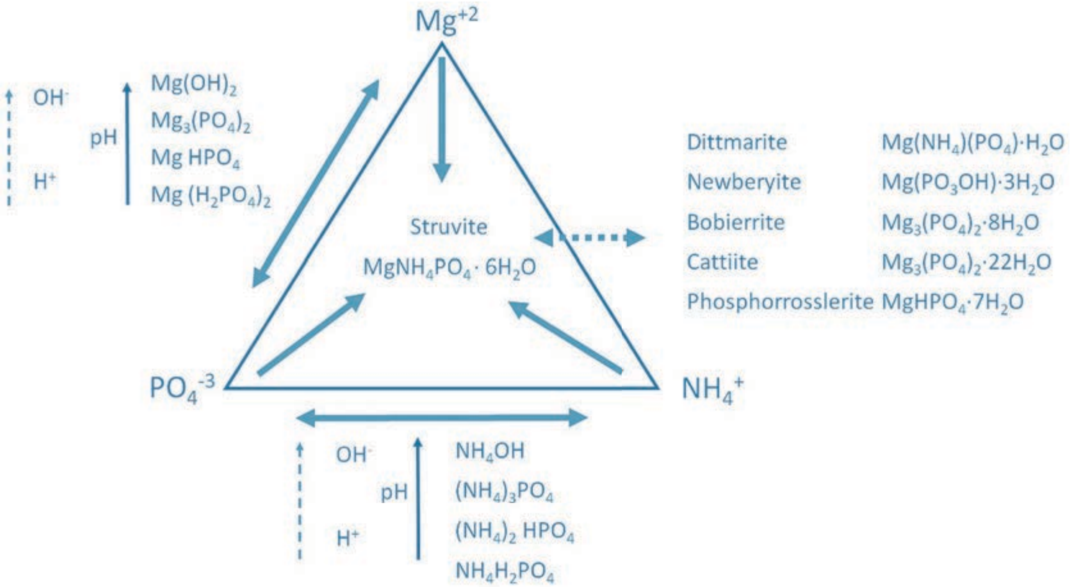
A Holistic Approach to Struvite Management

Key to Improved Operations and Decreased Operations/Maintenance Cost

Varun Srinivasan, PhD

Ph: (978) 983-2045

Email: VSrinivasan@brwncald.com



Co-authors:

Jose Jimenez, Adam Klein, Chris Muller, Natalie Sierra – **Brown and Caldwell**;
David Duest, Richard Adams – **MWRA**;

Impact of Nutrient Cycling from Solids Systems on Wastewater Operations

Why is this an issue?

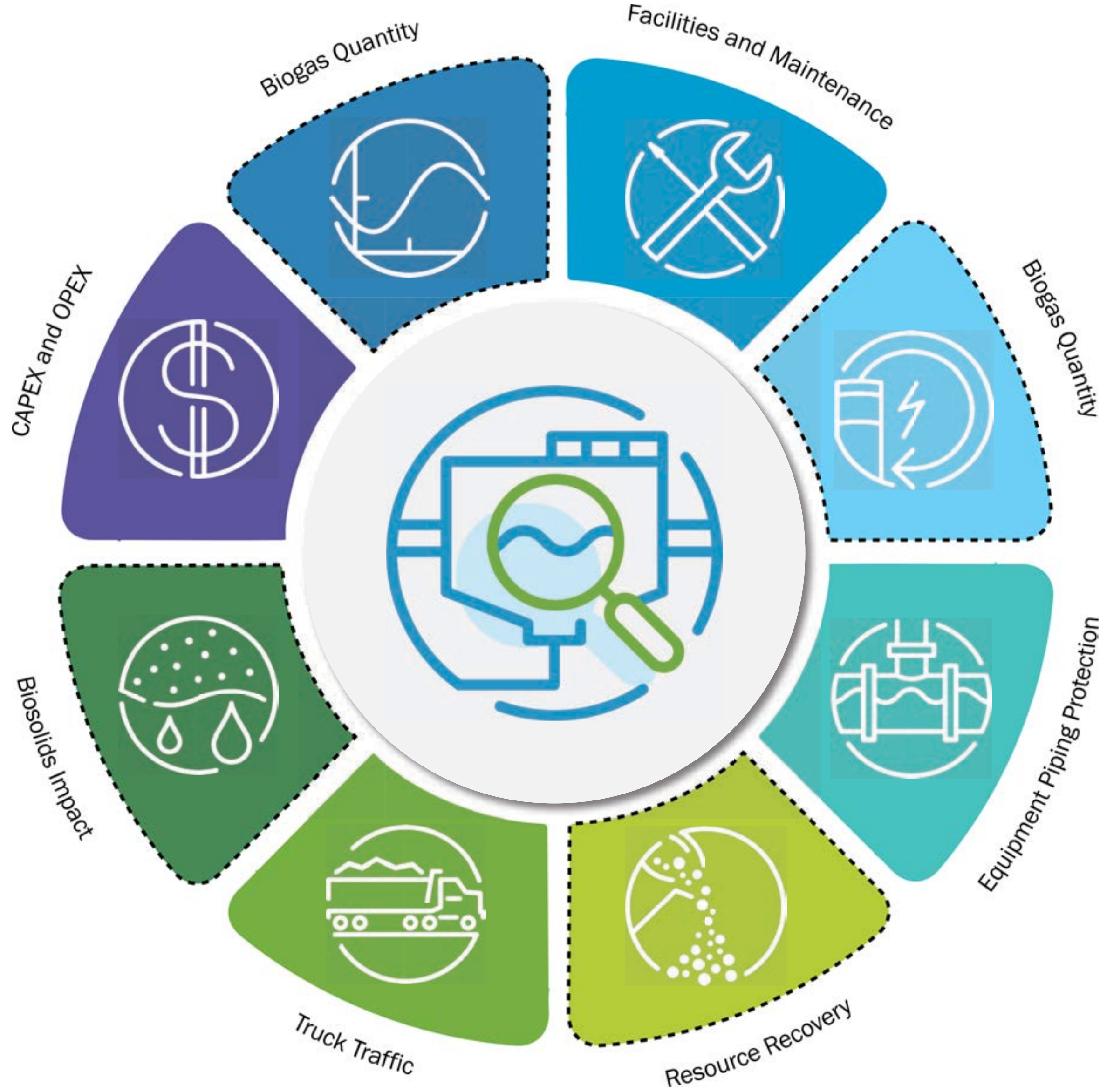
Non-process considerations

- Truck traffic
- Escalating chemical costs
- Ferric is problematic
- Additional sludge production
- P-Content in Sludge

	Nitrogen	Phosphorus	Sulfur
Anaerobic Digestion			
Nuisance Precipitate Formation (ex. struvite, vivianite)	✓	✓	
Process Toxicity	✓		✓
Biogas			
Combustion Emissions (ex. No_x)	✓		✓
Gas Treatment			✓
Equipment Life-Cycle (ex. corrosion)			✓
Dewatering			
Cake Solids	✓	✓	
Odors	✓		✓
Biosolids Management (ex. P-indexing)		✓	
Recycle Streams			
Secondary Sludge Flocculation	✓		
Nutrient Treatment Capacity	✓	✓	
Aeration Demand	✓	✓	

Holistic Nutrient Management

In the transition to resource recovery, the factors impacting decisions are increasing



What is Struvite?

- Struvite is a chemical precipitate of Magnesium, Ammonium and Phosphate
  - $MgNH_4PO_4.6H_2O$
- White, yellowish-white or brownish-white in color
- Very insoluble in water (pK_{so} =12.6 – 13.15)

