CONSTRUCTED WETLANDS FOR SMALL WASTEWATER TREATMENT PLANTS AND STORMWATER TREATMENT EMERGING TECHNOLOGIES FOR NITROGEN AND PHOSPHORUS REMOVAL

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Agenda

- Problem Statement
- Nitrification in Wetlands including Super Oxygenated Wetlands
- Annamox in Wetlands
- Phosphorous Removal – Geochemical Augmentation
- Biochemical Reactors – for Mine Water Treatment and Reverse Osmosis Brine Treatment

Problem statement

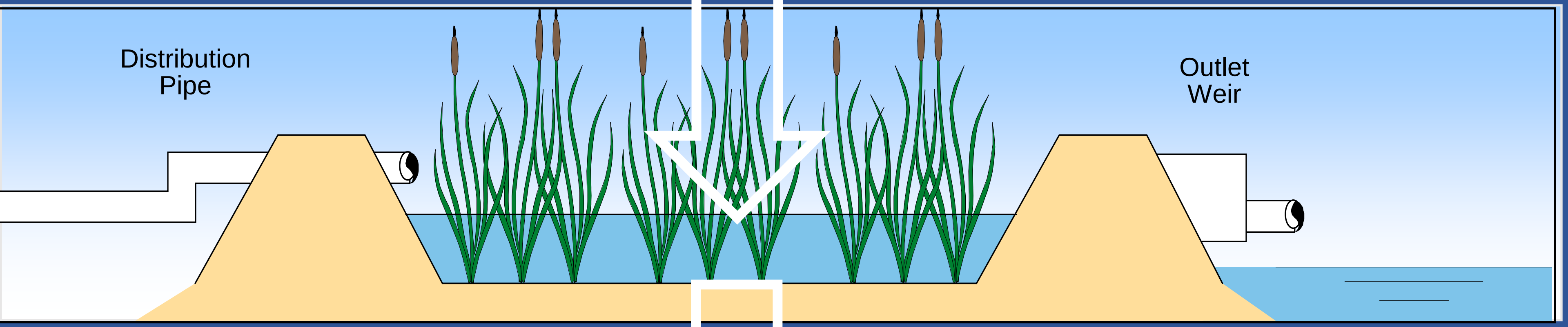
- Councils in NZ operate Pond Based WWTPs
- Wetlands as final polishing step
- Poorly maintained / undervalued
- Consent conditions becoming increasingly stringent
- N & P can be hard to meet with ponds alone
- Upgrade to more advanced treatment systems (i.e. MBR, SBR) can be costly
- Even with Capex Funding, ongoing operational costs are a burden to smaller councils

Innovations in Wetland Treatment

- Wetland treatment is improving with emerging technologies demonstrating good results globally
- Technologies are suitable for NZ
- Lost cost and passive solutions which can reduce N and P
- Treat at higher rates than passive systems
- Reduced footprint requirements through process intensification

Nitrification in surface flow wetlands

O_2 diffusion from atmosphere

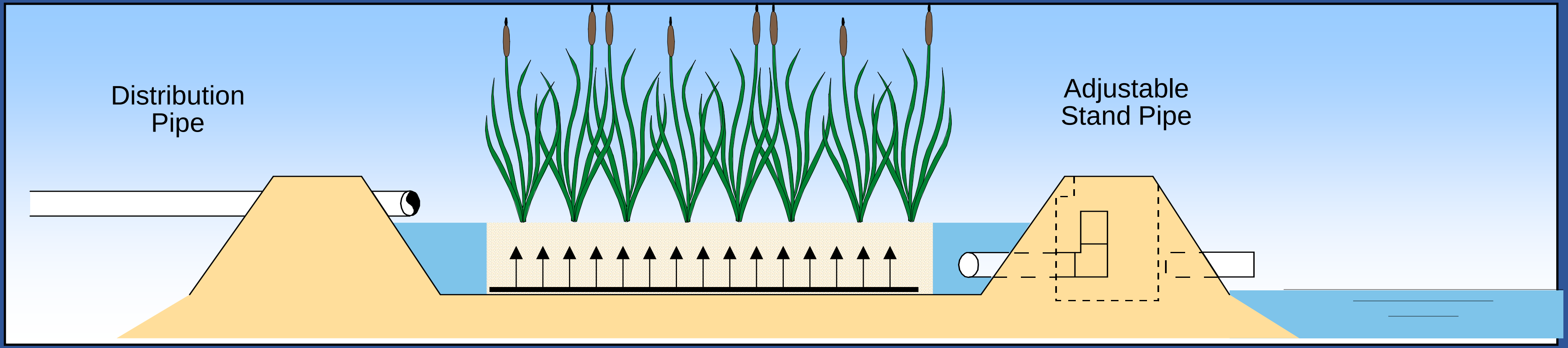


O_2 depletion from sediments

Sediment O_2 depletion > O_2 diffusion

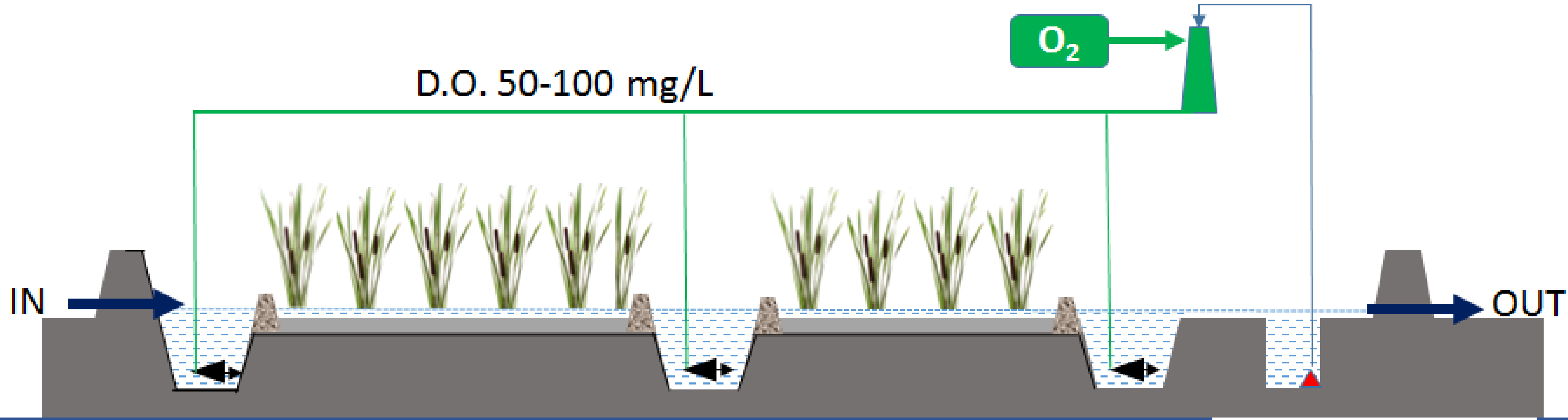
→ Poor oxidation of NH_4^+

Why not aerate to nitrify?

