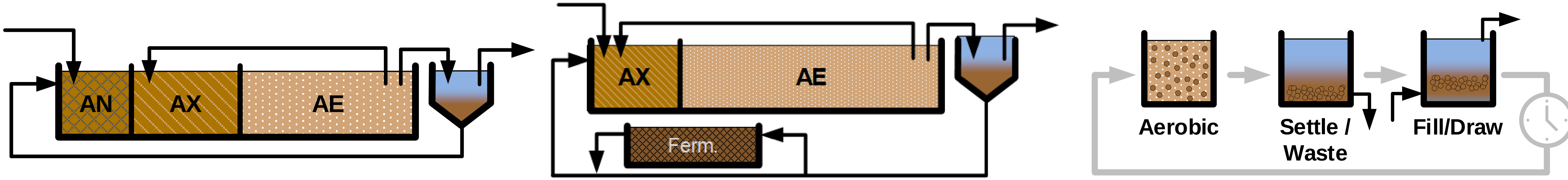
Diversifying the Carbon Portfolio Using Cranberry Syrup Waste as Supplemental Carbon Source in a Sidestream EBPR Demonstration.

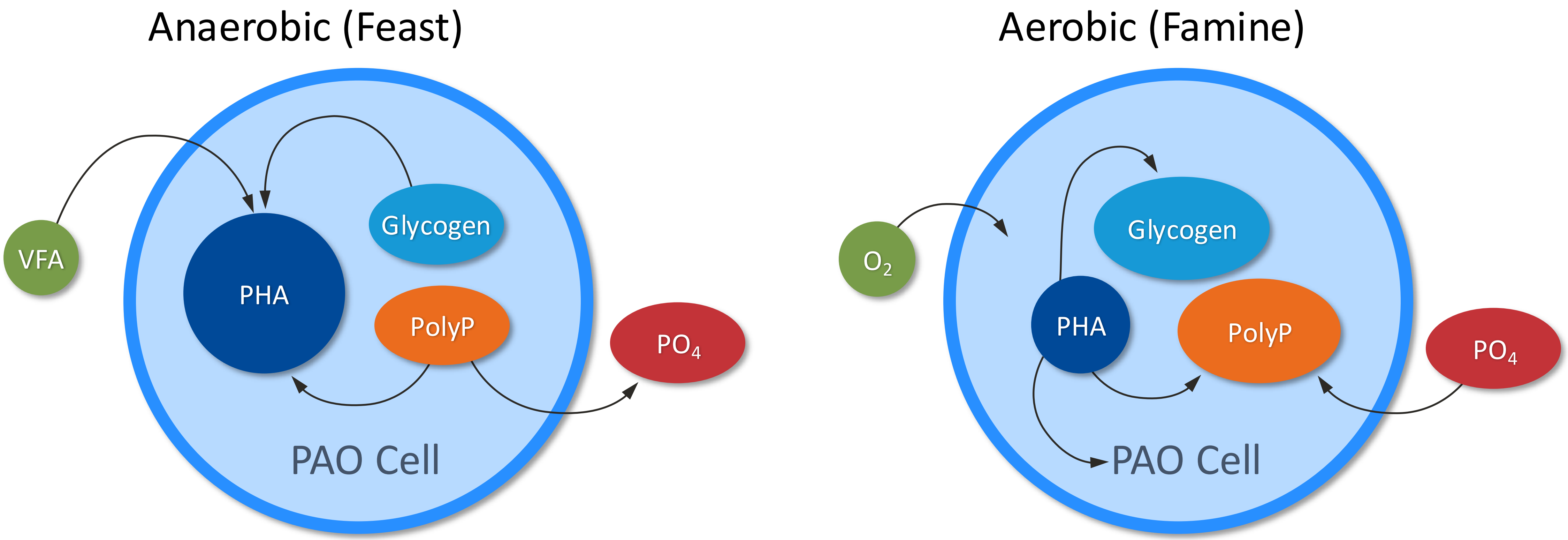
Patrick Dunlap, Fabrizio Sabba

“Enhanced” Biological Phosphorus Removal (EBPR)

- More **cost effective** and sustainable than chemical precipitation.
- Removal of P in excess of what is needed for normal biological growth by poly-phosphate accumulating organisms (**PAO**s)
- Selection of PAOs requires **cyclical** process conditions with **Anerobic (feast) Aerobic (famine) phases**.



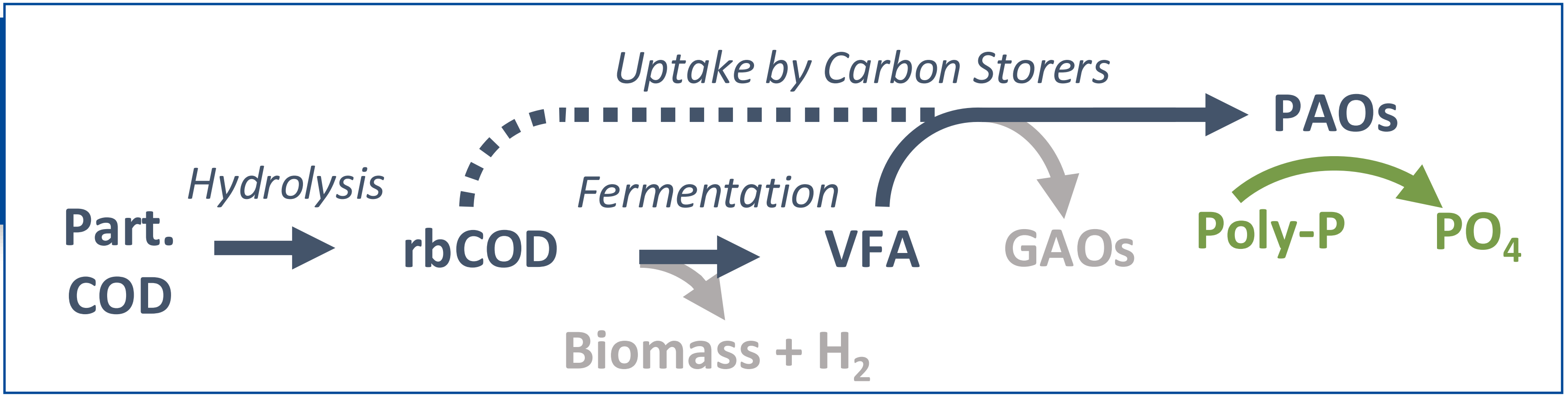
Classic Model of Poly-Phosphate Accumulating Biology



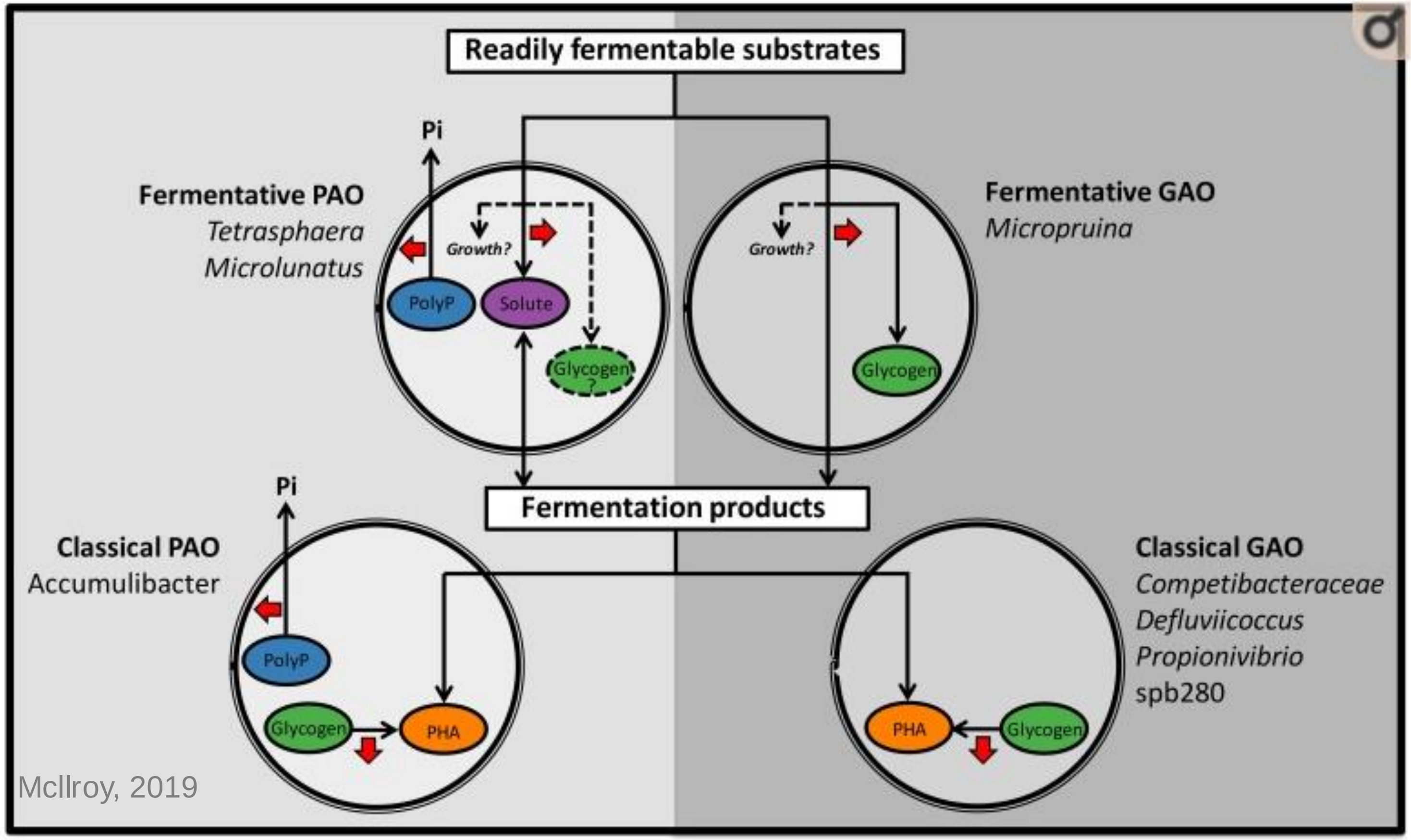
Need enough VFA to generate sufficient PHA

Sufficient PHA is required to uptake soluble phosphorus

Efficiency of EBPR Carbon Use



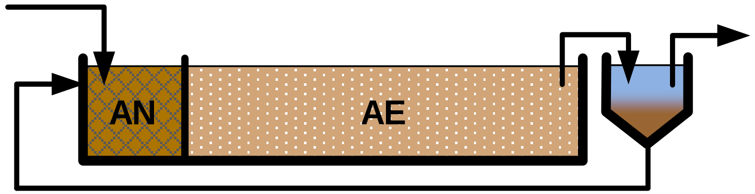
- **Multistep process:**
  - Hydrolysis is slow
  - Some loss in Fermentation
- **Anaerobic carbon storers may:**
  - Use rbCOD or VFA
  - Exhibit luxury P uptake (form Poly-P) or not