Draft tube mixer fouling

King County, WA

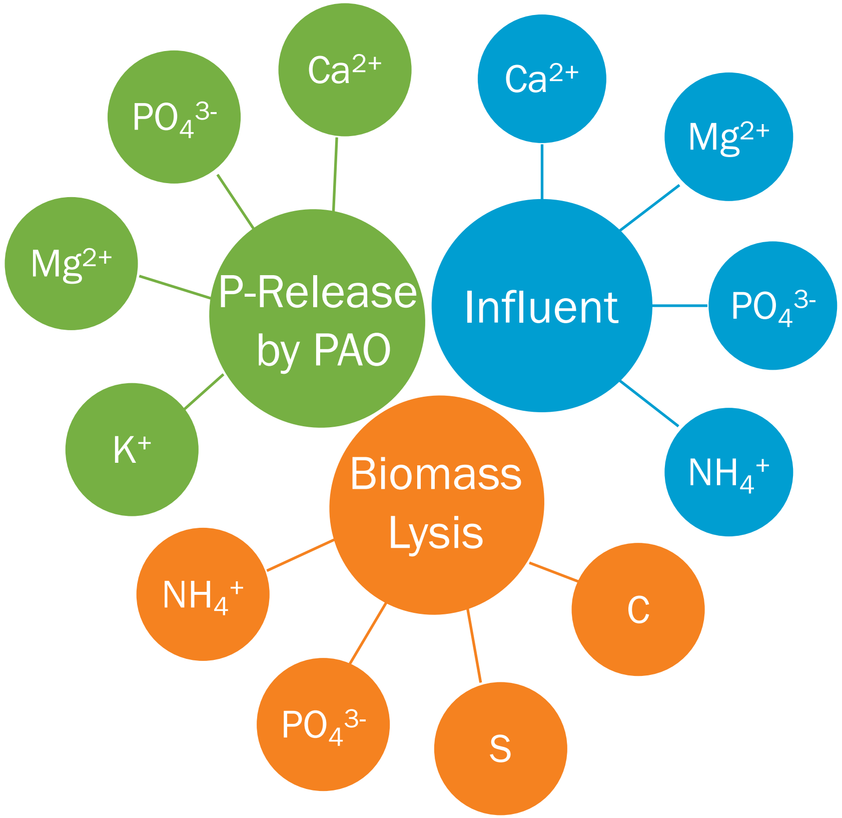
Digested piping

Sacramento, CA

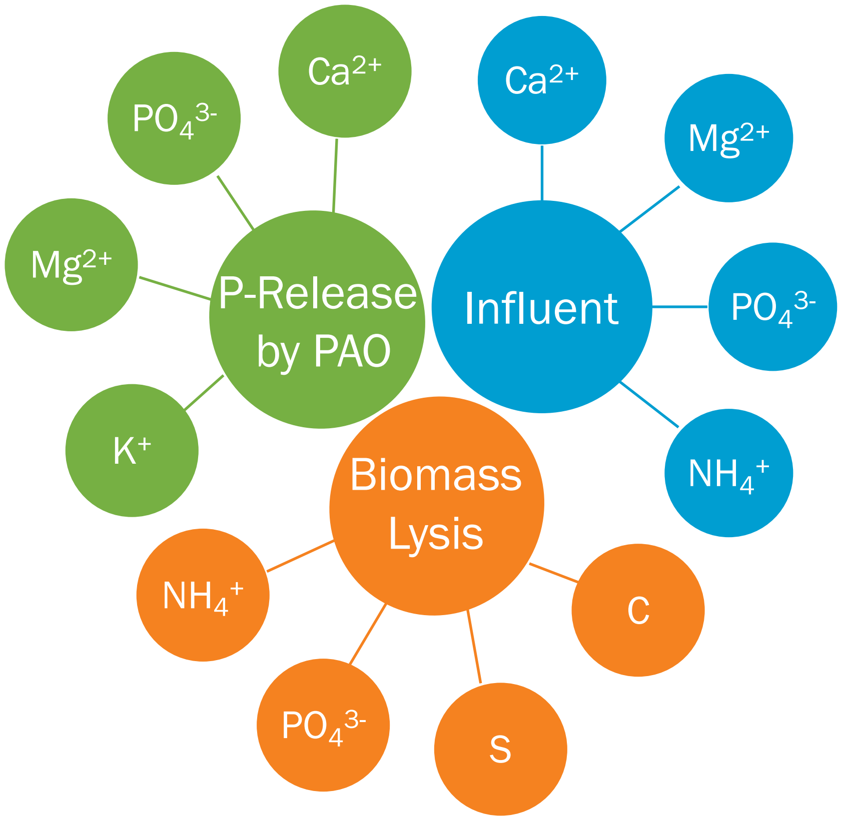
Digested sludge piping elbow

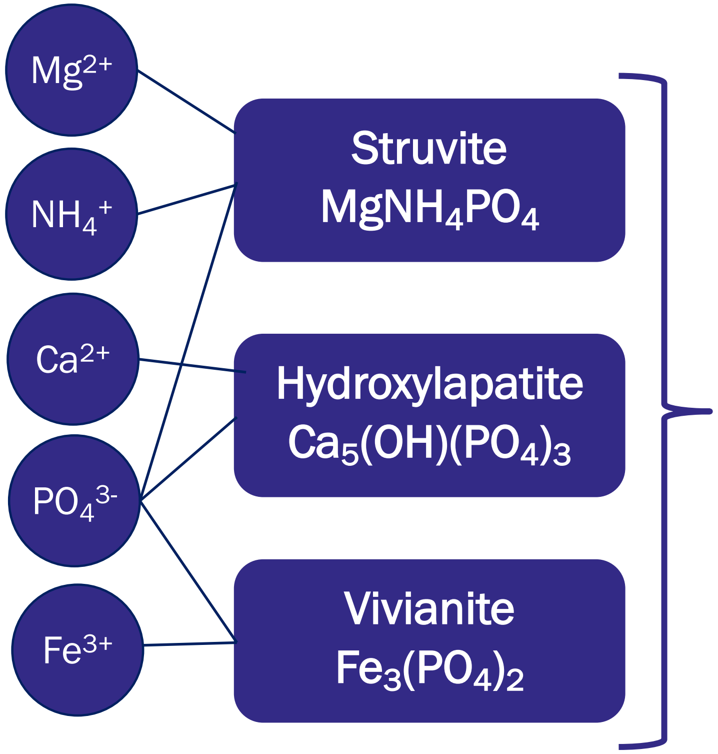
San Jose, CA

Biological and Chemical Interactions During Treatment



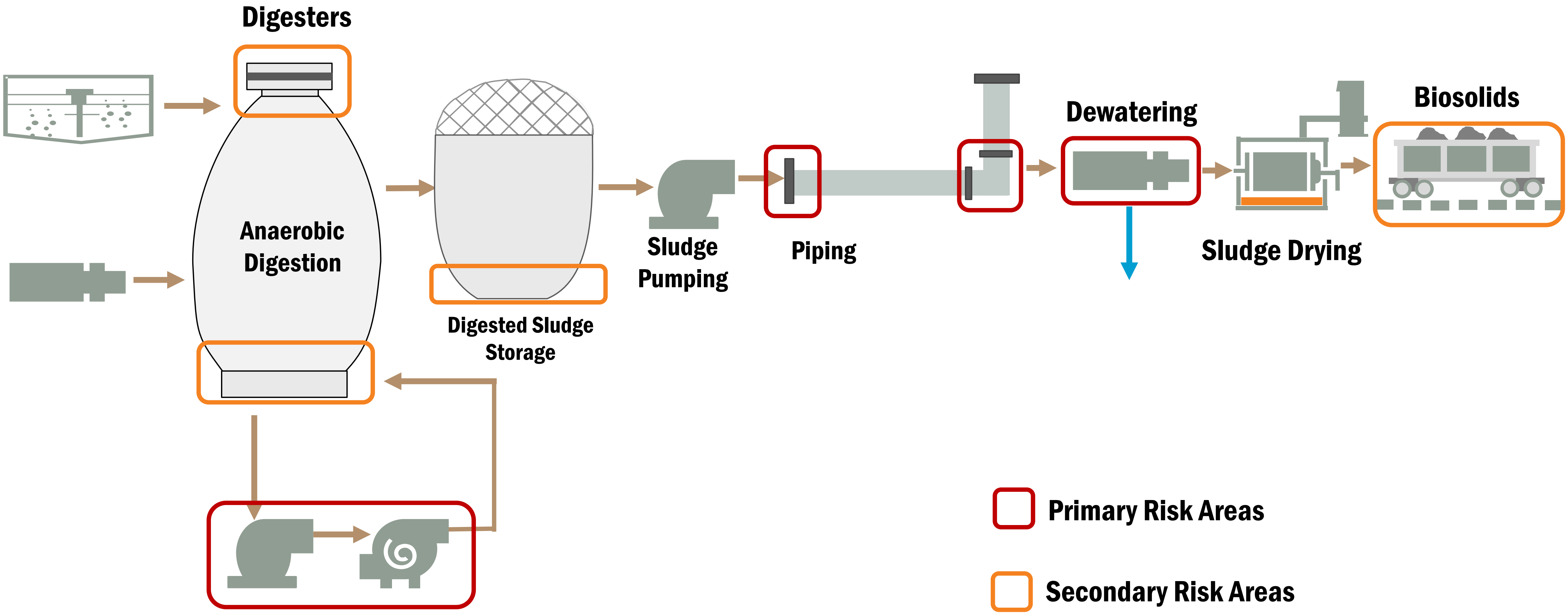
Biological and Chemical Interactions During Treatment



