Simulating Side-Stream EBPR (S2EBPR) in Full-Scale and Pilot-Scale Demonstration Studies

Modeling Approaches and Challenges

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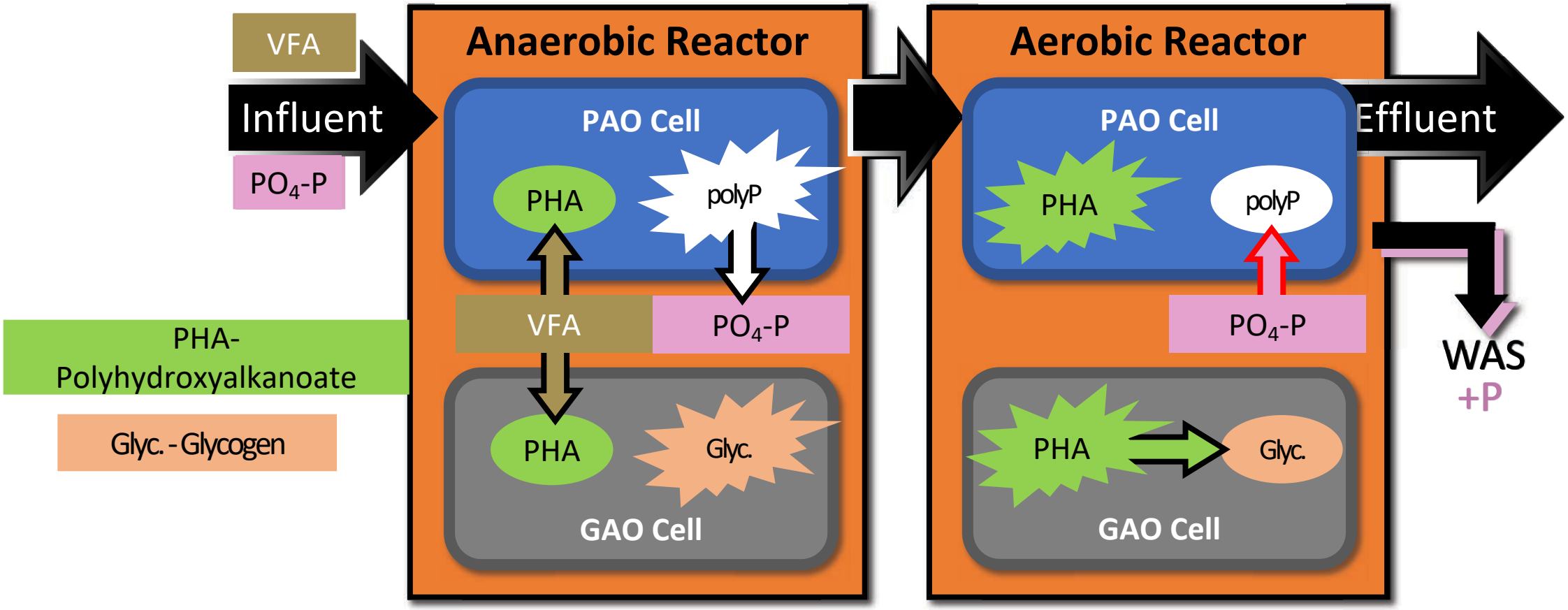
EBPR is a complex process



Modeling EBPR

Adapted from Santos et al., 2019

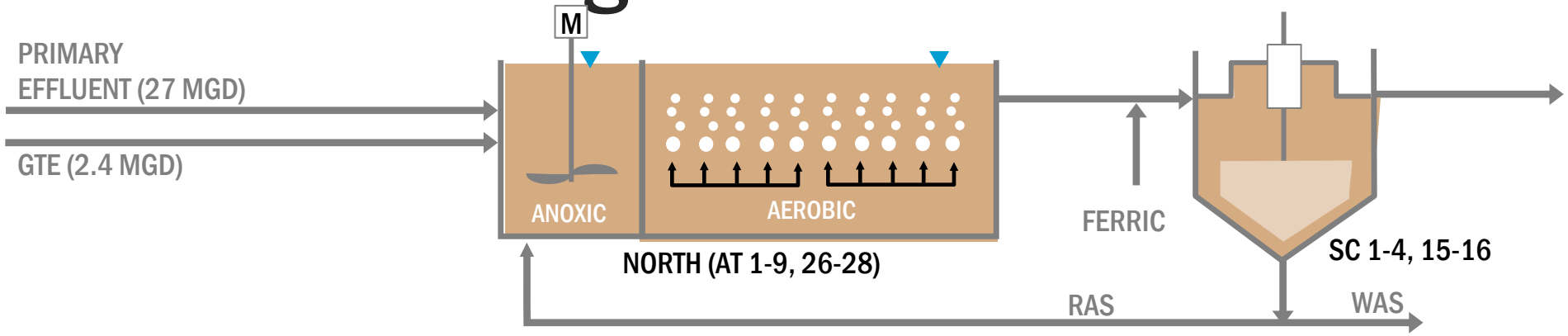
	ASM2d (Henze et al., 1999)	ASM2d + TUD (Meijer, 2004)	UCTPHO+ (Hu et al., 2007)	Barker & Dold (Barker and Dold, 1997)	META-ASM (This study)
# of EBPR processes	PAOs: 8 (GAOs activity neglected)	PAOs: 11 (GAOs activity neglected)	PAOs: 18 (GAOs activity neglected)	PAOs: 19 (GAOs activity neglected)	PAOs: 41 Two GAO groups: CPOs[a]: 21 DFOs[b]: 16
Fermentation	Transformation (VFA)	Transformation (VFA[e])	Transformation (VFA)	Anaerobic growth process (VFA)	Anaerobic growth process focused on distribution of fermentation products (Ac[c], Pr[d] and H_2) Different fermentation yields determined experimentally
Endogenous process in PAOs and GAOs	PAO: death-regeneration	PAO: endogenous respiration/cell maintenanc	PAO: endogenous respiration/cell maintenance and death-regeneration	PAO: endogenous respiration/cell maintenance and death-regeneration	Endogenous respiration/cell maintenance and death-regeneration
Energy source for anaerobic maintenance of PAOs and GAOs	No	PAO: Polyphosphate	PAO: Polyphosphat	PAO: Polyphosphate	PAO: polyphosphate and glycogen GAO: glycogen
Origin of reducing power and energy source in the anaerobic PAO metabolism	Reducing power: neglected; Energy: polyphosphat	Reducing power: Glycolysis; Energy: polyphosphate and glycogen	Reducing power: neglected; Energy: polyphosphate	Reducing power: neglected; Energy: polyphosphate	Reducing power: Glycolysis and others (e.g. TCA and propionyl-CoA conversion to acetyl-CoA); Energy: polyphosphate and glycogen

Complexity

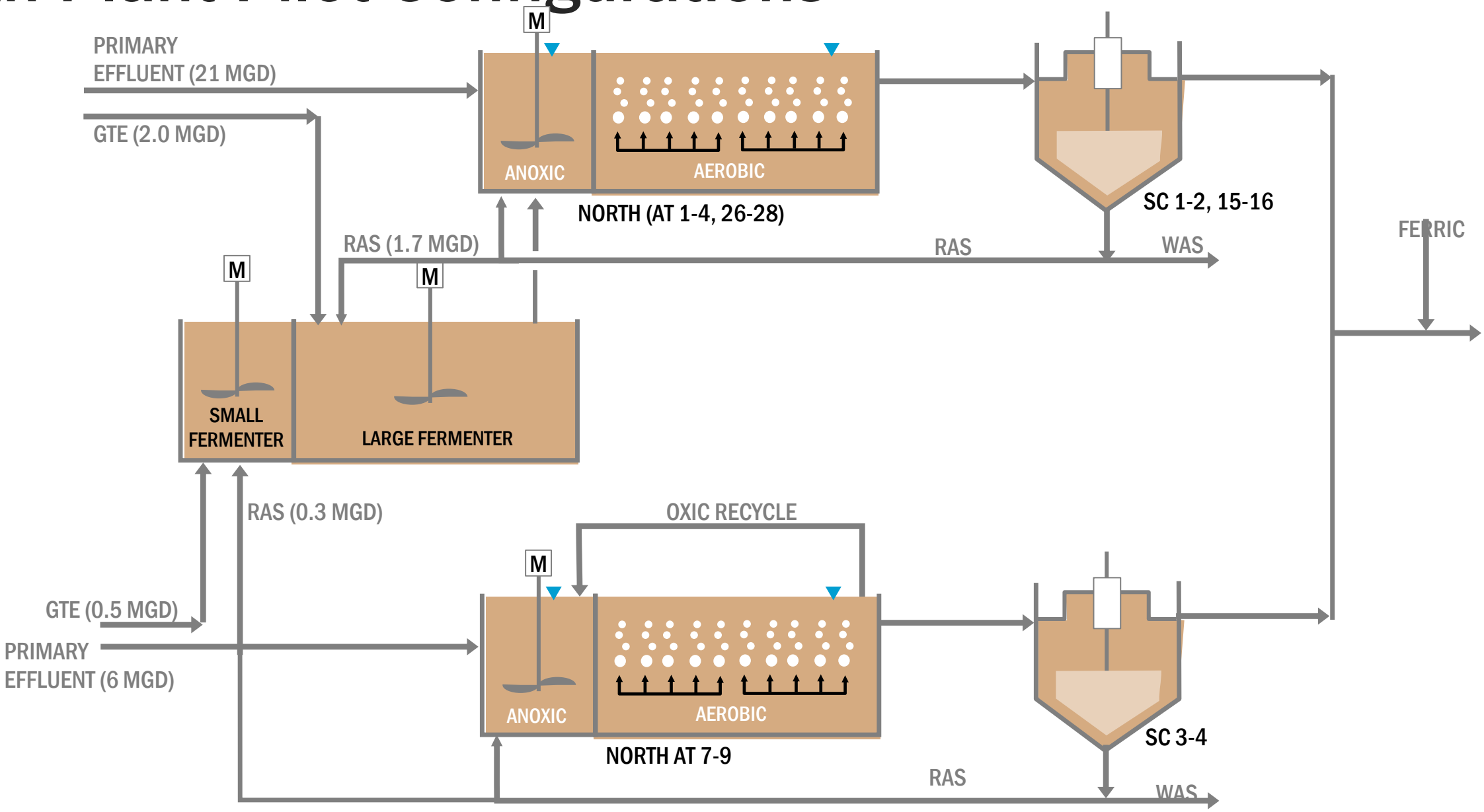
Calibration Techniques, Hydrolysis and Fermentation, Temperature Dependence

