



Activated Sludge Process Control: Total Nitrogen & Phosphorus Limits

60th Annual KWWOA Conference, Session 3: April 11, 2017

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Agenda

Overview of the Utopia Plant Upgrade Path

- Total Nitrogen and Phosphorus Limits

Utopia Plant Upgrade for BNR (TN & P)

Total Nitrogen Basics:

- Denitrification
- Step Feed for Carbon Source
- Reaeration
- Sidestream Pretreatment

Optimizing BNR at Utopia using BioWin Model

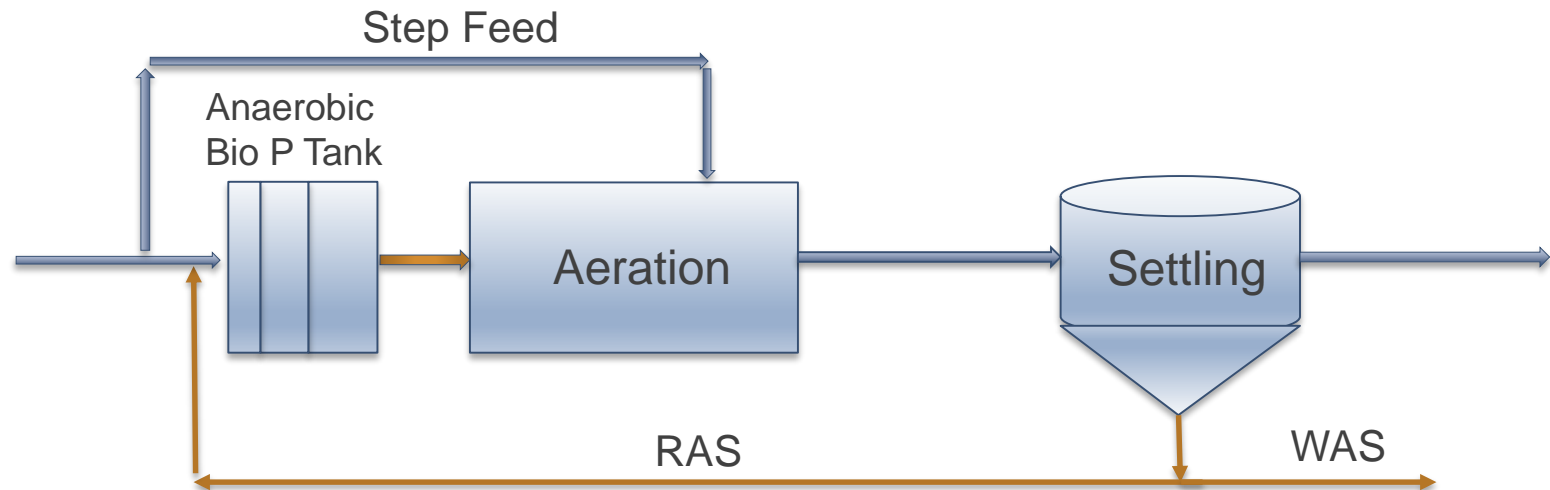
- Mixing Zones / Step Feed / Reaeration
- Optimum zone operation for BNR compliance

Questions

Utopia Wastewater Treatment Plant with Nitrification and Phosphorus Limits

Second Upgrade for Phosphorus Limits

Utopia Wastewater Treatment Plant Upgraded for Biological Phosphorus Removal



Utopia Water Reclamation Facility

Upgrade Path for maintaining flow rates and provide both total nitrogen and biological phosphorus removal

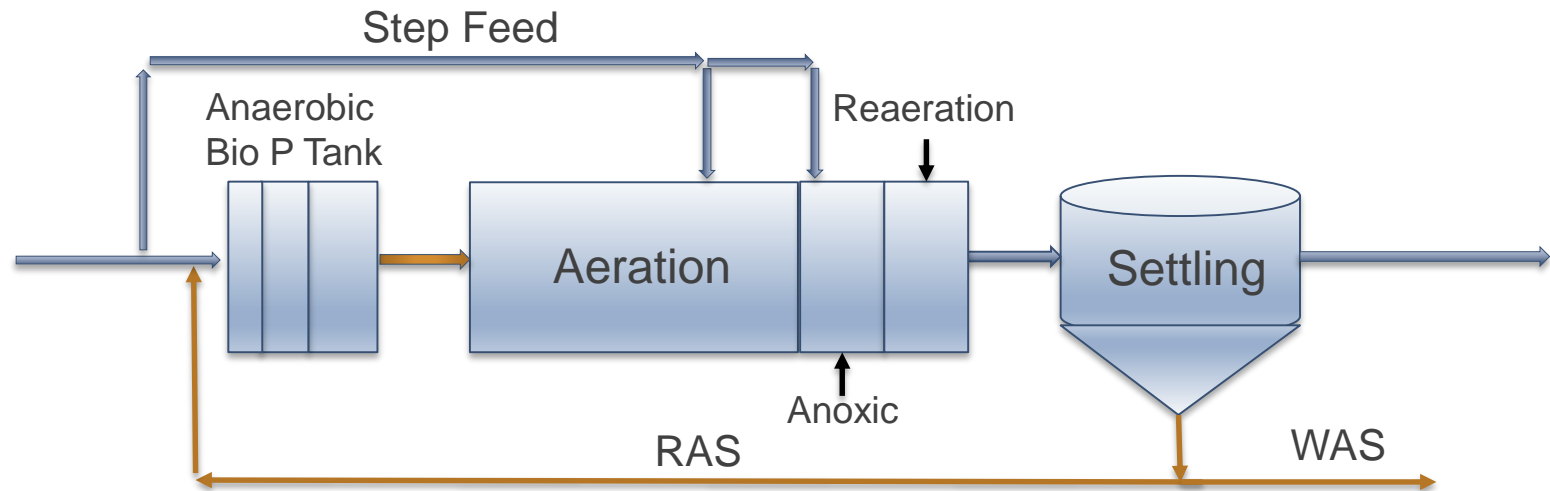
Third Upgrade to Water Reclamation Facility

- Sewer improvements continued and another KPDES cycle has also imposed total nitrogen limits in addition to cBOD5, TSS, ammonia and phosphorus.
- Total Nitrogen Limits of 7 mg/L were imposed in the new KPDES permit. The total of ammonia, nitrate and nitrite cannot exceed 7 mg/L. Ammonia could not exceed 1.5 mg/L while nitrate and nitrite cannot cause the total nitrogen to exceed 7 mg/L.
- Settling was excellent and the previous biological phosphorus removal operation prepared staff for an even tighter process control program.
- Effluent quality was improved to meet: 15 mg/L cBOD5, 18 mg/L TSS, 1.5 mg/L ammonia with TN less than 7 mg/L.

Utopia Wastewater Treatment Plant with Total Nitrogen and Phosphorus Limits

Third Upgrade for Total Nitrogen and Phosphorus Limits

Utopia Wastewater Treatment Plant Upgraded for full BNR Operation

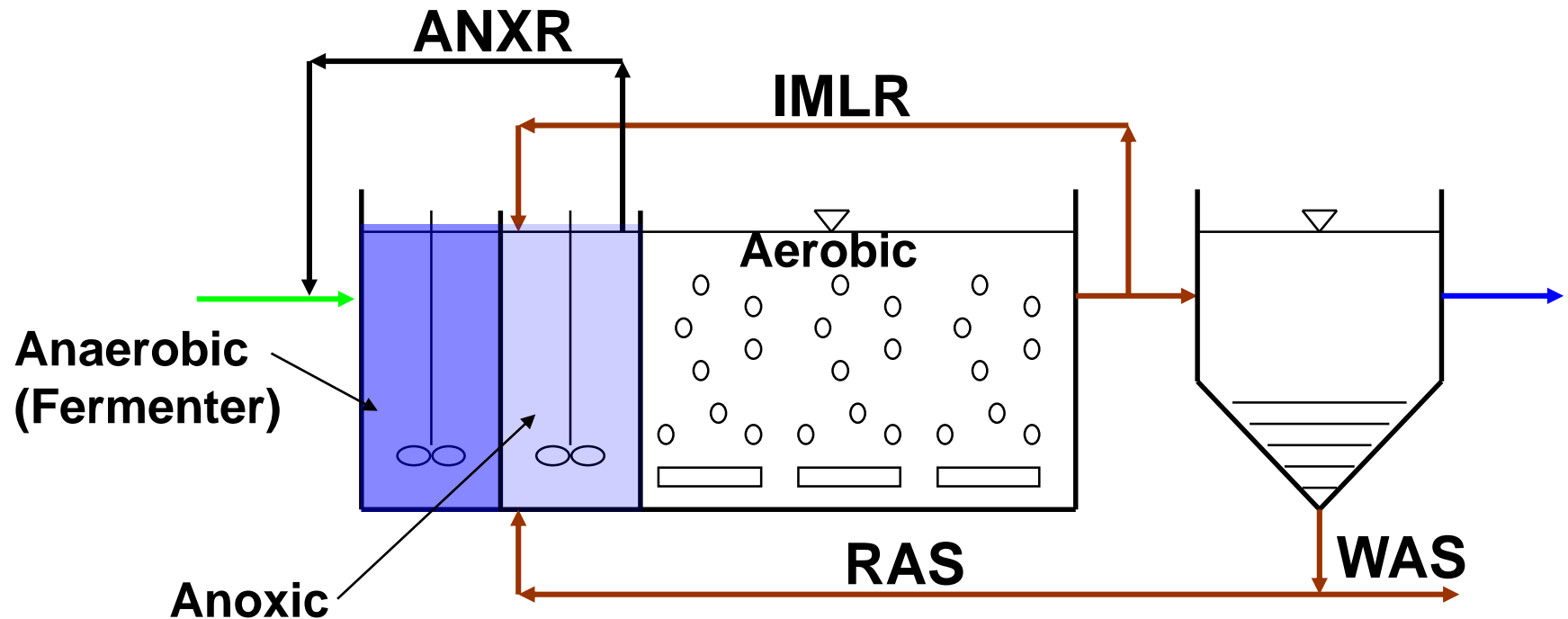


Total N??

Okay, fellas.
I'm gonna turn the
air off now!

Biological Process

Traditionally TN & TP Removal Systems Include Anaerobic, Anoxic, and Aerobic Zones with Internal Recycle Streams (internal to aeration)

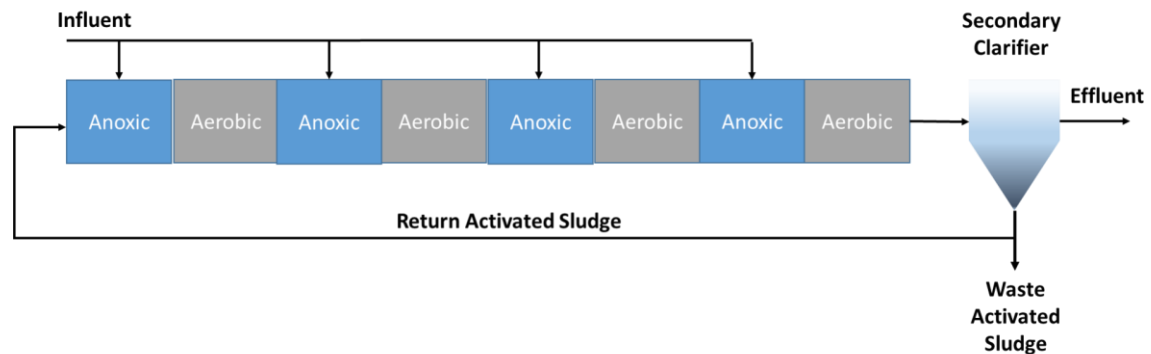


	Aerobic	Anoxic	Anaerobic
D.O.	Yes	No	No
Nitrate	Yes	Yes	No

Conventional Process Configurations for Achieving Nitrogen Removal

- Modified Ludzack-Ettinger (MLE)
- Step-Feed
- Bardenpho (4 Stage)
- Bardenpho (5 Stage)
- Integrated Fixed-Film Activated Sludge (IFAS)
- Moving Bed Bioreactor (MBBR)
- Denitrification Filter
- Membrane bioreactor

Combine aerobic and anoxic conditions to achieve nitrification and denitrification



Applying Step Feed and Air Control

Optimizing Nutrient Removal (Phosphorus and Nitrogen Removal)