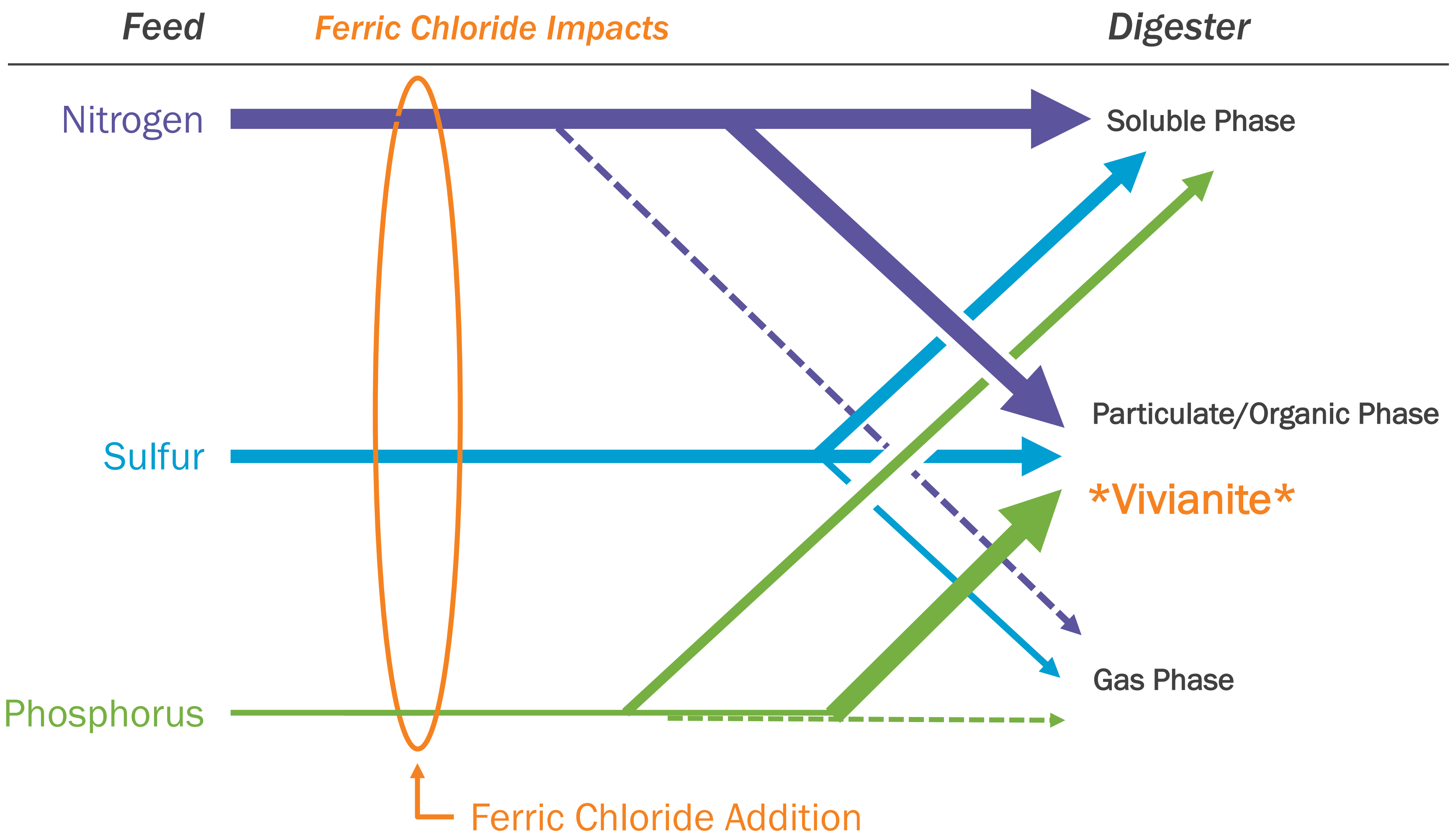


- Supersaturation
- Temperature
- pH
- Concentration of Ions
- Redox

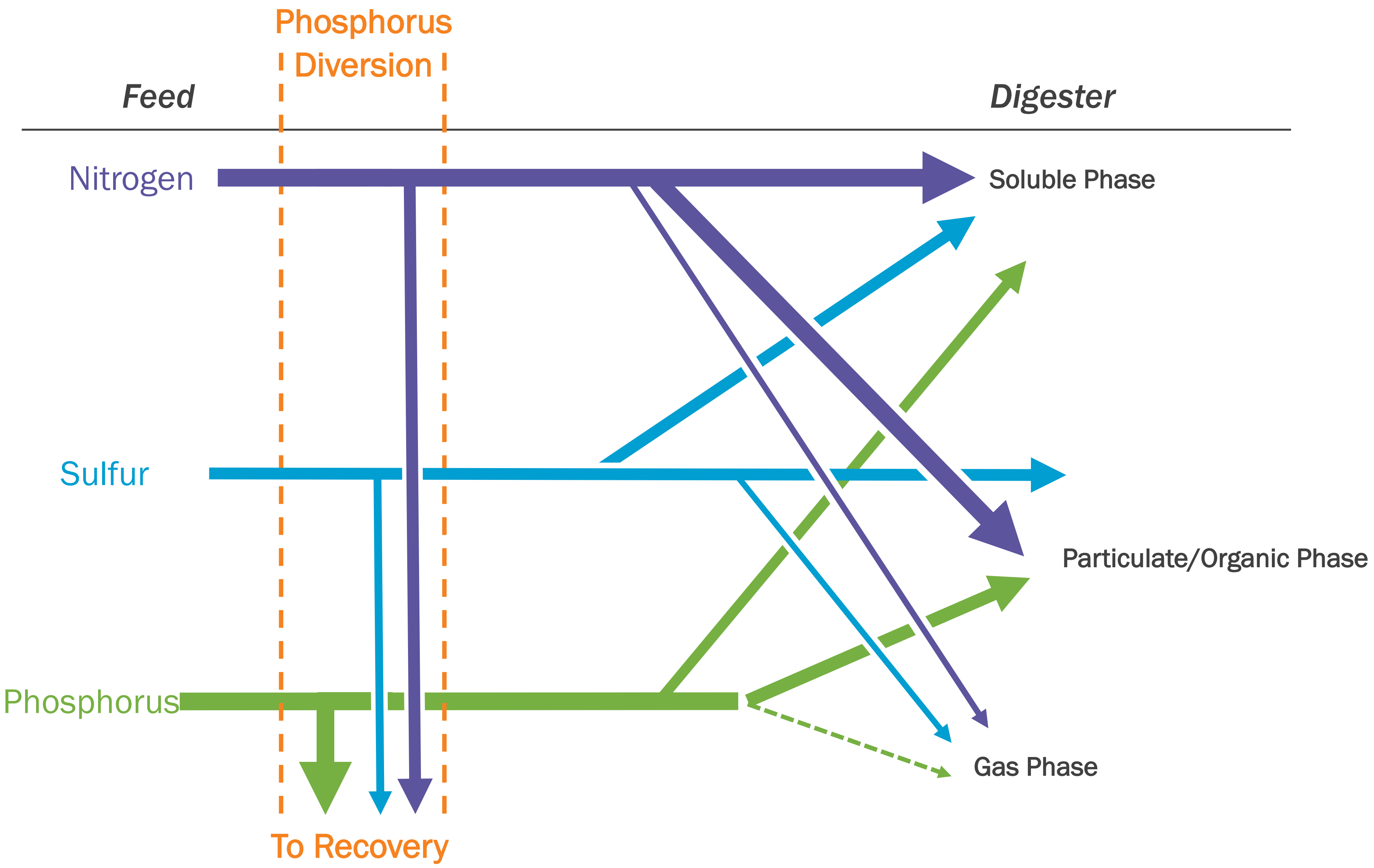
Where can it form?



Traditional Method for Managing Struvite



Emerging Processes Look to Divert Phosphorus from Digester

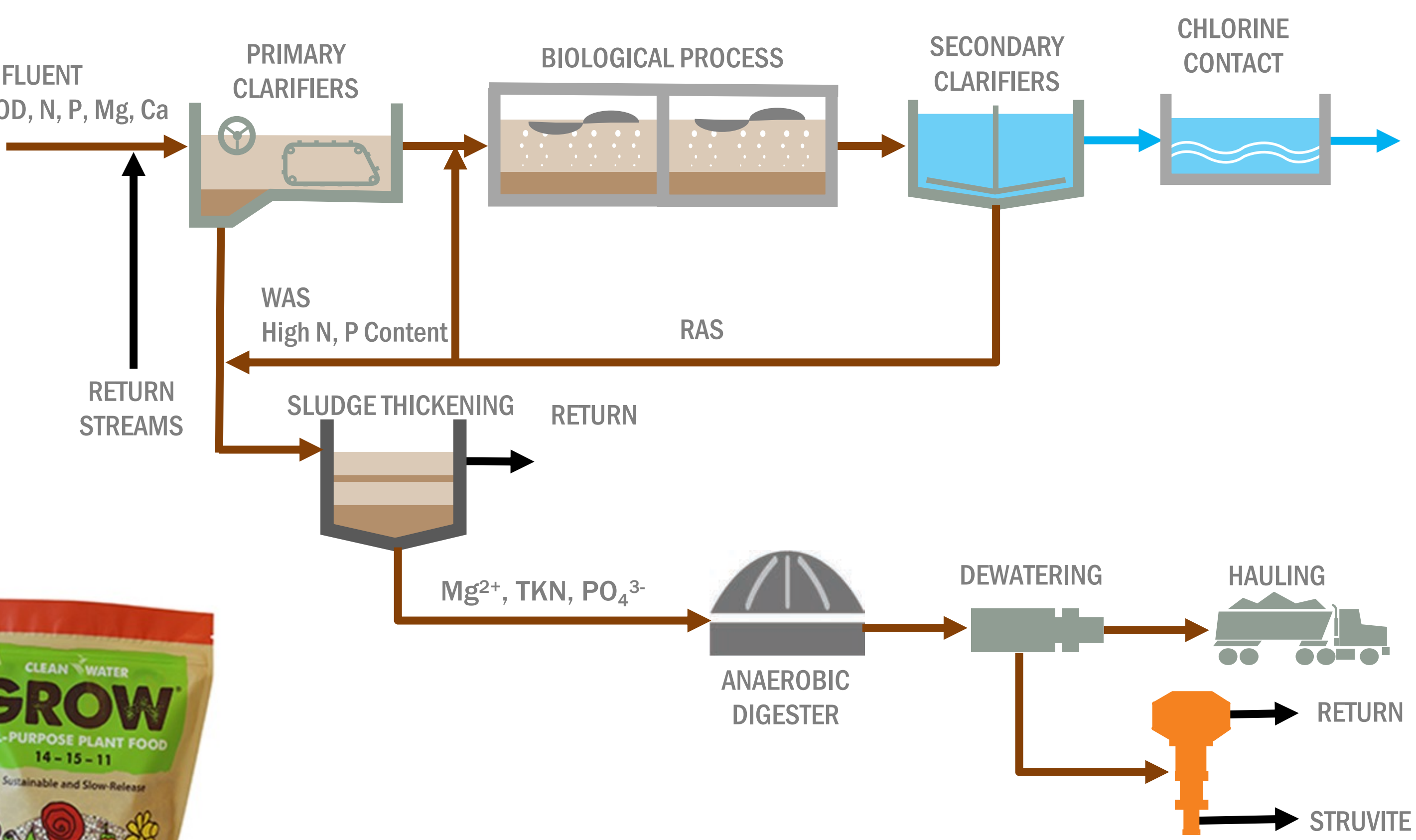


Struvite Management Processes

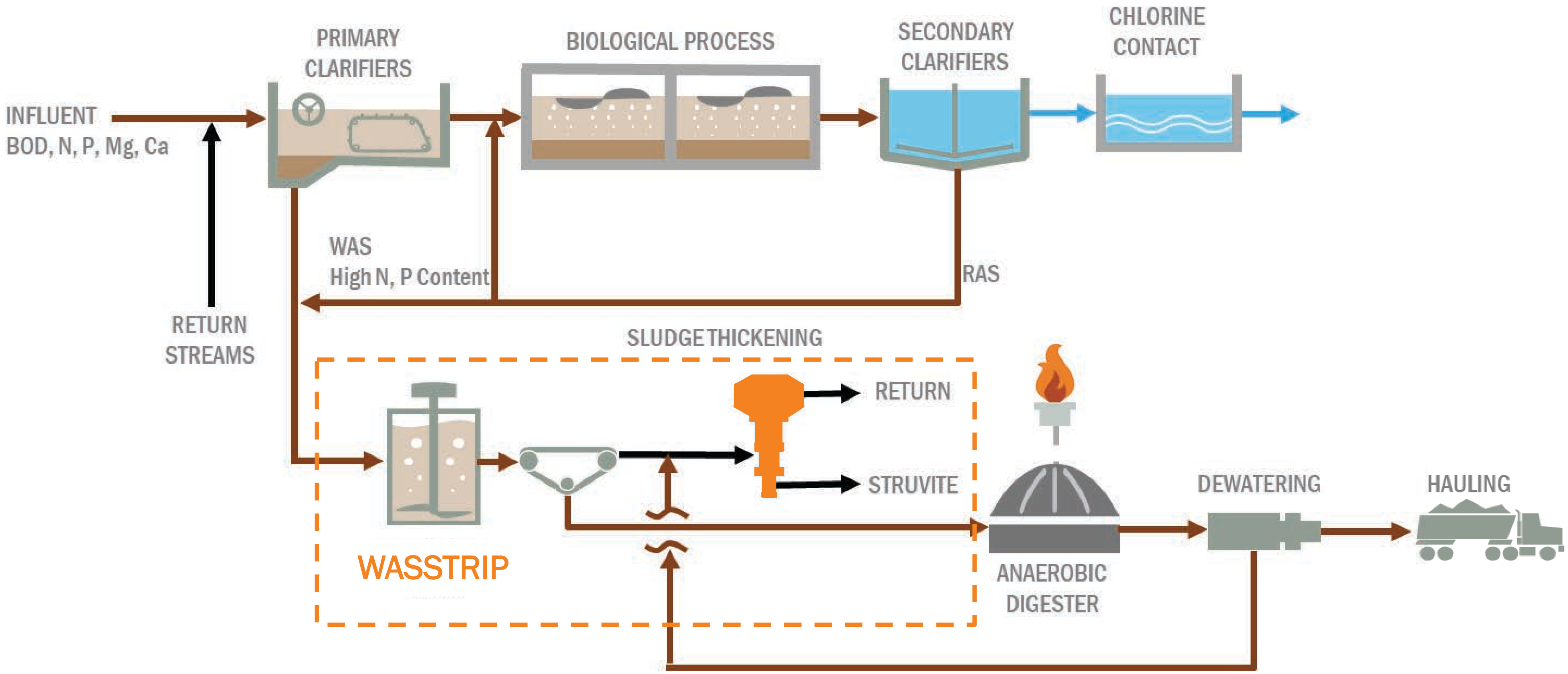
- Ostara Pearl®
- Ostara WASSTRIP
- CalPrex™
- MagPrex™
- CalPrex™ + MagPrex™
- Elovac-P
- PHOSPHAQ™
- PRI-DE™
- NuReSys

Ostara Pearl ®

- Uses thickening and dewatering filtrate/centrate
- Uses upflow fluidized bed reactor
  - Multiple diameter zones to promote crystal growth and strength
  - $MgCl_2$ addition for Mg source
  - NaOH addition for pH control
  - Recirculation of effluent around reactor (patented)
- Goal is to maximize product quality for sale

