Bio-P Operational Changes and Impacts

CSWEA Phosphorus/Nutrients Operations Seminar
Nov 14th 2019

Op2Myz, LLC – Greg Paul

UP FRONT

This info/discussion is from simple observation and study at numerous WWTP...

It is on going

Thanks to Those Who Have Shared

- Antioch
- Lindenhurst
- Medford
- Eleva-Strum
- Slinger
- LaCrosse
- Lake County, IL
- Many others

.....SUMMARY.....

WANT TO GO DEEPER

- Essentials → 
- Floc – FLOCOLOGY *(study of floc)*
  - Young/Old
  - Big/Small
  - Positive/Negative
  - Slime Layer
  - pH/Alkalinity
- Floc's Impact on EBPR Removal Efficiency
  - Fermentation
  - Uptake
  - TSS capture

.....ESSENTIALS.....

Activated Sludge Log

Foam/Scum Key

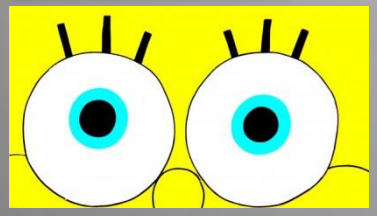
Qty. 0-None, 1-Small Amount, 2-Approx. Half, 3-Covered — 080507-Aeration-Foam-Scale.pdf

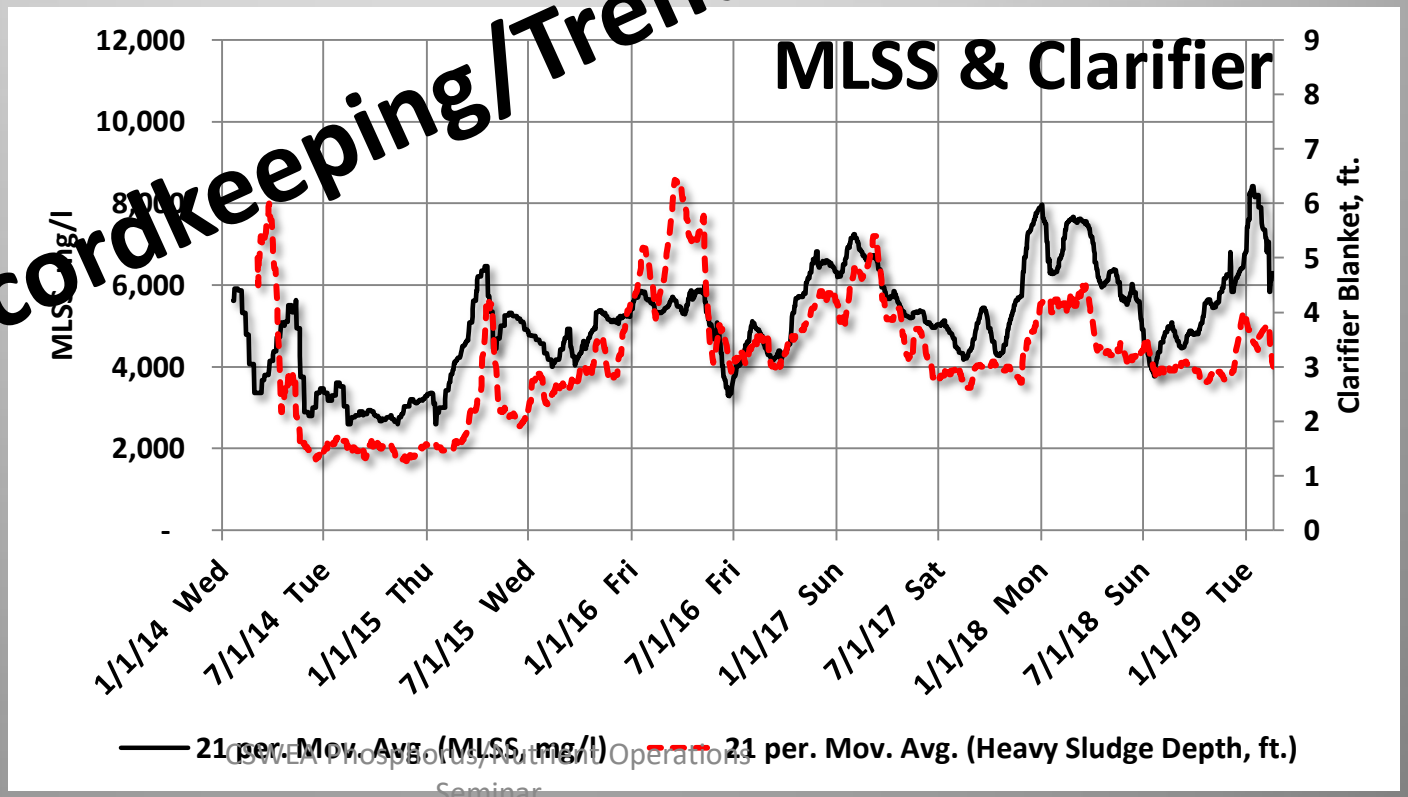
Color W-White, T-Tan, B-Brown, D-Dark Brown G-Gray BK-Black — 080428-Aeration-Scum-Scale.pdf

	Time of Day	Int	Pump On/Off	Pump Speed, Hz	Weekday Min/cycle	Week End Min/cycle	# of Cyc per day	Scum on Anaerobic Zones	Foam on Aerated Zones	Color of Foam on Aerated Zones	Scum on Final Clarifier Surface	Scum in Final Clarifier Centers	Which is Final Off	24 HR Avg SRT	Trending	SRT Target	Problem/Comment	Tried Solution	Did it Work?	Video/Pics/Files
1/16/00	5:00 PM	GJP	on	45	15	15	30	5	6	B/D	0	0	1				Eff/Sludge temp ~10 degree, the coldest I've seen it			
2/23/06	5:00 PM	GJP	On	45	75	35	11	1	1	T/B	0	1					Eff TSS and Phos are getting higher	Slowed the wasting down by putting week day minutes/cyc to 0. At midnight the weekend rate would pick up. Ran 2 hrs/day for aprt of the weekend		060223AC.mpg
3/11/06	1:00 PM	GJP															Calculating wasting settings			060311-Calculating-Wasting-Rates-Settings.xls
3/11/06	1:00 PM	GJP															Operational Problems, high TSS 10-15 m			060311-Operational-Changes.doc

Recordkeeping/Trends/Investigate

What,
Why,
Who,
When,
Where
and How





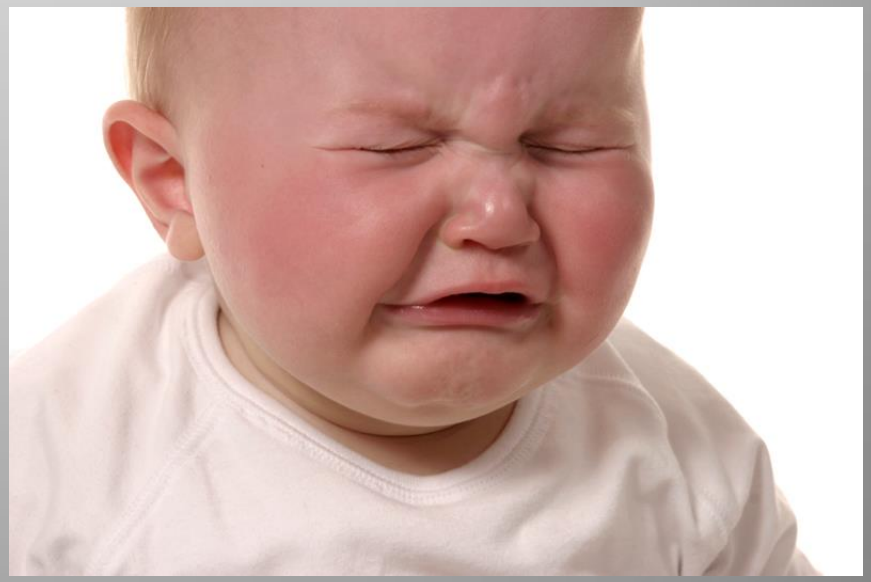
November 14, 2019

.....FLOCOLOGY.....

