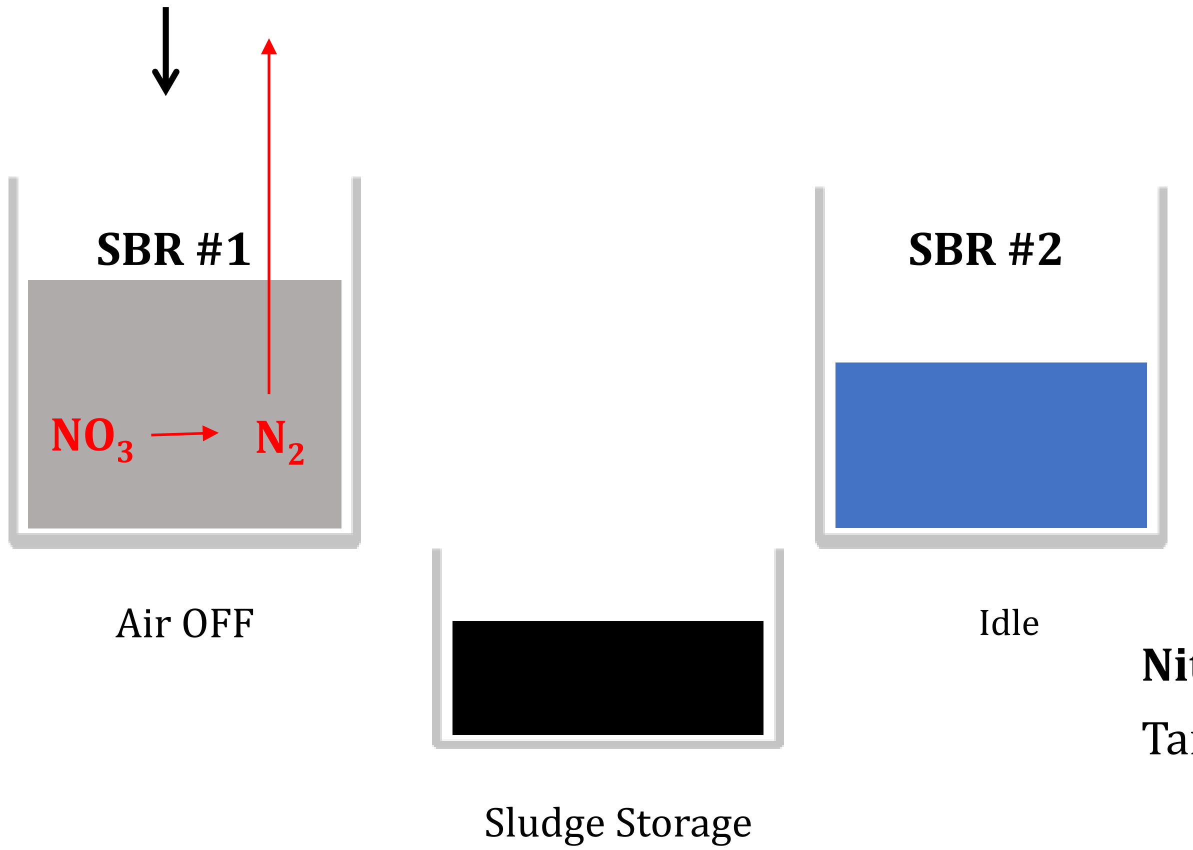
Sequencing Batch Reactor (SBR)
Ammonia (NH_4) Removal: Nitrification



Ammonia (NH_4) Removal

Target: $NH_4 < 0.5$ mg/L

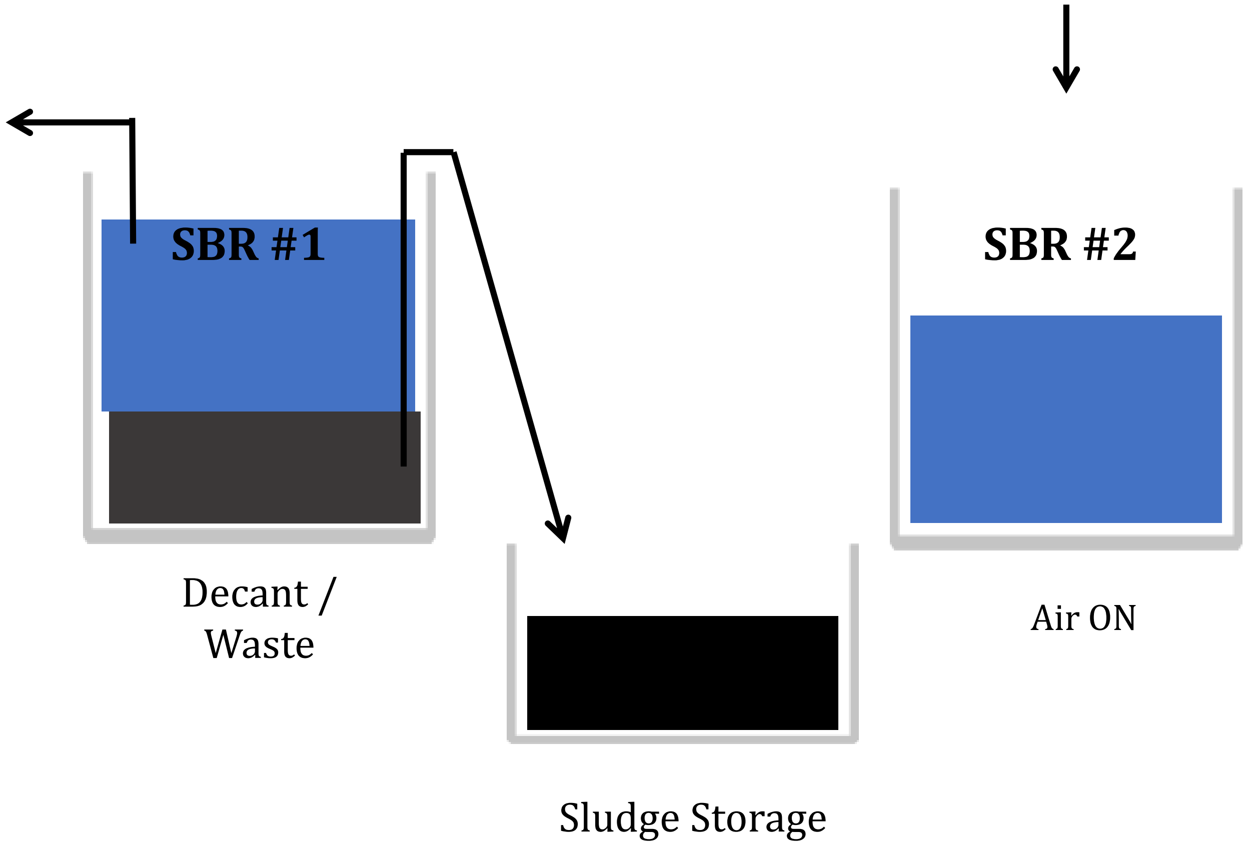
Sequencing Batch Reactor (SBR)
Nitrate (NO_3) Removal: Denitrification



Nitrate (NO_3) Removal

Target: $NO_3 < 4$ mg/L

Sequencing Batch Reactor (SBR)
Settle, Decant & Waste Sludge



Establish cycle times that are long enough to provide optimal habitats.

And, short enough to allow all of the flow to be nitrified and denitrified.

Optimizing SBR cycle time

Too short

Will not reach +100 mV for Ammonia (NH_4) Removal.

Will not reach -100 mV for Nitrate (NO_3) Removal.

Note: Temperature and BOD affect Air OFF cycle.

Too long

Wastewater will pass through tank before all Ammonia (NH_4) converted to Nitrate (NO_3).

And, before all Nitrate (NO_3) is converted to Nitrogen Gas (N_2).

Just right

Good habitats …

ORP of +100 mV for 60 minutes

And, ORP of -100 mV for 30 minutes.

Bonus: Changing conditions will serve as a selector.

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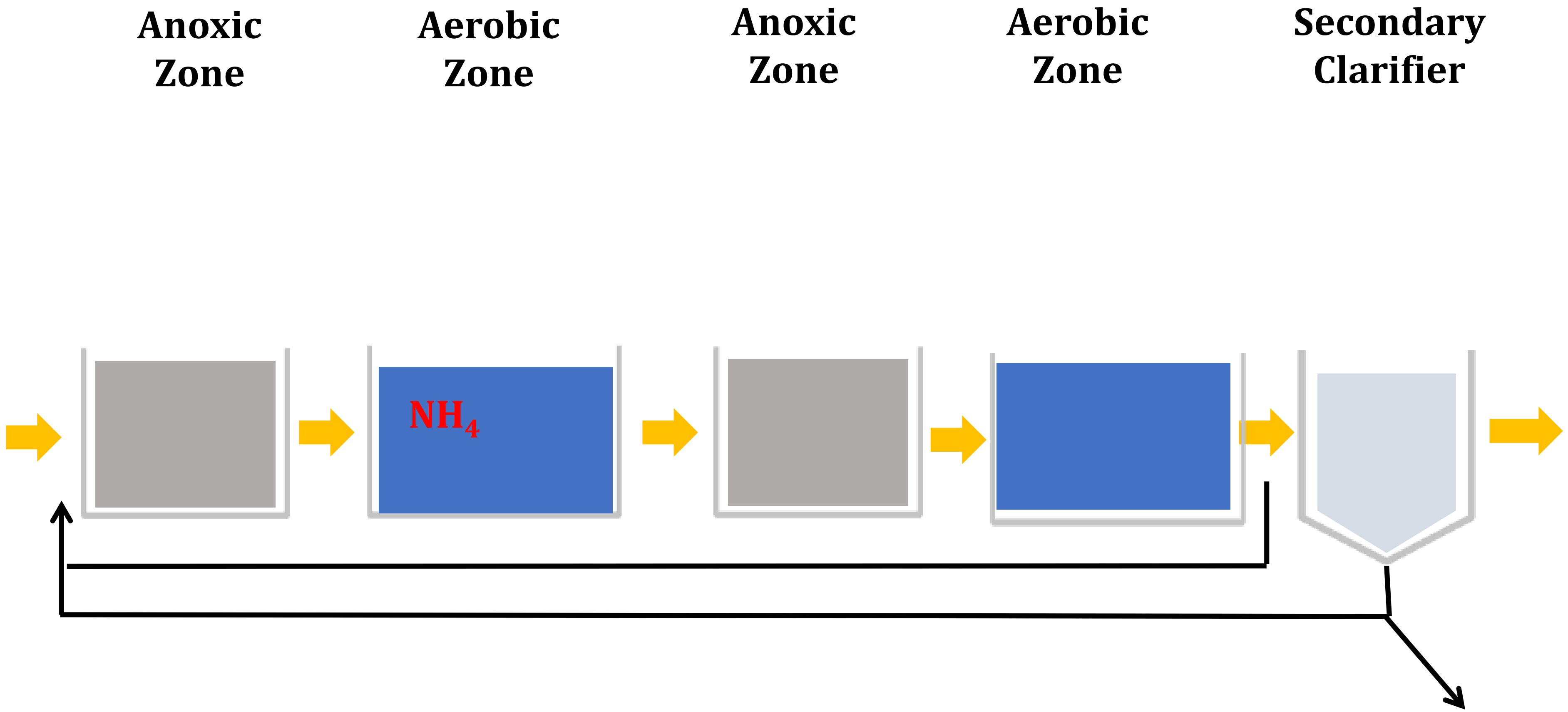
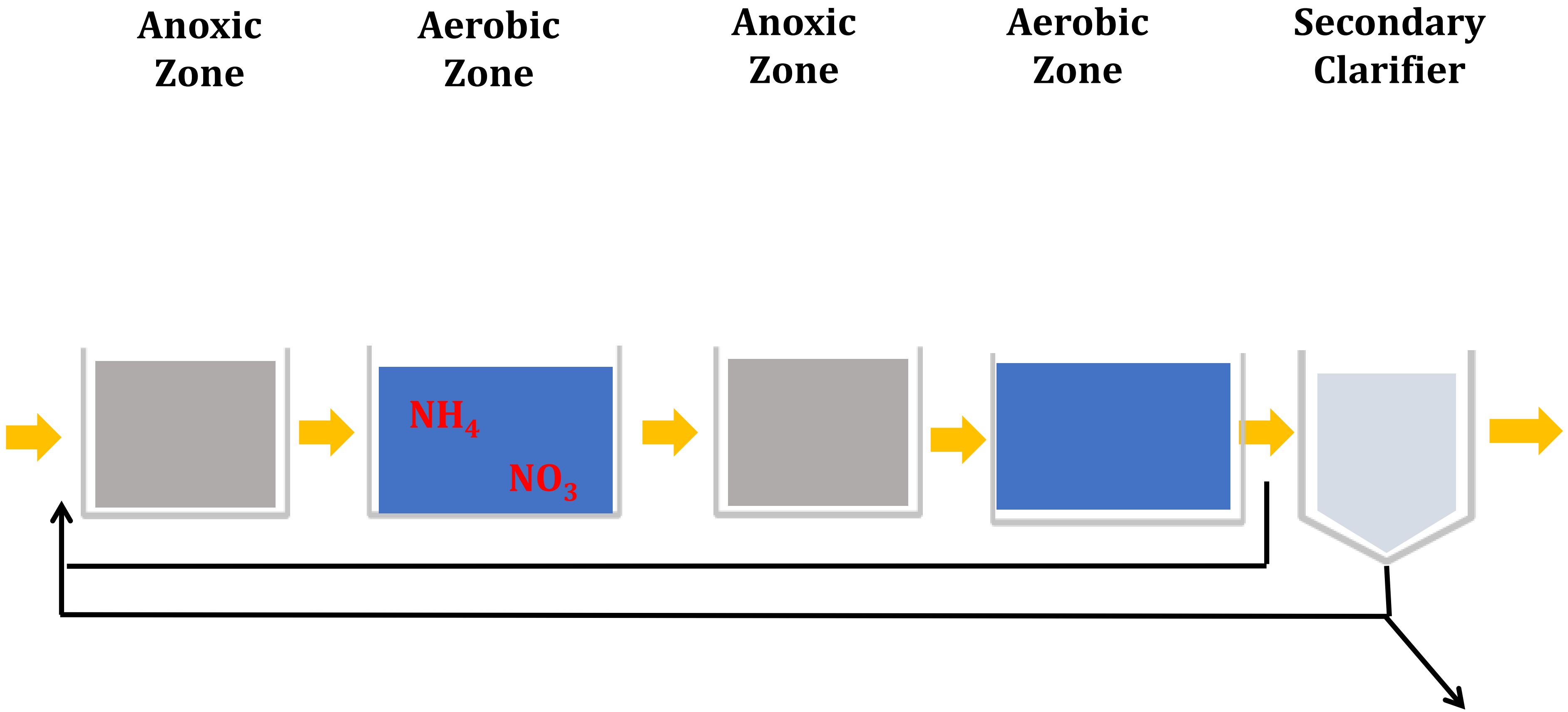
Oxidation Ditch