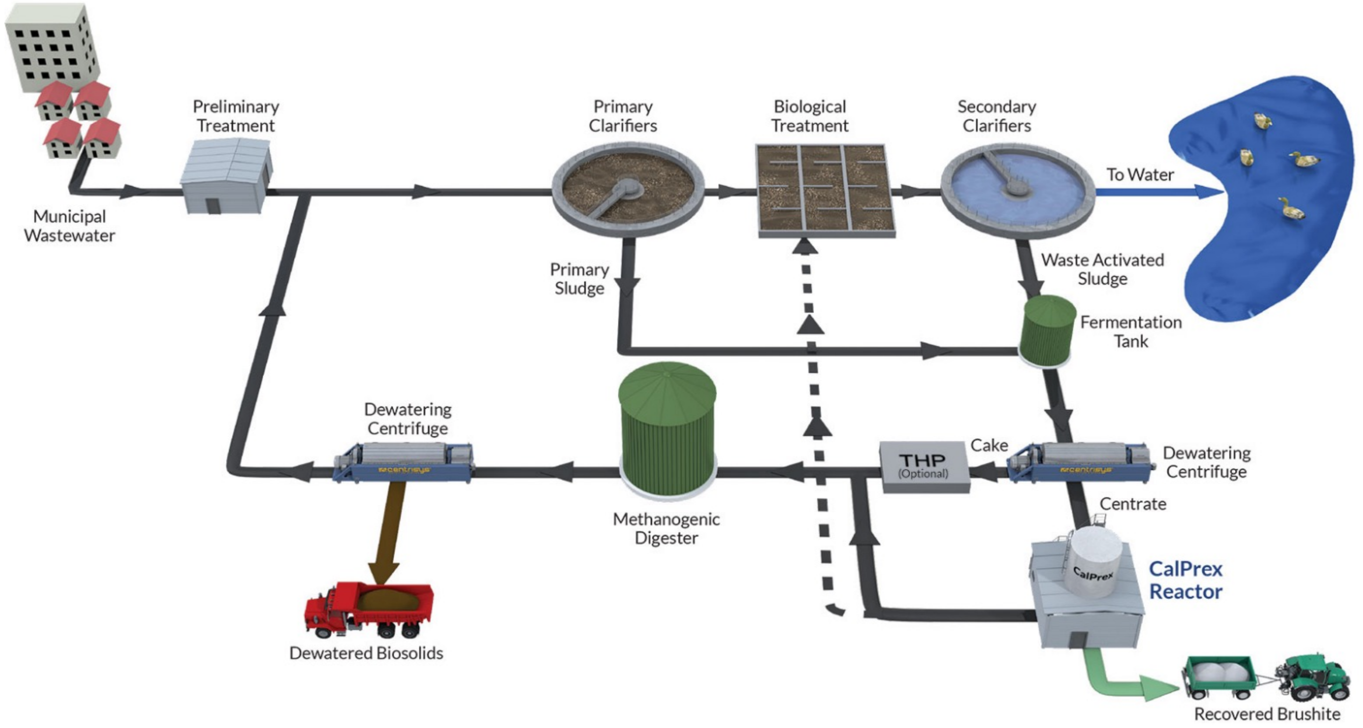


Ostara WASSTRIP + Pearl®



CalPrex ™

- Struvite control PRE digestion
- Uses a fermentation step to solubilize stored P
- The fermented solids are then dewatered and the centrate is sent to the CalPrex reactor
- Addition of $Ca(OH)_2$
- Precipitate phosphorus as brushite ($CaHPO_4 \cdot 2H_2O$)

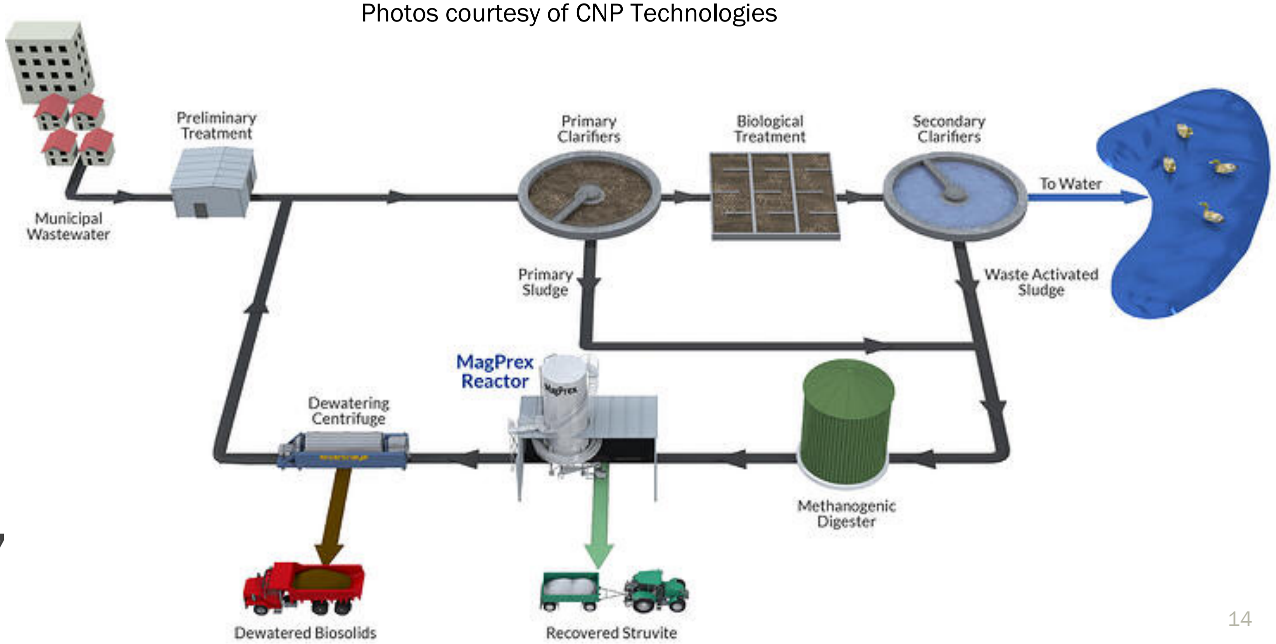


Photos courtesy of CNP Technologies

MagPrex ®

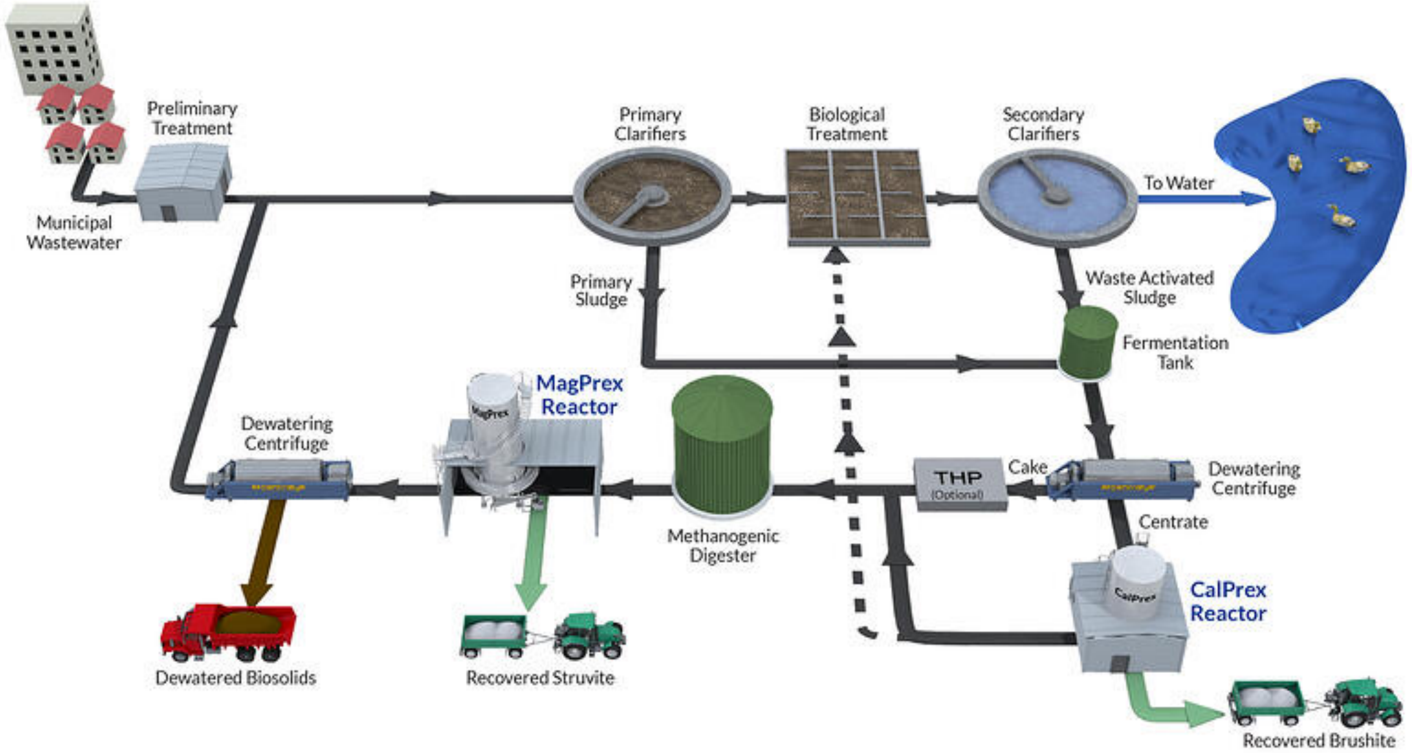
- Used on digested sludge to remove struvite prior to dewatering
- Not focused on purity of product
- $MgCl_2$ and NaOH addition
- Air addition for pH control
- Goal is not struvite recovery for sale, but P removal (claim 90–95%)
- Can sequester struvite and leave in sludge
- Can recover, but requires grit washing equipment
- Claim 3–5% improvement in dewatering, up to 30% reduction in polymer use

Photos courtesy of CNP Technologies



CalPrex^{TM} + MagPrex^{TM}

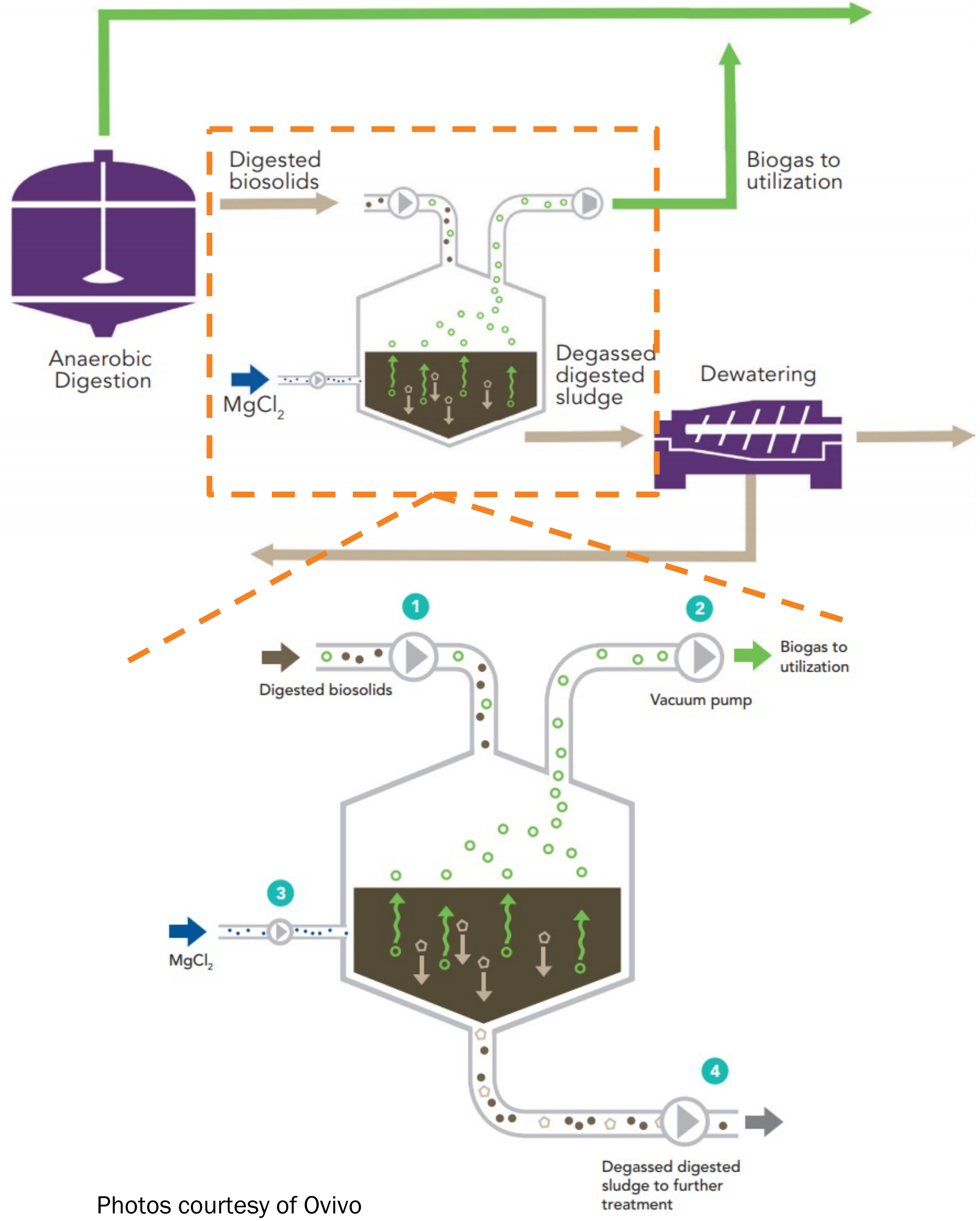
- Can combine CalPrex^{TM} and MagPrex^{TM} to mitigate struvite formation pre and post-digestion.
- Enables recovery as both brushite and struvite



Photos courtesy of CNP Technologies

EloVac ® - P

- Skid-mounted, plug and play phosphate sequestration system for struvite scaling prevention.
- Controlled struvite precipitation through
  - Increased pH by extraction of CO_2 using a vacuum pump
  - Addition of $MgCl_2$ for magnesium
- Aids in extraction of dissolved methane from digested biosolids and can help improve biogas production
- Typically, more applicable for smaller plants.
- Will only prevent struvite scaling downstream of the digester.