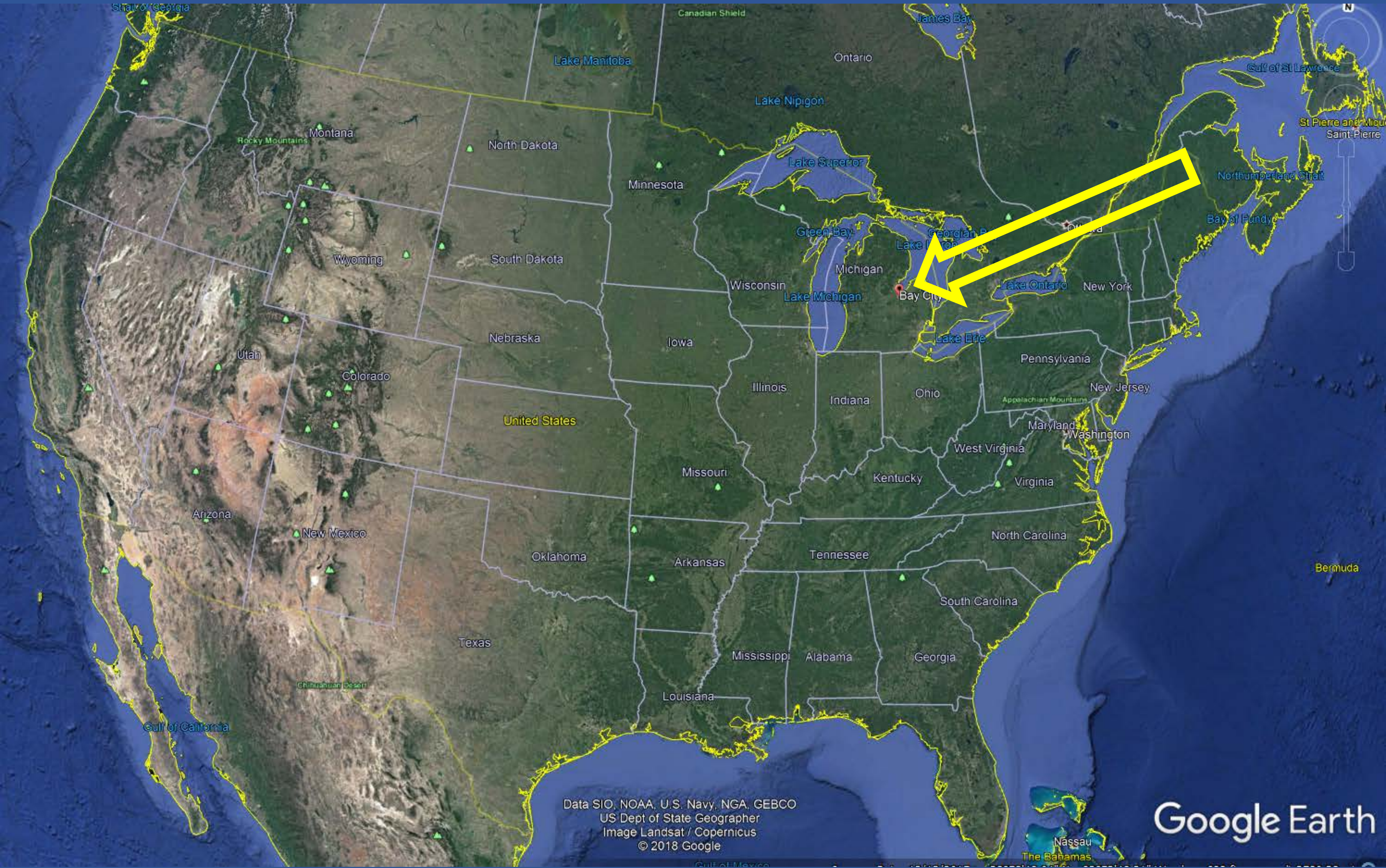


- Drip irrigation tubing under media (subsurface flow wetland also known as reed bed)
- Highly effective at nitrification
- Reasonable cost for 0.1 MLD, maybe up to 1 MLD
- 3 times unit cost of surface flow wetlands

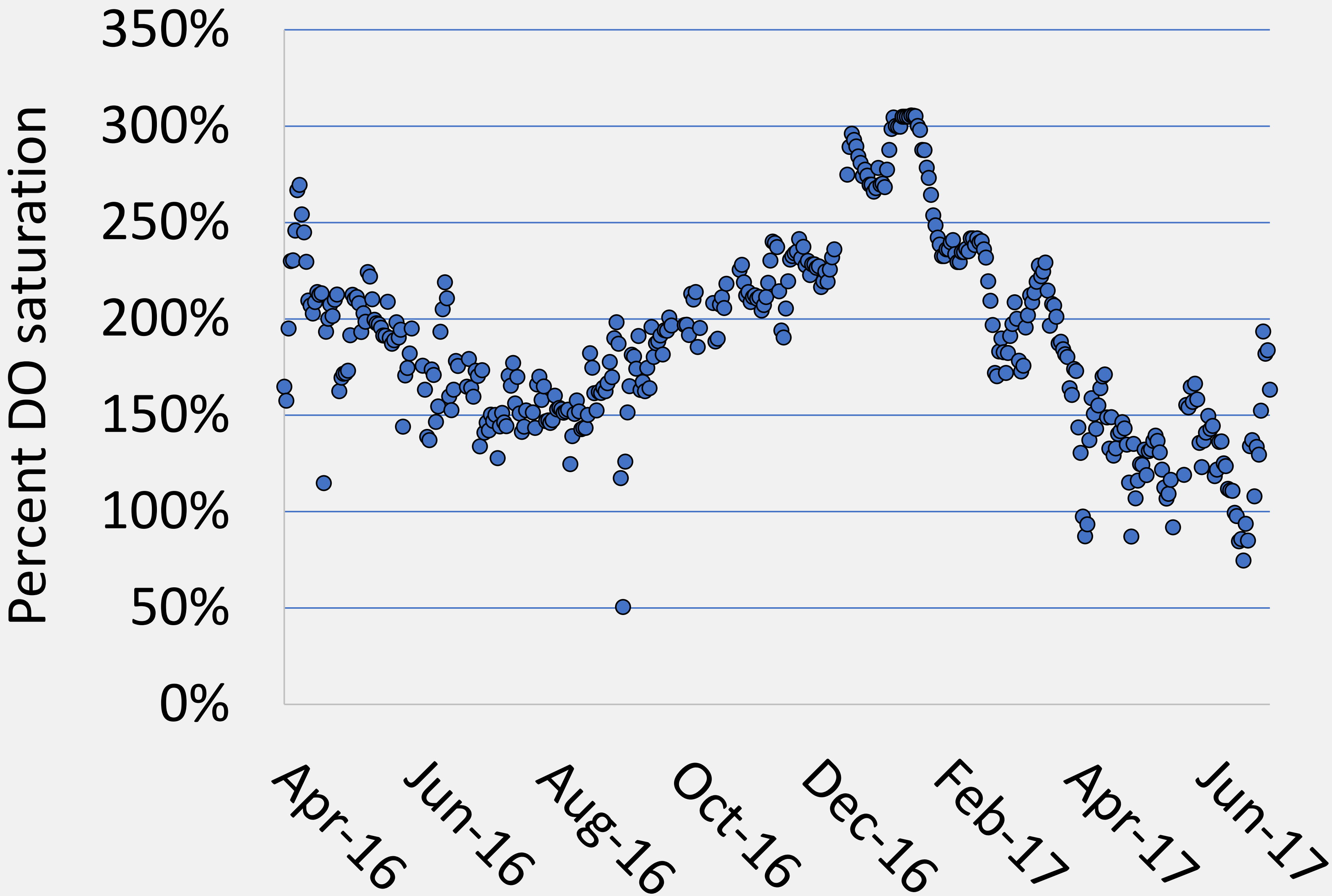
Super-oxygenated wetland: High rate nitrification