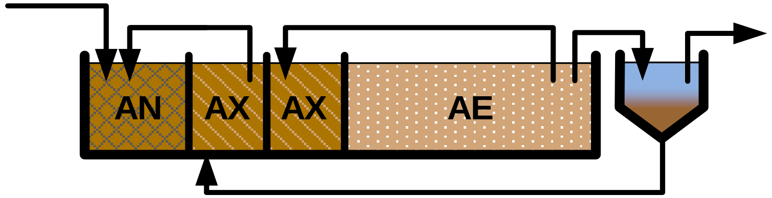
McIlroy, 2019

Conventional and S2EBPR

Conventional EBPR



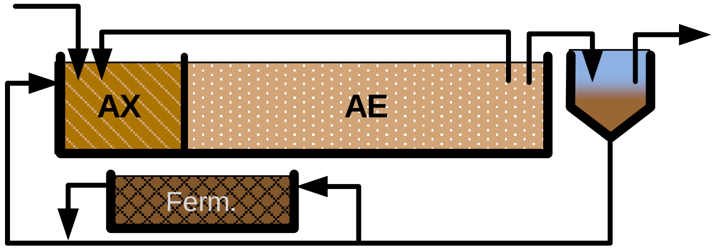
Phoredox (AO)



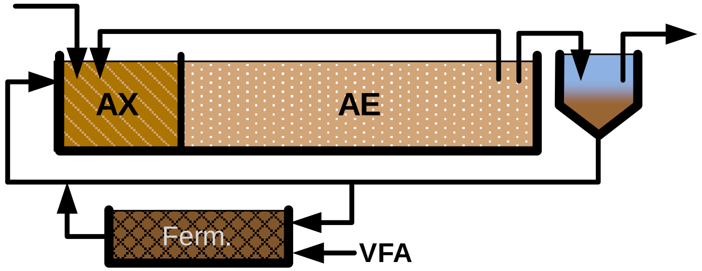
Modified University of Cape Town

- Differences are mainly N Limits and how to manage the nitrate to protect AN conditions.

Sidestream EBPR



Side-Stream RAS Fermentation (SSR)

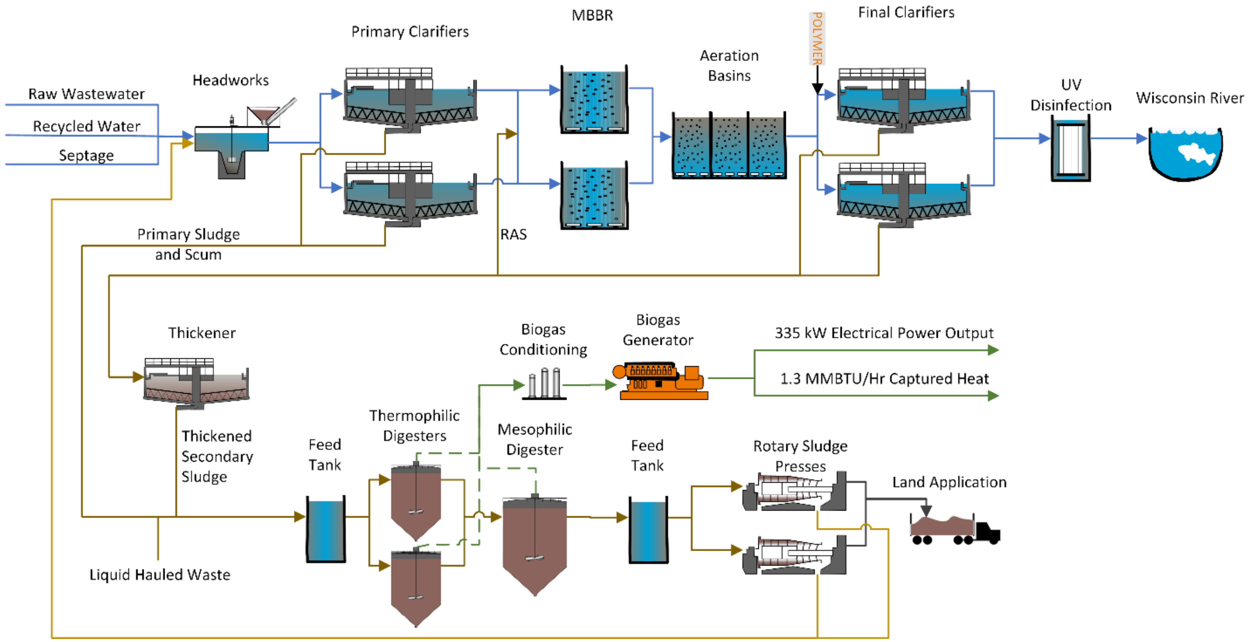


Side-Stream RAS Fermentation w/ Additional Carbon (SSRC)

- Tankage that could be repurposed
- Challenges upgrading to conventional EBPR
- High RAS nitrate / ability to split a portion of RAS
- Poor influent characteristics for EBPR or low C:P

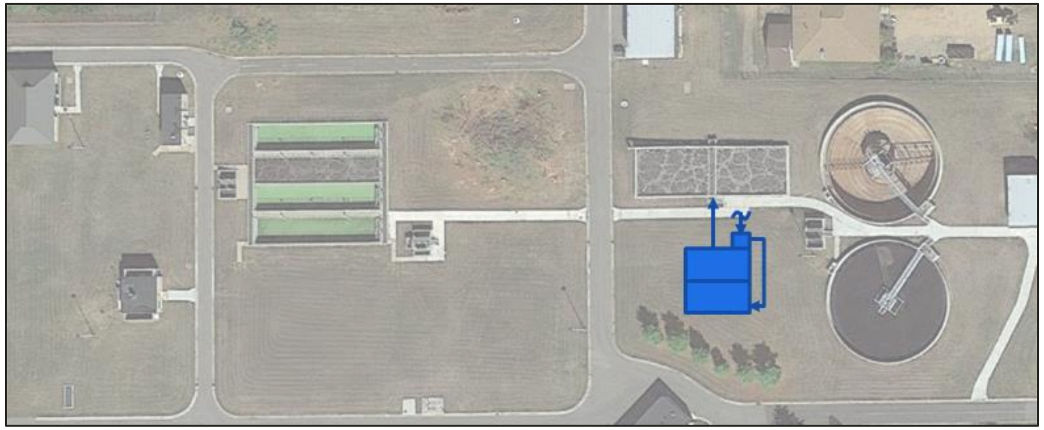
Wisconsin Rapids

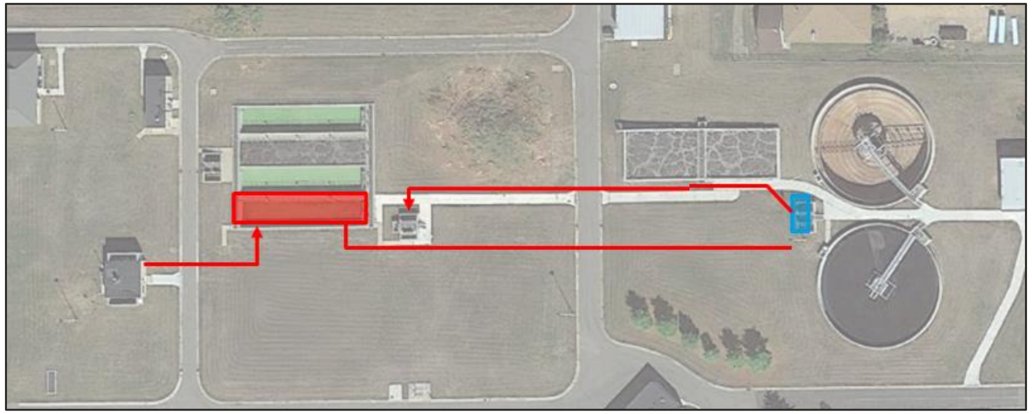
Wisconsin Rapids WWTP

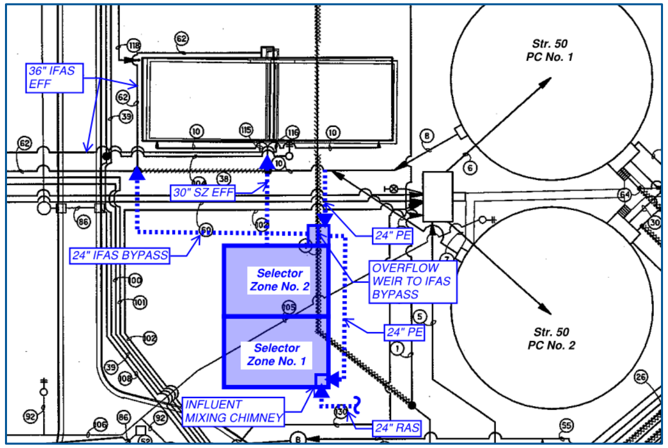


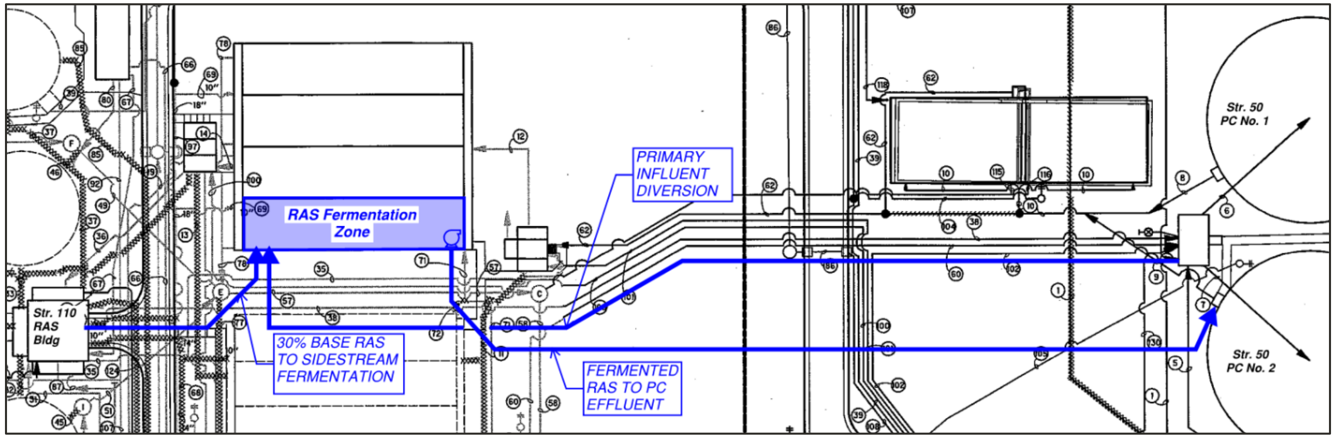
- Average flow is 3.5 mgd, Peak day flow is 12 mgd
- Future effluent P limit of 0.36 mg/L
- Currently remove with PACl to ~0.4-0.8 mg/L