O_2 Just Right

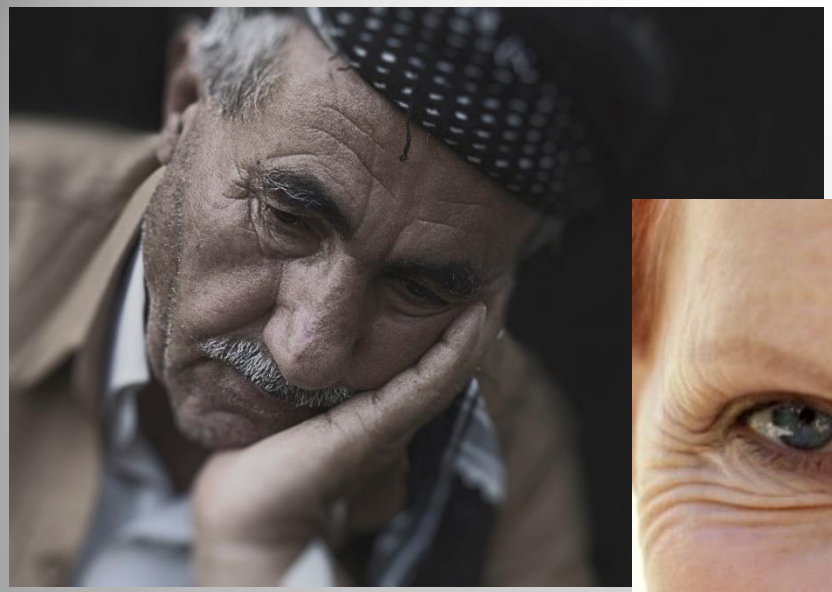
Young Sludges

TOO MUCH O_2



Not Enough O_2

Old Sludges



Too Much O_2

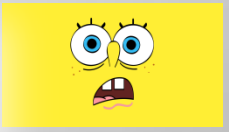
O_2 Just Right

Not Enough O_2

Young Sludges

ORP too Low

ORP Just Right

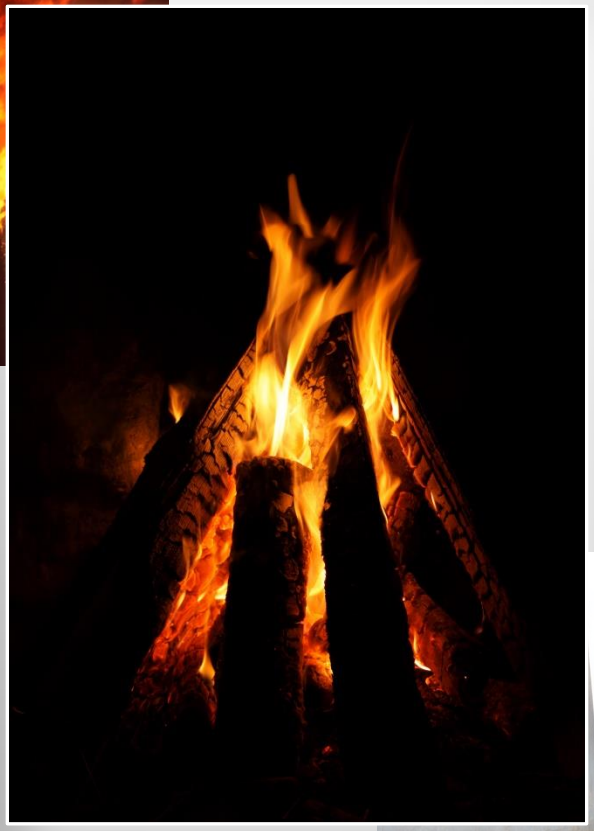


ORP Too High

Old Sludges

ORP too Low

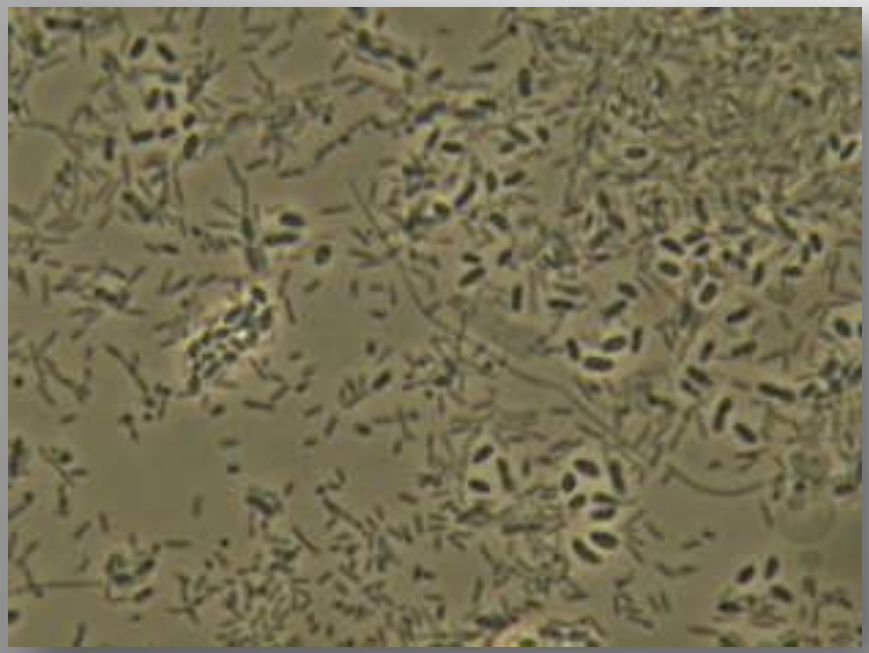
ORP Just Right



ORP Too High

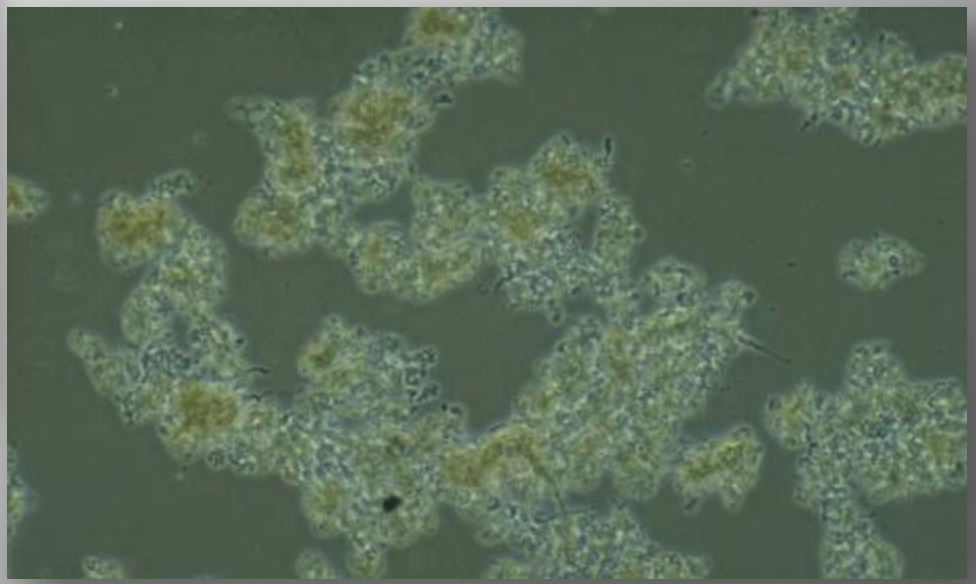
BIG/SMALL

Small



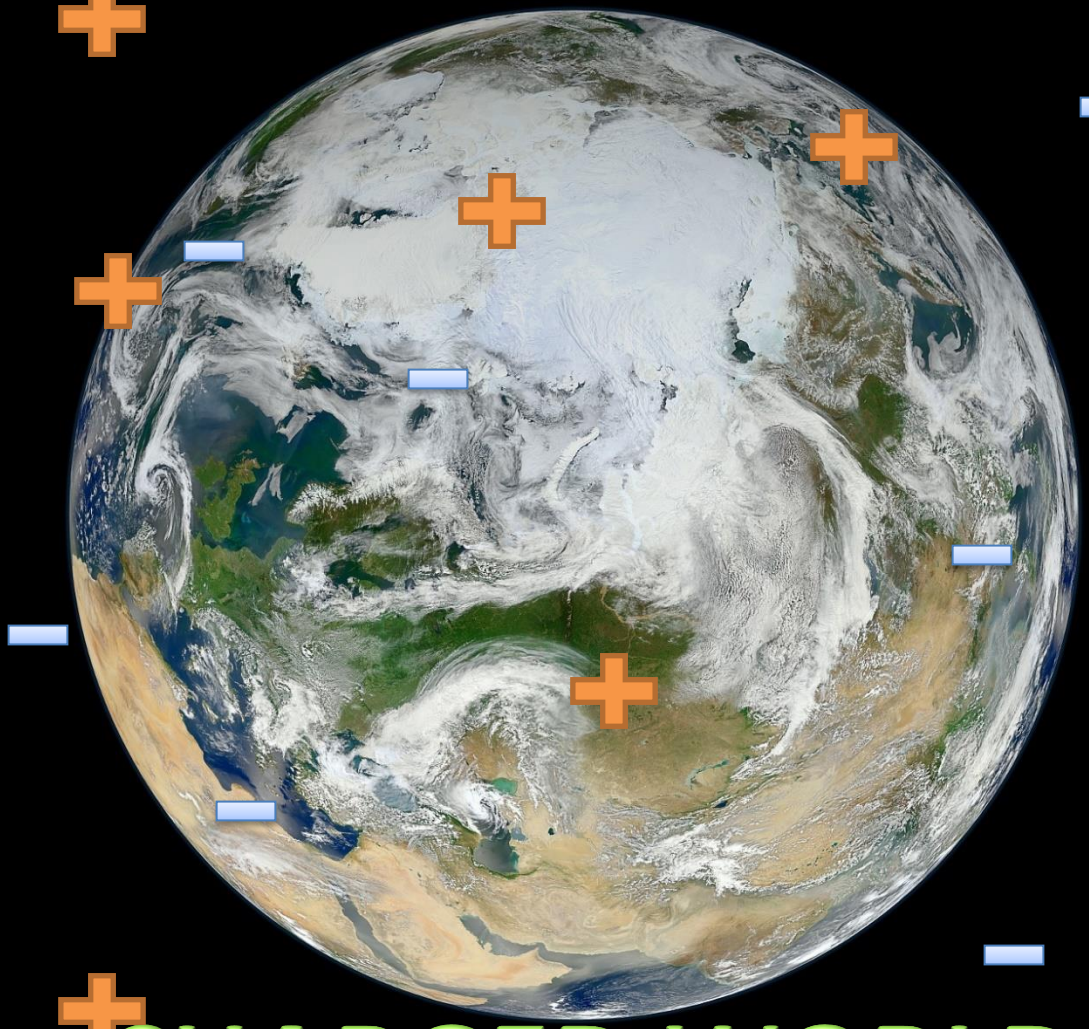
www.sustainopedia.com/activated-sludge-troubleshooting-through-microscopic-evaluation/

Big



web.deu.edu.tr

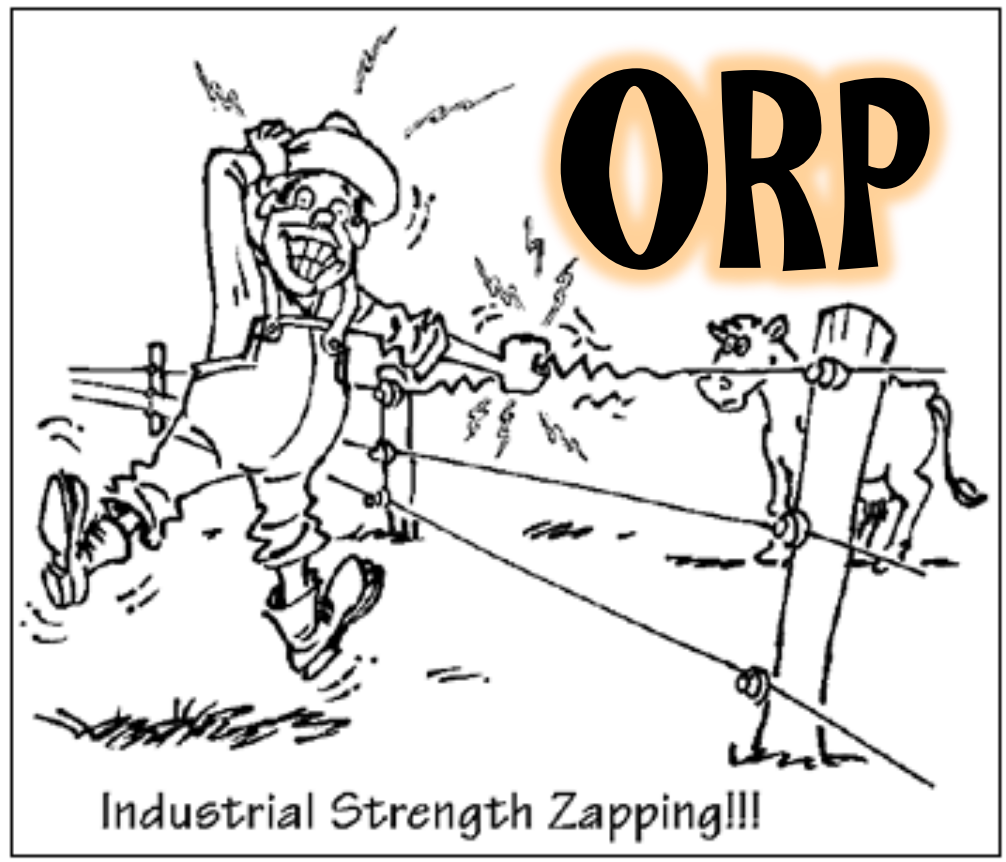
We Live in a



CHARGED WORLD

Positive/Negative

VERY SIMPLY- It is a *measurement* of an positive/negative *electrons* in a liquid



Oxidation-Reduction Potential Info from WEF MOP 37

- **O**xidation-**R**eduction **P**otential is a measurement of the ABILITY of a solution to **accept** or **donate** ELECTRONS.

+ **Positive ORP** ability to **ACCEPT** electrons

(oxidative environment - oxygen)

- **Negative ORP a**bility to **DONATE** electrons

(reductive environment - no oxygen)

From http://www.rhtubs.com/ORP.htm

From Robert's Hot Tubs!!!

- ORP Meter is **REALLY** just a millivolt meter, measuring the voltage across two electrodes

"Oxidation-Reduction" is used with a hyphen because the two chemical reactions are really "joined at the hip" - one cannot occur without the other also occurring

Electrically Charged Microbes

- Bacterial cell walls are negatively charged
- Charges change based on environment

SLIME LAYER

Slime Layers on Microbes

- **LPS** (Lipopolysaccharide) is a major **component of the outer membrane** of Gram-negative bacteria, contributing greatly to the structural integrity of the bacteria, and **protecting** the membrane from certain kinds of chemical attack. Endotoxins.

- **EPS** (Exopolysaccharides or Extracellular polymeric substances) are **compounds secreted** by microorganisms into their environment.

Why slime layer ?