McAlpine Creek WWMF S2EBPR Demonstration Study

North Plant Pilot Configurations

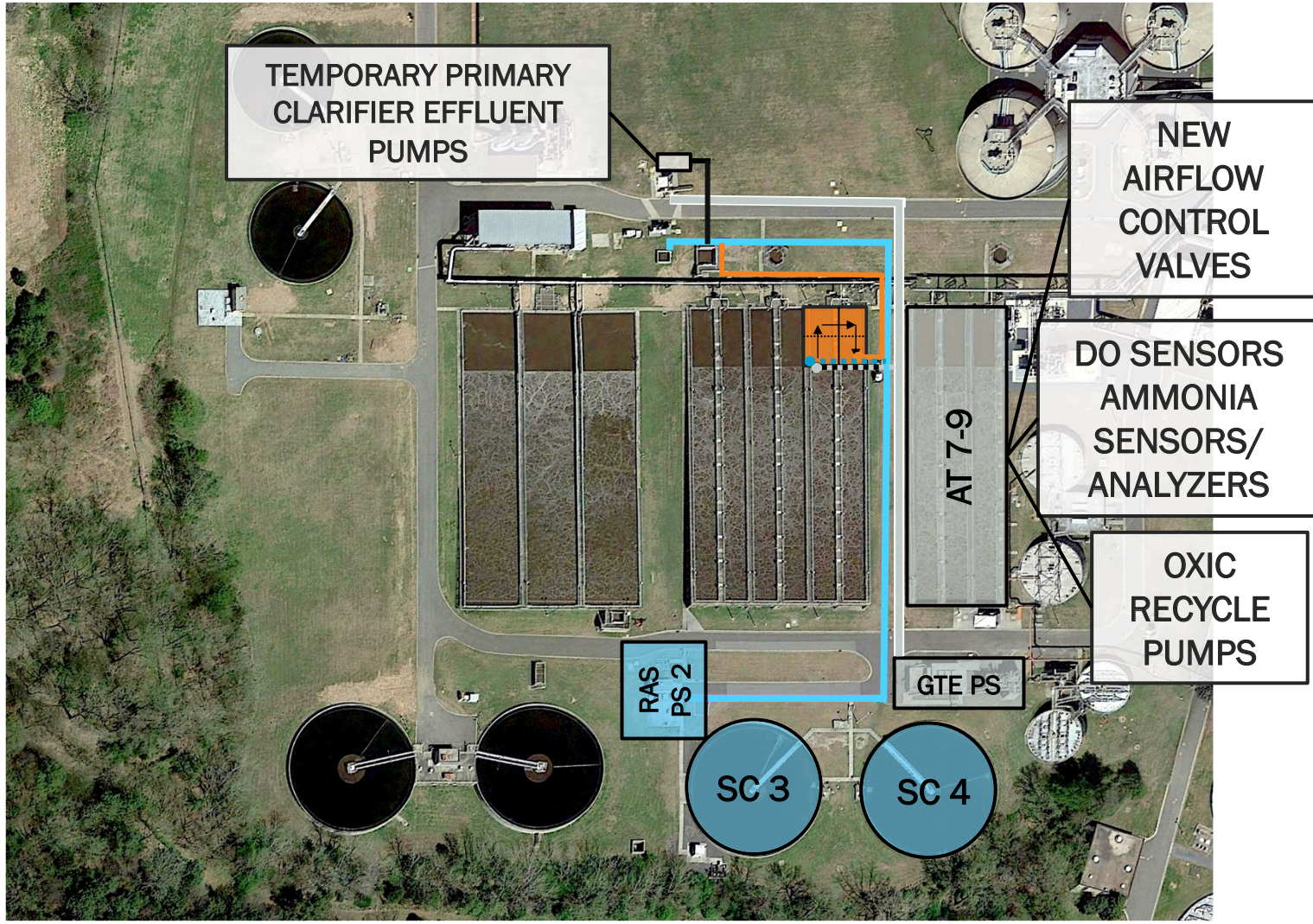


North Plant Pilot Configurations



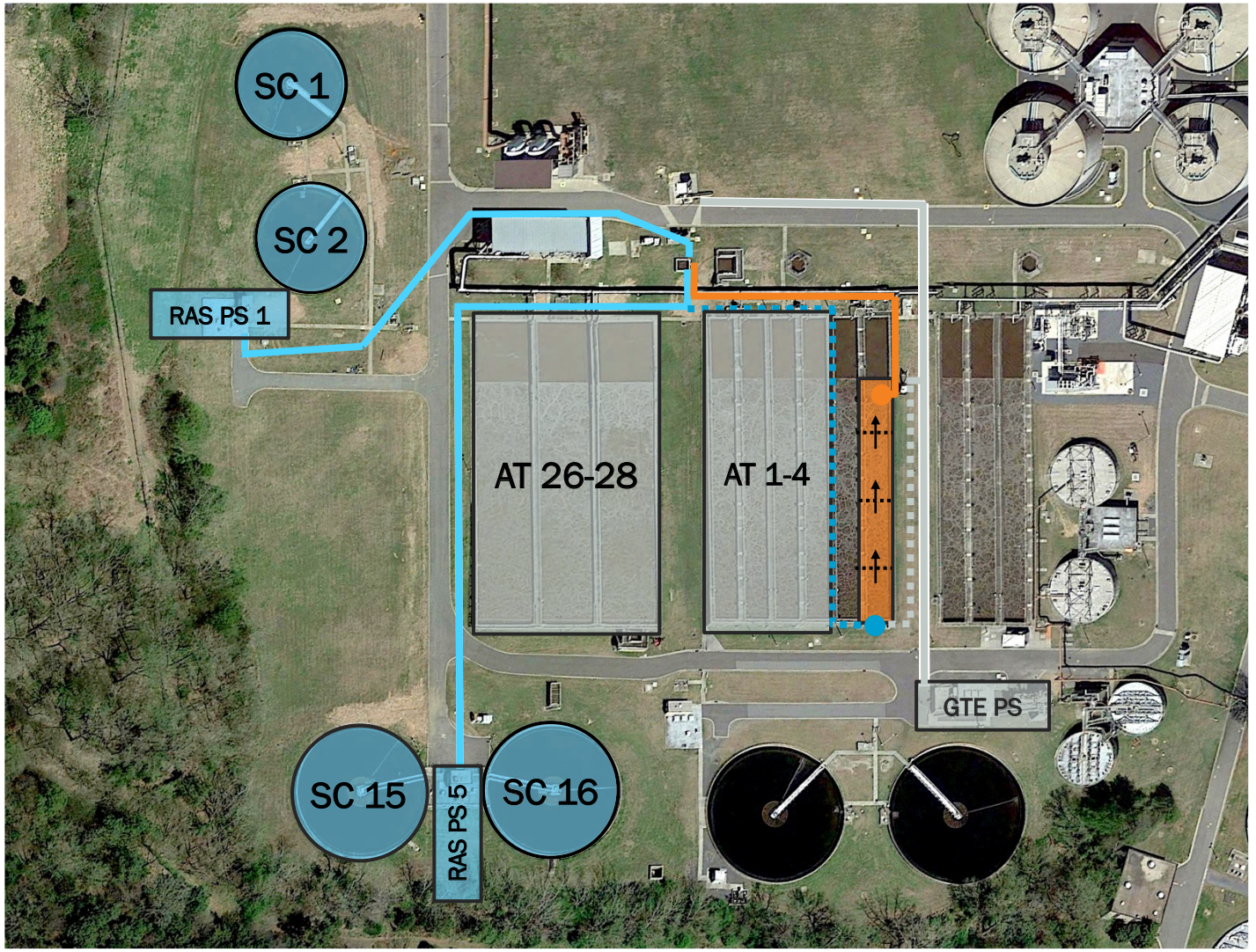
North AT 7-9 Plant: ABAC/MLE Configuration