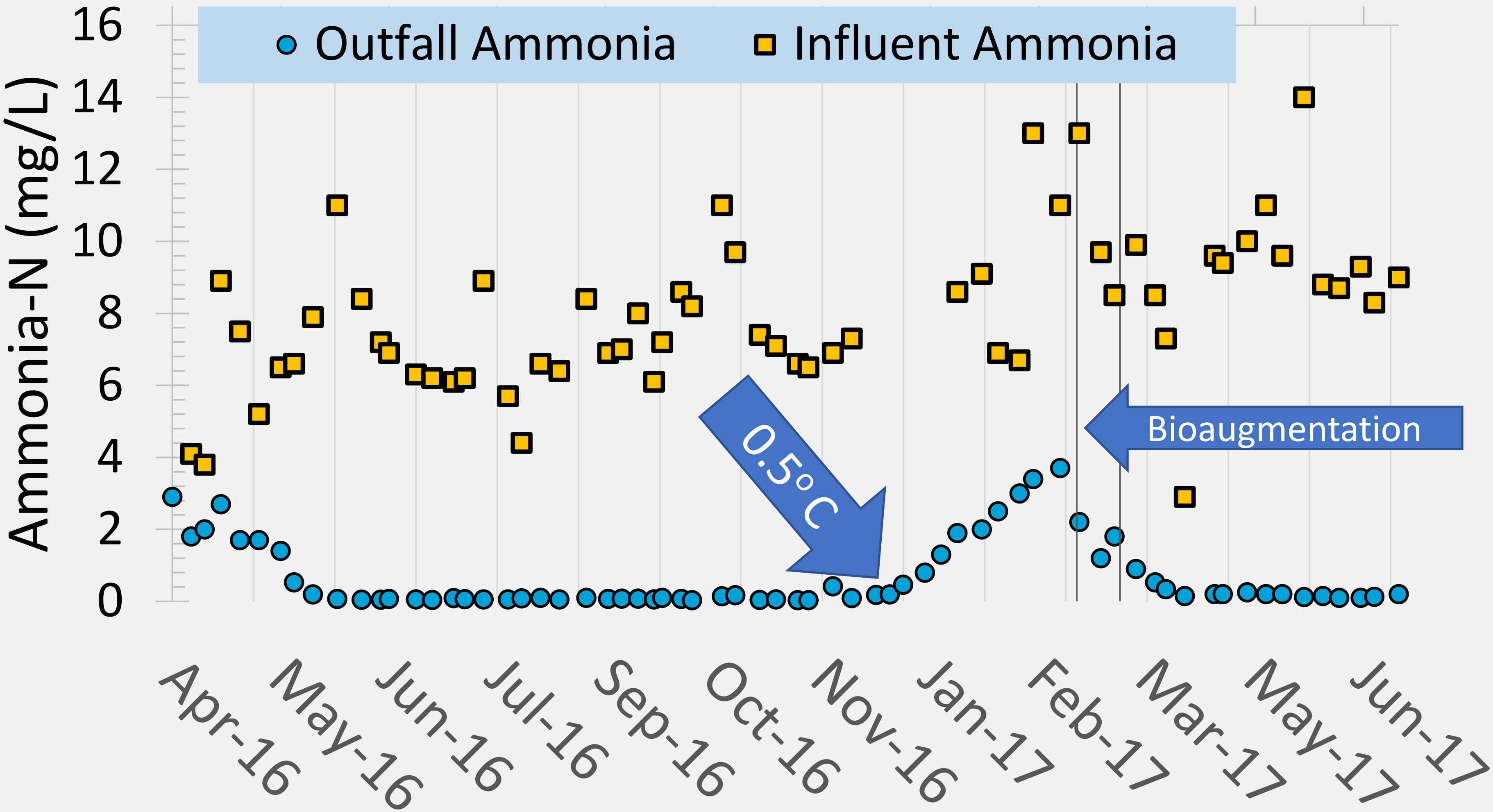
Project location



Dissolved oxygen percent saturation at outfall



Nitrification results (average flow 832 m^3/d)



Super-oxygenation impact on wetland area: example

- Nitrification rate about 100x over passive wetlands
- Example assumptions
  - Flow = 10 MLD
  - Influent NH_3-N = 10 mg/L
  - Effluent NH_3-N = 1 mg/L
  - P-k-C* model (Kadlec and Wallace, 2009)
- Passive surface flow wetland = 77 ha
- Super-oxygenated wetland = 4 ha

Advantages of super-oxygenation

- Extremely stable treatment in small footprint
- Surface flow wetlands never clog
- For small plants 1 – 10 MLD, consider doing all N treatment downstream of clarifier, Bio-P upstream
- Probable lowest possible GHG release from treatment because of very long SRT (~100 days) and high DO

Zeolite Anammox

- Sidestream system
- N removal from biosolids centre screw press filtrate
- 19 m^3/d, NH_3-N = 1,000 mg/L