- Slime layer is contains **glyco protein(1)** molecules are loosely associated with the cell wall

- Protection - Bacteria covered with this slime are protected from dehydration and loss of nutrients

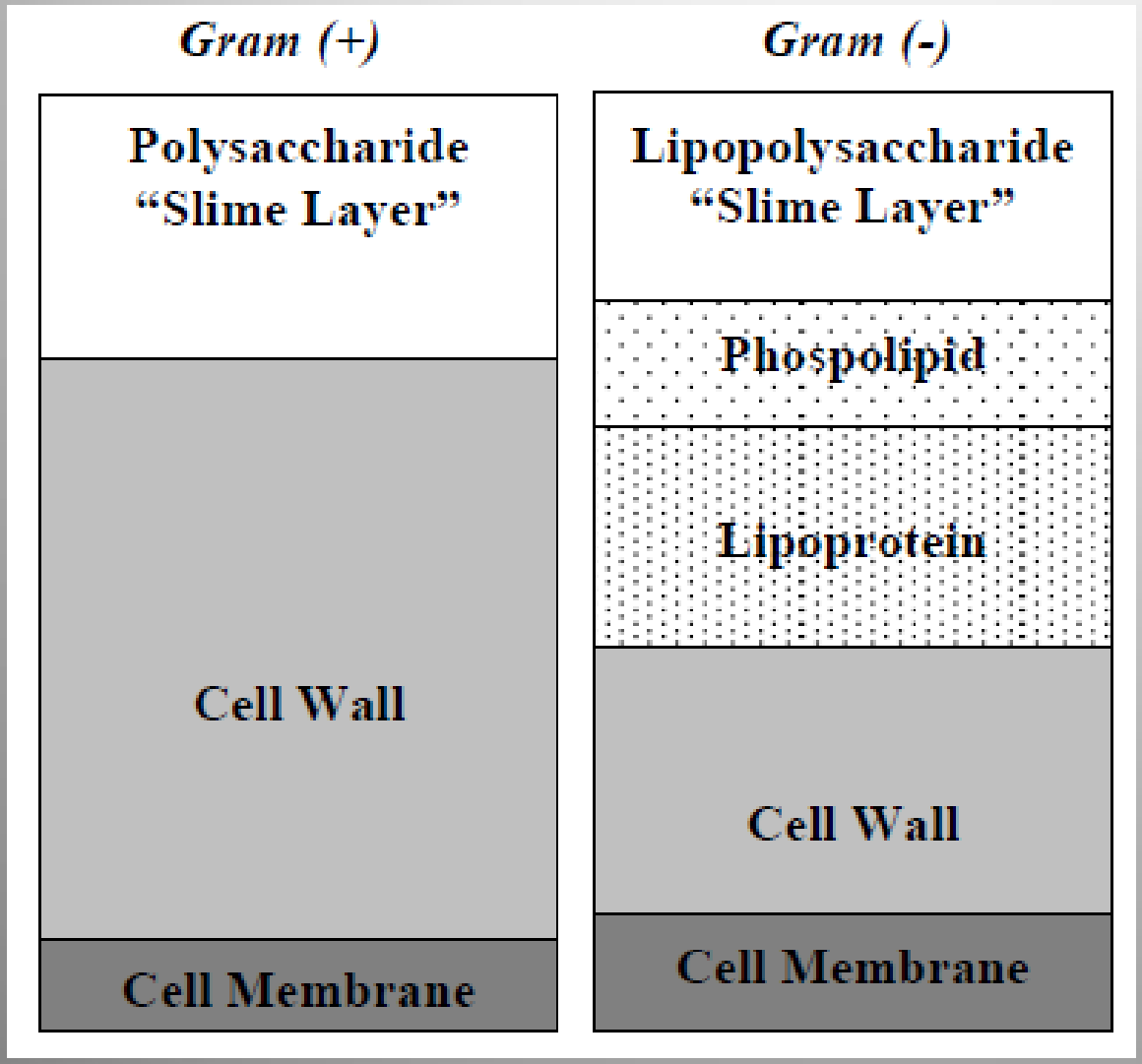
(1) Contains Nitrogen

How Does EPS Glue Floc Together?

- EPS helps glue floc together physicochemically
  - It glues particles-microbes together by **ELECTROSTATIC INTERACTIONS**
    - Between the multivalent cations (Ca2+, Mg2+) and **negatively charged** EPS
    - Also by hydrophobic interactions

From - Fatty Acids of Lipid Fractions in Extracellular Polymeric Substances of Activated Sludge Flocs By - Arnaud Conrada, Merja Kontro (Suutari)b,c, Minna M. Keinänenb, Aurore Cadoreta, Pierre Faured, Laurence Mansuy-Huaultd, and Jean-Claude Blocka,*

LPS in Activated Sludge



What causes LPS in WWTP?

Nutrient deficiency and/or toxicity

BOD:N:P – 100:5:1

Looking at our digestive track what causes nutrient deficiency?

High carbon diets – 200:5:1

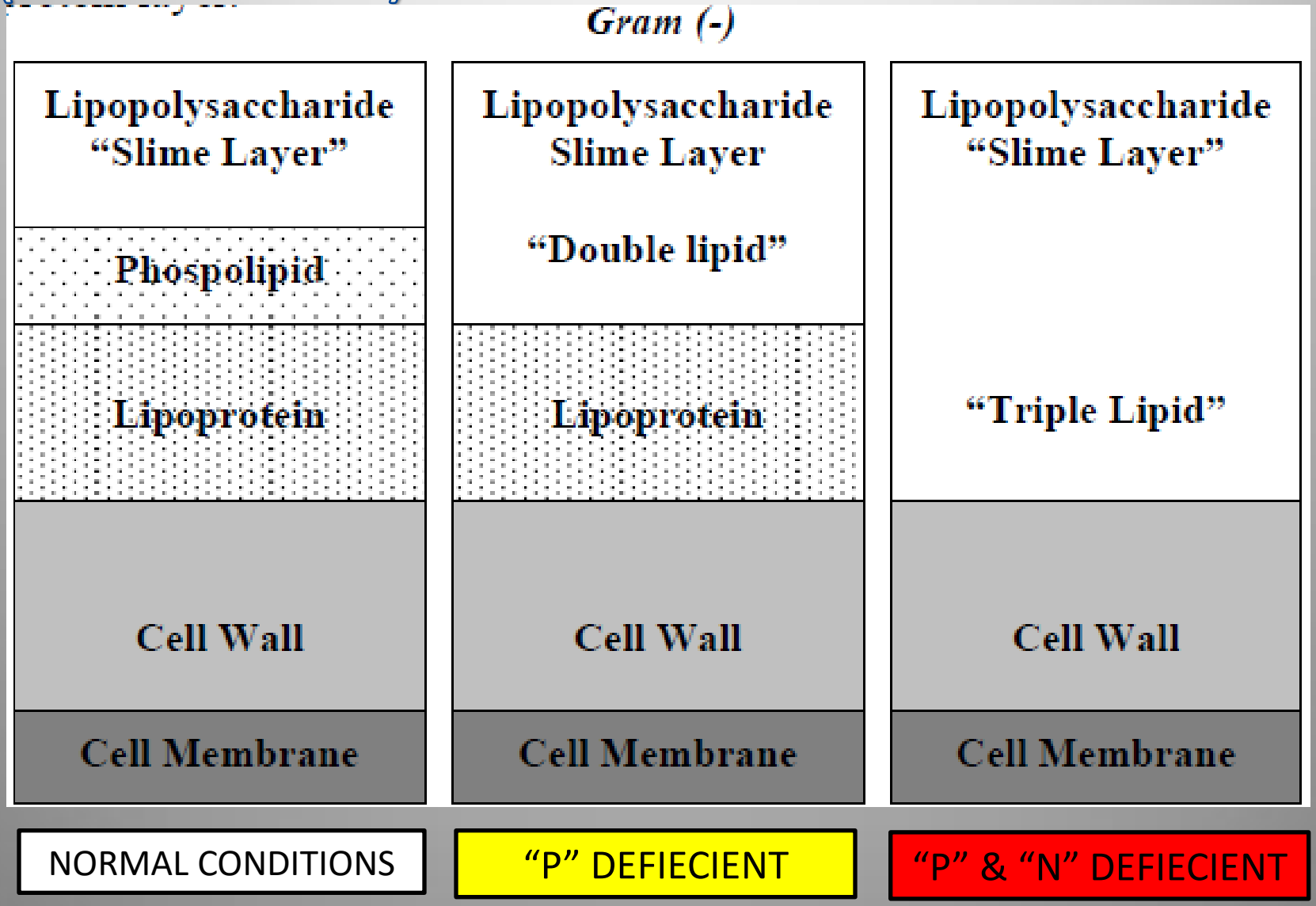
Why is LPS a problem in human biology?

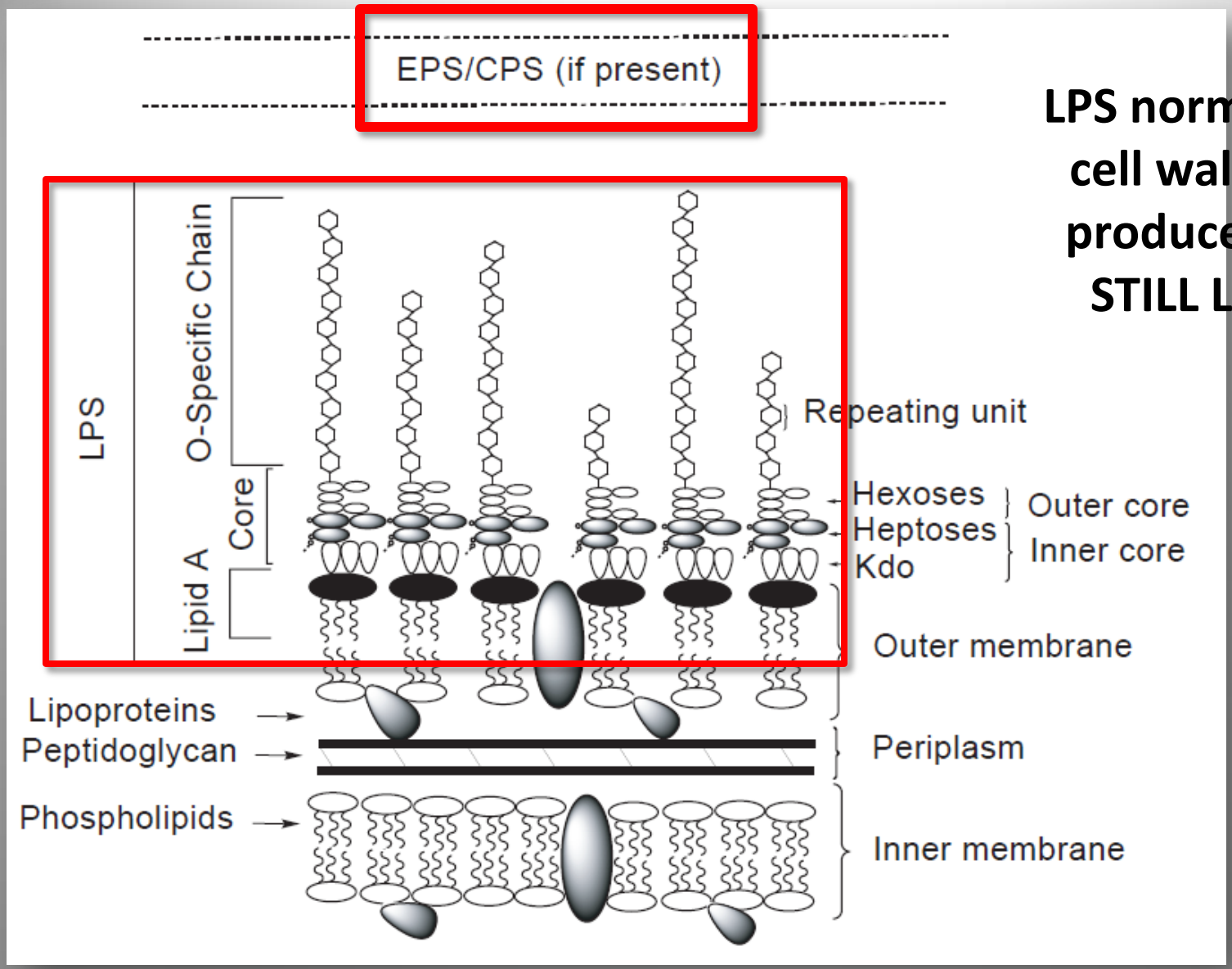
Causes inflammation in any place within the body

NORMAL CONDITIONS

LPS in Activated Sludge

(WWTP BIG Gut)





LPS normal part of cell wall – EPS is produced by LPS STILL Learning

From - Structural Studies of Some Bacterial Lipopolysaccharides and Extracellular Polysaccharides using NMR Spectroscopy and Mass Spectrometry - Semiha Dag

From - Understanding the role of extracellular polymeric substances in an enhanced biological phosphorus removal granular sludge system

NOTE - P, K, Mg and Ca retained in EPS before transferring into PAOs

Abstract

The role of extracellular polymeric substances (EPS) in the enhanced biological phosphorus removal (EBPR) process was investigated in a P-accumulating granular sludge system by analyzing the distribution and transfer of P, K^+, Mg^{2+} and Ca^{2+} in the sludge phase, EPS, and the bulk liquid. In the sludge phase, about 30% P, 44.7% K^+, 27.7% Mg^{2+}, 28% Ca^{2+} accumulated in the EPS at the end of aeration. The rate of P, K^+, Mg^{2+} and Ca^{2+} released from the EPS matrix into the bulk liquid in the anaerobic phase was faster than the rate they were adsorbed from the bulk liquid into the EPS in the aerobic phase. P, K^+, Mg^{2+} and Ca^{2+} were retained in EPS before transferring into the phosphorus accumulating organisms (PAOs). These results suggest that EPS play a critical role in facilitating the accumulation and transfer of P, K^+, Ca^{2+} and Mg^{2+} between PAO cells and bulk liquid.