RAS Fermenter Parameter	Value
Fermenter Volume	0.28 MG
Fraction of North AT 7-9	10.2%
RAS Flow	0.2-0.4 MGD
GTE Flow	0.3-0.7 MGD
HRT	8-12 hours
SRT	8-45 hours
Mixing	0.23 HP/kft^3



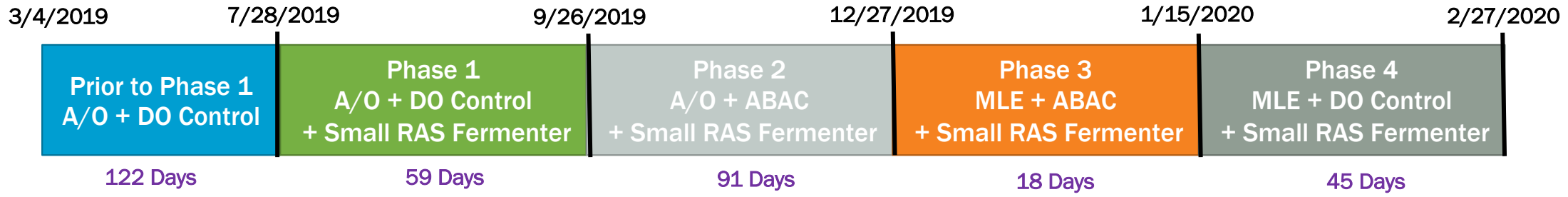
North Plant: Existing A/O Configuration

RAS Fermenter Parameter	Value
Fermenter Volume	0.58 MG
Fraction of North Plant	6.3%
RAS Flow	1.2-3.0 MGD
GTE Flow	2.0-2.6 MGD
HRT	3.6-4.3 hours
SRT	5-23 hours
Mixing	0.12 HP/kft^3