Photos courtesy of Ovivo

Case Study 1 – Whole Plant Modeling

MWRA - Deer Island Treatment Plant

Deer Island Treatment Plant

- MWRA provides wholesale water and wastewater services to 3 million customers in 61 communities (34% of population in MA)
- Deer Island Treatment Plant (DITP)
  - 2nd Largest Wastewater Treatment Plant in the US
  - Capacity
    - 1,300 MGD Peak Capacity (700 MGD through secondary treatment)
    - 361 MGD Average Design Flow

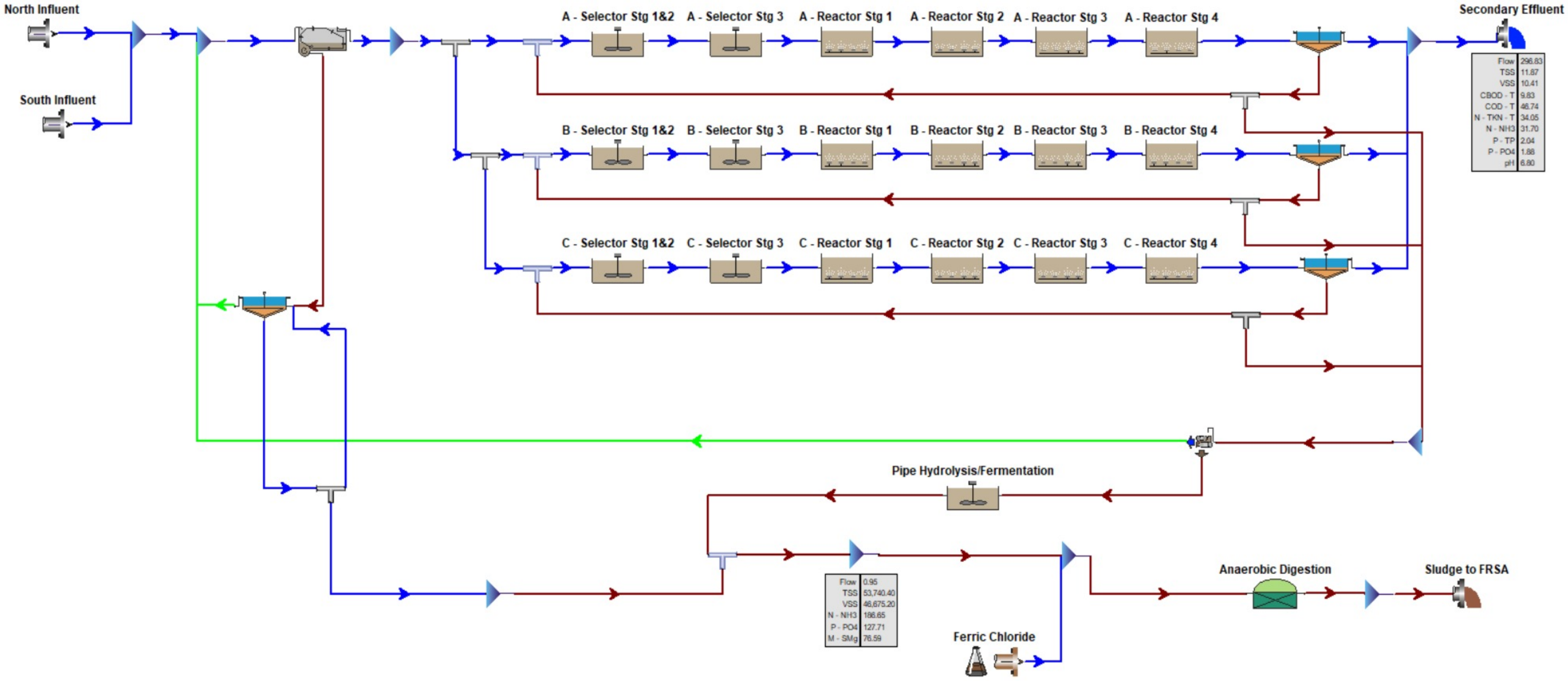
The ultimate Recycling Facility:

Water – Cleaned and returned to Water Cycle, 94% solids & organics removal

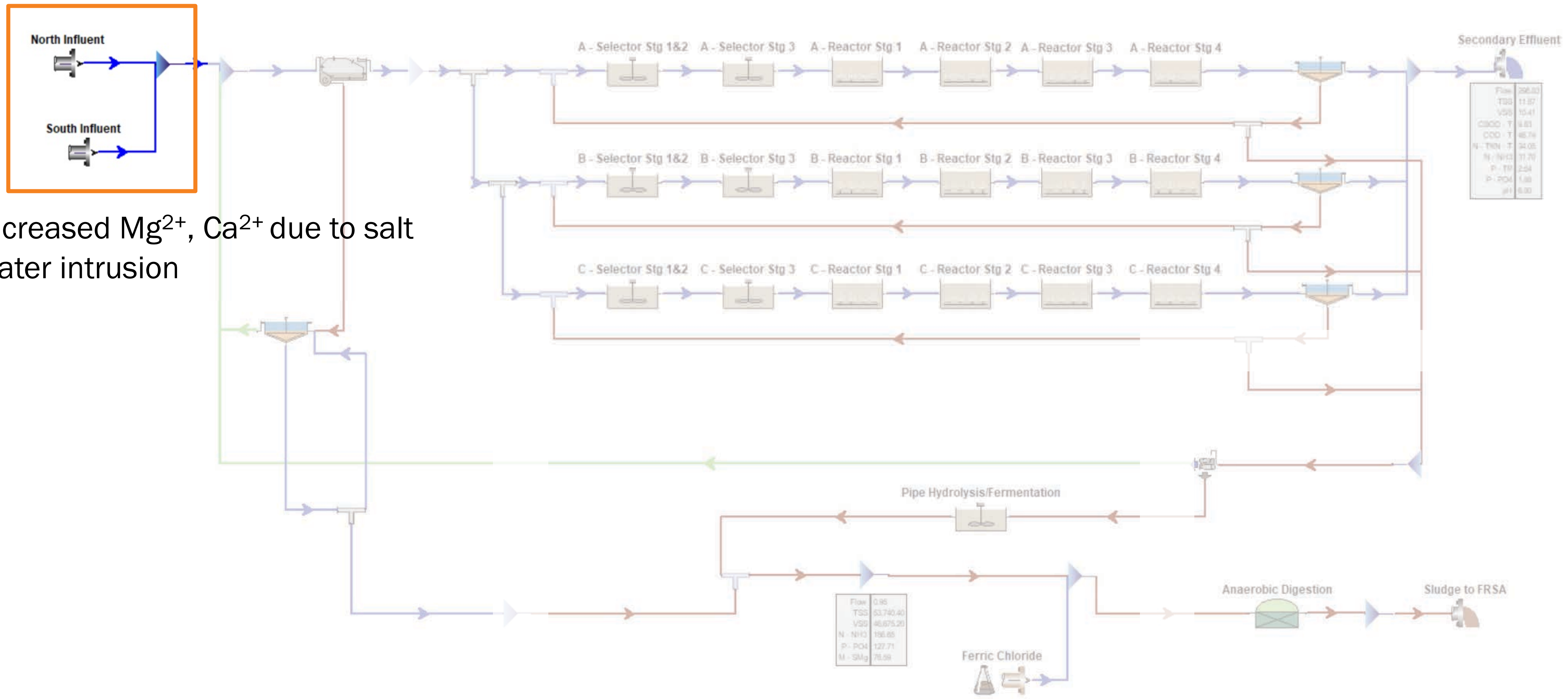
Solids removed -

Anaerobically Digested – Produce Heat & Power
Remaining Solids – converted to Fertilizer Pellet

Process Flow



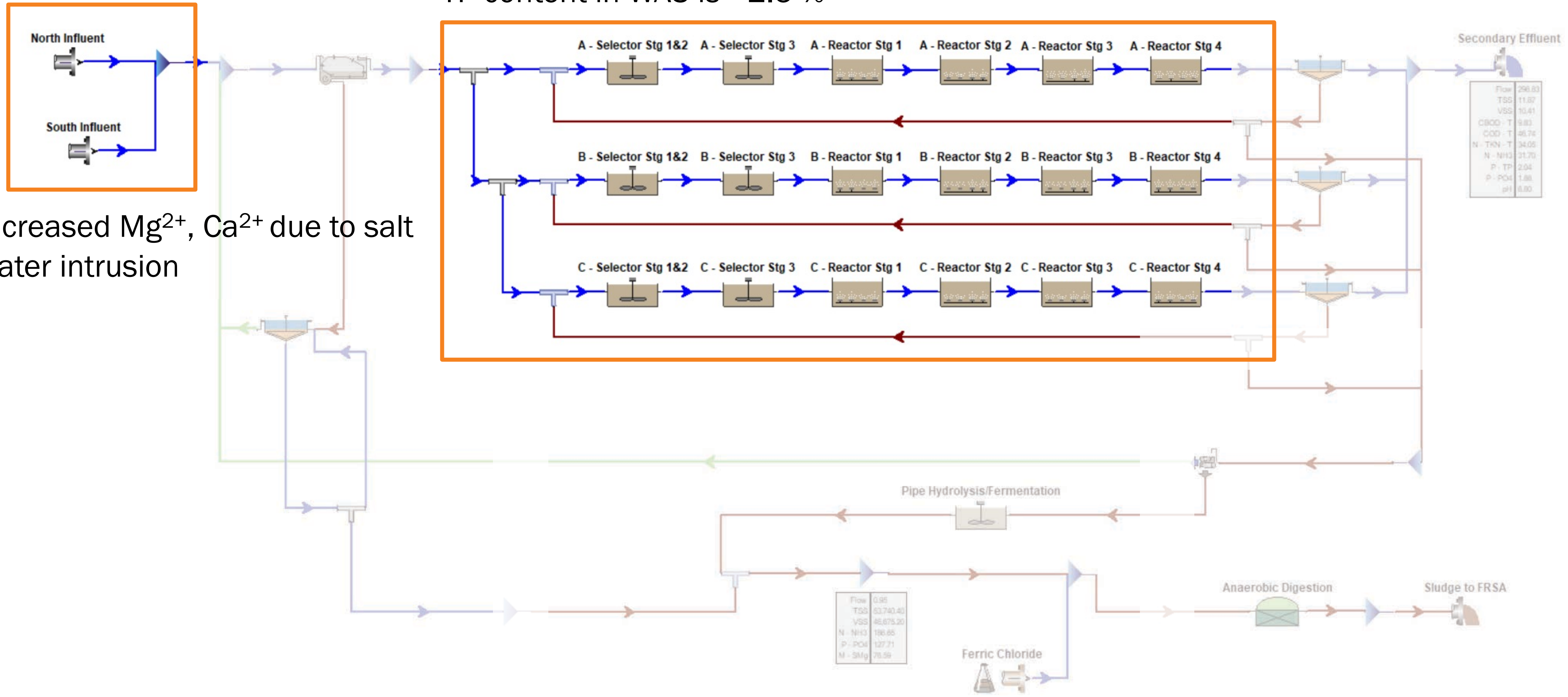
Biological Modeling Insights



Increased Mg^{2+}, Ca^{2+} due to salt water intrusion

Biological Modeling Insights

P-removal in the mainstream process is primarily through assimilation
TP content in WAS is ~2.5 %