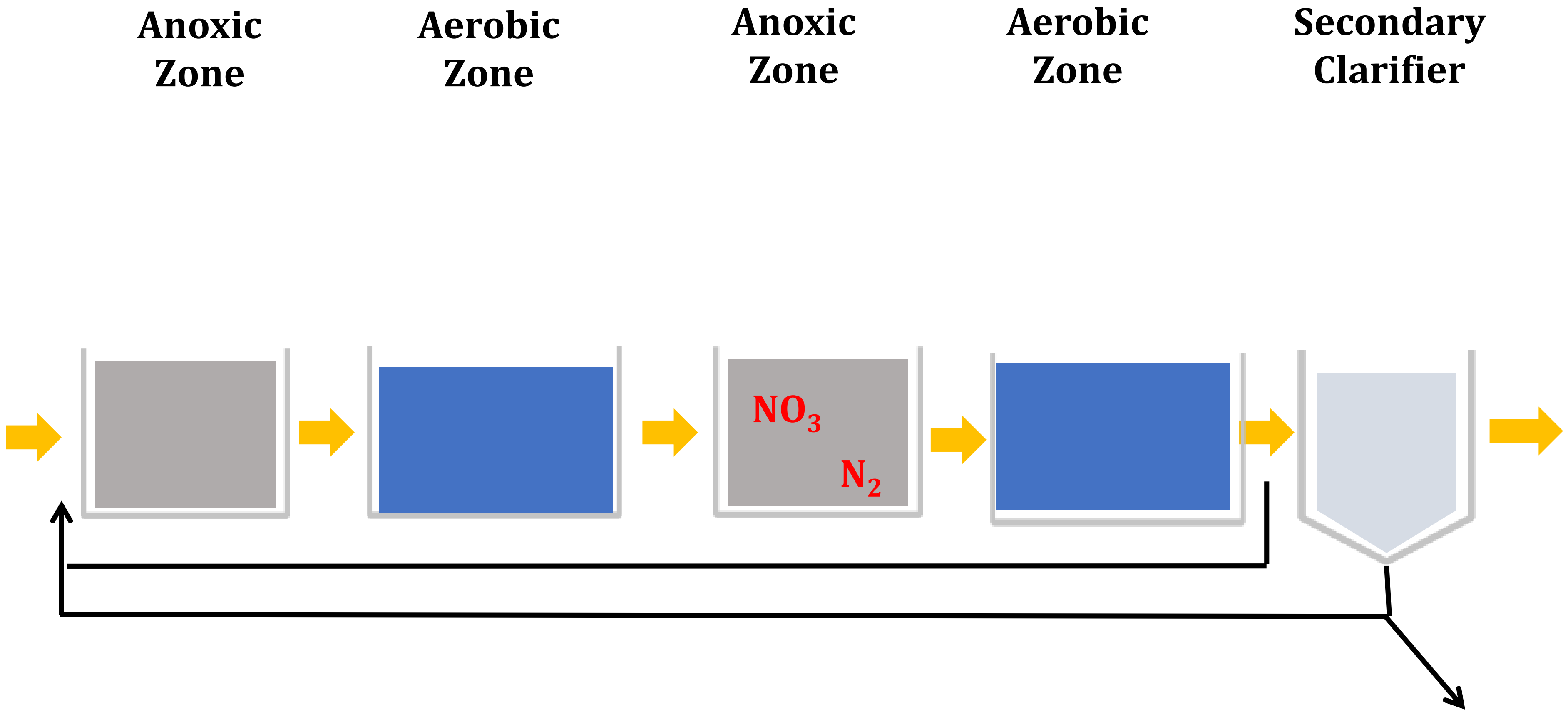
Oxidation Ditch



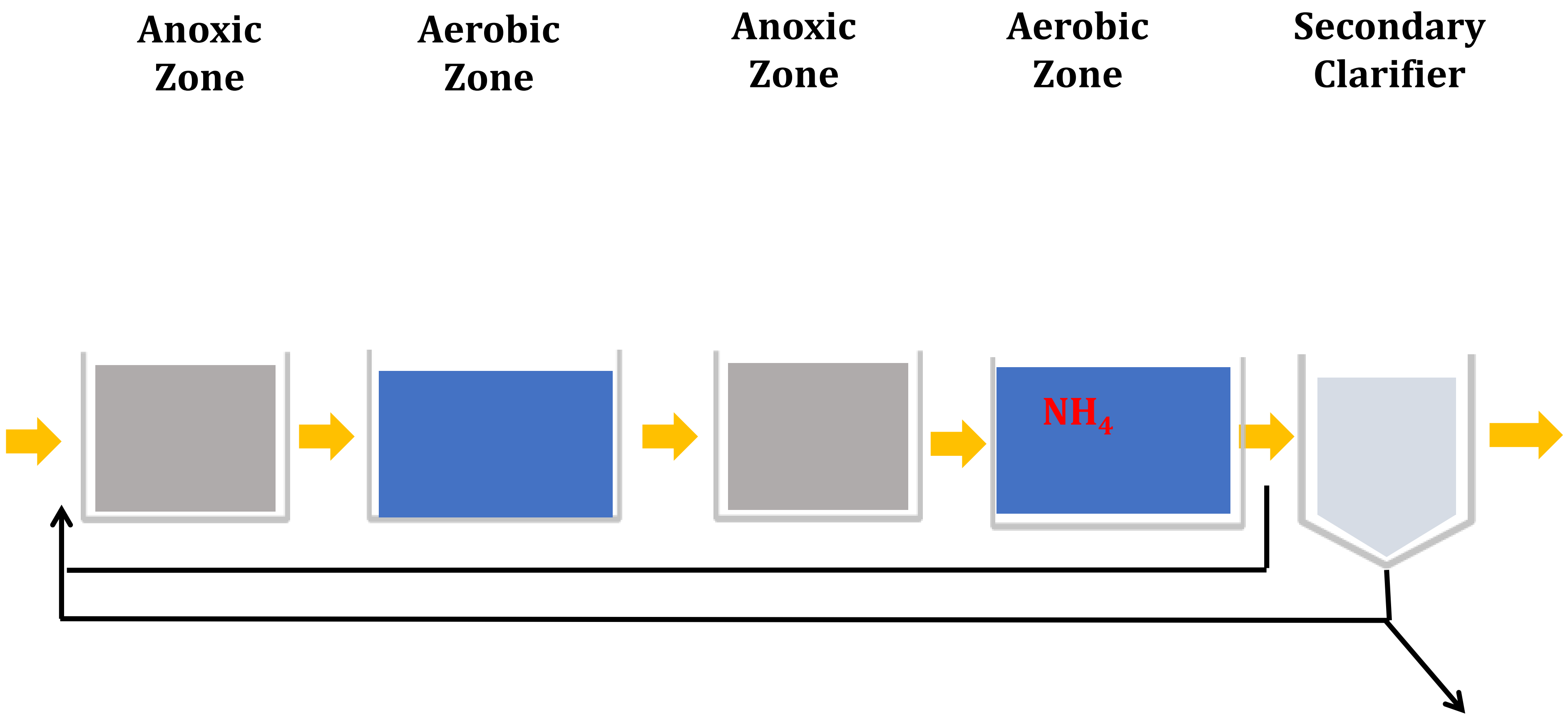
Oxidation Ditch



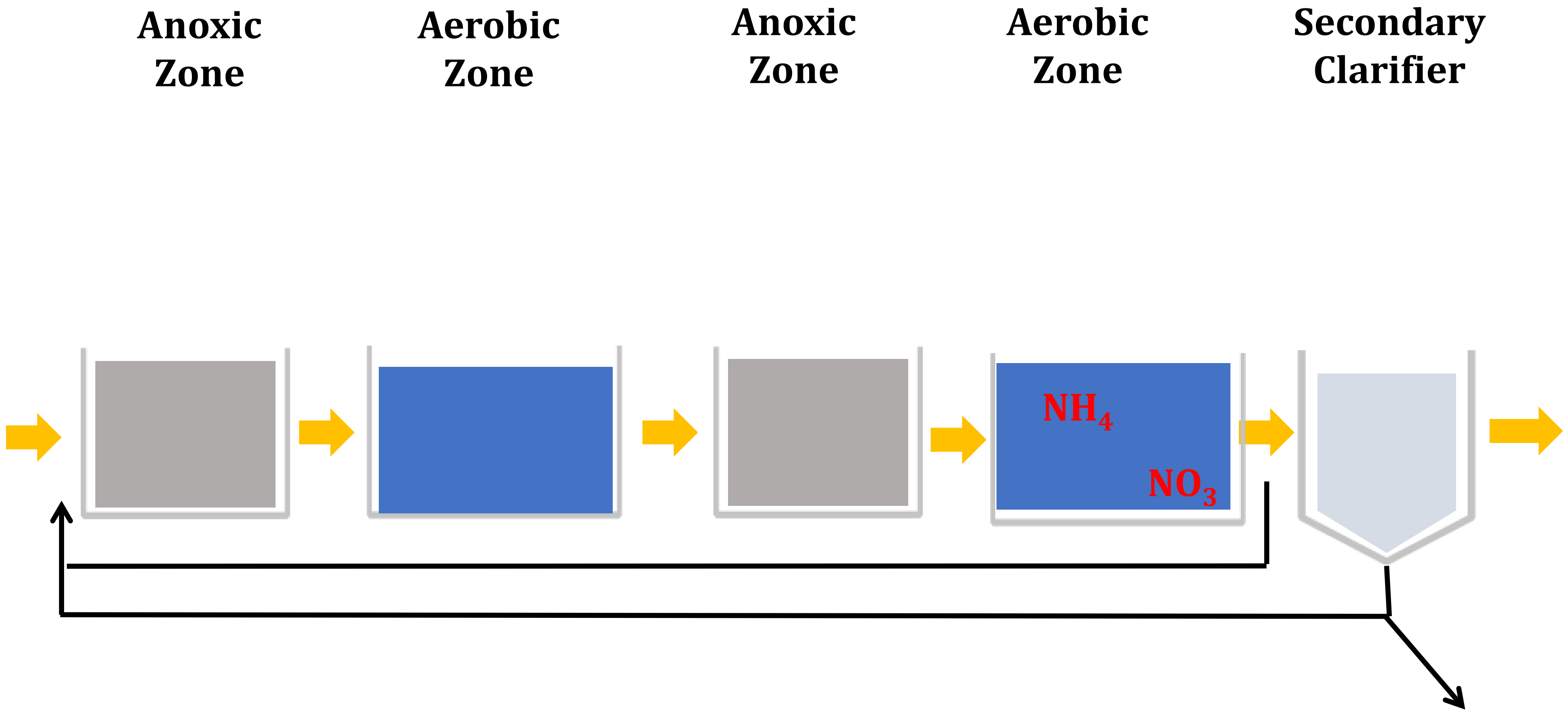
Oxidation Ditch



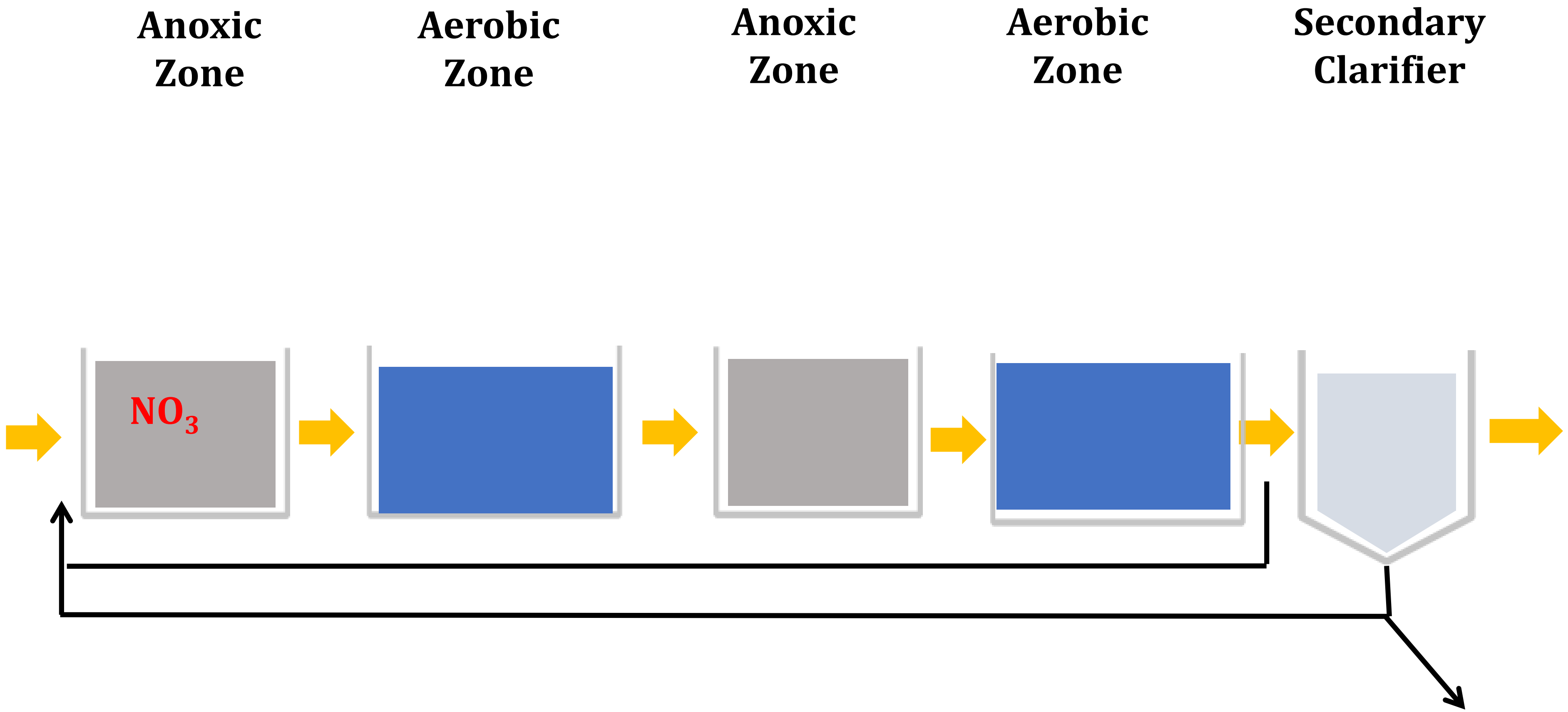
Oxidation Ditch



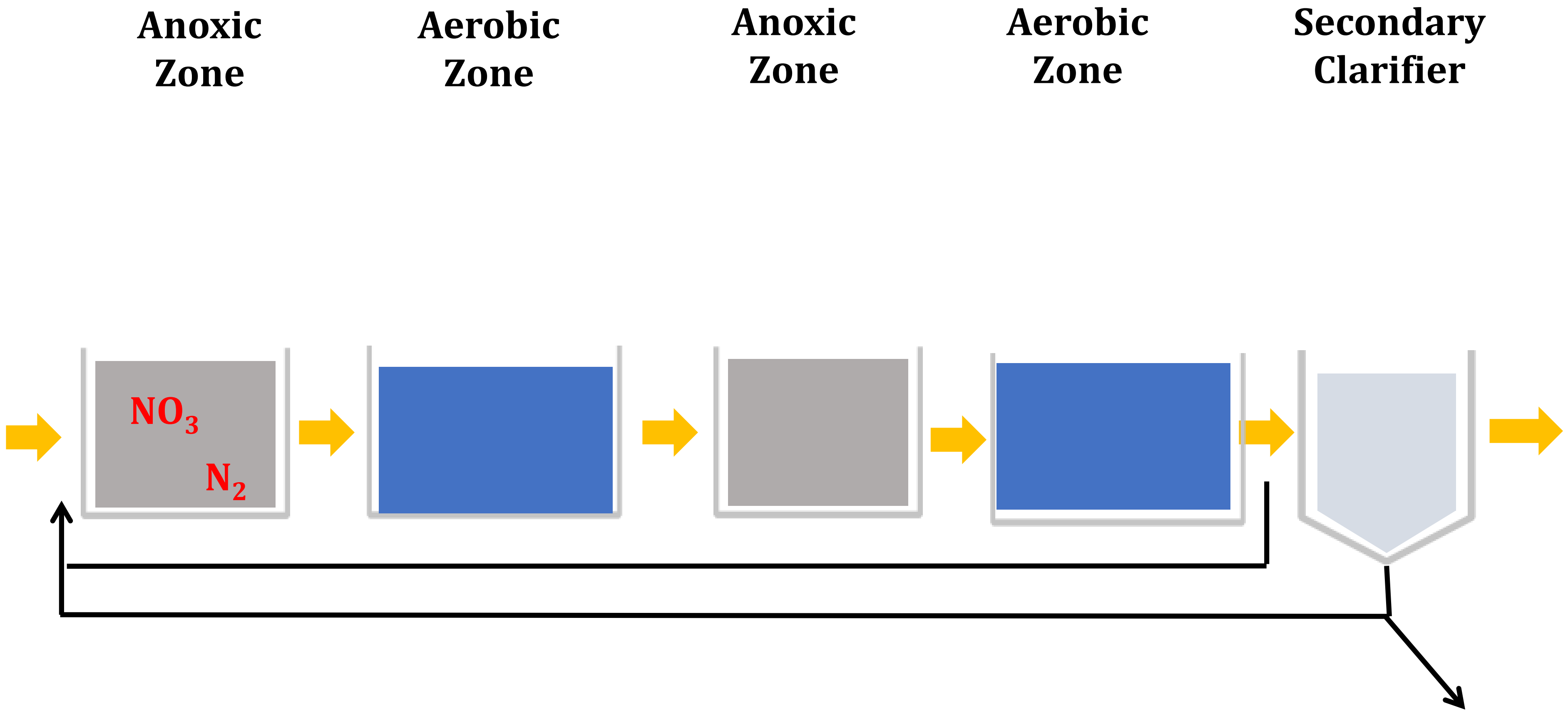
Oxidation Ditch



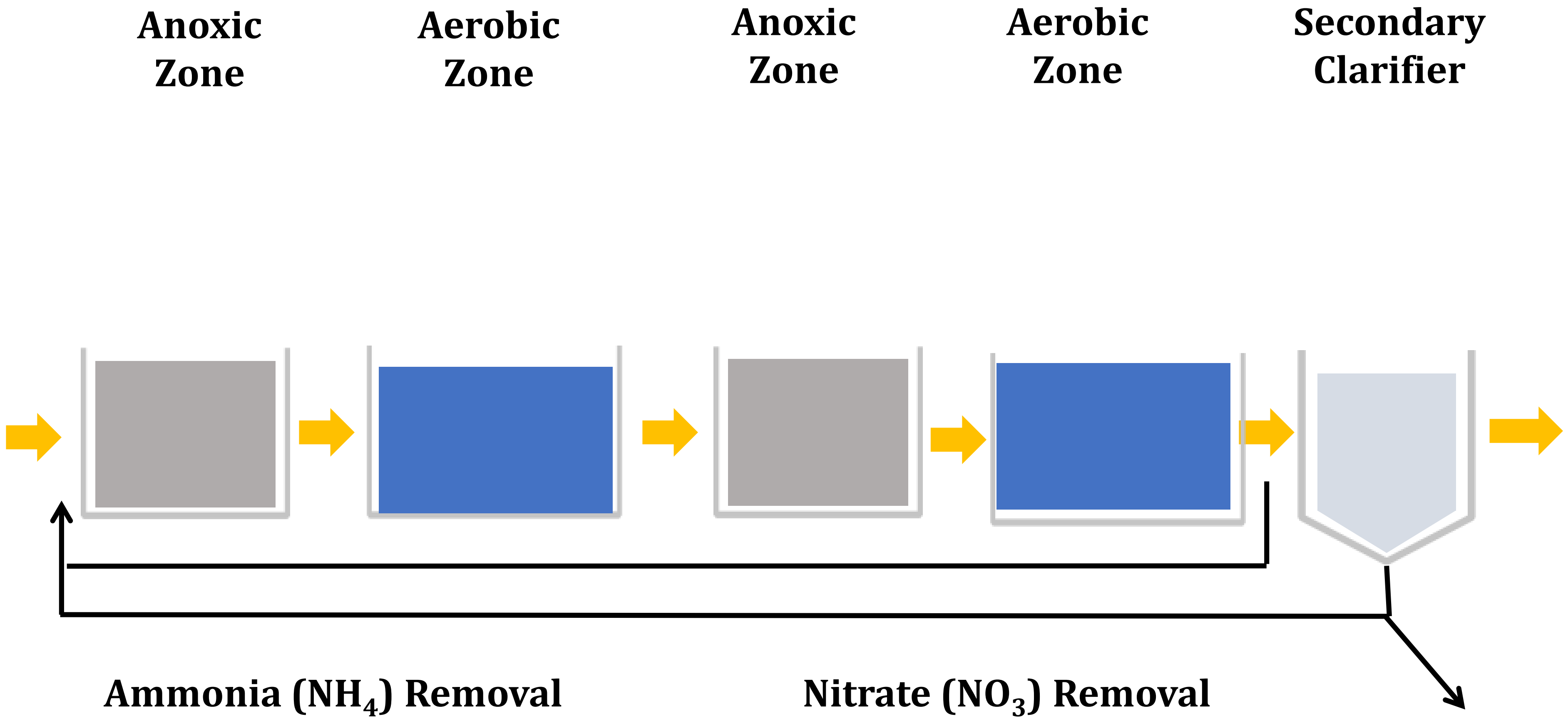
Oxidation Ditch



Oxidation Ditch



Oxidation Ditch



Ammonia (NH_4) Removal

Target: $NH_4 < 0.5$ mg/L

Nitrate (NO_3) Removal

Target: NO_3 of 1-4 mg/L

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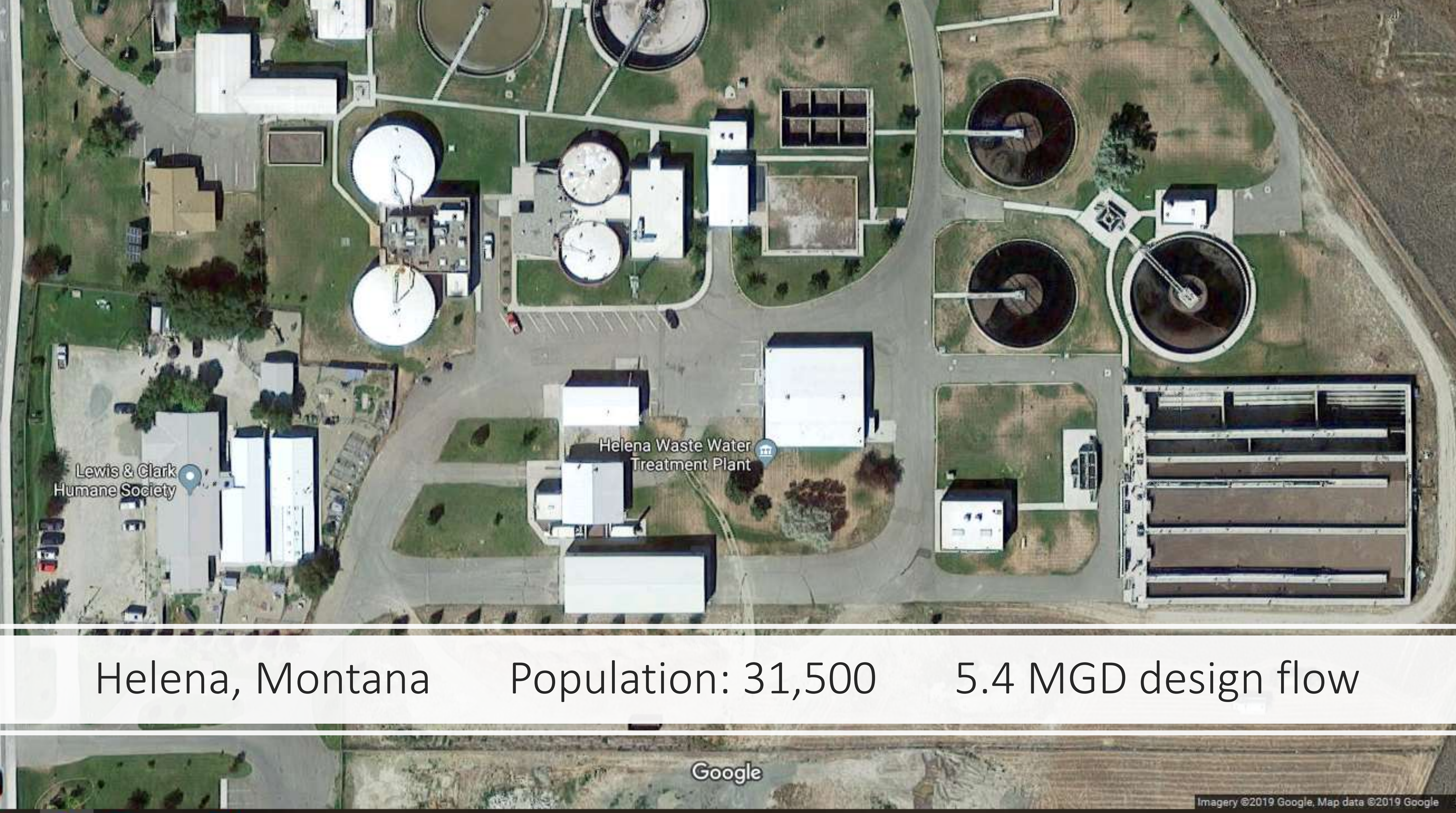
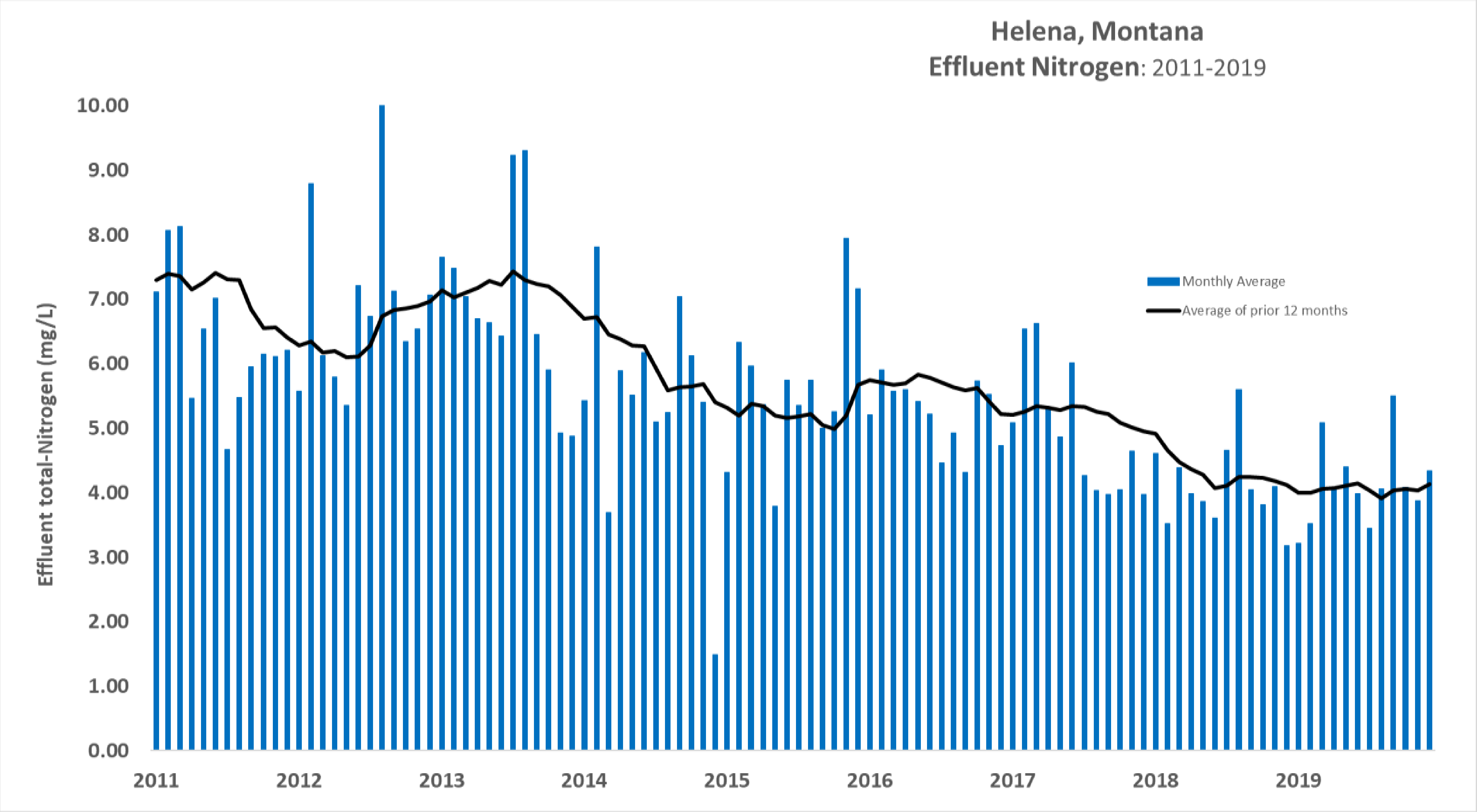
Comments please

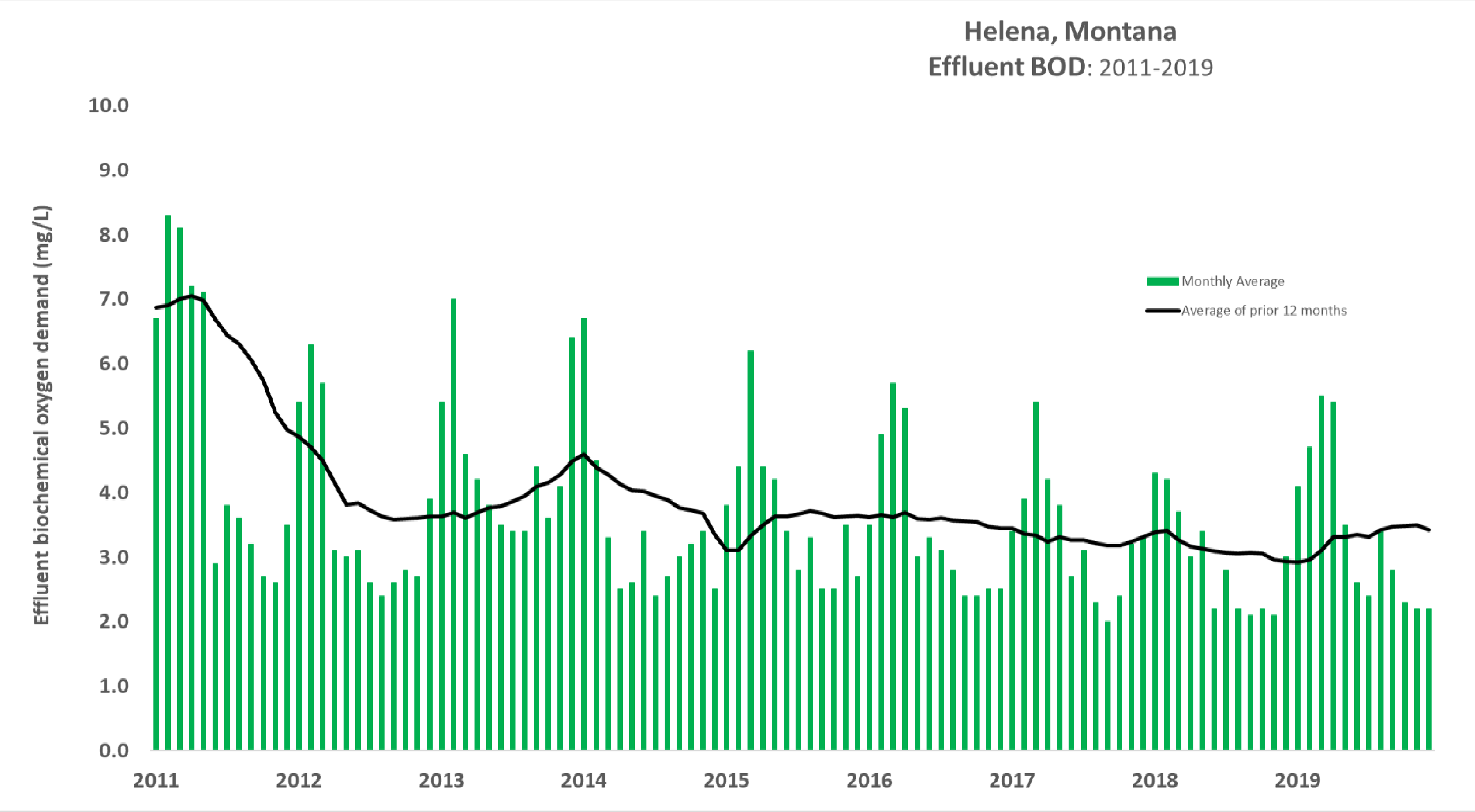