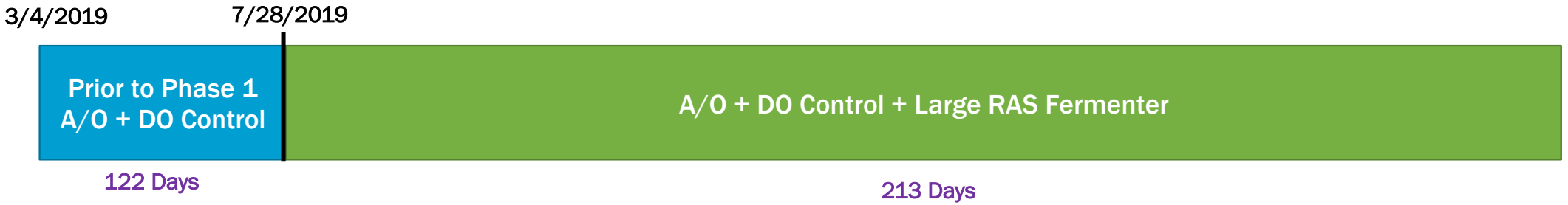


Operational Phases

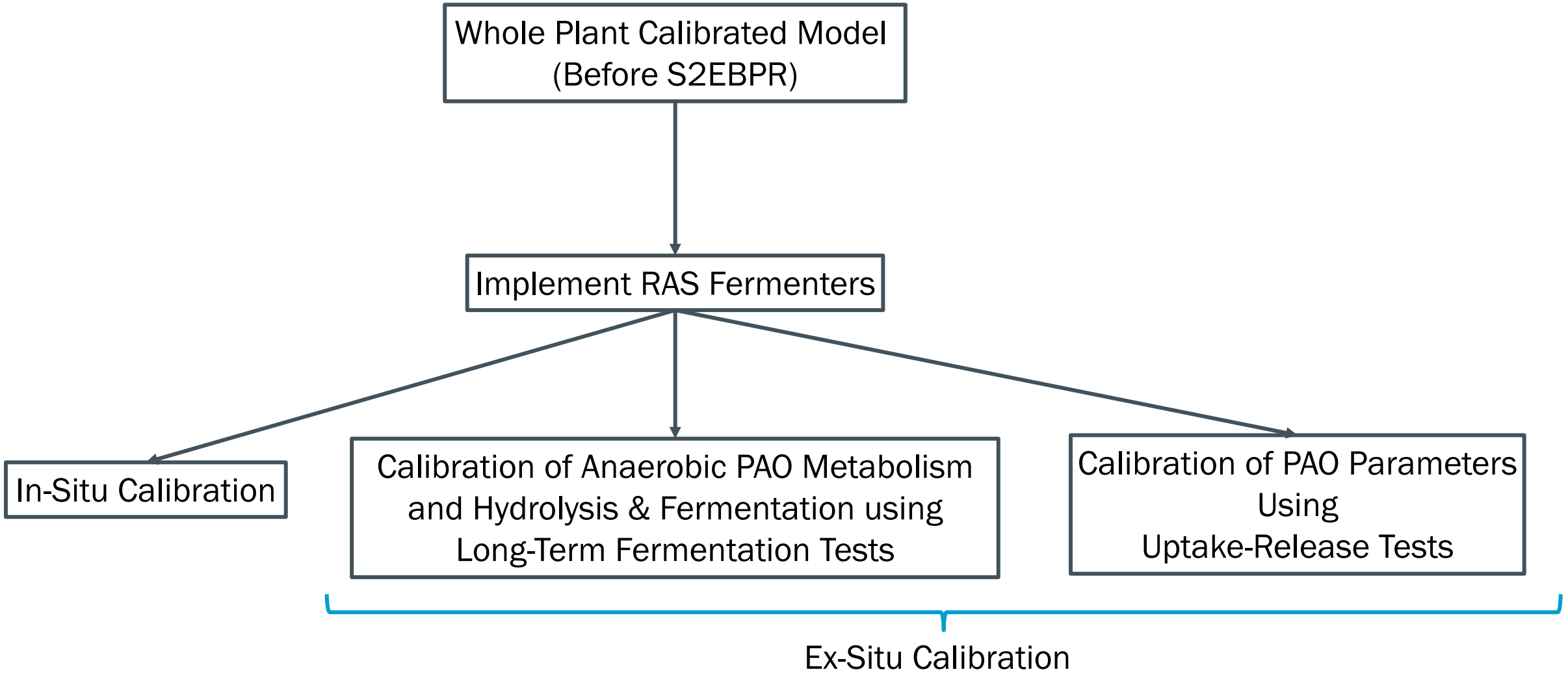
North AT 7-9 Operational Phases



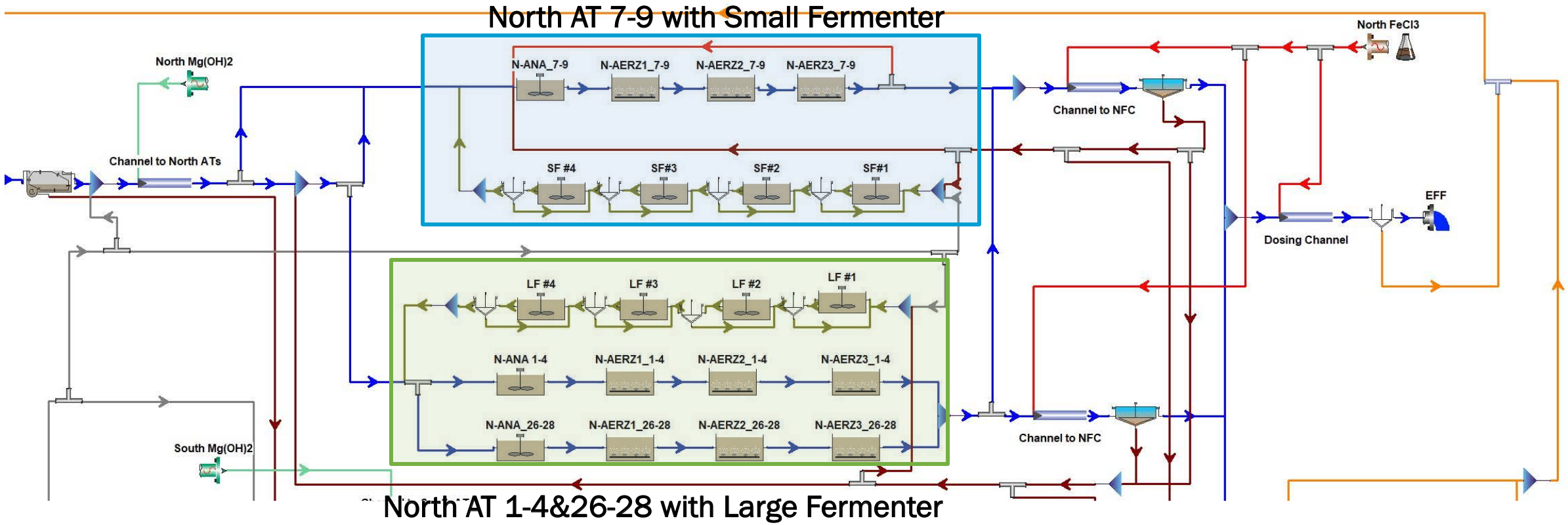
North Plant Operational Phases



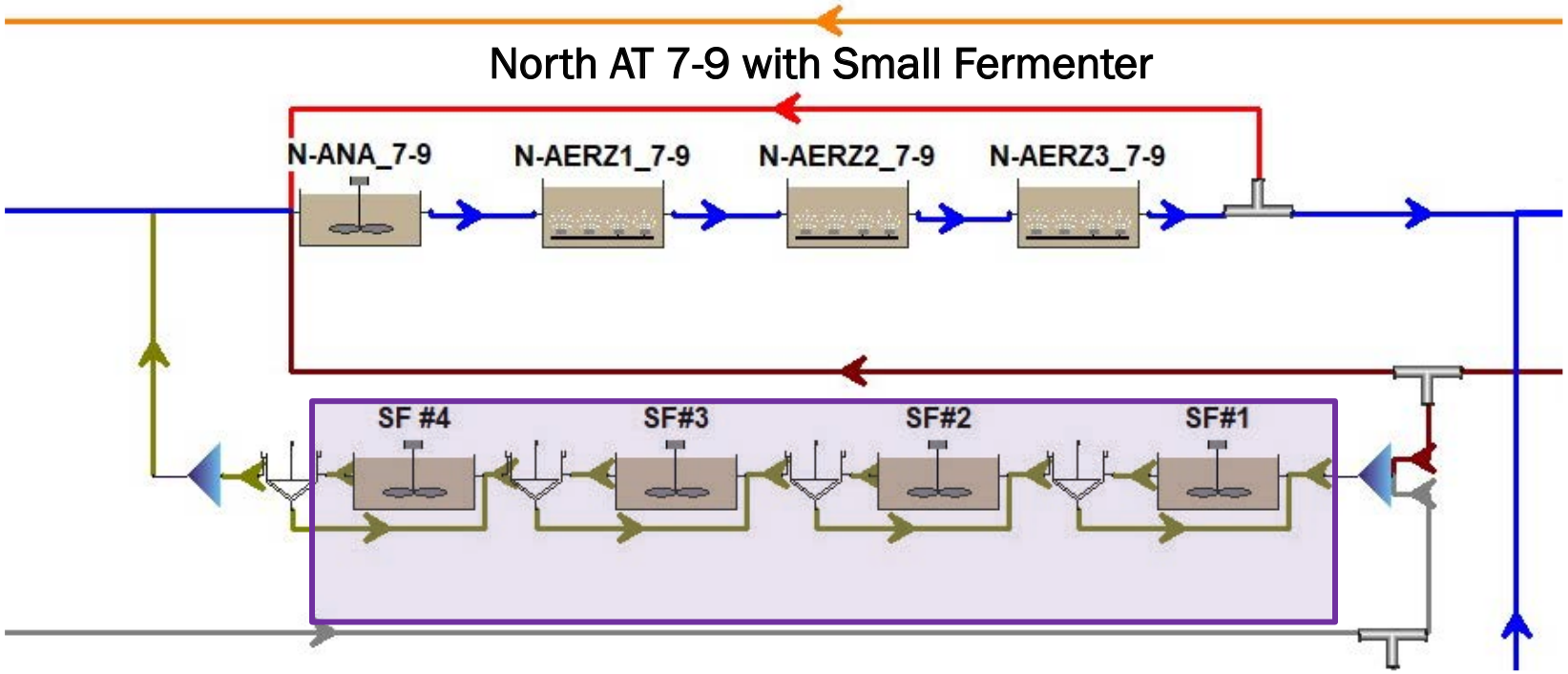
Modeling Approach



Model

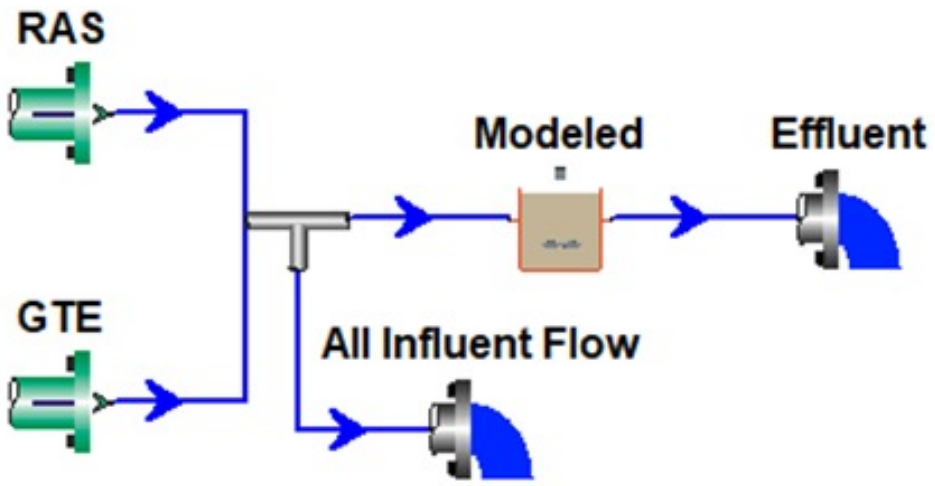

North AT 7-9 with Small Fermenter
North Mg(OH)2
Channel to North ATs
N-ANA_7-9
N-AERZ1_7-9
N-AERZ2_7-9
N-AERZ3_7-9
SF #4
SF#3
SF#2
SF#1
North FeCl3
Channel to NFC
EFF
Dosing Channel
LF #4
LF #3
LF #2
LF #1
N-ANA 1-4
N-AERZ1_1-4
N-AERZ2_1-4
N-AERZ3_1-4
N-ANA_26-28
N-AERZ1_26-28
N-AERZ2_26-28
N-AERZ3_26-28
South Mg(OH)2
Channel to NFC
North AT 1-4&26-28 with Large Fermenter

