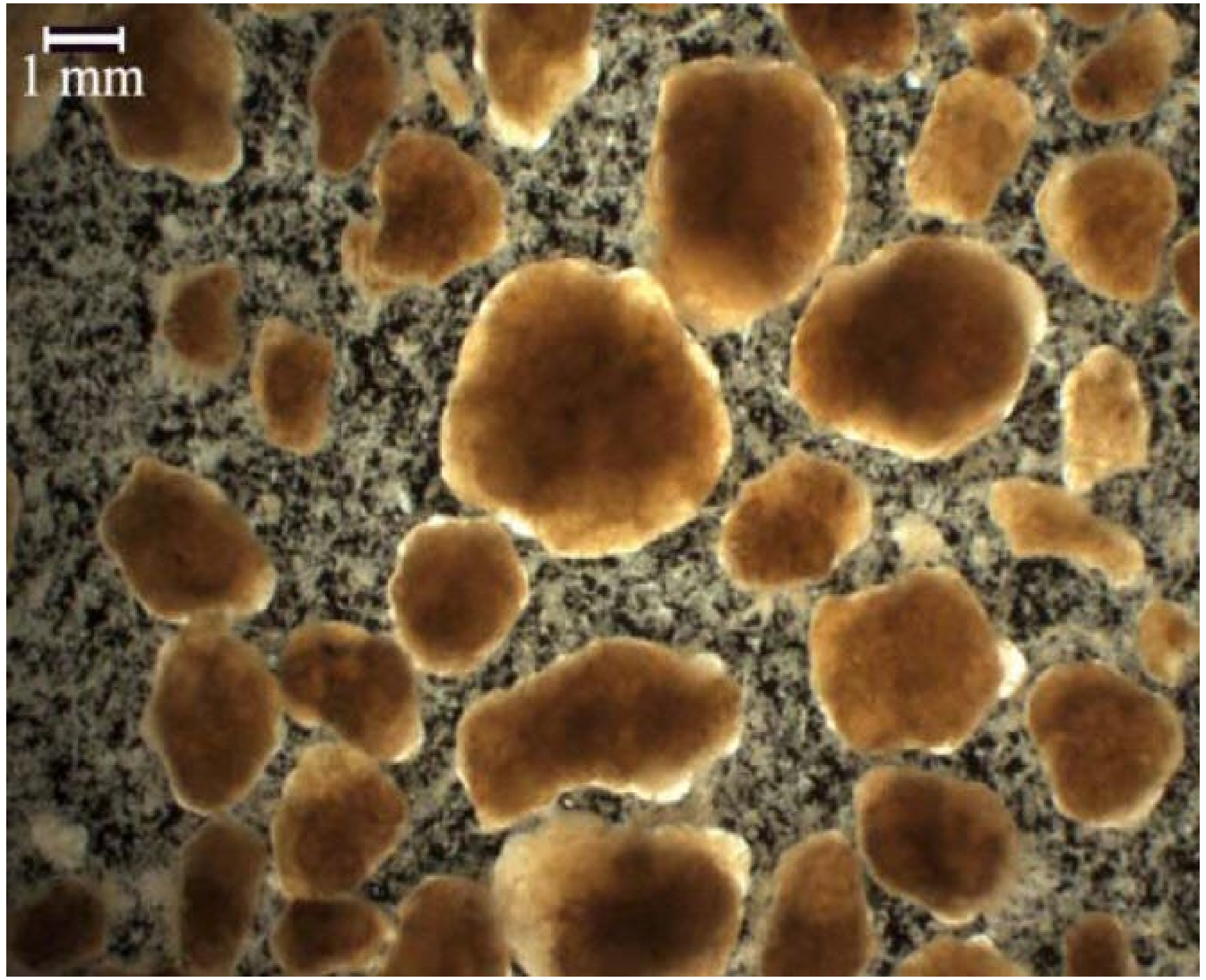
Developing a Nutrient Management Strategy or Roadmap

JB Neethling, PhD, PE and Leon Downing, PhD, PE

So you have 10.5-years to Reduce Nitrogen?

What is the Plan?



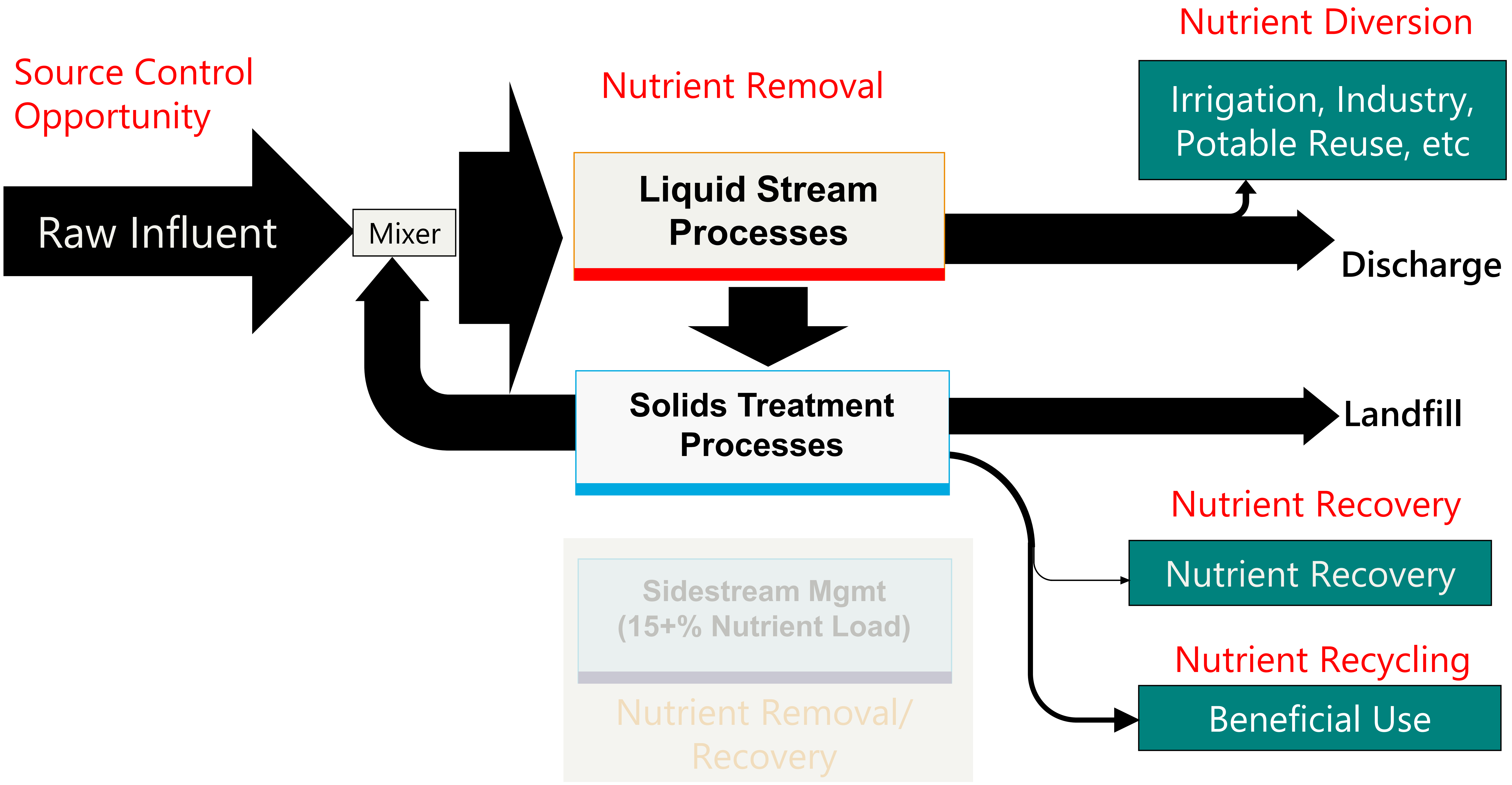
Strategies to Reduce Nutrients Entering the Bay

What are the challenges to overcome in Treatment Plants?

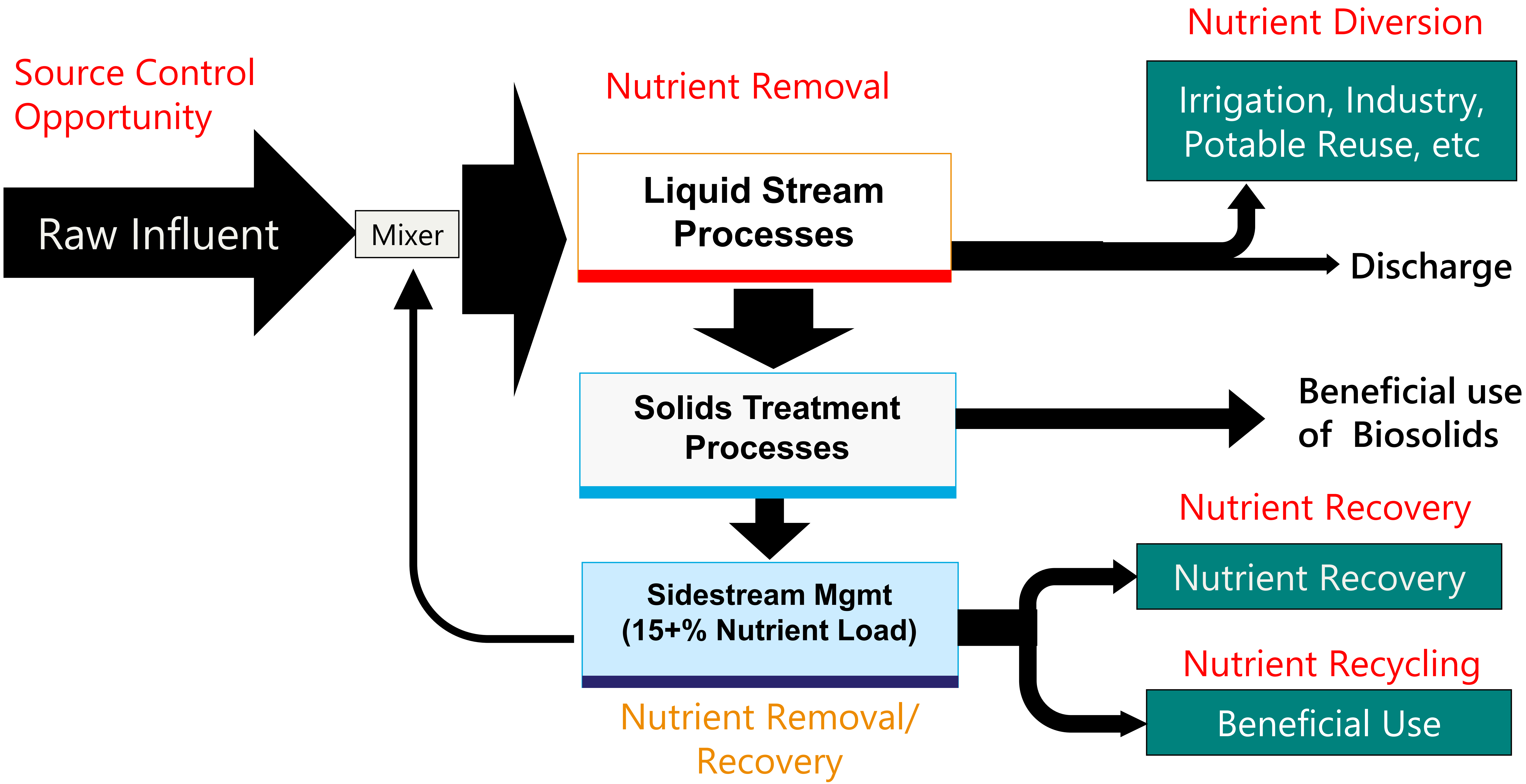
What other strategies can reduce nutrient discharges to the SF Bay?

Poll Question 1: What are the Challenges to modify a Secondary Process to Reduce Nutrient Discharges?