Case Study
research
case
subject
circumstan
studies
criteria
sampling
offer
based
information
object
cases
knowledge
multiple
established
typology
may
thus
focus
event
Outlier
theory-testing
evidence
historical
approach
become
data
researchers
theory-building
exploratory
study
retrospective
whether
local
theoretical
single
selecting
frame
researcher
in-depth
key
qualitative
quantitative
nested
evaluative
choice
set

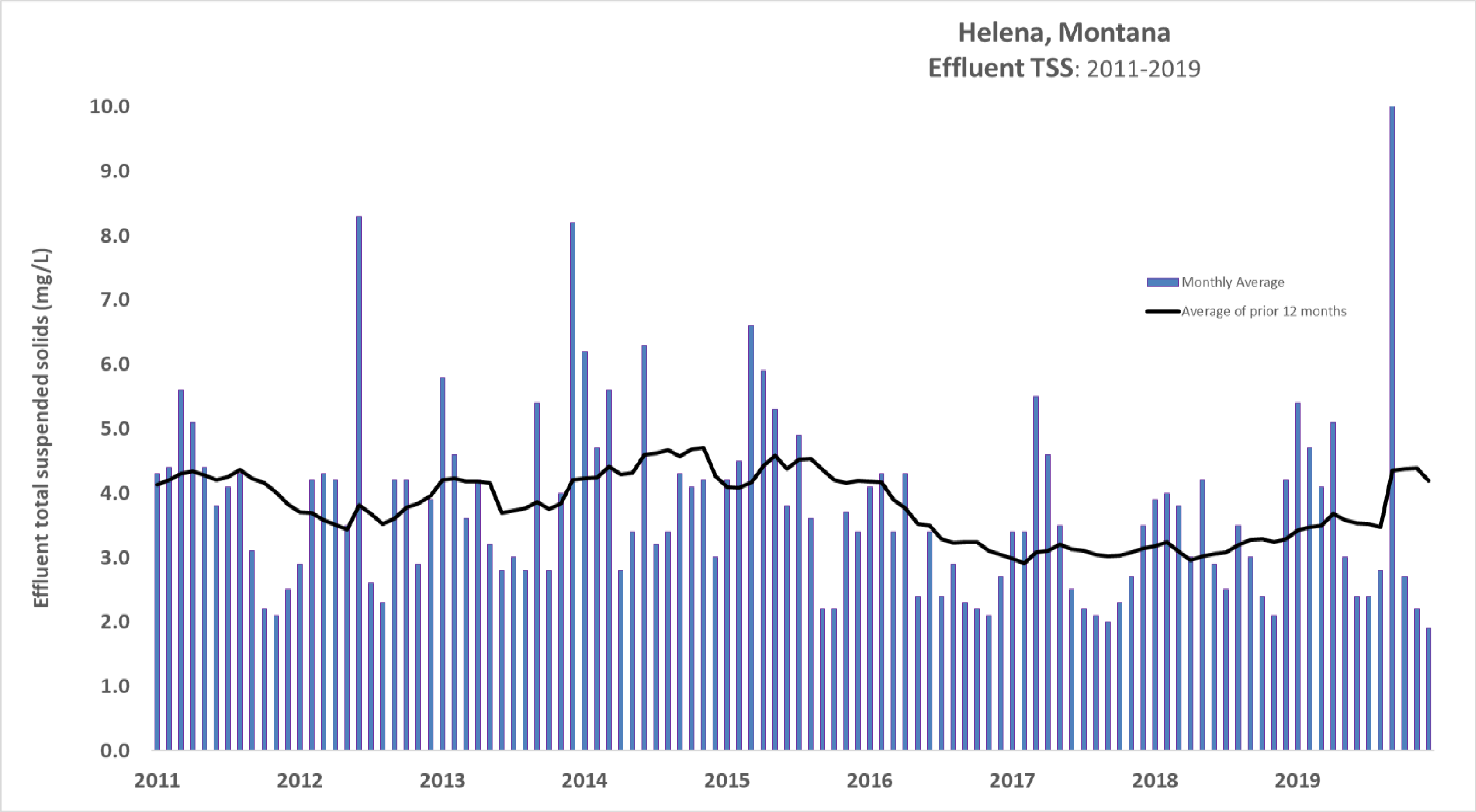

MONTA
NA



Helena, Montana Population: 31,500 5.4 MGD design flow


Helena, Montana
Effluent Nitrogen: 2011-2019
Effluent total-Nitrogen (mg/L)
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
2011
2012
2013
2014
2015
2016
2017
2018
2019
Monthly Average
Average of prior 12 months


Helena, Montana
Effluent BOD: 2011-2019
Effluent biochemical oxygen demand (mg/L)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Monthly Average
Average of prior 12 months
2011
2012
2013
2014
2015
2016
2017
2018
2019



Helena, Montana
Effluent TSS: 2011-2019
Effluent total suspended solids (mg/L)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
2011
2012
2013
2014
2015
2016
2017
2018
2019
Monthly Average
Average of prior 12 months


Helena Waste Water Treatment Plant
Lewis & Clark Humane Society
Google
Imagery ©2019 Google, Map data ©2019 Google

Questions?
Comments?