From - Roles of extracellular polymeric substances in enhanced biological phosphorus removal process
By - Wen-WeiLiHai-LingZhangGuo-PingShengHan-QingYu

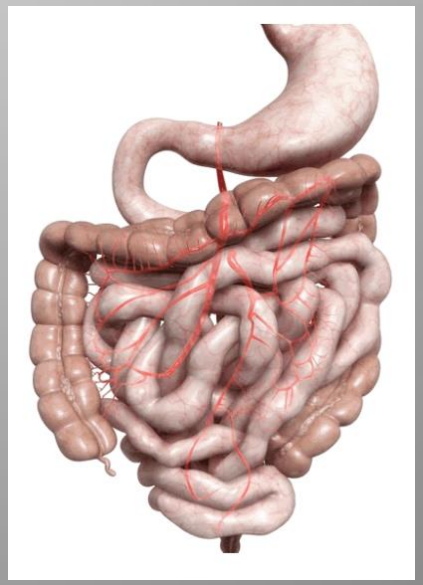
EBPR process is known to mainly rely on the ability of phosphorus-accumulating organisms to take up, transform and store excess amount of phosphorus (P) inside the cells.

However, recent studies have revealed *considerable* **accumulation of P** also **in** the extracellular polymeric substances (**EPS**) of sludge, implying a non-negligible role of EPS in P removal by EBPR sludge.

If Ca or Mg is added to increase alkalinity does it also get stuck in EPS and combines with sRP or sNRP ???

US & BIO - SLIME LAYERS

- Plaque
  - Slime Layer in the Mouth
  - Created by **Streptococcus mutans**
  - This traps Other microbes too
  - Accumulation on tooth enamel
  - Can be 100's cells thick
  - Causes Cavities
- Tartar
  - Plaque build-up mineralized
- Nose/mouth/digestive system →



pH - ALKALINITY

pH/Alkalinity

- **GAO** predominance impacted by pH
- pH impacted by alkalinity
- Alkalinity **impacted** by
  - Influent levels – ***drink water alkalinity***
  - Levels of **nitrification/denitrification**
- Alkalinity impacts P removal as well by;
  - Improved **BIOLOGY** with better pH
  - Slight **chemical** removal impact
  - **Coagulant** impact with colloidals solids (possible sNRP removal)

GAO – pH/Temp/Acetate-Propionate

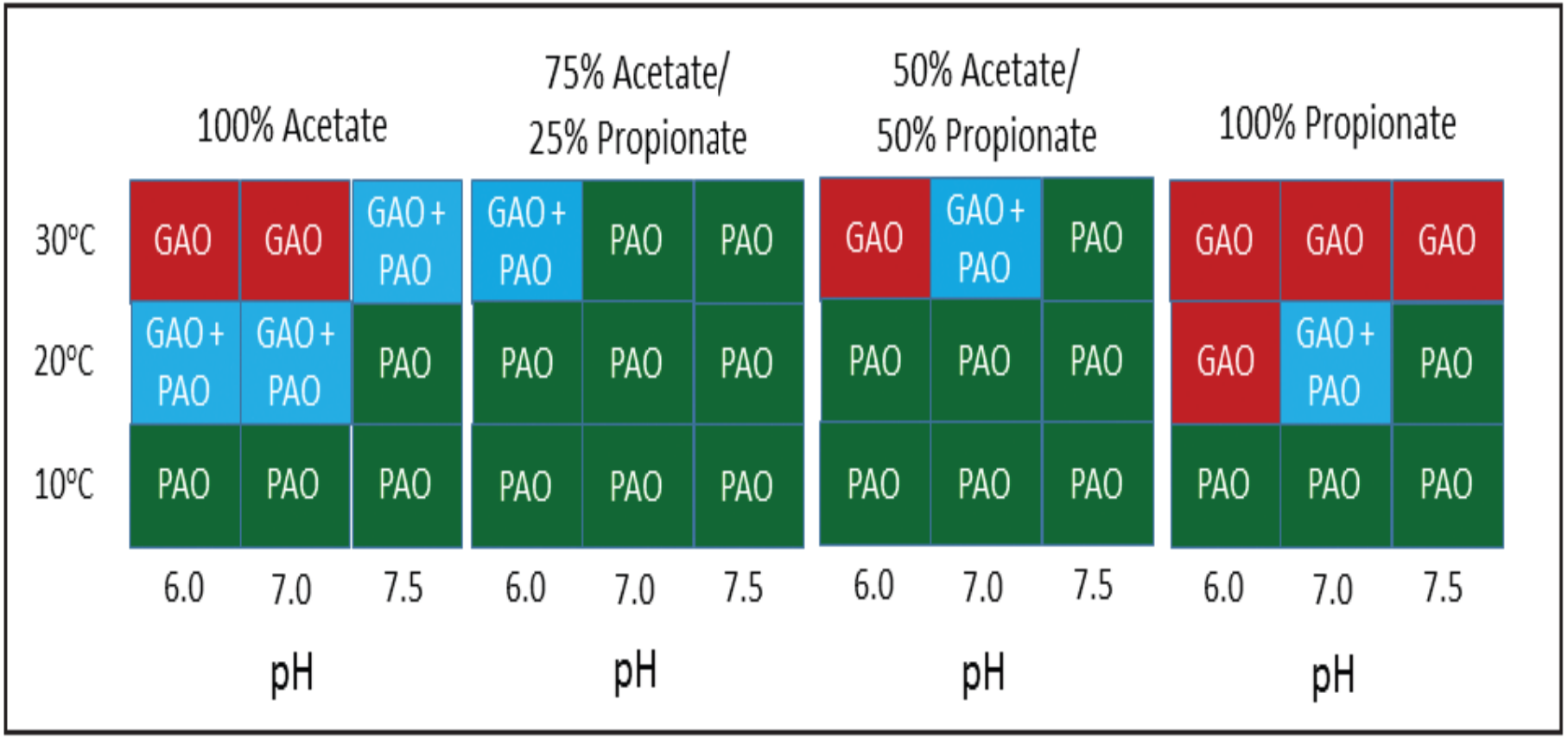
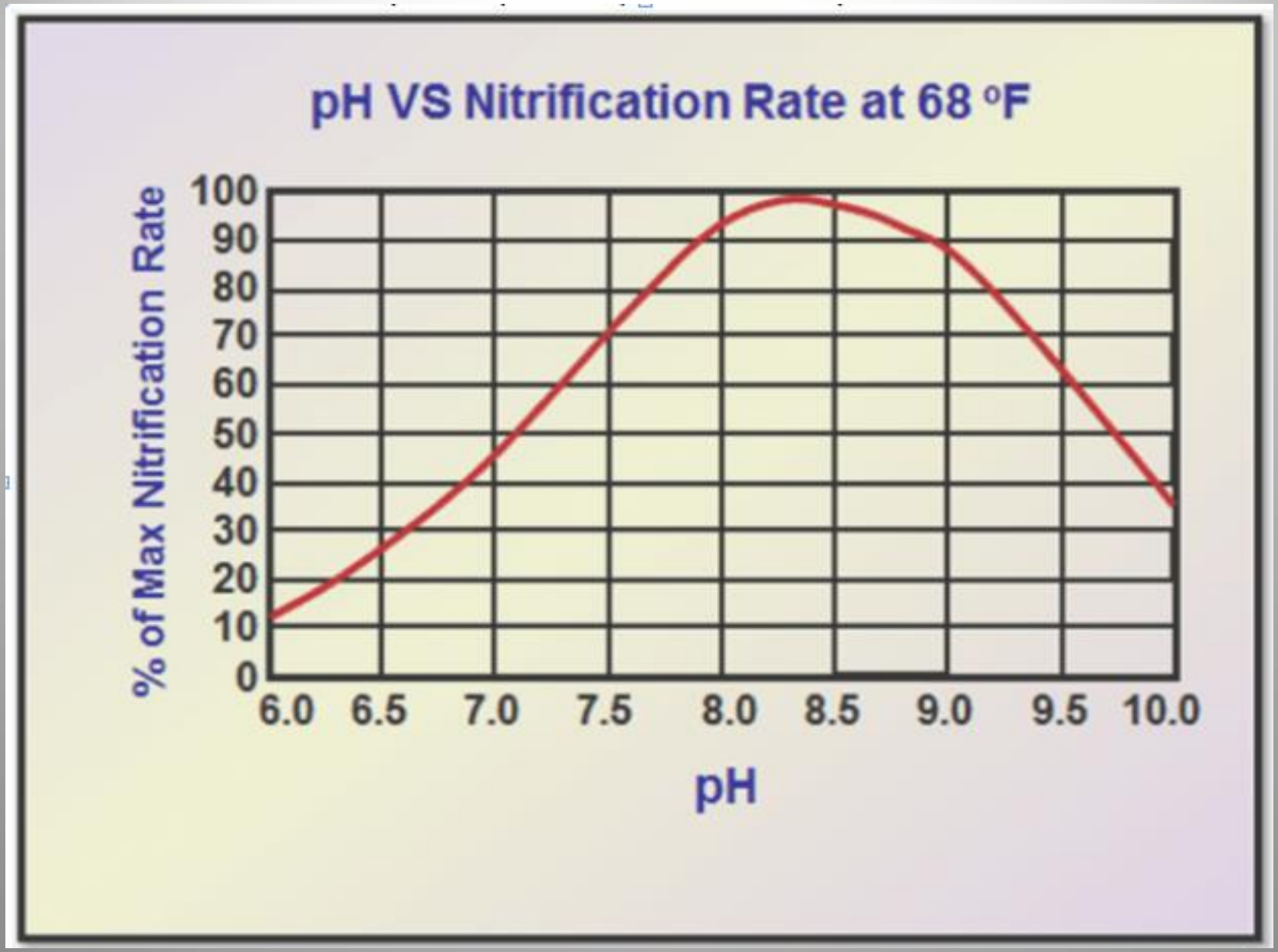


Figure 7: Population Distribution of PAOs and GAOs (Vazquez et al., 2009)

From - Sam Jeyanayagam Article


pH VS Nitrification Rate at 68 °F
% of Max Nitrification Rate
100
90
80
70
60
50
40
30
20
10
0
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
pH

..... Floc's Impact on EBPR Removal Efficiency Fermentation.....

Floc's Impact on EBPR Removal Efficiency - FERMENTATION

- Minimum ORP in -150 mV – for regular PAOs growth
  - Less than -150 mV better
  - Around -250 an below possible growth of **Tetrasphaera** (high bred PAOs)
- **Theory** – the lower you go the more you hydrolyze your floc
  - Hydrolyzed floc → break into fines (negatively charged)
  - Floc needs more repair
  - If no repair effluent TSS has more fines
    - Colloidal solids – sNRP ???