Consider Overall Typical Nutrient Flow

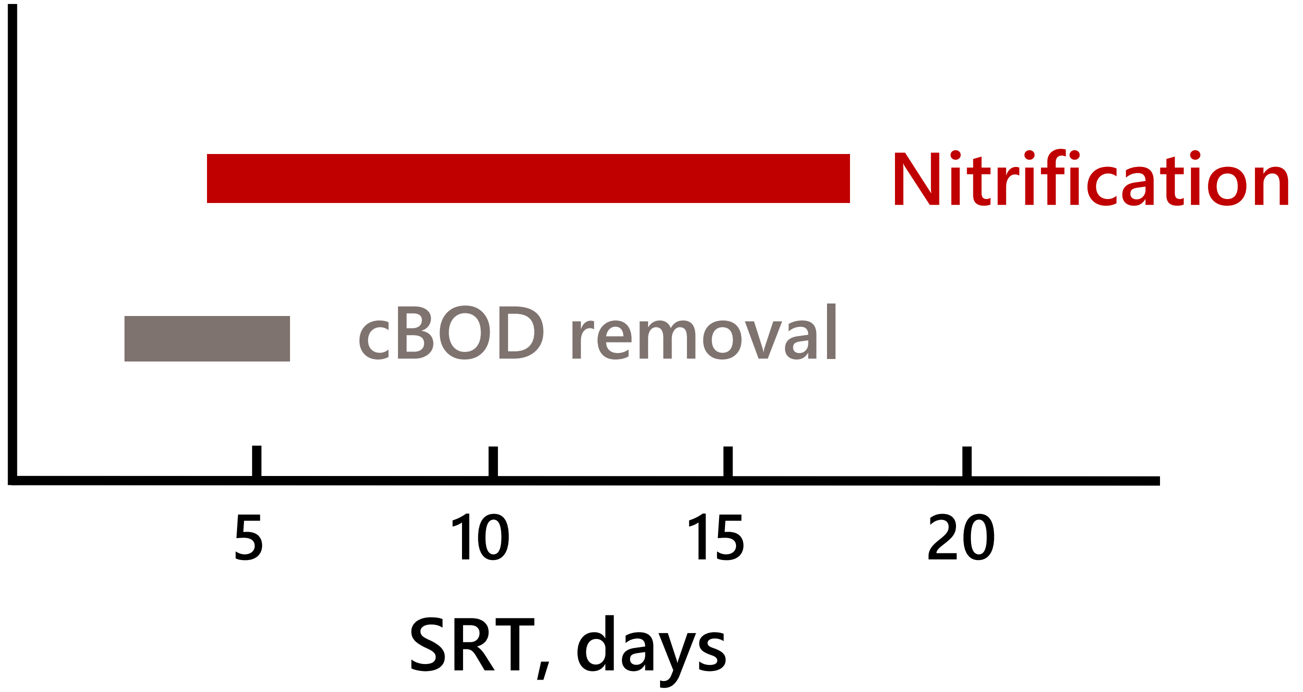


Consider Overall Nutrient Removal Potential



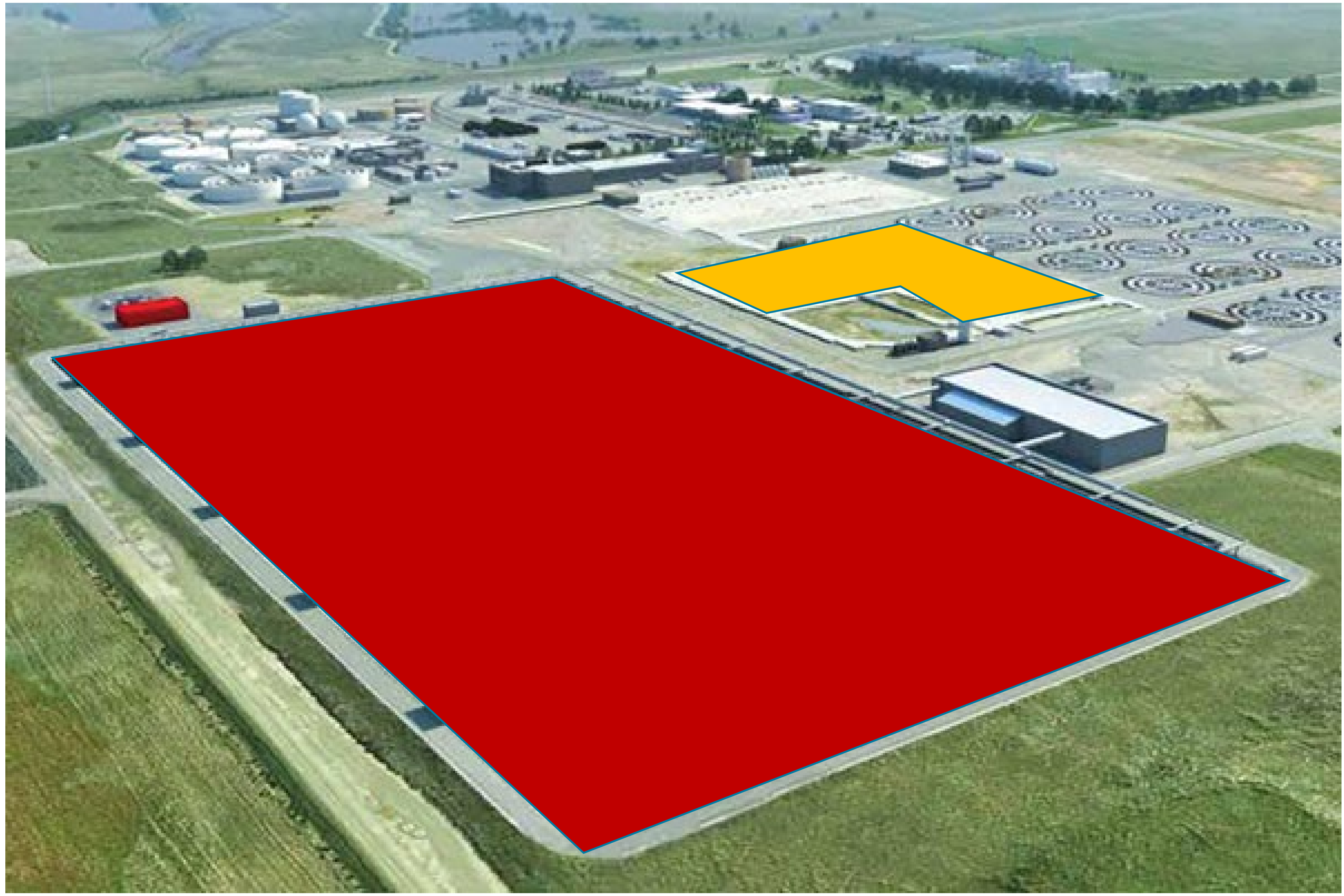
Why is it Challenging to Transition from Secondary Treatment to Nitrogen Removal?

- **Issue:** nitrogen removal requires a longer sludge age to grow microbes that remove ammonia (aka, nitrifiers)
- **Longer sludge age** requires:
  - Aeration basins
  - Blower capacity
  - Secondary clarifier, etc.
- **Environmental conditions:**
  - Sufficient DO
  - Neutral pH – ideally $\geq$7.2
  - Sufficient alkalinity to stabilize process
  - Favorable temperature



Potential Challenges Transitioning to Nutrient Removal?

- Aging Infrastructure
  - Incentive or Limitation?
- Facilities
  - Space requirements
  - Existing infrastructure fragmented
  - Support facilities inadequate
    - e.g. blowers, power supply …
- More Skilled Labor Force
- Funding
- Sea Level Rise



Footprint for BOD removal (yellow) vs. Nutrient Removal (red)

On-Going and Future Treatment Themes

- **<u>Treatment and Process</u>** <u>("Squeeze" More Out of Process)</u>
  - Optimization
  - Sidestream Treatment
  - Upgrades
- **<u>Themes at Plant</u>**
  - Process Intensification
  - Resource Recovery
  - Advanced Controls
- **<u>Themes Outside the Plant</u>**
  - Supply/Reuse
  - Nature-based Solutions
  - Others

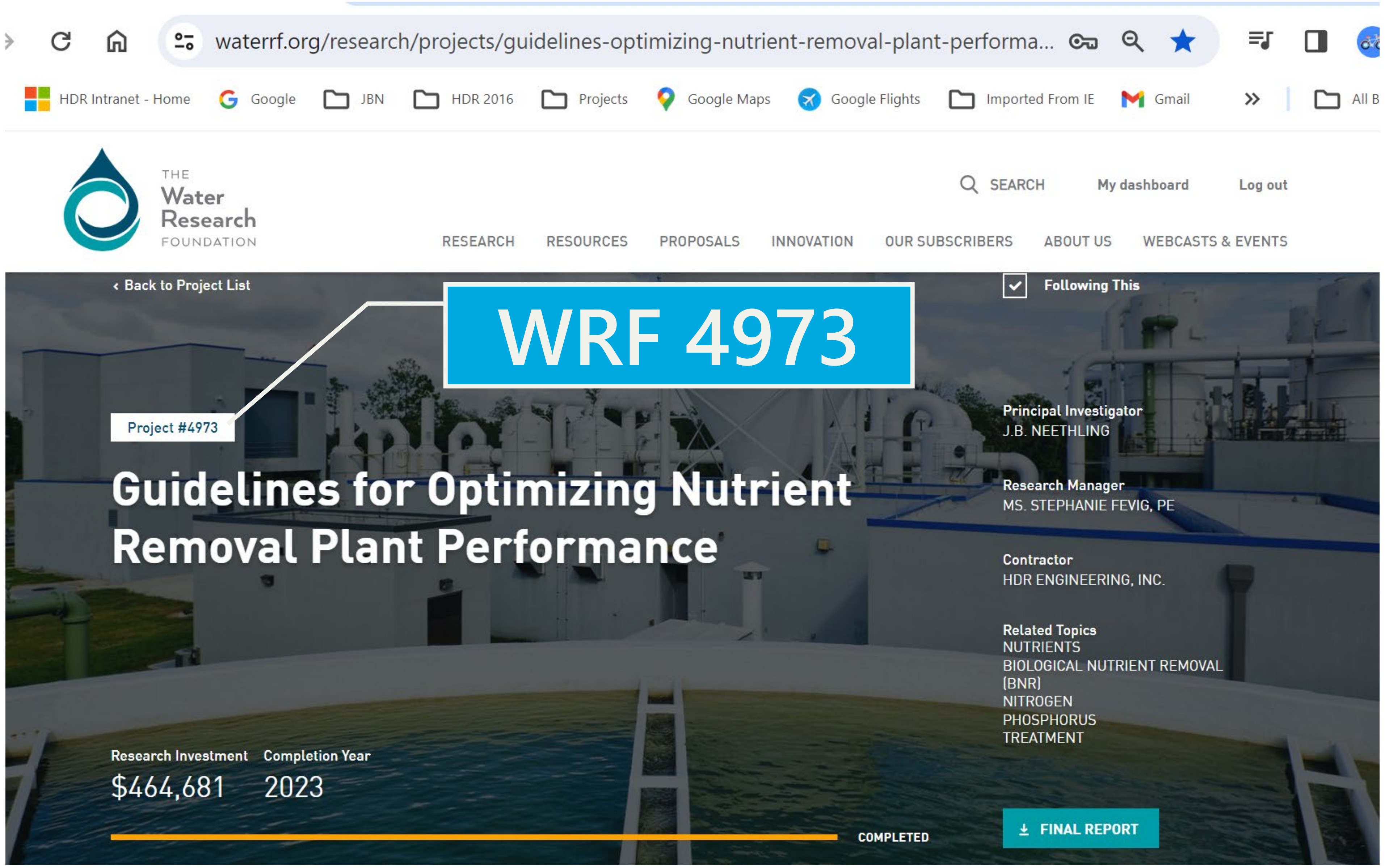
Optimization Tool (WRF 4973): Web-Based and Free to the Public (NOTE: Requires a FREE WRF Log-in)

Decision Trees to Stream-Line Optimization (6 Steps!)

Steps	Process	Example
1	WRRF Type	Secondary OR Nutrient Removal
2	Existing Treatment Process	Activated sludge, TF, BNR, lagoon, etc.
3	Nutrient of Interest	NH4, TN, TP
4	Objective	1) Improve reliability; 2) Reduce nutrients 3) Reduce cost
5	Metric/Benchmark (MOST CHALLENGING)	Yardstick – kWh/MG, $/lb nutrient removed, effluent concentration, etc.
6	Strategies	List potential approaches/strategies to achieve the above goals

The Water Research Foundation

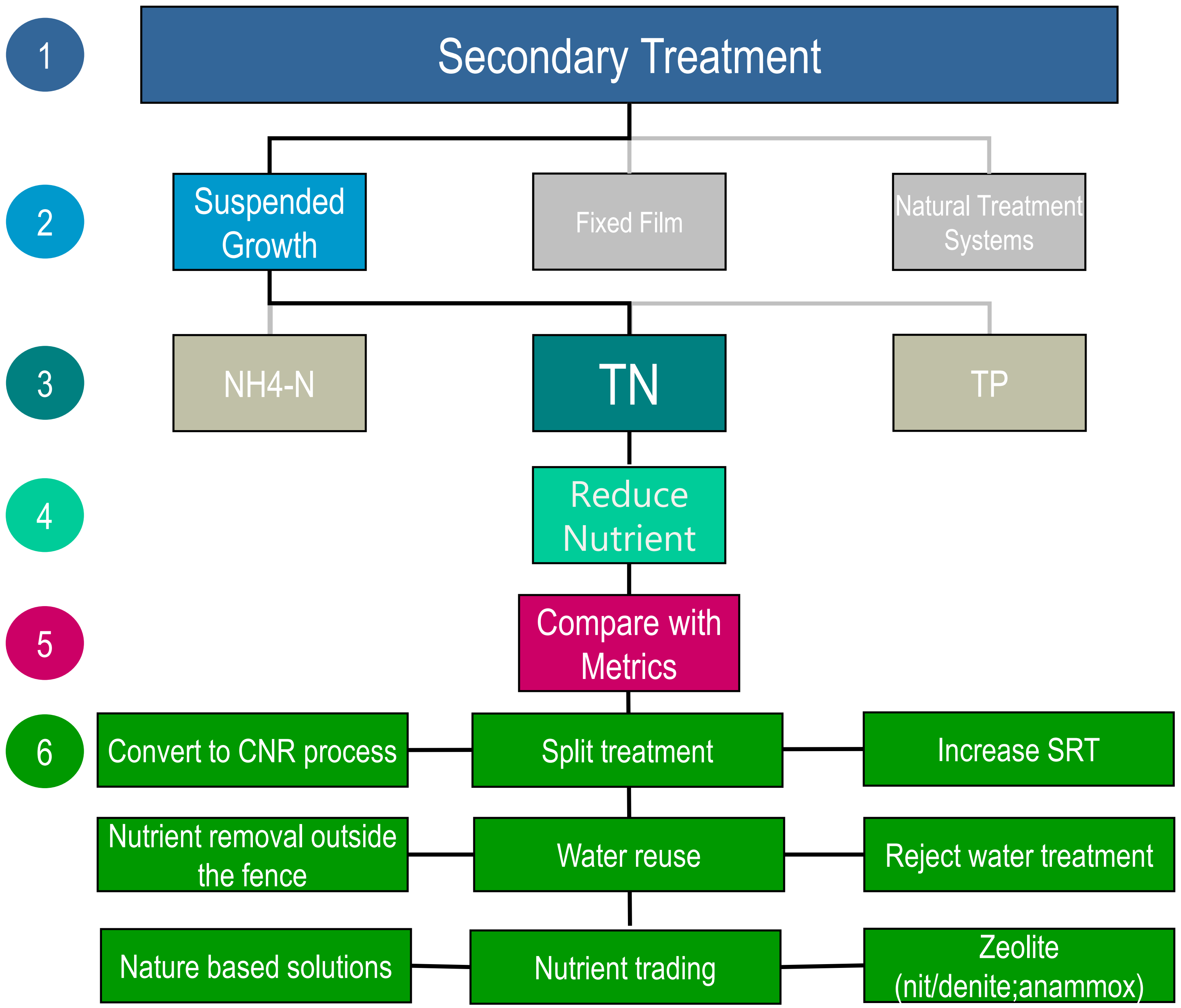
https://www.waterrf.org/



Download and Access

- Final Report (all reports)
- Online Optimization Tool
- Webinars
- Fact Sheets
- ....