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TENNESSEE

Nashville Dry Creek Population: 678,000 24 MGD design flow


Nashville Dry Creek
Cumberland Blvd
Edenwood Rd
Dry Creek
Cumberland River
Myatt Dr


Nashville Dry Creek
Cumberland Blvd
Edenwood Rd
Myatt Dr
Dry Creek
Cumberland River


Nashville Dry Creek
Cumberland Blvd
Dry Creek WWTP
Dry Creek
Cumberland River

Nashville Dry Creek

Nashville Dry Creek


Nashville Dry Creek
Cumberland Blvd
Dry Creek
Cumberland River

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KANSAS

Wichita, Kansas Population: 390,000 54.4 MGD design flow

Wichita Pilot Study

Nitrogen Removal
Cycle aeration on/off in
Aeration Basin 6

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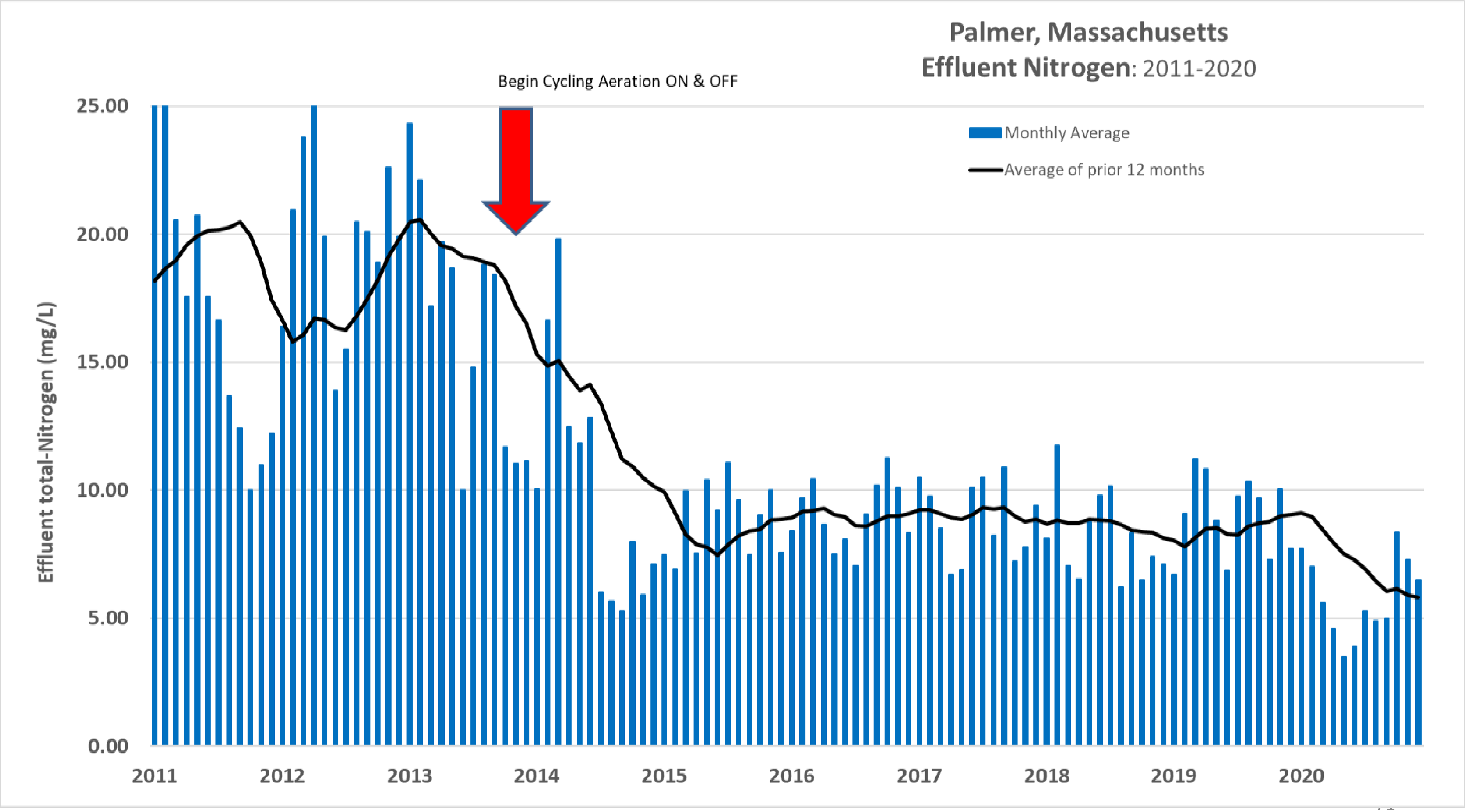
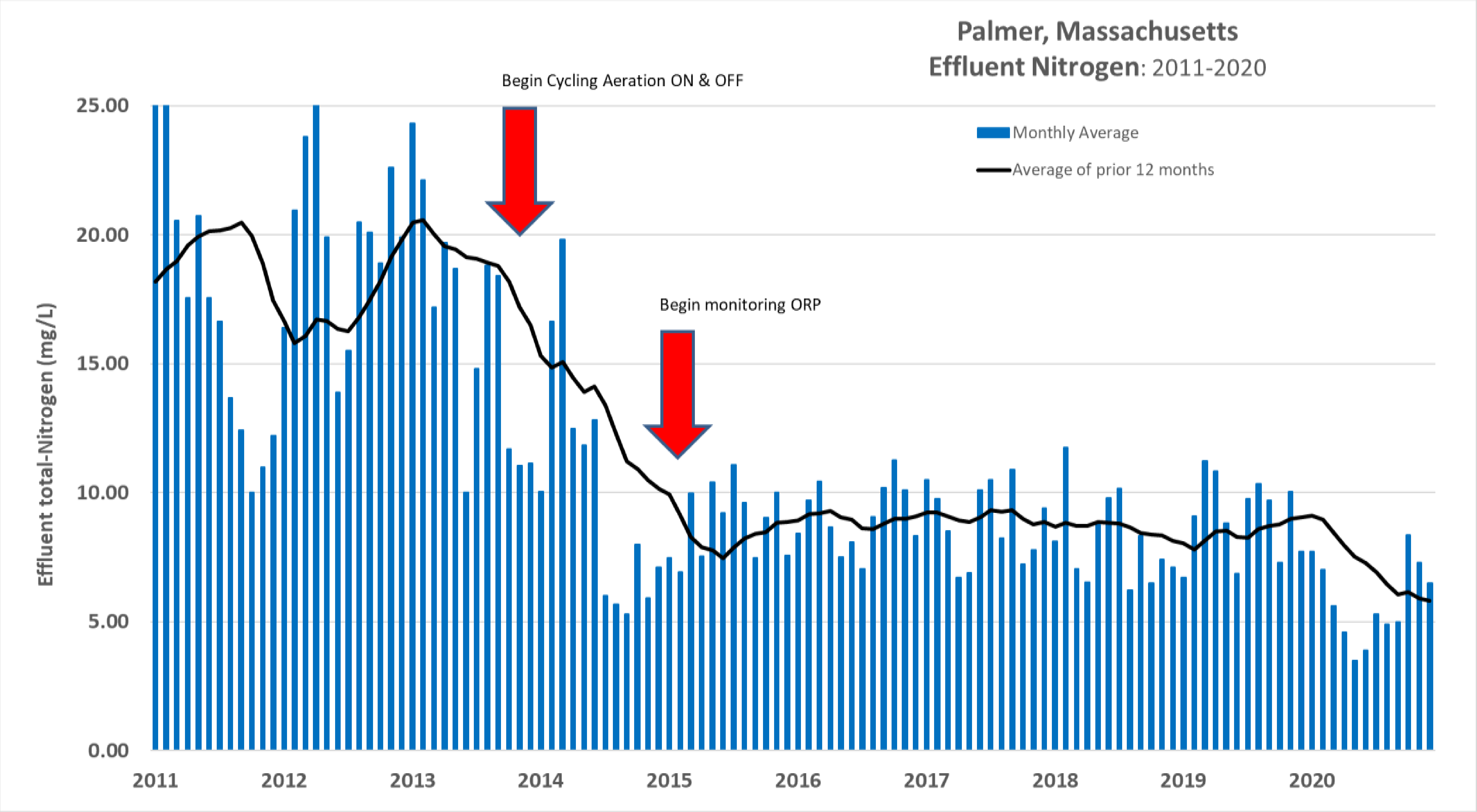
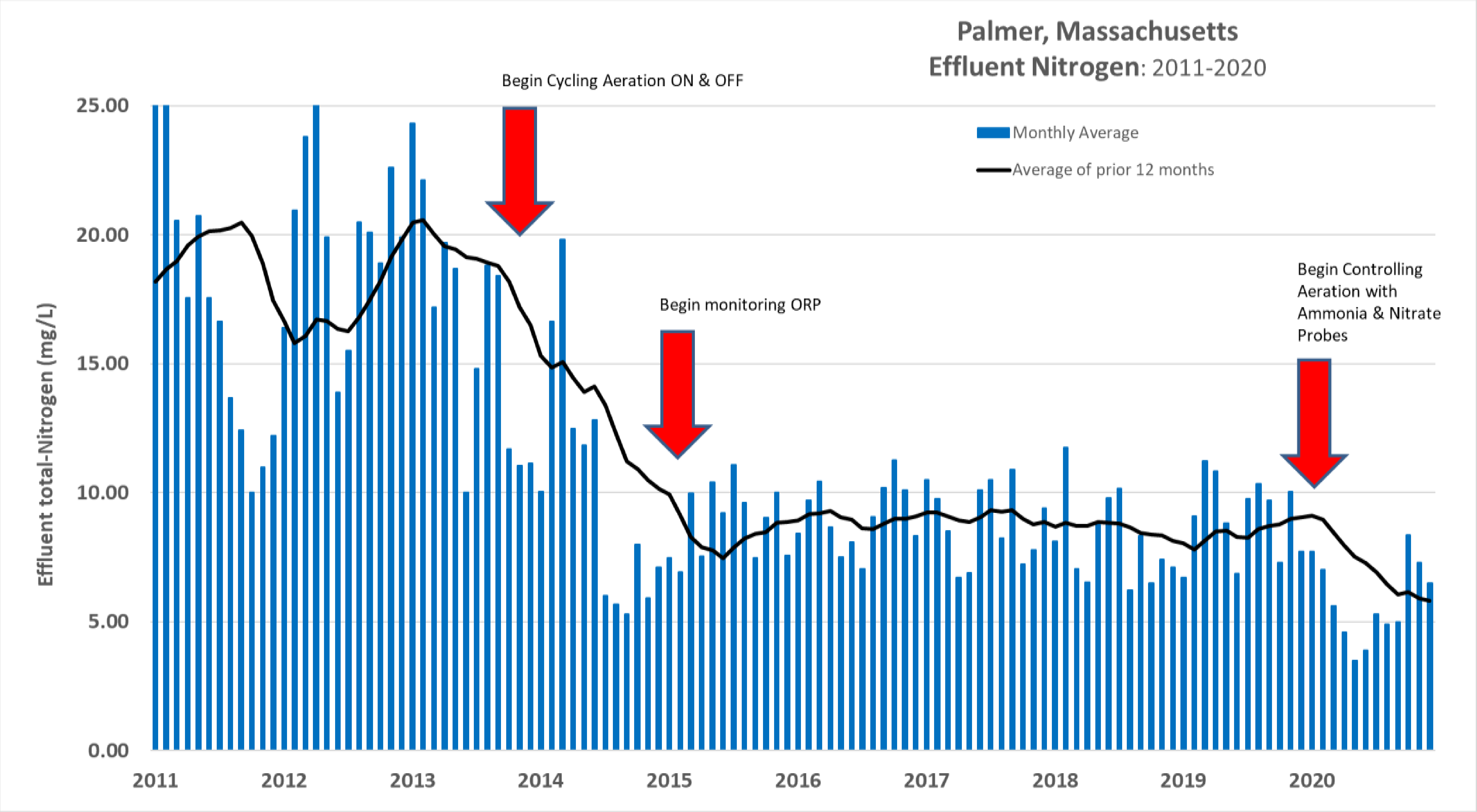
MASSACHUSETTS