Upgrade Options for EBPR

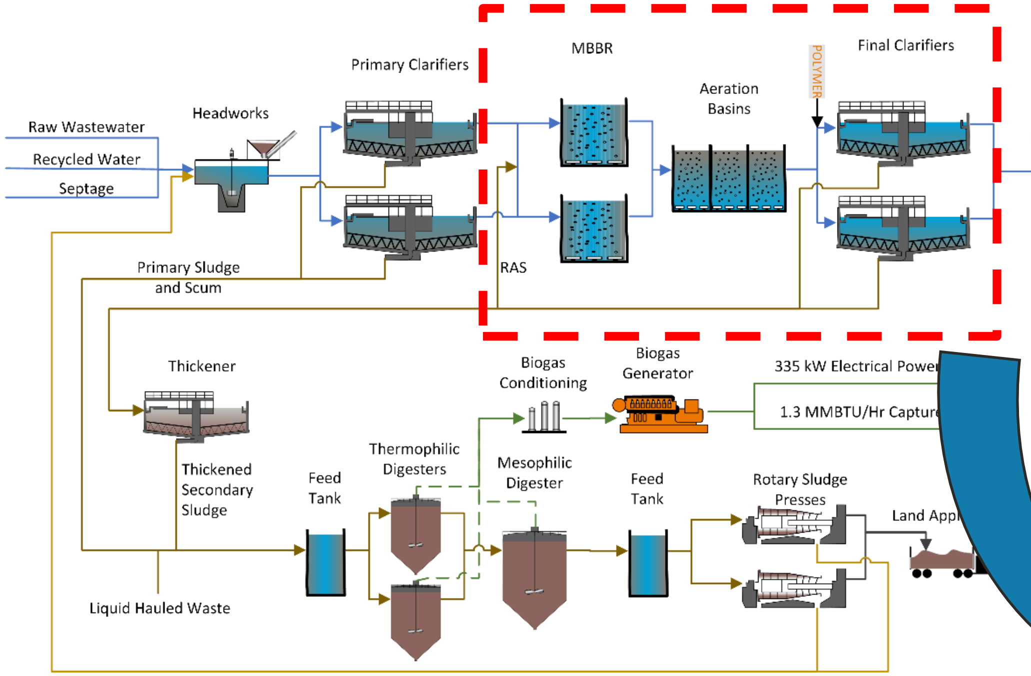


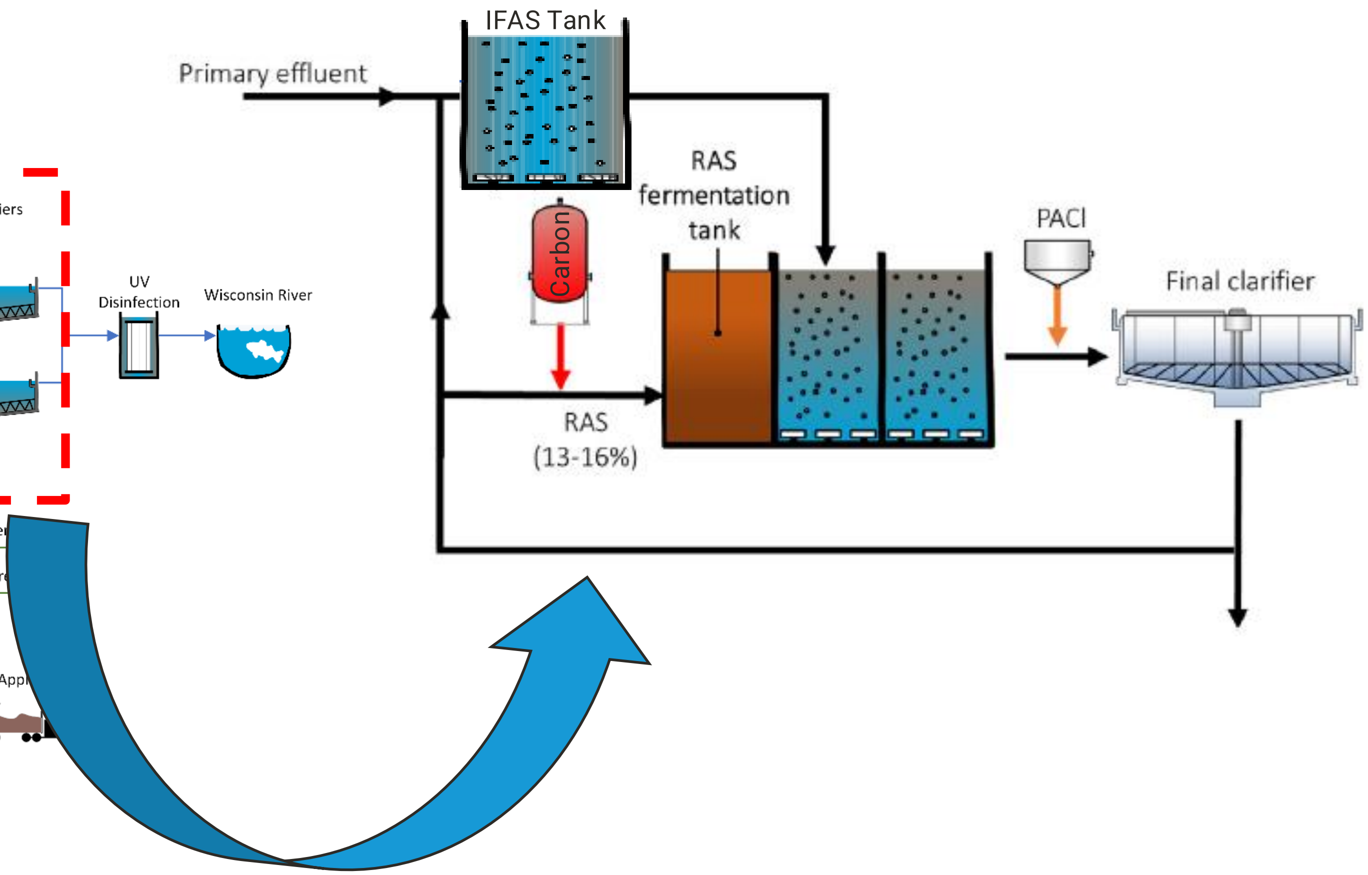




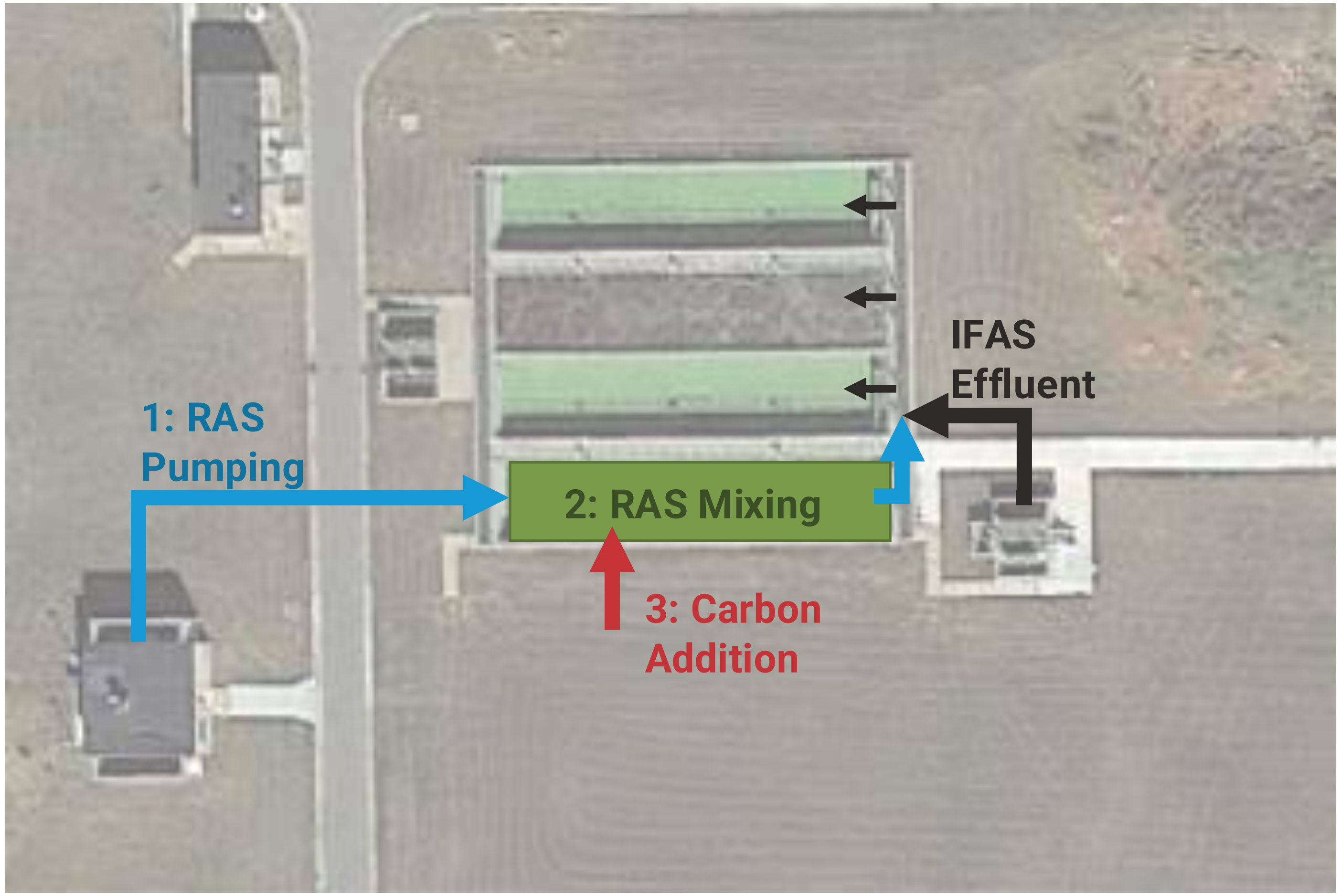


RAS Fermentation + Carbon Demonstration Concept



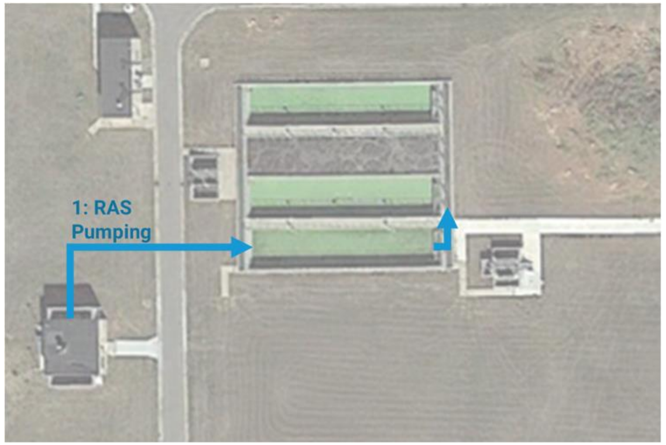


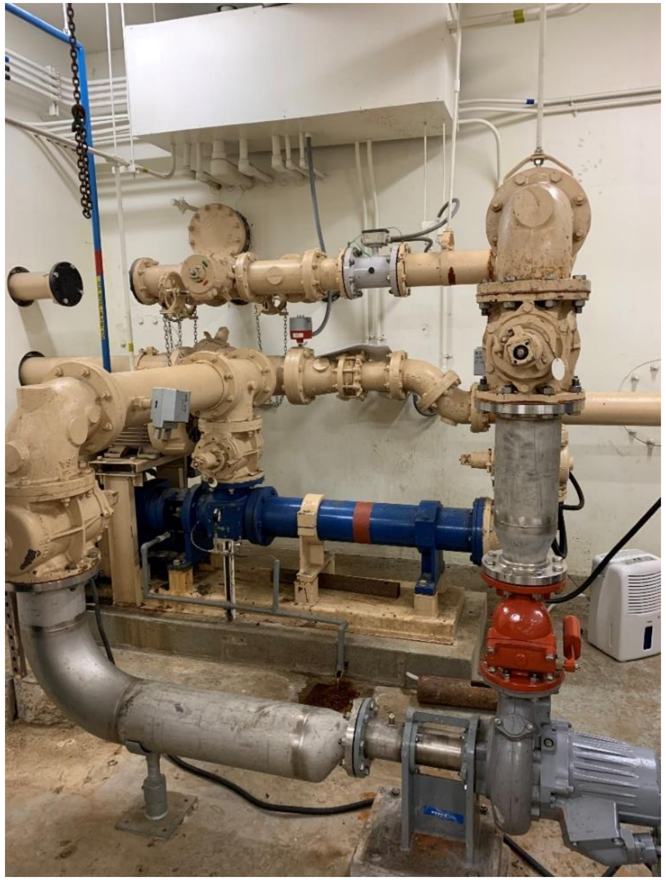
How to Cost Effectively Demonstrate Fermentation Process with Specific Carbon Source?



