Overview of Nitrogen Removal and the IFAS Process for the Narragansett Bay Commission

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Background

- Discharge of nitrogen to Narragansett Bay contributes to:
  - Algae blooms and reduced dissolved oxygen
  - Impaired fish habitats
- Fields Point WWTF has 5 mg/L permit limit for Total Nitrogen (TN).
  - Took effect May 1, 2014.
  - TN Permit is seasonal for May 1 through Oct 31.
- The Integrated Fixed Film Activated Sludge (IFAS) process designed and built to meet TN permit limit.

Theory of Biological Nitrogen Removal

Biological Nitrogen Removal

- Two step process:
  - Step 1 – Nitrification – Ammonia present in wastewater is converted to nitrate (and a little nitrite).
  - Step 2 – Denitrification – Nitrate and Nitrite are converted to nitrogen gas and leaves wastewater to the atmosphere.

Nitrification

- First step in biological nitrogen removal process.
- $NH_4^+ + 2O_2 \xrightarrow[\text{nitrifiers}]{} NO_3^{-1}$ (nitrate) + $2H^+ + H_2O$
- Aerobic process, requires air.
  - DO > 2 to 3 mg/L

Nitrification

- Requires longer sludge age to maintain nitrifiers.
- Generates hydrogen ions / consumes alkalinity
- Temperature dependent: works faster in warmer water.

Denitrification

- Second step in the biological nitrogen removal process.
- Carbon + $2NO_3^{-1} \xrightarrow[\text{Facultative bacteria}]{} N_2$ (nitrogen gas) $+ 2CO_2 + 2OH^-$
- Anoxic process, takes place without air.
  - DO < 0.3 mg/L
  - Nitrate used as energy source (electron acceptor) instead of oxygen.

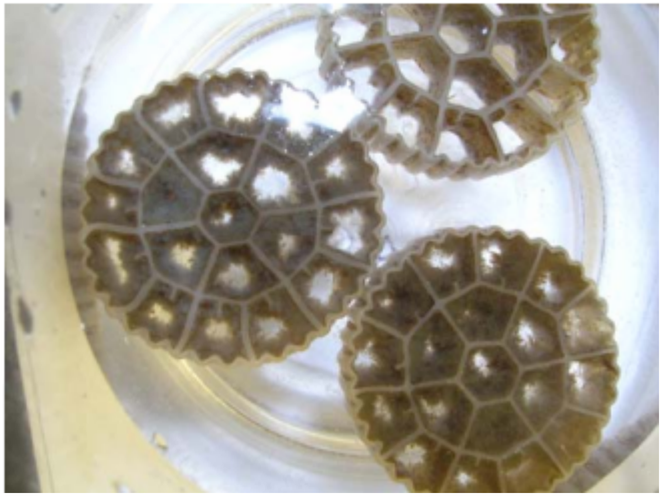
Denitrification

- Requires carbon source (BOD) for reaction.
- Generates hydroxide ions / recovers alkalinity.
- Process slows down when nitrate concentrations low.

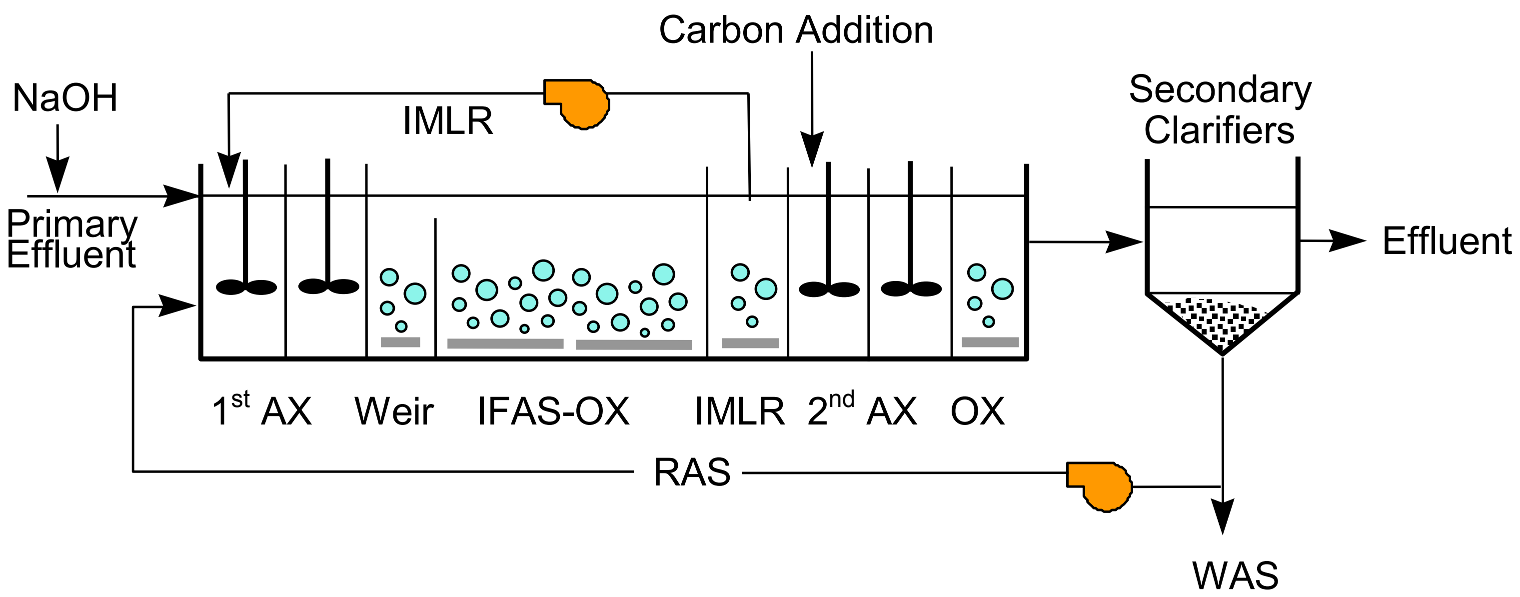
Total Nitrogen Removal in the IFAS Process (IFAS = Integrated Fixed Film Activated Sludge)