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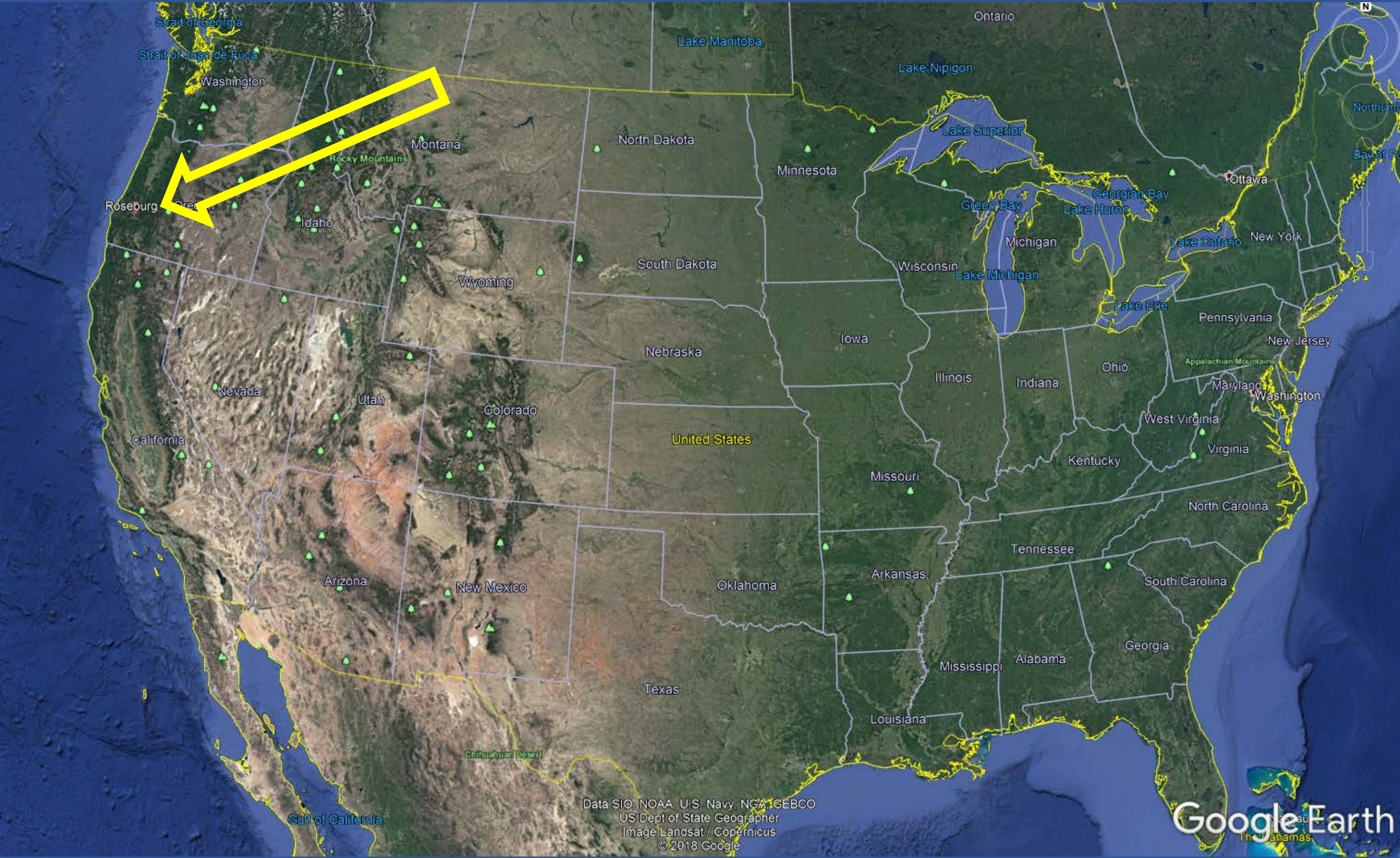
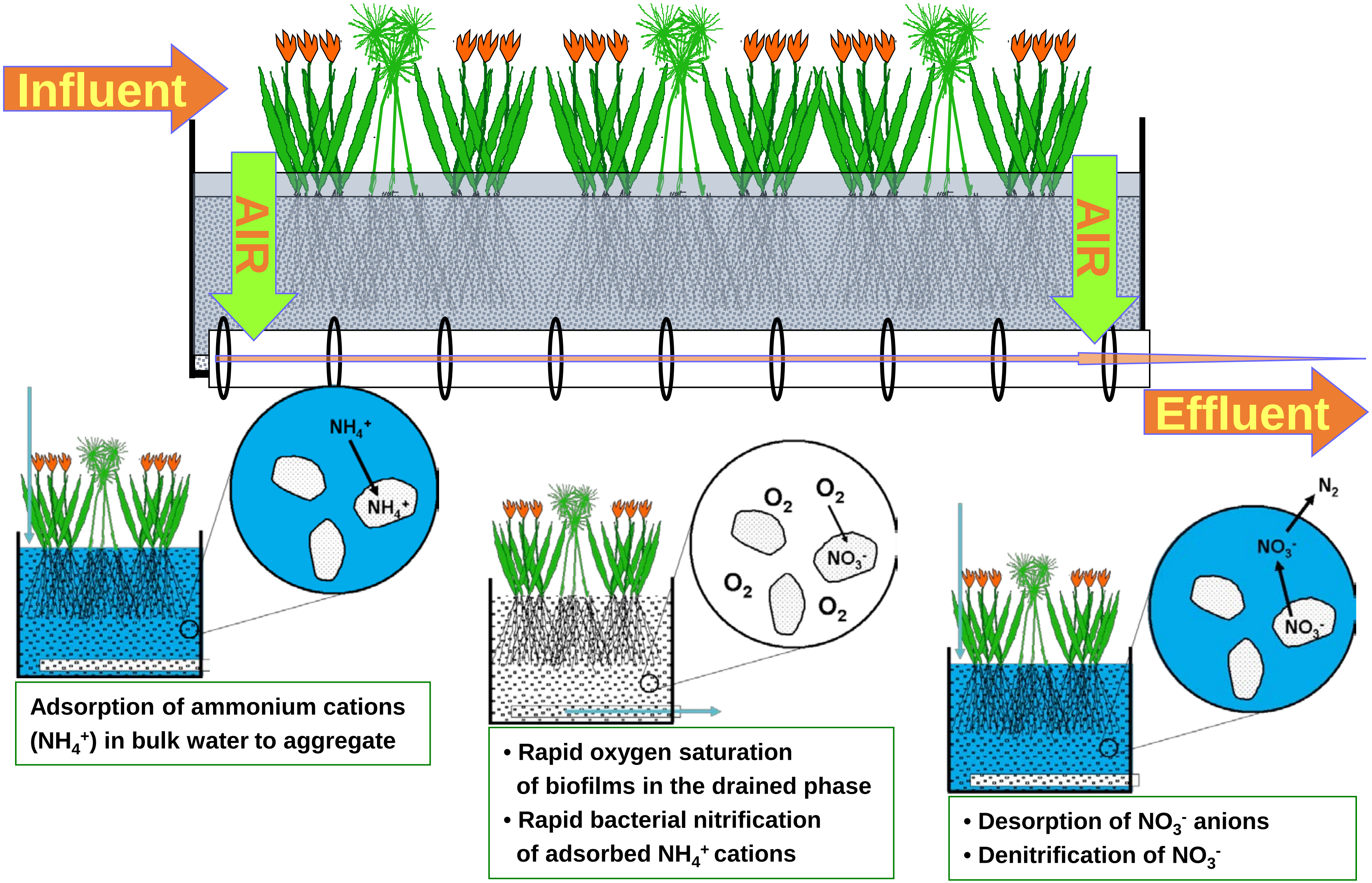
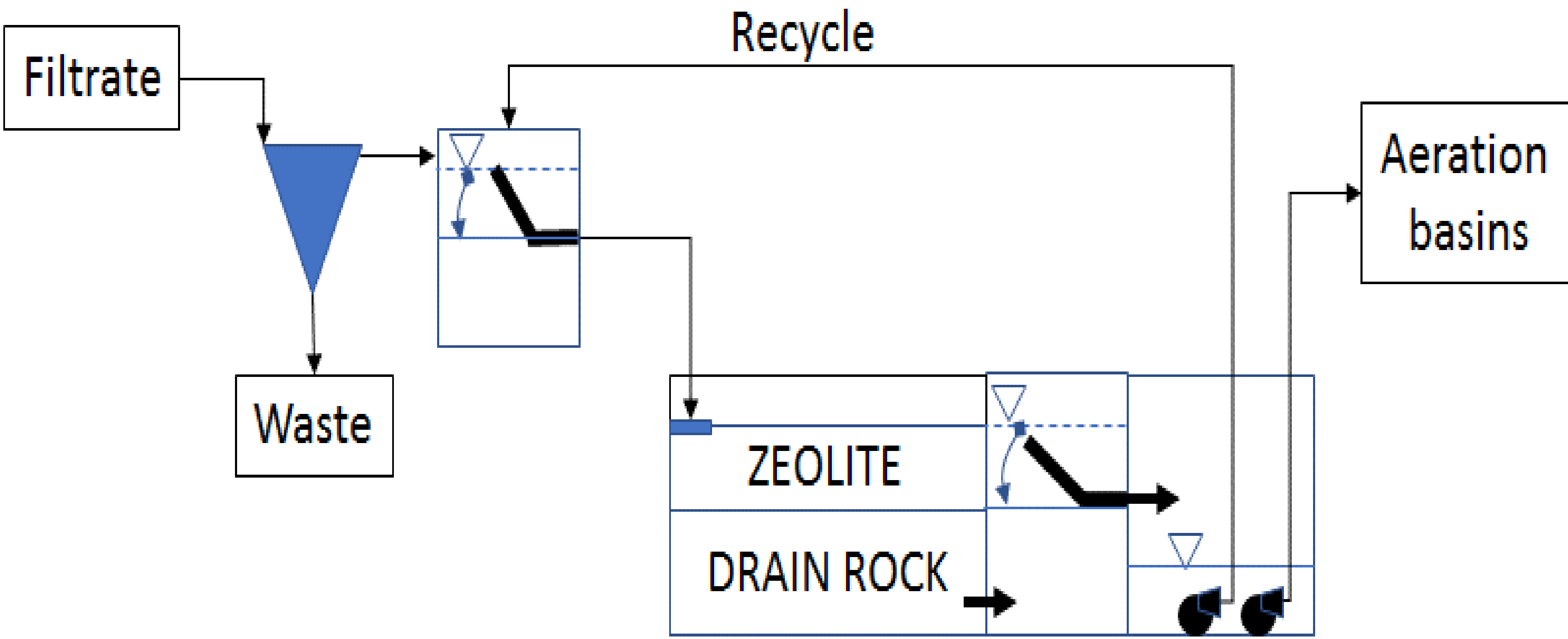
Project location



