Side Stream Nutrient Considerations and Nutrient Harvesting

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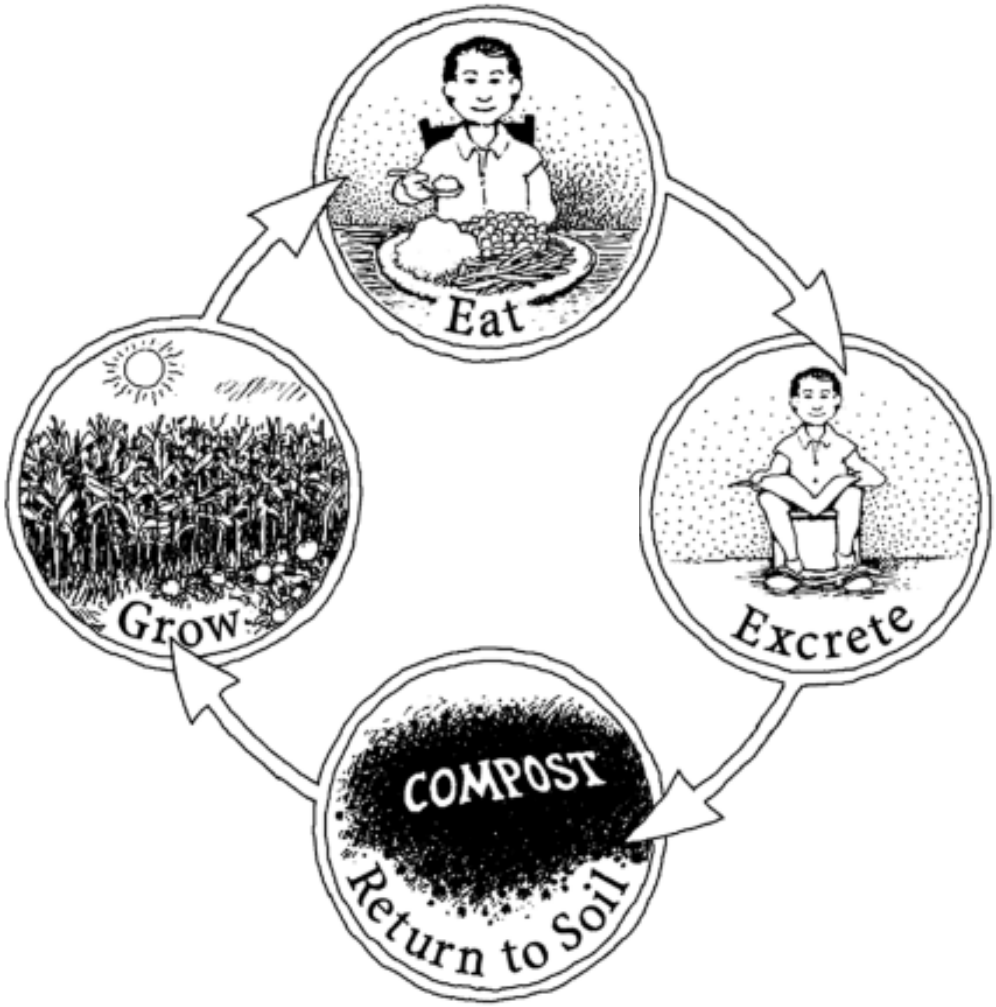
Agenda

- High Strength Side Streams
- Drivers
  - Permit, Cost to treat, O&M and equipment
- Nitrogen Treatment Alternatives
- Phosphorus Treatment Alternatives
  - Treat or Harvest
- Summary and Conclusions



Side Stream Characterization

	Primary Sludge Thickening Return	Secondary Sludge Thickening Return	Dewatering Return	Digestate Return
TSS - Conc., mg/L	557	444	330	2000
BOD - Conc., mg/L	300	300	200	50
Ammonia - Conc., mg NH3-N/L	15	15	500	1000
Total Phosphorus - Conc., mg TP/L			13	200

- Predict BOD and Ammonia from typical wastewater (MOP8) and CDM Smith Clients

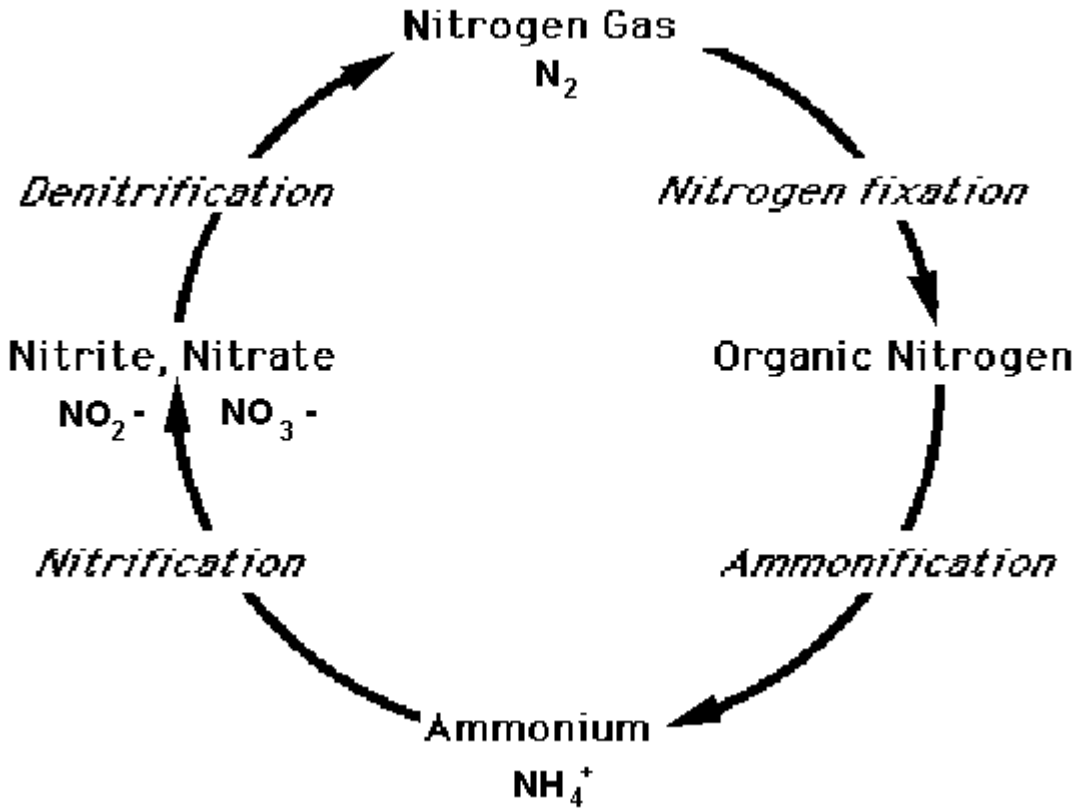
Nitrogen Side Stream Treatment Options

- Non-proprietary
  - Equalization
  - High Rate Nitrifying Activated Sludge Process
- Proprietary
  - InNitri® ("Inexpensive Nitrification")
  - SHARON® ("Single Reactor High Activity Ammonia Removal Over Nitrite") Process
    - AOx-DN ("Ammonia Oxidation-Denitrification Over Nitrite") – similar to SHARON®
  - Anammox® ("Anaerobic Ammonium Oxidation") Process
    - DEMON (suspended growth)
    - ANITA Mox (fixed film)
  - Other Nitrogen Removal Processes
    - AT-3 ("Aeration Tank 3", NYCDEP – 26th Ward)
    - BABE® ("Bio-Augmentation Batch Enhanced")
    - CaRRB ("Centrate and RAS Reaeration Basin")

Nitrification

$$NH_4^+ + 1.5O_2 \rightarrow NO_2^- + 2H^+ + H_2O$$

$$NO_2^- + \tfrac{1}{2}\, O_2 \rightarrow NO_3^-$$



Side Stream Process Alternatives

Side Stream Process	Description
Equalization	EQ flow over 24 hr period, or only at night; need mixing
Aerated Equalization	Aerate the centrate only; At 1 day SRT, should get most ammonia removed
High rate nitrifying activated sludge	Activated sludge plant for dewatering Side Stream (aeration tank and clarifier); Can be done in an SBR
InNitri® (m^2t technologies)	Treats Side Stream in a separate activated sludge system (with clarifier), produces an enriched population of nitrifying bacteria, which is used to seed the mainstream reactor, no denite step

Side Stream Process Alternatives

Side Stream Process	Description	Advantages	Disadvantages
Equalization	EQ flow over 24 hr period, or only at night; need mixing	• Easy, low cost solution • Distributes load throughout day	• Load still treated in main process • Large storage tank needed
Aerated Equalization	Aerate the centrate only; At 1 day SRT, should get most ammonia removed	• Thousand Oaks example – achieve 50% ammonia removal	• More equipment and operational costs than EQ only • No denite of Side Stream
High rate nitrifying activated sludge	Activated sludge plant for dewatering Side Stream (aeration tank and clarifier); Can be done in an SBR	• Non-proprietary • Uses high temp of dewatering Side Stream • Dallas example - ~800 mg/L ammonia down to <10 mg/L with 3 day SRT; saved $400K & double equipment cost compared with SHARON®	• Separate Side Stream process • No denite of Side Stream
InNitri® (m^2t technologies)	Treats Side Stream in a separate activated sludge system (with clarifier), produces an enriched population of nitrifying bacteria, which is used to seed the mainstream reactor, no denite step	• Increased capacity of mainstream nitrification process • Uses high temp of dewatering Side Stream to speed reaction	• No denite of Side Stream • Alkalinity needed • Poor settling of Side Stream → hard to maintain SRT