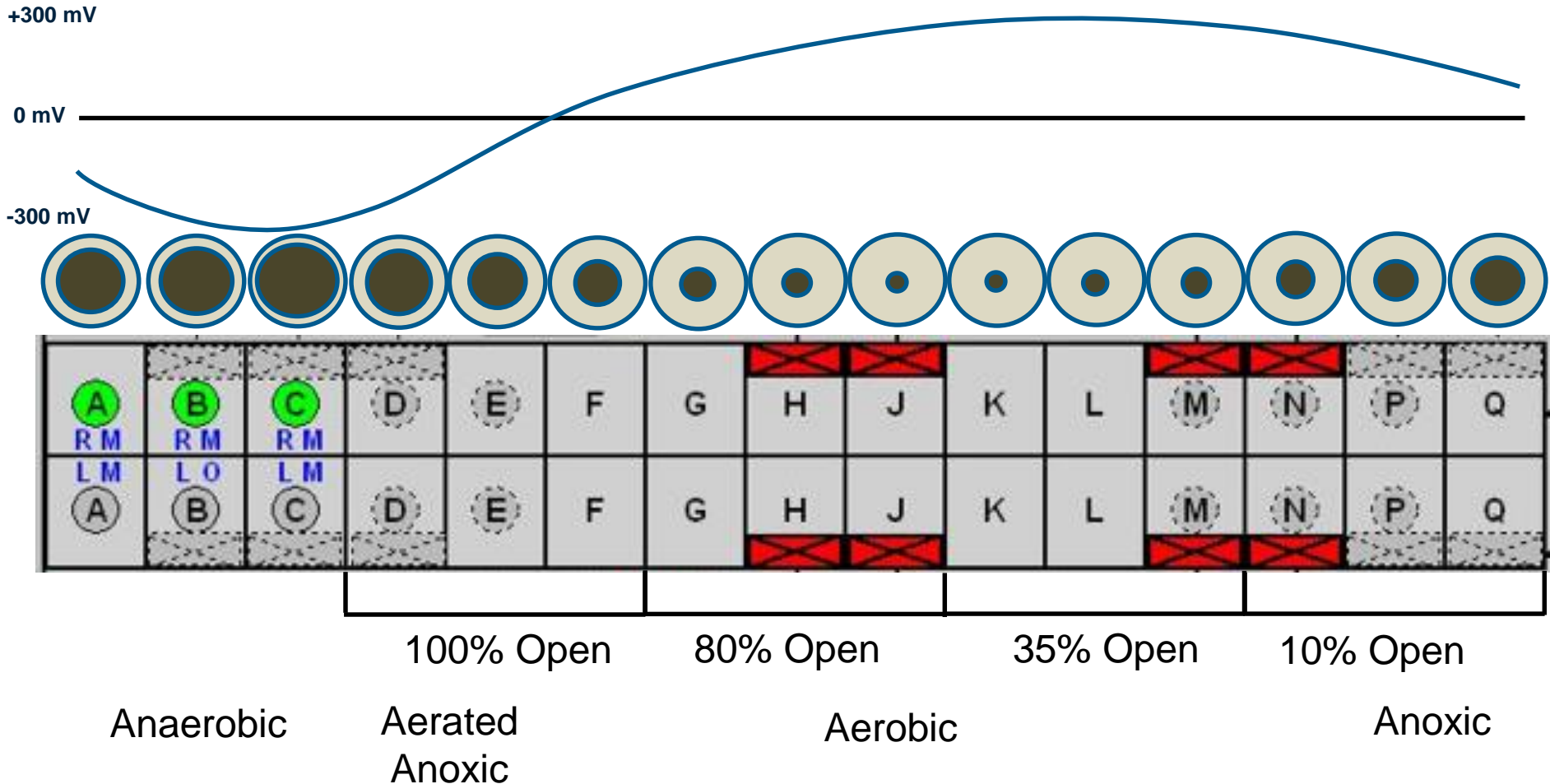
- Nutrient removal systems typically recycle flow streams containing oxygen and nitrates to the carbon (cBOD₅) influent location.
- Step feed sends some of the carbon around the nitrification process and enables the nitrates to be removed.
- Step feed (or contact stabilization) typically is used to increase the wet weather processing capability of the WWTP.

BNR – Control of ORP/MLSS Oxygenation

- With the 3D floc condition concept in mind, the BNR process must cycle between aerobic nitrification and phosphorus uptake, then when returned as RAS, deep cycle into an anaerobic state for phosphorus release and anaerobic cBOD₅ uptake.
- If the process is too aerobic and the floc is fully aerobic, a longer cycle time is required before the floc can return to an anaerobic condition. Time and carbon are squandered if over-aerated at the back of aeration.
- Total N compliance also requires the MLSS floc to fluctuate again between aerobic and anoxic/anaerobic conditions with remaining carbon.
- It is not uncommon for plants with tight total nitrogen limits (<5 mg/L TN) to use a carbon source (methanol) to denitrify.

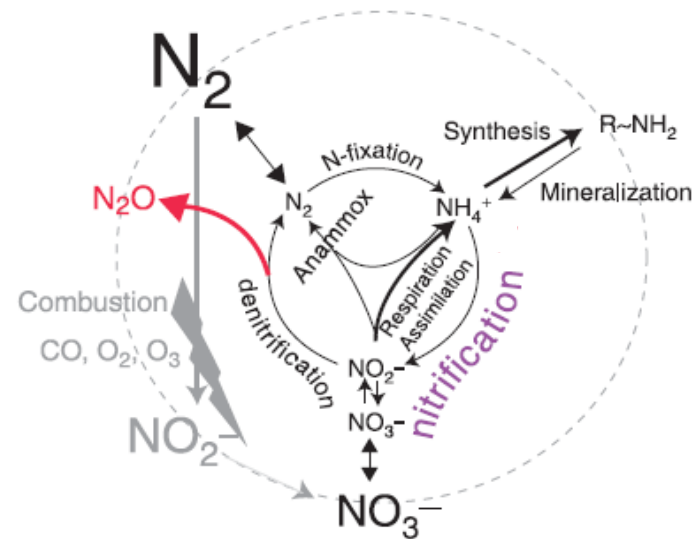
Floc Condition and with tight ORP Control of Aeration

Anaerobic
 Anoxic
 Aerobic

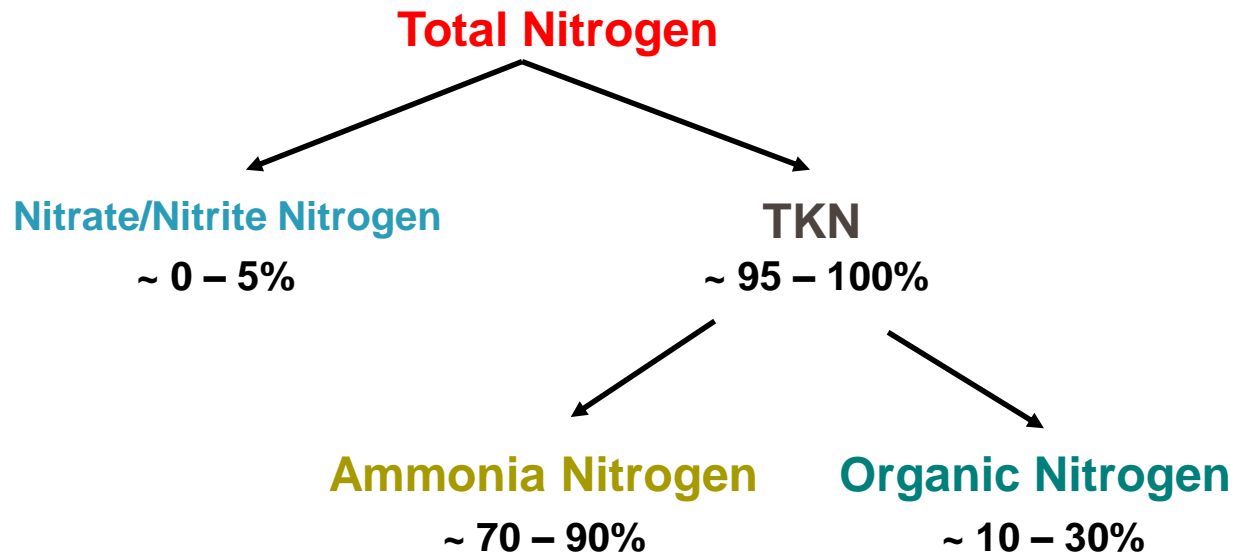


Conventional Nitrogen Removal

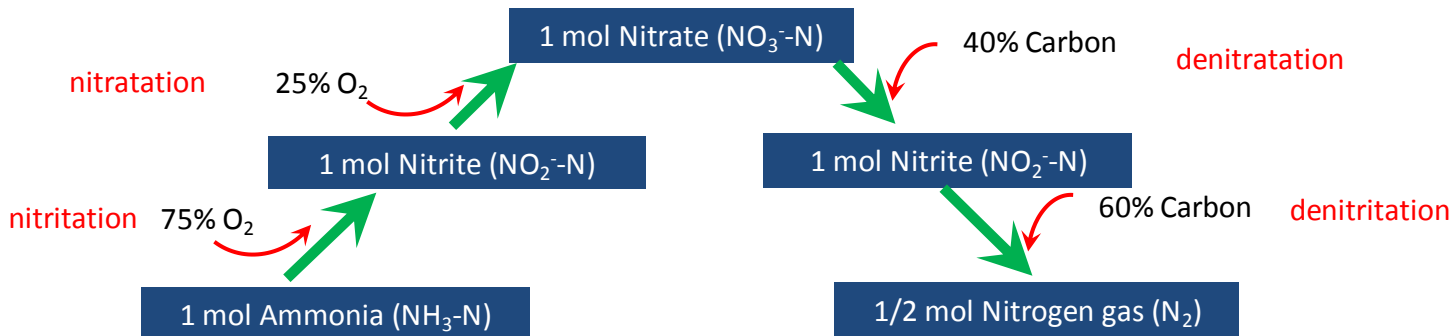
Goal has been to produce N_2 gas in most cost effective manner



Nitrogen Species Impacts Treatment Approach



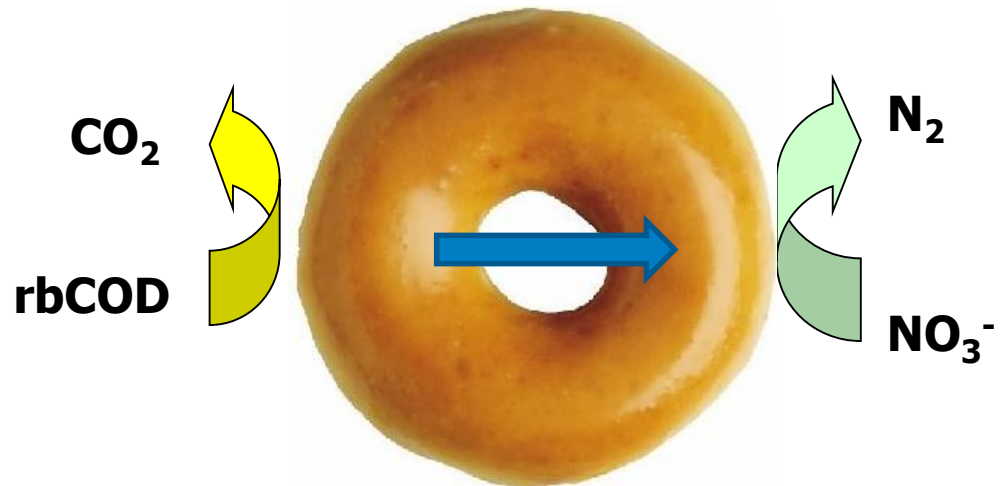
Conventional Approach for Performing Nitrogen Removal at WRRFs



- Ammonia converted to nitrogen gas using nitrification and denitrification
- Process requires:
 - 4.6 lb O_2 /lb NH_3 removed
 - 7.1 lb Alk/lb NH_3 removed
 - 4 to 6 lb COD/lb NO_3 removed

Denitrification

- Conducted by heterotrophic facultative aerobes under **anoxic** conditions
- Typical Rate is:
~4-6 mgNO₃/gVSS/hr



Denitrification: Facultative Anaerobes

- In general, denitrifiers are facultative anaerobes and use the same basic biochemical pathways during both aerobic (O_2) respiration and anoxic (NO_3) reduction
- Biological denitrification is the microbial reduction of nitrate to nitrite to gaseous forms of nitrogen (N_2 and N_2O).
- Denitrification can occur in the presence of free molecular oxygen.
 - Low ORP can drive the denitrification reaction through external load conditions
 - The concentration of nitrates can also drive denitrification at relatively high dissolved oxygen values (if the nitrate concentration is correspondingly higher).

Denitrification: Facultative Anaerobes

- Micro zone “denitrification” during “oxygenation” is the phenomenon commonly used to describe both high levels of ammonia oxidation and low nitrate release. Aerated Anoxic.
- “Aerobic denitrification” is the rule rather than the exception with high loading rates (front of aeration)
- In general, dissolved oxygen can be a regulating factor for aerobic denitrification as load decreases.
 - As dissolved oxygen decreases, denitrification increases (with carbon)

Denitrification: Facultative Anaerobes

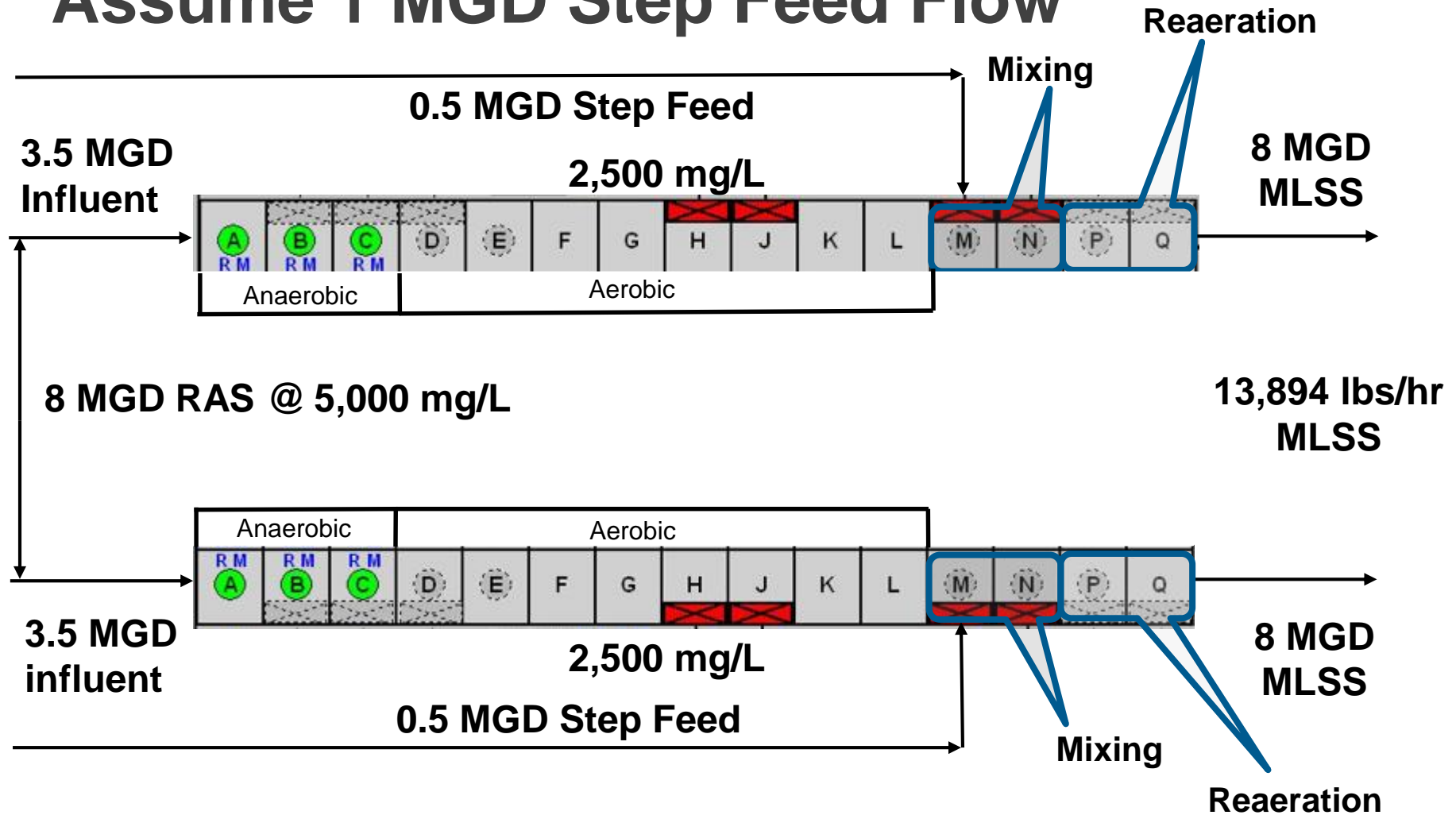
- Endogenous respiration cannot generate its own carbon source to drive the anoxic reaction and strip nitrates. A carbon source is necessary to drive the anoxic reaction (step feed for Utopia).
- Denitrification requires approximately 4 parts of BOD_5 to reduce each part of nitrate nitrogen.
- A rule of thumb for aerobically operated facilities, the equivalent oxygen utilization rate under nitrate respiration (2.86 parts of CBOD_5 removed for every part of nitrate destroyed) is equal to half the oxygen utilization rate under aerobic conditions.