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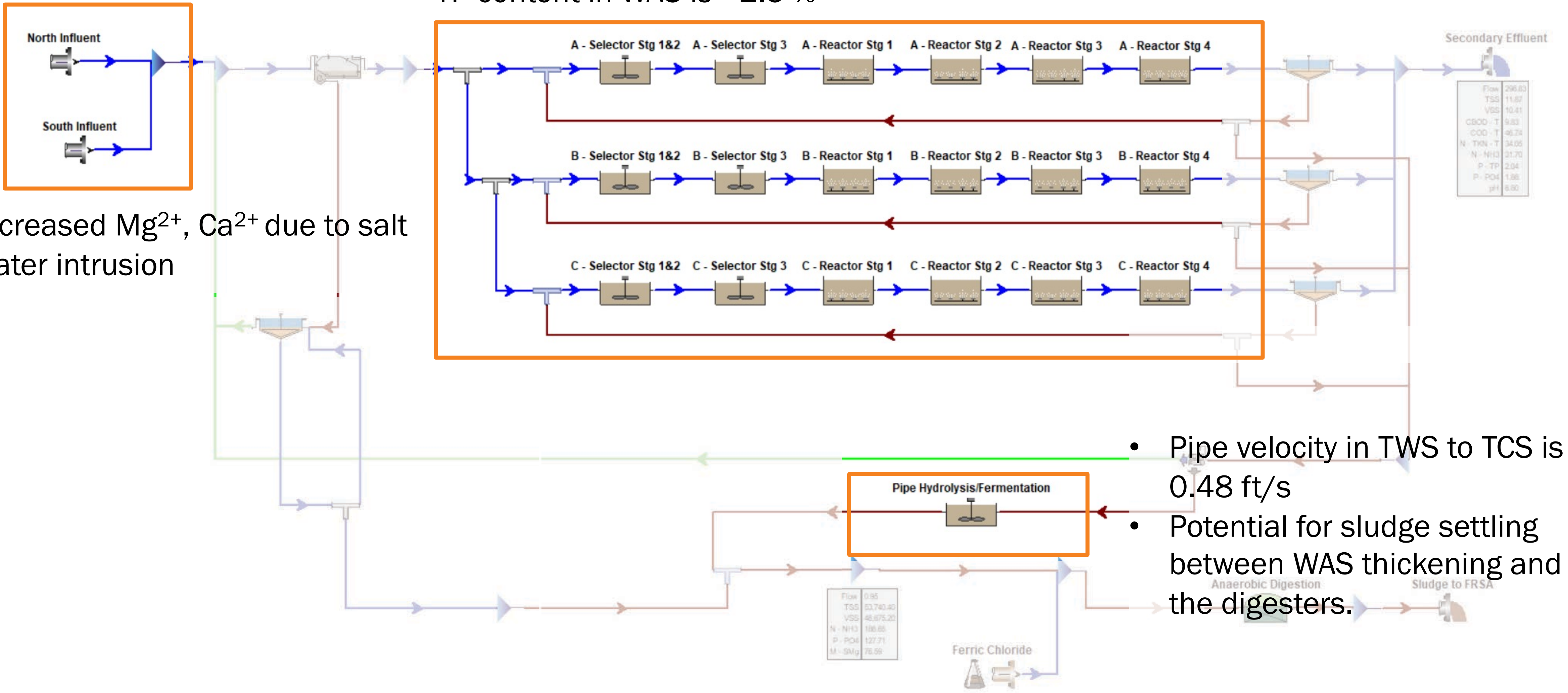

Increased Mg^{2+}, Ca^{2+} due to salt water intrusion

- Pipe velocity in TWS to TCS is 0.48 ft/s
- Potential for sludge settling between WAS thickening and the digesters.

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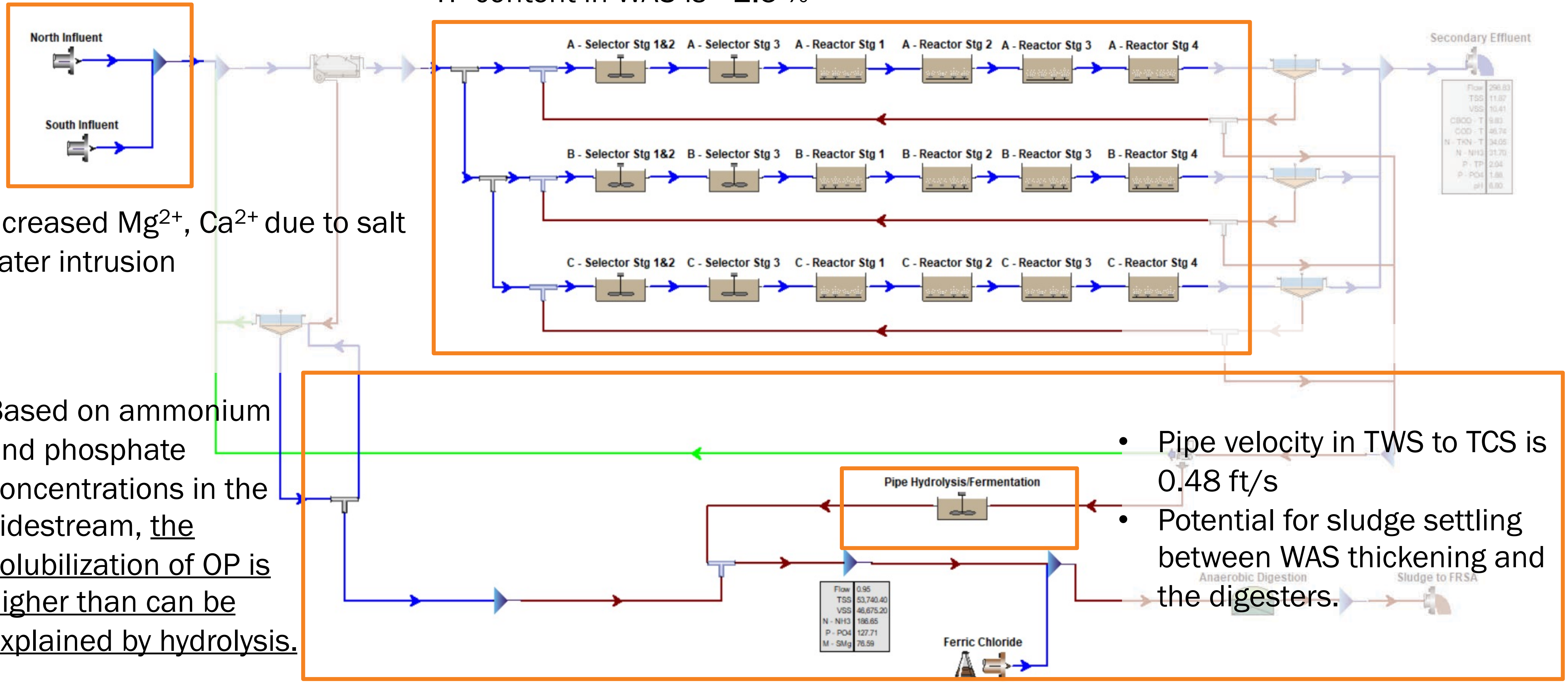


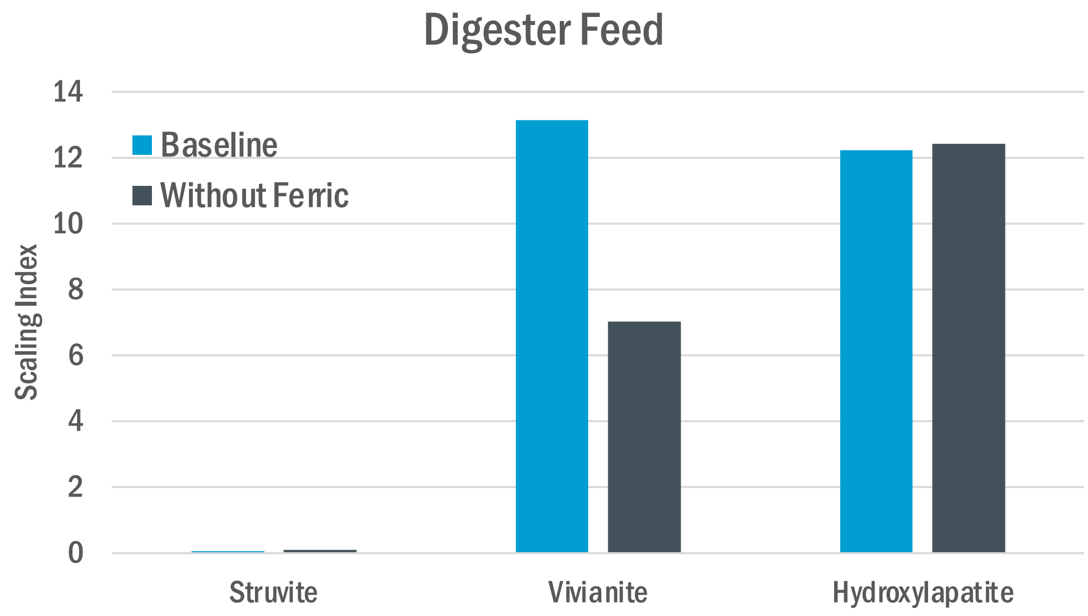
Increased Mg^{2+}, Ca^{2+} due to salt water intrusion

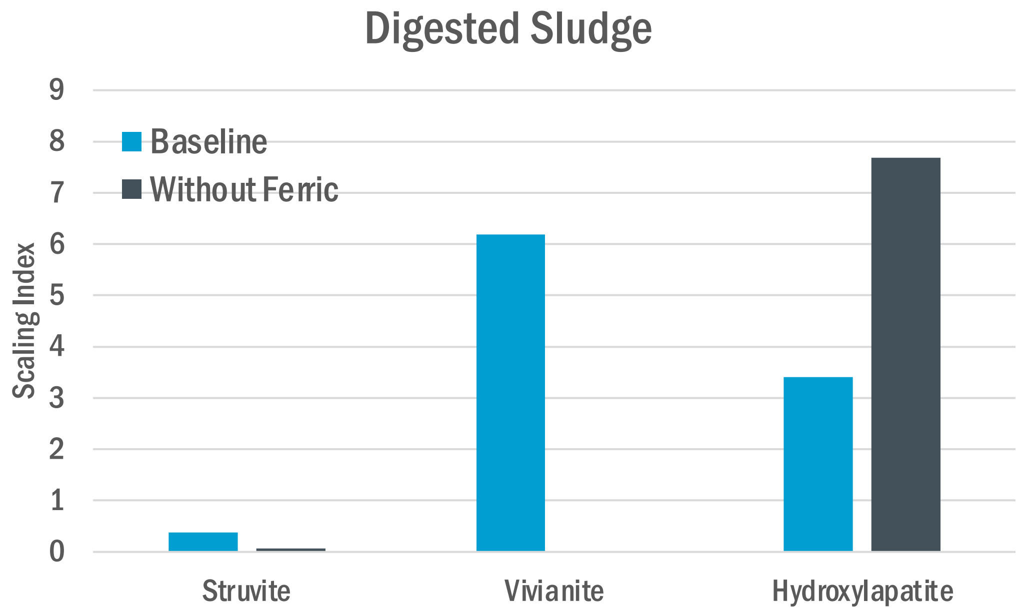
Based on ammonium and phosphate concentrations in the sidestream, <u>the solubilization of OP is higher than can be explained by hydrolysis.</u>

- Pipe velocity in TWS to TCS is 0.48 ft/s
- Potential for sludge settling between WAS thickening and the digesters.