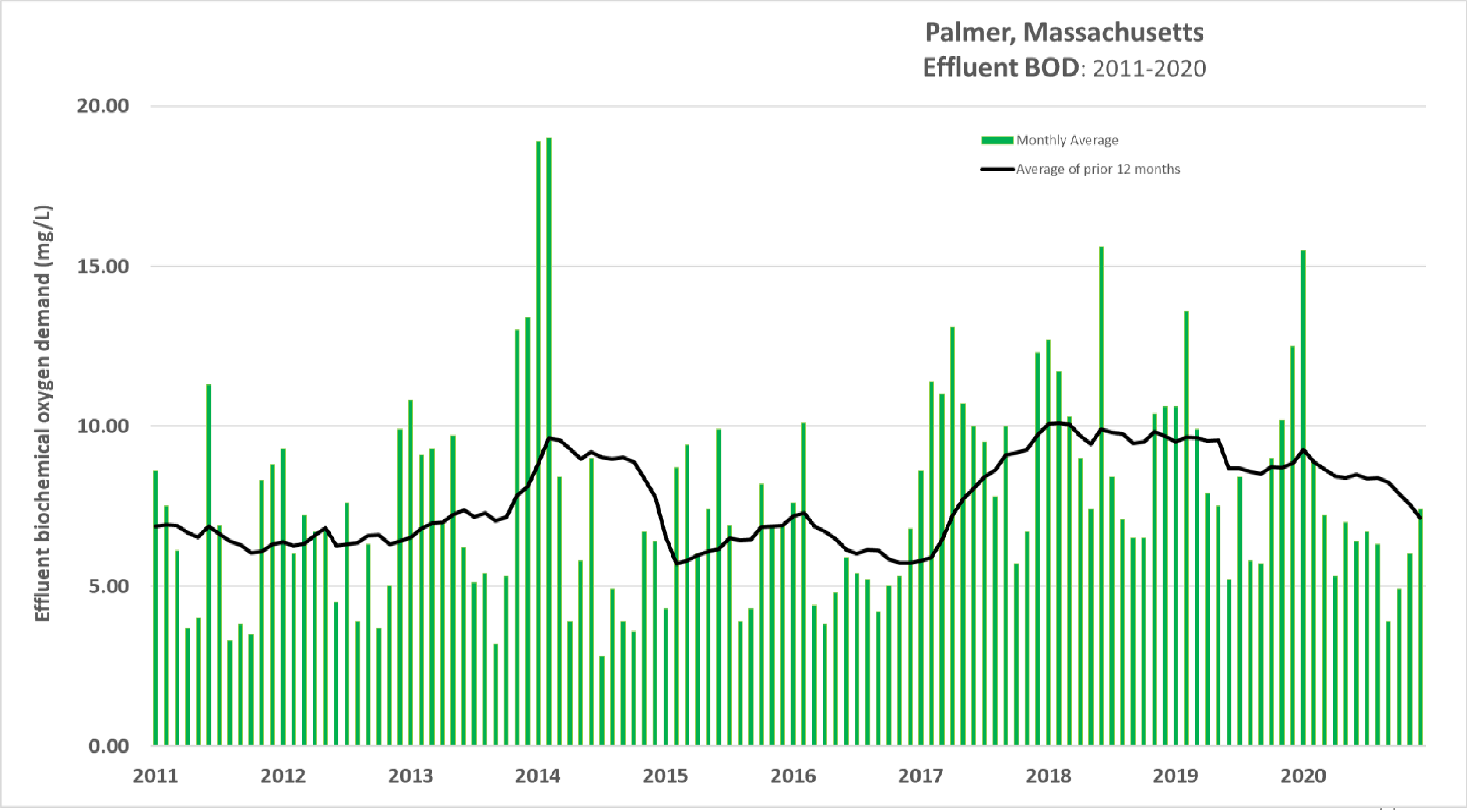
Palmer, Massachusetts Population: 12,200 5.6 MGD design flow


Palmer, Massachusetts
Effluent Nitrogen: 2011-2020
Begin Cycling Aeration ON & OFF
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
2020

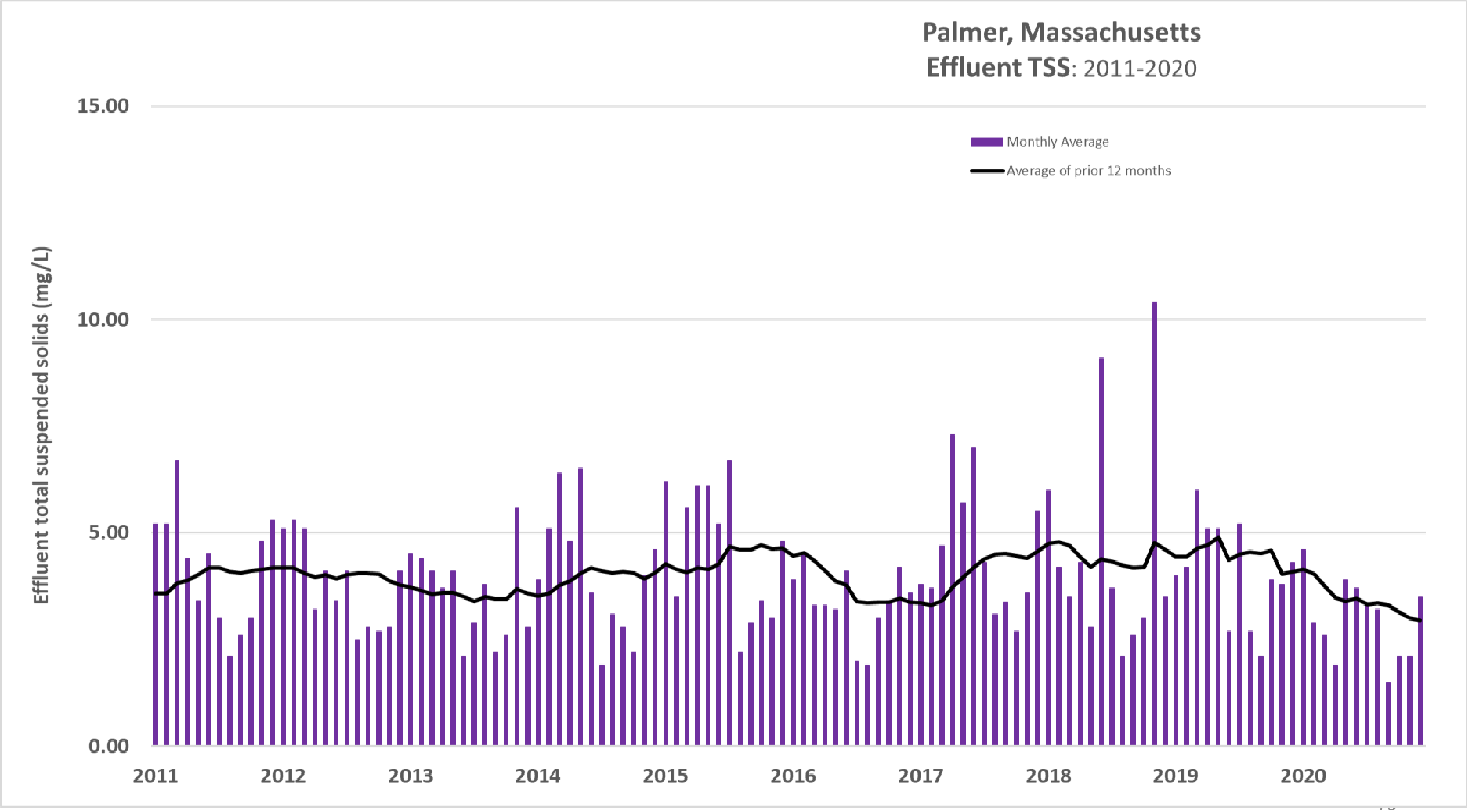

Palmer, Massachusetts
Effluent Nitrogen: 2011-2020
Begin Cycling Aeration ON & OFF
Begin monitoring ORP
Monthly Average
Average of prior 12 months
Effluent total-Nitrogen (mg/L)
25.00
20.00
15.00
10.00
5.00
0.00
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020



Palmer, Massachusetts
Effluent Nitrogen: 2011-2020
Begin Cycling Aeration ON & OFF
Begin monitoring ORP
Begin Controlling Aeration with Ammonia & Nitrate Probes
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
2020



Palmer, Massachusetts
Effluent BOD: 2011-2020
Monthly Average
Average of prior 12 months
Effluent biochemical oxygen demand (mg/L)
20.00
15.00
10.00
5.00
0.00
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020


Palmer, Massachusetts
Effluent TSS: 2011-2020
Monthly Average
Average of prior 12 months
Effluent total suspended solids (mg/L)
15.00
10.00
5.00
0.00
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

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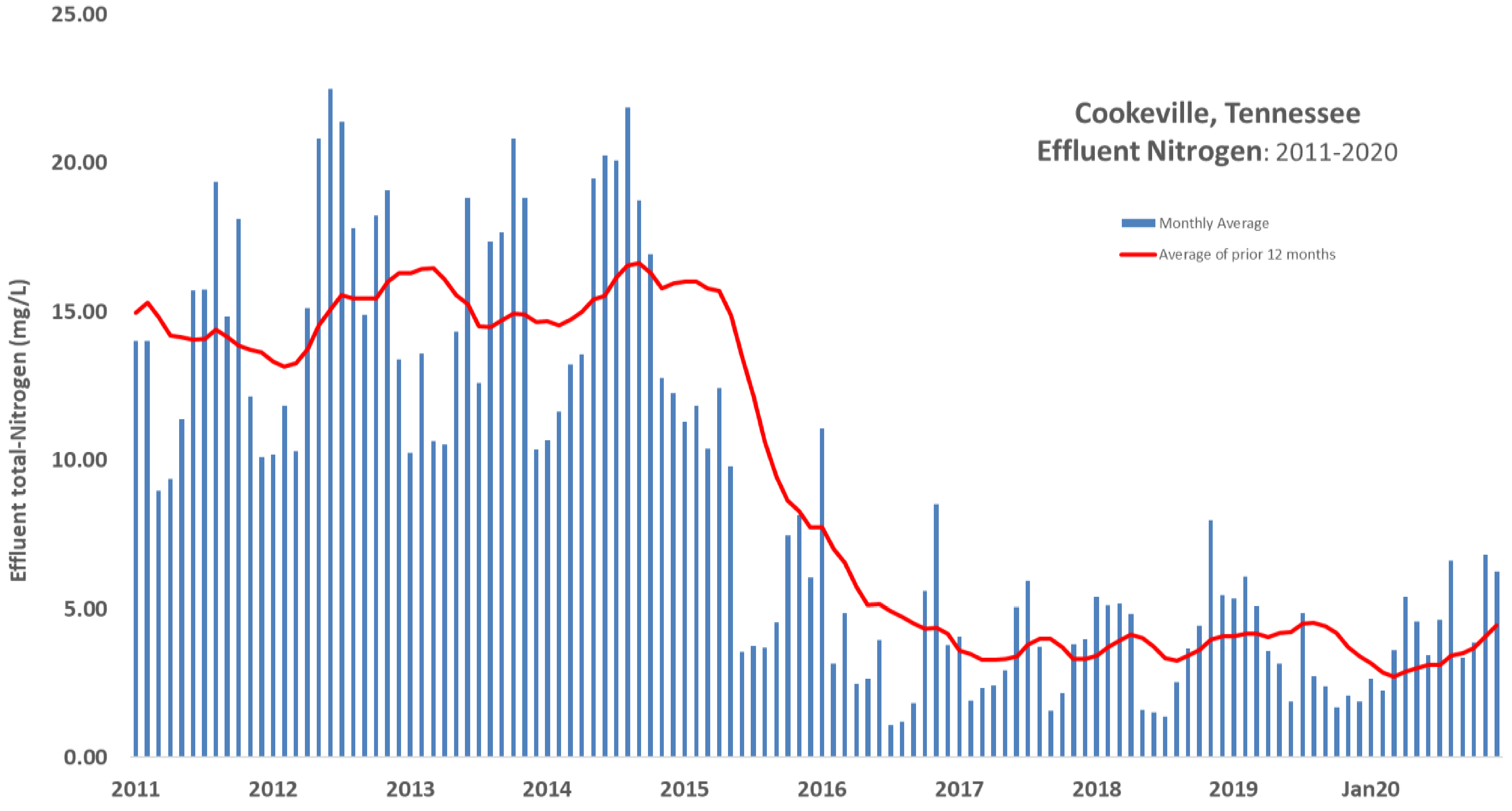
TENNESSEE