IFAS Process

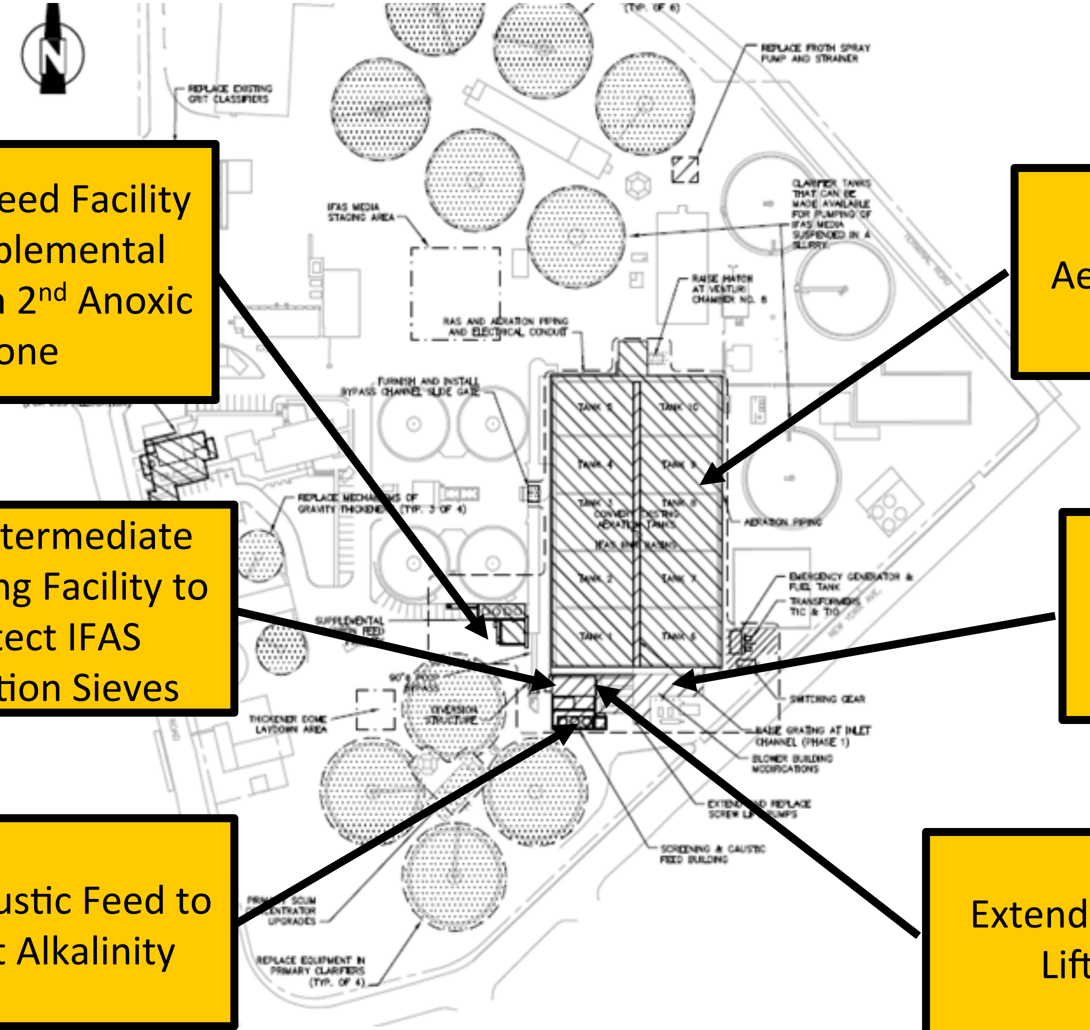
- IFAS process selected in Preliminary Design.
  - Allowed for reuse of existing ATs.
- Process entails adding high surface area media to AT.
  - Solids grow on media to increase MLSS.
- Fixed growth:
  - Increases capacity in aeration zone.
  - Increases sludge age.
  - Promotes nitrification.