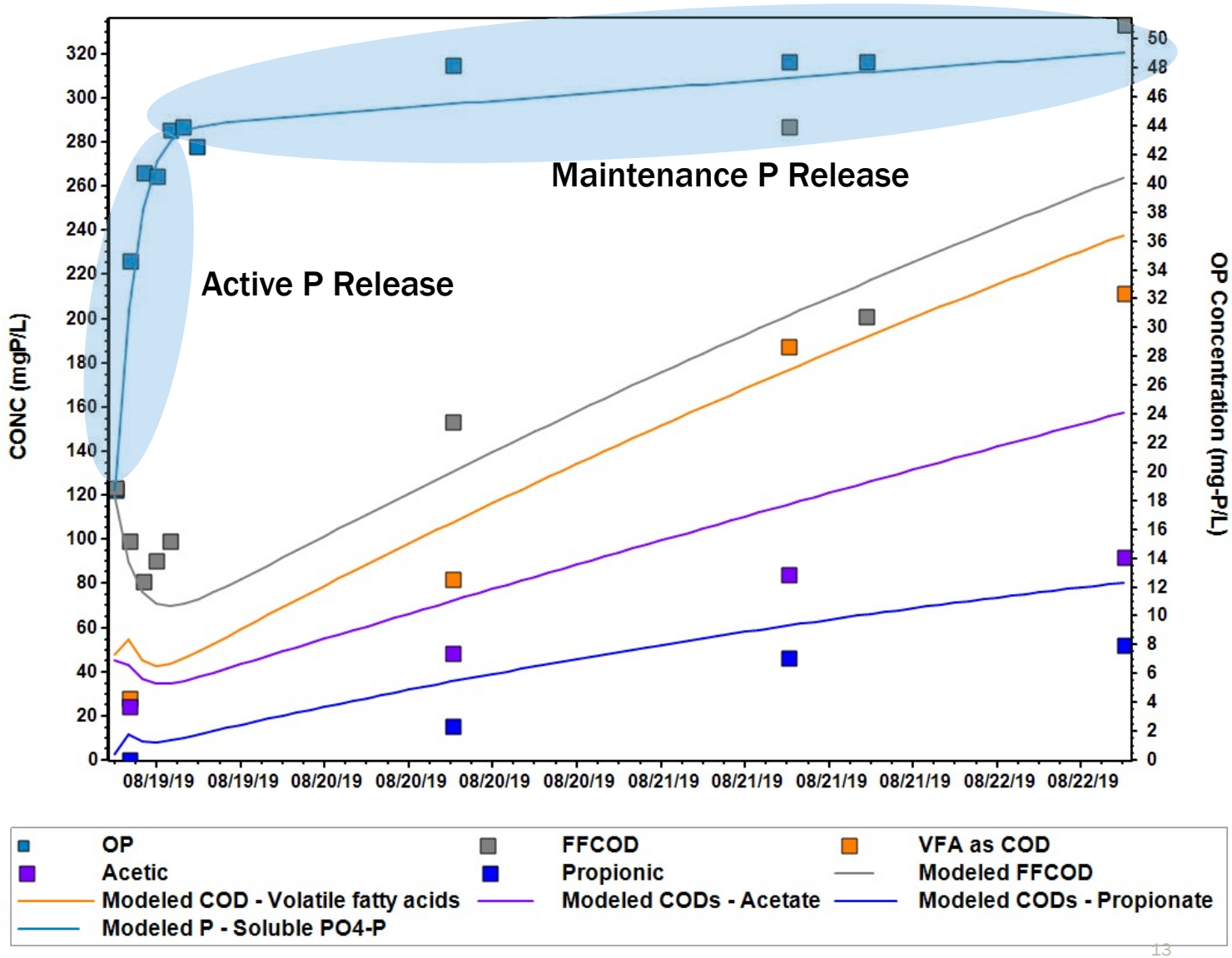
Model



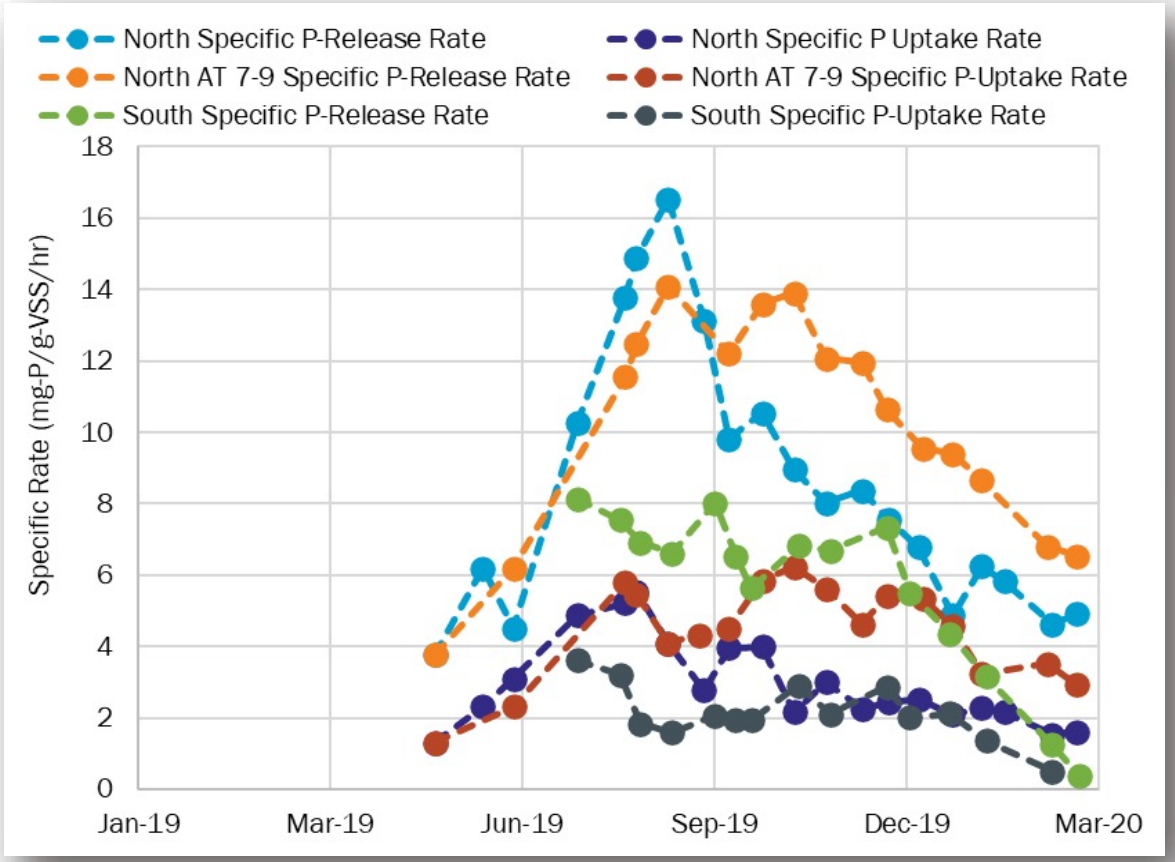
Point Clarifiers were used to simulate intermittent mixing

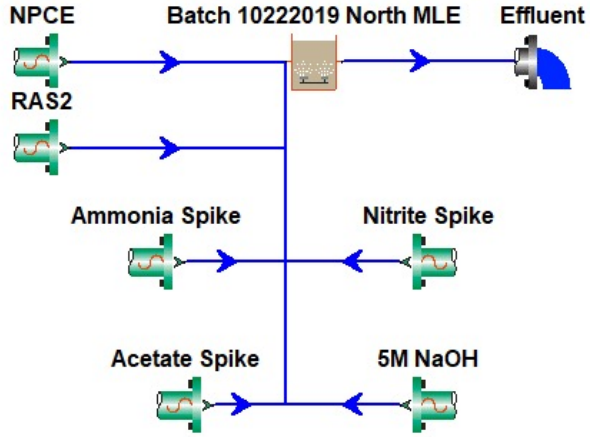
Activity Tests// Long Term Fermentation Test