Secondary Process - TN – Suspended Growth Process

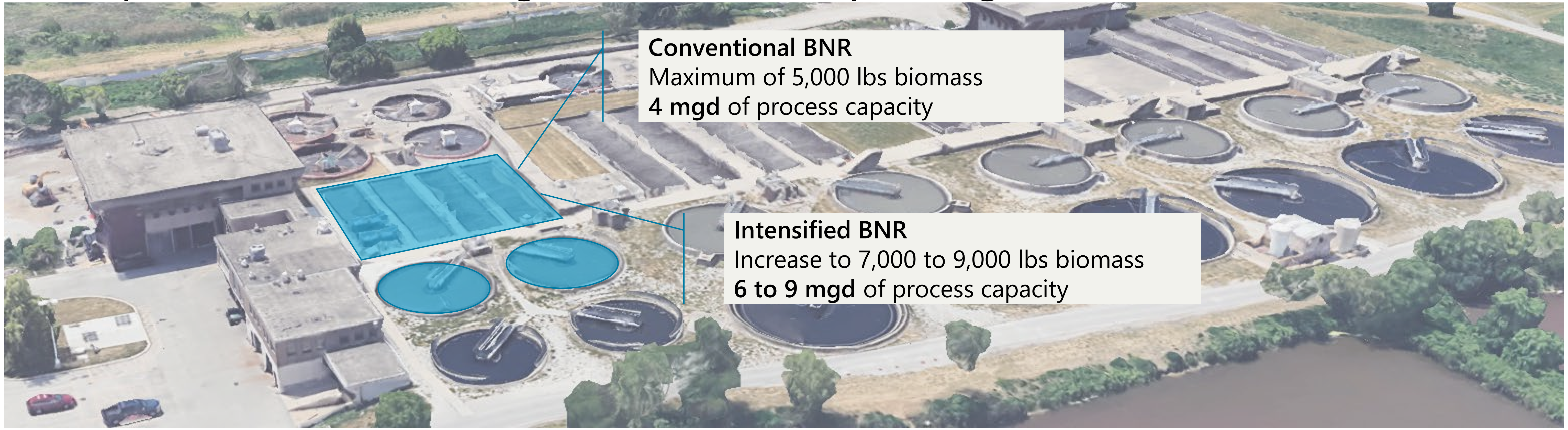


Intensification

Poll Question 2: When you hear intensification, what comes to mind?

What are we trying to accomplish with intensification?

- What does Google tell us?
  - *"the action of making or becoming more intense"*
- How does our industry use the term?
  - Technologies that enable more biomass per unit volume *OR* less biomass requirement, meaning less concrete per mgd treated



How do we achieve more biomass per unit volume?

Intensified BNR

- **Biofilm processes**
- **Improved settleability**
- Increased primary treatment performance
- Decreased SRT requirements

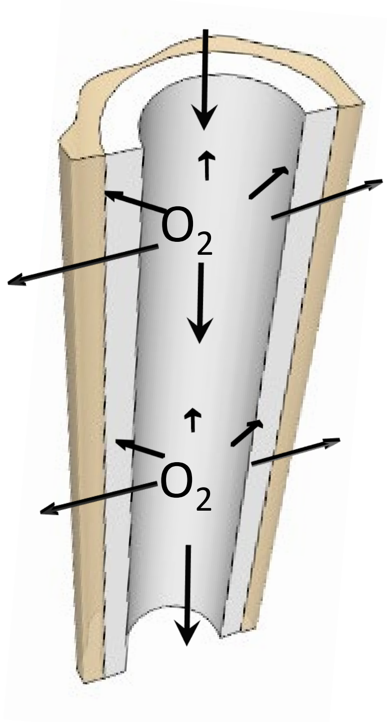
Focus on two for today's workshop

The membrane aeration biofilm reactor (MABR) adds biomass on “breathing” membranes

MEMBRANES

- *Dense, hydrophobic material*
- *Hollow fiber or flat sheet configuration*

AIR DELIVERY



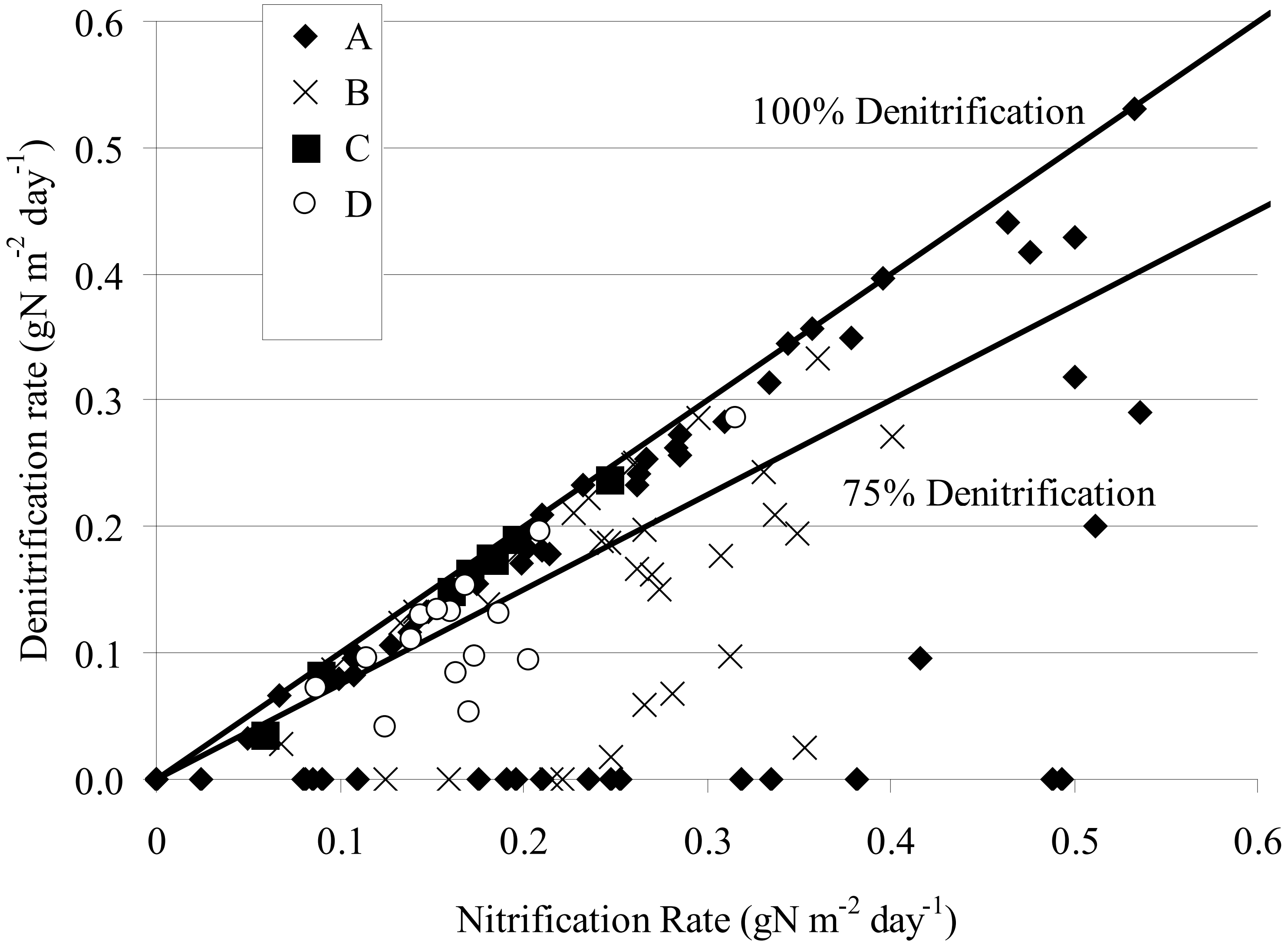
Flow-through mode

SUBSTRATE

- *COD*
- *Ammonia (NH_4-N)*

“Breathing” Biofilms!

Application of these membrane in a hybrid configuration accelerated adoption



Downing and Nerenberg (2008) Total Nitrogen Removal in the Hybrid Membrane Biofilm Process. Water Research.

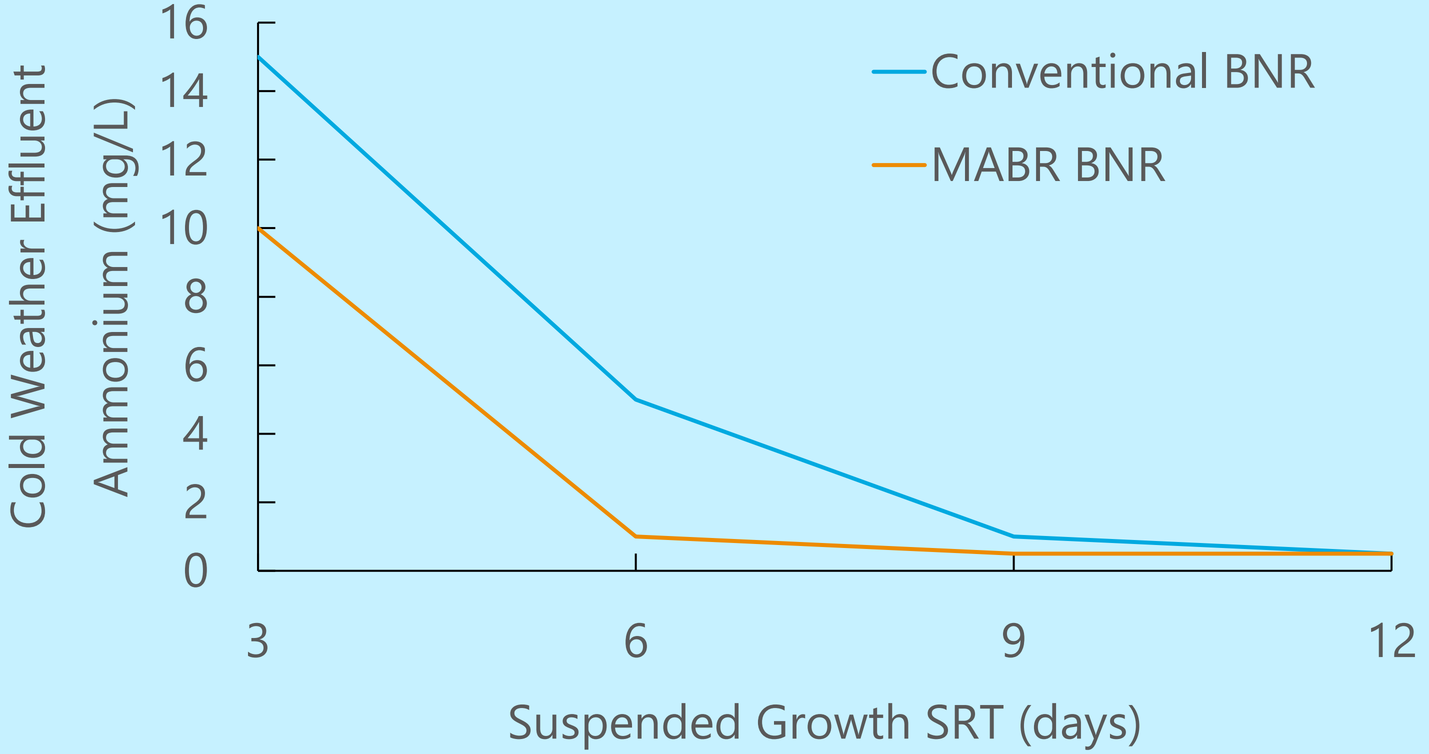
Research into the MABR has identified key operational parameters

- Three-year pilot project
- Black & Veatch sponsored research project
- Partnered with Suez and City of Hayward, California

Research Goal: Identify the key operational parameters that will influence MABR design

Key for the Bay Area and intensification is how low can the bulk liquid MLSS be reduced while achieving BNR

MABR reduces the suspended growth SRT requirements by 30%, reducing the required MLSS for nutrient removal

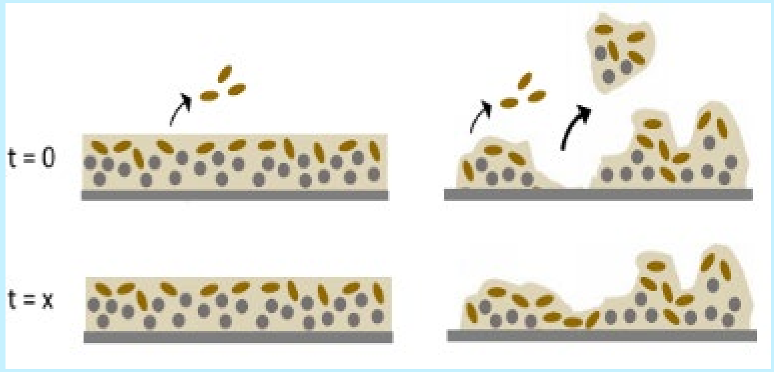


Why?

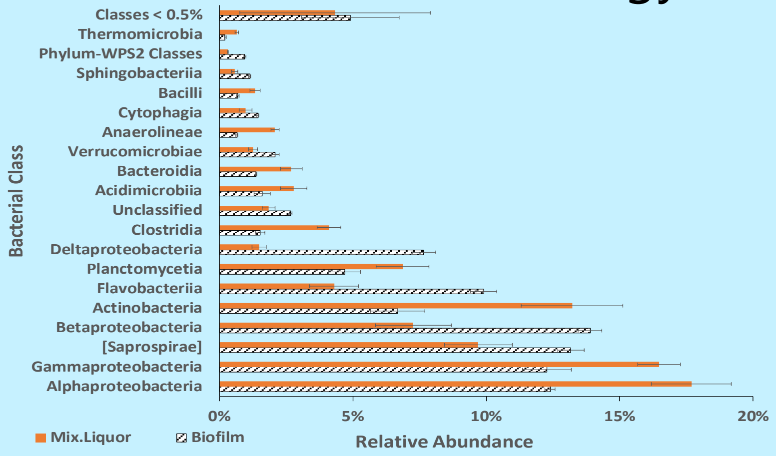
1. *Lower nitrification "work" required by suspended sludge*

2. "Seeding" effect by the biofilm.