Side Stream Process Alternatives – SHARON®/ Annamox®

Side Stream Process	Description
SHARON® (m^2t technologies)	Nitrifies ammonia to nitrite then reduces the nitrite to nitrogen gas in a continuous-flow, completely mixed reactor without sludge recycle at the temperature of centrate
AOx-DN (f.r.mahony &associates, inc.)	Similar to SHARON® in fixed film reactor; controls nitrification by intermittently aerating the reactor; at high temp of centrate
DEMON (World Water Works)	In Anammox, nitrite and ammonia are converted to nitrogen gas. Batch operation, suspended growth, two reactors (Min.), one flow EQ tank
ANITA Mox (Kruger, Inc.)	Anammox in continuous flow reactor, Fixed Film Growth (MBBR) or combined Fixed Film and Suspended Growth (IFAS)
SHARON®/ Anammox (m^2t technologies)	Anammox downstream of SHARON®, with SHARON® operated to provide approximately equal parts of ammonia and nitrite

Side Stream Process Alternatives – SHARON®/ Annamox®

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SHARON® (m^2t technologies)	Nitrifies ammonia to nitrite then reduces the nitrite to nitrogen gas in a continuous-flow, completely mixed reactor without sludge recycle at the temperature of centrate	• Decrease nitrogen load to mainstream • Decrease oxygen & carbon	• Additional process to maintain • Proprietary, can be costly
AOx-DN (f.r.mahony &associates, inc.)	Similar to SHARON® in fixed film reactor; controls nitrification by intermittently aerating the reactor; at high temp of centrate	• Decrease nitrogen load to mainstream • Decrease oxygen & carbon	• Additional process to maintain • Proprietary, can be costly
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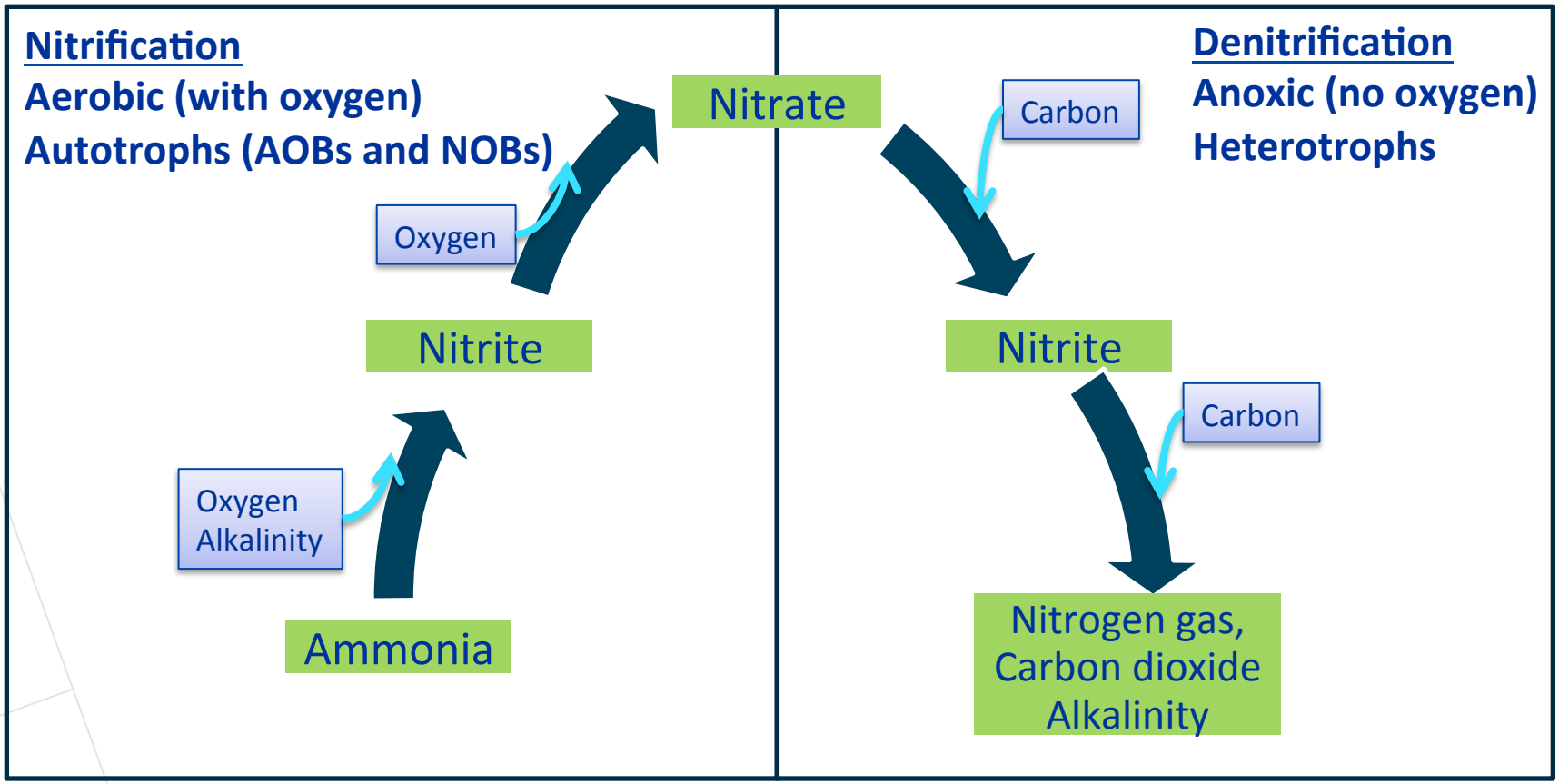
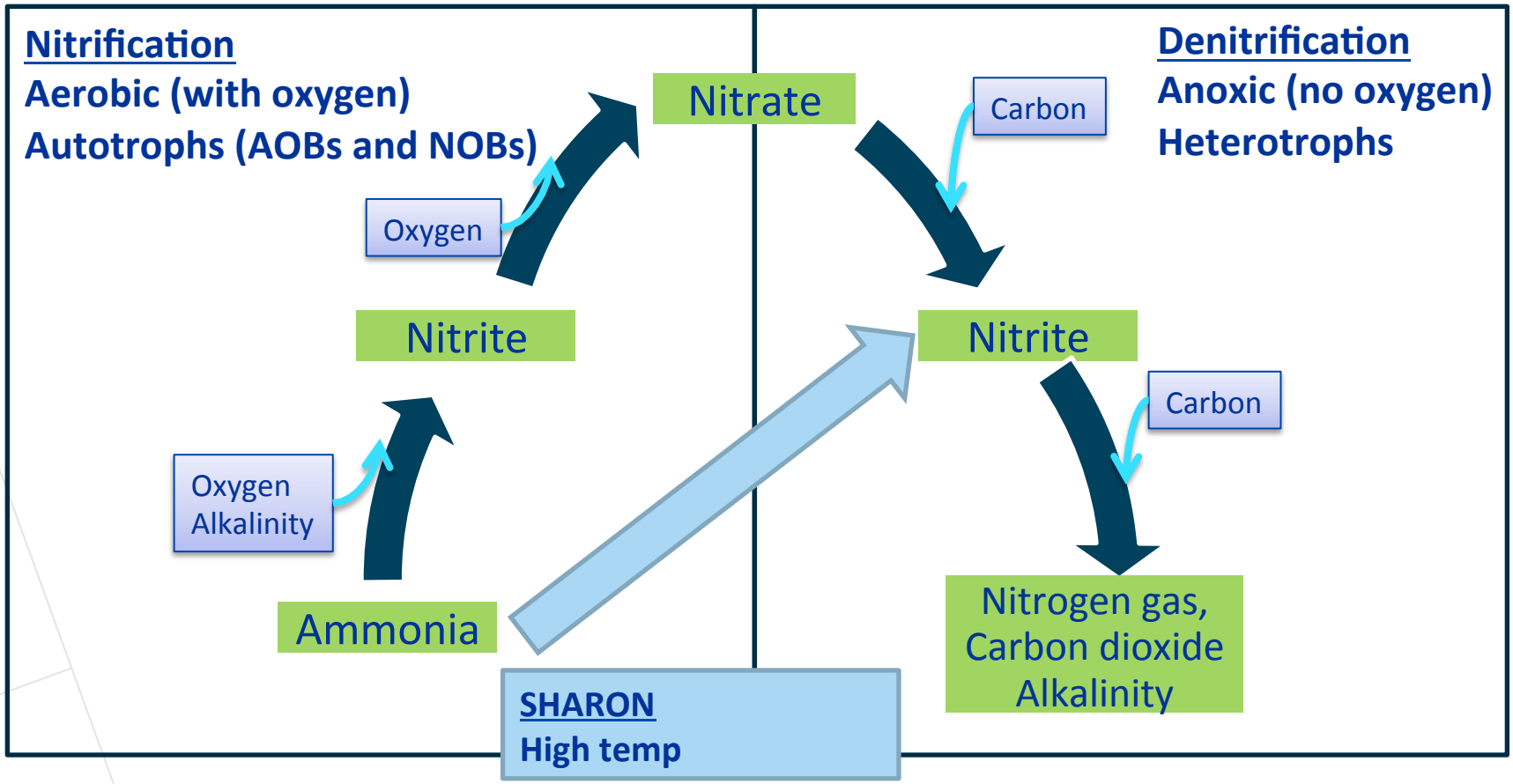
SHARON®/ Anammox (m^2t technologies)	Anammox downstream of SHARON®, with SHARON® operated to provide approximately equal parts of ammonia and nitrite	• Decreases oxygen use by ~63% compared to conventional nitrification • Does not consume COD	• Additional process to maintain • Heat generated by Anammox, may need cooling