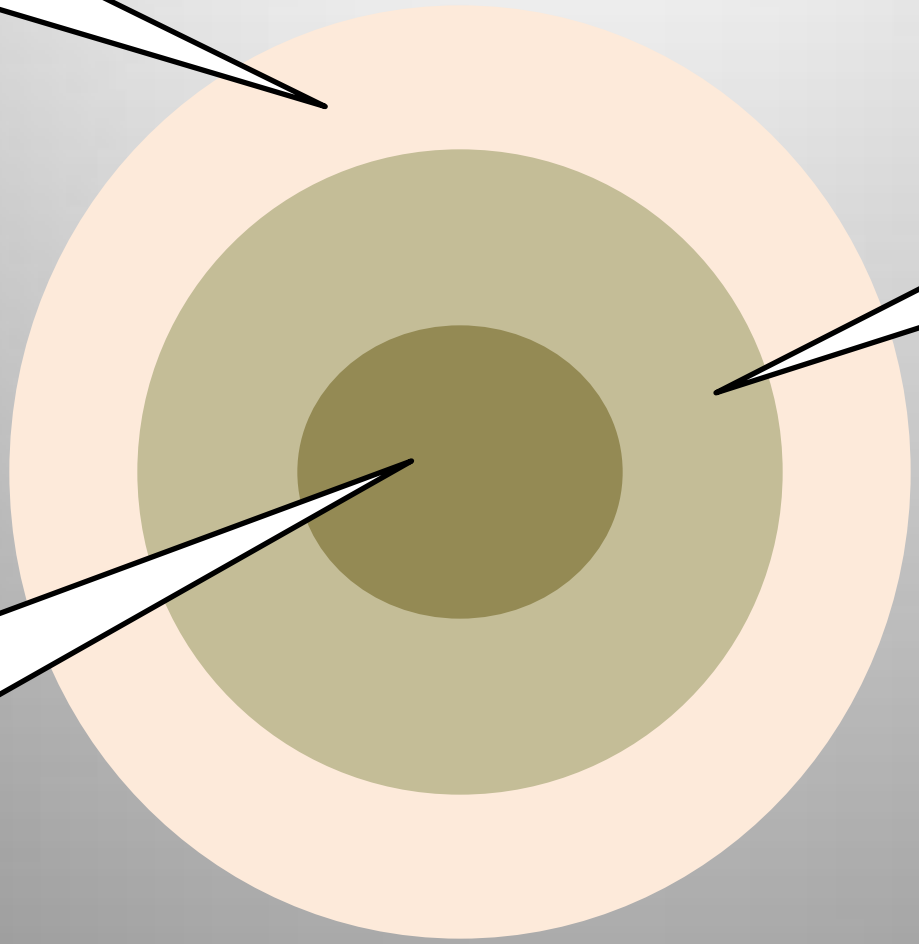
..... FLOC'S IMPACT ON EBPR REMOVAL EFFICIENCY P UPTAKE.....

Floc's Impact on EBPR Removal Efficiency – **P UPTAKE**

- Adequate (Proper) D.O. (ORP) necessary
  - Not TOO Much
  - Not Too little
- D.O. set point relative to MLSS or SRT
  - mg MLSS/mg D.O. ratio
  - See D.O. Control

D.O. CONTROL

Floc Oxygen



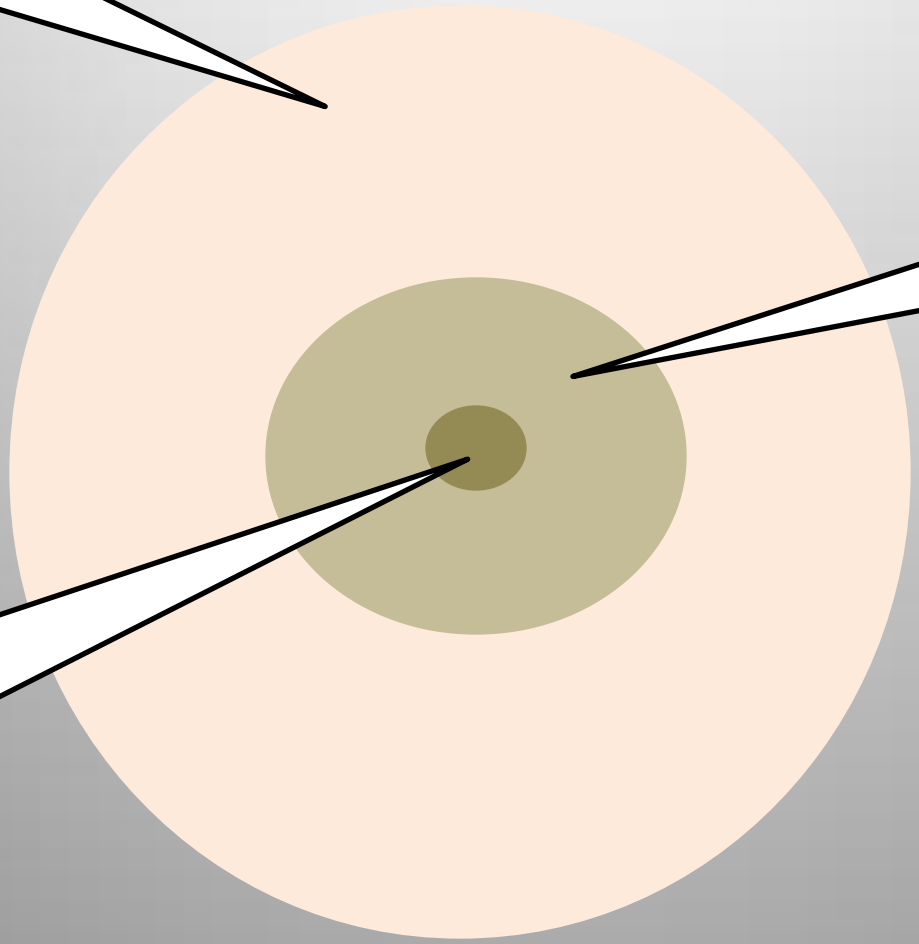
Aerobic Layer Similar D.O. to measured D.O.

Anoxic Layer D.O. diminished from measured D.O.

Anoxic to Anaerobic Layer Little to NO D.O.

mg MLSS/mg D.O. = 900

Aerobic Layer Similar D.O. to measured D.O.

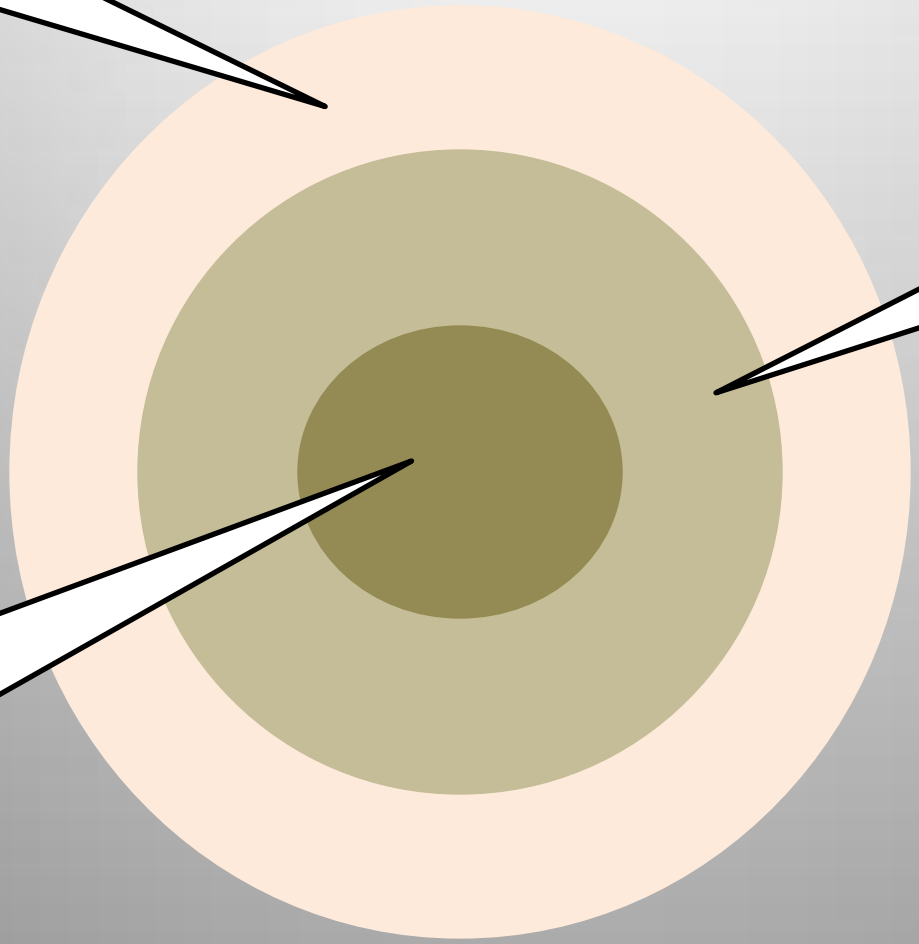


Anoxic Layer D.O. diminished from measured D.O.

Anoxic to Anaerobic Layer Little to NO D.O.

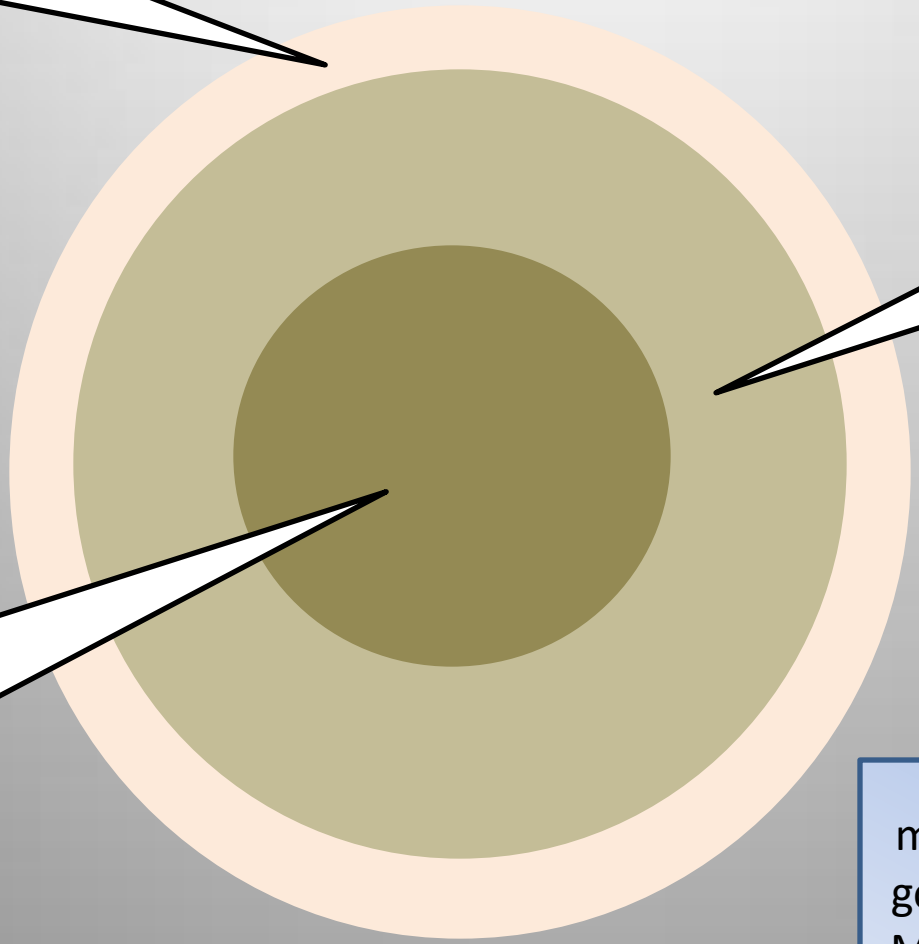
Low mg MLSS/mg D.O. are smaller floc – lower MLSS concentrations

mg MLSS/mg D.O. = 1,200



mg MLSS/mg D.O. = 2,500

Aerobic Layer Similar D.O. to measured D.O.