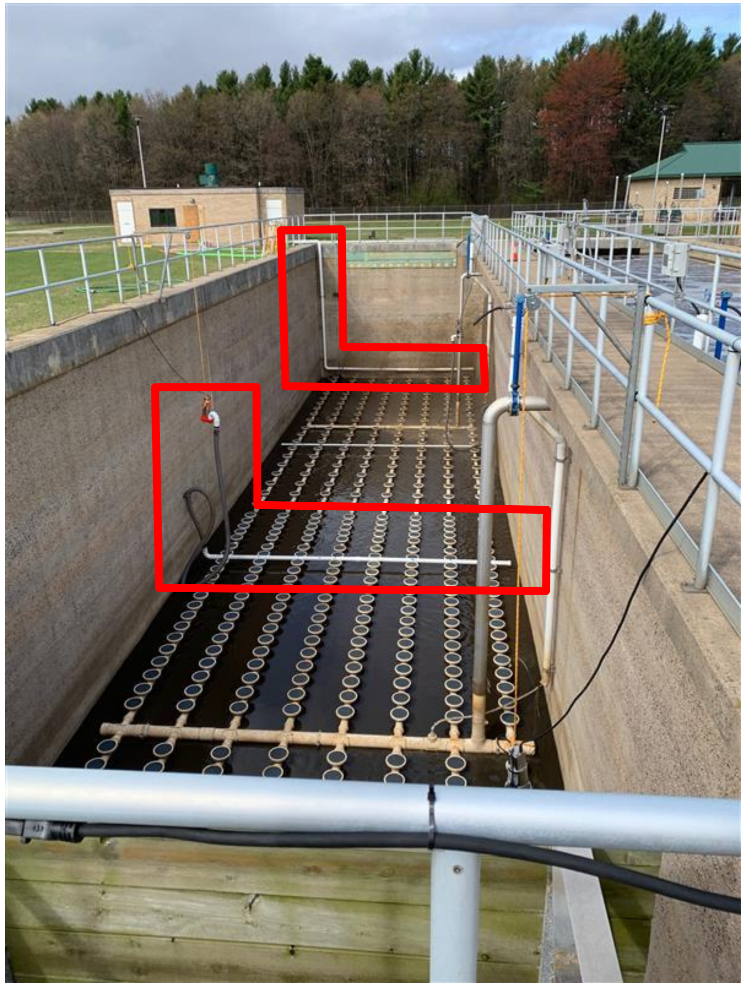
1: RAS Diversion

- Temporary piping from RAS building
- Utilized backup WAS pump for diversion
- Preliminary sizing: 30% RAS diversion, 1,000 gpm
- Existing pumps: limited to approximately 500 gpm