Denitrification: Facultative Anaerobes

- A separate culture of denitrifiers must also be optimized for removal of the oxidized ammonia byproducts (nitrite/nitrate) for total N compliance
- Excess Nitrogen (nitrogen not contained in the biomass) must be oxidized and then denitrified and discharged into the atmosphere to maintain total nitrogen compliance.
- Carbon is necessary to that process and the carbon can be provided to the nitrate area of aeration with the use of step feed.

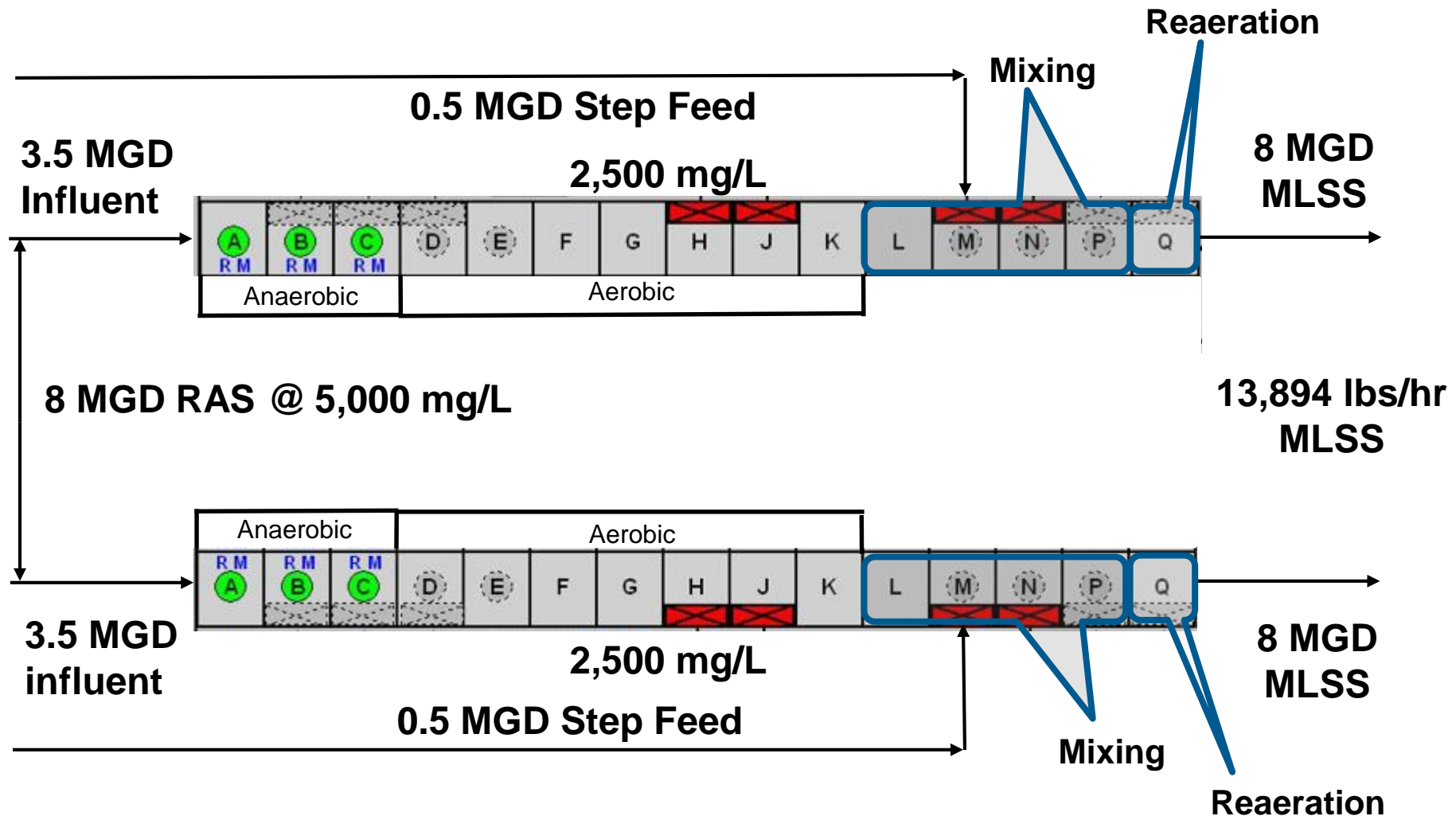
Step Feed for Carbon/Nitrate

Assume 1 MGD Step Feed Flow



Step Feed for Carbon/Nitrate Operations Control

1 MGD Step Feed Flow



Step Feed Loading for Nitrogen Control

- 1.0 MGD (total step feed – 50% for each reactor)
 - 180 mg/L cBOD₅ = 1,500 lbs cBOD₅.
 - 37 mg/L TKN (22 mg/L required to nitrify) = 183 lbs ammonia.
 - Assume 10 mg/L NO₃ @ 8 MGD (667 lbs NO₃)
 - Enough carbon (if readily available) to drive 375 lbs of nitrate reduction.
- Carbon bypass to an anoxic zone with sufficient contact for uptake, decrease in ORP and stripping of nitrates.

Step Feed Loading for Nitrogen Control

- Reaeration necessary to:
 - Polish oxidize ammonia that was with the step feed carbon source and the organic nitrogen that was converted in the anoxic mixing stages.
 - Raise the ORP and make the floc condition more aerobic prior to settling.
 - Ensure phosphorus uptake due to some anoxic release in mixing zones. Reaeration will provide for aerobic uptake of any phosphorus release and uptake of phosphorus that was present in the step feed.
 - Denitrification will also provide for P uptake. Simultaneous phosphorus uptake and denitrification.

Sidestreams are more critical for pretreatment. Utopia should also consider pretreating sidestreams.

Consider two 20 MGD facilities employing 5-stage BNR for N and P removal

- *City of Durham, North Carolina operates two 20 MGD WRFs*
 - *North Durham WRF (Plant A)*
 - *South Durham WRF (Plant B)*
- *Similar operations*
 - *5-stage BNR*
 - *23-hour HRT*
 - *Similar influent characteristics*



Sidestreams account for a significant fraction of the nutrient load...

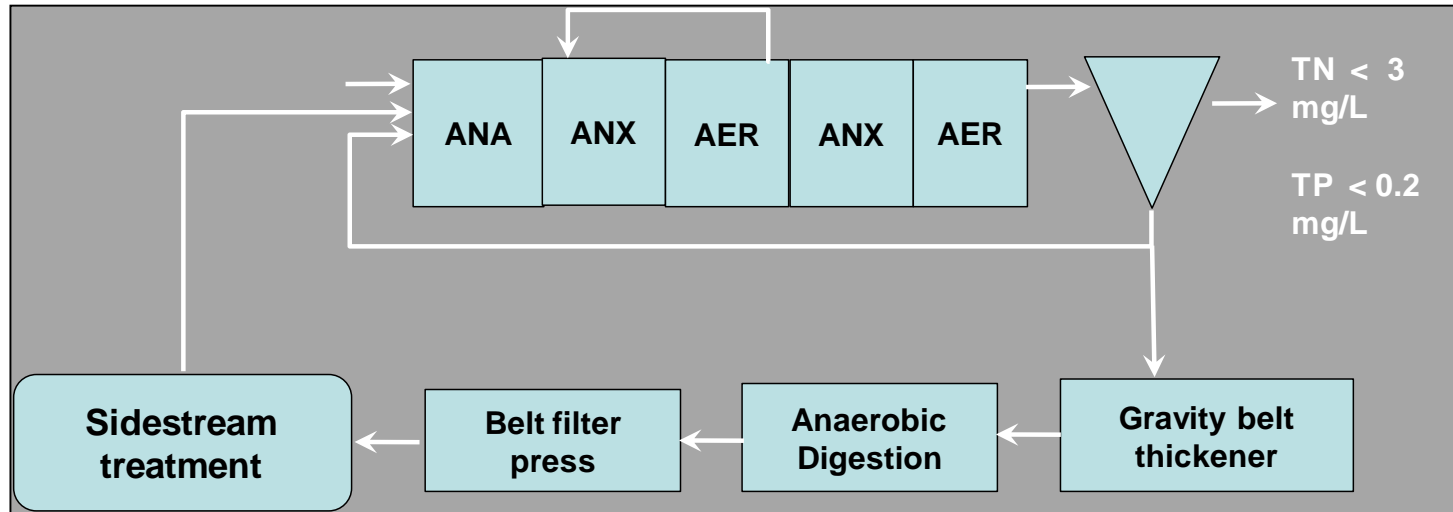
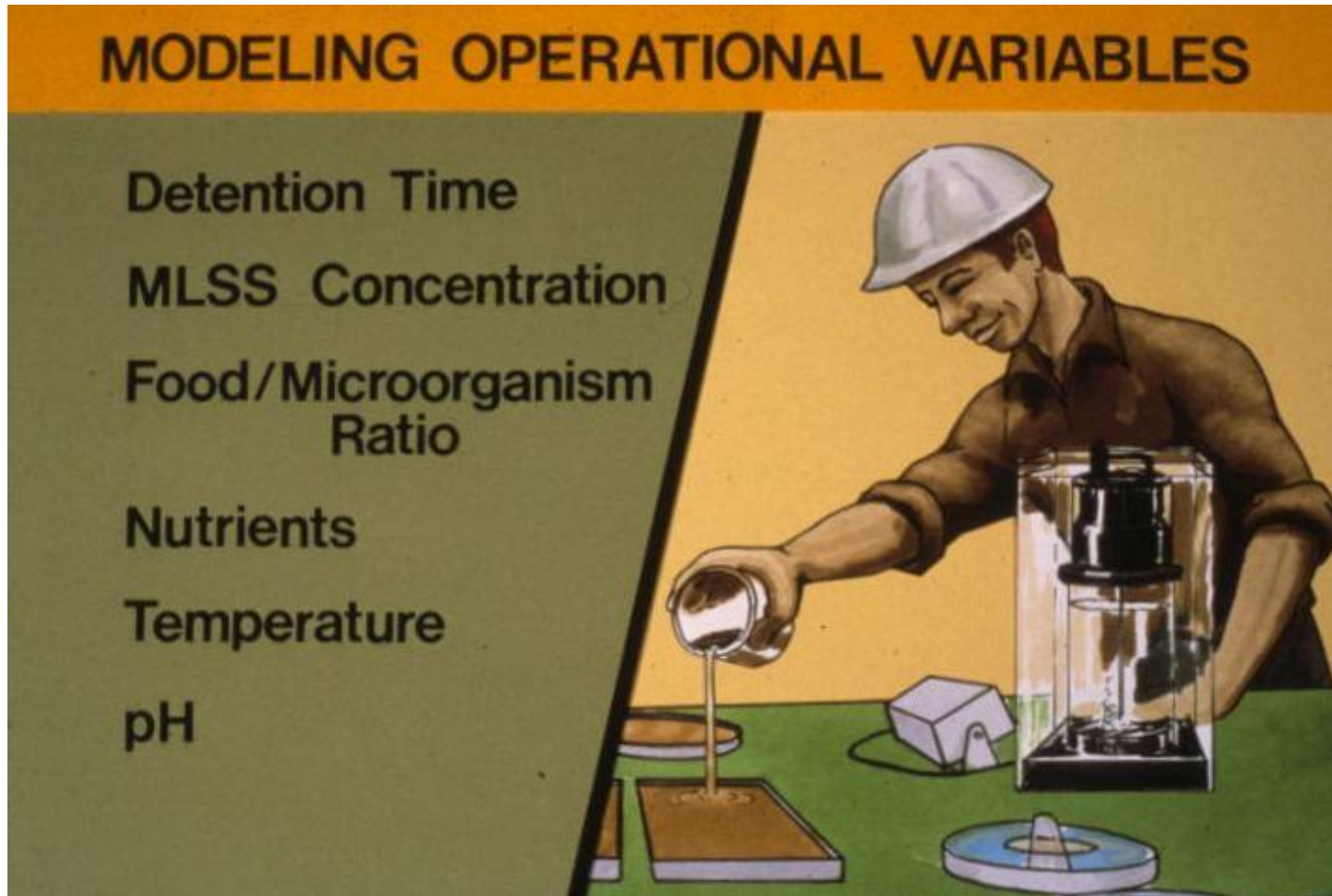