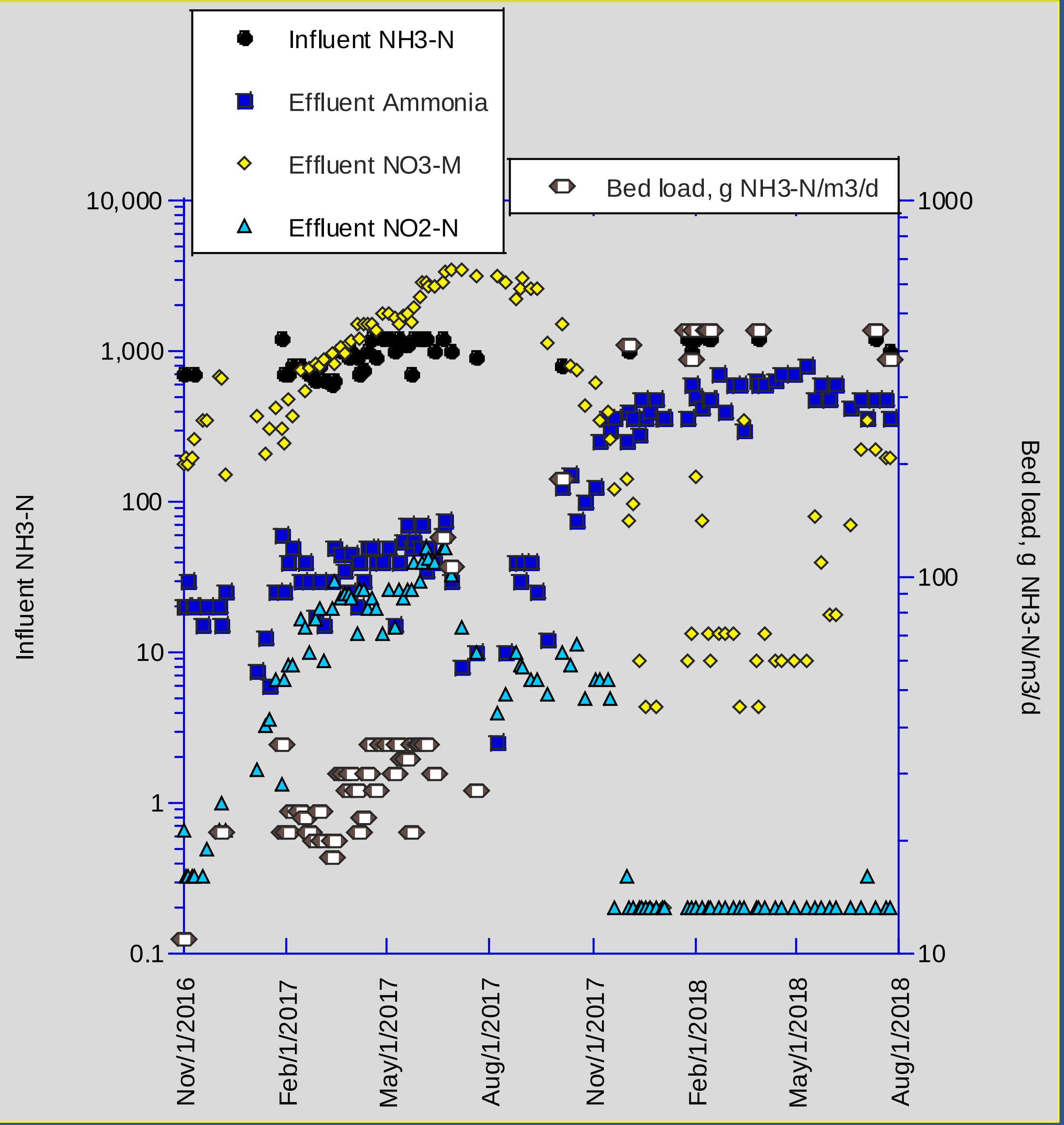
Ammonia oxidation to nitrification



Zeolite-anammox tidal flow system schematic



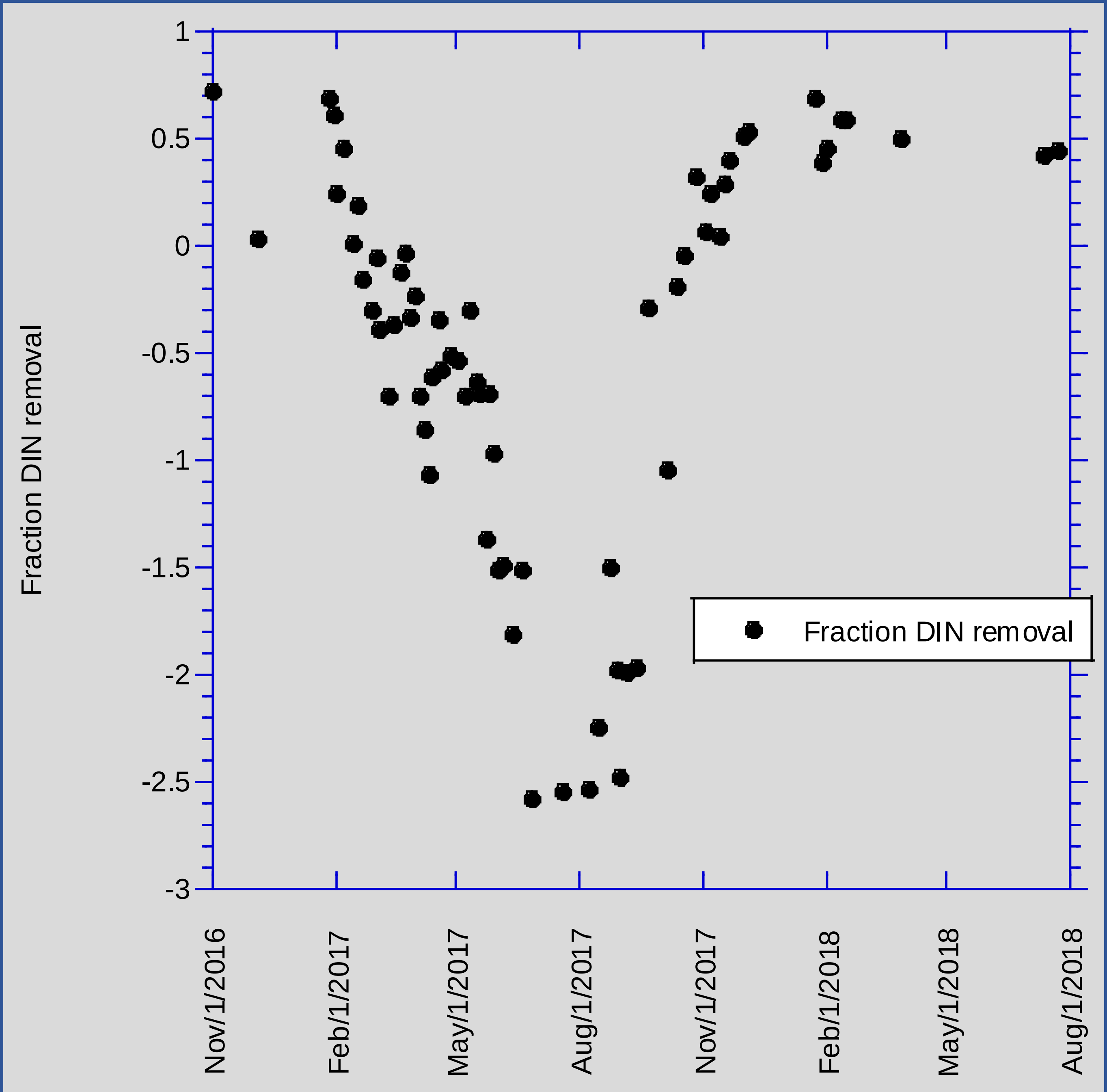
First commercial system (2017). Public domain technology