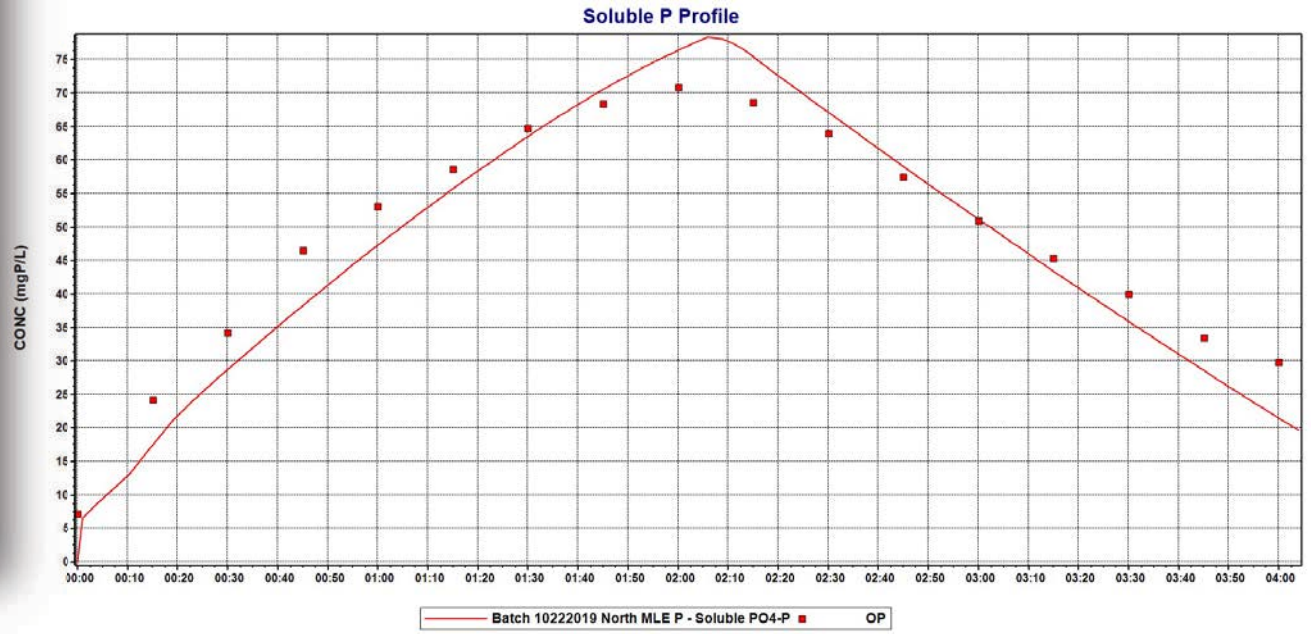




Activity Tests// Phosphorus Uptake and Release Tests







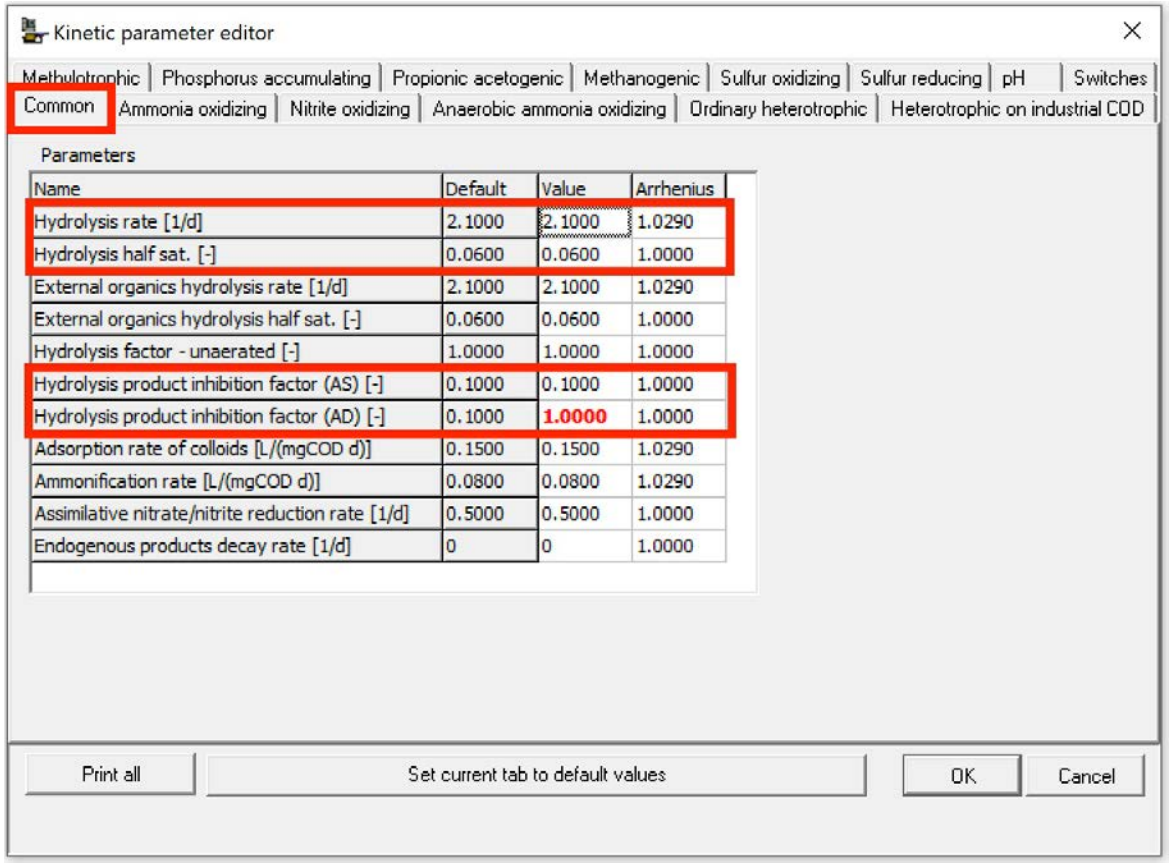
Hydrolysis // Modeling Challenges

- Model calibration in BioWin 6.2 suggested few issues
  - Hydrolysis rates were found to be variable between the gravity thickener, mainstream process and side-stream fermenters.
  - Significant change in hydrolysis factors had to be made to match both activity test and plant performance data.
  - Propionate utilization stoichiometry also varied between different processes, and this could not be adjusted in the model.
  - Transition between A/O to MLE not captured well by the model.

Hydrolysis // Model Changes

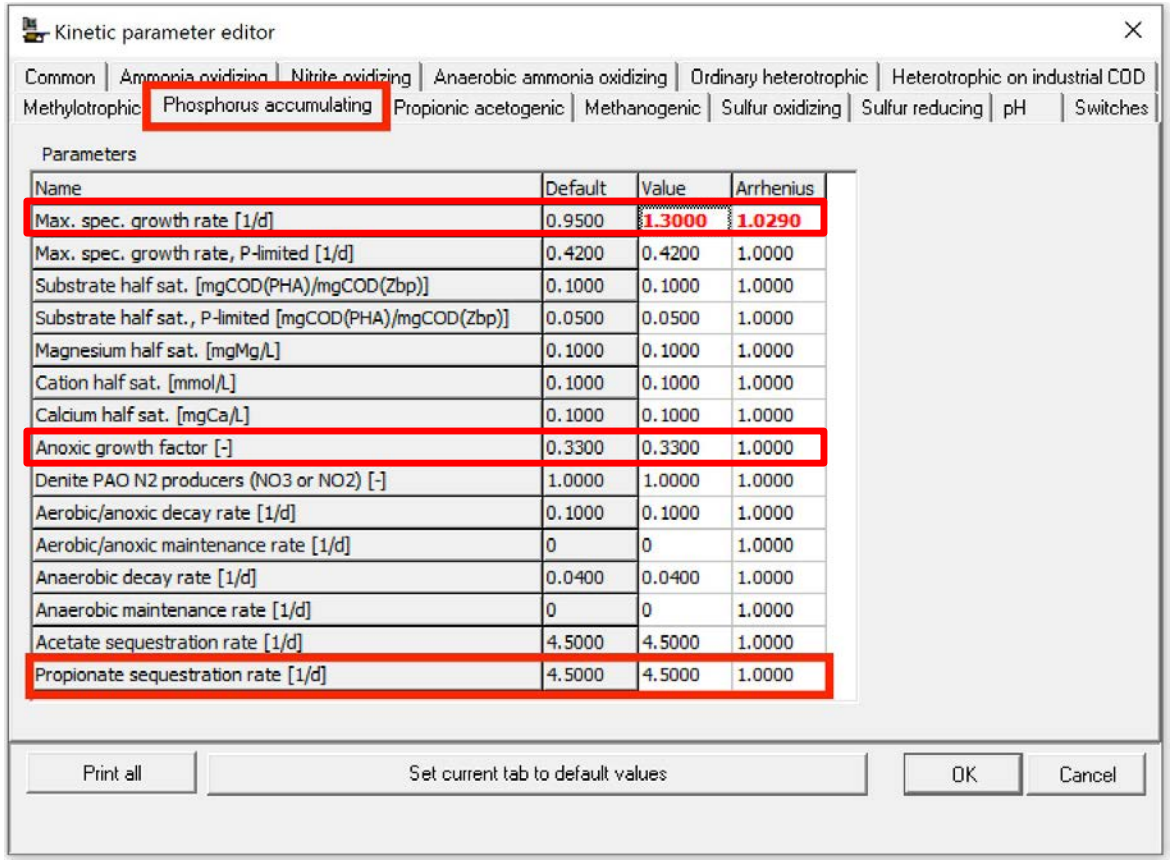
EnviroSim embarked on an intensive study to re-evaluate hydrolysis modeling

- Changed the traditional hydrolysis IWA ASM type model
- Adopted a new hydrolysis formulation based on standard product inhibition kinetics
- Accumulation of rbCOD from hydrolysis slows down the rate
- New hydrolysis formulation depends on biomass concentration, particulate substrate concentration, and the concentration of rbCOD from hydrolysis
- Neta factor (η) for adjusting the rate under AS unaerated conditions (anoxic or anaerobic) or AD



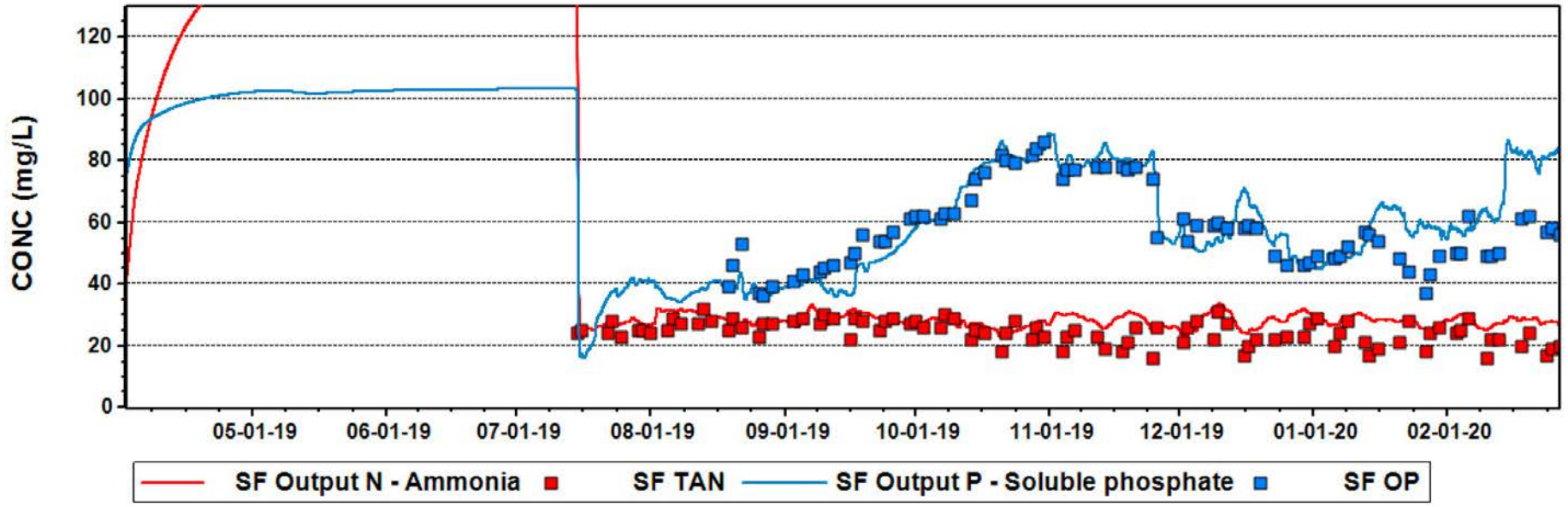
PAO// Kinetics and Stoichiometry

- Phosphorus accumulating shows newly surfaced propionate sequestration rate. Default is identical to acetate.
- New default Max. spec. growth rate will likely be 1.3 [1/d].
- New default Anoxic growth factor may be changed to 0.5.
  - McAlpine calibration worked well with the current default anoxic growth factor of 0.33.
- Temperature dependence of PAO kinetics increased from default of 1.0 (no dependence) to 1.0290