IFAS Process Schematic



IFAS Upgrade Summary



Carbon Feed Facility for Supplemental Carbon in 2nd Anoxic Zone

New Intermediate Screening Facility to Protect IFAS Retention Sieves

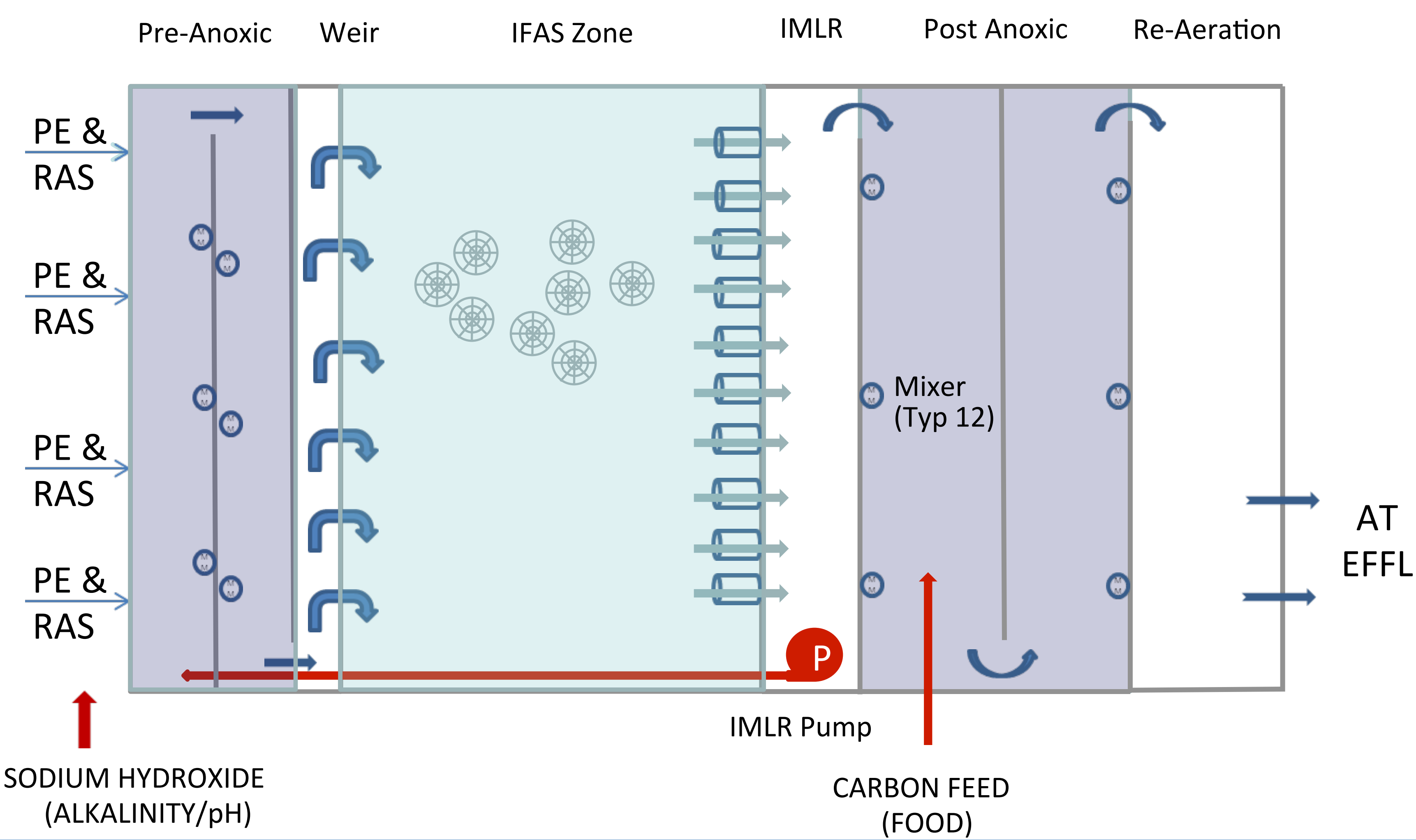
New Caustic Feed to Adjust Alkalinity

Modify All Ten Aeration Basins for IFAS Process