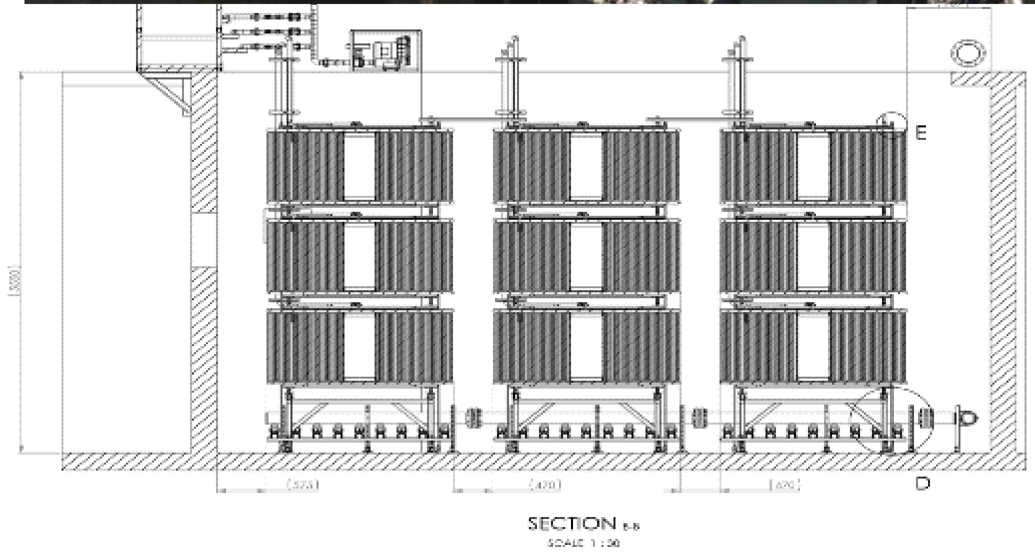
Theory

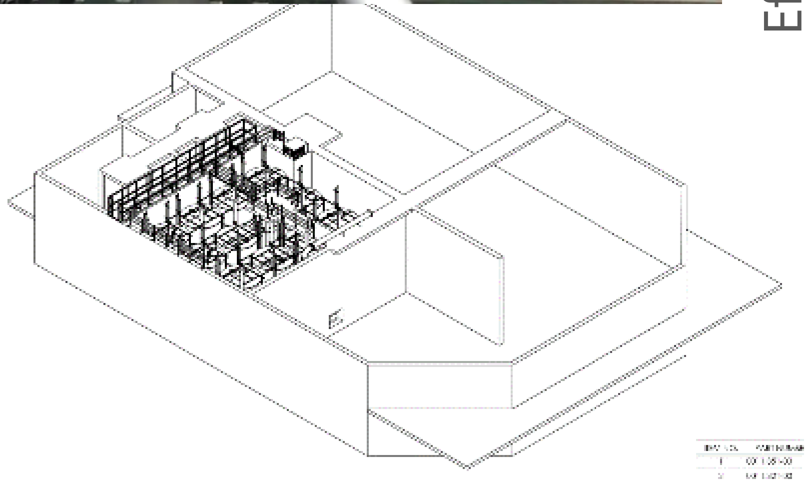


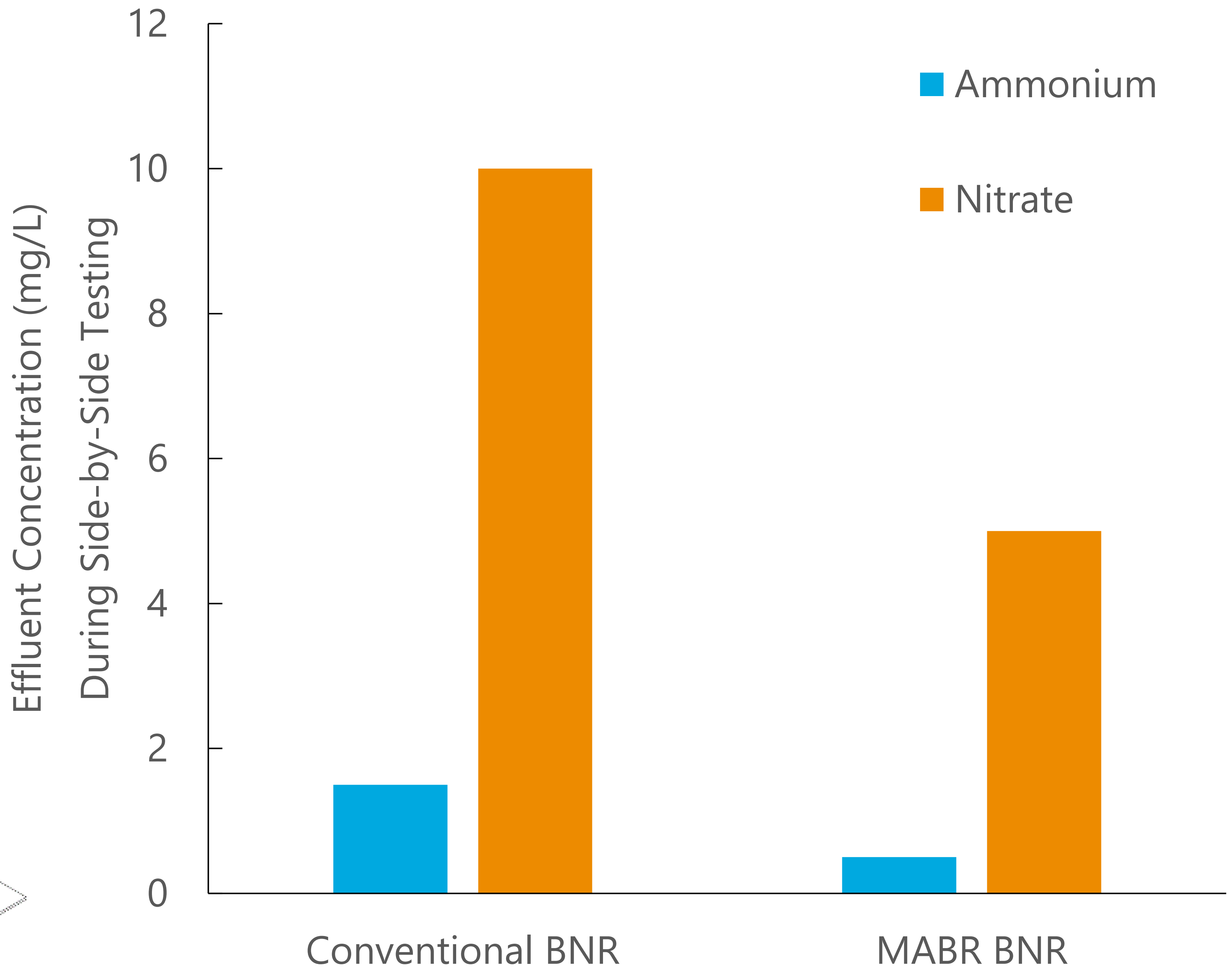
Confirmation with ecology



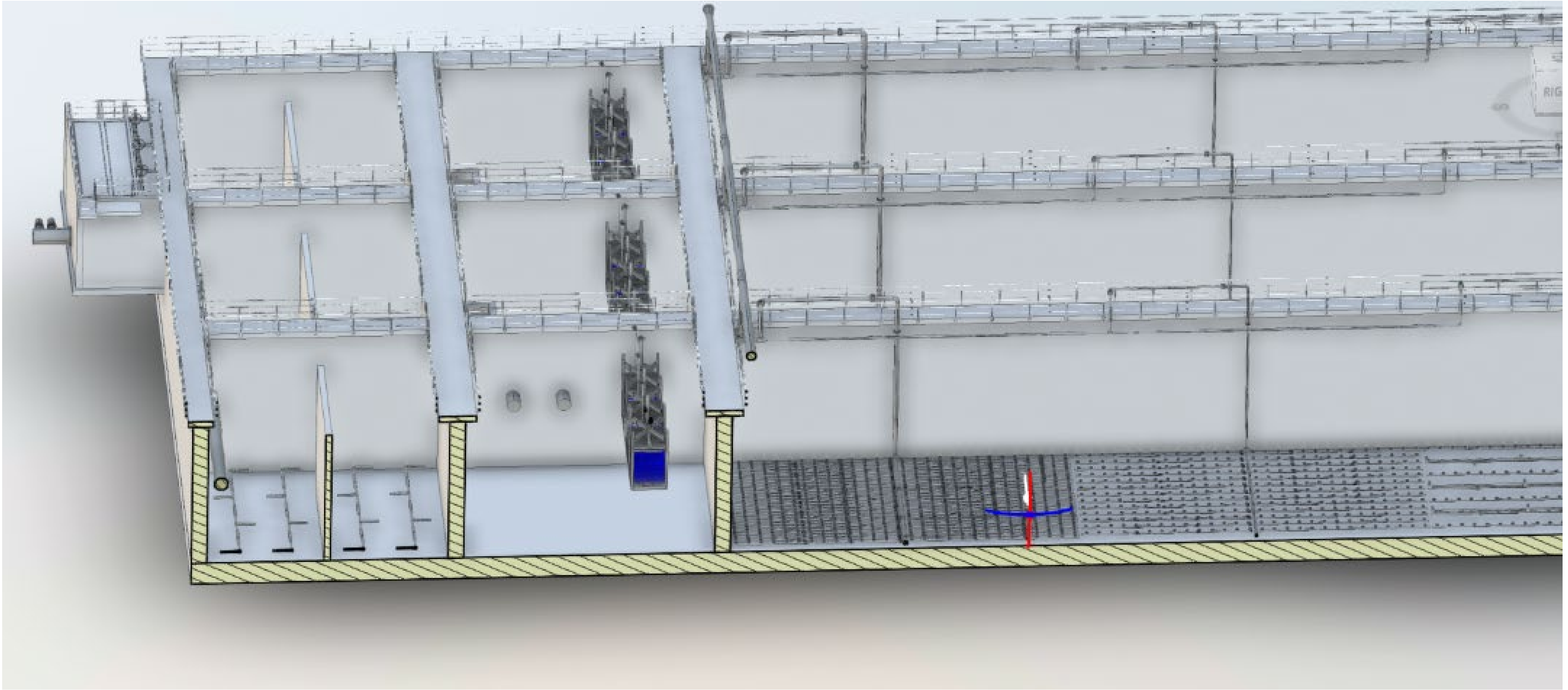
Full-scale experience in Israel at the May'an Z'vi WWTP highlighted the benefit of MABR versus conventional BNR







MABR can be retrofit into existing or new anoxic volume to increase capacity and achieve TN removal

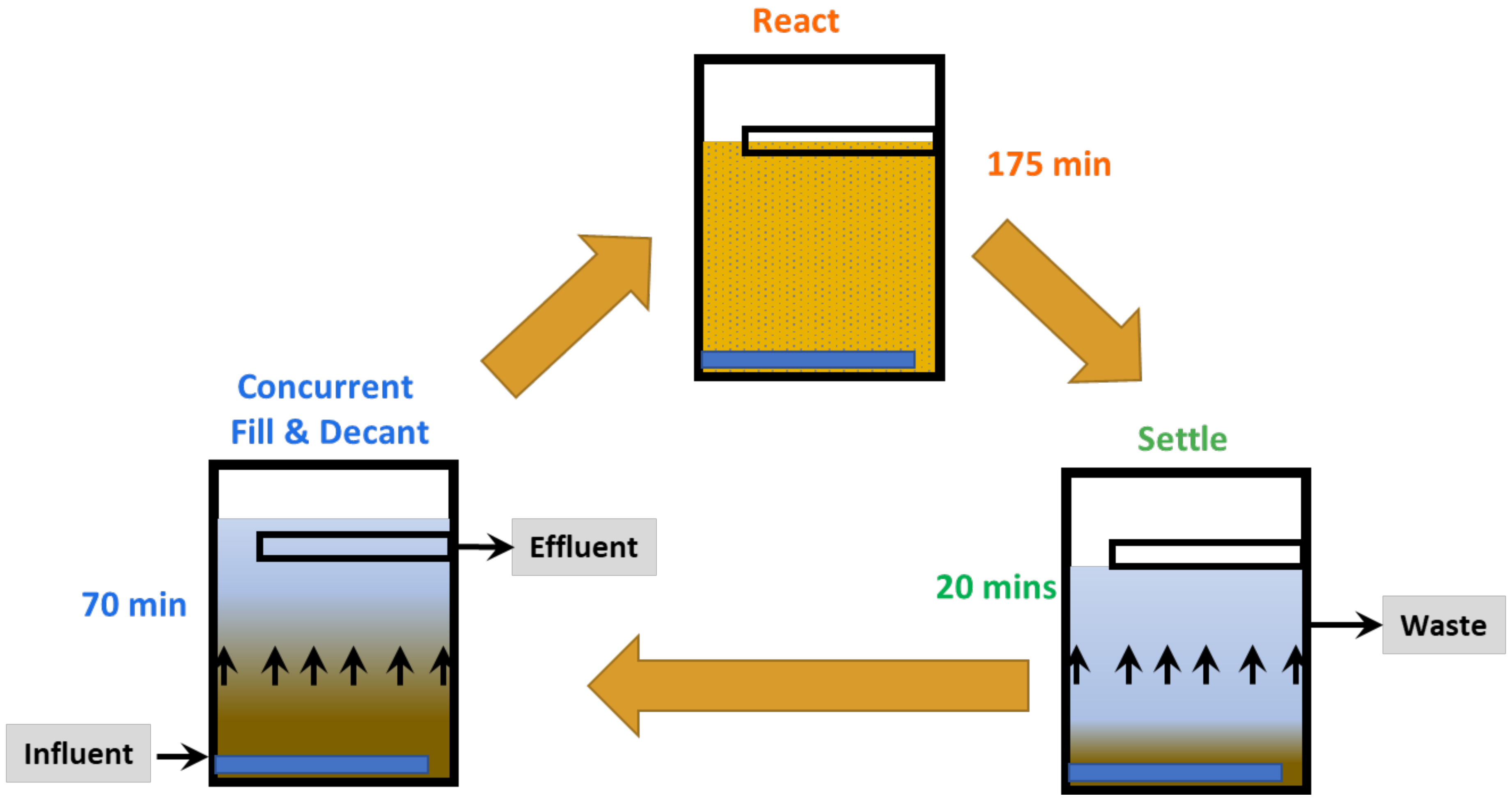


Densification is making sludge settle faster, allowing for more biomass in bioreactor while still allowing settling in clarifiers