RESULTS

- 50% TN removal via anammox
- > 90% nitrification at start until anammox took over
- Key to anammox is load
- > 120 g NH_3-N/m^3/d

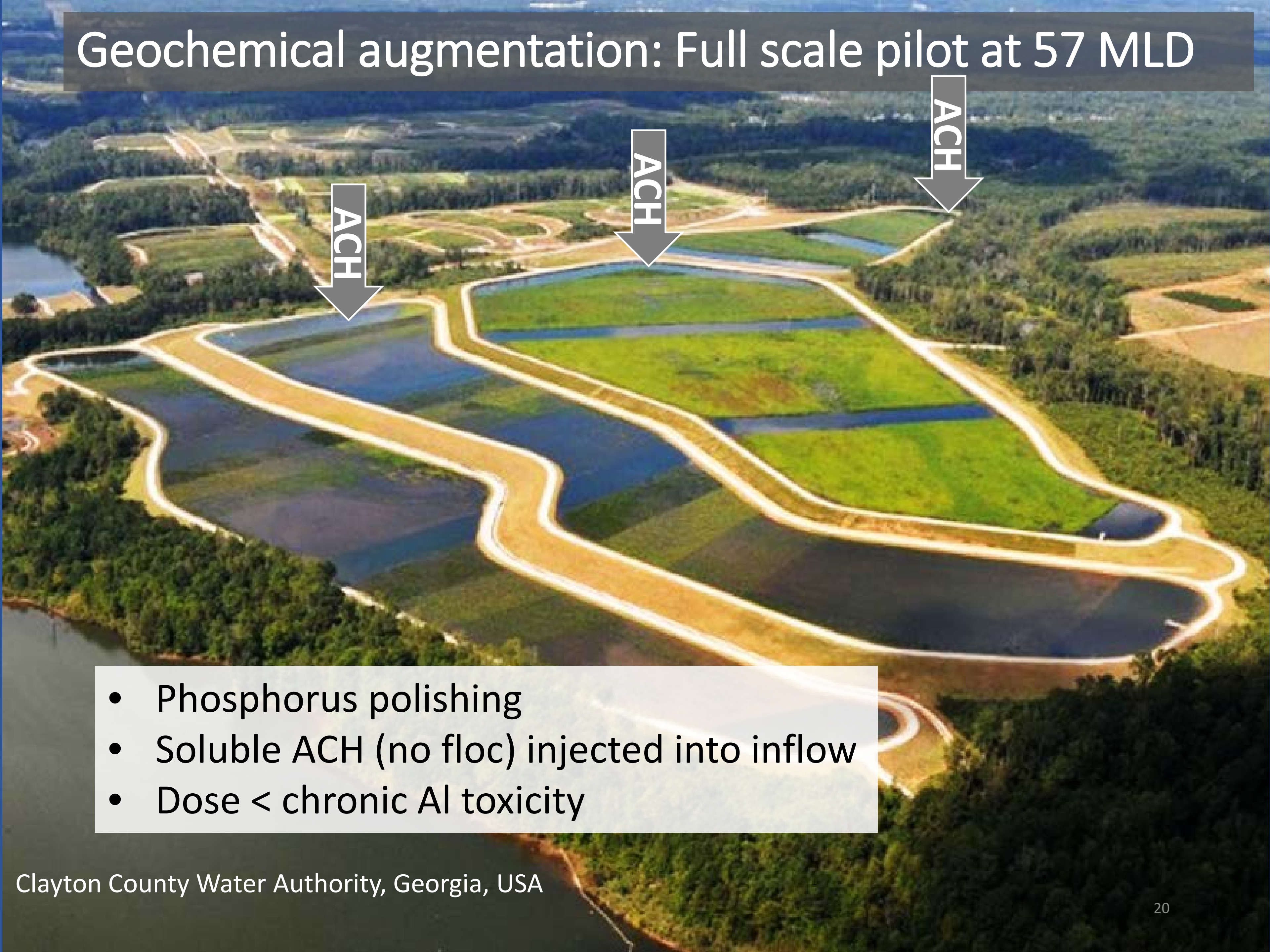
Fraction DIN removal



Key features of zeolite-anammox

- Open source technology
- Low energy requirement
- Limited by BOD and TSS loading to prevent clogging
- Good zeolite available in New Zealand and Australia
- Nitrification is immediate
- Anammox takes time to grow (1 to 2 years)

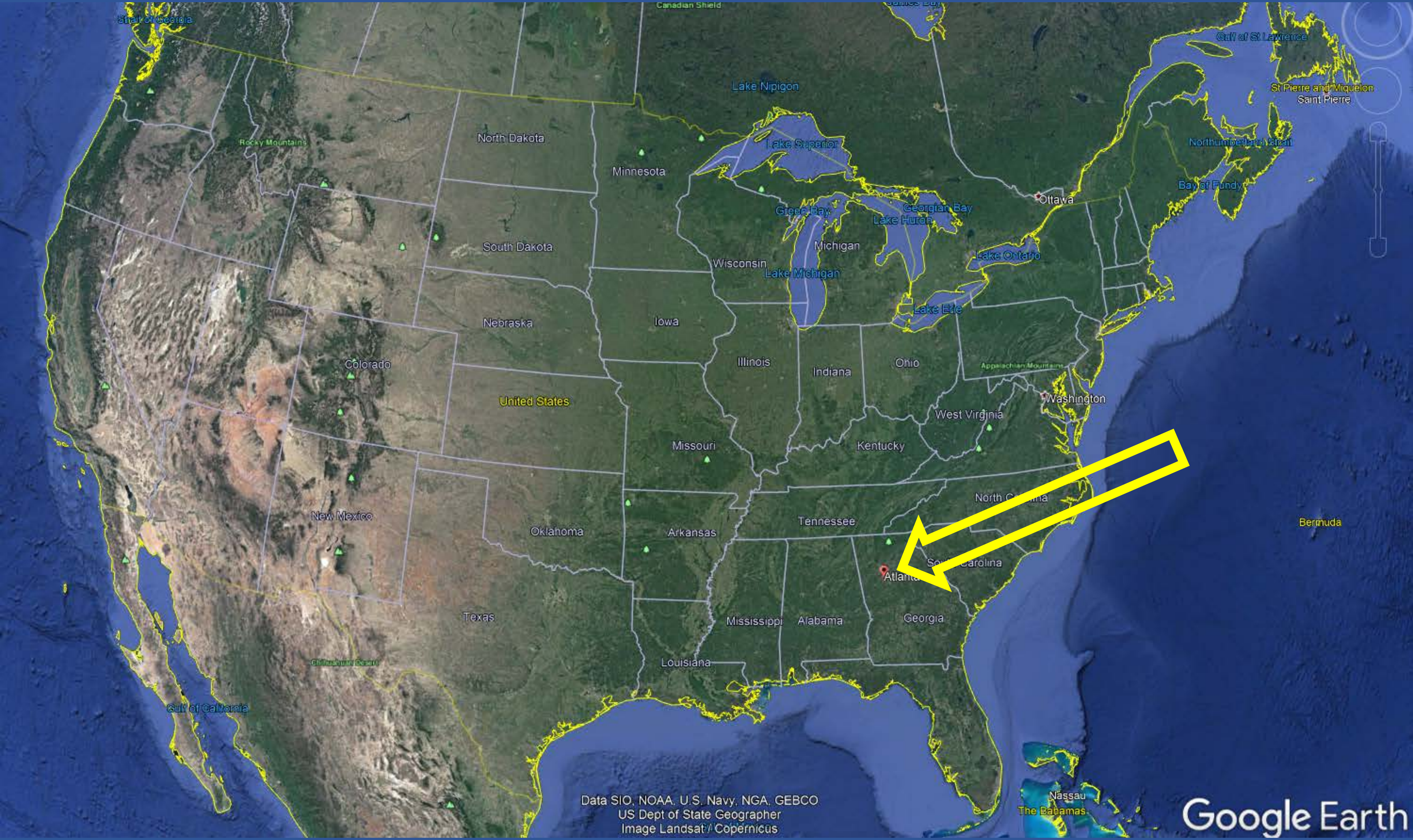
Geochemical augmentation: Full scale pilot at 57 MLD