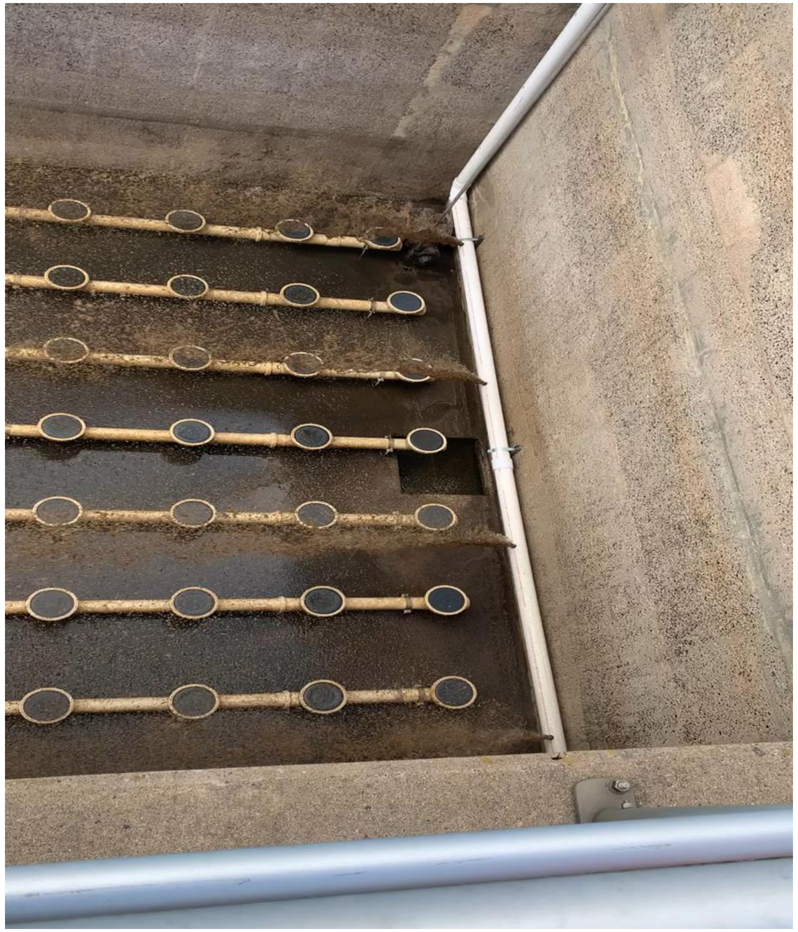




2: RAS Mixing

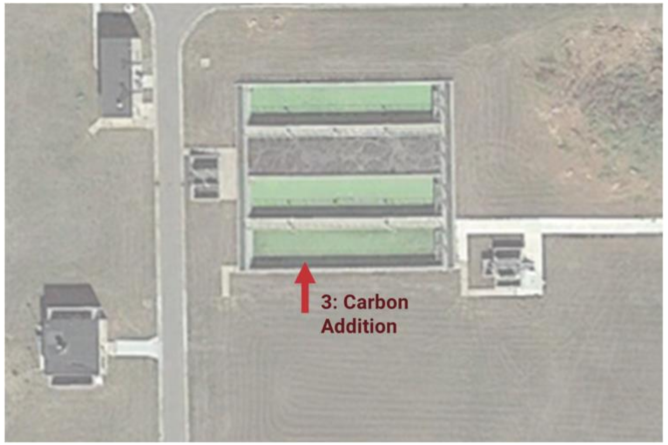


2: RAS Mixing

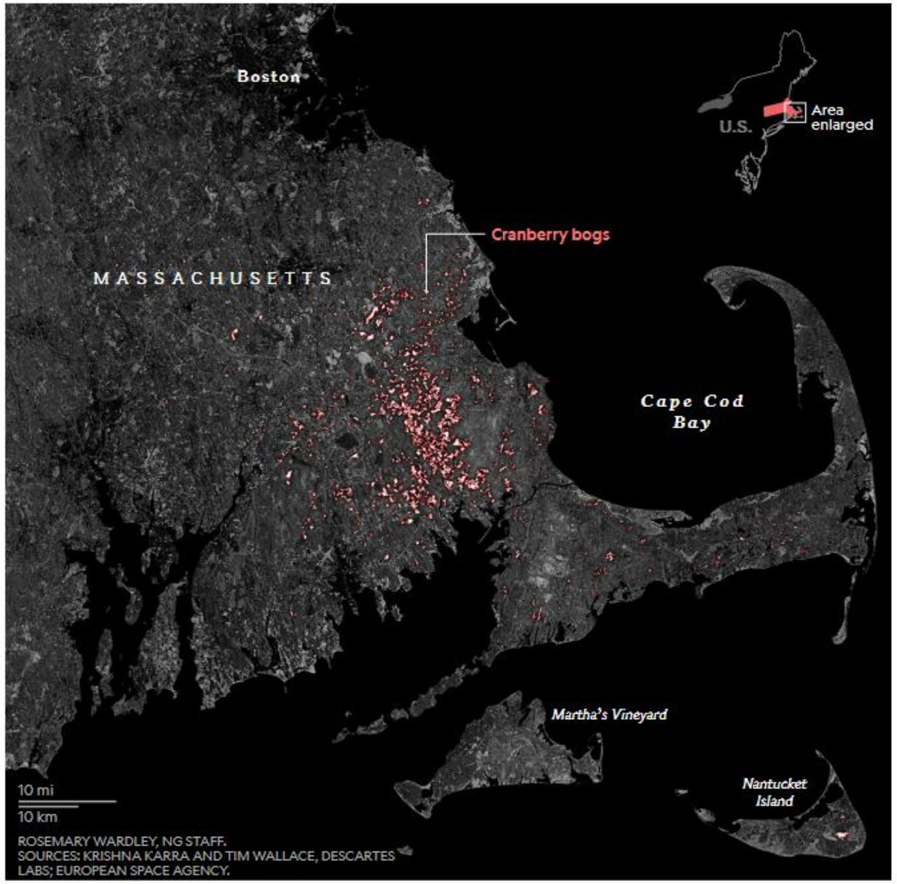


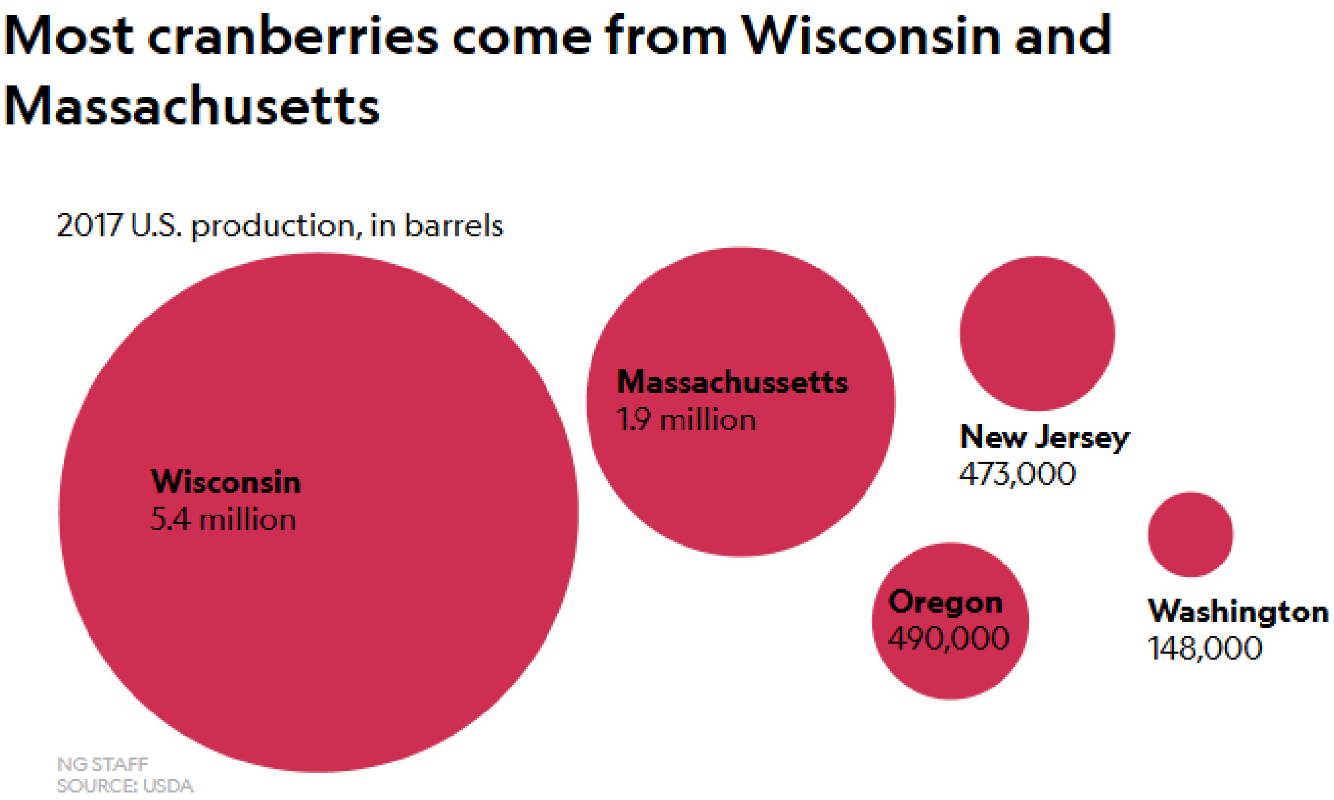
3: Carbon Addition

- Explore sources of industrial or food processing waste with concentrated carbon (rbCOD)
- Soda wastes, brewery wastes, glycerol, glycol
- Here we used cranberry syrup waste as C source



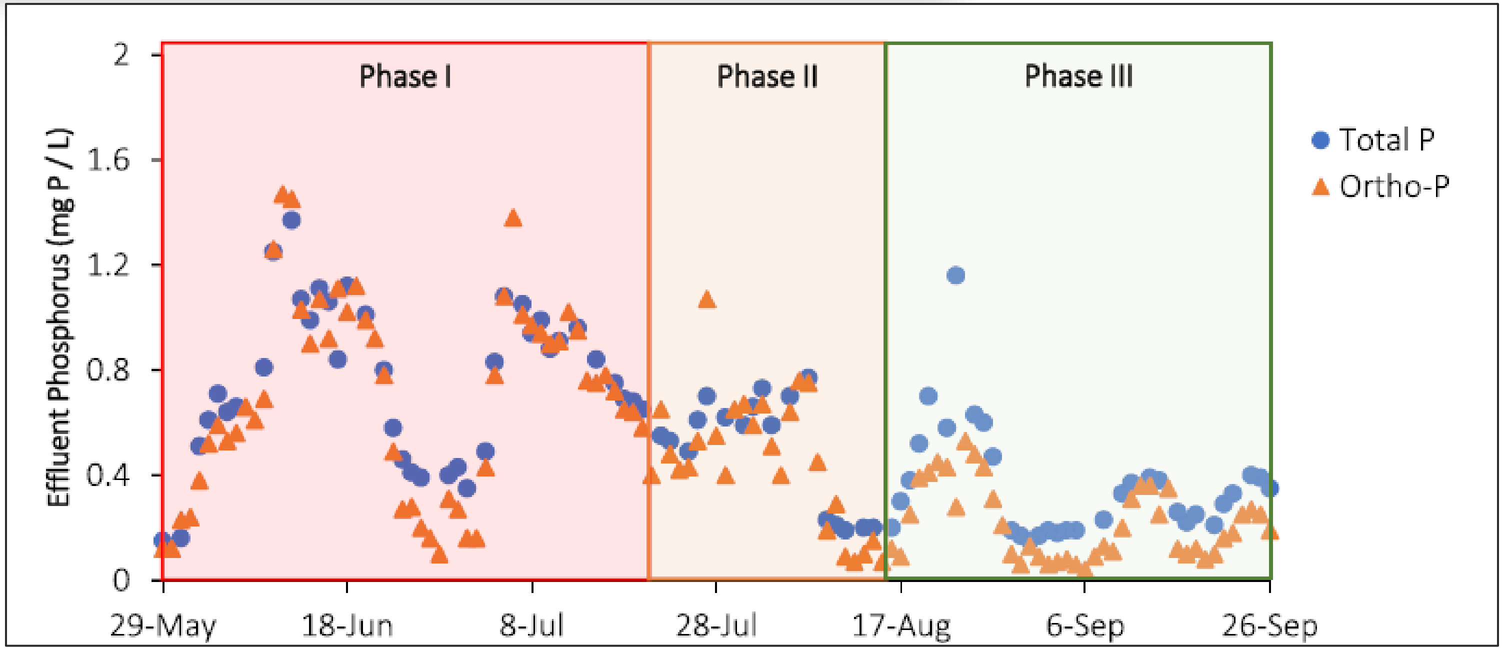
3: Carbon Addition

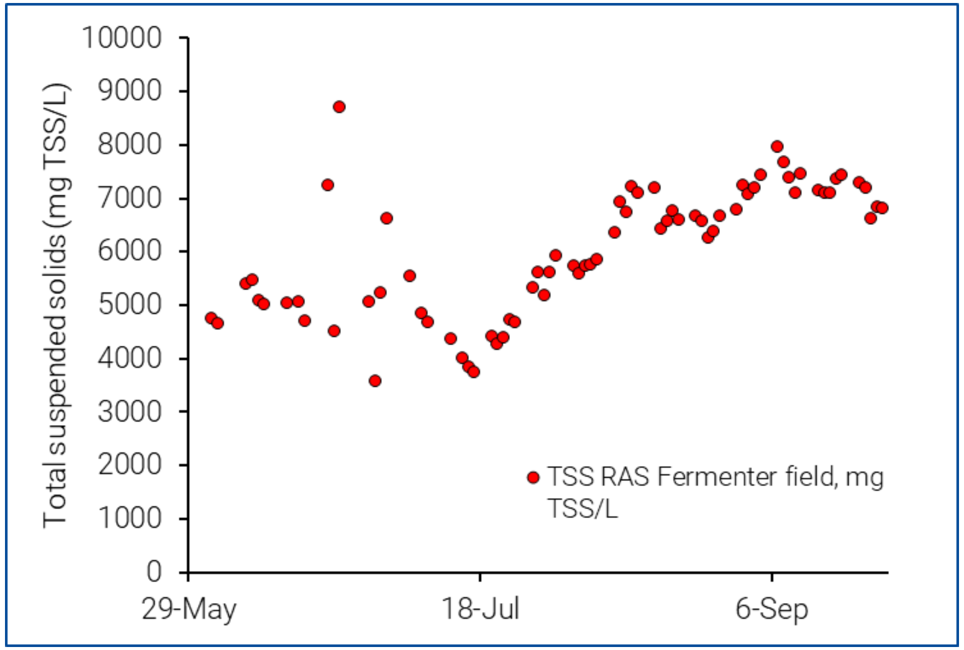




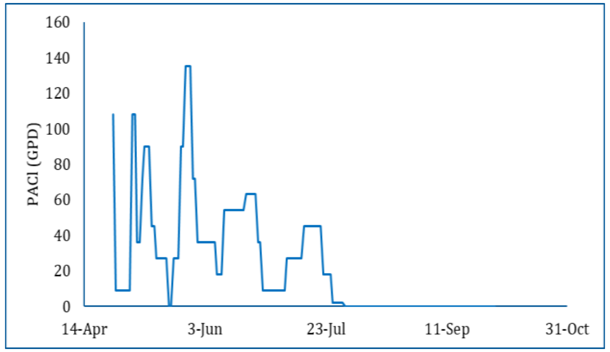
www.nationalgeographic.com/history/article/united-states-cranberry-harvest-explained-charts