New Turbo Blowers for Increased Aeration Requirements

Extend Four Screw Lift Pumps

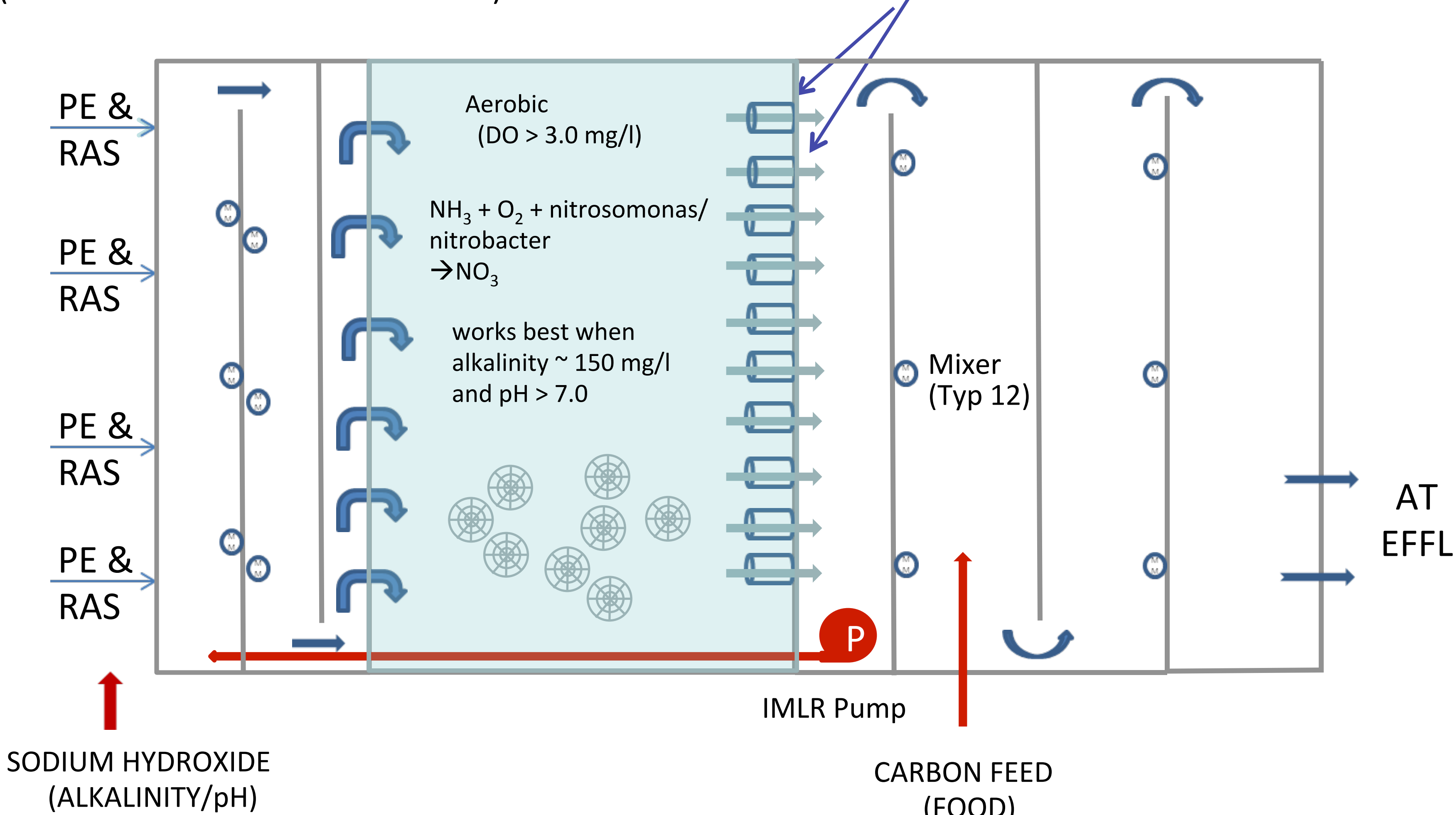
IFAS System



Pre-Anoxic
Weir
IFAS Zone
IMLR
Post Anoxic
Re-Aeration
PE & RAS
PE & RAS
PE & RAS
PE & RAS
Mixer (Typ 12)
P
AT EFFL
IMLR Pump
SODIUM HYDROXIDE (ALKALINITY/pH)
CARBON FEED (FOOD)

IFAS (AS) ZONE – Contains IFAS Media (Aerobic)