Table 1: Percent of Influent Nutrient Load that Comes from the Sidestream

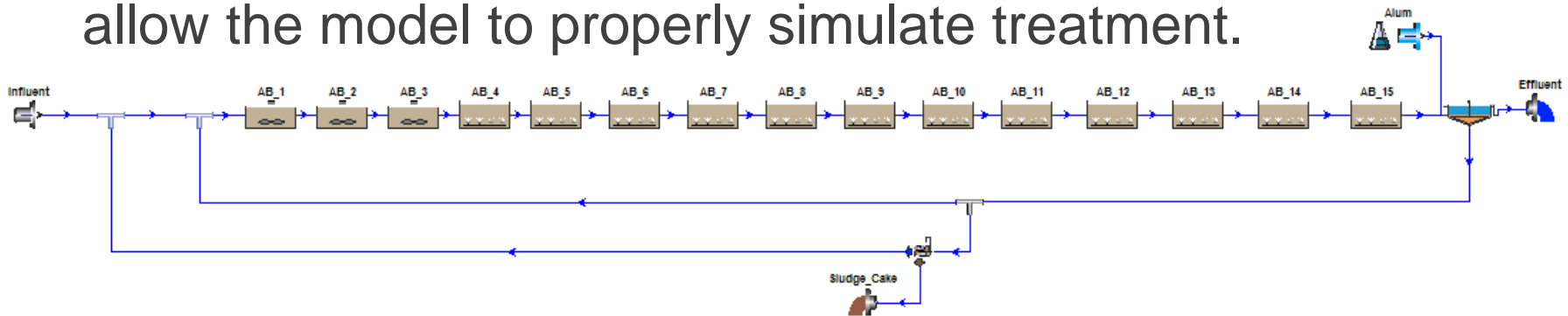
Parameter	% of Influent Nutrient Load from Sidestream	
	Plant A	Plant B
Nitrogen	19	21
Phosphorus	30	25

Modelling operational variables



BioWin Modeling Operations Support

- BioWin by EnviroSim is a wastewater treatment process simulator.
- Extensive sampling and testing was done for the Utopia 2009 Design - BioWin Model.
- The model inputs for process treatability were used in the design of the facility, now the model is being used for operations.
- Fractionation of samples (done in the field) are used to allow the model to properly simulate treatment.



Sample Fractionation for Model Inputs

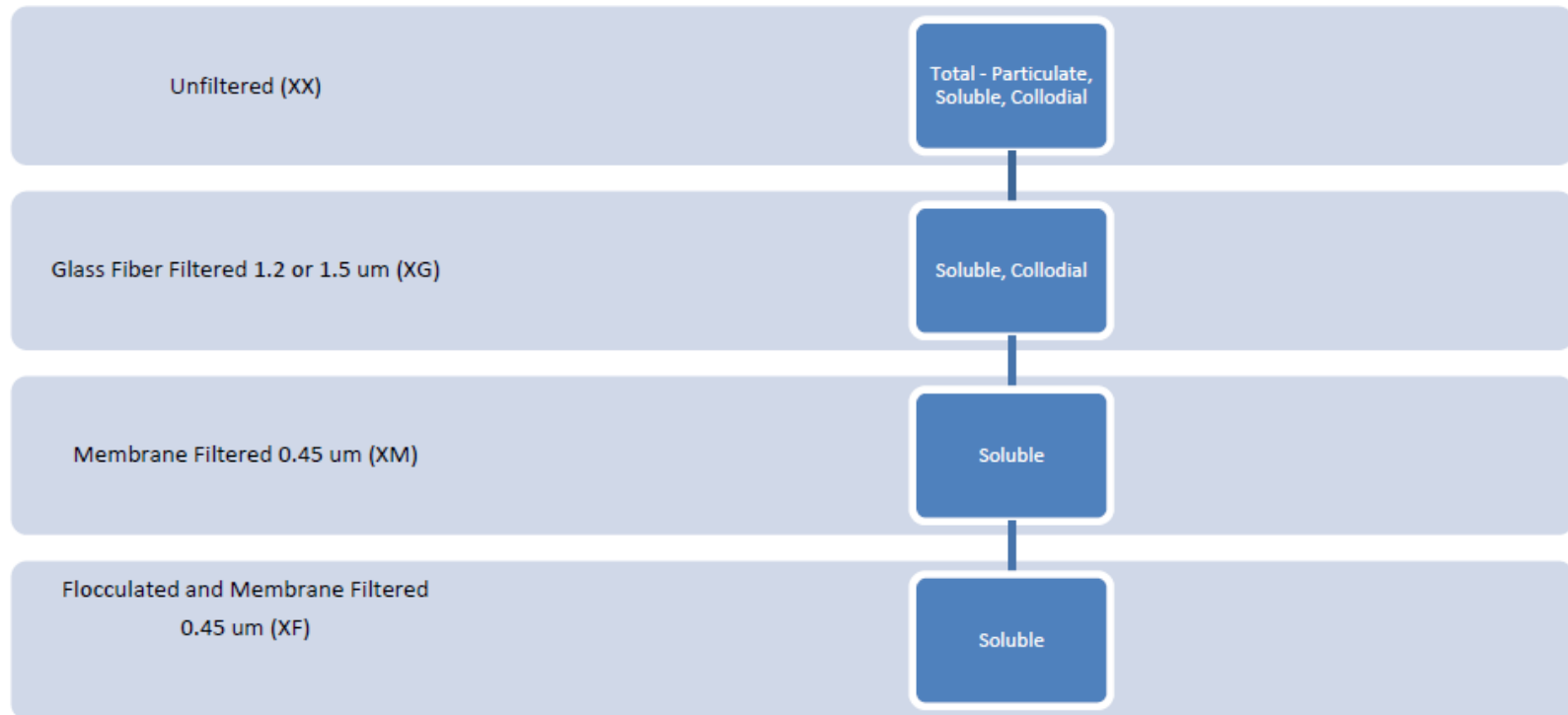


Figure 6.3: Fractions Typically Quantified in Special Sampling For BioWin Characterization

COD Fractionation for BioWin

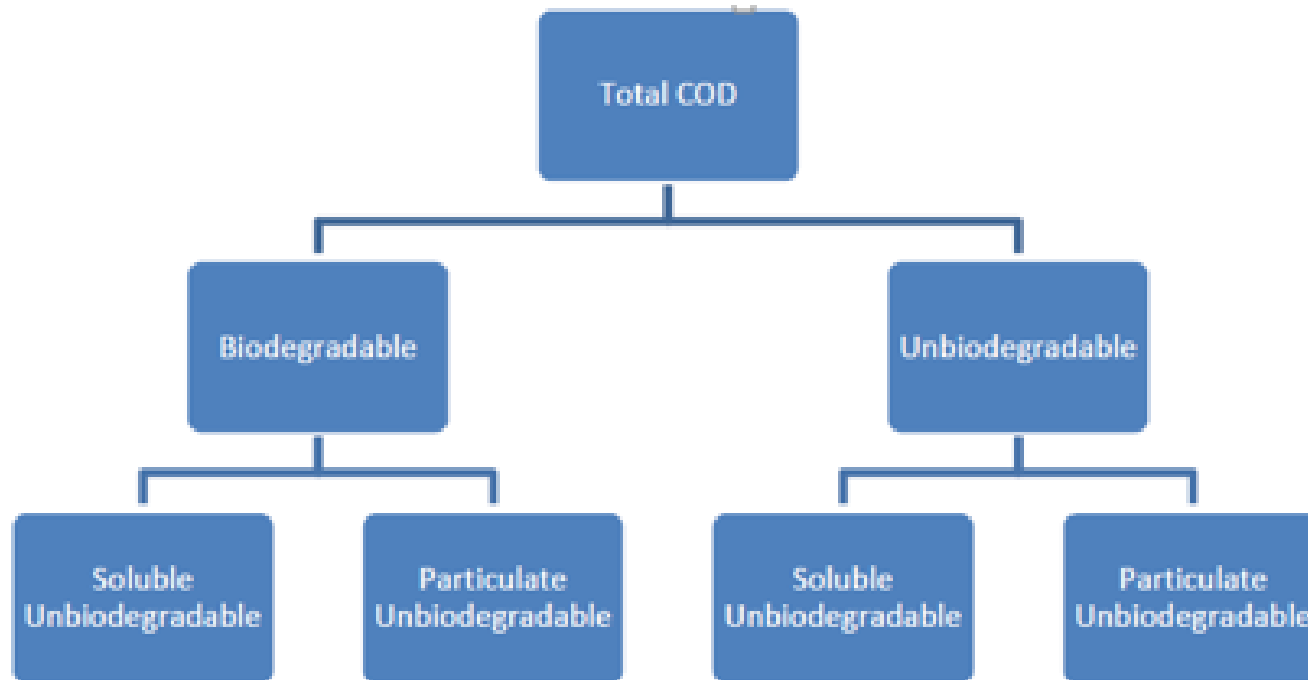


Figure 1: Detailed Fractionization of COD Included in BioWin

TKN Fractionization for BioWin

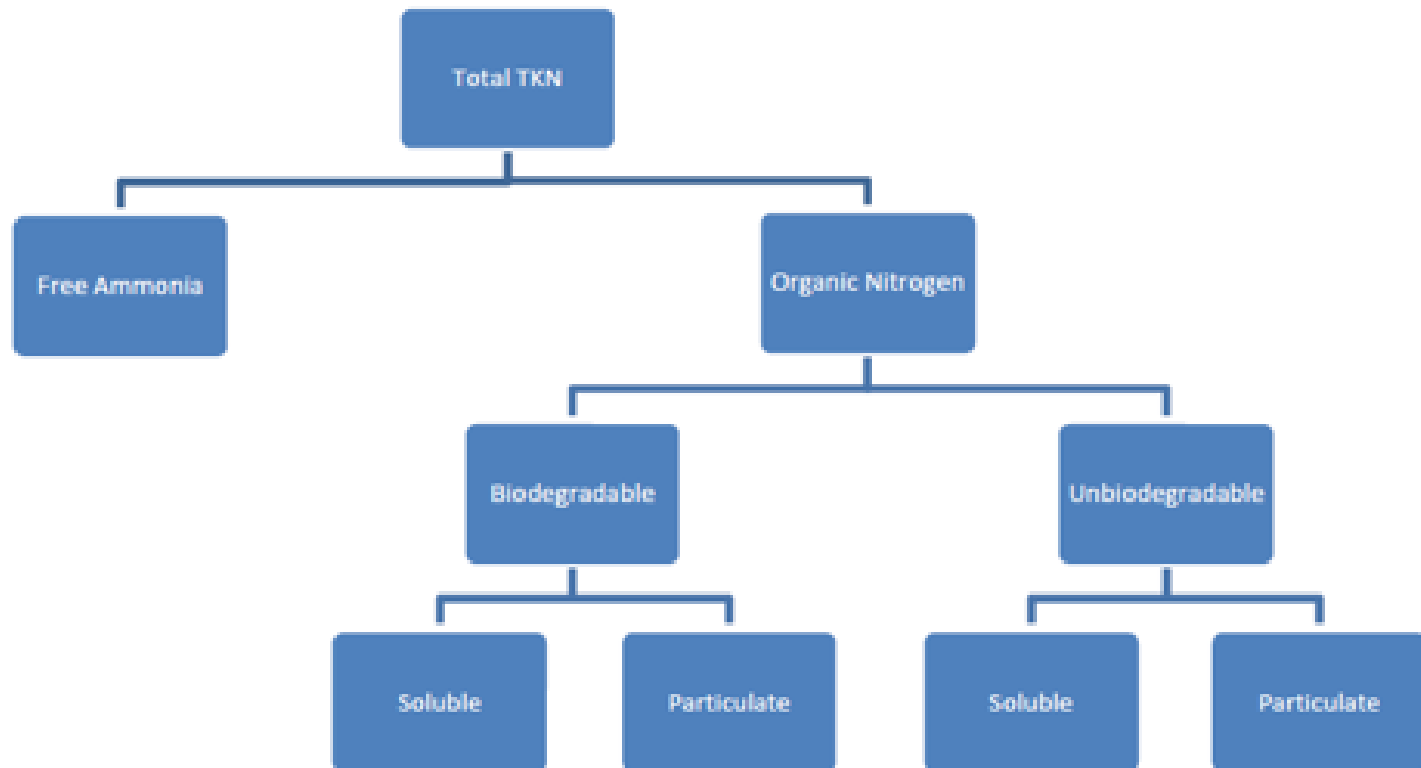
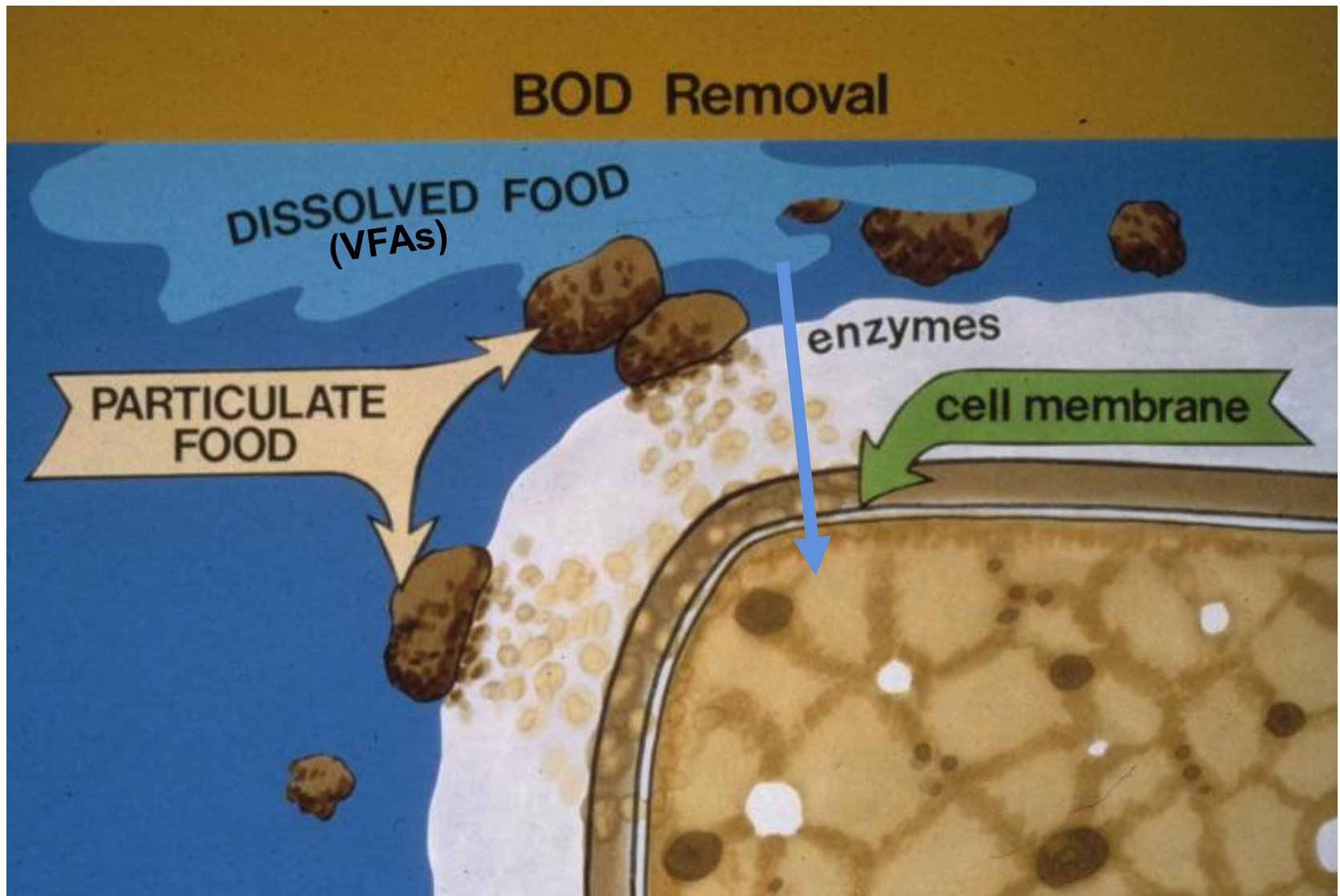