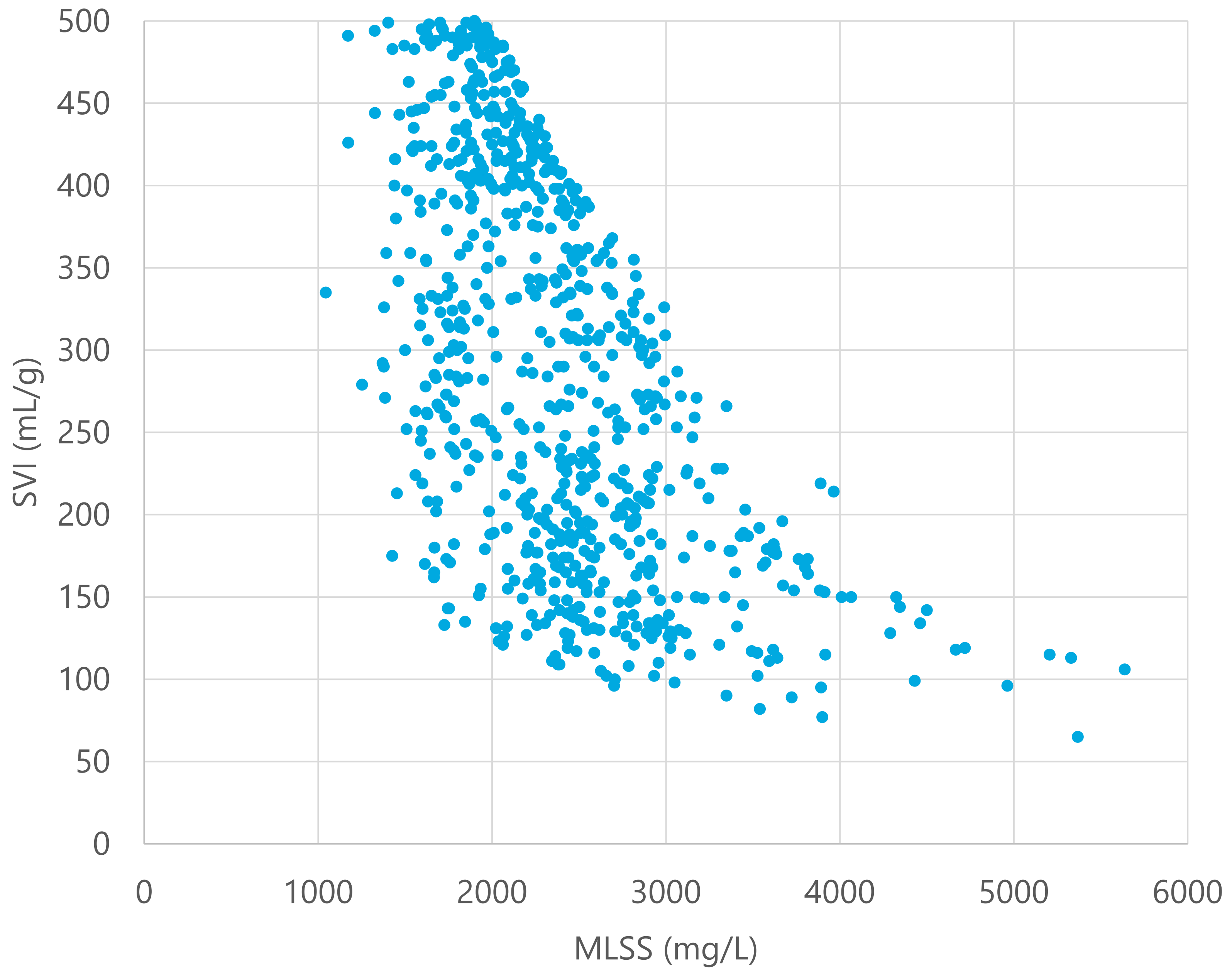
Why does this matter?
Increase the solids inventory by 30% without requiring more aeration basins and clarifiers

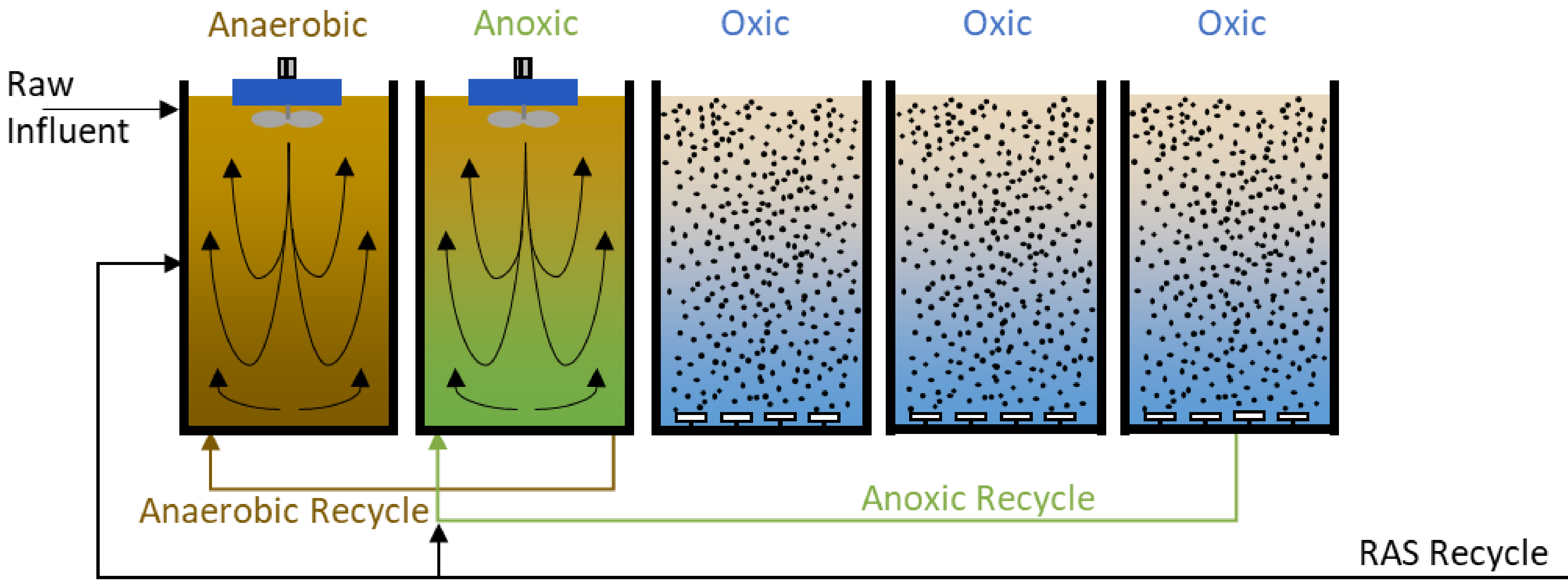
Densification can be achieved in a propriety reactor

Four Rivers Sanitation Authority AGS reactor in construction



Growth pressures in the influent of an aeration basin are a critical aspect for flow-through densification