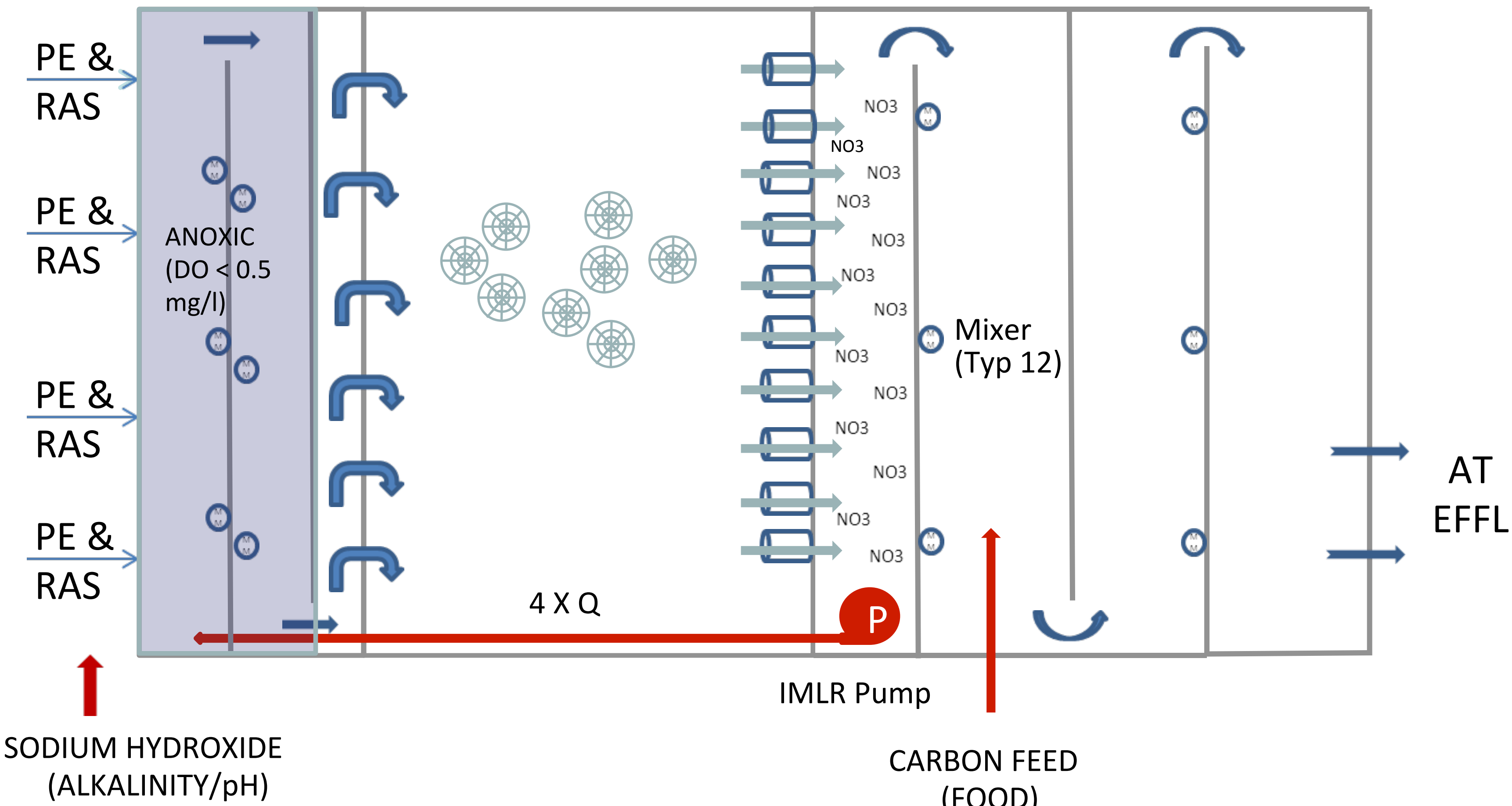
Location for Nitrification
(conversion of ammonia to nitrate)



FIRST (Pre) ANOXIC ZONE - DO < 0.5 mg/l

Location for Initial Denitrification
(conversion of nitrate to nitrogen gas)