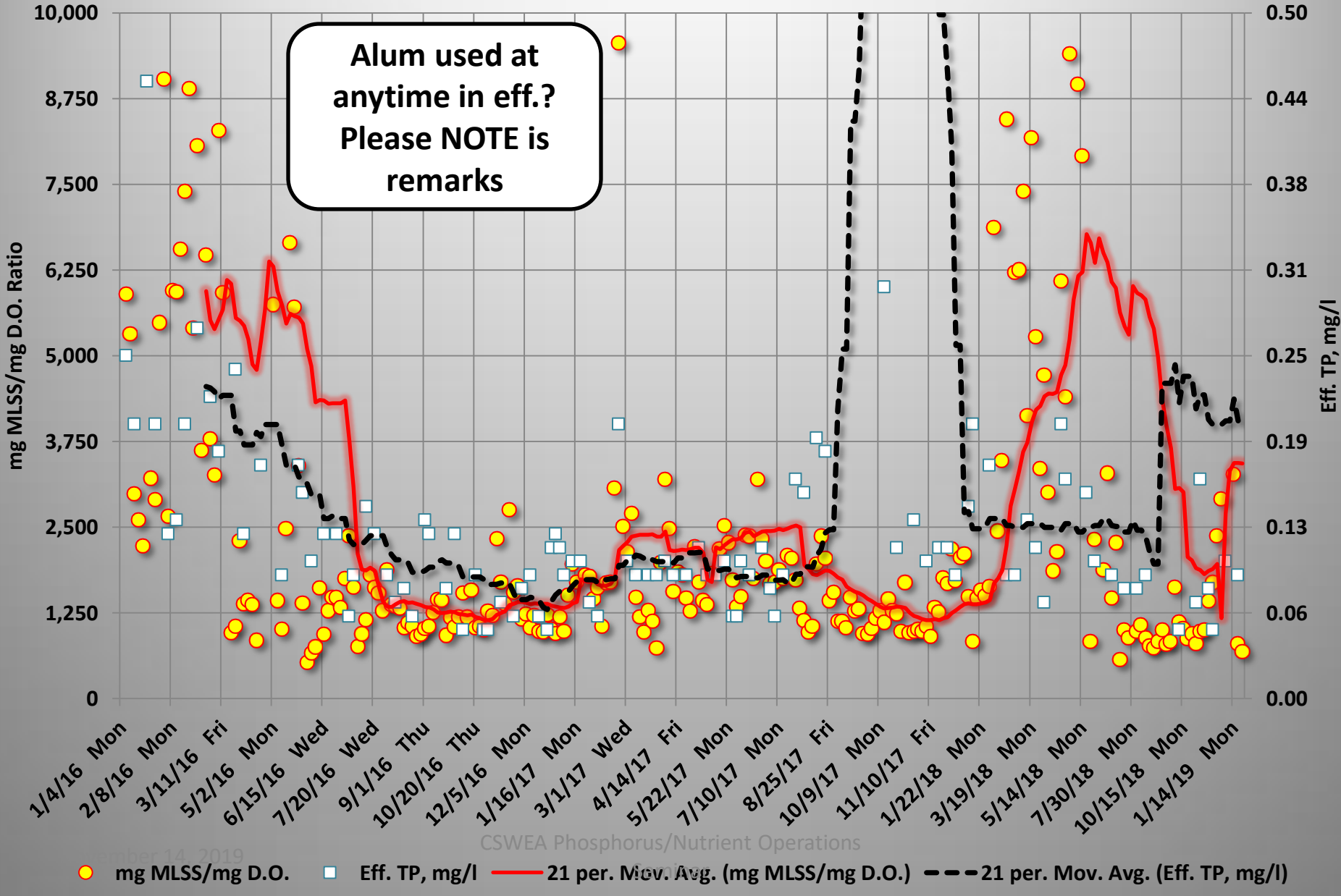
Anoxic Layer D.O. diminished from measured D.O.

Anoxic to Anaerobic Layer Little to NO D.O.

Plays into AN ORP

mg MLSS/mg D.O. generally goes up a you INCREASE the MLSS concentration and the floc get bigger

mg MLSS/mg D.O. vs. Eff. TP



Info on mg MLSS/mg D.O.

1. To Increase the ratio
   A. Increase MLSS
   B. Decrease D.O
   C. Or Both
2. To Decrease the ratio
   A. Decrease MLSS
   B. Increase D.O.
   C. Or Both
3. A high ratio is a floc which is more anoxic/anaerobic
4. A low ratio is a floc which is more aerobic if not all aerobic

Calculating mg MLSS/mg D.O.

Divide MLSS by D.O.			
MLSS, mg/l	2,500		
D.O. setpoint, mg/l	3.2		
Calculated mg MLSS/mg D.O.	781		

MLSS mg/l divided by D.O. setpoint = mg MLSS/mg

Table to Estimate D.O. Setpoint

Still Experiment
Summer/Winter
Maybe each have its own setpoint
Find Your Sweet Spot

MLSS, mg/l	mg MLSS/mg D.O.						
	900	1000	1100	1200	1300	1400	1500
3,800	4.2	3.8	3.5	3.2	2.9	2.7	2.5
4,000	4.4	4.0	3.6	3.3	3.1	2.9	2.7
4,200	4.7	4.2	3.8	3.5	3.2	3.0	2.8
4,400	4.9	4.4	4.0	3.7	3.4	3.1	2.9
4,600	5.1	4.6	4.2	3.8	3.5	3.3	3.1
4,800	5.3	4.8	4.4	4.0	3.7	3.4	3.2
5,000	5.6	5.0	4.5	4.2	3.8	3.6	3.3
5,200	5.8	5.2	4.7	4.3	4.0	3.7	3.5
5,400	6.0	5.4	4.9	4.5	4.2	3.9	3.6
5,600	6.2	5.6	5.1	4.7	4.3	4.0	3.7
5,800	6.4	5.8	5.3	4.8	4.5	4.1	3.9
6,000	6.7	6.0	5.5	5.0	4.6	4.3	4.0
6,200	6.9	6.2	5.6	5.2	4.8	4.4	4.1
6,400	7.1	6.4	5.8	5.3	4.9	4.6	4.3
6,600	7.3	6.6	6.0	5.5	5.1	4.7	4.4
6,800	7.6	6.8	6.2	5.7	5.2	4.9	4.5
7,000	7.8	7.0	6.4	5.8	5.4	5.0	4.7
7,200	8.0	7.2	6.5	6.0	5.5	5.1	4.8
7,400	8.2	7.4	6.7	6.2	5.7	5.3	4.9
7,600	8.4	7.6	6.9	6.3	5.8	5.4	5.1

..... Floc's Impact on EBPR Removal Efficiency

Effluent TSS.....

Floc's Impact on EBPR Removal Efficiency – EFFLUENT TSS

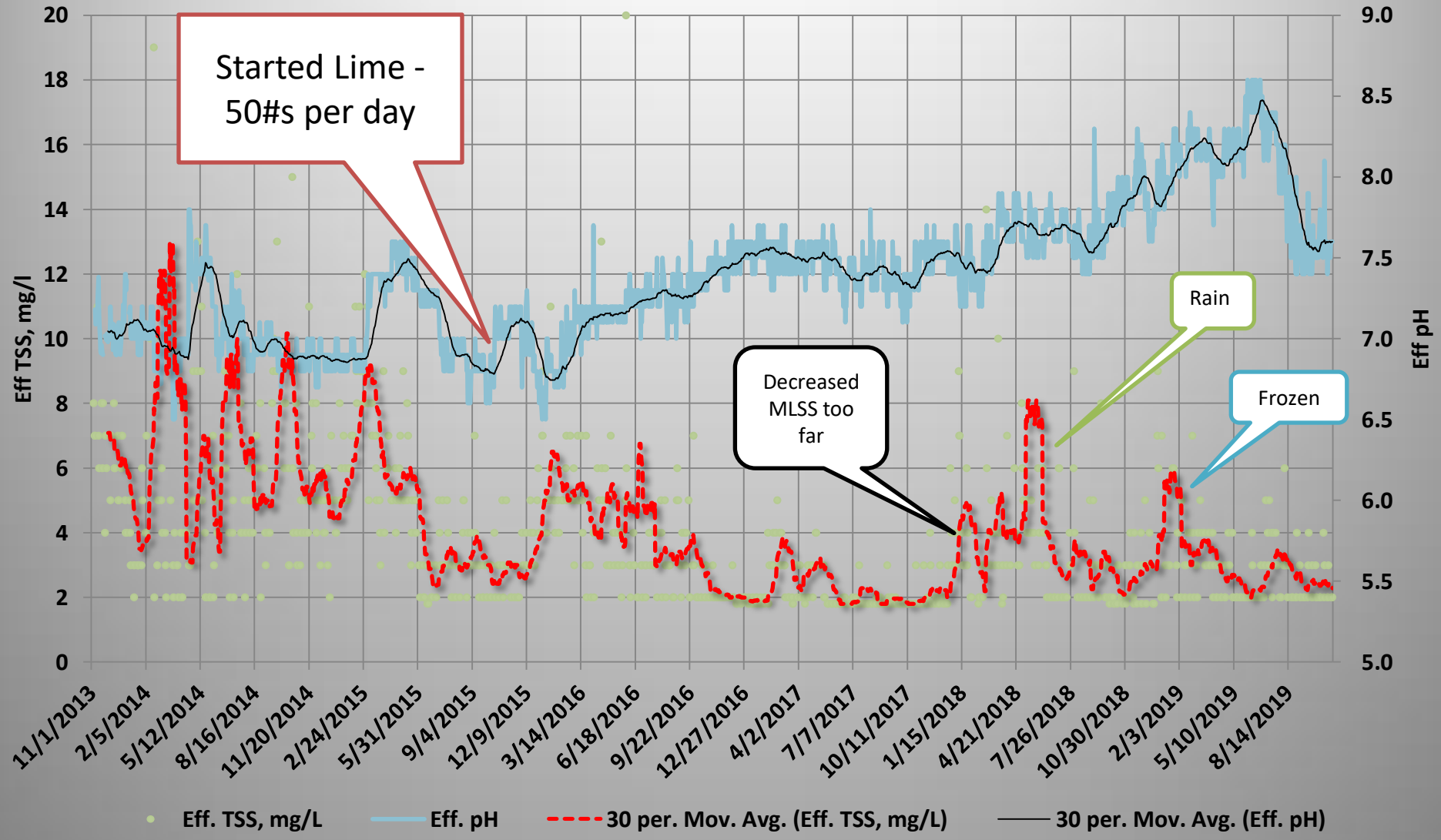
- **Theory still trialing** – D.O. Setpoint based on MLSS
  - mg MLSS/mg D.O. ratio
    - Ratio too high – drive ORP up in AN zone
    - **TOO low** – create too much anoxic or anaerobic condition in floc
  - Higher the MLSS – the bigger the floc
    - At High ratios floc becomes TOO anaerobic and breaks – hydrolyzes
  - See "Floc's Impact on EBPR Removal Efficiency – P Uptake" section for more info on mg MLSS/mg D.O.

WHAT ELSE NEGATIVELY IMPACTS EFF. TSS?