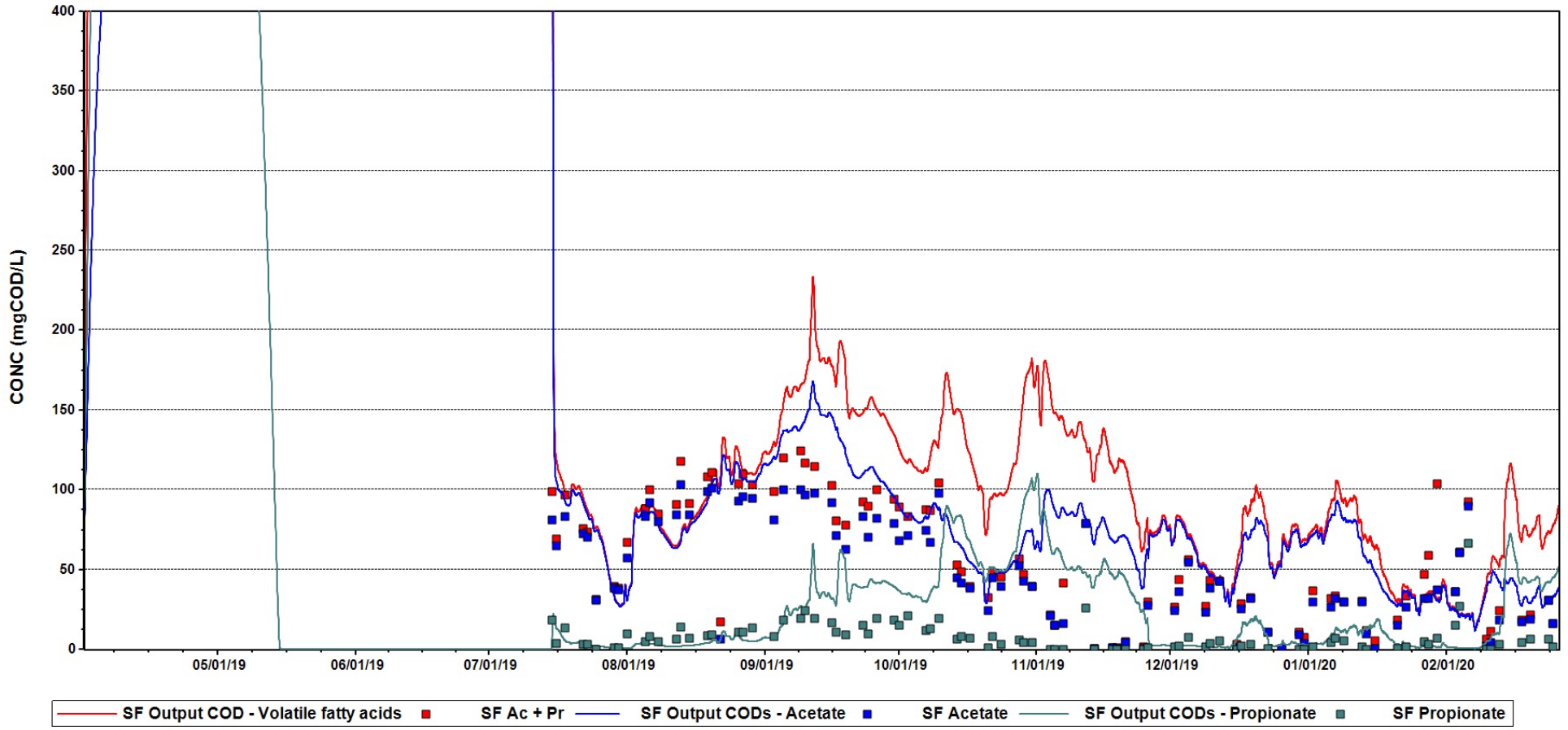


Results// Small RAS Fermenter Effluent

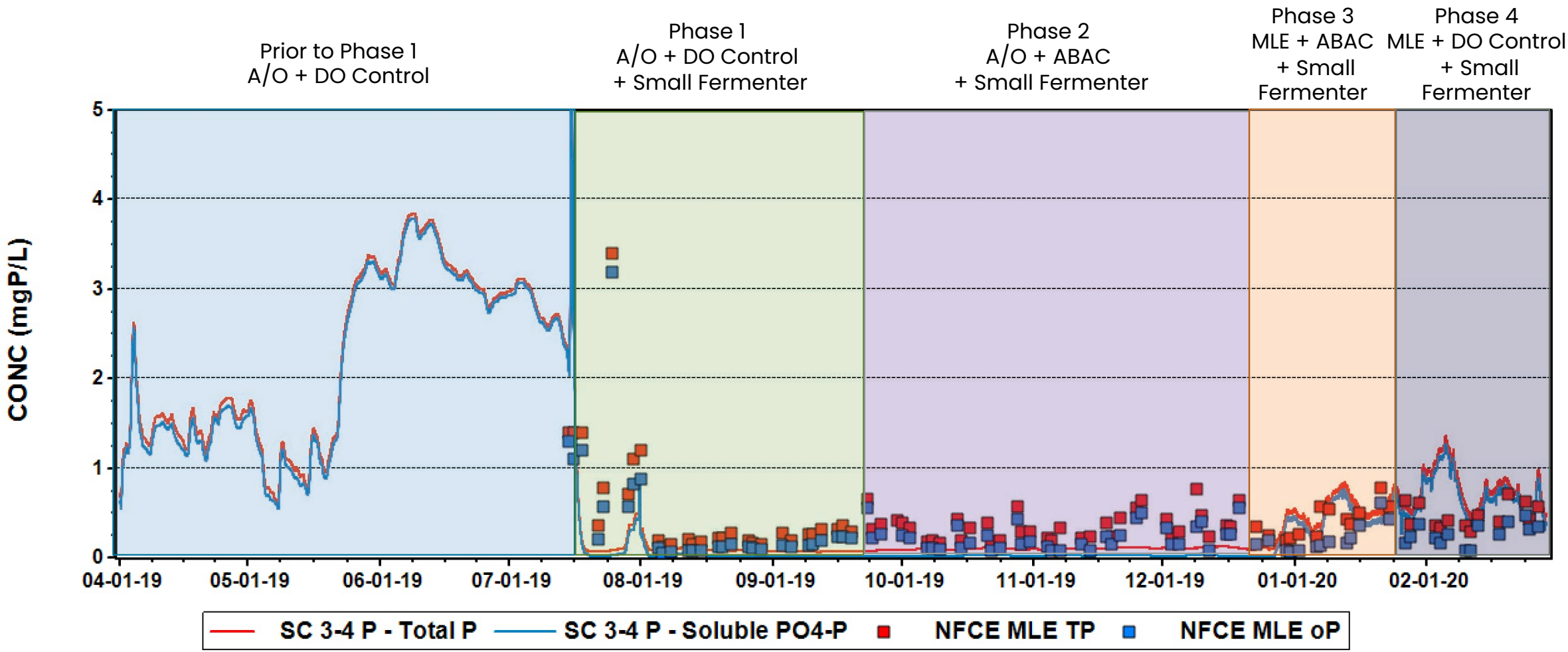
- P concentration reflects complete release of stored Poly-P in the RAS
  - Yield of Low PP = 0.995 (new default)
- P concentration impacted by changing dilution with changing GTE flow
- Model also tracks the ammonia concentration which can be used as a surrogate for hydrolysis.