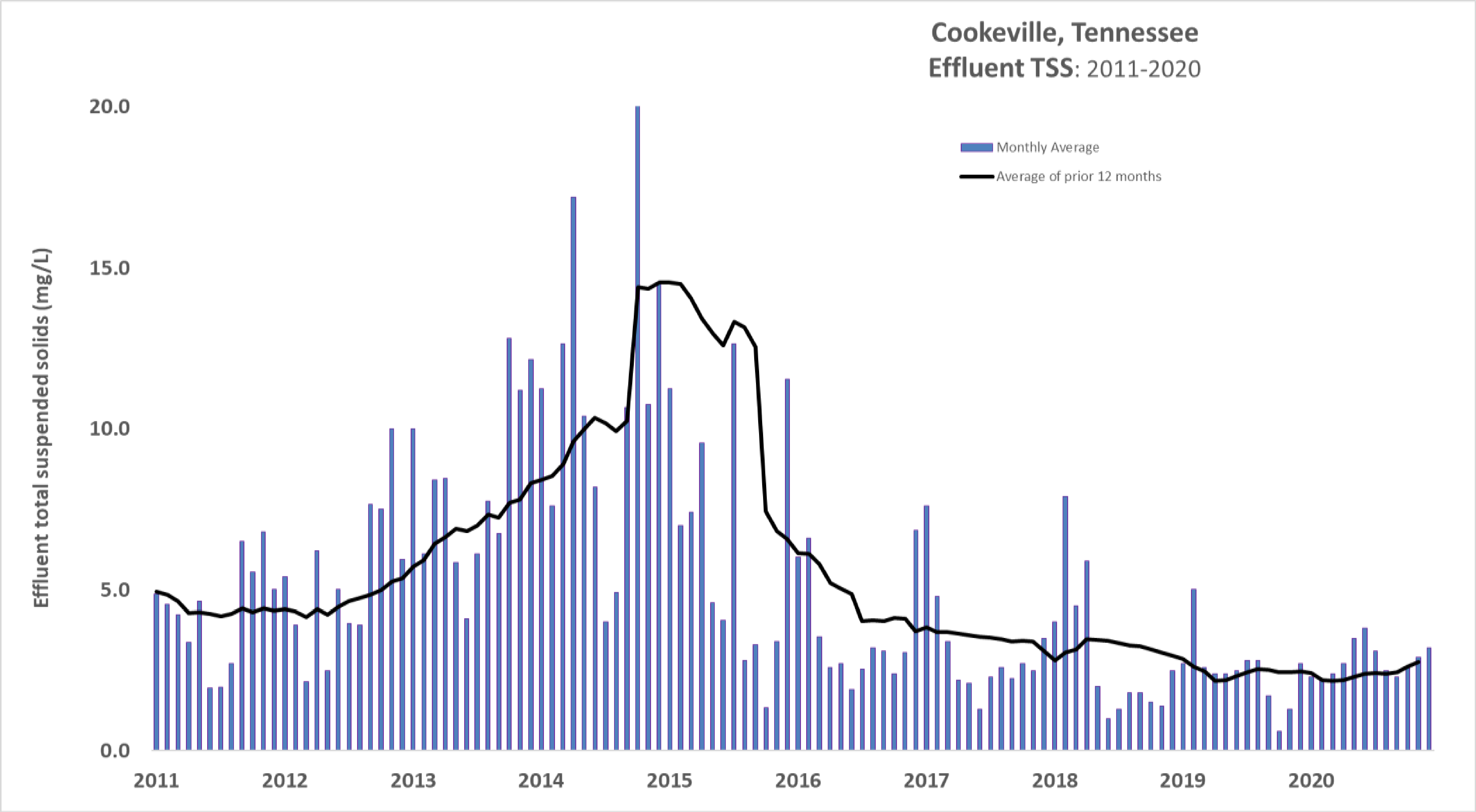
Cookeville, Tennessee Population: 33,500 15 MGD design flow


Cookeville

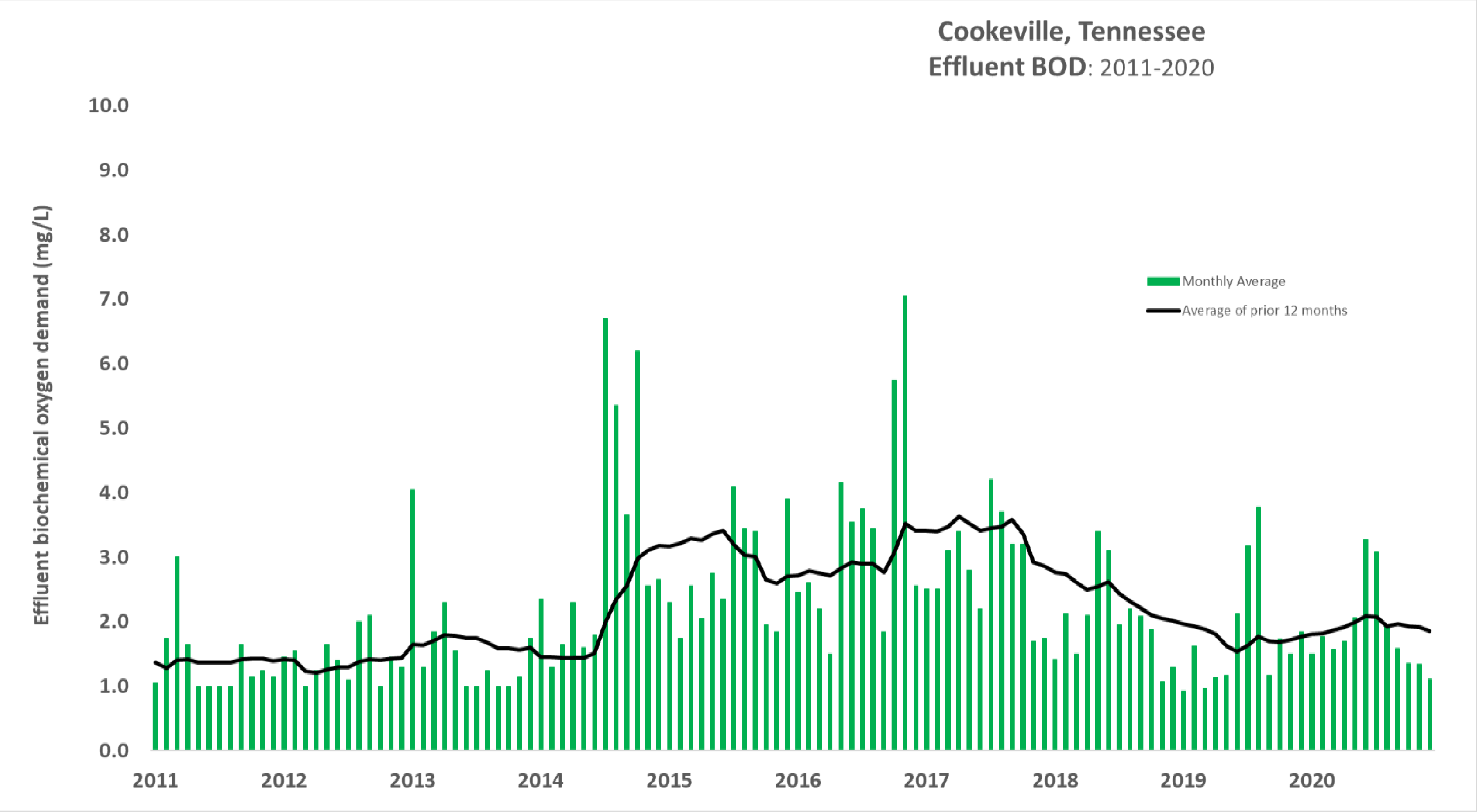

TREATMENT PLANT OPERATOR
tpo
IN MY WORDS:
Treatment innovations
for small communities | 22
TECH TALK:
A new approach
to flood protection | 14
From Learner
to Mentor
MICHELE HIGDON SAYS THANKS
FOR HER SUCCESS BY GIVING BACK
AS A VOLUNTEER
PLANT
PROFICIENCIES

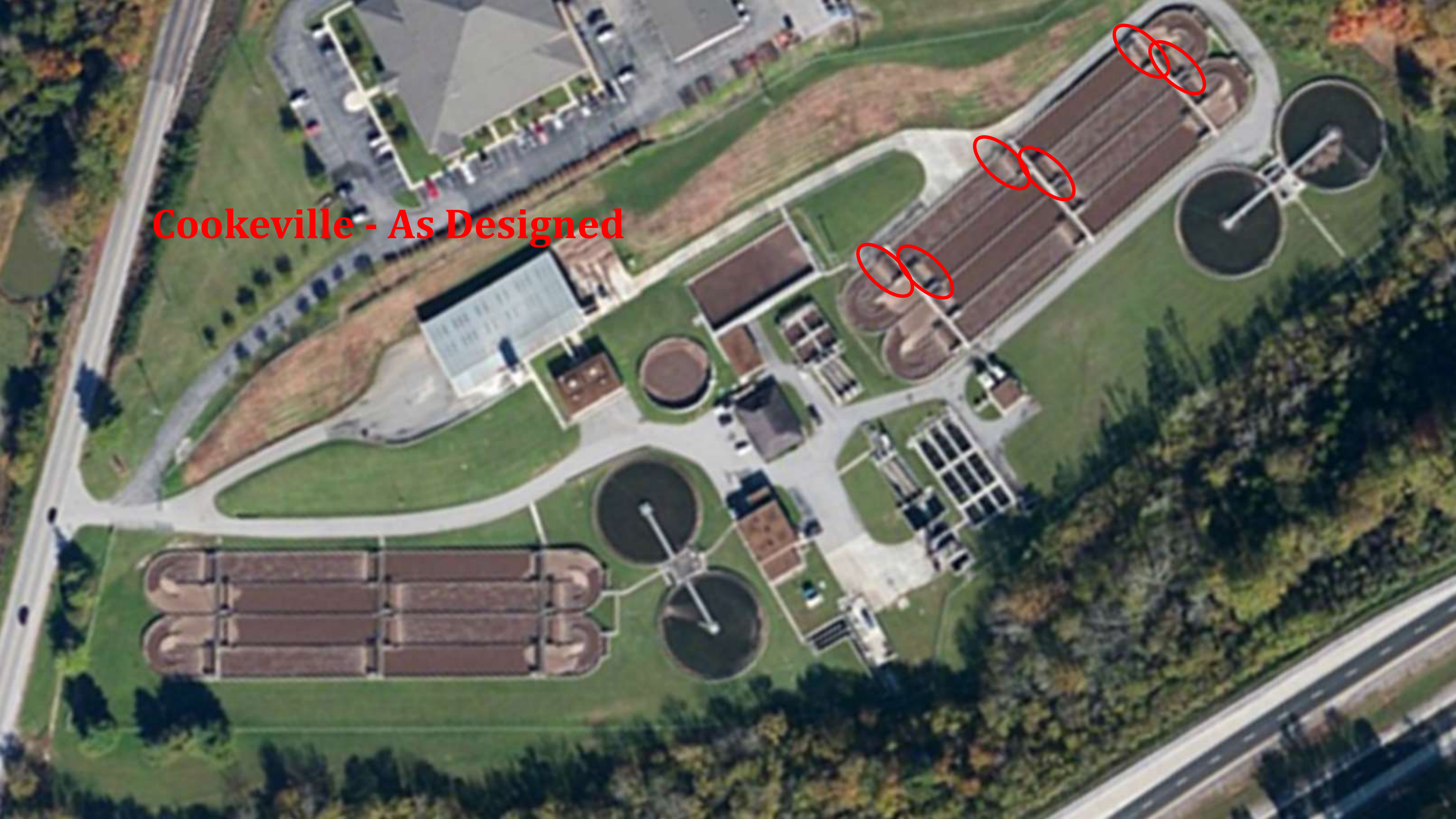


Cookeville, Tennessee
Effluent Nitrogen: 2011-2020
Monthly Average
Average of prior 12 months
Effluent total-Nitrogen (mg/L)
25.00
20.00
15.00
10.00
5.00
0.00
2011
2012
2013
2014
2015
2016
2017
2018
2019
Jan20



Cookeville, Tennessee
Effluent TSS: 2011-2020
Monthly Average
Average of prior 12 months
Effluent total suspended solids (mg/L)
20.0
15.0
10.0
5.0
0.0
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020


Cookeville, Tennessee
Effluent BOD: 2011-2020
Effluent biochemical oxygen demand (mg/L)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Monthly Average
Average of prior 12 months