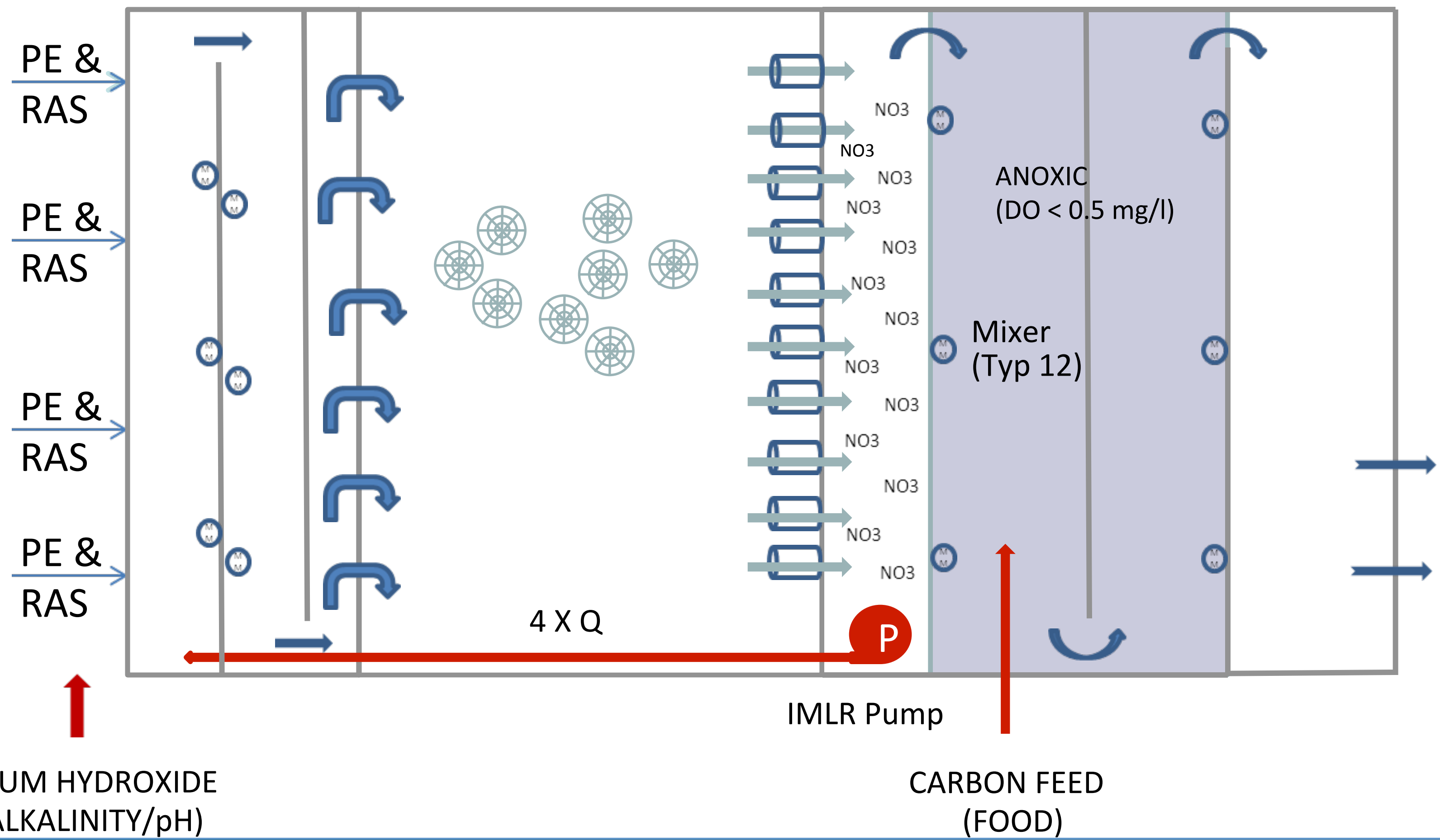
NO3 + PE (food) + RAS (bugs) = N(gas) + BOD removal (Total Nitrogen to 8-9 mg/l)
Mixers but slow enough not to generate O_2
Internal recycle of NO_3 enriched ML from IFAS zone



SECOND (Post) ANOXIC ZONE - DO < 0.5 mg/l

Location for Final Denitrification
(conversion of nitrate to nitrogen gas)

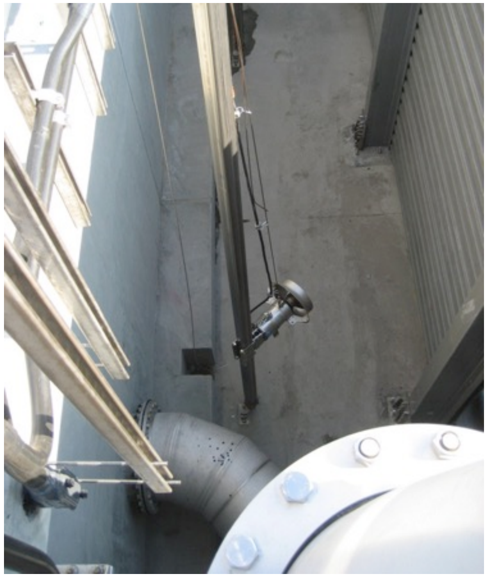
In second anoxic zone there will still be some NO_3 enriched MLSS, but no food:
NO_3 + food (carbon source) + bugs = N_2 (gas)↑



Process Equipment

Anoxic Mixers

- Each Aeration Basin has 12 Submersible Mixers.
- Mixers keep solids suspended in Anoxic Zones.
- Mixers operate 24 hrs/day
- HOA switch at each mixer and on Kruger PLC.
  - In Auto, mixers will automatically operate via Kruger PLC.
  - Hand mode provided for testing only.



IMLR Pump

- Each Aeration Basin has 1 IMLR Pump.
  - IMLR = Internal Mixed Liquor Recycle
- Recycle nitrates from Pump zone to Pre-Anoxic Zone.
  - Flow = 3 to 4 X Q, VFD Controlled
- Pumps operate 24 hrs/day.
- HOA switch at pump and on Kruger PLC.
  - In Auto, pumps will automatically operate via Kruger PLC:
    - Flow Pace, Flow pace w/ nitrate trim, Constant flow rate
    - Flow meter to verify flow and for control feedback.
  - Hand mode provided for testing only.

IFAS Media

- Each IFAS Zone filled with Media.
  - 52% Media Fill
- Media retained by Sieves.
- Screens are installed at tank drains and scum outlets in concrete divider walls.