Low ORP in AN or AX zones

Low ORP in AN or AX *increases fermentation* which breaks up the floc (hydrolyzes) – creating very small (fines) pieces of floc

Eleva-strum – Eff. TSS vs. Eff. pH(Alkalinity)



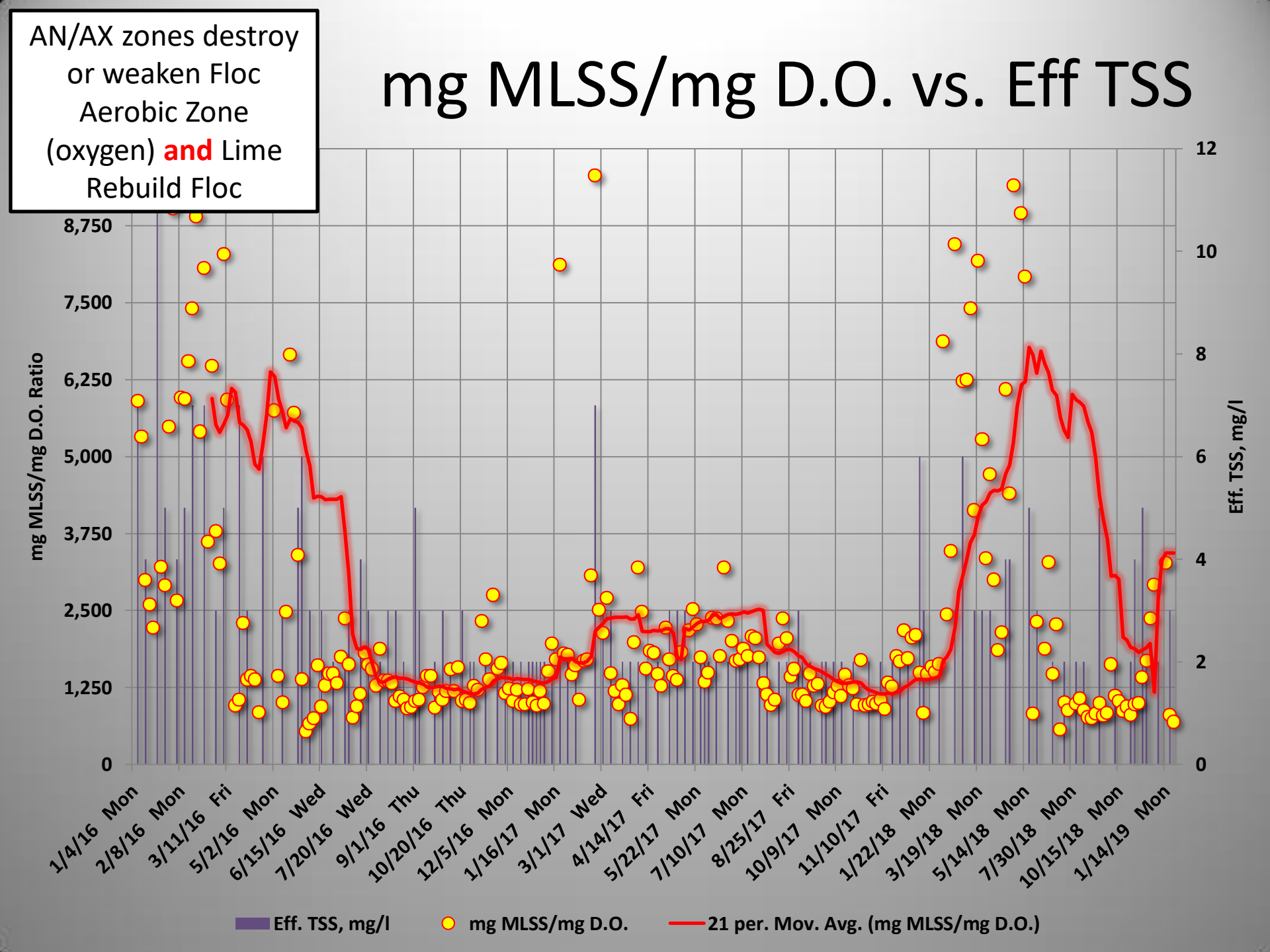
Crewe, VA – Effluent Clarifier

Crewe, VA – Effluent Clarifier

Slinger, WI – Effluent Clarifier

AN/AX zones destroy or weaken Floc Aerobic Zone (oxygen) **and** Lime Rebuild Floc

mg MLSS/mg D.O. vs. Eff TSS



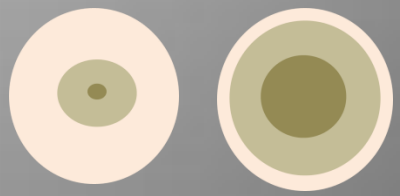
ADDENDUM

--- ORP ---

% AN of (AN to AB Delta)

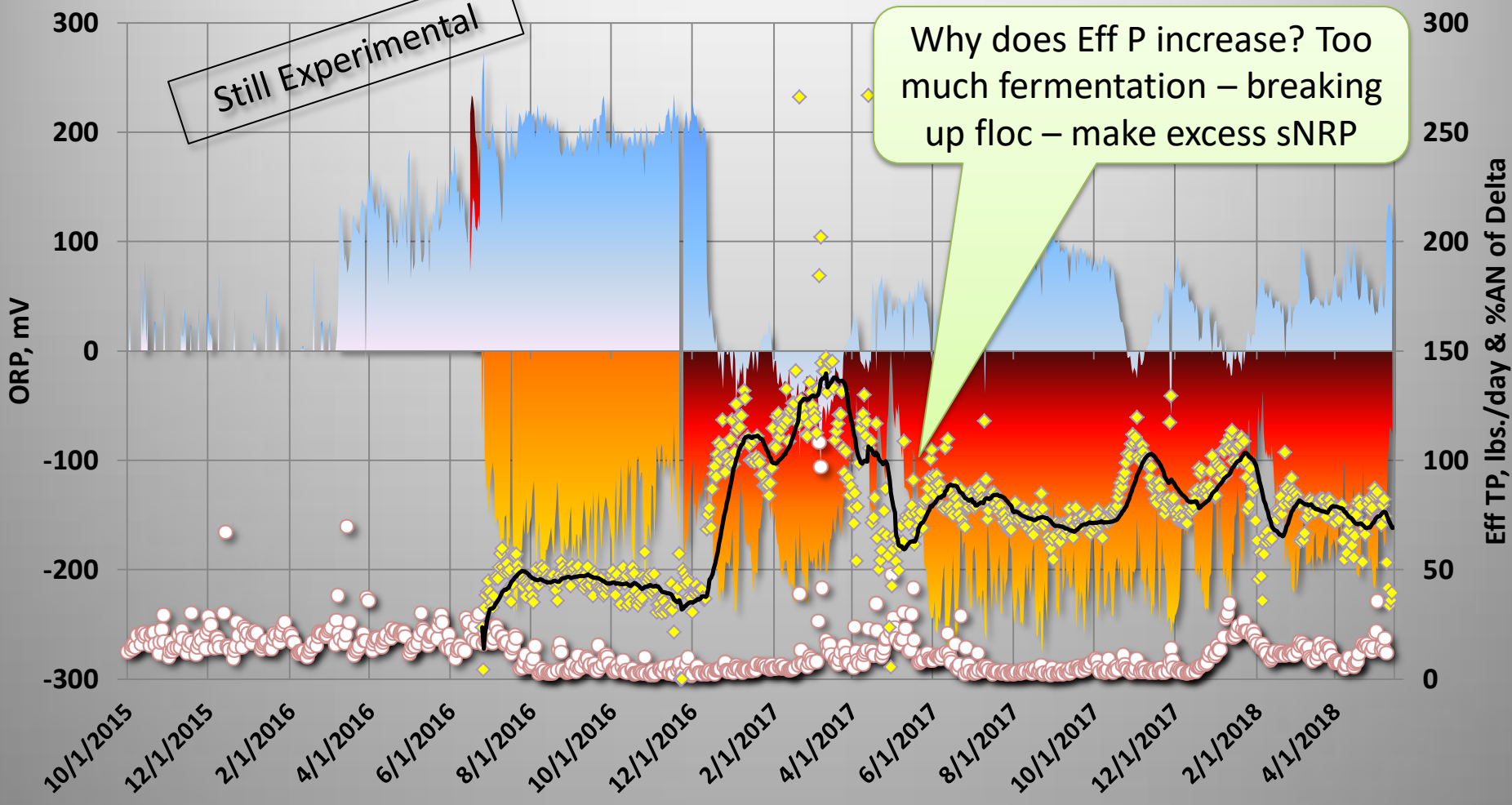
--- ORP --- % AN of (AN to AB Delta)

1. Formula
   A. %AN ORP of Delta ORP (AN min to AB Max)
2. The logic behind looking and tracking this – why do it
   A. Create constant biological conditions
   B. DO & ORP are apples and oranges
3. WEF – can have 2 mg/l DO with a – 50 mV or +200 mV
   A. Linden – NH_3-N treatment issue
   B. Flocology – biological logic
      A. Floc dead
      B. More AN zone – less AB - drawing