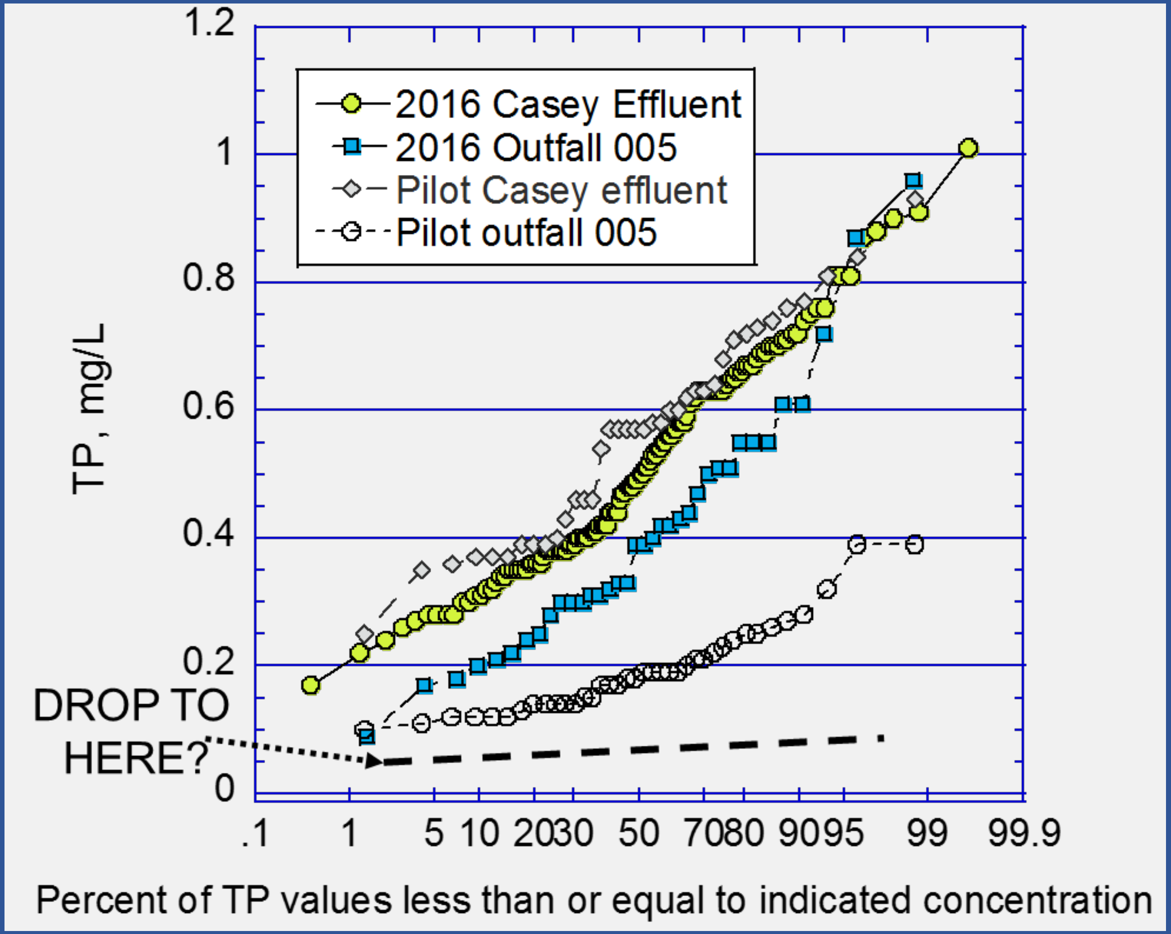
- Phosphorus polishing
- Soluble ACH (no floc) injected into inflow
- Dose < chronic Al toxicity