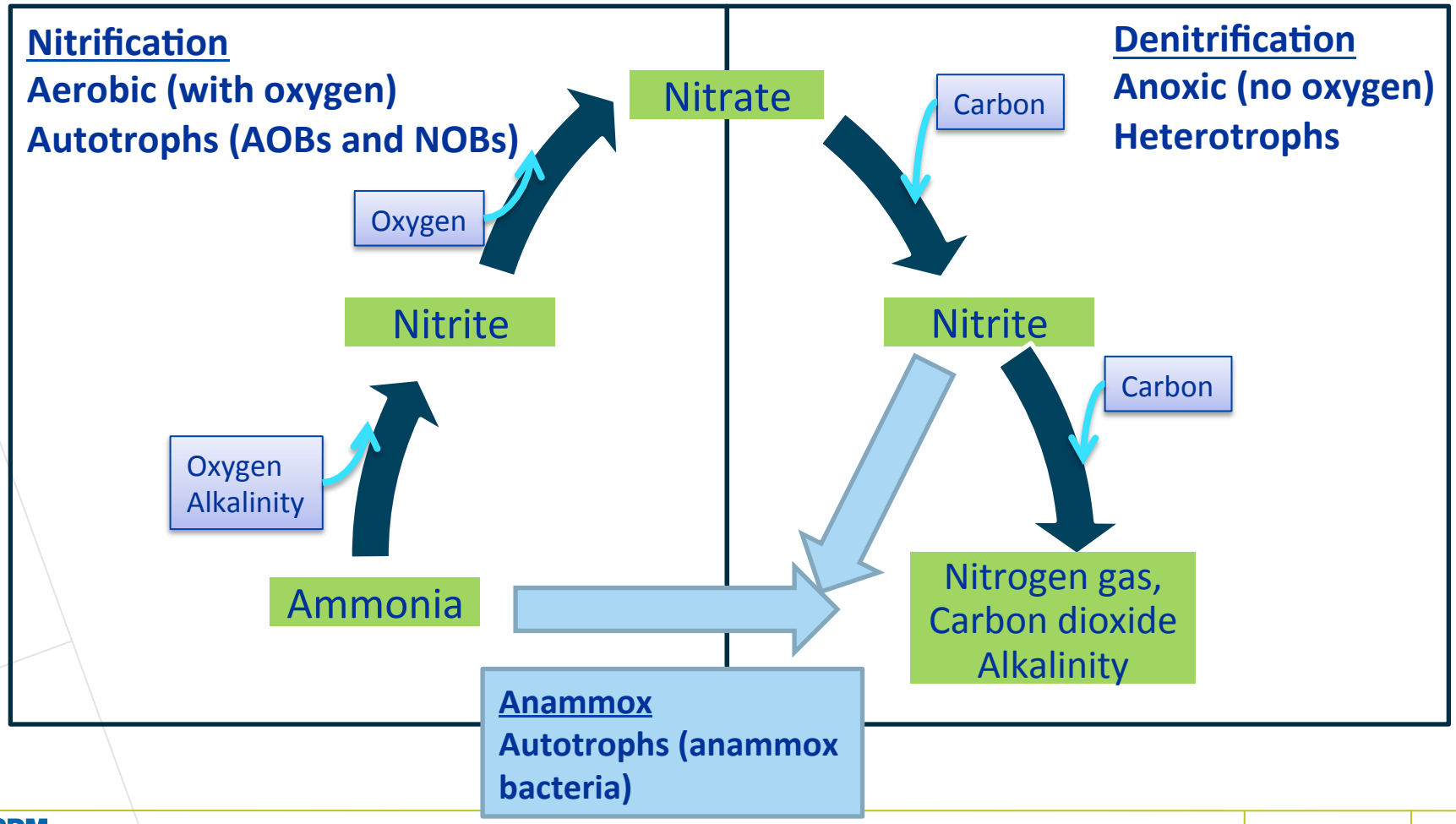
Biological Nitrogen Removal



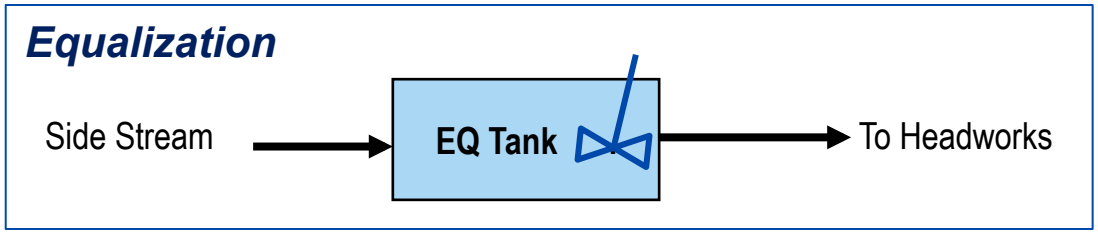
SHARON® Process Short-cuts Nitrification to Reduce Energy and Carbon Requirements

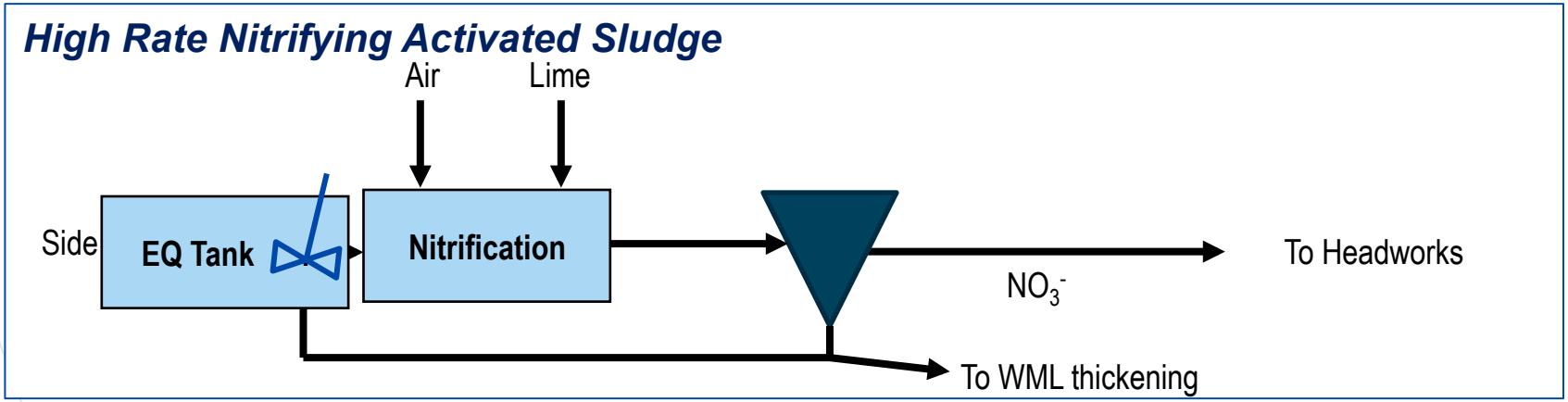


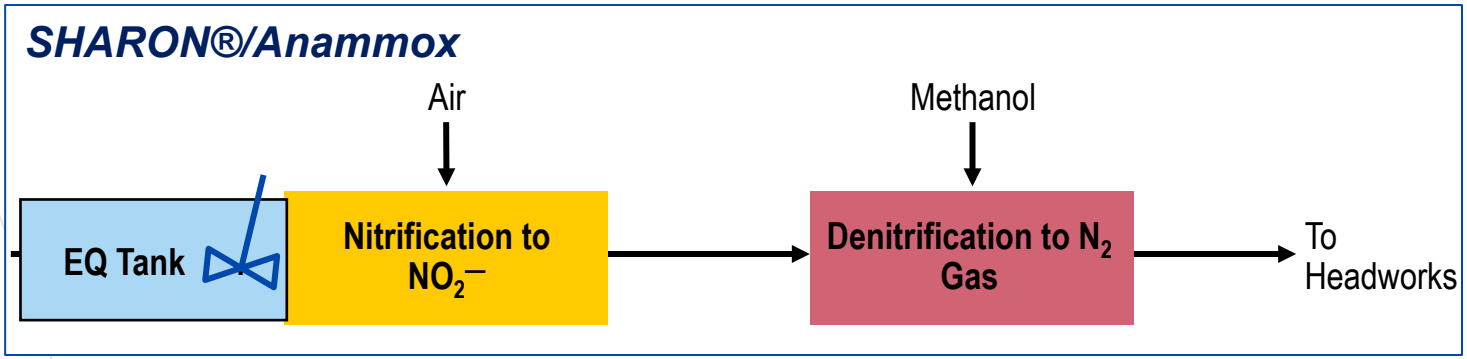
Anammox® Process Achieves Shortest Route to Remove Nitrogen at Low Operating Cost (low oxygen, no carbon)