Cookeville - As Designed


Cookeville - As Now Operated


Cookeville - As Now Operated


Cookeville - As Now Operated

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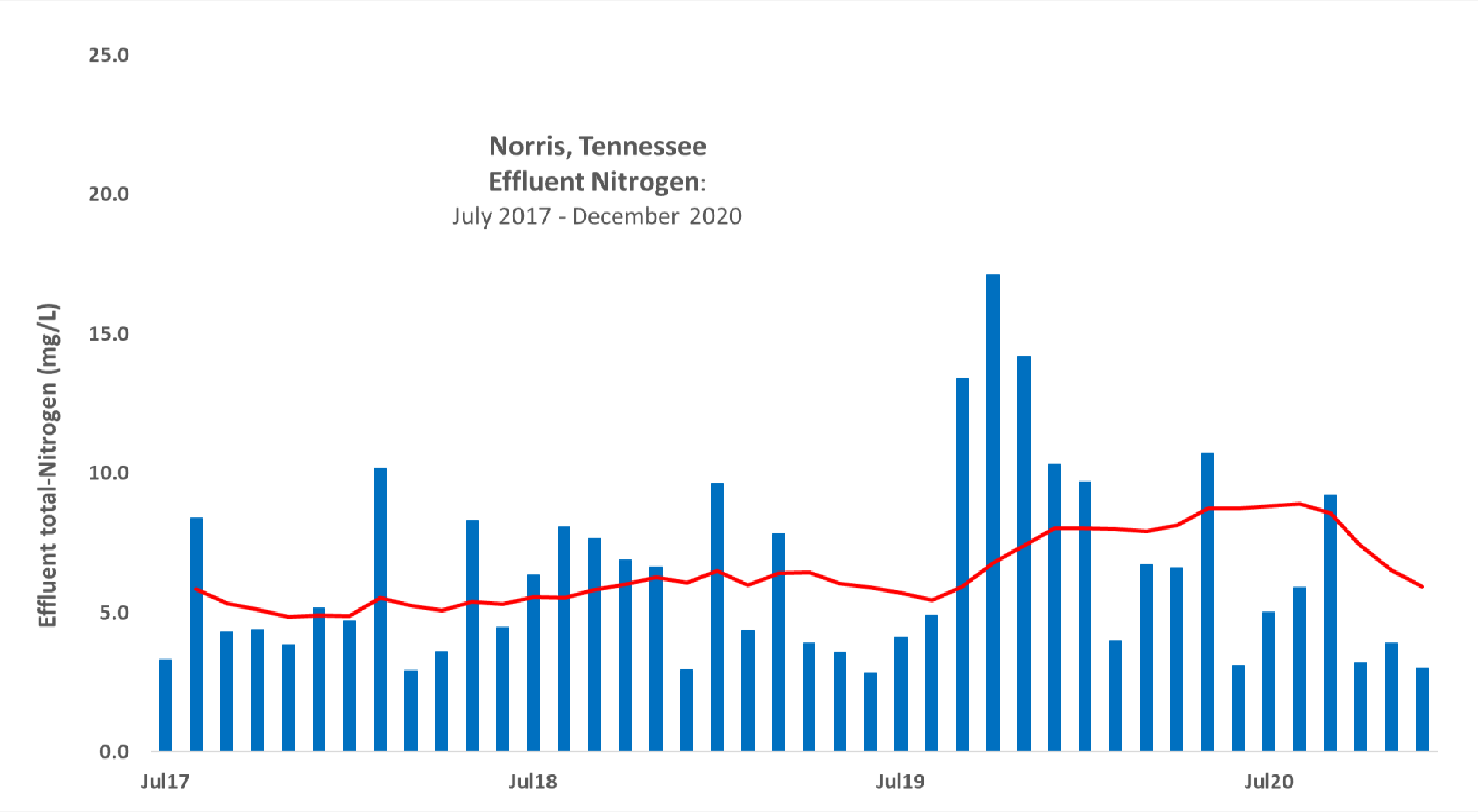
Norris, Tennessee Population: 1,450 0.2 MGD design flow

GOVERNOR'S ENVIRONMENTAL STEWARDSHIP AWARDS

Norris


Norris, Tennessee
Effluent Nitrogen:
July 2017 - December 2020
Effluent total-Nitrogen (mg/L)
25.0
20.0
15.0
10.0
5.0
0.0
Jul17
Jul18
Jul19
Jul20

Questions?
Comments?

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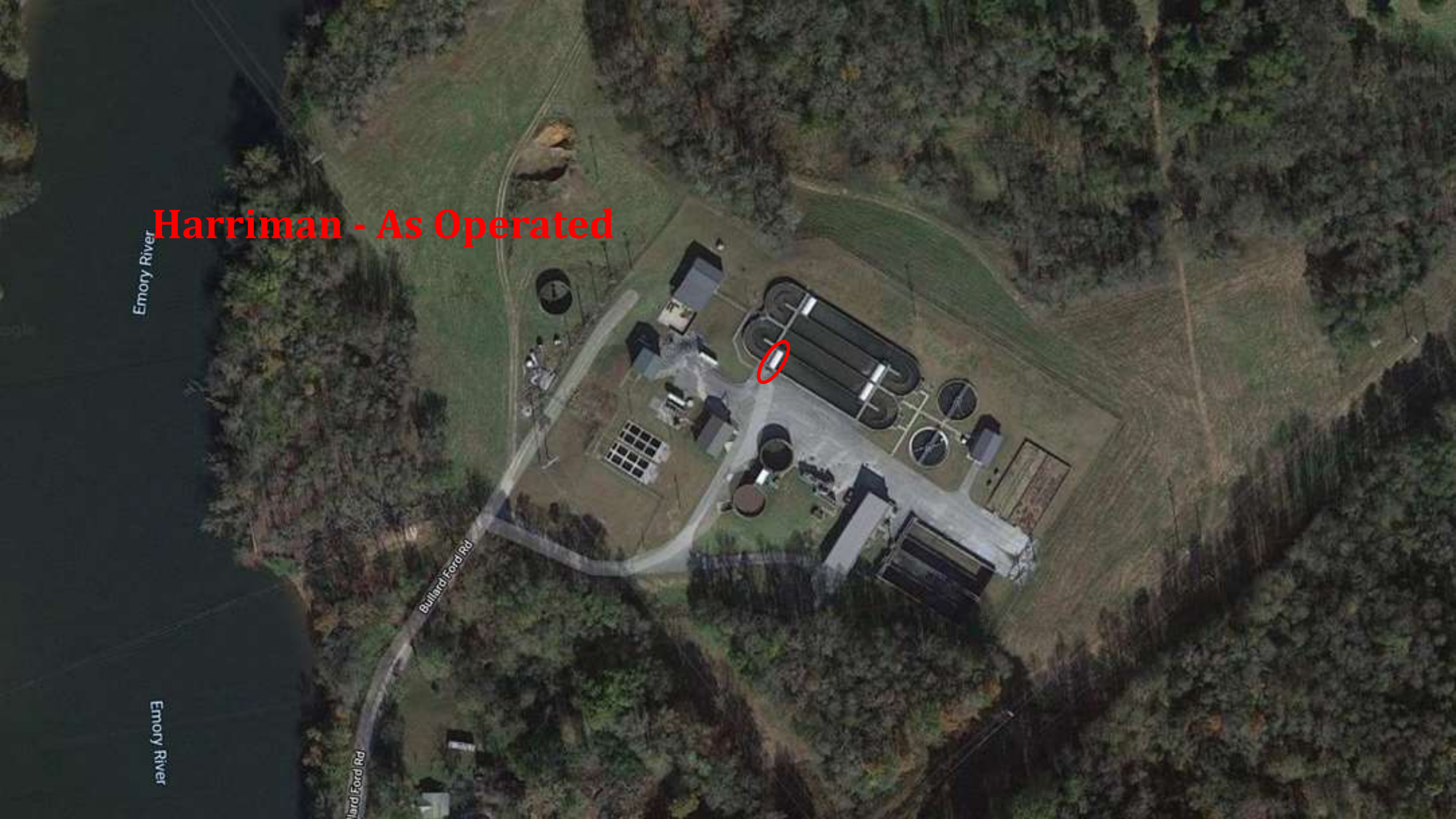
Harriman, Tennessee   Population: 6,200   1.5 MGD design flow

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

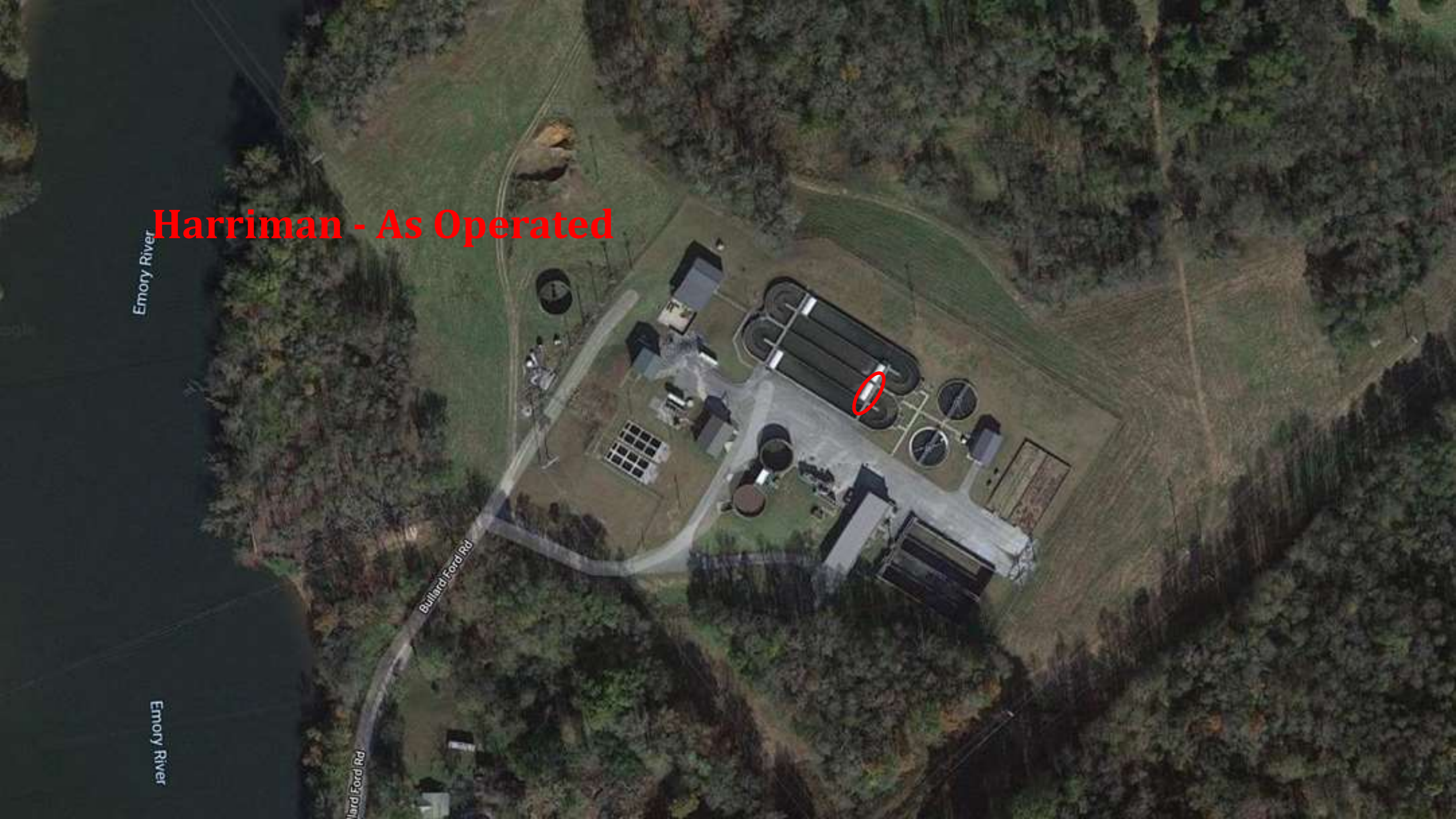
Harriman - As Designed

Harriman - As Operated


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


Harriman - As Operated
Emory River
Emory River
Bullard Ford Rd

Harriman - As Operated



Harriman - As Operated
Emory River
Emory River
Bullard Ford Rd

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Acknowledgements

US EPA
Brendan Held & Craig Hesterlee

NC DEQ
Terry Albrecht, Corey Basinger & Ron Haynes

U MEMPHIS
Larry Moore, PhD

TENNESSEE Karina Bynum, Sherry Wang, George Garden & Jenny Dodd (**TDEC**), Brett Ward (**UTenn-MTAS**), Dewayne Culpepper (**TAUD**), Tony Wilkerson & Doug Snelson (**Norris**), Ronnie Kelly, Tom Graham & John Buford (**Cookeville**), David Tucker & Johnnie MacDonald (**Nashville**) & Ray Freeman (**Harriman**)
MASSACHUSETTS Gerry Skowronek & Kenny Lord (**Palmer**)
KANSAS Tom Stiles, Rod Geisler (retired), Shelly Shores-Miller, Nick Reams & Ryan Eldredge (**KDHE**), Jamie Belden & Becky Lewis (**Wichita**)
MONTANA Paul Lavigne (retired), Pete Boettcher, Josh Vial & Ryan Weiss (**MDEQ**), Eric Miller (**Chinook**), Keith Taut (**Conrad**) & Mark Fitzwater & staff (**Helena**)

… and, many more!

Next Week's Webinar
Activated Sludge: part 1
Oxygen Demand and Supply

Thursday, February 25
10:00 - 11:45 AM

Activated Sludge: part 2
***Bio-Tiger Model** (3/4)*

***Phosphorus Removal** (3/11 & 3/18)*

***NC Case Studies** (3/25,4/8 & 4/29)*

***Energy Management** (4/15 & 4/22)*

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Volunteer for Case Study sessions!

And?

Grant Weaver
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Questions
Comments
Discussion