Figure 2: Detailed Fractionization of TKN Included in BioWin

Readily Biodegradable BOD

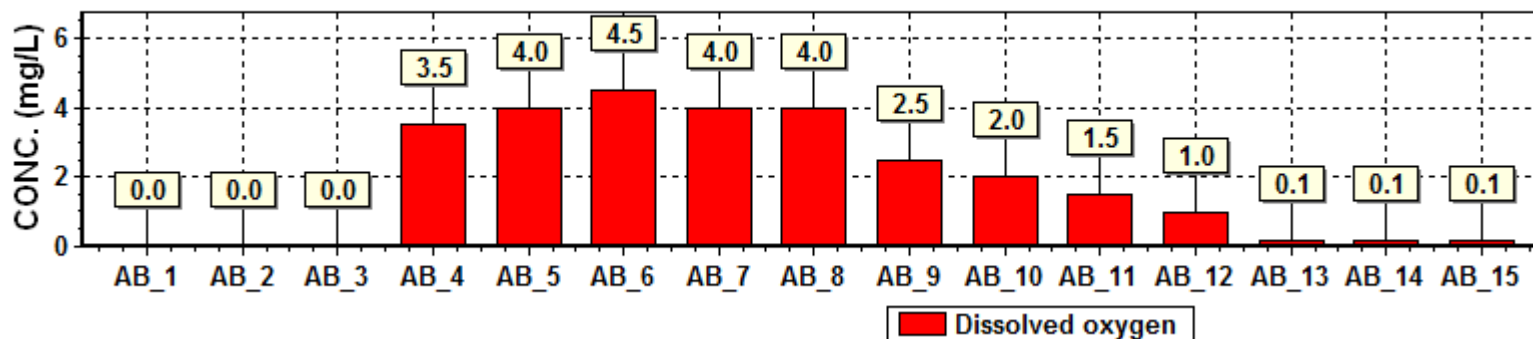


BioWin Modeling of Process Changes

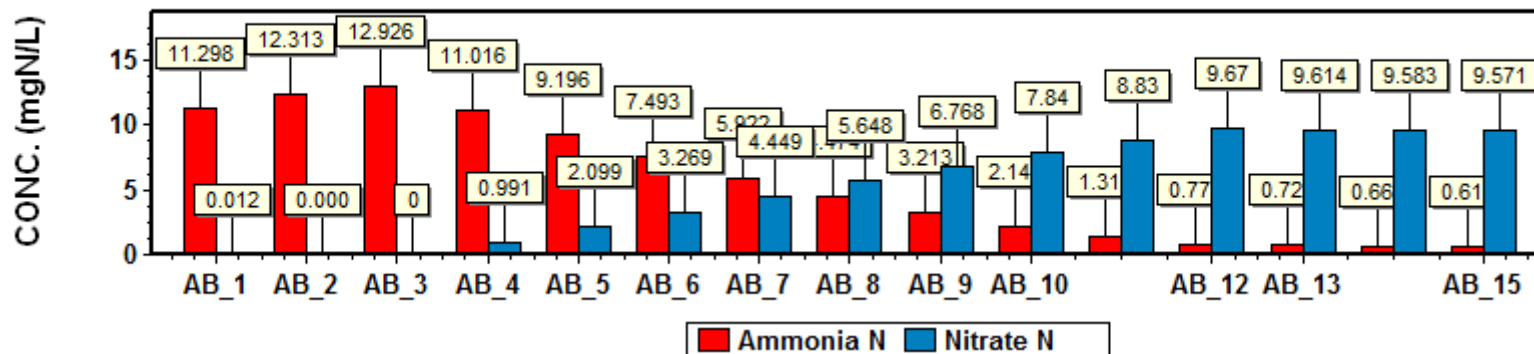
- Conditions were “calibrated” to the following inputs:
 - MLSS: 3,000 mg/L
 - WAS: 6,000 lbs/day TSS
 - Manually entered air flow of 3,800 scfm
 - Dissolved oxygen levels manually entered based on available air flow
 - Provided a 4 ft blanket in the clarifiers
 - Operating temperatures at 13°C (a couple @ 20°C)

Existing Conditions
 3,000 mg/L, 3,800 scfm
 4 ft blanket.

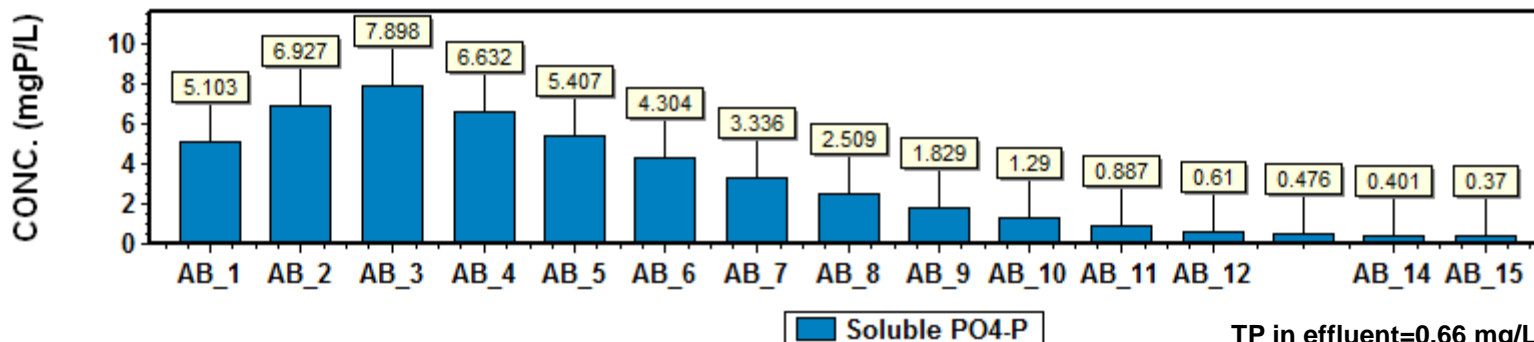
DO Profile



BioWin Chart

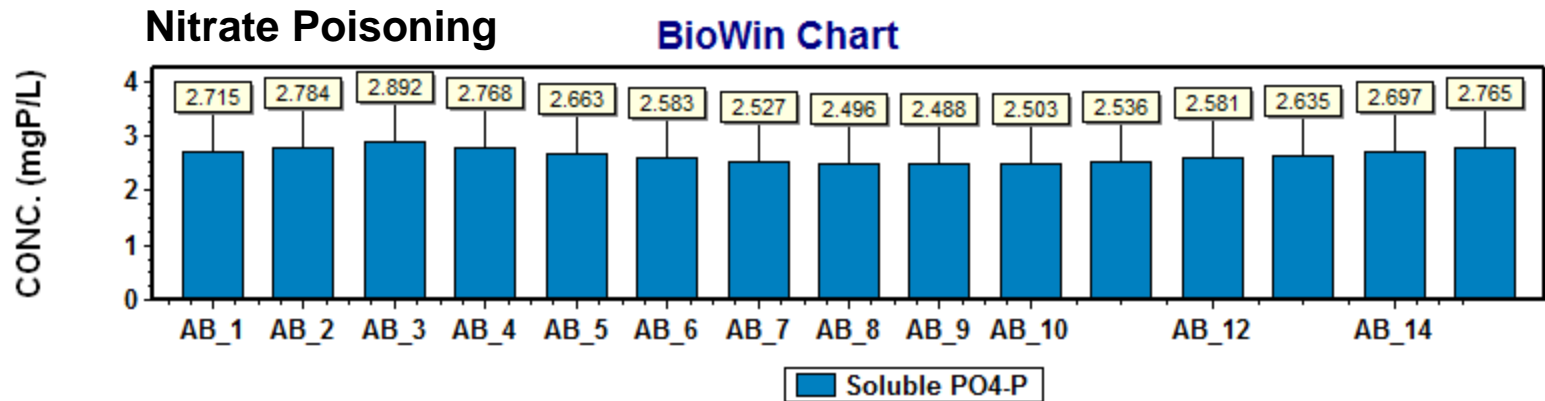
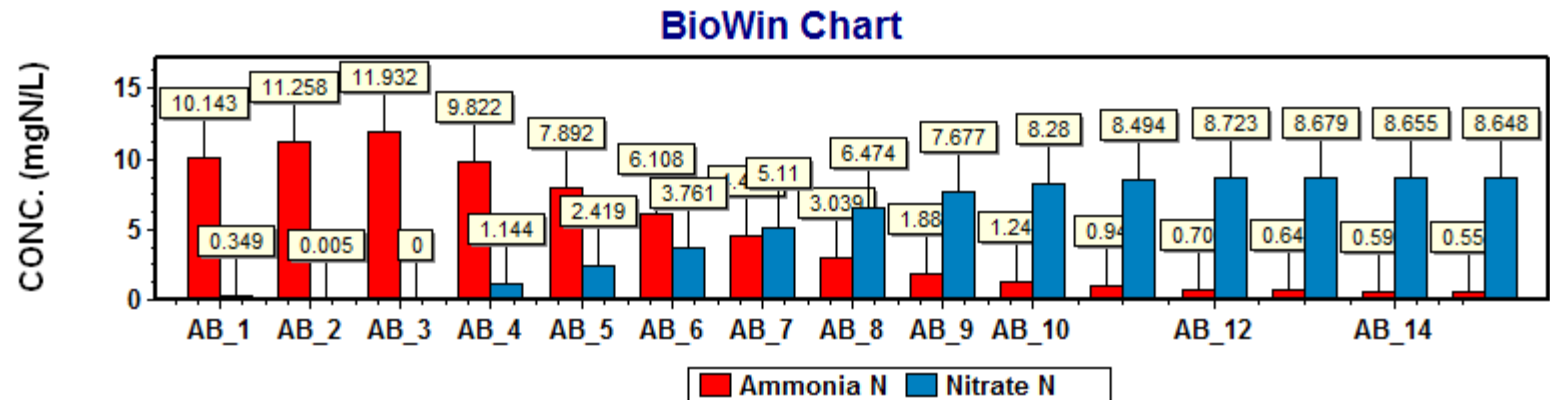
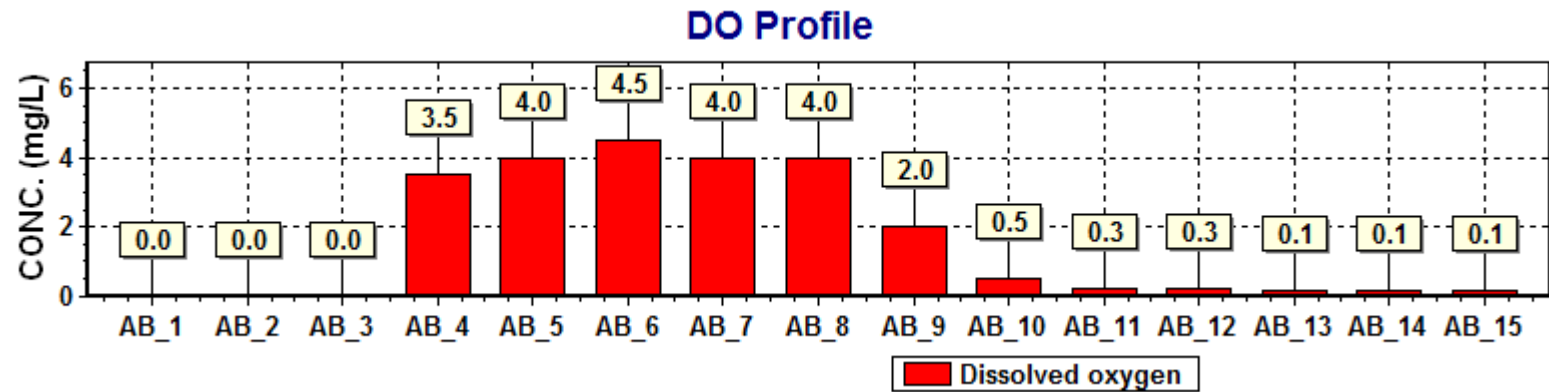