Side Stream Process Flow Schematics







Side Stream Process Alternatives - Other

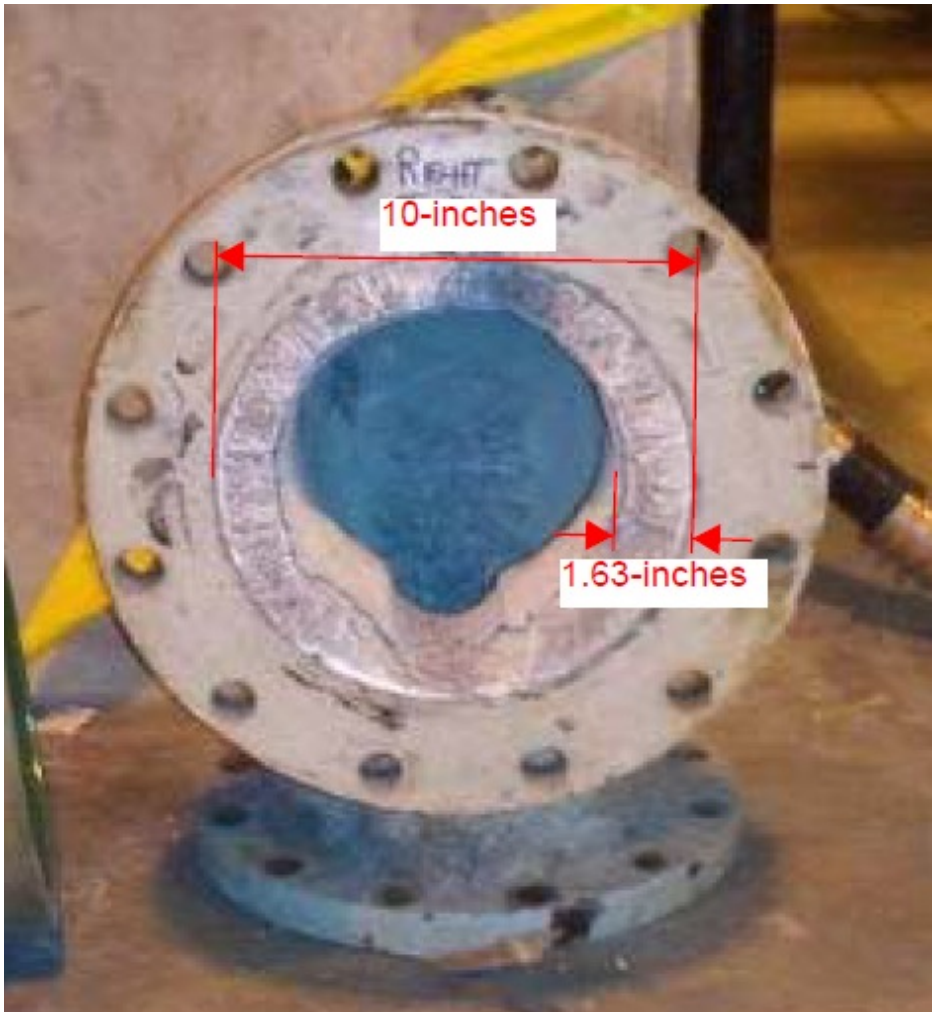
Side Stream Process	Description
AT-3 ("Aeration Tank 3", NYCDEP – 26th Ward)	Treats Side Stream in a separate activated sludge system, plug flow
BABE ("Bio-Augmentation Batch Enhanced")	Divert portion mainstream RAS and blend with Side Stream to feed into reactor, usually SBR
CaRRB ("Centrate and RAS Reaeration Basin")	Side Stream (centrate) and RAS in bioreactor with aeration for nitrification before return to mainstream

Side Stream Process Alternatives - Other

Side Stream Process	Description	Advantages	Disadvantages
AT-3 ("Aeration Tank 3", NYCDEP – 26th Ward)	Treats Side Stream in a separate activated sludge system, plug flow	• Increased capacity of mainstream nitrification process	• Limited full-scale installations • No denite of Side Stream
BABE ("Bio-Augmentation Batch Enhanced")	Divert portion mainstream RAS and blend with Side Stream to feed into reactor, usually SBR	• Settles better than InNitri® because of RAS addition • Can achieve some denite with SBR	• Limited full-scale installations • Additional process to maintain
CaRRB ("Centrate and RAS Reaeration Basin")	Side Stream (centrate) and RAS in bioreactor with aeration for nitrification before return to mainstream	• Reduced load to mainstream process • Can provide biomass storage for wet weather	• Additional process to maintain
Ostara PEARL™ Nutrient Recycling	Controlled struvite precipitation for phosphorus & ammonia removal	• Produces struvite, a product that can be sold	• P benefit, not much N benefit • Costly

Faces of Struvite

Faces of Struvite



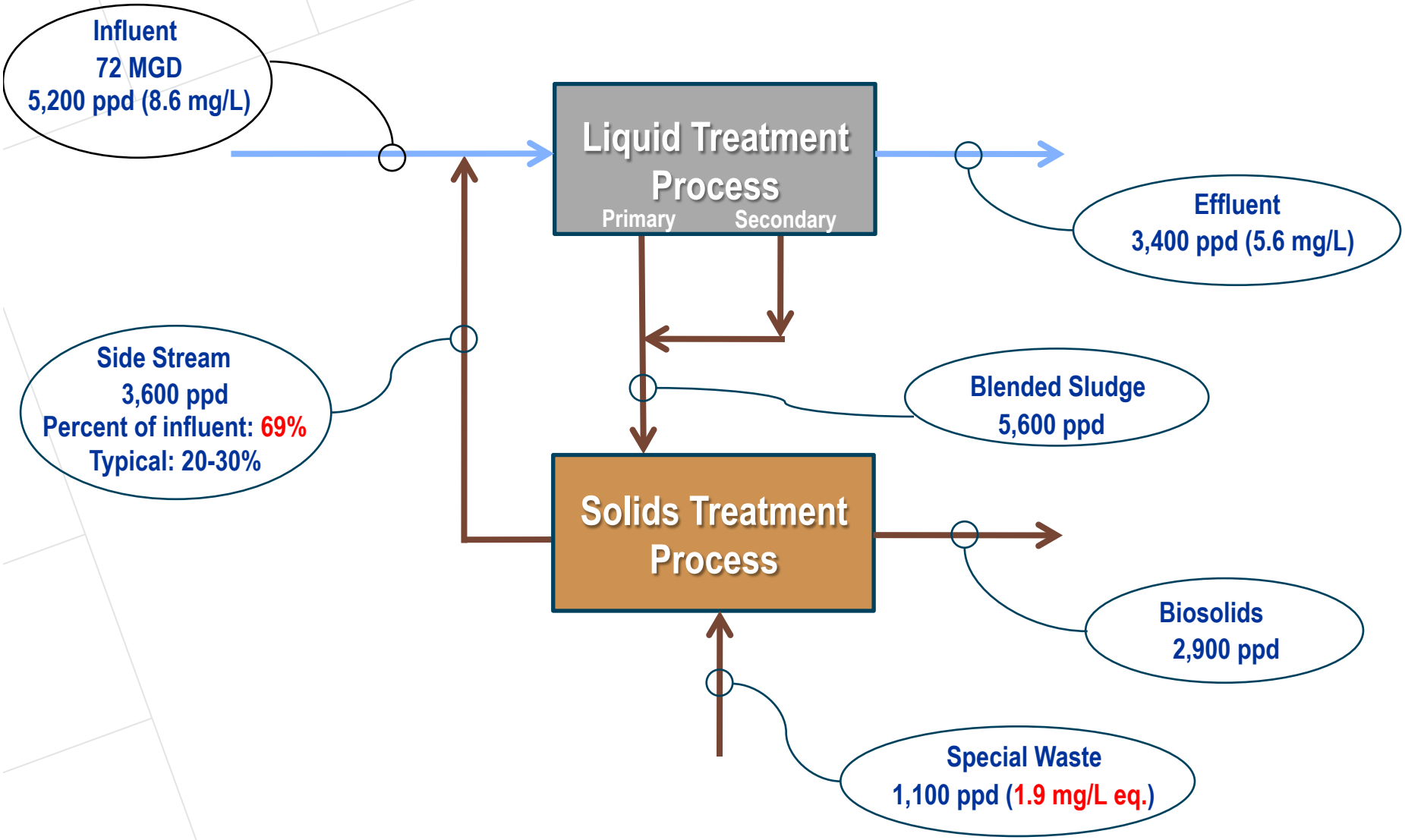
Drivers for Harvesting Phosphorus

- Struvite Chemical and Cleaning Costs Increasing
  - **$170,000/yr and growing at Des Moines**
  - **$750,000/yr and growing at Deer Island (Ferric only)**
- Potential Effluent Nutrient
- Potential Restrictions on Land Applied P at Des Moines