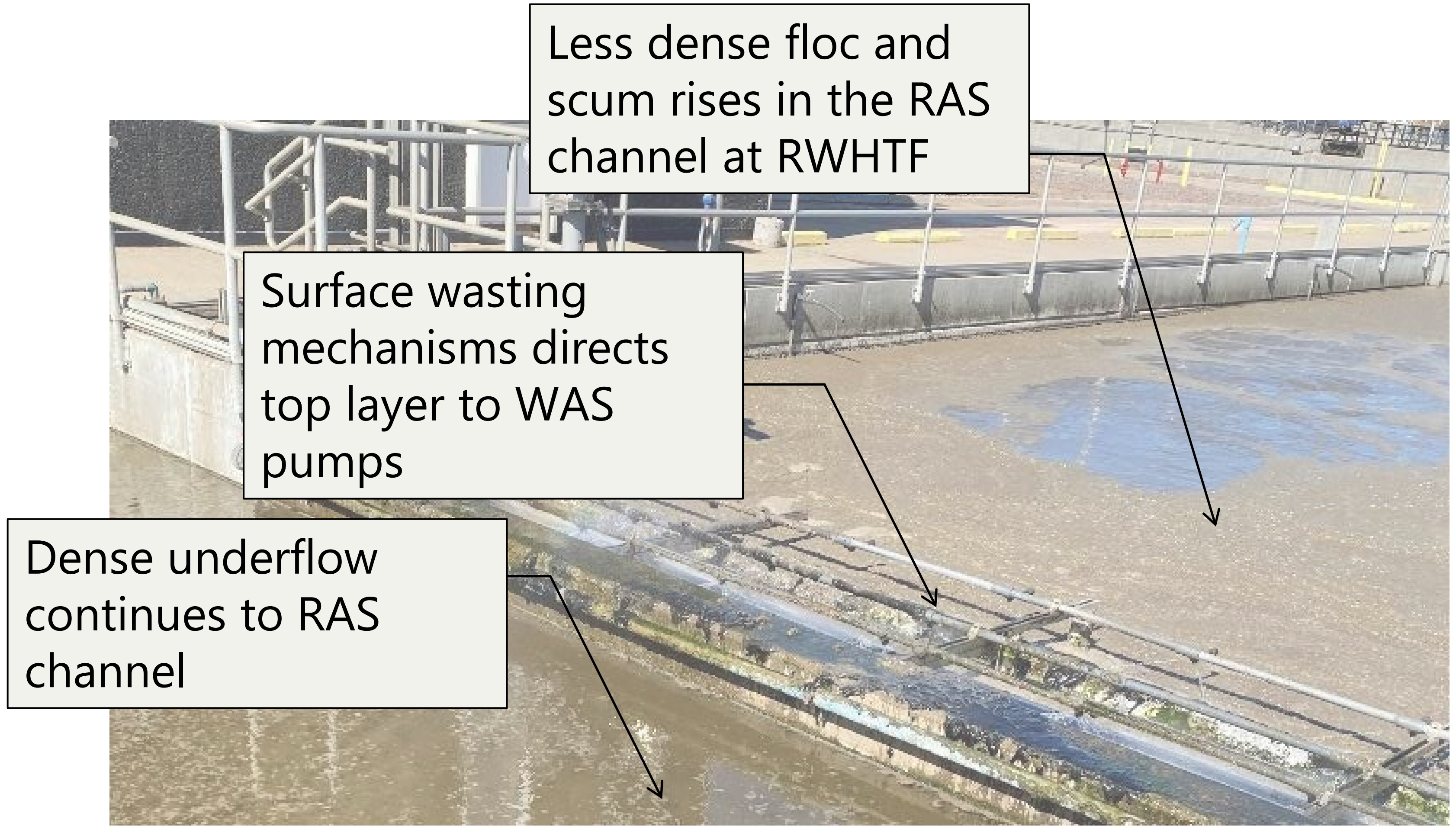




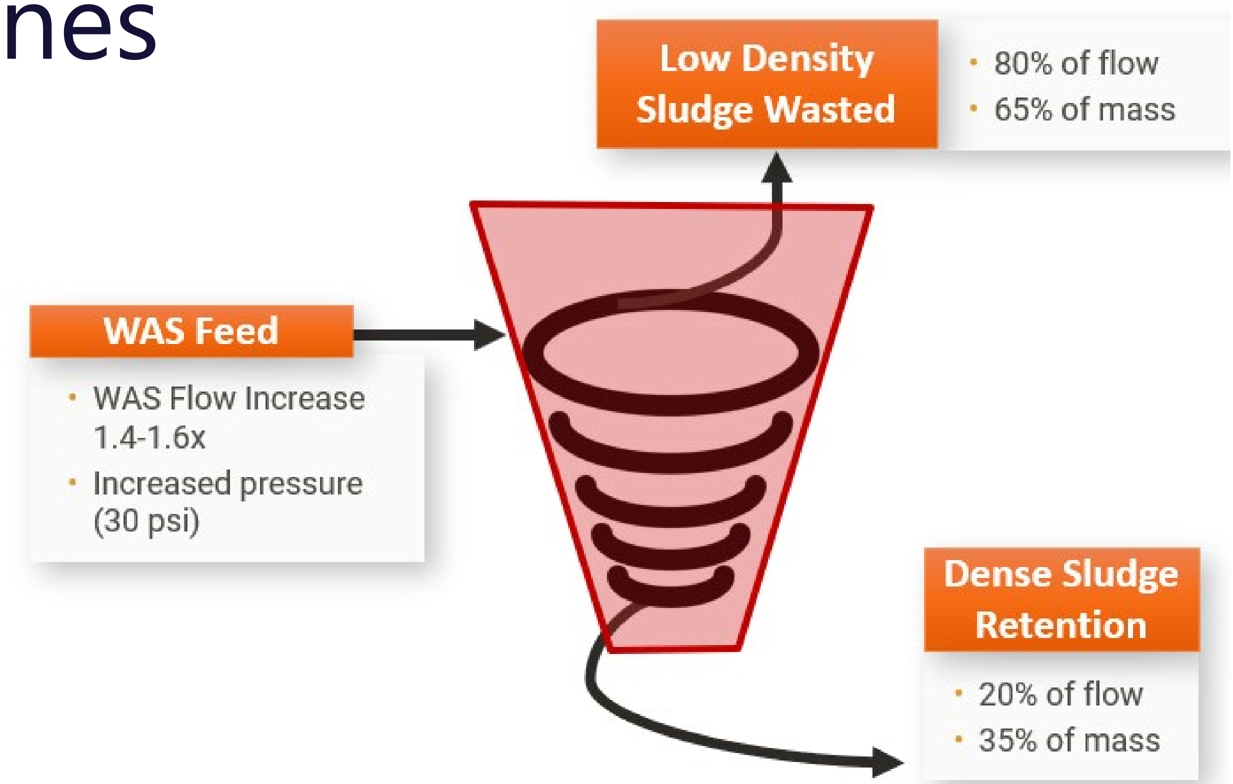
Wisconsin Rapids WWTP, Wisconsin

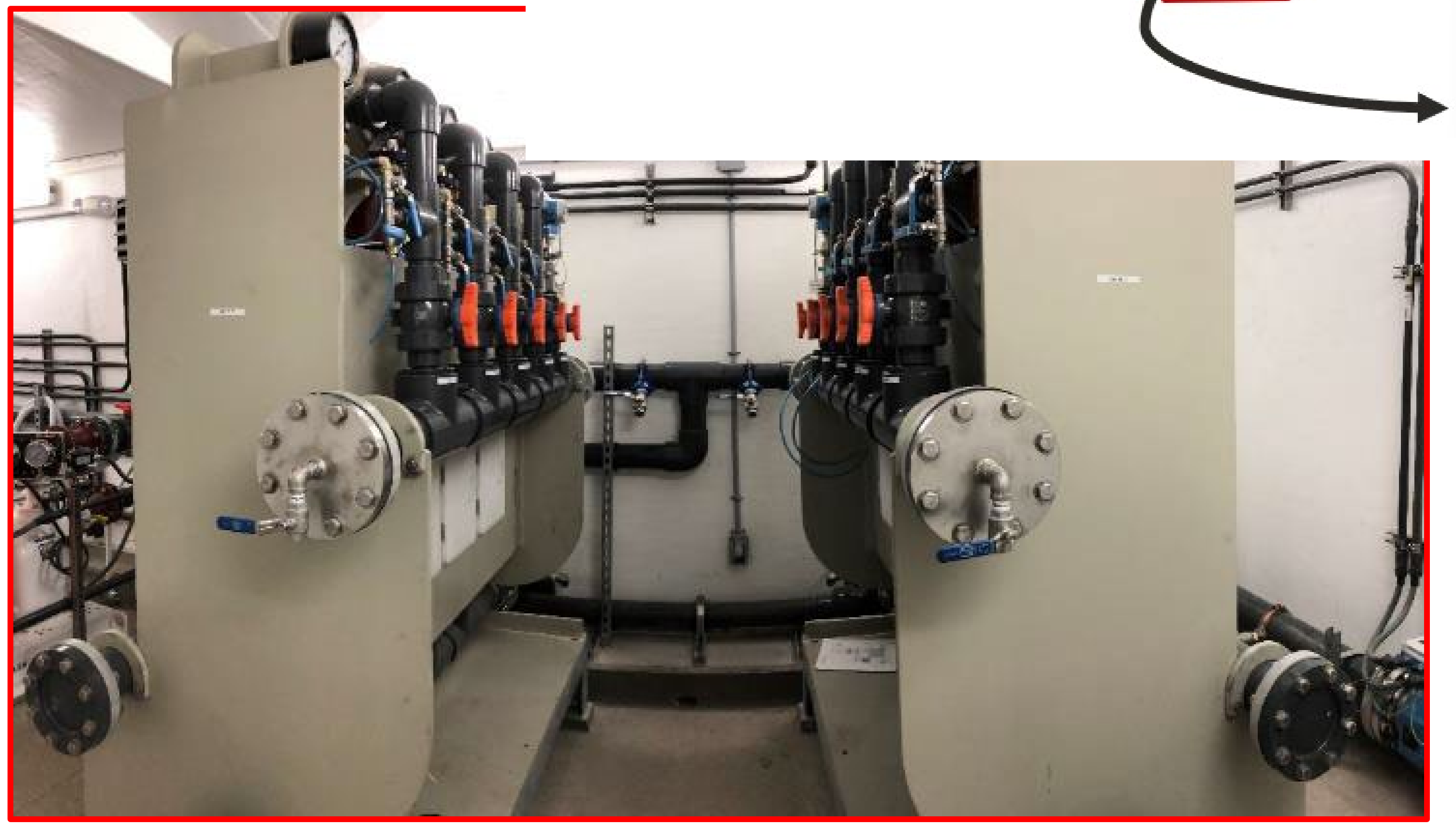
Selective retention of large flocs is also a key development

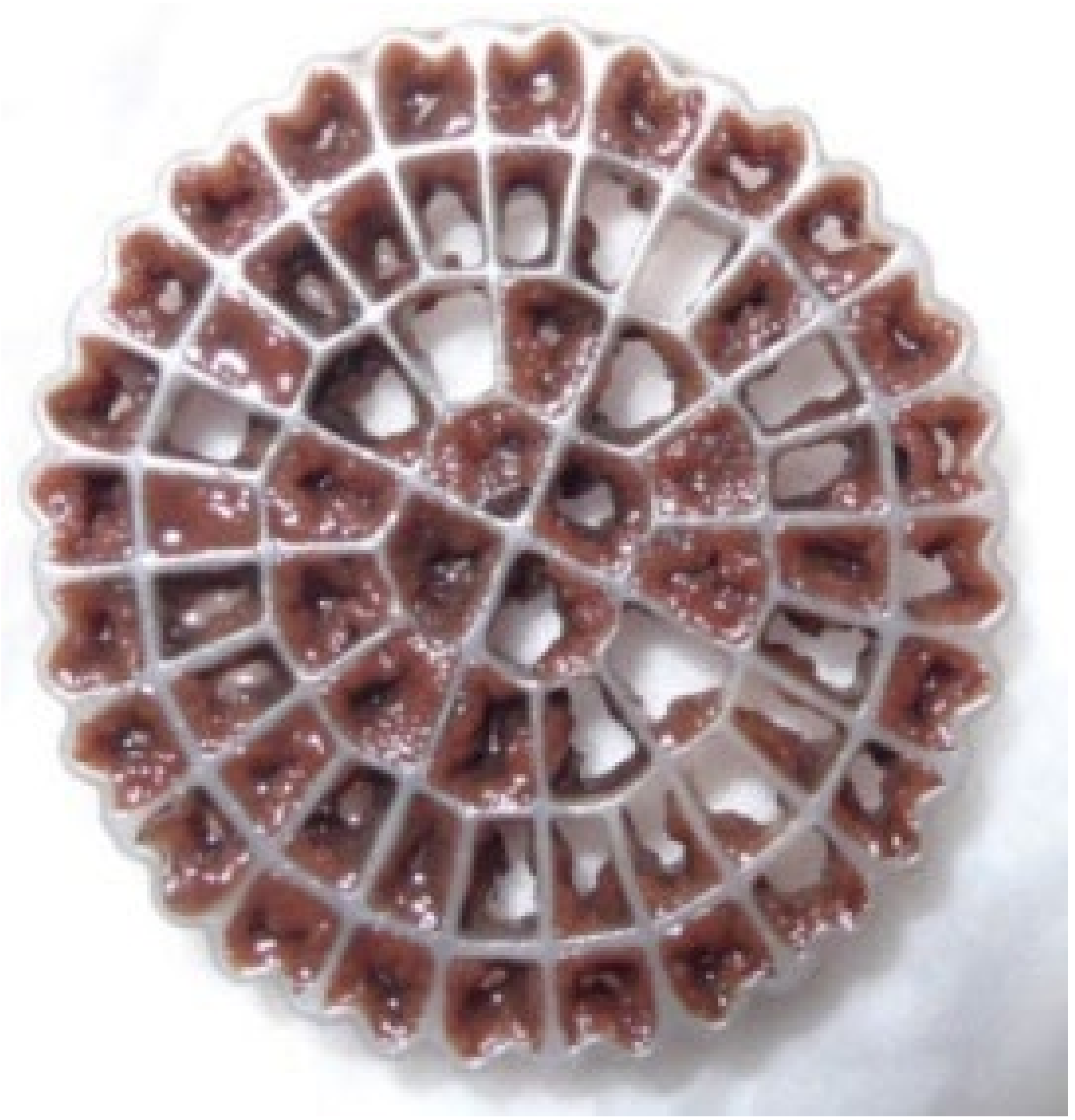
Surface Wasting



Hydrocyclones



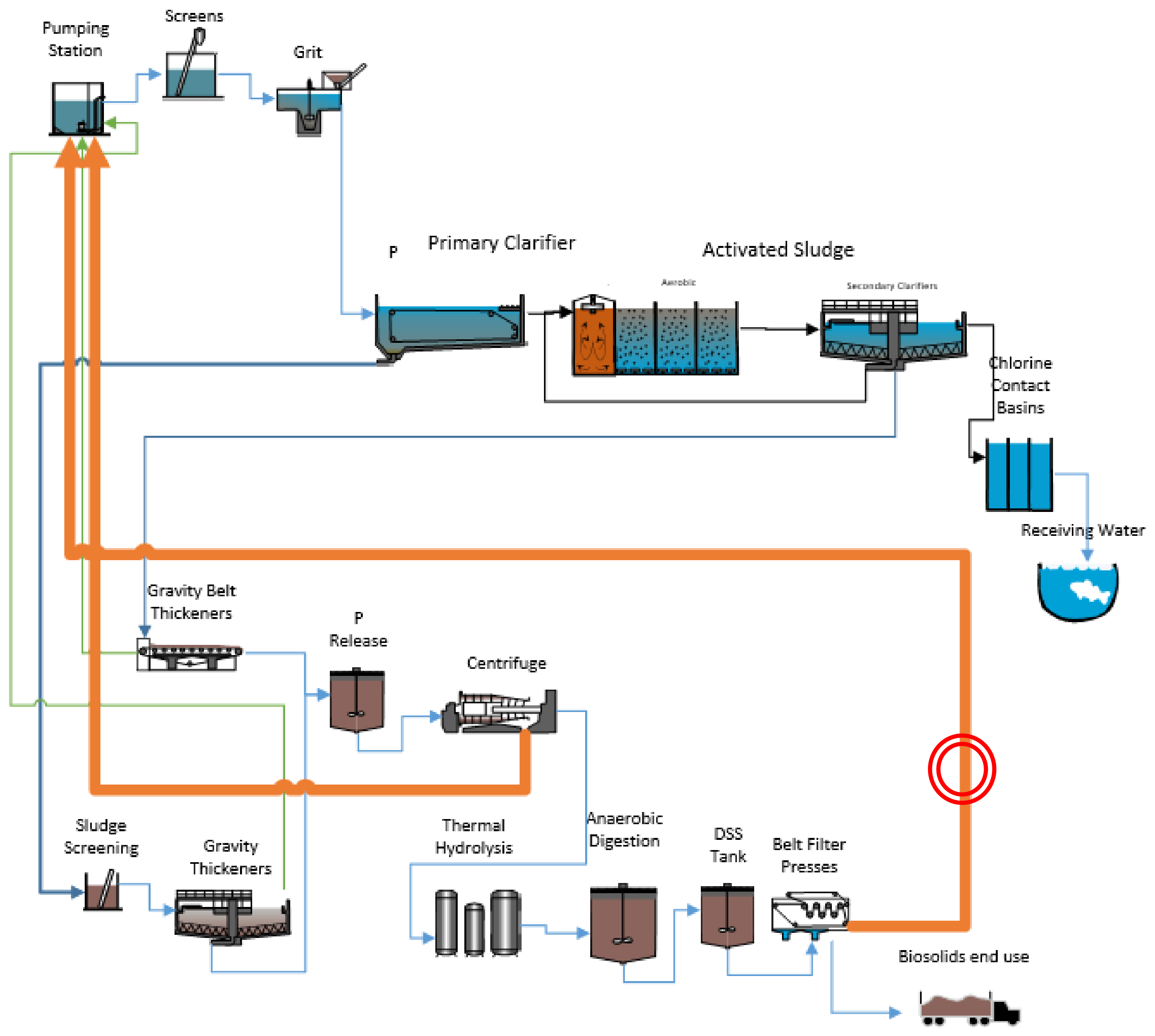




Sidestream

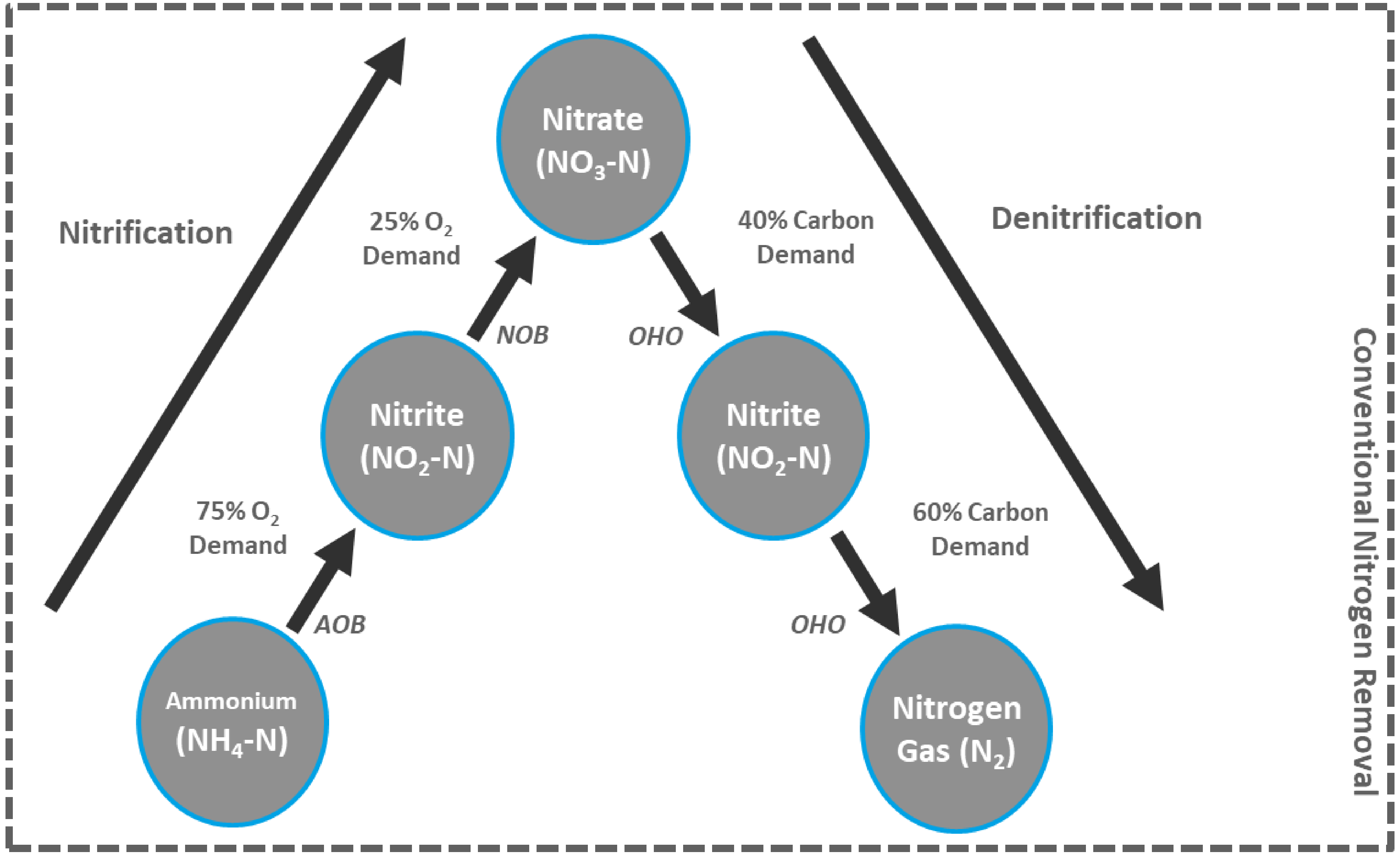
Poll Question 3: How is sidestream nitrogen removal different than mainstream?