Key operational phases

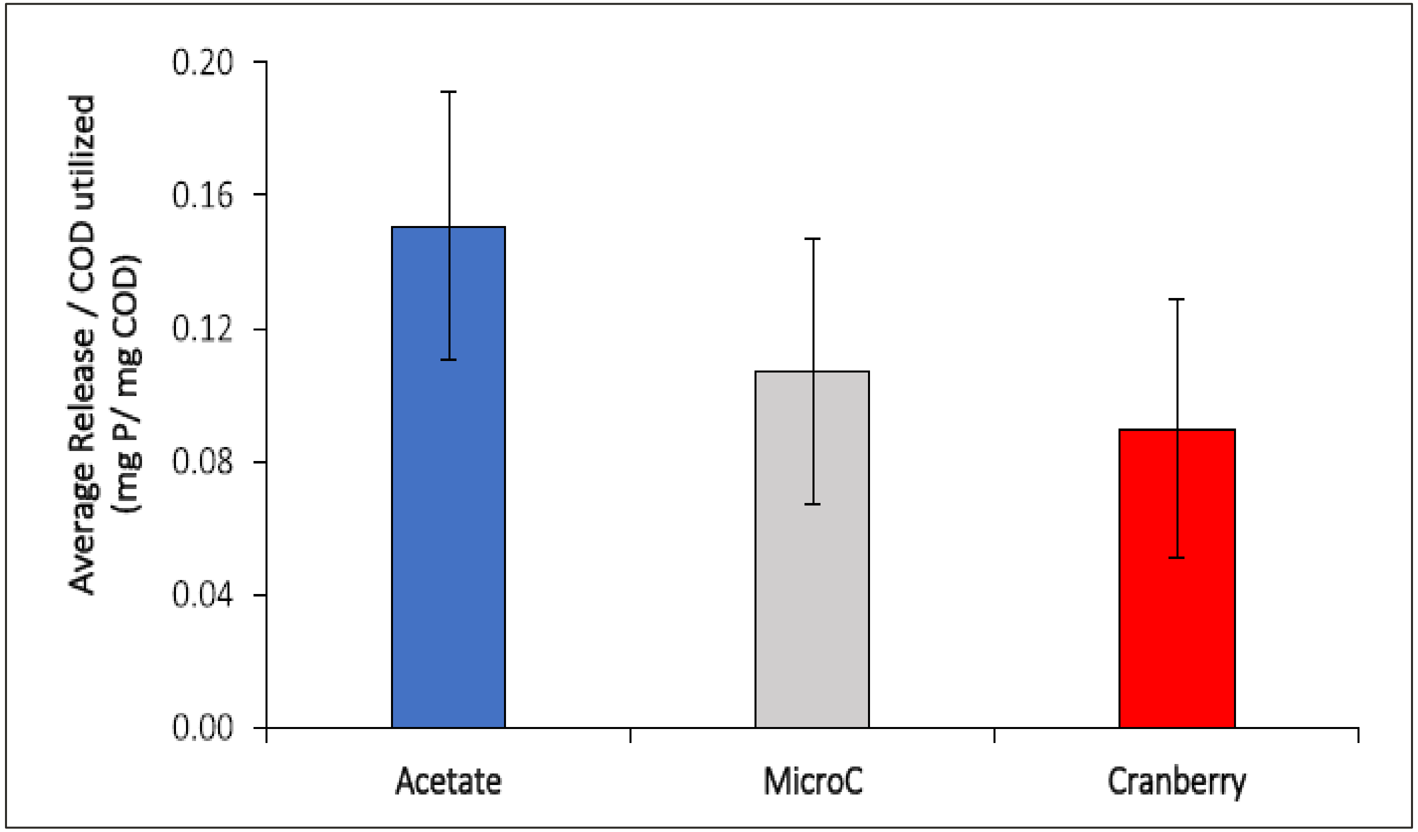


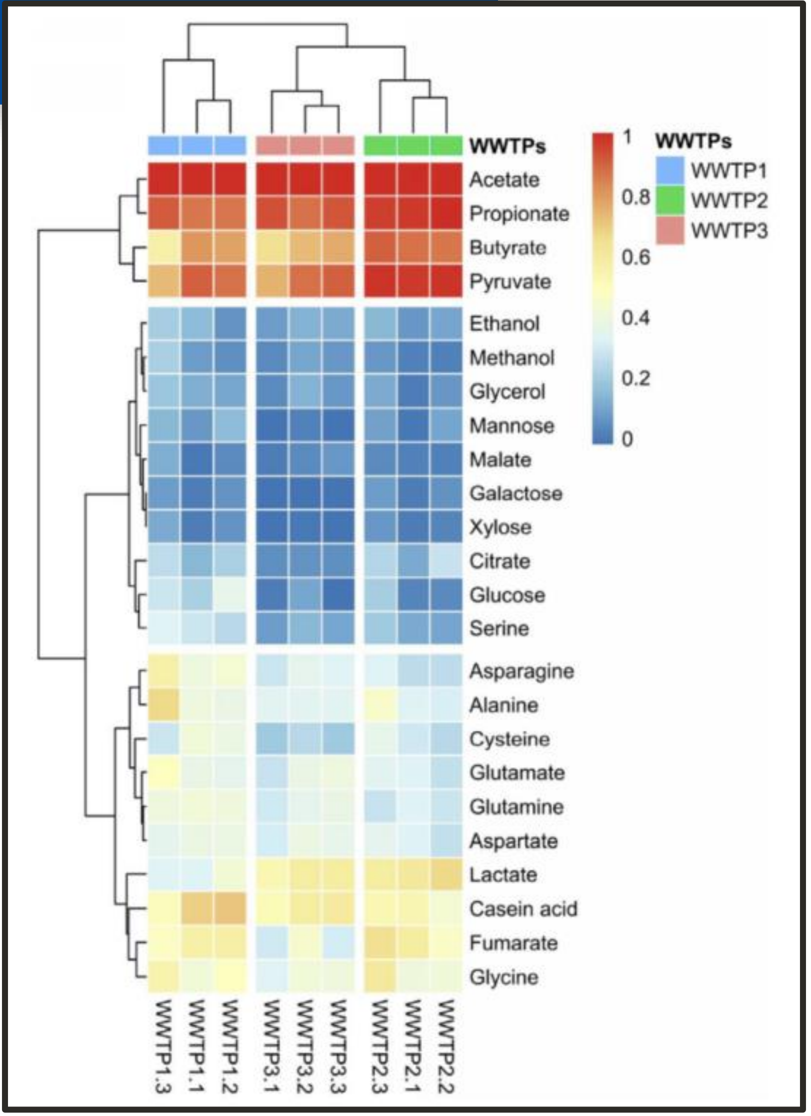


Period	RAS Diversion (% of Total RAS)	RAS Flow (gpm)	RAS TSS (mg/L)	Fermenter HRT (hours)	VSS Load to Fermenter (lb VSS/d/gal)	Carbon Feed (ppd)	PACl Addition (gpd)	Average Effluent TP (mg/L)
1	13%	297	5570	16.9	5.76	0	438.10	0.60
2	16%	380	4604	13.3	5.60	230	293.60	0.77
3	15%	393	6708	12.8	8.42	240	1.21	0.29



Cranberry syrup waste addition to batch test drives phosphorus release





Qui, 2019

WRF 4975 was a large effort with many contributors

Principal Investigator: Leon Downing

Co-PI: April Gu

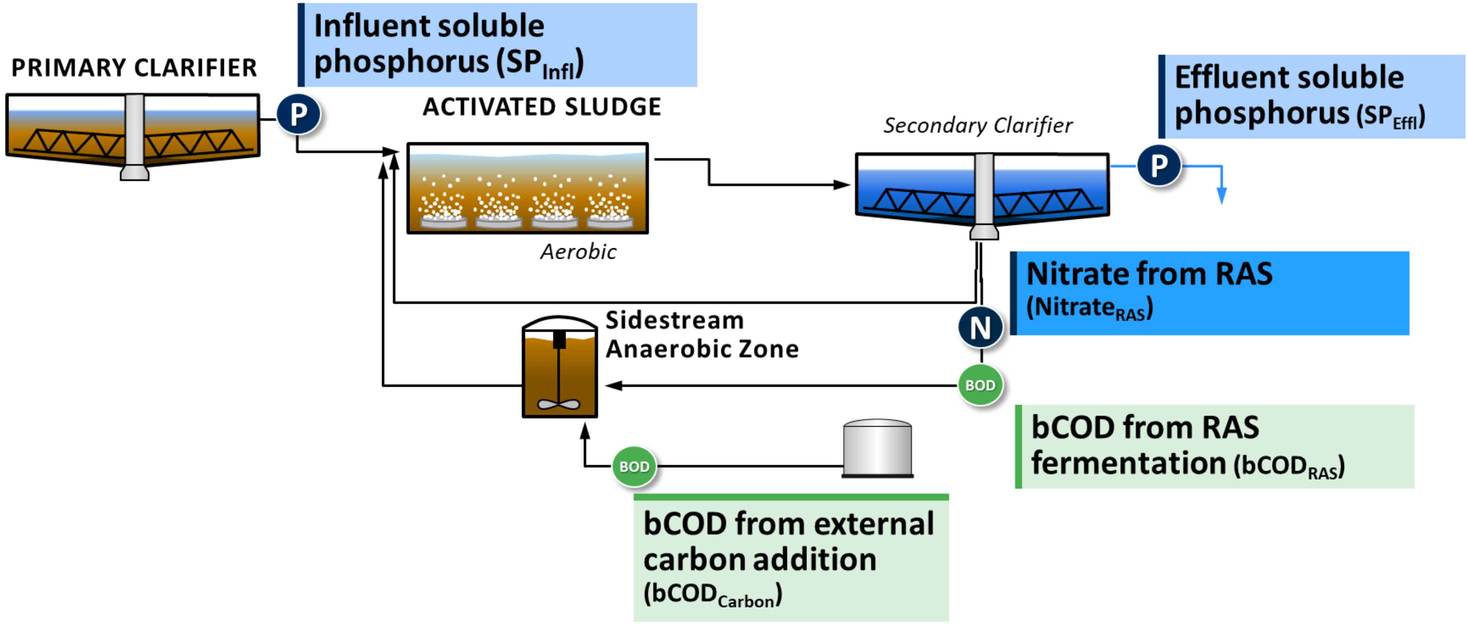
Key contributors

- Numerous utilities (19) and consultants
- Patrick Dunlap
- James Barnard
- Fabrizio Sabba

Goals:

- Develop design criteria for the processes
- Identify operational tools for EBPR
- Recommend process modeling guidelines

Carbon Balance for Sidestream EBPR



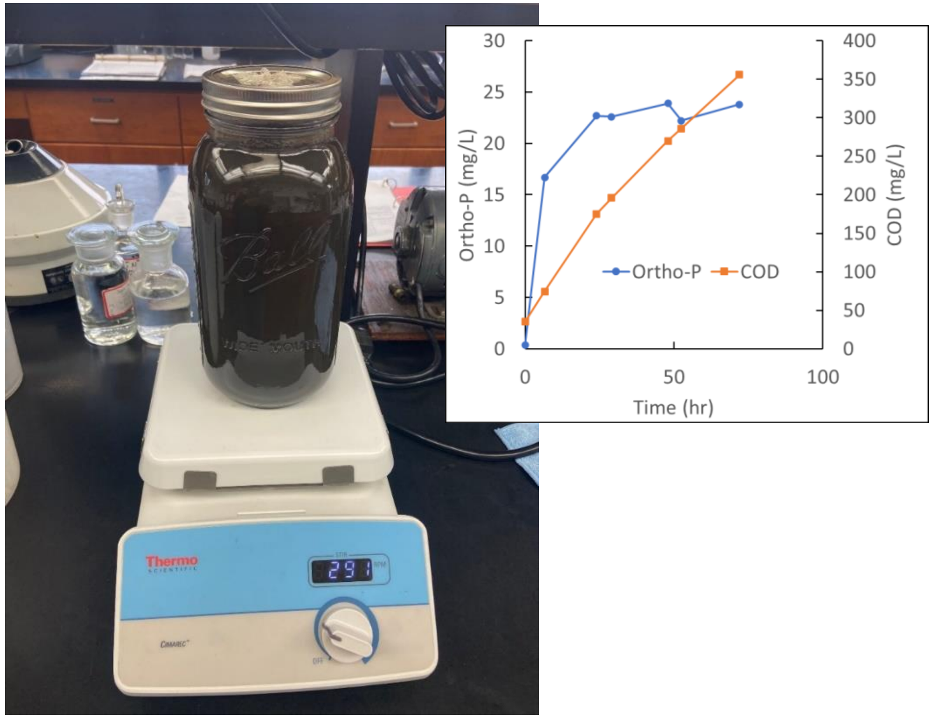
bCOD required = bCOD available

bCOD for EBPR + bCOD for RAS Denite = **bCOD Produced by RAS Fermentation** + bCOD Added