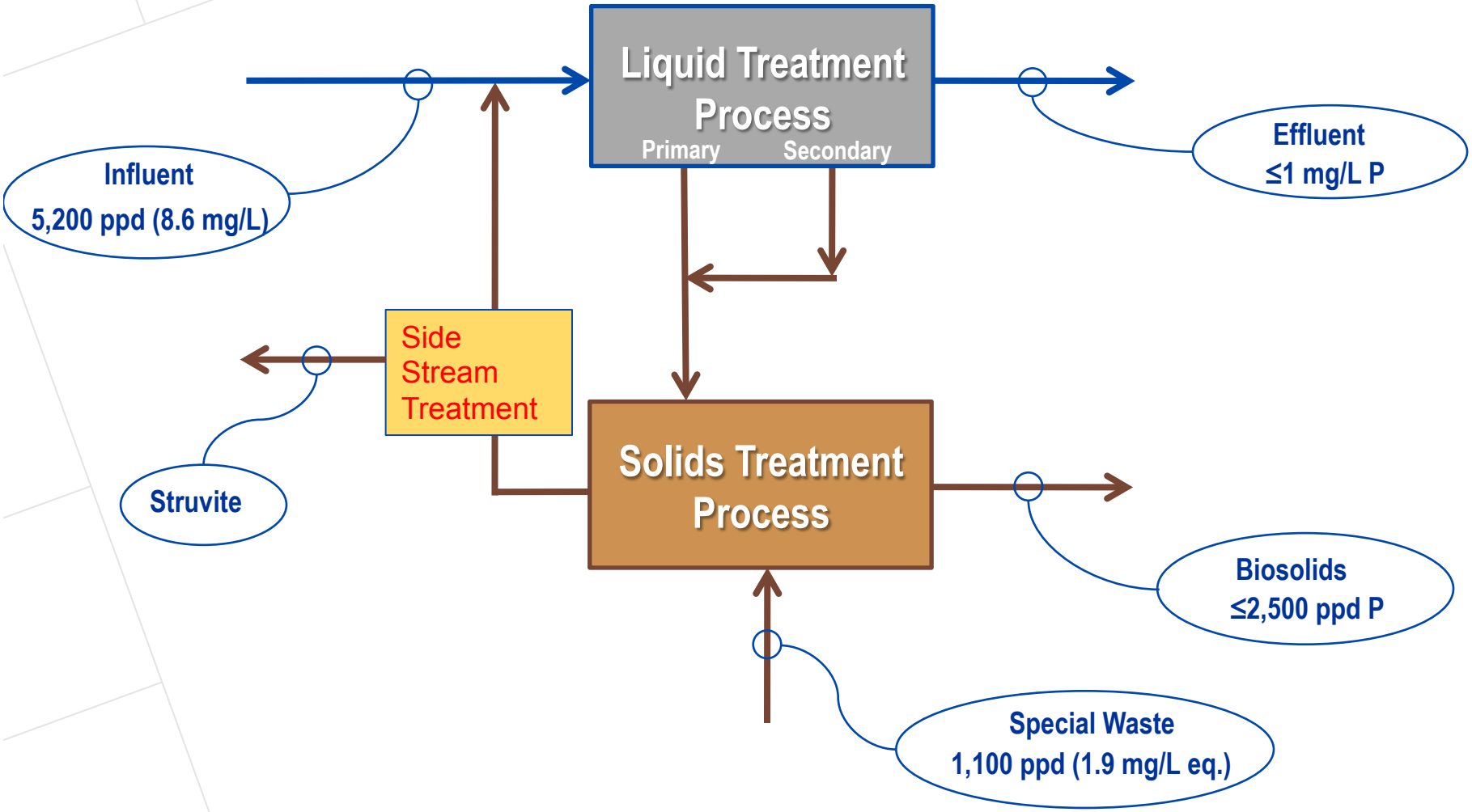
Phosphorus Side Stream Treatment Options

- Non-proprietary
  - Biological
  - Chemical
    - iron salts
    - Alum
    - pH adjustment
  - Carbon Dioxide Injection
- Proprietary
  - Chemical Addition
    - Struvout 2520
  - Harvest
    - DHV – Crystalactor
    - Paques – Phosphaq
    - CNP - Airprex
    - Multiform Harvest
    - Ostara PEARL™

Plant Phosphorus Balance



Proposed Solution
Side Stream Nutrient Removal



Proposed Solution
Side Stream Nutrient Removal

cnp

PAQUES

revitalizing resources

OSTARA

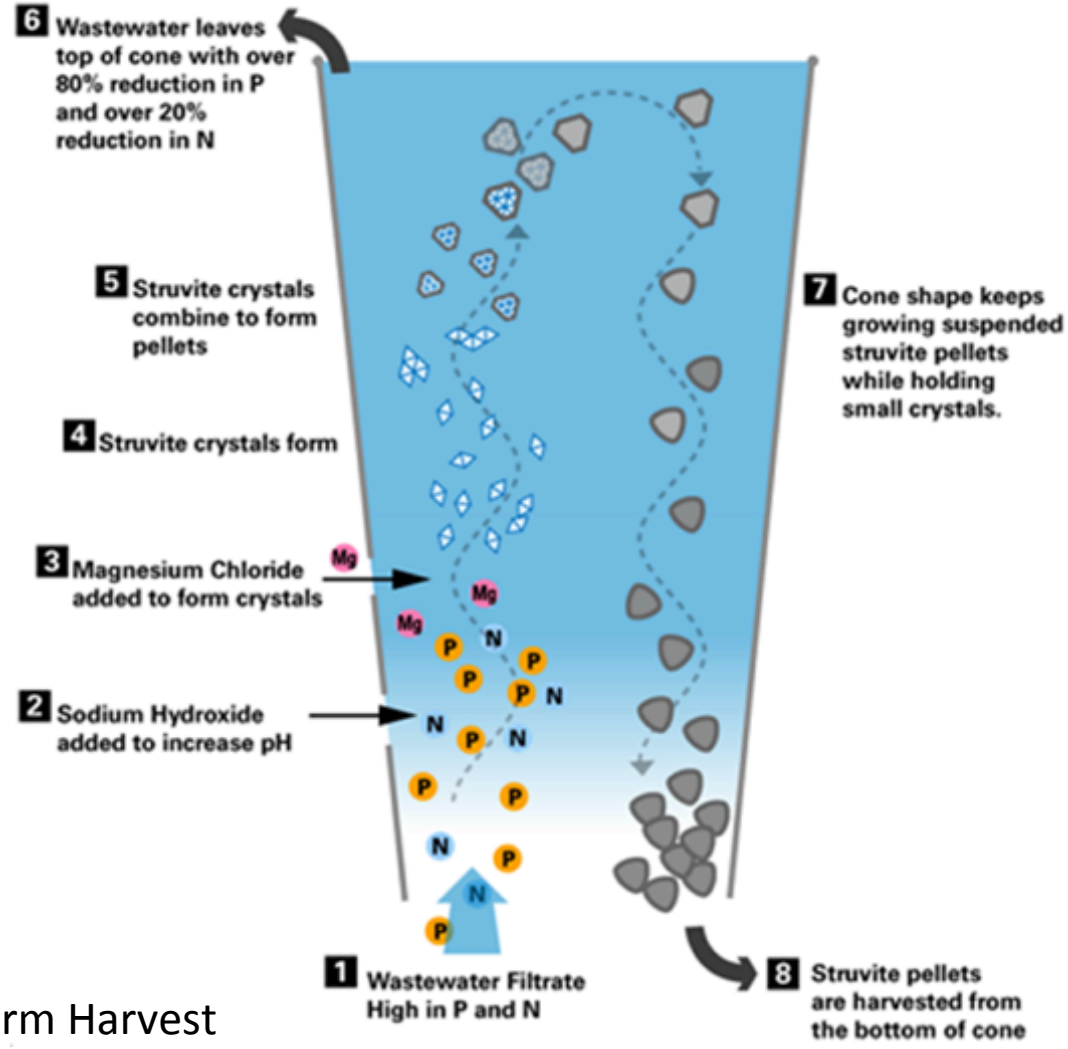
Creating Value from Waste

MULTIFORM HARVEST

Crystalactor®

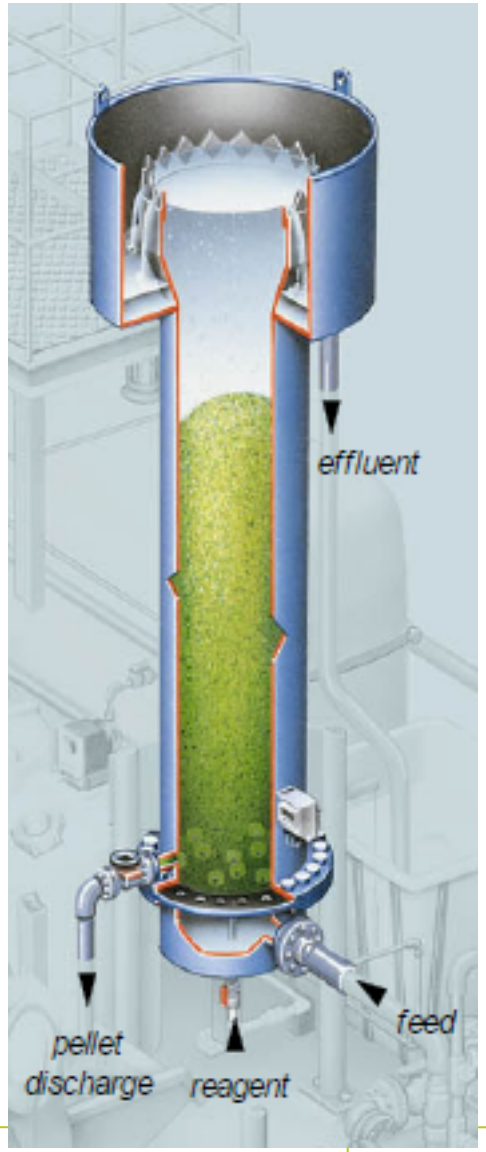
$$Mg^{2+} + NH_4^{+} + PO_4^{3-} + 6\,H_2O \rightarrow MgNH_4PO_4 \cdot 6H_2O$$ *struvite*