Clayton County Water Authority, Georgia, USA

Project location

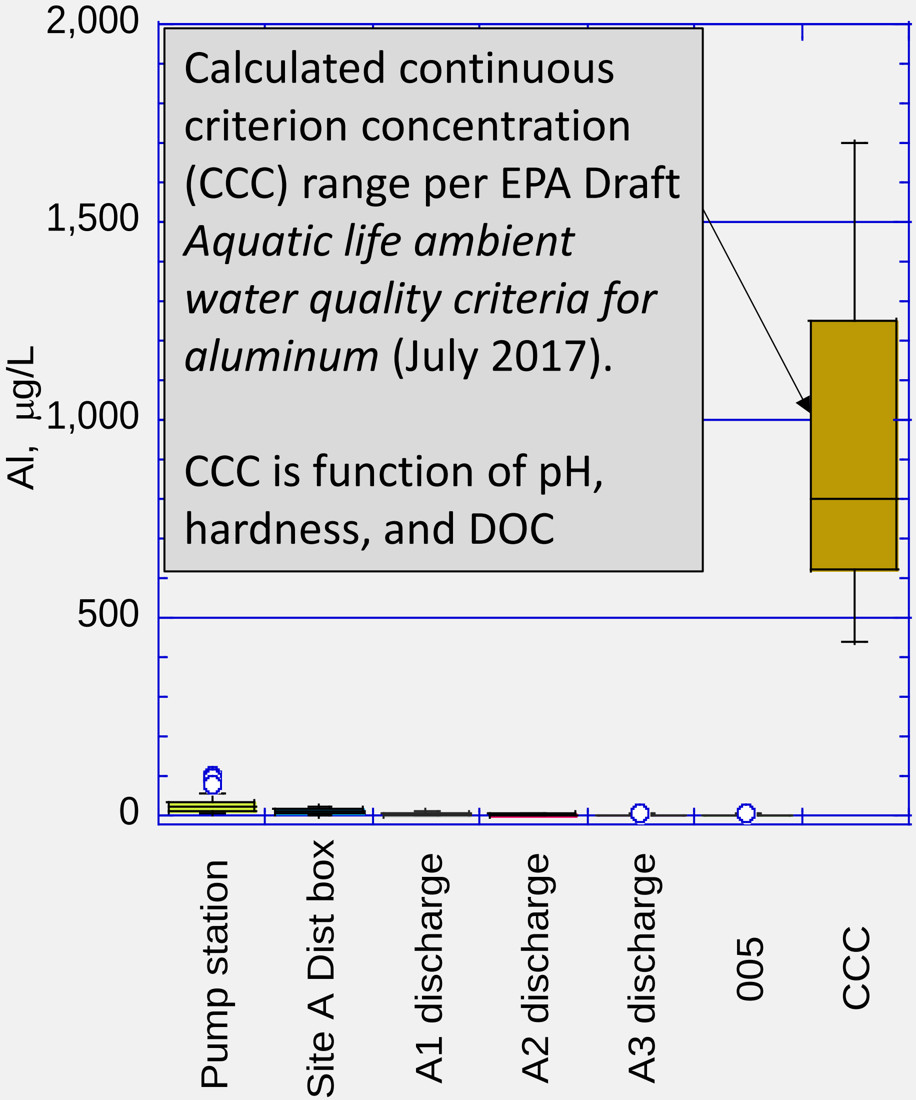


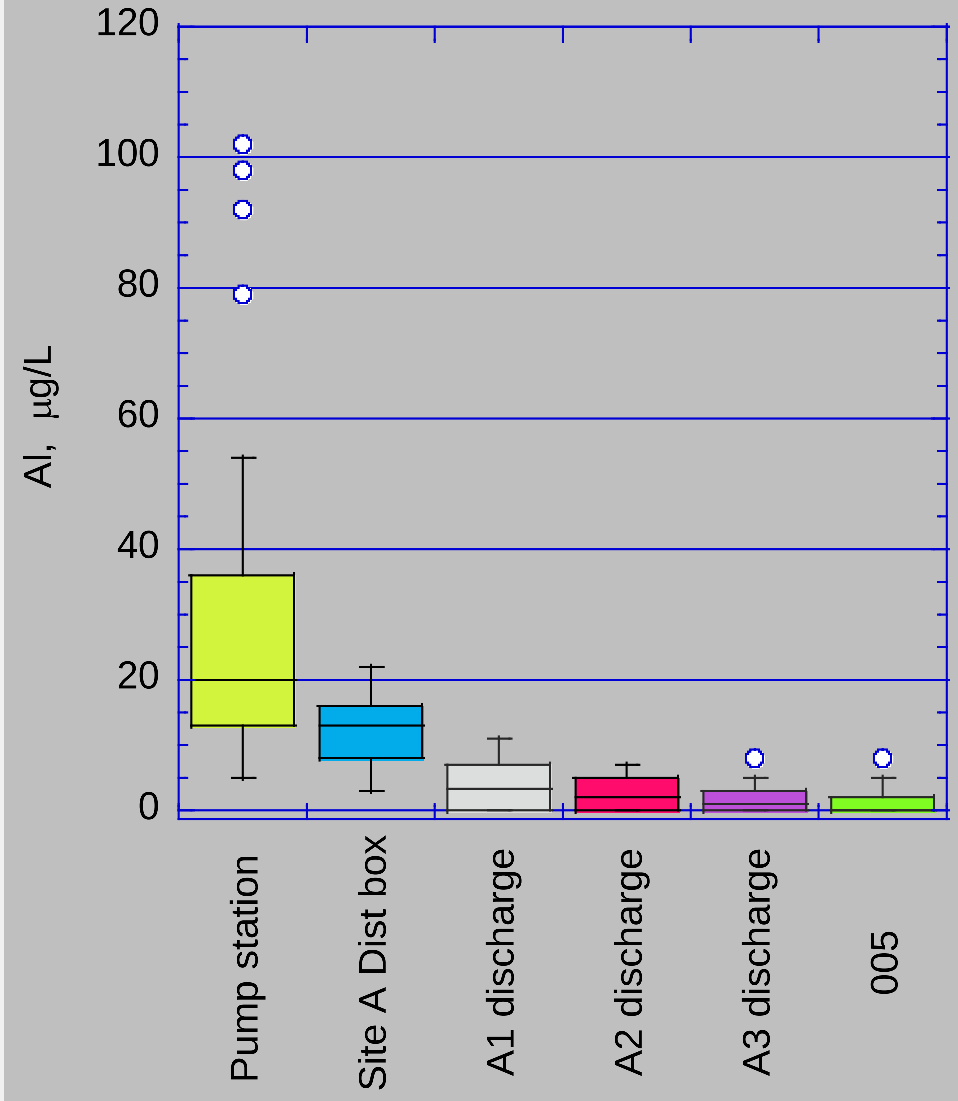
Results-TP Removal



- Casey Water Reclamation Facility treats TP to 0.5 mg/L
  (Bio-P + Ferric sulfate)
- Inflow median TP
  - 2016: 0.50
  - 2017 Pilot: 0.57
  - Significance? $p < 0.12$
- Outflow Median TP
  - 2016: 0.39
  - 2017 Pilot: 0.19
  - Significance? $p < 0.0001$

Results-Aluminum





Advantages of geochemical augmentation

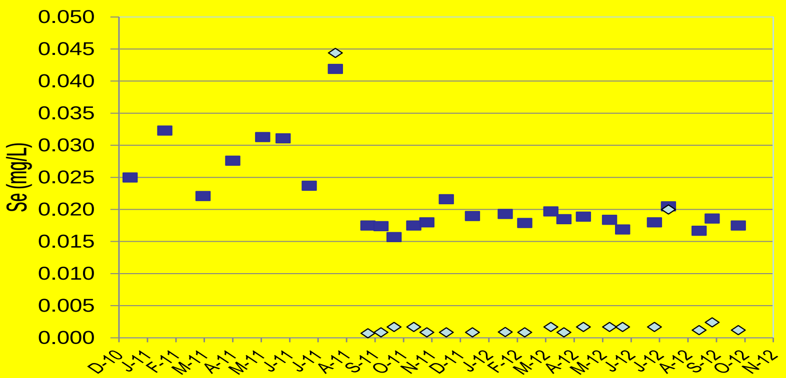
- Economical P-polishing, important when discharge is to sensitive freshwater bodies
- Hard process reality for P removal – sequestration of P in insoluble minerals is the only P-removal mechanism of long term relevance to P removal in wetlands
- Probably 10-30% area of textbook P removal wetlands

Biochemical Reactors (BCR) - Components

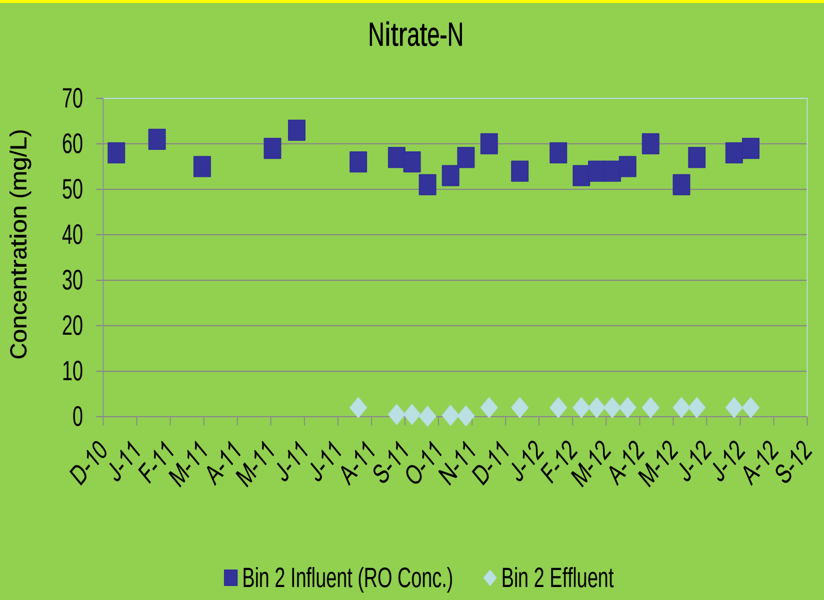
- Labile and recalcitrant organic carbon sources
  - Wood - Chips, sawdust
  - Grass - Hay
  - Wetland Plants - Bulrush, cattail
- Manure and Soil
- Limestone chips
- Sulfur (sometimes)
- Note: BRC is kind of a silly name because all biological treatment is biochemical, but that is the name we are stuck with

(BCR) for RO brine treatment pilot

Organic media



Se: 20 µg/L → < 4 µg/L



NO_3-N: 60 mg/L → ND

BCR observations

- Proven technology for mine water treatment (thousands of systems)
- Denitrification rates about 10 times textbook wetland rates
- Candidate technology for denitrification of wastewater flows less than about 2 MLD
- Organic media not appropriate for drinking water treatment, but probably can be adapted for NO_3-N removal with limestone/gypsum media

Conclusions

- New generation of treatment wetlands
- Sharp reductions in treatment area for nitrification and P-polishing
- Super-oxygenation and geochemical augmentation for P-polishing suitable for flows 1 to 10 MLD (or more)
- Zeolite-anammox too new to understand upper limit of flows (4 MLD?), but suitable for even very small flows
- BCRs extremely effective at denitrification, but may be economical only to about 4 MLD

Questions