Scaling Potential

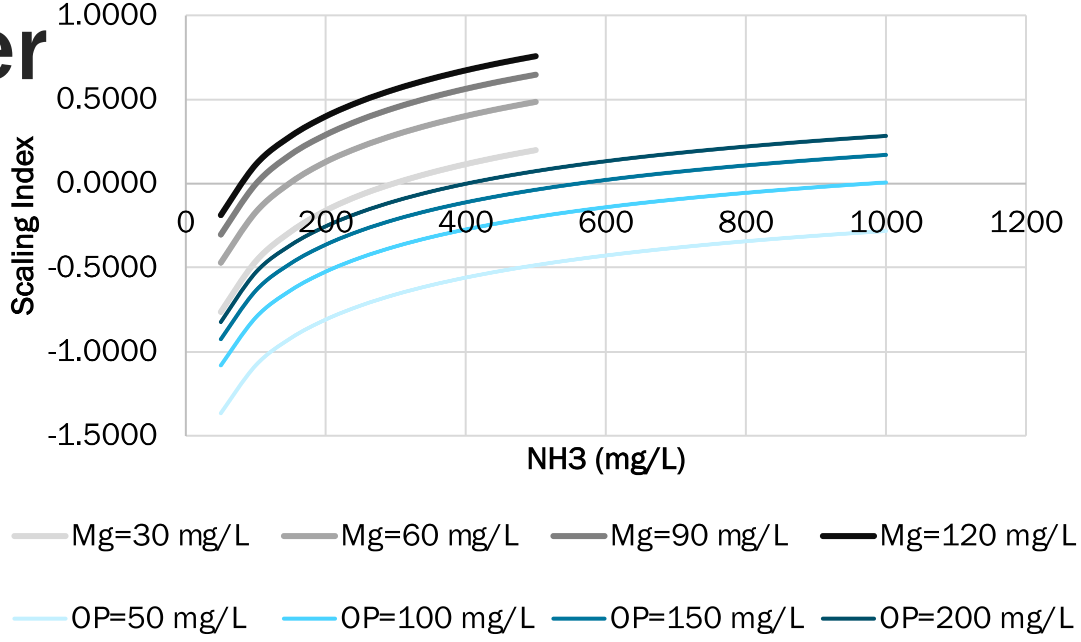
- Scaling index indicates the potential for the solids (precipitates) to form
  - SI > 0 – High solid forming potential
  - SI < 0 – Low solid forming potential
- Concentrations of ions were assumed based BC expertise.
- Modeling was used to infer scale formation potential.
- Based on chemical precipitation modeling,
  - Calcium phosphate has the highest scale forming potential in digester feed and digested sludge

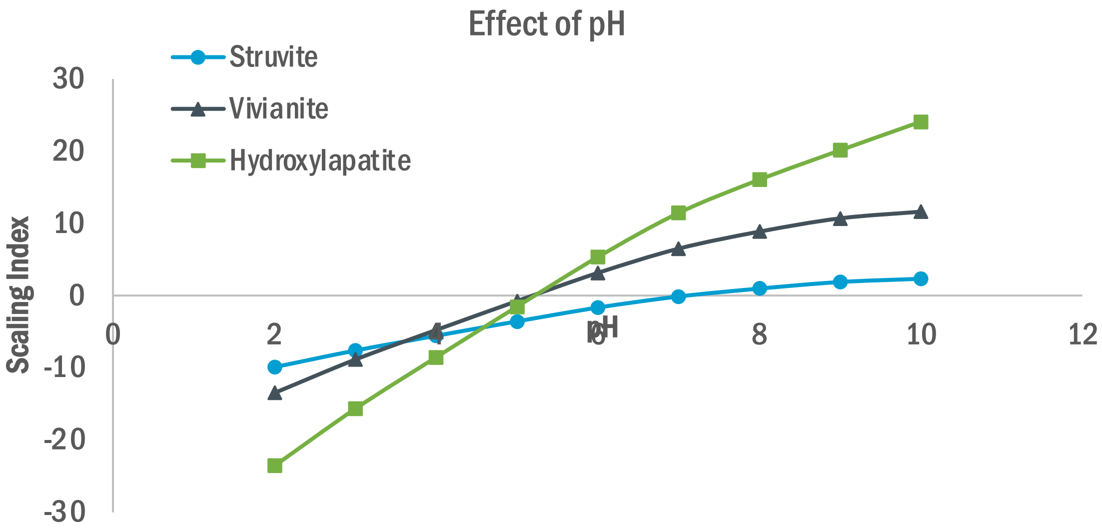




Struvite Formation in the Digester

- Dynamic interactions in the digester can influence struvite formation potential.
  - Volatile solids reduction leading to release of assimilated P, N, Mg^{2+}.
  - Hydrolysis and fermentation leading to pH changes, N and P release.
  - Solubilization of P from precipitates due to pH changes.





Conclusions

- Calcium phosphate precipitates have a higher scaling potential compared to struvite.
- Under changing pH conditions (eg: digesters, gravity thickeners, etc.), there could be solubilization of calcium phosphates which could then result in struvite formation.
- Model is sensitive to concentrations and activity of cations and anions in solution.
  - Detailed characterization of critical anions and cations can enable more accurate modeling.
  - Important to consider salt water intrusion in coastal WRRFs.

Case Study 2 – Design and Implementation

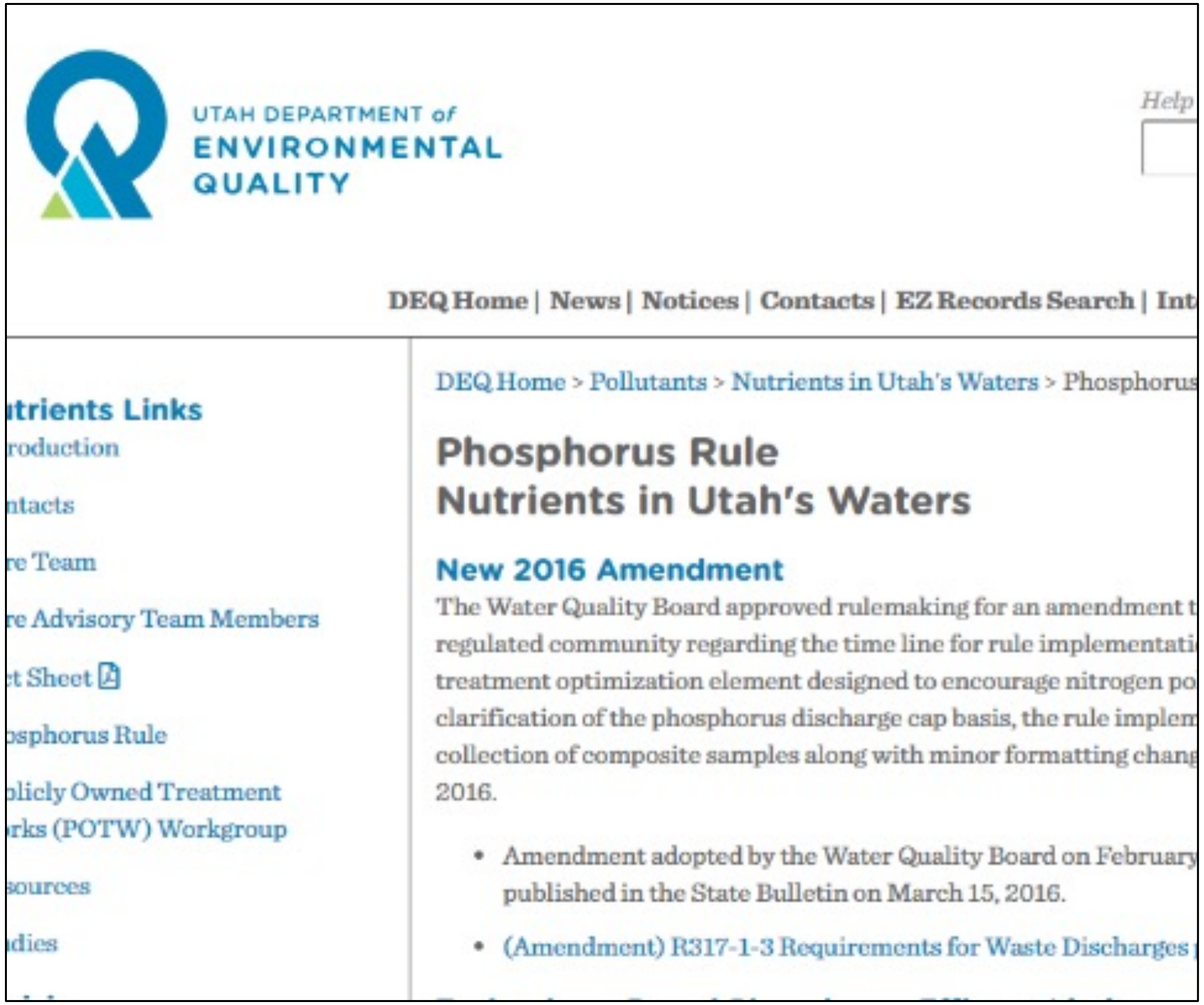
Central Valley WRF

Central Valley Water Reclamation Facility

- Plant secondary treatment system is 35-year old TF/AS process
- Design flow = 84 mgd, current flow = 54 mgd
- Current permit specifies BOD, TSS, and ammonia removal