Can we add biomass in a different location than the secondary treatment system?



- Sidestream refer to recycle streams
- Recycle from digested sludge dewatering contains significant nitrogen (15 to 25% of influent nitrogen load)
- Can we grow biomass in a separate tank with this stream?

Nitrogen removal involves several reactions and bacteria types



Conventional Nitrogen Removal

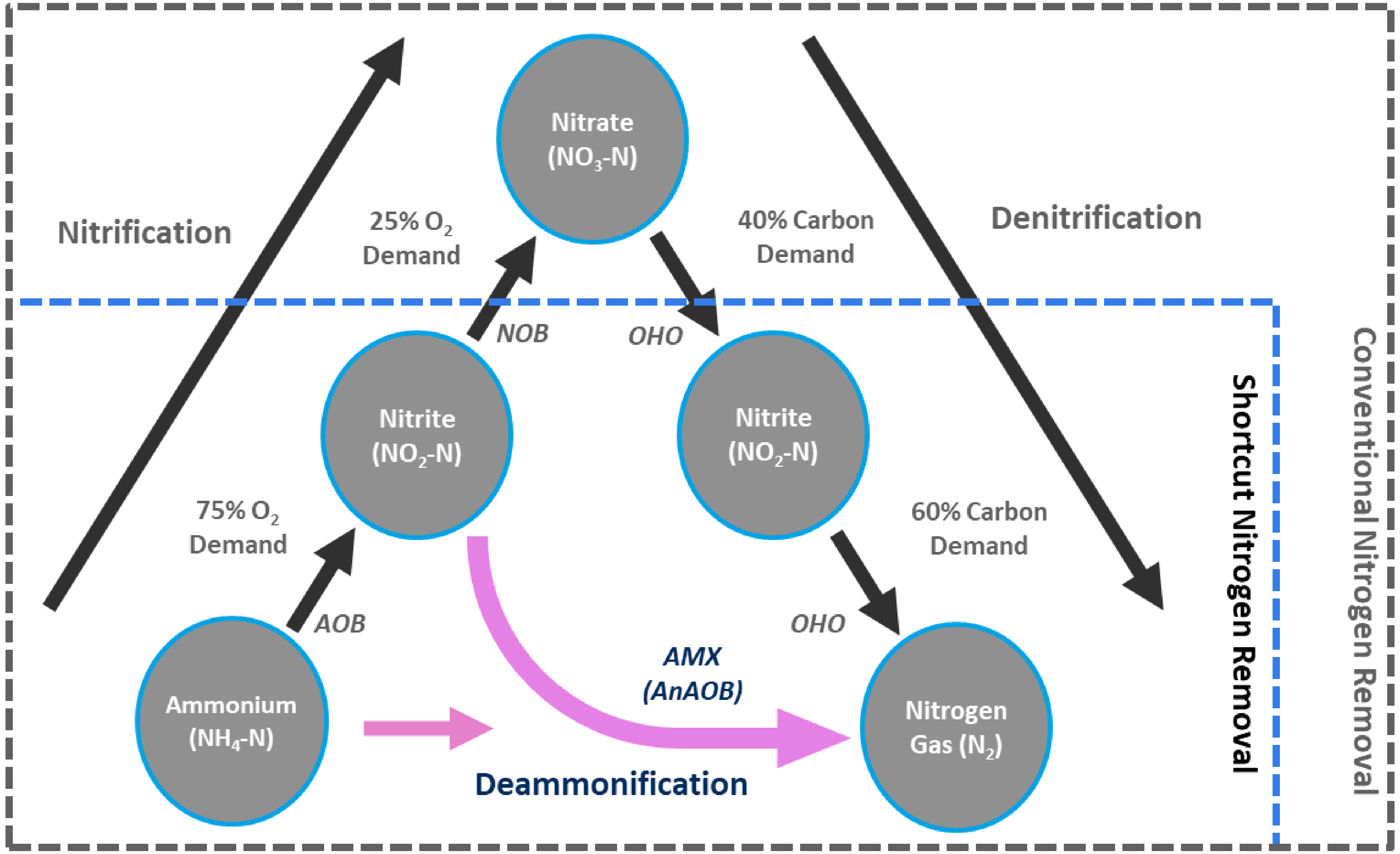
<u>1.0 - Complete Nitrification and Denitrification</u>

Oxygen Demand: 4.57 mg O_2/mg N

Carbon Demand: 2.85 mg O_2/mg N

Managing different groups of bacteria can help us achieve nitrogen removal at lower chemical and energy costs.

Deammonification: shortcutting the nitrogen cycle



Conventional Nitrogen Removal

1.0 - Complete Nitrification and Denitrification

Oxygen Demand: 4.57 mg O_2/mg N

Carbon Demand: 2.85 mg O_2/mg N

Shortcut Nitrogen Removal

3.0 - Deammonification

Oxygen Demand: 63% Savings

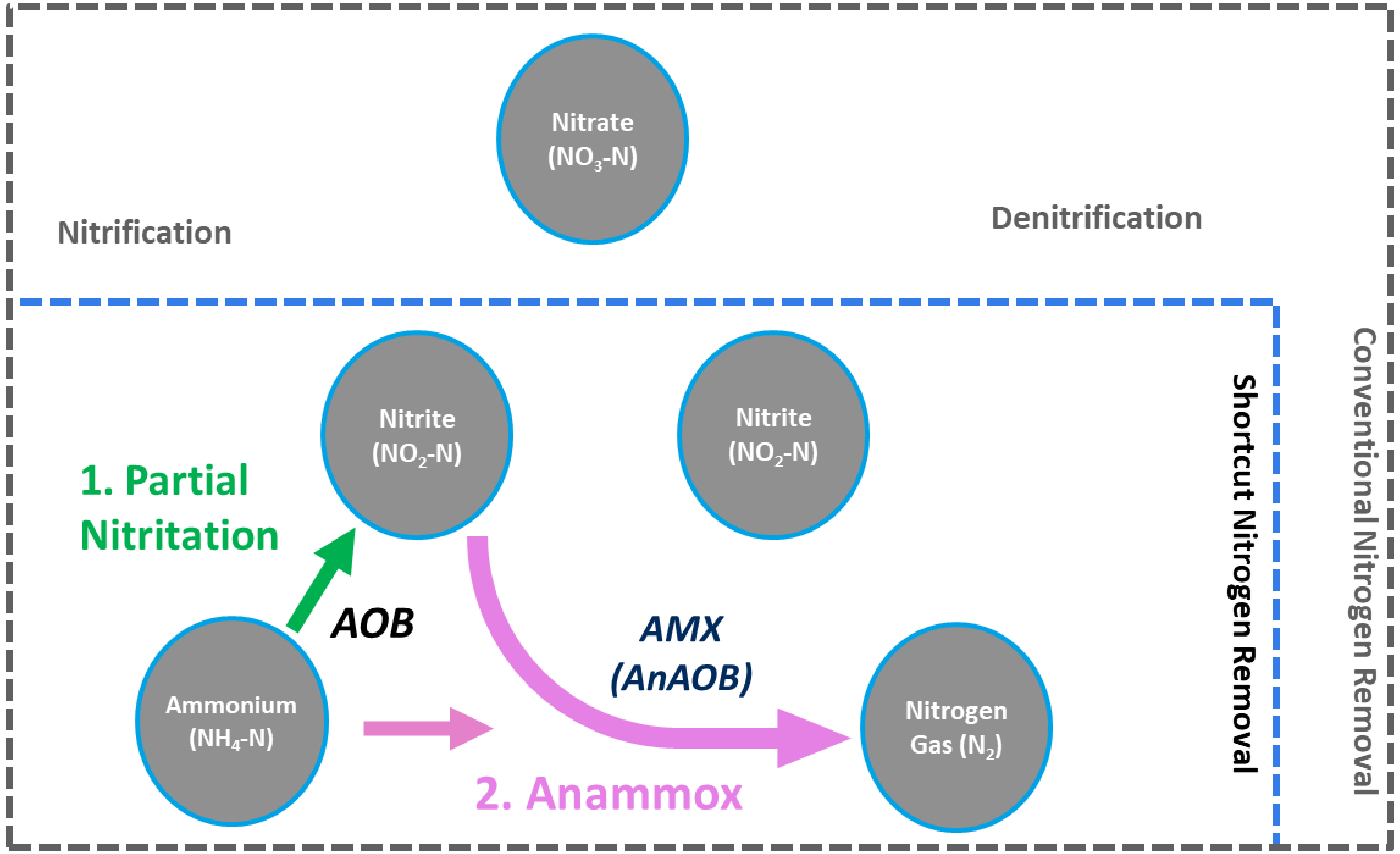
Carbon Demand: 100% Savings

- Save carbon for biogas
- Avoid chemical carbon addition

Sludge Reduction

Footprint Reduction

Deammonification: shortcutting the nitrogen cycle



A two-step process: PNA

(simplified)

Partial Nitritation

$NH_4 + O_2 \rightarrow NO_2$ (Nitrite)

Anammox

$NH_4 + NO_2 \rightarrow N_2$ Gas + NO_3

Sidestream nitrogen process utilize the anammox pathway to achieve deamonification

New Bugs:
Nitrogen Transformers

High N Removal in *Compact Footprint*

- Up to 17 lbs N per 1000gal tankage

65% Energy Savings over N/DN

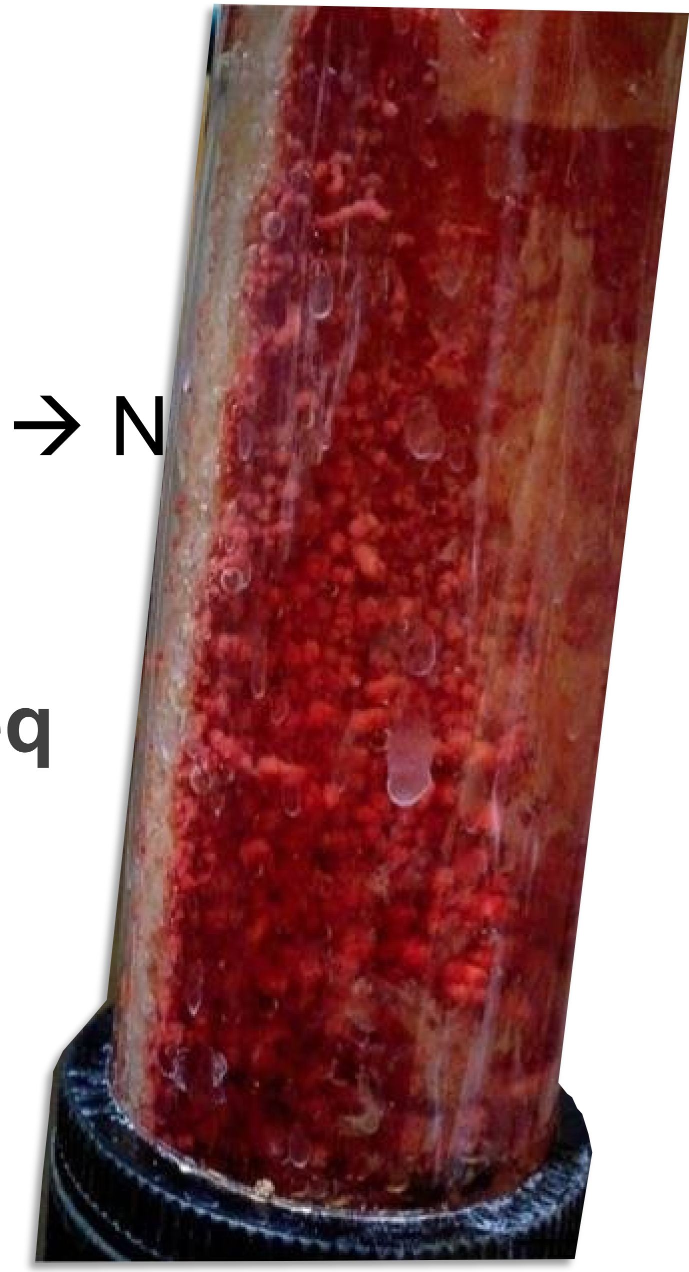
- 50% less NH_4 → NO_2, No air for NO_2 → N