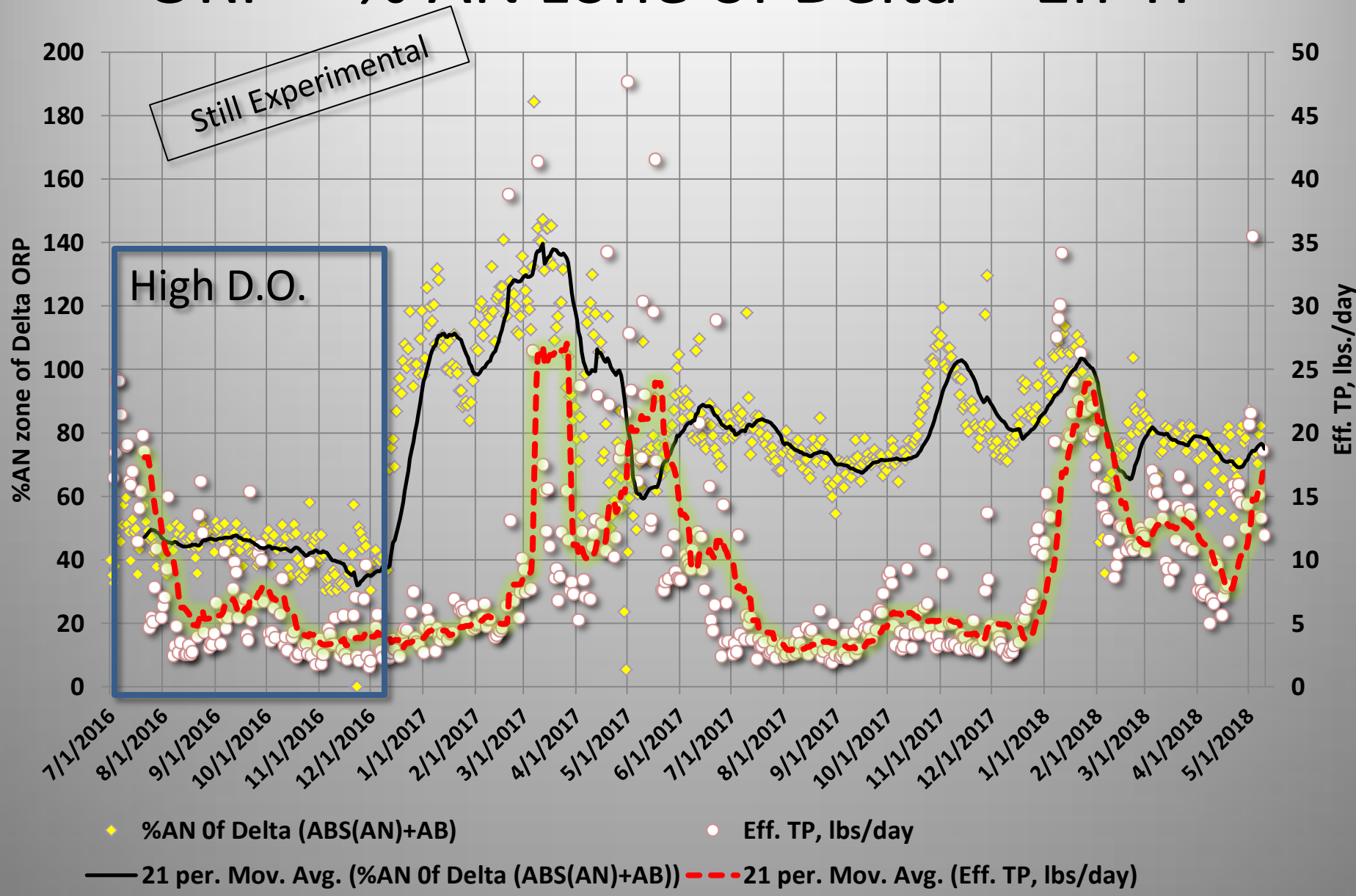
Marshfield

ORP – AN & AB Zone & Delta – Eff TP



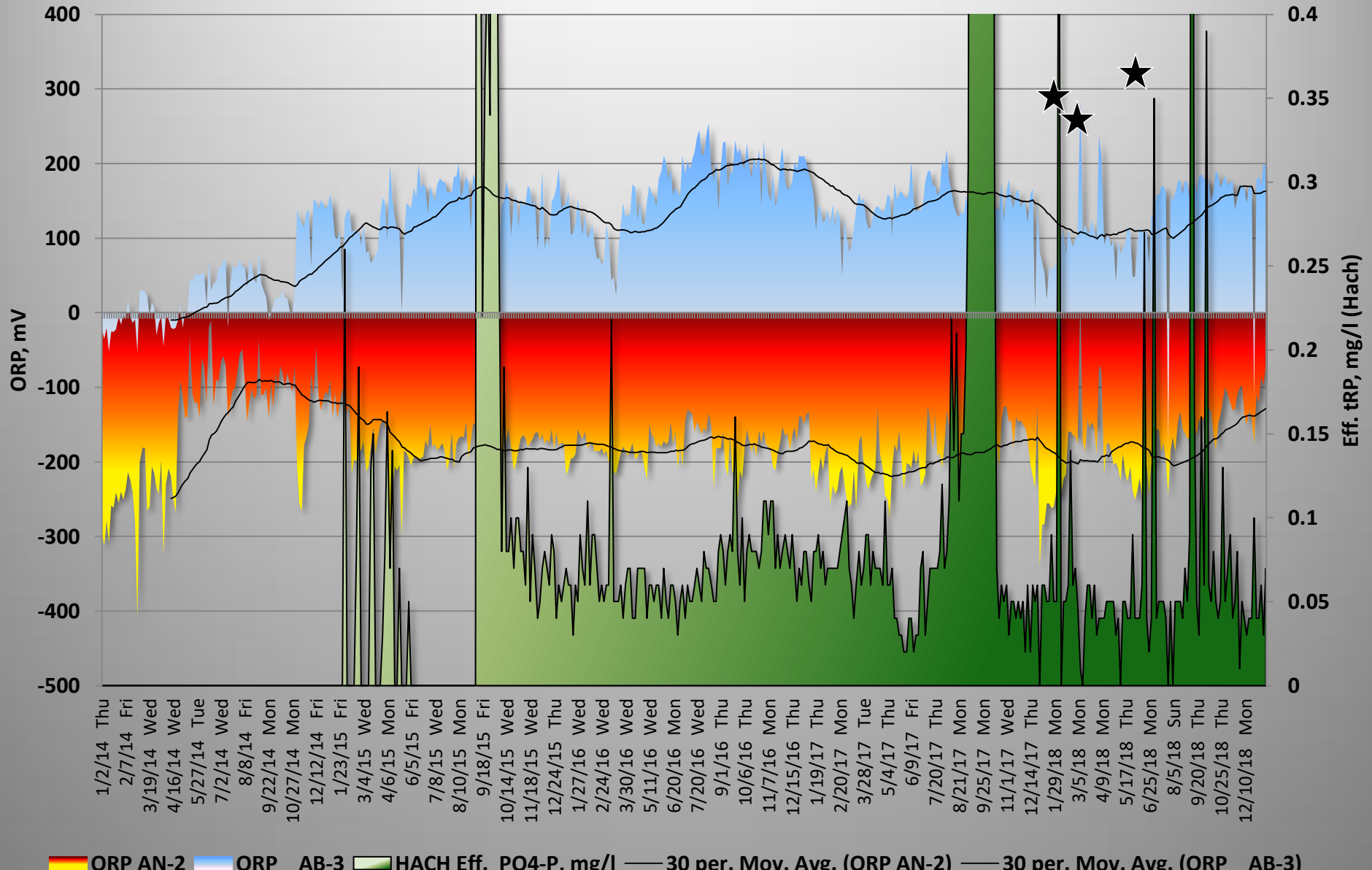
Marshfield

ORP – % AN zone of Delta – Eff TP



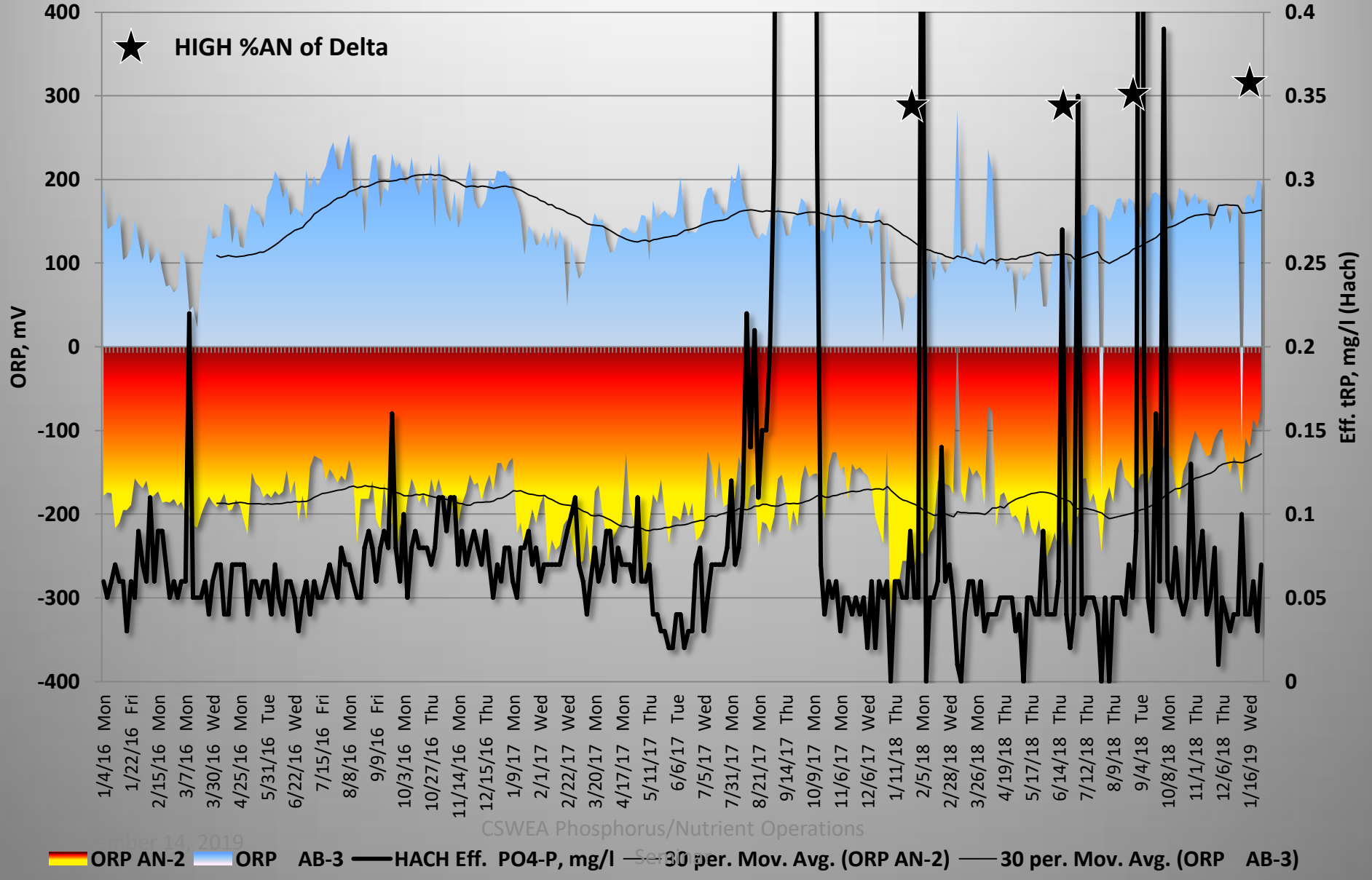
Eleva- Strum

ORP – AN & AB Zone & Delta – Eff tRP



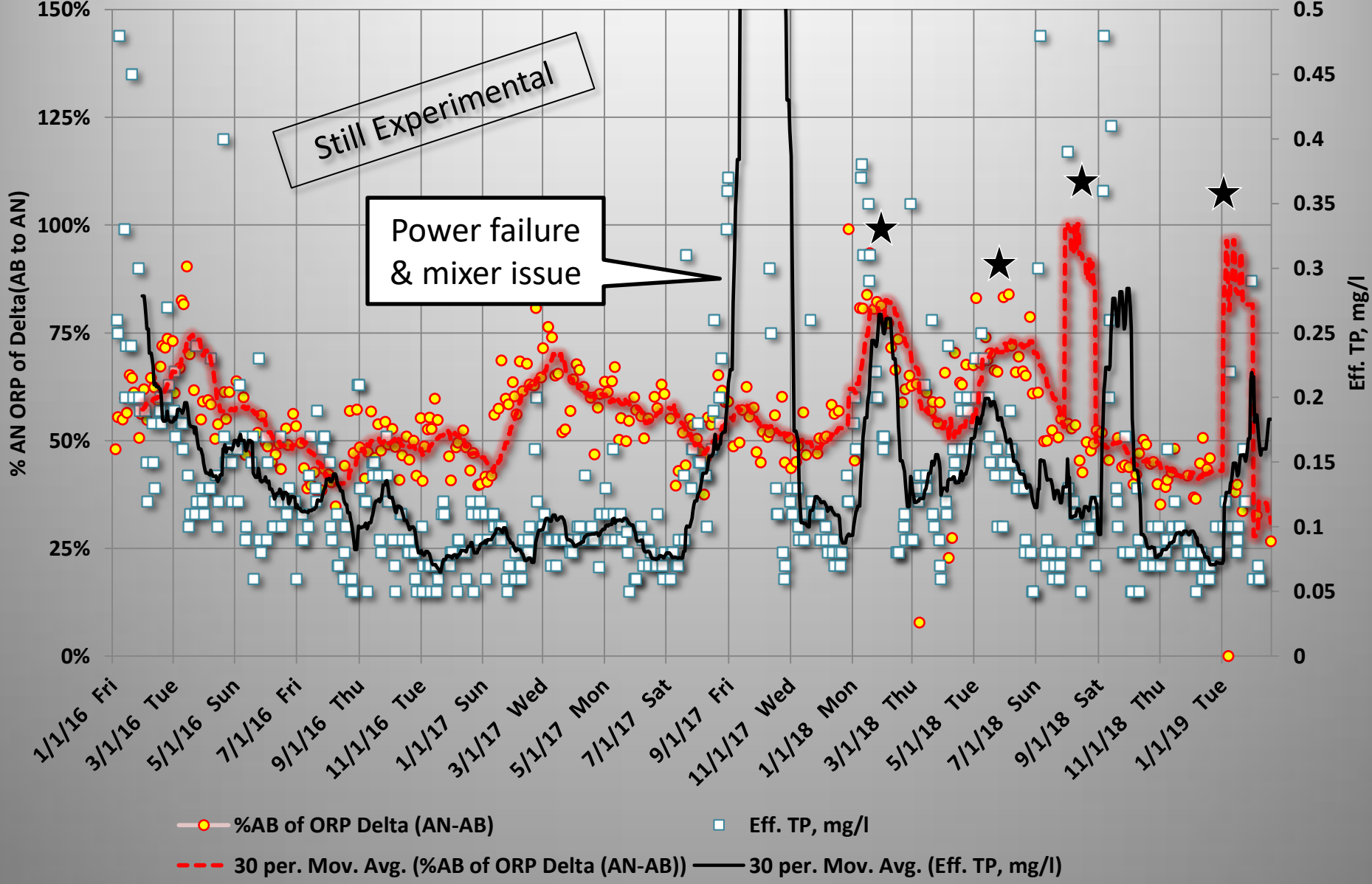
Eleva- Strum

ORP – AN & AB Zone & Delta – Eff tRP



Eleva-Strum

ORP – % AN zone of Delta – Eff TP




Thank Ya'll
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