Project Objective

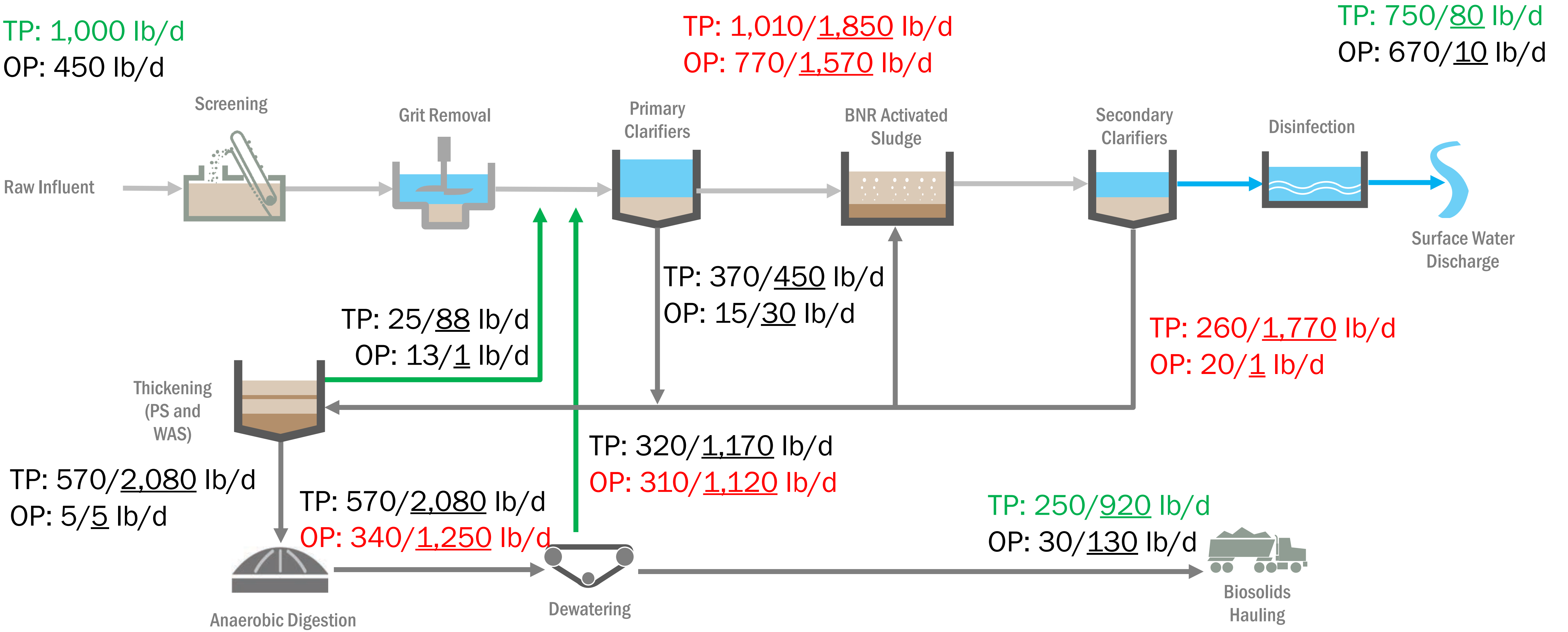
- State of Utah Technology-Based Phosphorus Effluent Limits (TBPEL) go into effect Jan 1, 2020
- TP < 1.0 mg/L
- N limits proposed but not yet promulgated
- CVWRF granted extension to Jan 1, 2025 based on initial planning work



Justification for Sidestream P Removal Process

- Reduce risk and maintenance associated with struvite
- Reduce P load on secondary process and make it easier to meet the new P regulations
  - Goal is provide P removal with no supplemental carbon

Phosphorus Balance
Shift from BOD removal to EBPR Operation

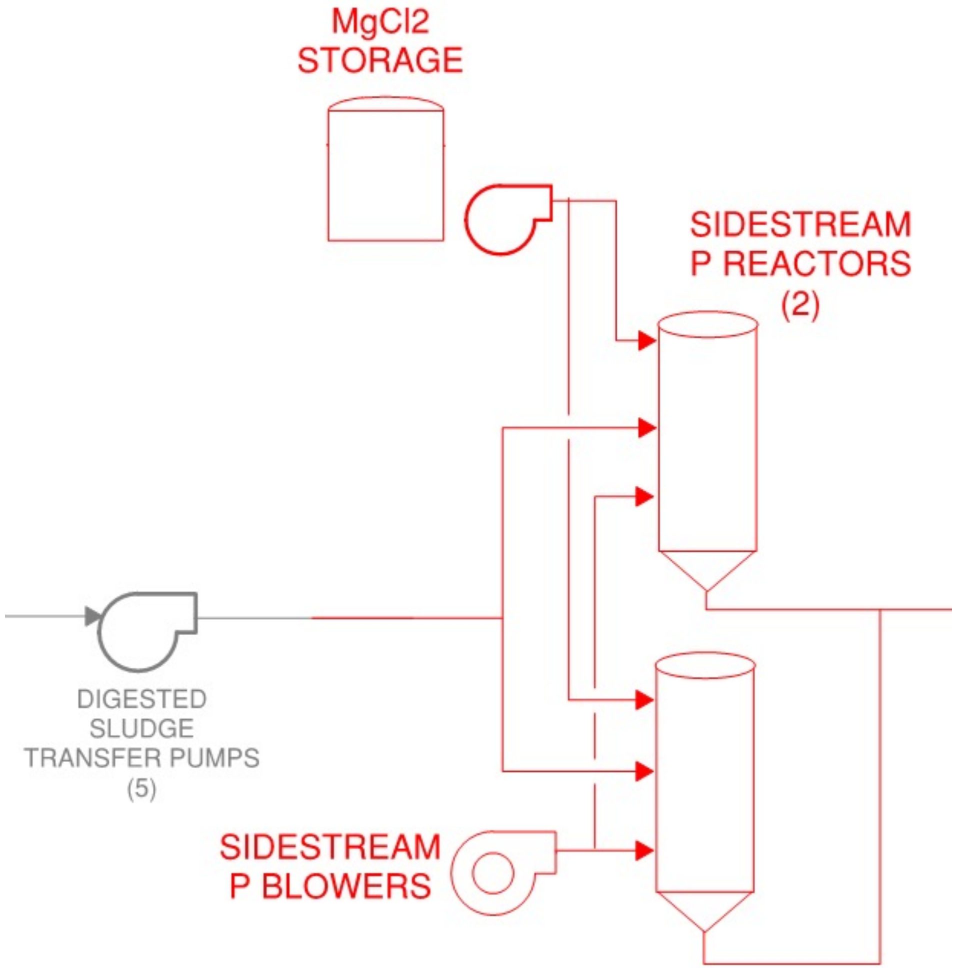


Struvite Mitigating Strategies

Struvite risk is proportional to the OP concentration

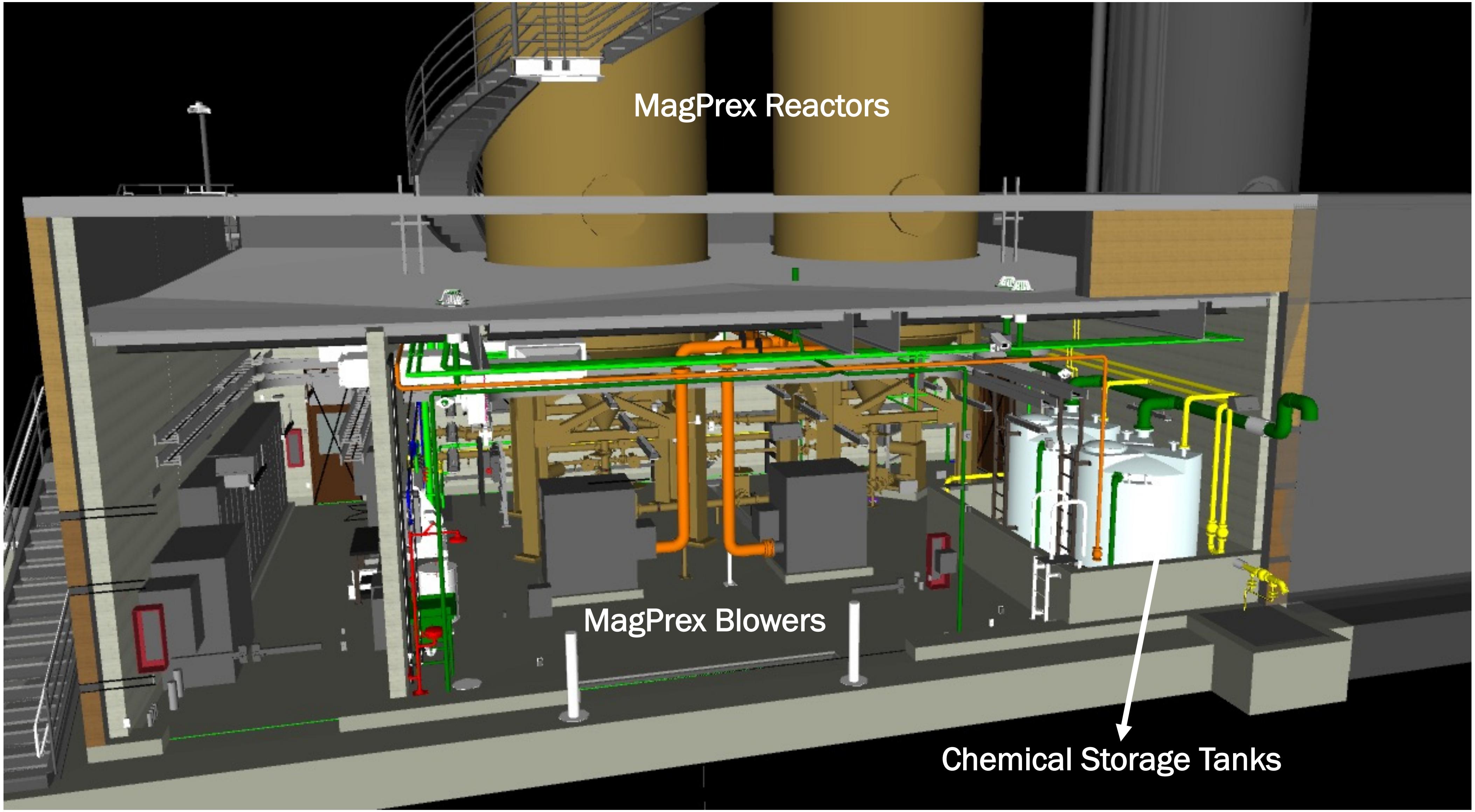
		Secondary influent TP, mg/L	Digester PO4-P, mg/L	Dewatering PO4-P, mg/L	Treated Centrate PO4-P, mg/L	Struvite, lb/d
	BOD removal only	6.0	344	344	309	0
	Shift to EBPR	10.8	1,013	1,013	1,013	0
MagPrex NuReSys	With digested sludge treatment	4.4	481	48	48	4,239
Ostara NuReSys PhosPAQ	With filtrate treatment	4.6	496	496	74	3,705
Ostara+ WASSTRIP	With filtrate treatment and WAS P release	4.6	407	407	23	4,604

Sidestream P Removal System
MagPrex pre-selected based on evaluated bid



- Design loadings
- Flow rate
  - 128-415 gpm
- OP loading
  - 1,000 – 2,000 lb/d
- $MgCl_2$ demand
  - 1,500 – 3,000 gpd
- Struvite production
  - 10,000 – 14,250 lb/d


MagPrex Reactors


MagPrex Reactors
MagPrex Blowers
Chemical Storage Tanks

Summary

- Struvite is a critical issue facing several WRRFs, particularly ones with anaerobic digestion.
- Struvite formation is a complex process involving multiple competing and contributing biological and chemical processes.
- Biological and chemical modeling can identify critical factors and interactions between the influent water quality, operation and maintenance of mainstream and side-stream processes and formation of struvite and/or other precipitates.
- A holistic whole-plant approach is critical to mitigating struvite and ensuring optimal operation of all unit processes.

Thank you.

Questions?

Ph: (978) 983-2045
Email: VSrinivasan@brwncald.com

Brown AND Caldwell