BioWin Chart



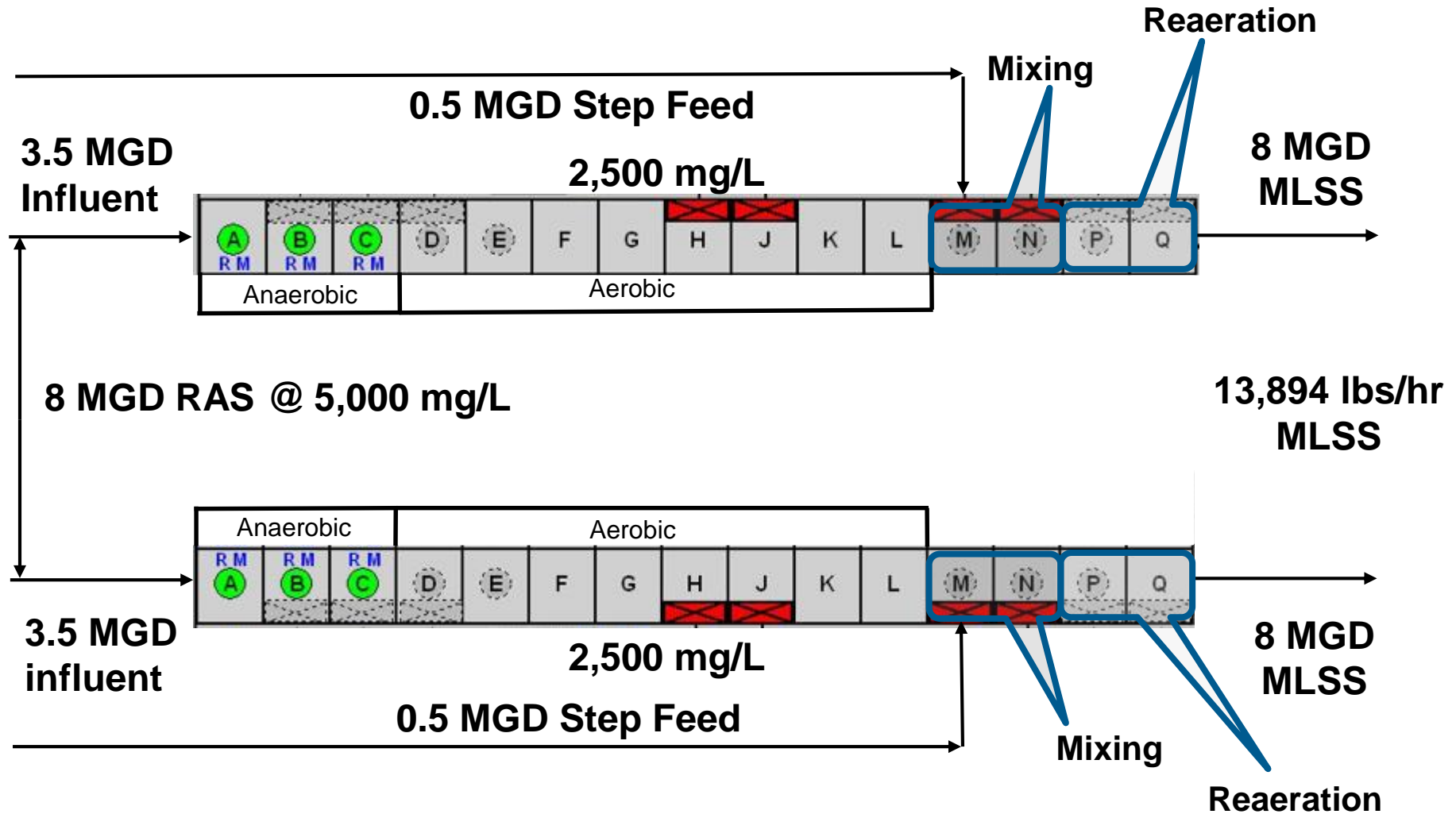
TP in effluent=0.66 mg/L

Existing Operation changed to < 1 ft blanket



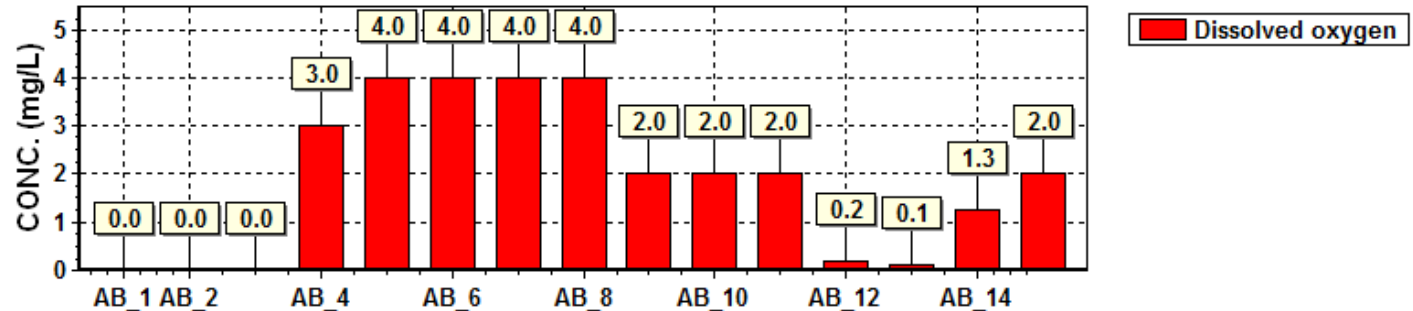
Step Feed for Carbon/Nitrate

Assume 1 MGD Step Feed Flow

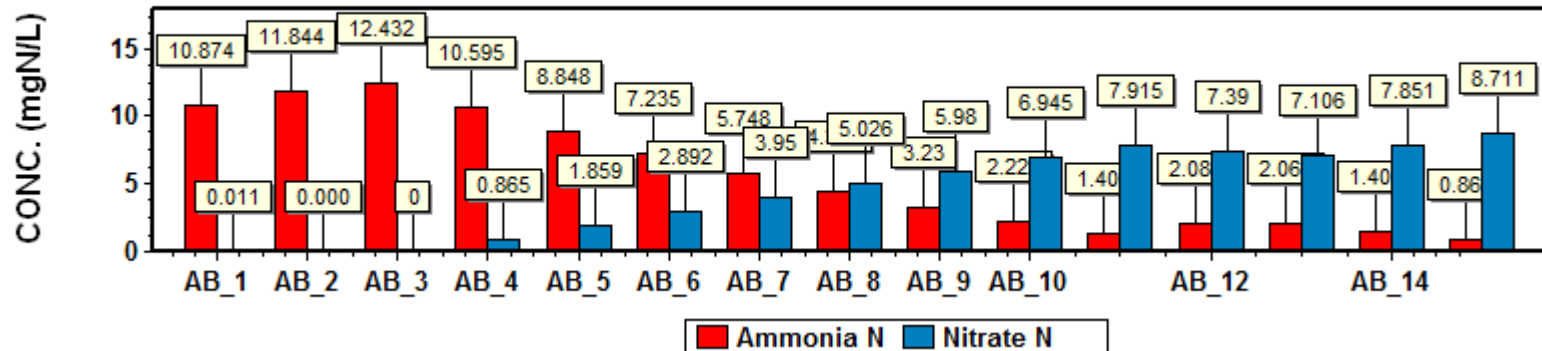


Proposed: 2,500 mg/L, 3,800 scfm
 1 MGD Step Feed, 2 Unaerated Zones (M,N)
 Temperature 13 C