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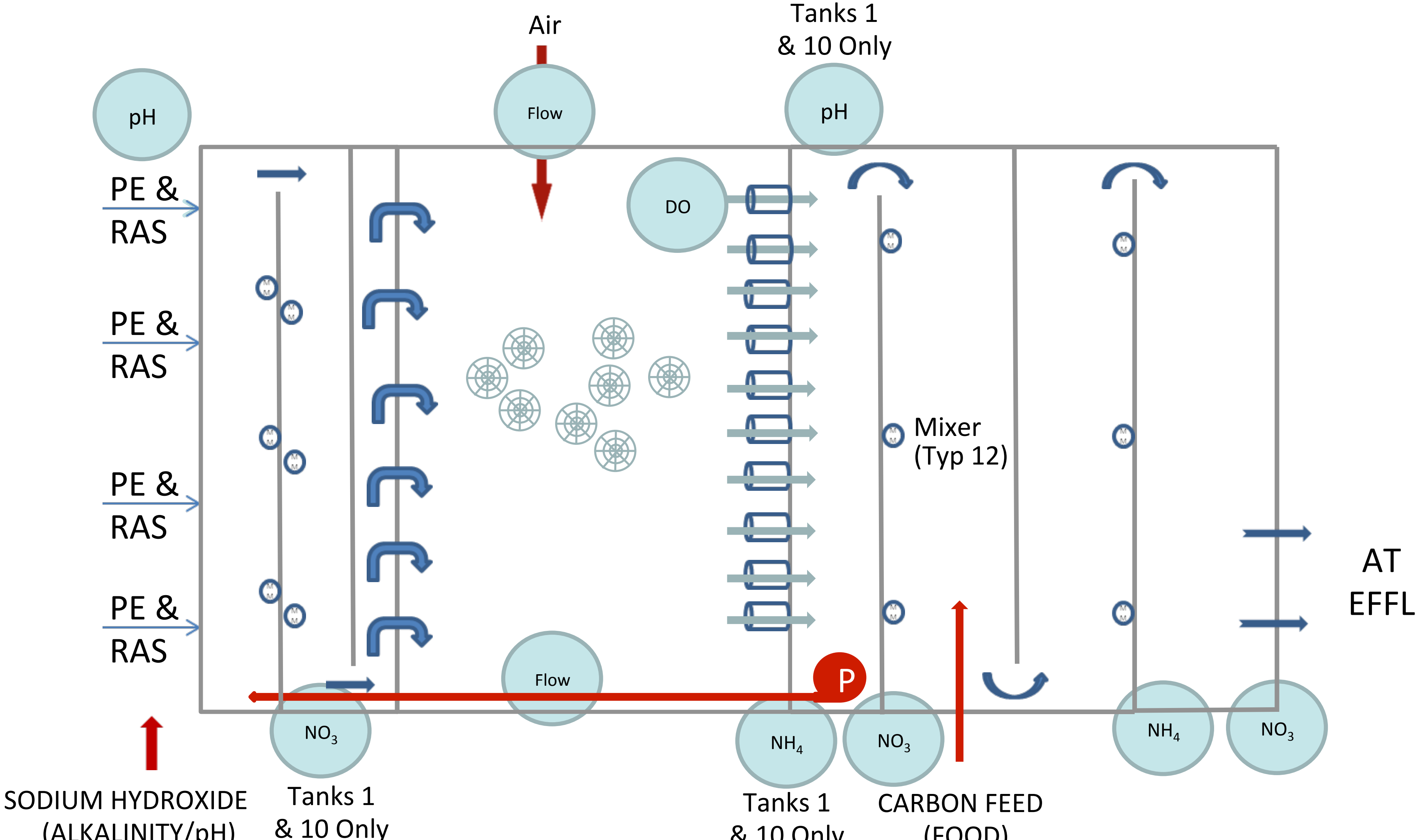
Aeration

- Coarse Bubble Diffusers at bottom of IFAS Zones.
- Aeration to IFAS Zones controlled to maintain target DO.
  - Each IFAS Zone has DO Probe, air flow meter, and control valve.
- Other aerated zones manually adjusted
  - Weir zone, Pump Zone, + Re-aeration Zone

Return Activated Sludge

- New RAS Pipe provided to AT Influent Channel.
  - Better RAS distribution from clarifiers.
  - Reduce DO in Pre-Anoxic Zone.
- New RAS Pipe has a flow meter and control valve.
- Existing RAS control valves and flow meters not modified.

Process Instrumentation



Operations and Control

IFAS Process Control – NaOH Feed

- Caustic feed controlled pH > 7.0 in IMLR Pump Zone.
- pH Meter in IMLR Pump Zone (Tanks 1 and 10 only) used to verify mixed liquor pH after nitrification.
- Caustic feed pumps are flow paced.
  - Controls trim with AT Influent Channel pH meter.
  - Adjust metering pump stroke and control set point to get target IMLR Pump Zone pH.

IFAS Process Control – Aeration

- Air Flow to IFAS Zone controlled to get target DO.
  - IFAS Zone DO will vary from 3 to 6 mg/L as needed to fully nitrify.
  - Ammonia meter in Re-aeration Zone and in IMLR Pump Zone (Tanks 1 and 10 only) monitors nitrification.
  - Target ammonia for full nitrification = Less than 1 mg/L as NH_4-N.
- Adjust DO setpoint seasonally as needed to fully nitrify.