$$3Fe^{2+} + 2\,PO_4^{3-} \rightarrow Fe_3(PO_4)_2\,8\,H_2O$$ *vivianite*

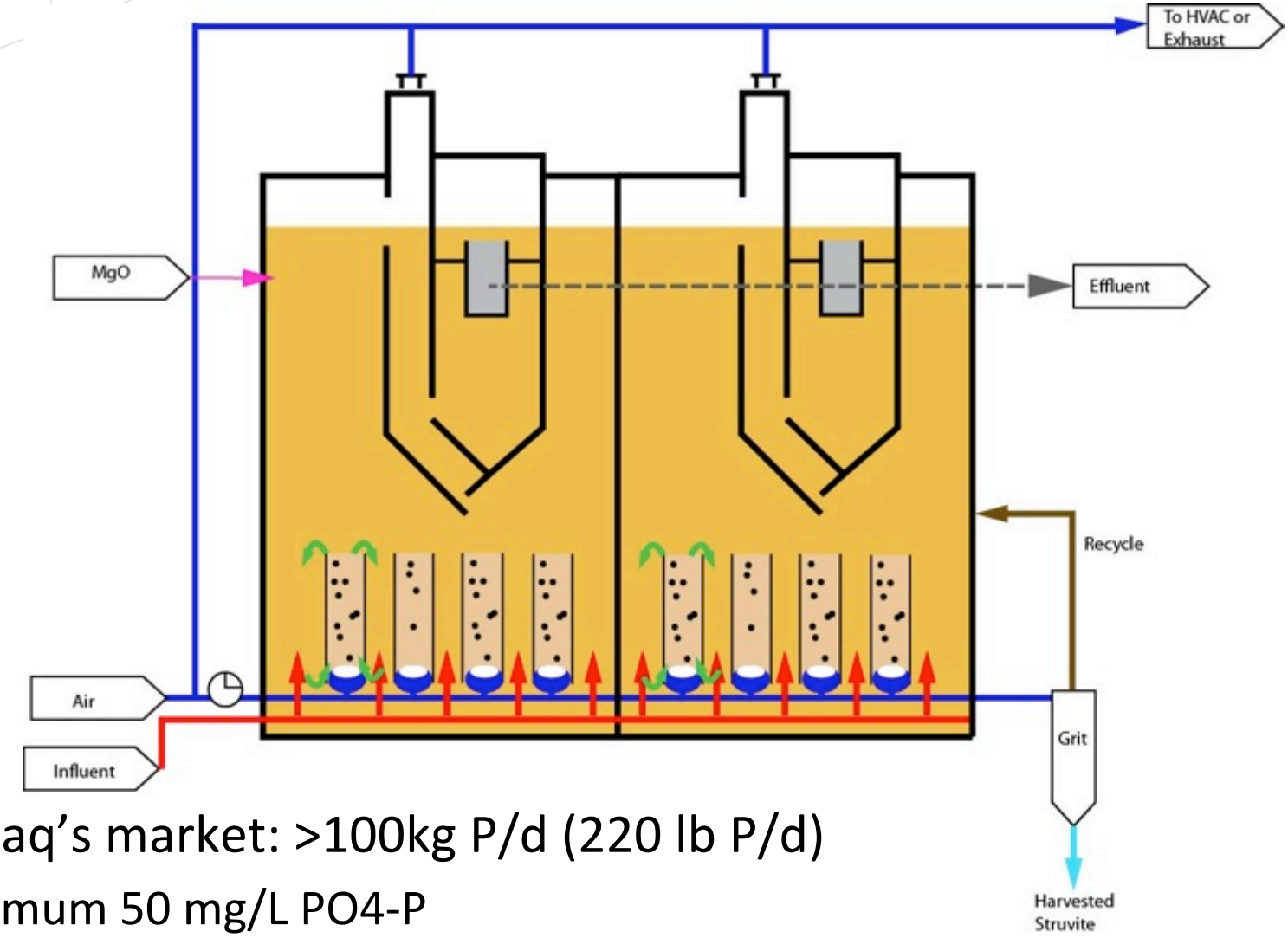


Source: Multiform Harvest

DHV - Crystalactor



Paques PHOSPAQ®

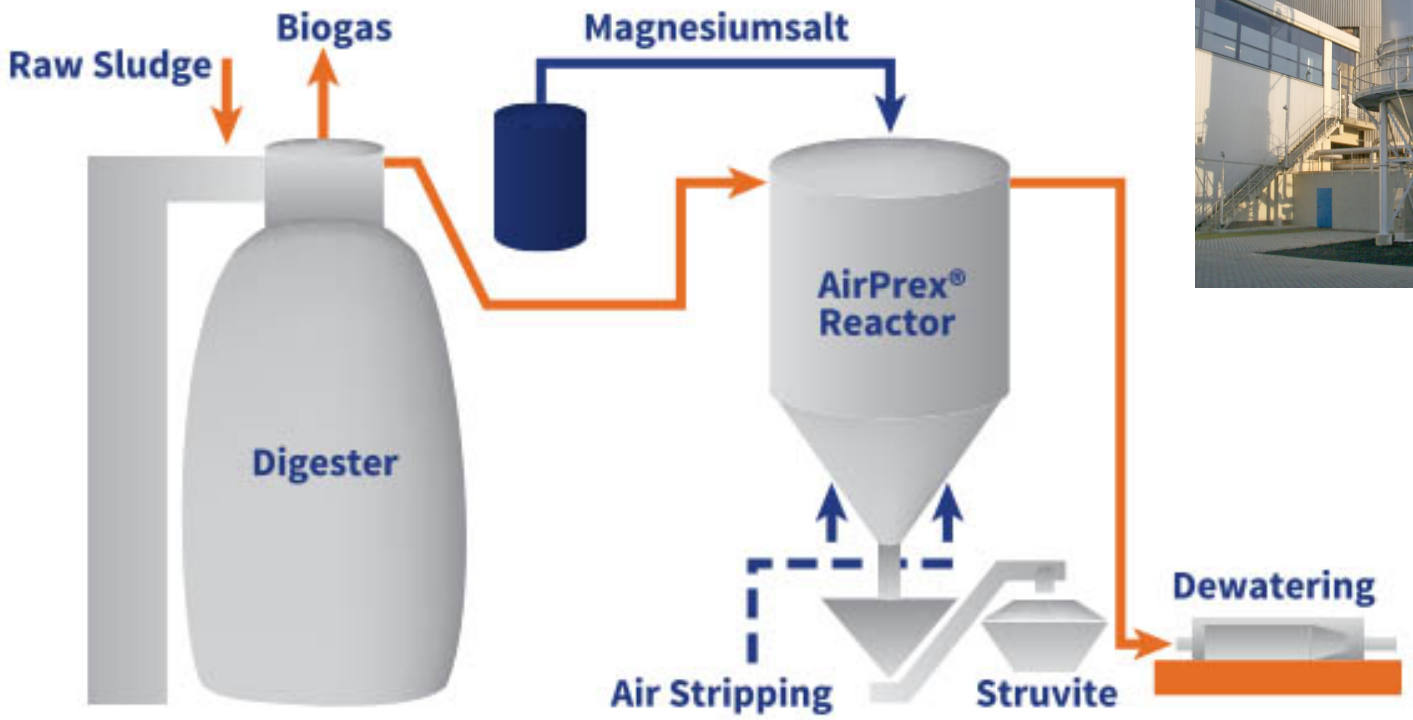


- Phosphaq's market: >100kg P/d (220 lb P/d)
  - Minimum 50 mg/L PO4-P
  - Minimum 200 mg/L NH4-N