Results// Small RAS Fermenter Hydrolysis and Fermentation



Results// North AT 7-9 Secondary Effluent TP and OP

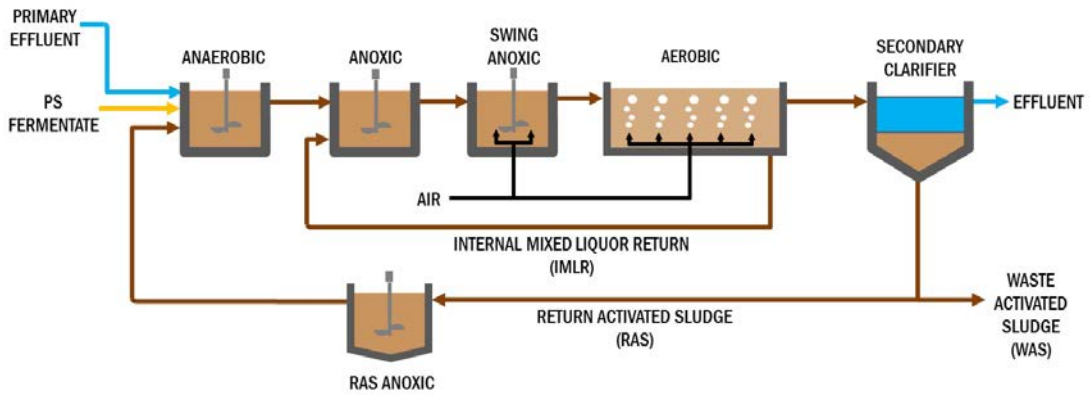


Validation of Model Calibration

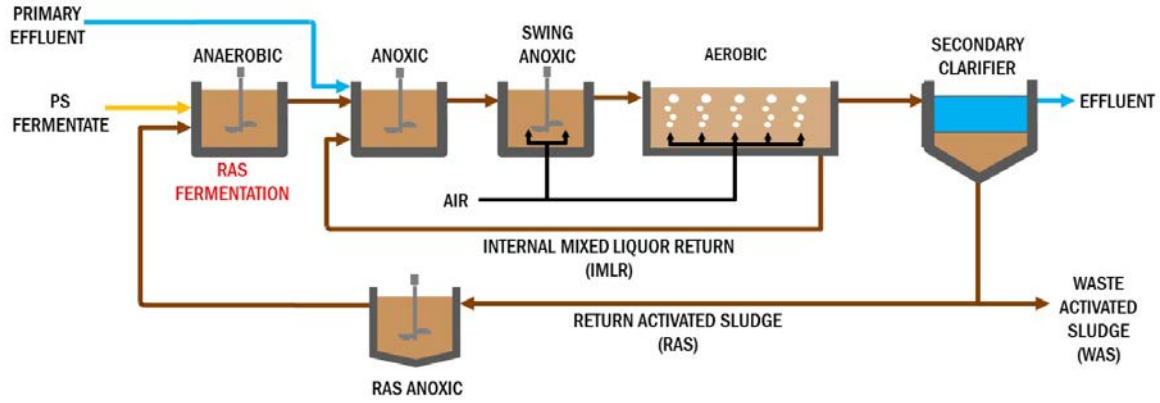
Central Valley WRF S2EBPR Pilot

Central Valley WRF Pilot

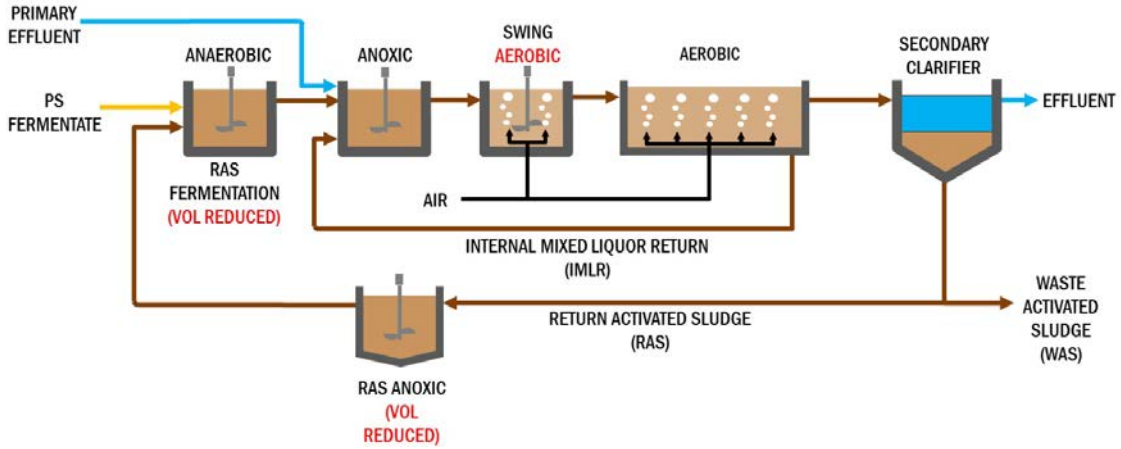
Phase 1 – A2O



Phase 2 – SSRC (Anaerobic HRT = 4.2 hrs)



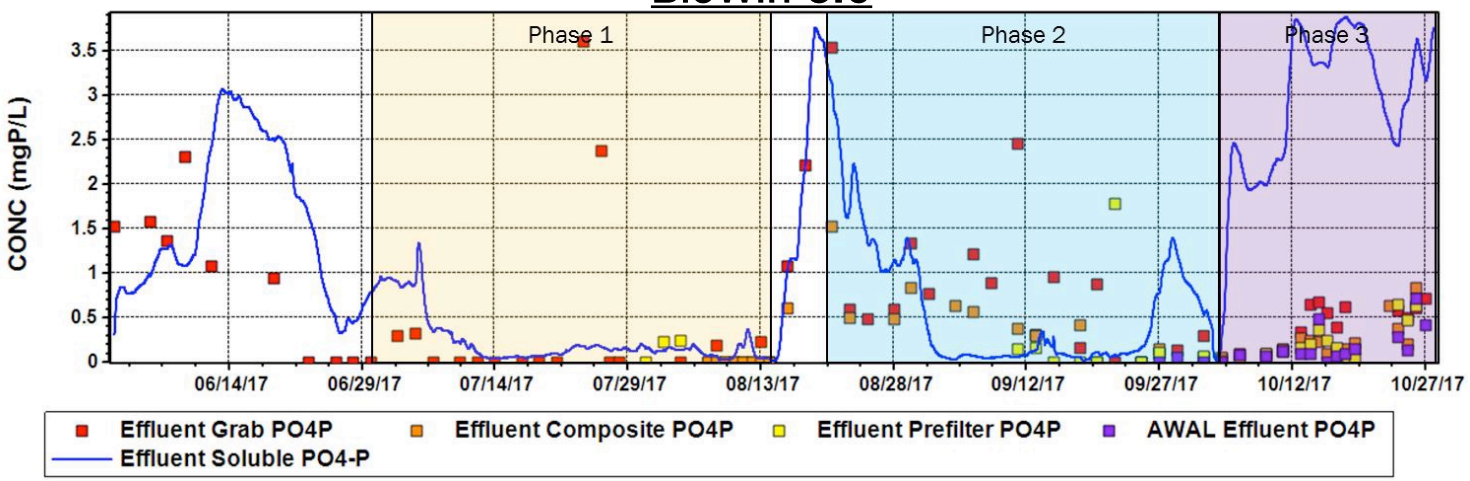
Phase 2 – SSRC (Anaerobic HRT = 2 hrs)



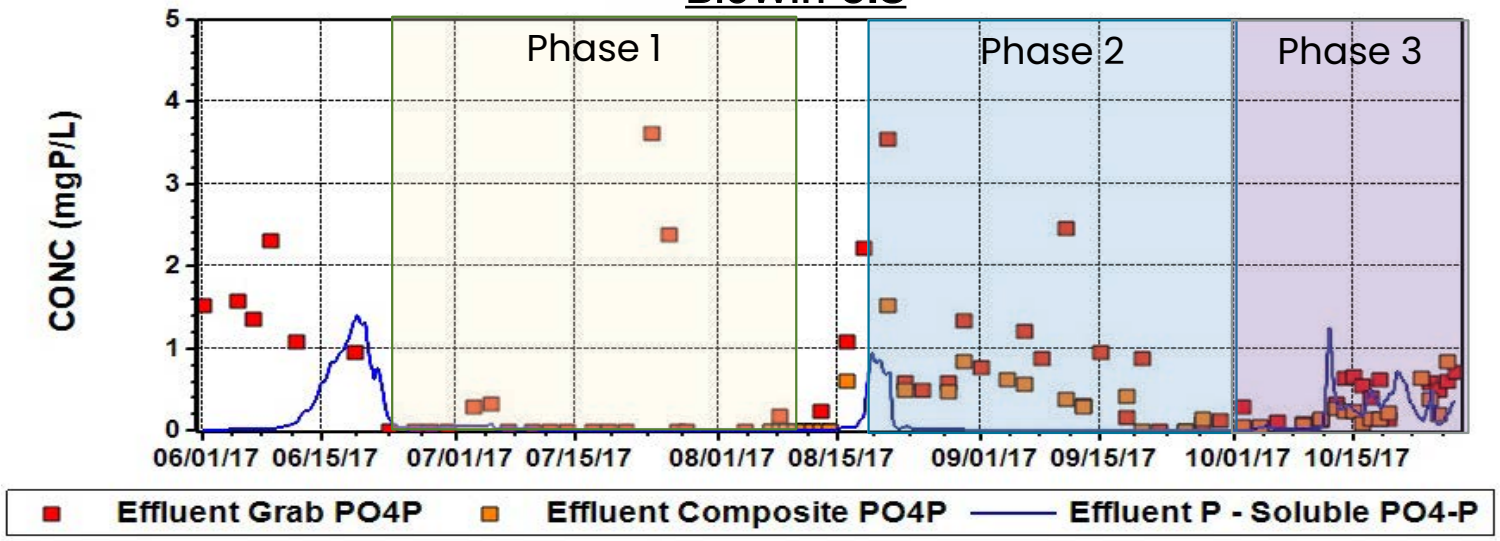
Validation of BioWin 6.3 Model

- Used same parameters as McAlpine calibration.
- Default values in BW 6.3.

BioWin 6.0



BioWin 6.3



Conclusions and Future Outlook

- A combination of in-situ and ex-situ calibrations can yield a more robust calibration of full-scale models for S2EBPR.
- A deeper understanding and improved modeling of hydrolysis and fermentation is critical to simulate EBPR processes.
- It is important to calibrate full-scale S2EBPR models to model temperature effects on hydrolysis and PAO metabolism.
- Validation of developed models with more full-scale S2EBPR systems is important with a focus on transferrable calibration parameters.

Thank you.

Questions?

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Brown AND Caldwell