IFAS Process Control – Aeration (cont.)

- Air to IFAS Zone controlled to maintain DO setpoint.
  - DO Meter, flow meter, and control valve provided at IFAS Zone for aeration control.
- Minimum aeration required for mixing and to keep media from accumulating at sieves.
  - Controls do not go below the minimum aeration set point.

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IFAS Process Control – IMLR Pump & VFD

- IMLR Flow Rate controlled to get target nitrate in IMLR Pump Zone.
  - IMLR Pump Zone nitrate range = 1 to 2 mg/L as NO_3-N.
- IMLR Flow Rate varied with Kruger PLC.
  - Three control loops to select from: Flow Pace, Flow pace w/ nitrate trim, Constant Flow Rate.
  - Nitrate in Pre-Anoxic Zone (Tanks 1 and 10 only) used w/ nitrate trim.
- IMLR Flow meter used for control feedback.

IFAS Process Control – Carbon Feed

- Carbon feed adjusted to minimize effluent nitrate.
- Carbon feed rate varied with Kruger PLC.
  - Three control loops to select from: Nitrate Load, Nitrate Reference Table, Constant Feed.
  - Nitrate meters in IMLR Pump Zone and Re-aeration Zone used w/ nitrate load mode.
- Adjust metering pump stroke and control loops to minimize Re-aeration zone nitrate.

RAS / WAS / Clarifier Process

- Set RAS and WAS Rates as needed to maintain MLSS.
  - Design MLSS of 2,750 mg/L.
  - This MLSS does not include the fixed growth.
- Kruger's suggested clarifier loading rates:
  - Hydraulic = 400 to 630 gpm/ft^2
  - Solids = 14 to 22 lbs/ft^2/day
- Monitor clarifier blanket depths and settling / SVI.
  - IFAS not expected to significantly change SVI.

Process Monitoring

Parameter	Frequency	Method
AT Influent pH	1 / per shift	On Line Instr.
IFAS Zone DO	1 / per shift	On Line Instr.
IMLR Zone Nitrate	1 / per shift	On Line Instr.
AT Eff. NH_3 and NO_3	1 / per shift	On Line Instr.
Air Flow Rate	1 / per shift	Flow Meter
IMLR Flow Rate	1 / per shift	Flow Meter
RAS Flow Rate	1 / per shift	Flow Meter / DCS
WAS Flow Rate	1 / per shift	Flow Meter / DCS
Clarifier Blanket Depth	1 / per shift	Blanket Meter / DCS
Caustic Feed Rate	1 / per shift	Chemical Use
Carbon Feed Rate	1 / per shift	Chemical Use

Sampling and Analysis for Process Control

Parameter	Frequency	Method
AT Inf. TSS	1 / per day	Lab Test
MLSS TSS and VSS	1 / per day	Lab Test
Attached Growth on Media	1 / per week	Lab Test
AT Inf. and Eff. BOD	1 / per day	Lab Test
AT Inf. and Eff. COD	1 / per week	Lab Test
AT Inf. and Eff. TKN / NH_3 / NO_3	1 / per day	Lab Test
AT Inf., Eff., & Pump Zone Alk. & pH	1 / per day	Lab Test
IFAS Zone Dissolved Oxygen	1 / per day	Portable Probe
IFAS Zone Temperature	1 / per day	Thermometer

Process Differences from Former Process

- No significant change in effluent BOD or TSS.
- No significant change in MLSS expected.
  - Design MLSS = 2,750 mg/L.
- No significant change in SVI expected.
  - Slight improvement in settling seen at other IFAS plants.
- Decreased chlorine use in Chlorine Contact
  - Less chlorine is required for disinfection.
  - Reduced nitrate and ammonia in effluent to oxidize.

Kruger IFAS Design Capacities

Design Capacities & Variables

- Internal Recycle = 230 MGD
- RAS = 65 MGD
- WAS (max conditions) = 42,000 lbs/day
- MLSS = 2750 mg/L
- Solids Retention Time = 5.08 days
  1. Anoxic SRT = 2.44 days
  2. Aerobic SRT = 2.64 days
- Clarifier Rates
  1. Overflow Rate = 400 – 630 gallons/ft2/day
  2. Solids Loading Rate = 14 – 22 lbs/ft2/day

Kruger IFAS Operating Parameters

Permit season – May 1 – October 31

Variable	**Setpoint/Target**	**Description**
HYBAS DO (IFAS)	3 – 6 mg/L	**as required to establish full nitrification (<1 mg/L NH4-N) out of pump zone**
IMLR	5.0 – 23.0 MGD	**as required to maintain NOX-N in the pre-HYBAS zone between 1 – 2 mg/L**
MLSS/WAS	2750 mg/L	
RAS	1.0 – 6.5 MGD	
C/N ratio	**4.6 or as required**	**May vary depending on actual field conditions**

Questions?

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