PHOSPAQ Struvite Product

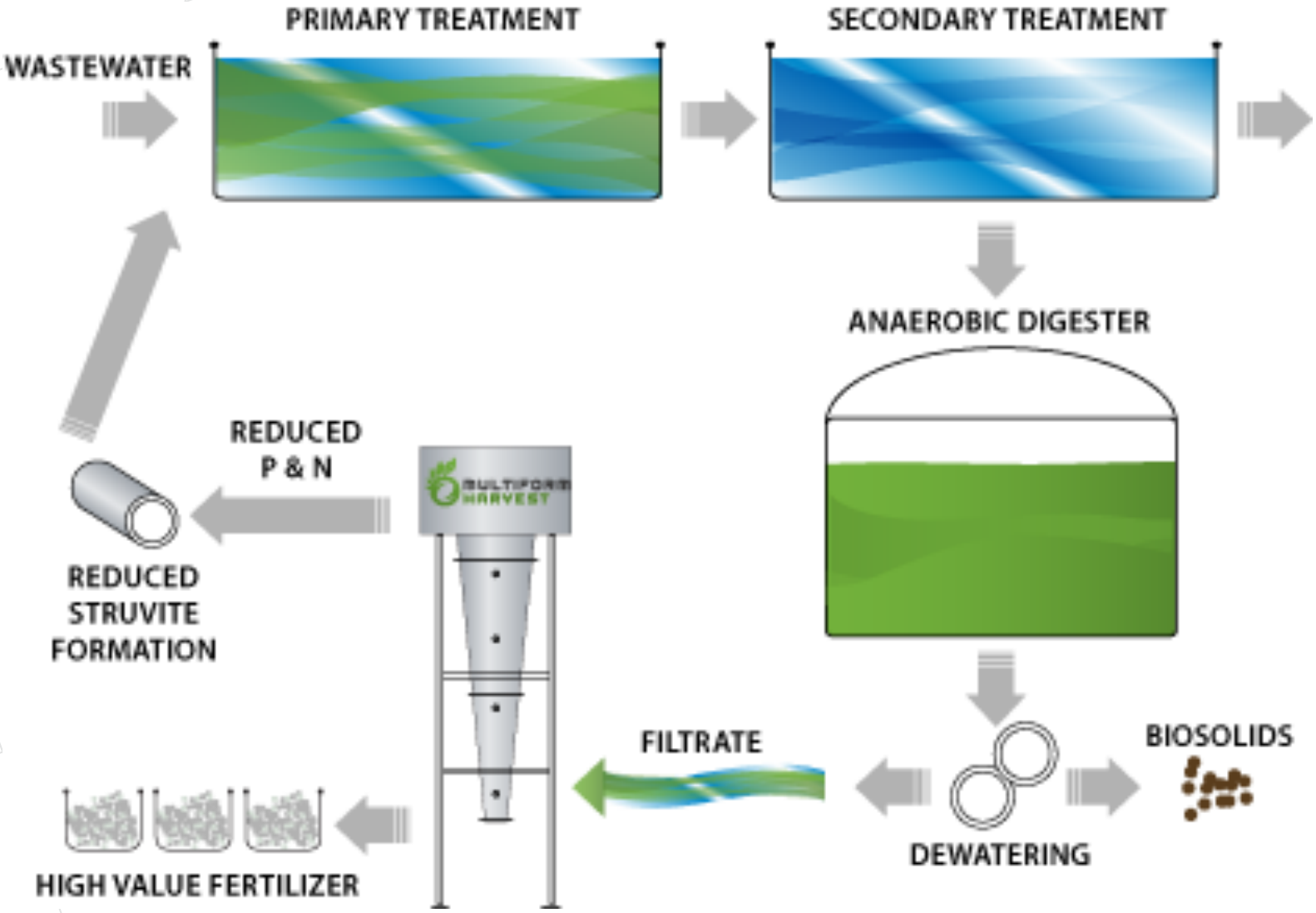
SOURCE: YouTube

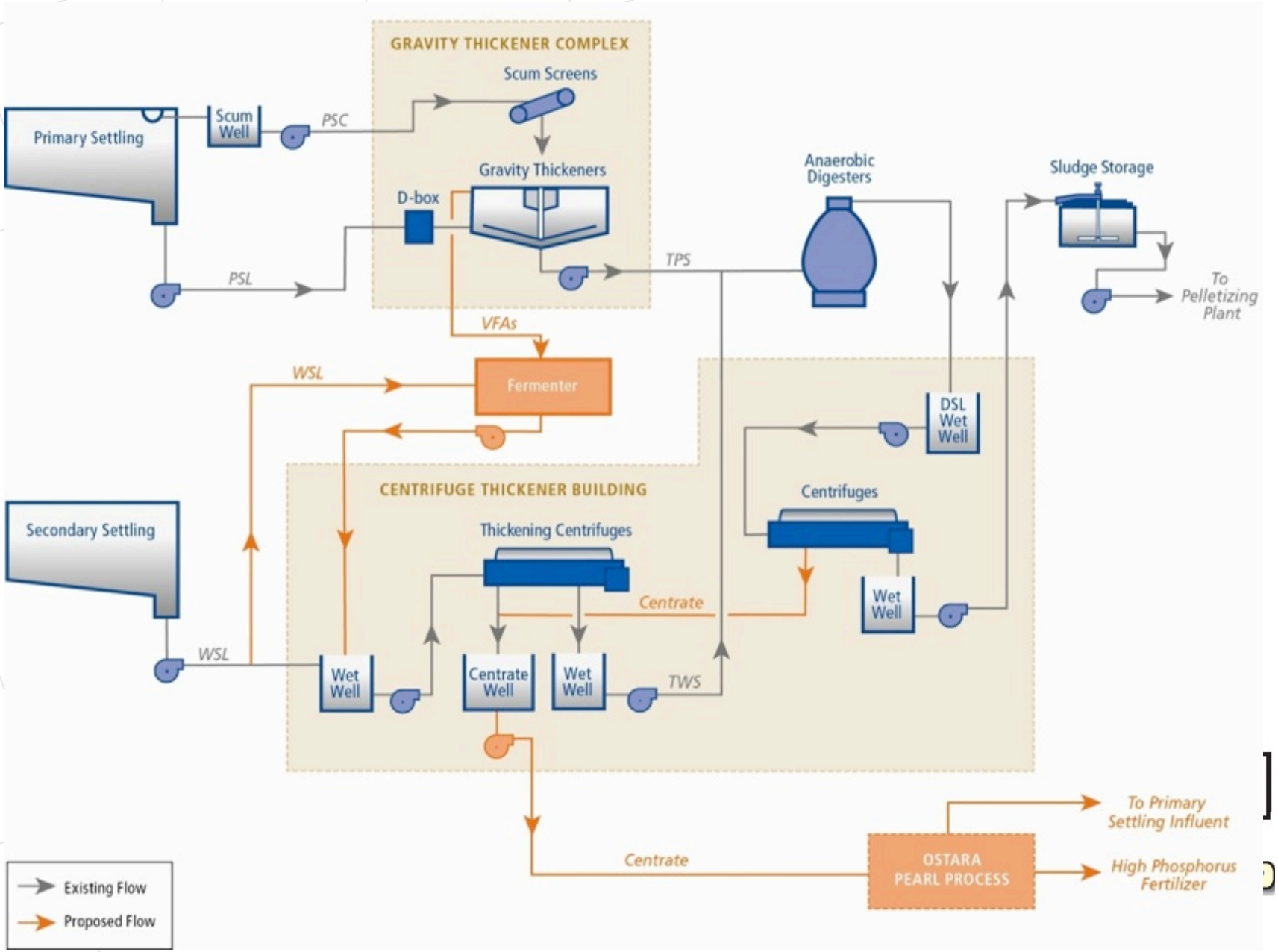
CNP – AirPrex®



- **Reduce Polymer by up to 30%**
- **Reduce Disposal Costs by up to 20%**
- **Reduce Phosphorus Recycle Load by up to 90%**
- **Reduce Maintenance Costs by up to 50%**
- **Increase Revenue up to 10% from Fertilizer**

Multiform Harvest




GRAVITY THICKENER COMPLEX
Scum Screens
Primary Settling
Scum Well
PSC
Gravity Thickeners
D-box
PSL
TPS
Anaerobic Digesters
Sludge Storage
To Pelletizing Plant
VFAs
Fermenter
WSL
DSL Wet Well
CENTRIFUGE THICKENER BUILDING
Centrifuges
Secondary Settling
Thickening Centrifuges
Centrate
Wet Well
WSL
Wet Well
Centrate Well
Wet Well
TWS
To Primary Settling Influent
Centrate
OSTARA PEARL PROCESS
High Phosphorus Fertilizer
Existing Flow
Proposed Flow