Save Your Carbon

- **Only 10% nitrate = little/no denit req**

>40% Less Sludge per pound N

- **Annammox bacteria grows slow**



Sidestream Technologies By Reactor Configuration

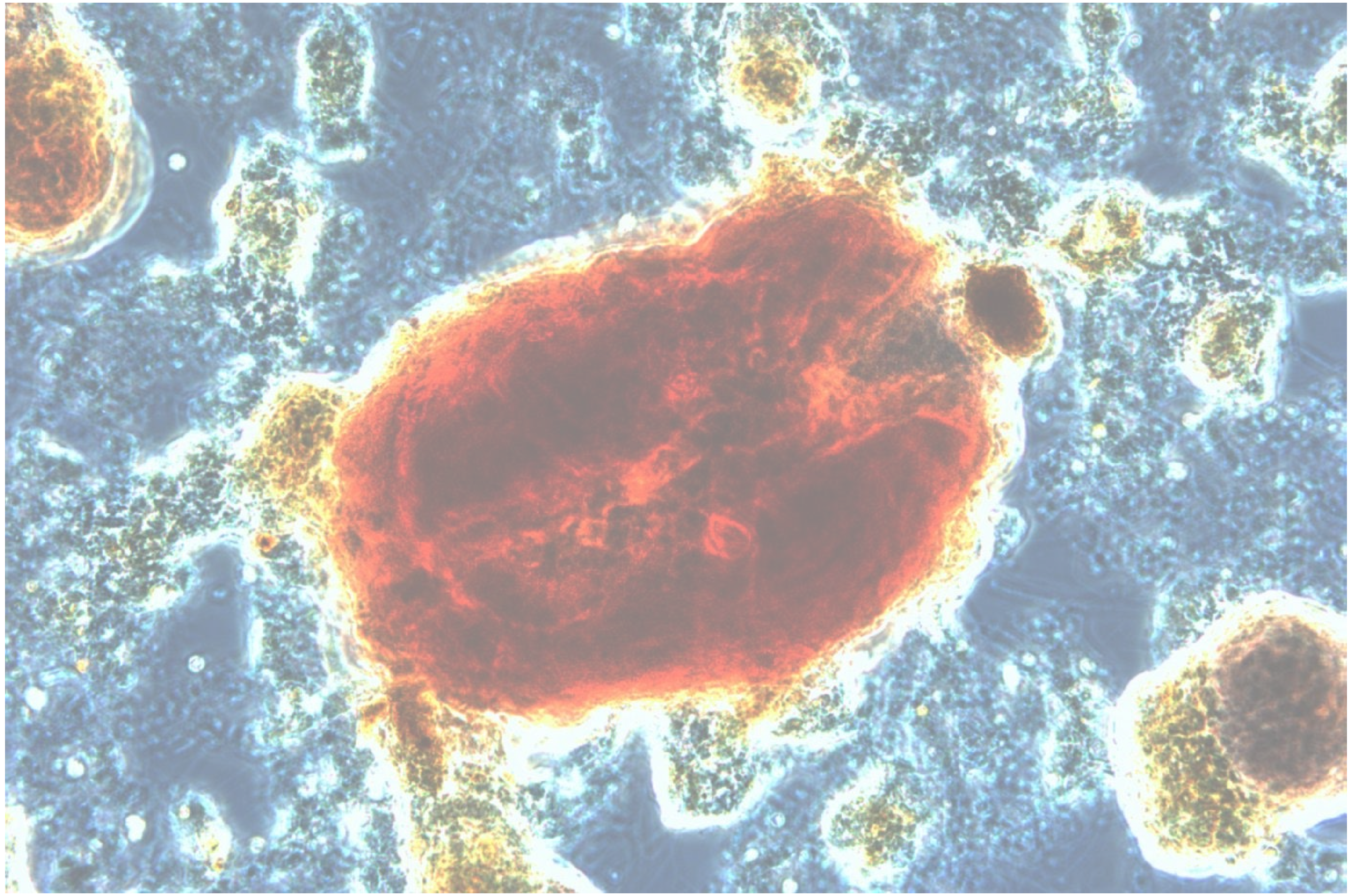
	ANITA™ Mox	AnammoPAQ®	DEMON®	AMX-BBF	DigestivorePAD™
Flow Stream	Recycle Liquid	Recycle Liquid	Recycle Liquid	Recycle Liquid	Digestate
Reactor Configuration	MBBR, IFAS	Upflow CSTR	SBR with hydrocyclone, CSTR with Microscreen	Upflow	CSTR
Process Configuration	Fixed-Film	Biofilm Granules	Suspended Growth	Fixed-Film/ Granules	Suspended Growth
Vendor/ Technology Provider	Veolia	OVIVO	World Water Works	BKT/Tomorrow Water	OVIVO

Different systems utilizes different means for biomass retention

- The big three
  - ANITA Mox: Biofilm carriers
  - AnammoPAQ: large anammox granules and rapid settling
  - DEMON: small granules, physical selection
- Other technologies exist, but these are the most common

Why are anammox technologies become more common?

- Modular, stand-alone technology
- Add high biomass content in a relatively small footprint
- Manage increased nitrogen in sidestreams from co-digestion operations

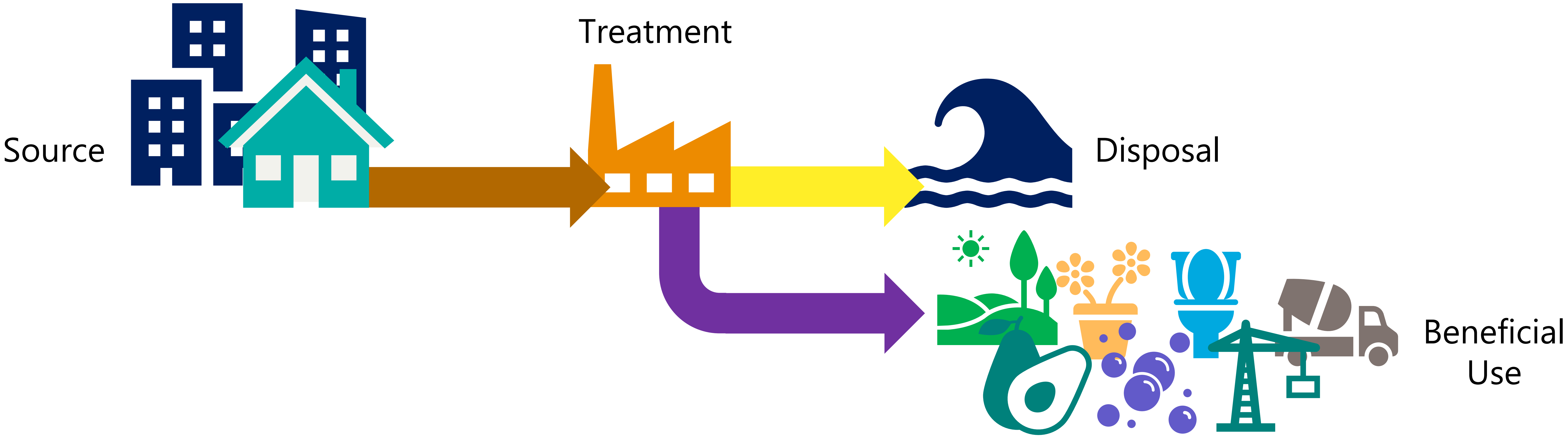


Multi-Benefit and Regional Solutions

Poll Question 4: What strategies are available (beyond liquid treatment) for reducing nitrogen discharged to the Bay?

Diversion of Water and Nutrients for Beneficial Use

- Receiving waters are increasingly impacted by nutrient loads
- While de-facto recycling already occurs, water reuse puts water and nutrients to better use

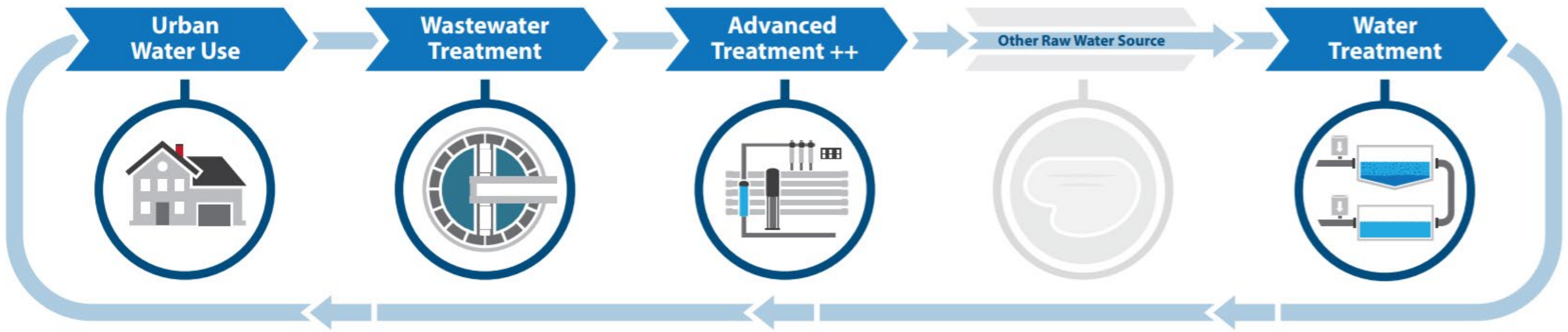


Forms of Recycled Water

Level of Treatment

- Non-potable uses
- Irrigation (agricultural and landscape)
- Commercial
- Industrial (e.g., cooling towers)
- Dual-plumbed buildings
- Recreational
- Specialty Industrial (e.g., boilers)

- Groundwater augmentation
- Surface water augmentation
- Raw water augmentation
- Potable water augmentation



Nature-based Solutions for Nutrient Management

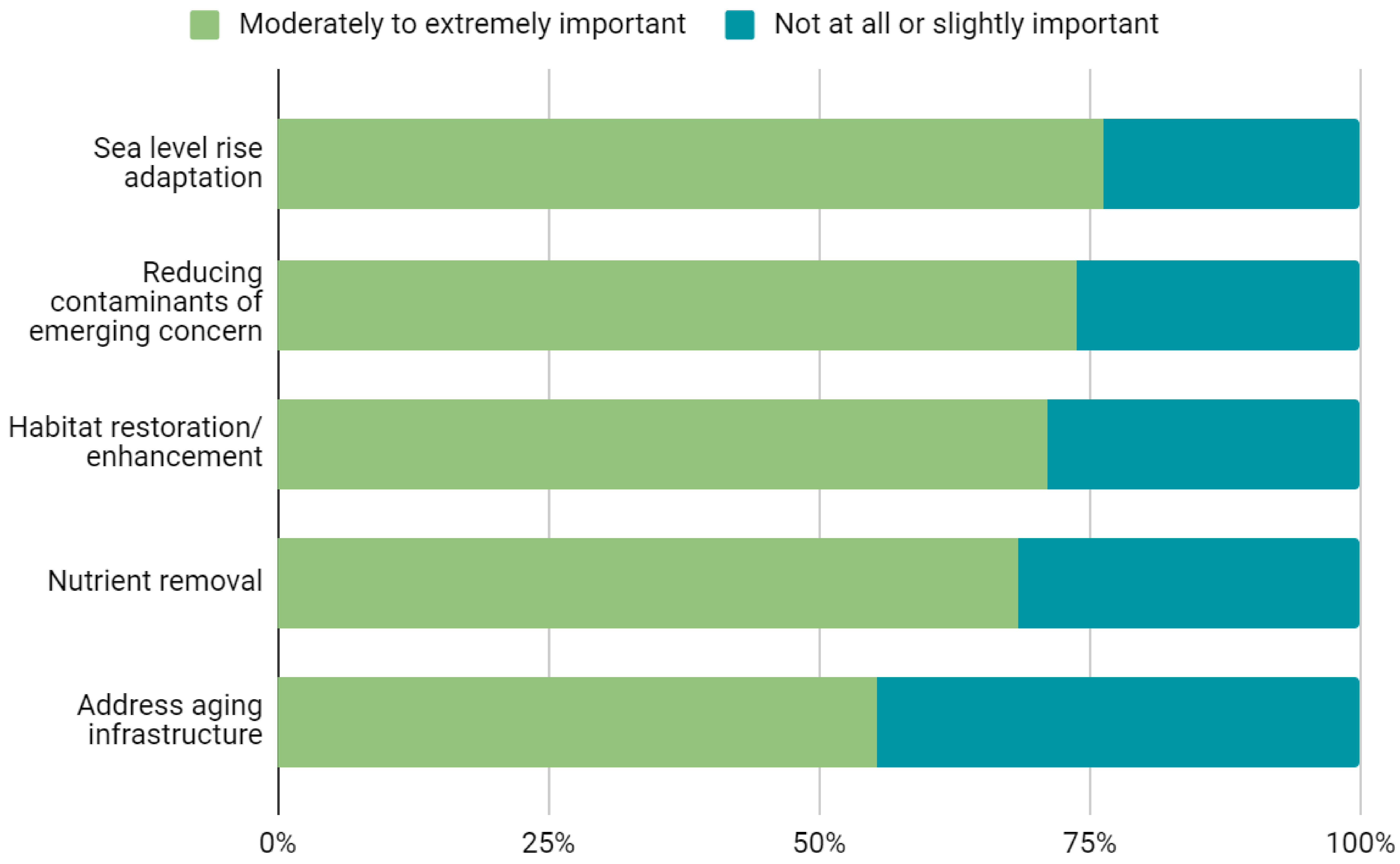
What are Nature-based Solutions?

Engineered interventions that exploit natural processes to foster urban resilience and sustainability.

Grey Infrastructure		Natural Processes		Nature-Based Solutions
Pump Stations		Photolysis		Open-Water Wetlands
Outfalls & Stage Controls		Denitrification		Subsurface Flow Wetlands
Attached/Fixed Growth Nitrification	+	Infiltration	=	Agriculture & Forest Irrigation
Distribution		Carbon sequestration		Woodchip Bioreactors
Impermeable Liners		Habitat connectivity		Horizontal Levees

Survey Results

Rate your agency's interest in pursuing NbS according to the following objectives:



Unit-Cell Open Water Wetlands

Photo: David Sedlak

Horizontal Levees

Oro Loma horizontal levee. Photo: SFEP

What is a Horizontal Levee?

https://youtu.be/OHt7qtI1kso?si=fB6O44YwxIRpHTRd

Short Overview of Oro Loma/Castro Valley Horizontal Levee Project

The Future?

WRRF

Effluent

Advanced Treatment

Purified Water

Reverse Osmosis

Concentrate

Horizontal Levee: Treat RO Concentrate & Address Sea Level Rise/Habitat Restoration

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Questions?