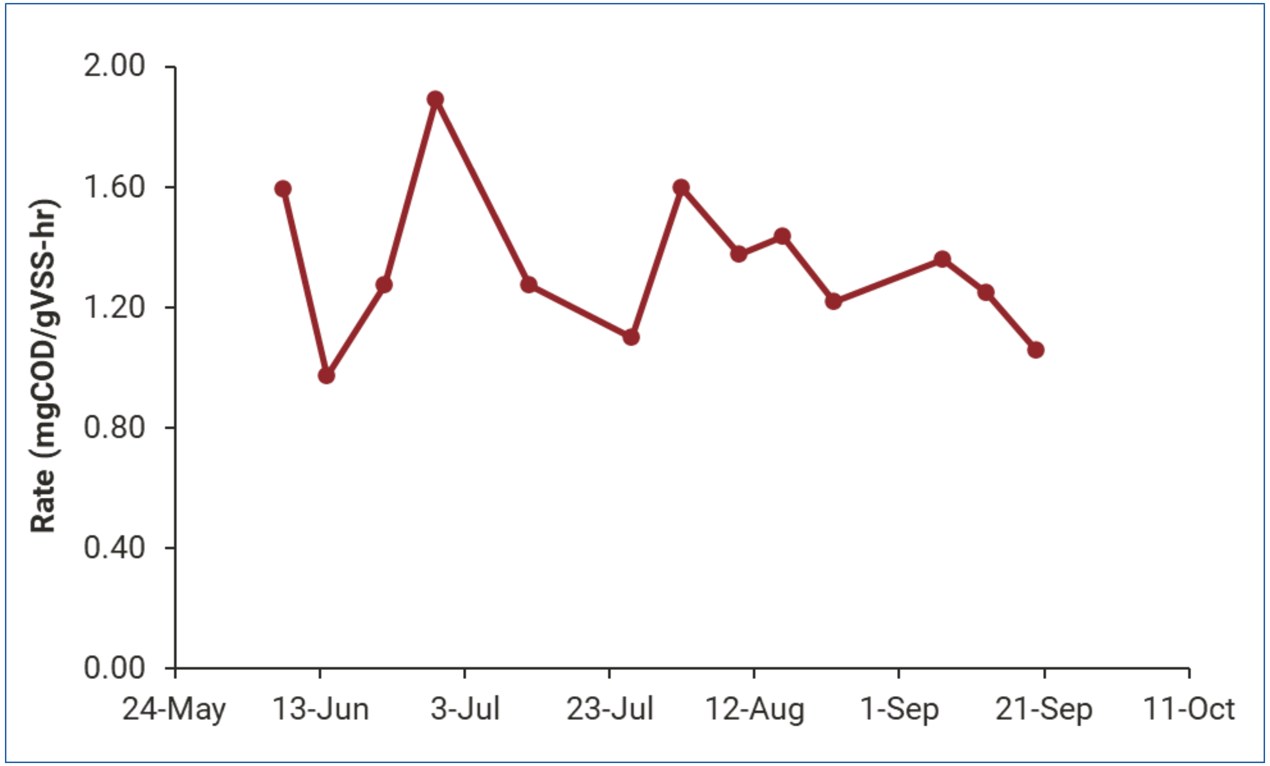
↓

Apparent Fermentation Rate x RF Inventory

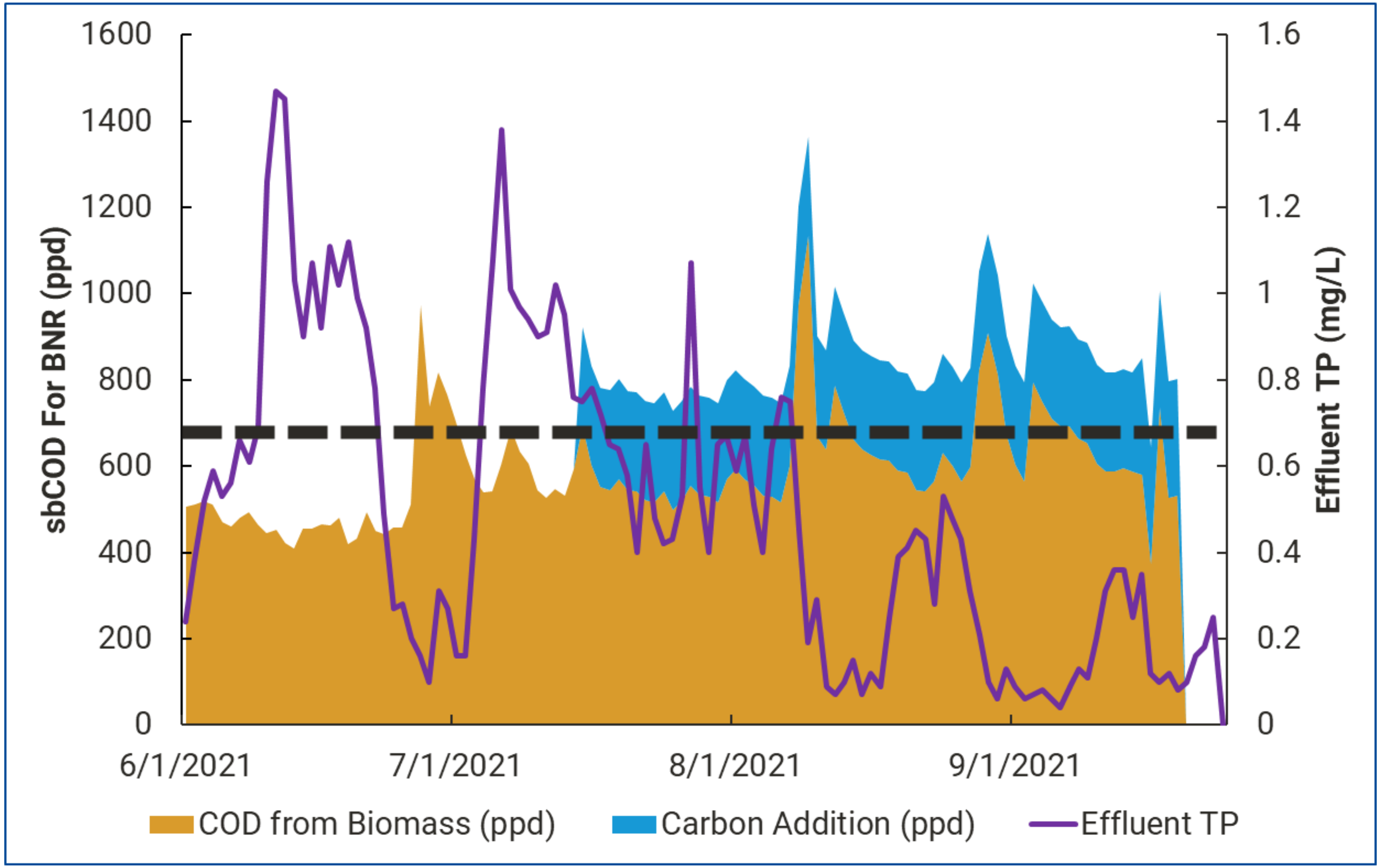
Biomass fermentation rate was relatively consistent throughout testing period

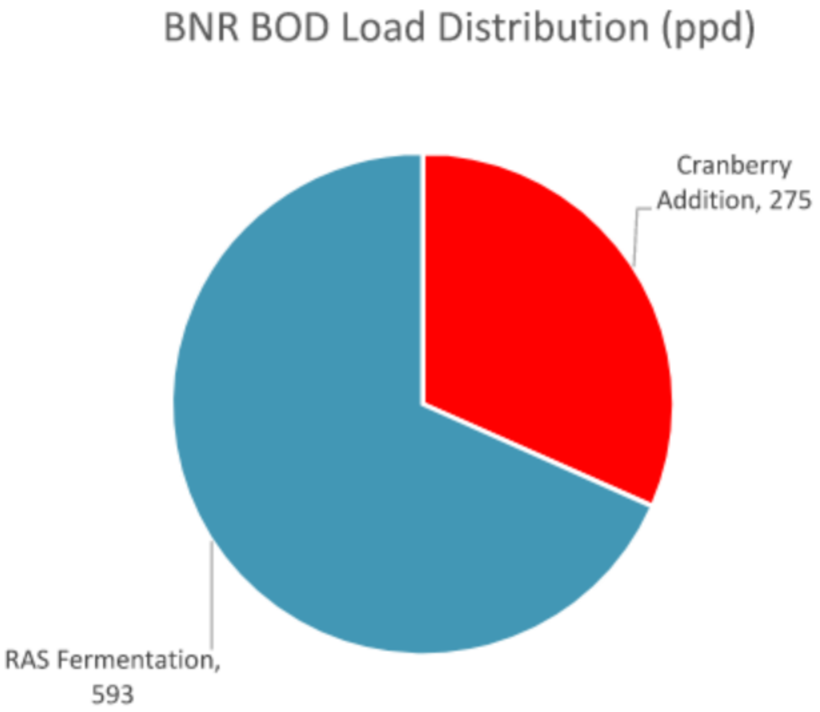


$$\text{Apparent Fermentation Rate} = \frac{\left[\text{Soluble COD Produced} + \text{OrthoP Released} \times \left(\frac{\text{sCOD Uptake}}{\text{OrthoP Release}}\right)\right]}{[\text{VSS} \times \text{T}]}$$



RAS fermentation could achieve 0.36 mg/L TP *with* carbon addition



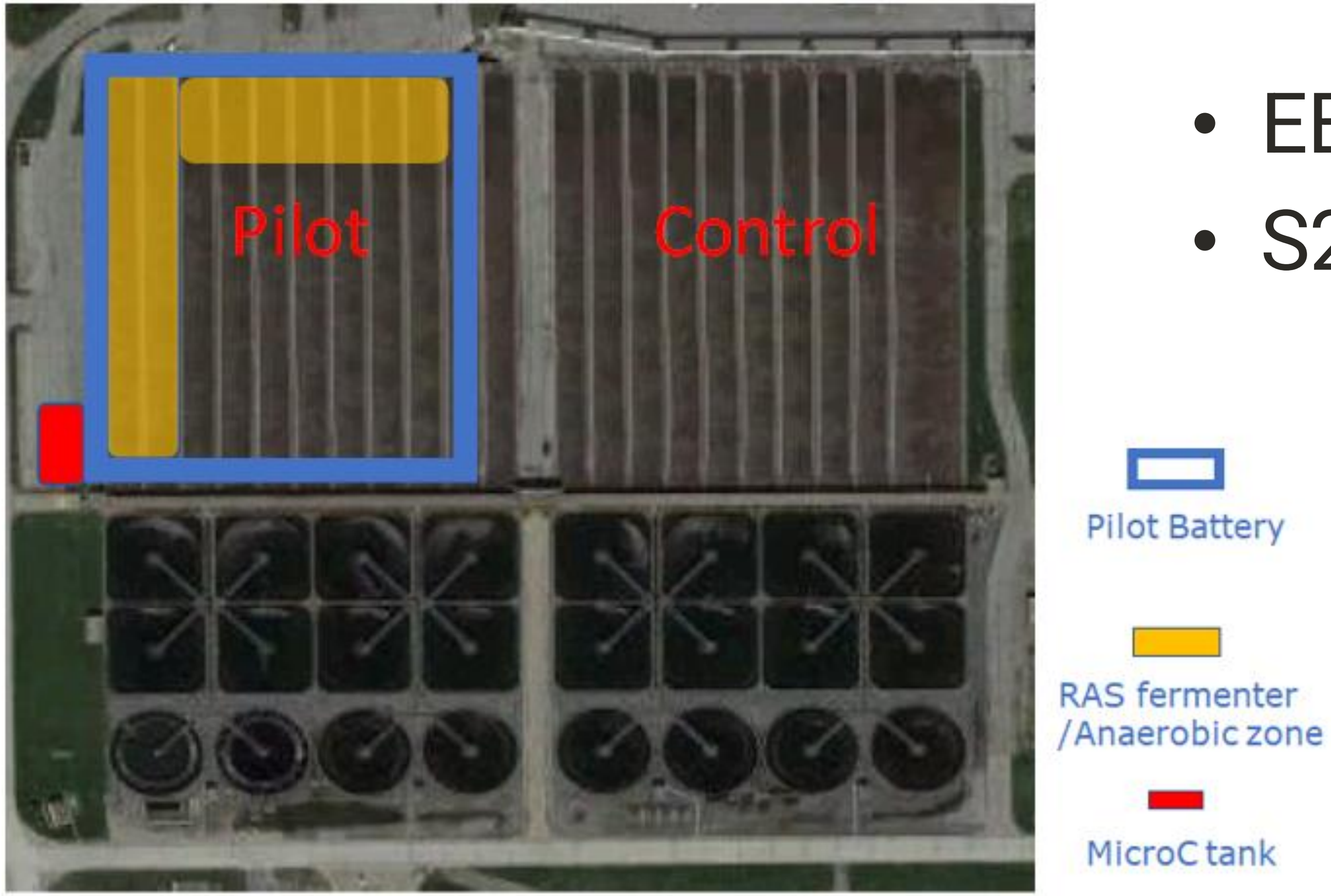


What if you don’t have cranberry syrup?