Crystal Green® Fertilizer

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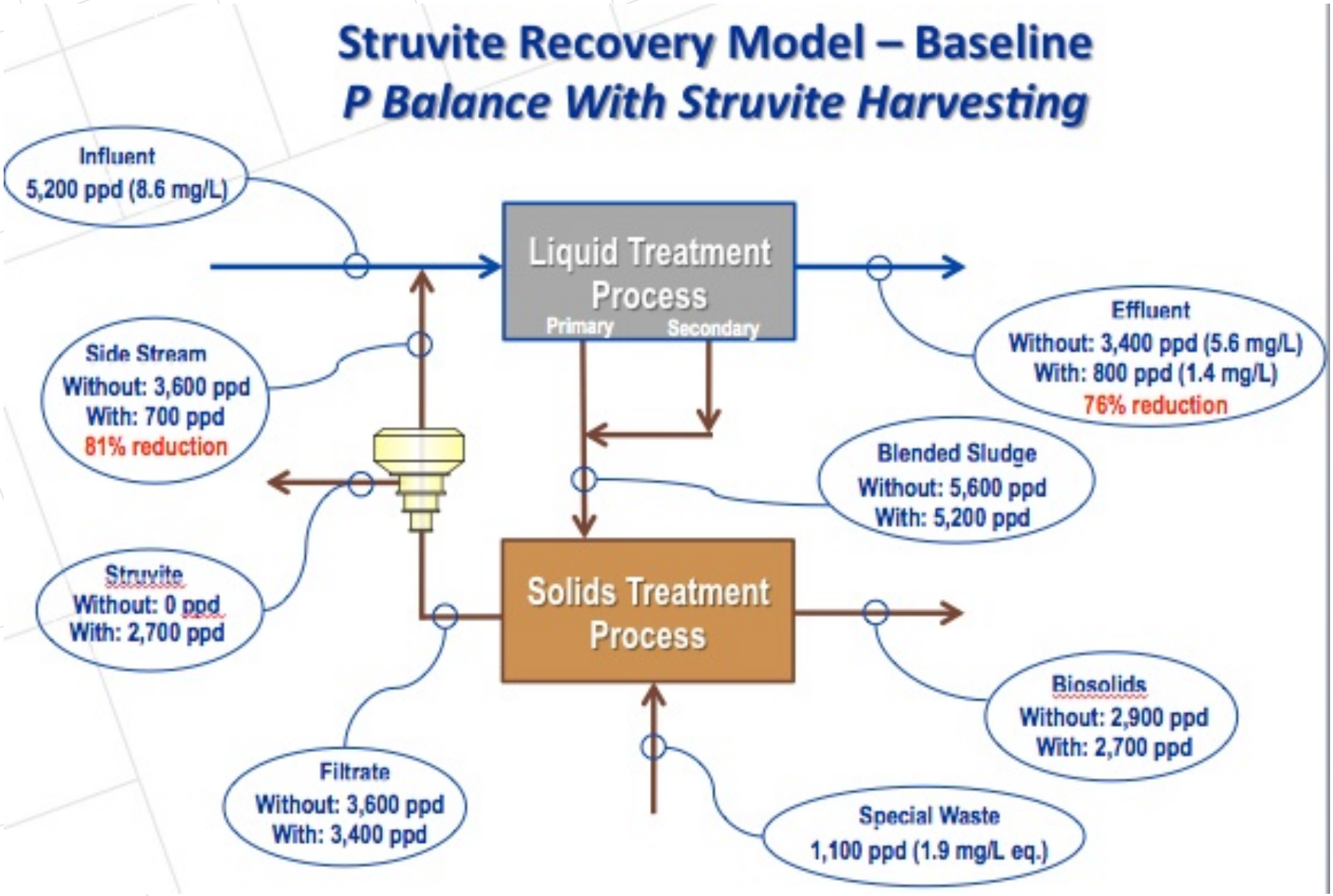
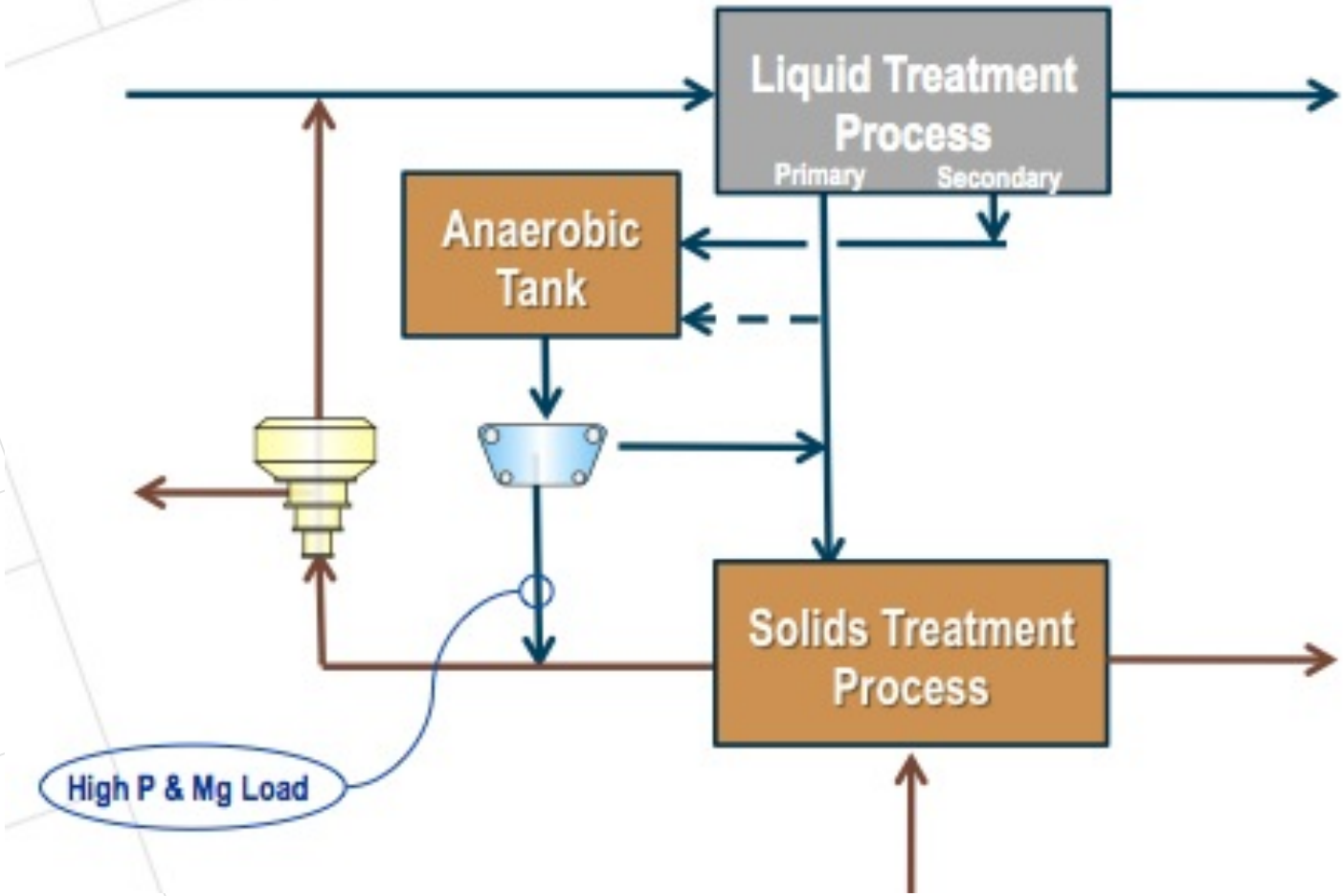
Struvite Recovery Model – Baseline

P Balance With Struvite Harvesting

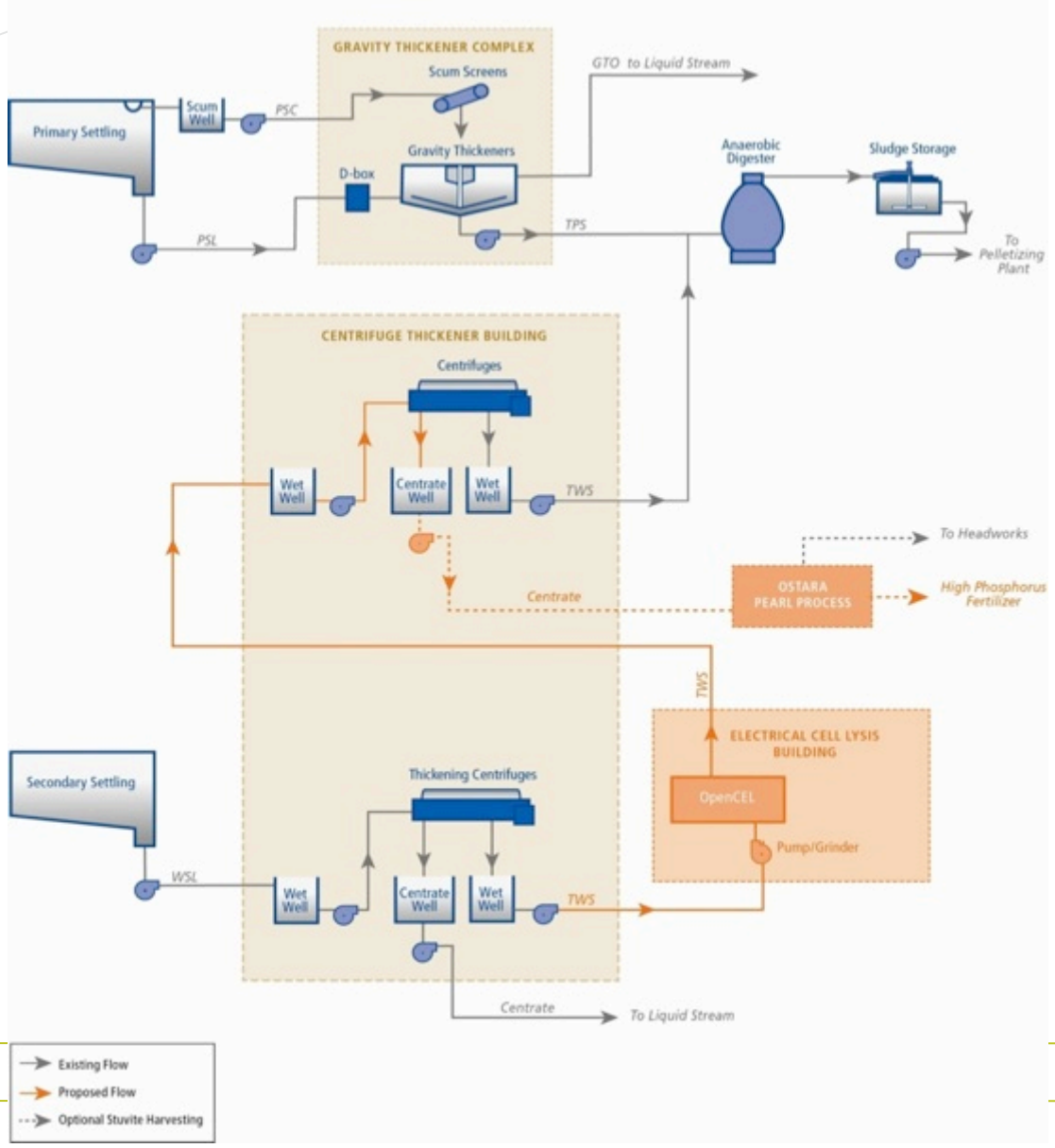


WASSTRIP$_{TM}$ recommended to protect digester



Struvite Prevention

Electrical Cell Lysis to Aid Struvite Harvesting



Summary

- Compared several nitrogen and phosphorus side stream treatment alternatives
- Evaluated several struvite recovery technologies spanning perceived range from low- to high-tech
- Proposed further study with non Bio-P plants and implications of Iron Salt addition.

Questions

Contact Information:

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