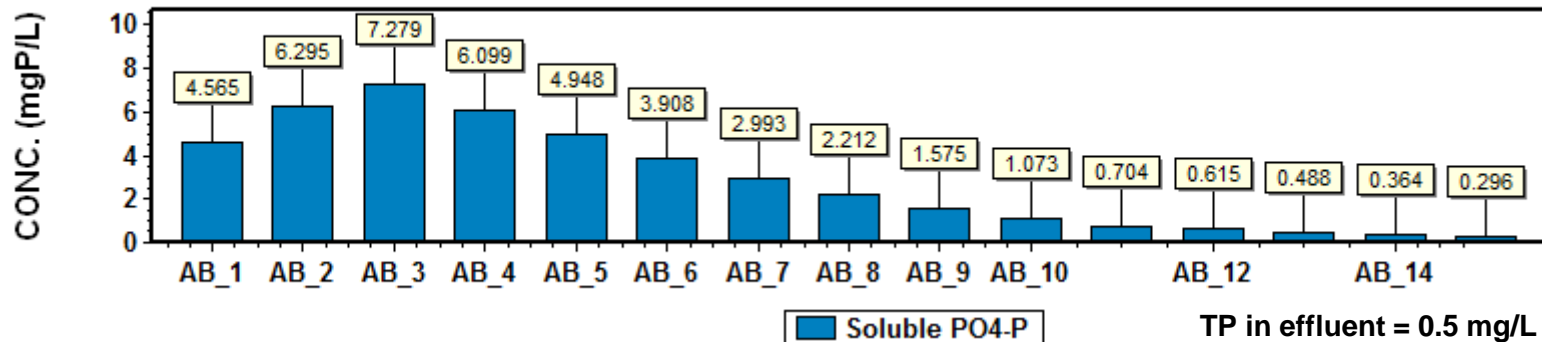
DO Profile



BioWin Chart



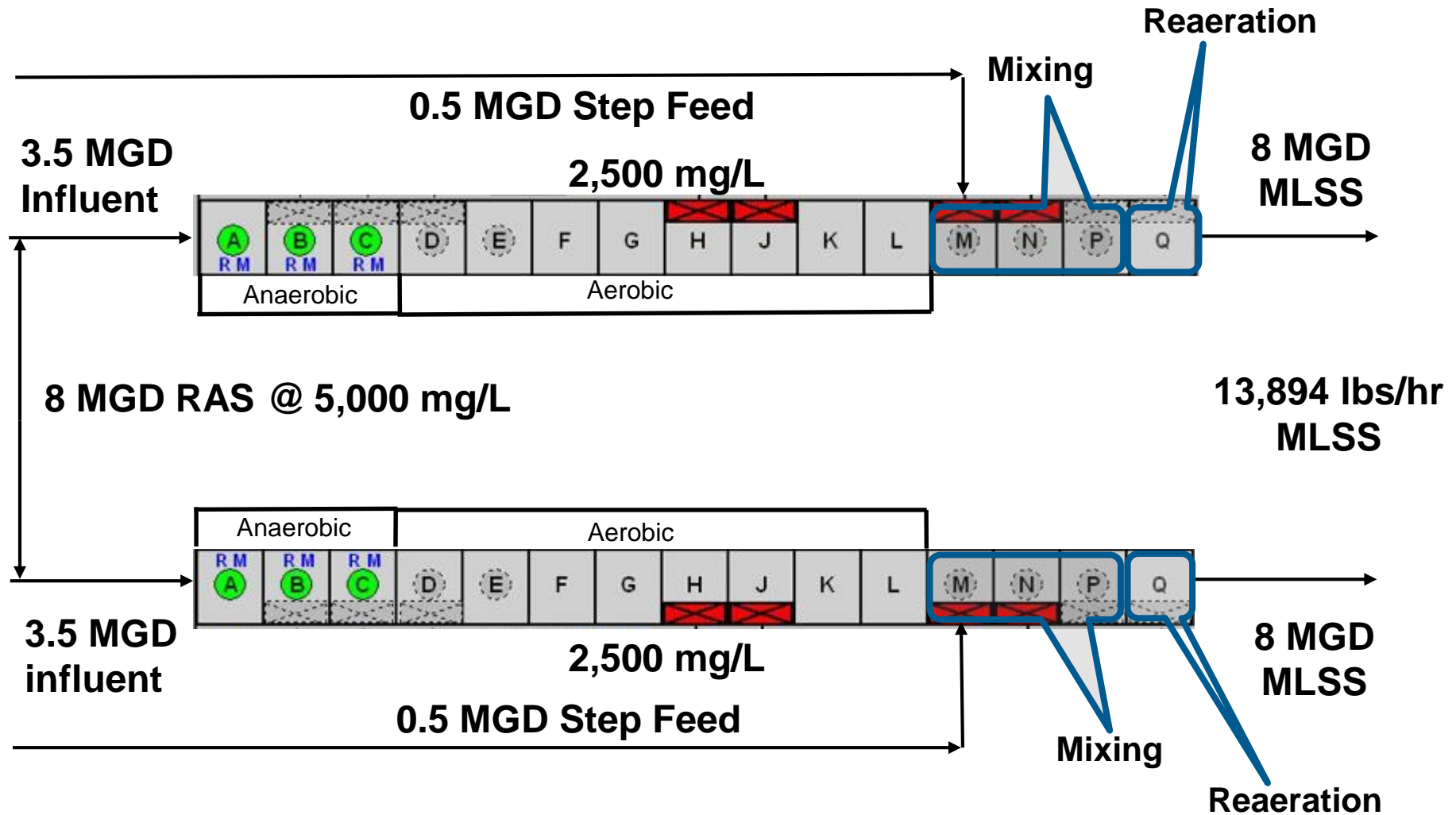
BioWin Chart



TP in effluent = 0.5 mg/L

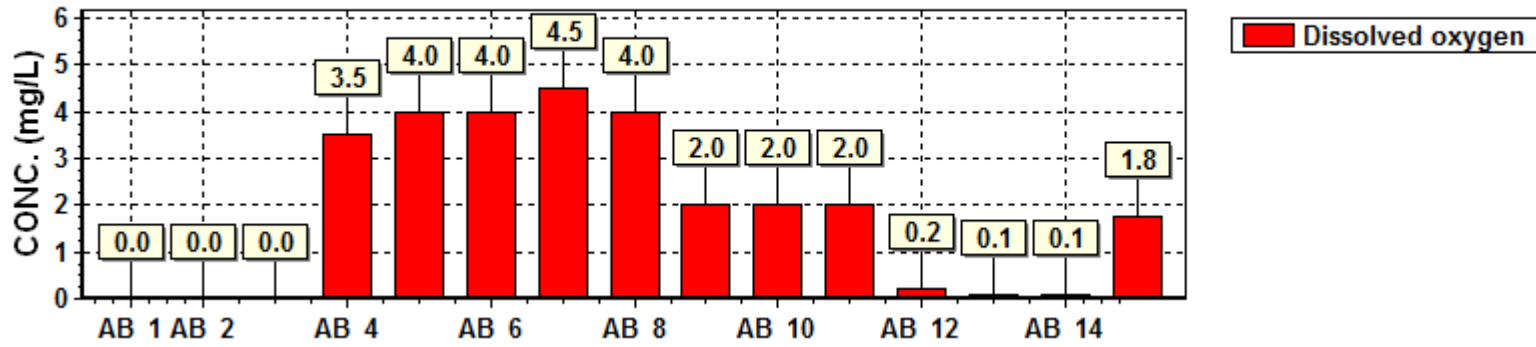
Step Feed for Carbon/Nitrate

Assume 1 MGD Step Feed Flow

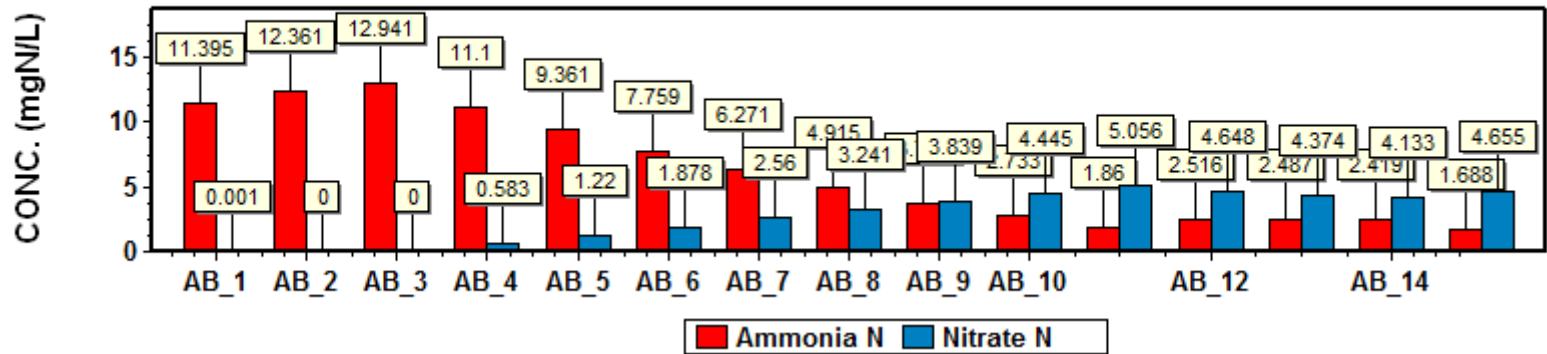


1 MGD Step Feed, 3 Un-aerated Zones (M,N,P):
TP in effluent = 0.31 mg/L, 3,800 scfm
Temperature 13 C

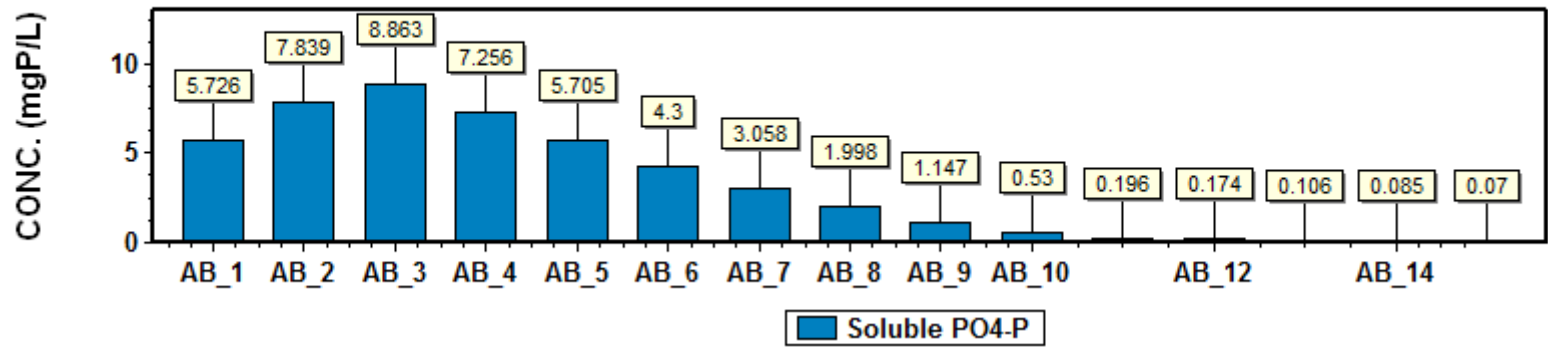
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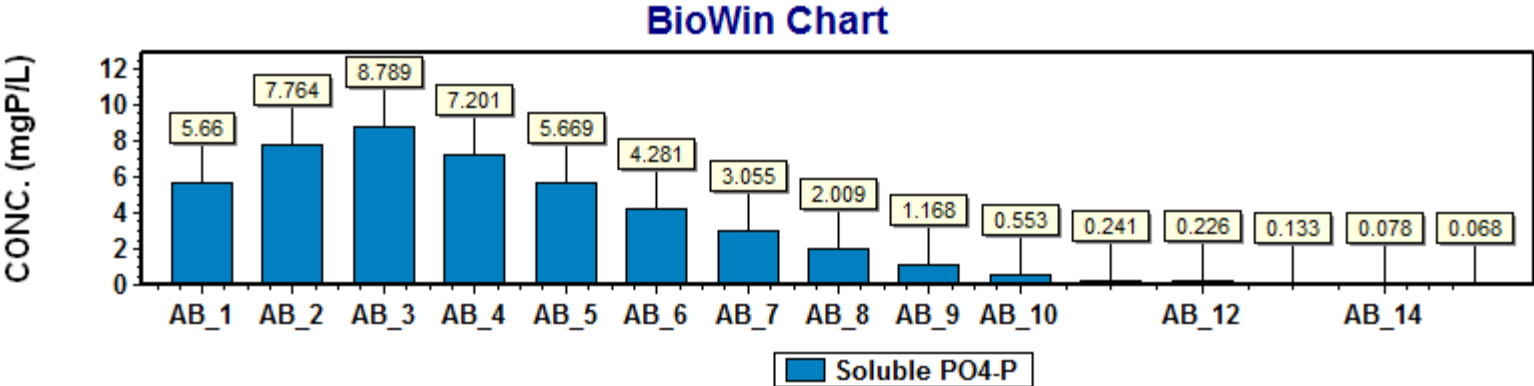
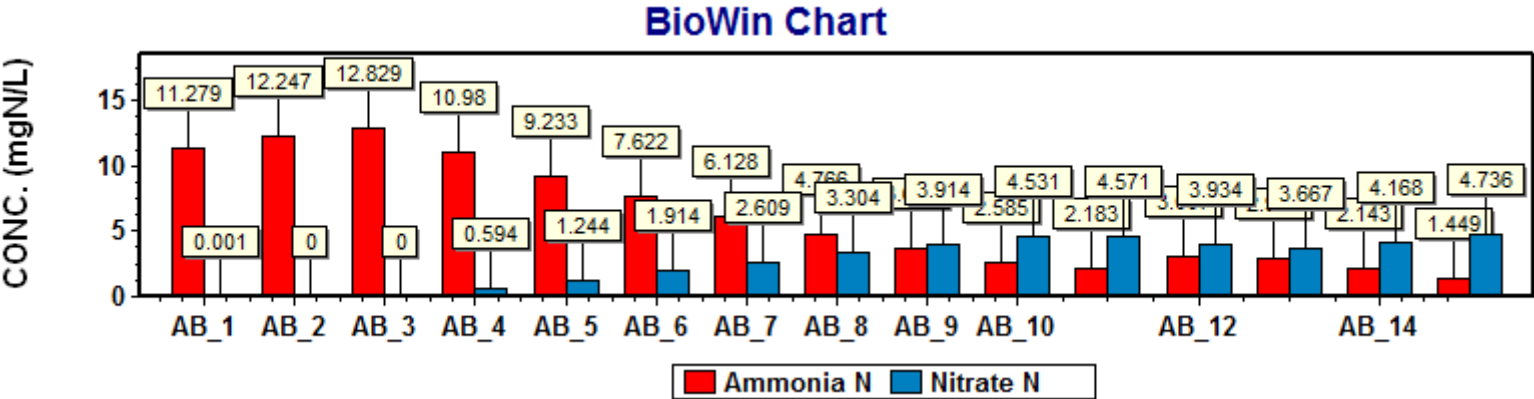
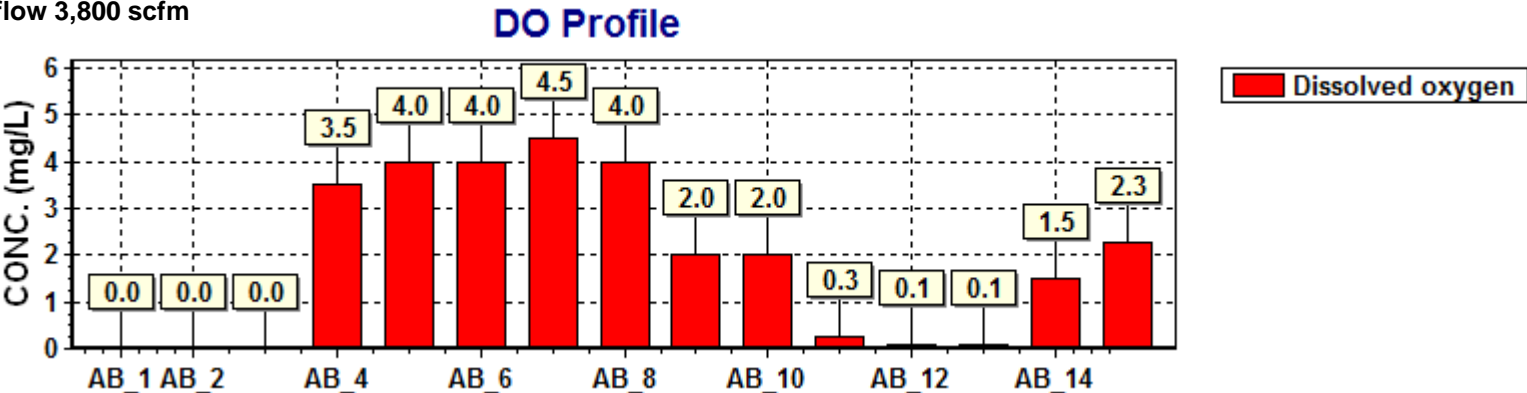
BioWin Chart