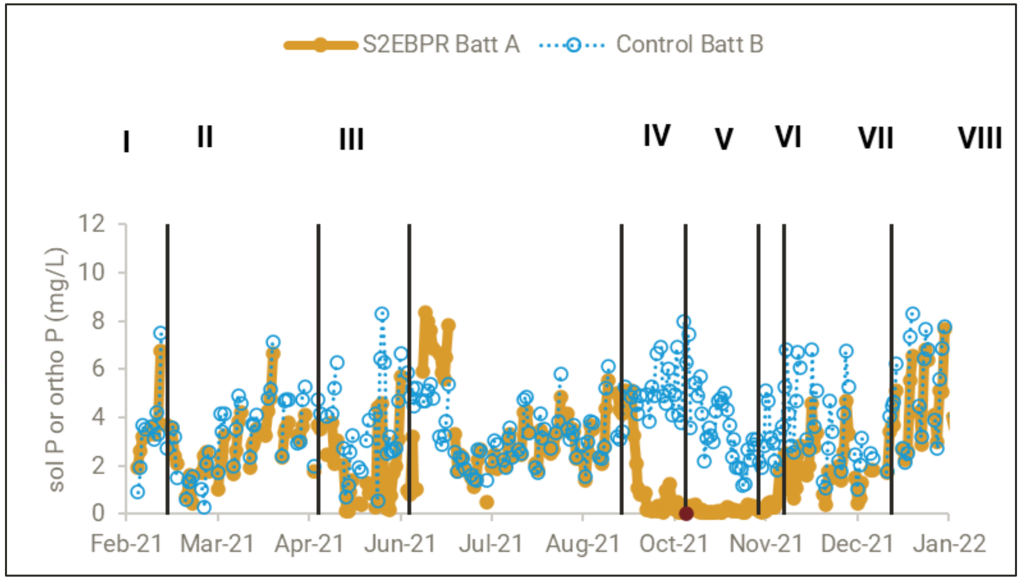
Considering Carbon Options

- Conventional EBPR (i.e. use influent carbon)
- Fermentation
  - Primary sludge fermentation
  - RAS Fermentation
- Other carbon sources?
  - Sugar
  - Glycerol
  - Glycol
  - Brewery Waste

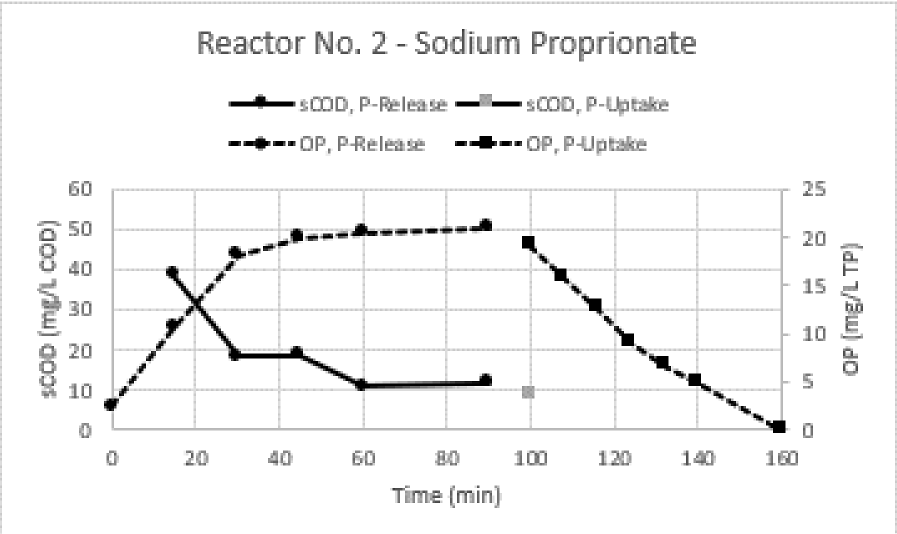
MWRDGD Calumet Facility (MicroC 2000)

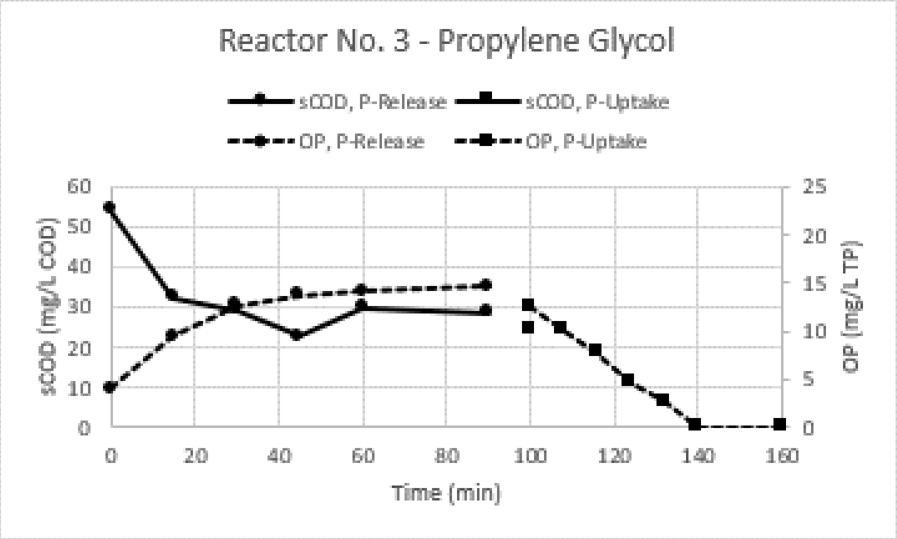


- EBPR Pilot: 25:1 BOD:P
- S2EBPR Pilot: 14:1 BOD:P

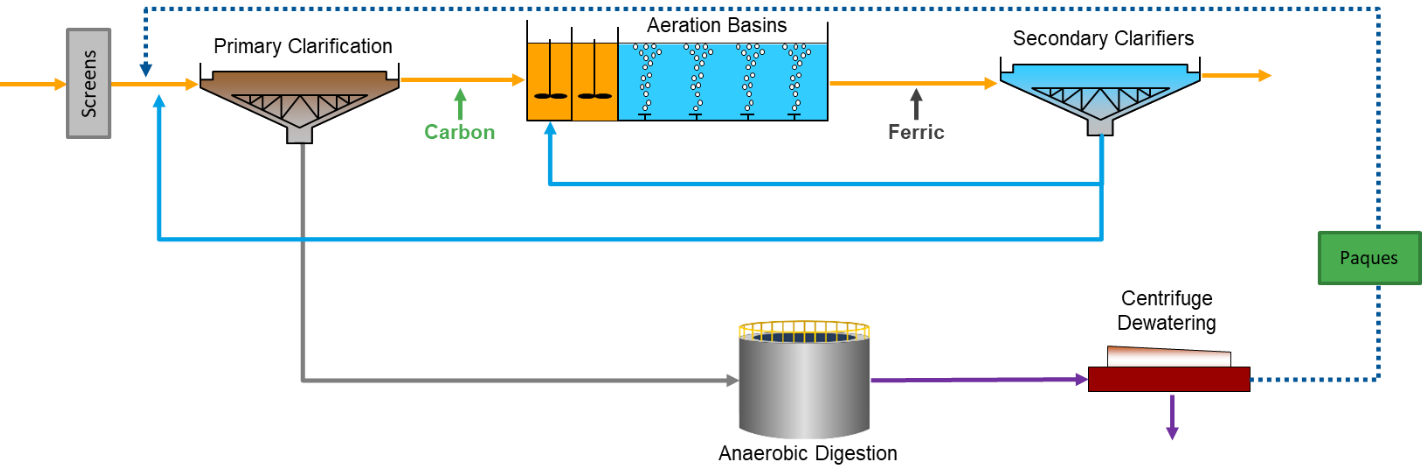


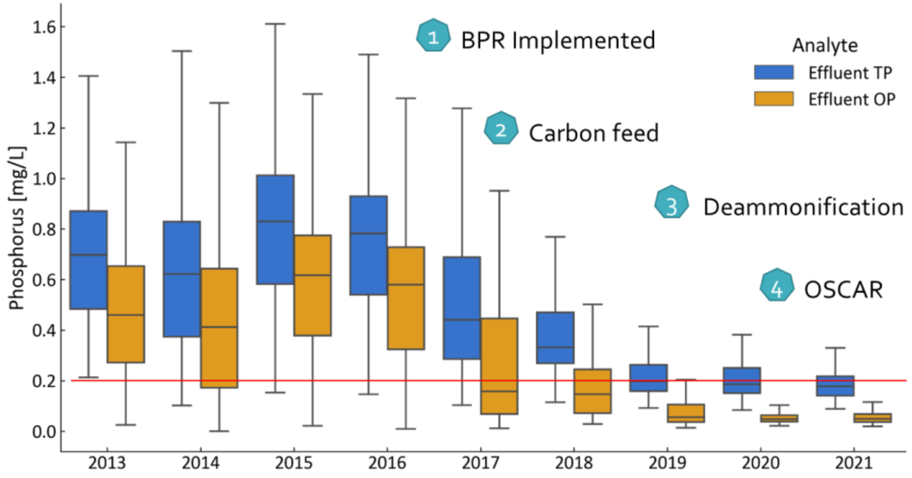
Decatur (Primary Sludge & Industrial Carbon





Fond du Lac (expired soda)





- Mainstream Process (Anaerobic / Oxic)
- Goal to achieve very low effluent P without filters
- Access to high volumes of expired soda (basically free)
- Backup with Chemical P using coagulants (not free)
- High volume of soda waste has enabled very consistent / low effluent ortho-P

Questions? More Information?

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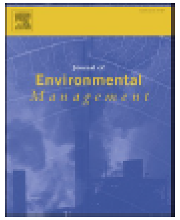

Research article

Enhancing resource recovery via cranberry syrup waste at the Wisconsin Rapids WRRF: An experimental and modeling study

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A R T I C L E I N F O

Keywords:
Orthophosphate
Hydrolysis
S2EBPR
RAS fermentation
Carbon
SUMO modeling

A B S T R A C T

The Wisconsin Rapids Wastewater Treatment Plant (WRWWTP) is faced with a more stringent effluent phosphorus requirement that will drive capital investment between 2020 and 2025. The facility will need to achieve a monthly average value of 0.36 mg L^{-1} of total phosphorus (TP). While the facility has sufficient influent carbon to drive a conventional enhanced biological phosphorus removal (EBPR) configuration, the existing infrastructure makes the addition of influent selector zones cost prohibitive. Underutilized aeration basin capacity was repurposed for testing return activated sludge (RAS) fermentation. The WRWWTP began pilot testing of RAS fermentation in April 2021. The facility moved through a series of operational setpoints to optimize phosphorus removal in a sidestream RAS (SSR) configuration, including RAS diversion, decrease of DO in aeration basins and