BioWin Chart

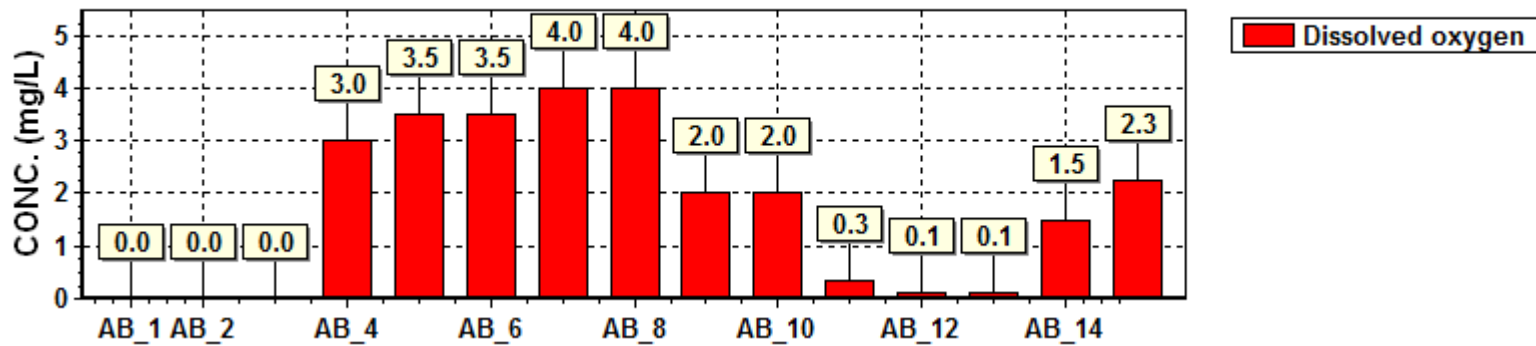


1 MGD Step Feed, 3 Un-aerated Zones (L,M,N):
TP in effluent = 0.31mg/L,
Temperature 13 C Air flow 3,800 scfm

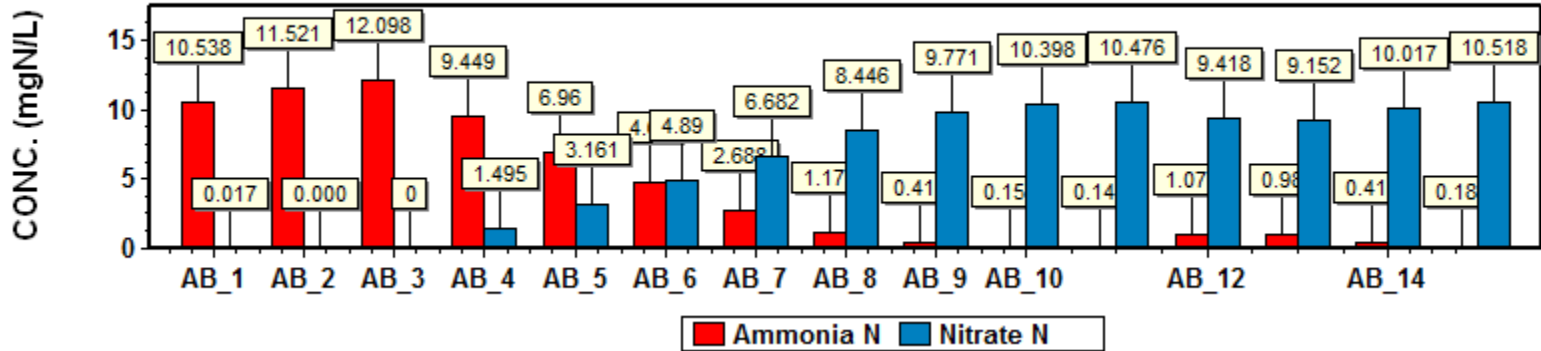


1 MGD Step Feed, 3 ANX (L,M, N)
2,500 mg/L MLSS, 4,100 sfc
Temperature 20 C

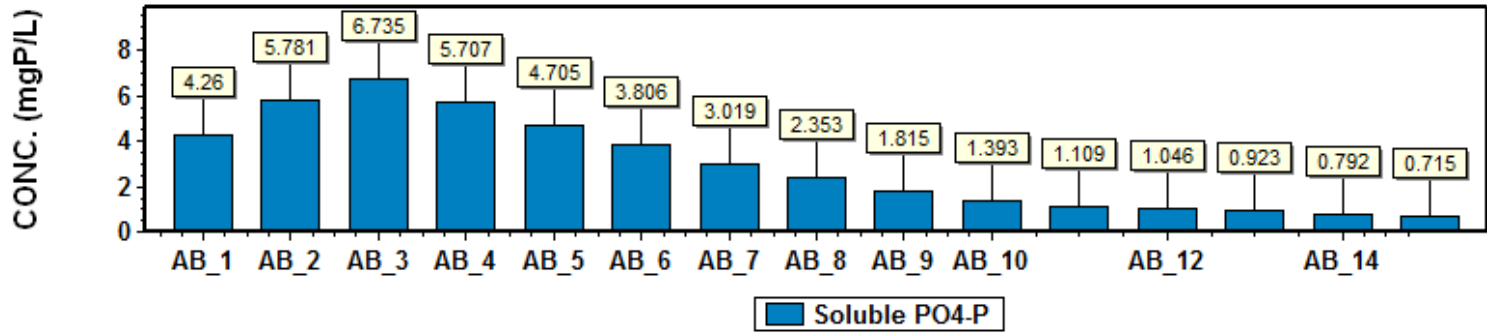
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BioWin Chart

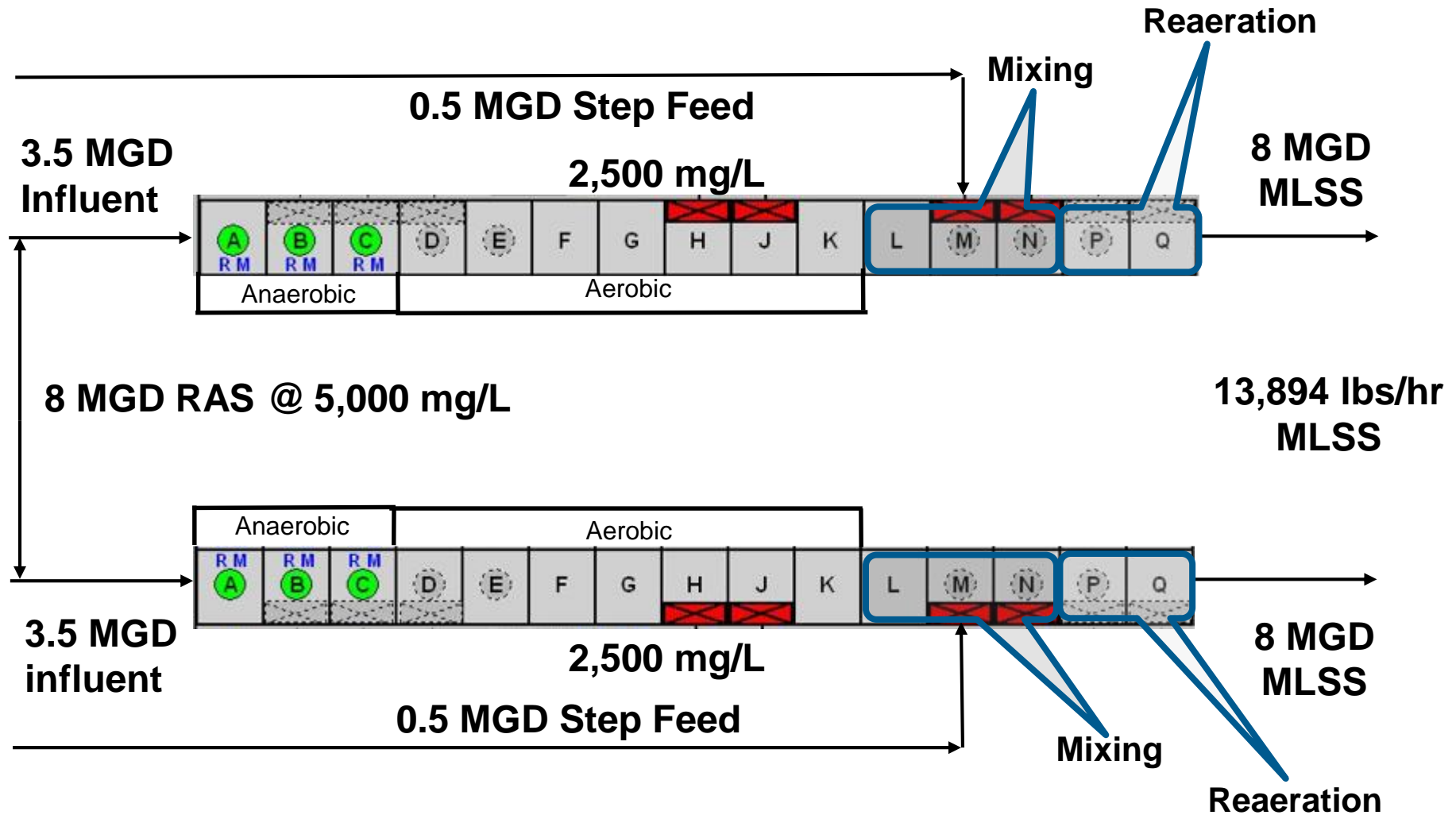


BioWin Chart

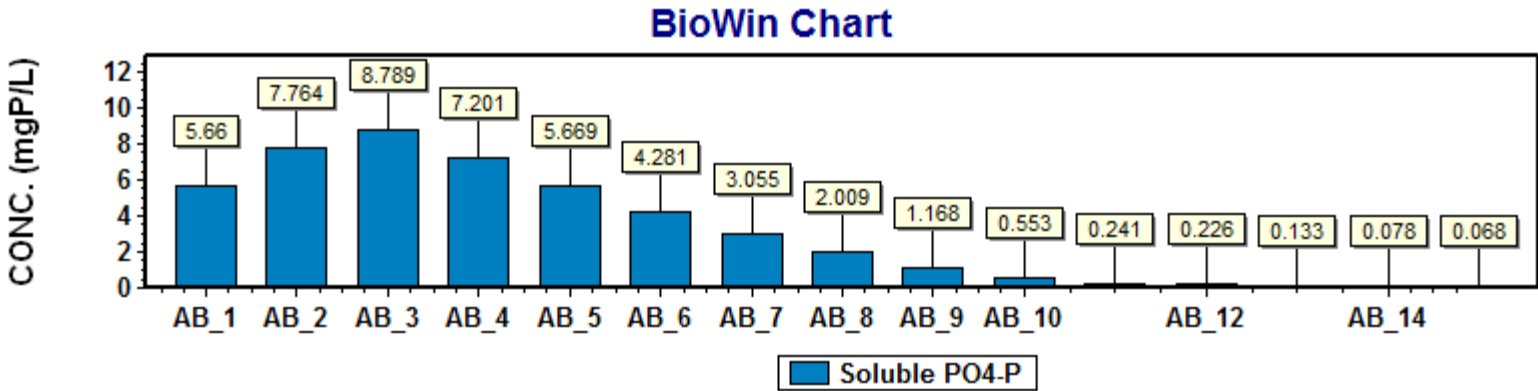
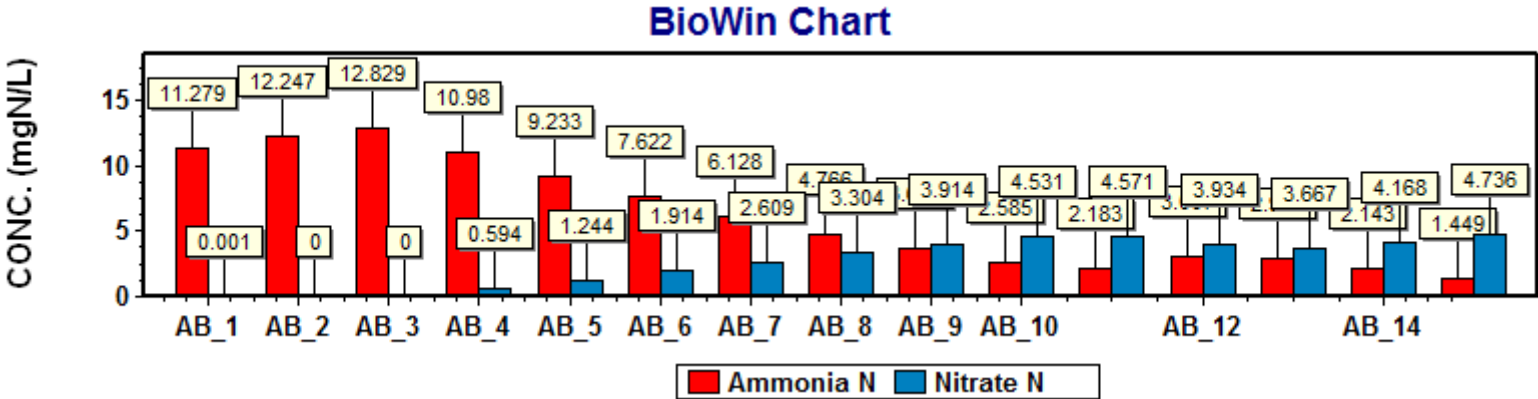
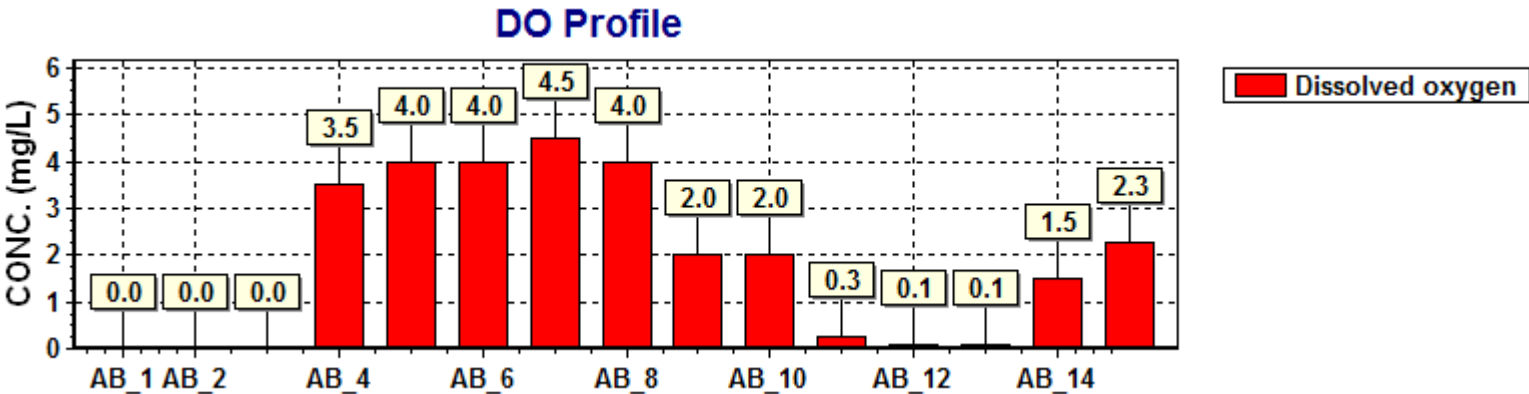


Step Feed for Carbon/Nitrate

Assume 1 MGD Step Feed Flow



Proposed: 1 MGD Step Feed, 3 Un aerated Zones (L,M,N):
TP in effluent = 0.31mg/L, Temperature 13 C



Utopia's future KPDES permits

Utopia must plan for tighter phosphorus and total nitrogen limits.

- Utopia is on a stream designated as a national resource and scenic waterway that enters a drinking water supply lake. Future permits are rumored to require additional nutrient controls.....Phosphorus may be 0.5 mg/L and total N may be reduced to 5 mg/L.
- Additional processes may be required. Tertiary filtration with deep bed filters that can be used to remove particulate phosphorus along with providing denitrification.
- It could be worse, F. Wayne Hill outside of Atlanta has a 0.08 mg/L TP Limit. Utopia staff will adjust process control include tertiary filtration.

Hazen and Sawyer

Questions



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