Intensifying Wastewater Treatment

CSEAO Annual Winter Conference

Rob Smith

Senior Process Engineer

Agenda

- Wastewater Treatment Intensification
- High-Rate Clarification / Filtration
- Sludge Densification
- Aeration Intensification
- Questions and discussion

Wastewater Treatment Intensification

What is WWT Intensification?

WWT intensification is the improvement of the efficiency of wastewater treatment. By addressing choke points, it allows existing plants to treat more wastewater and to do it better, cheaper, and faster within their existing footprint.

WWT intensification offers an opportunity to reduce the cost and environmental impact of wastewater treatment

Drivers

- Site constraints
- Service Area Growth
- New discharge limits
- Excessive operating cost
- Chemical usage
- GHG reduction
- Cogeneration

An intensification technology may address one or more of the above drivers

Targets for Intensification

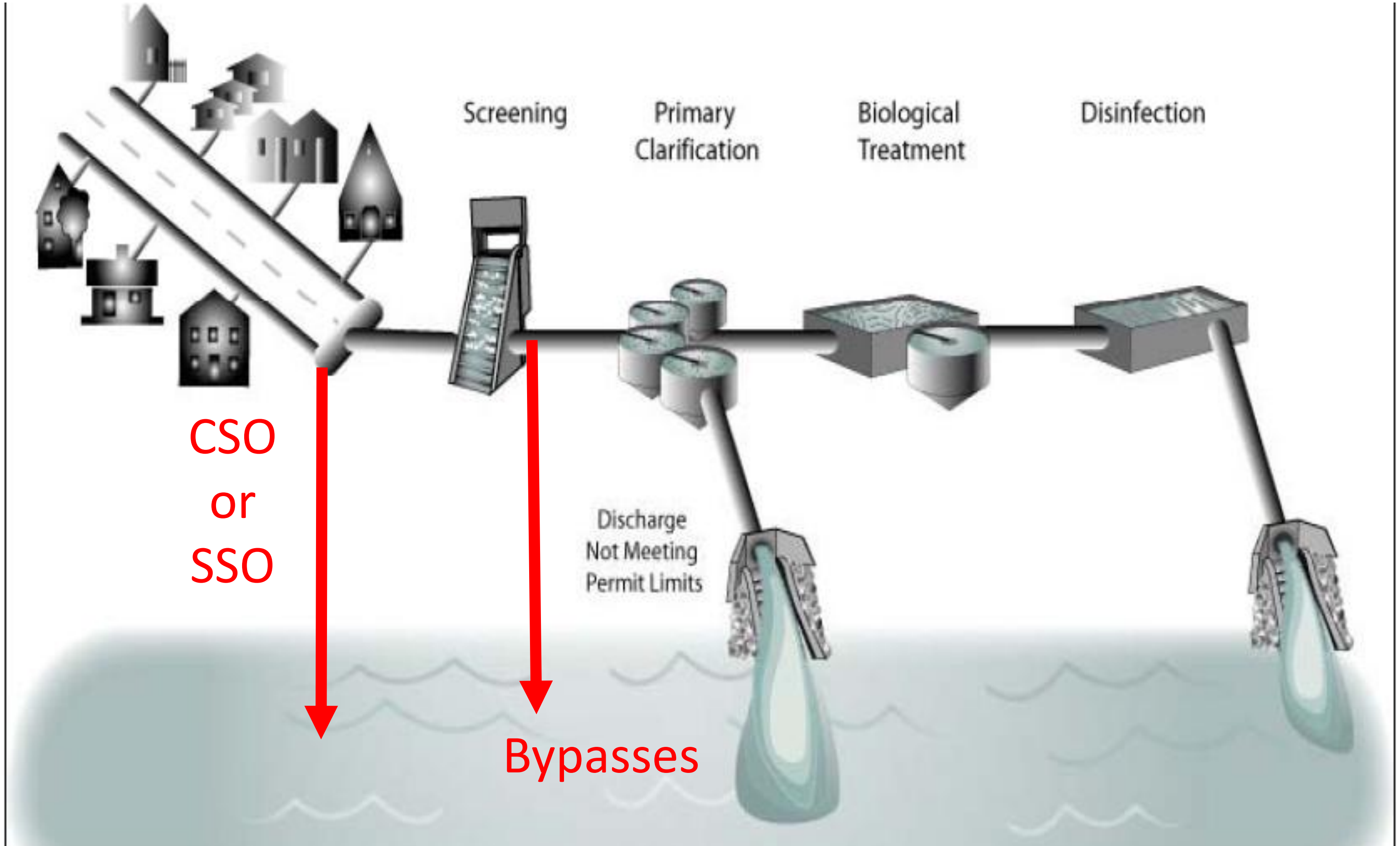
- Capacity Increase
  - Wet Weather and Dry Weather
- Nutrient Removal
  - Phosphorus and Nitrogen
- Energy
  - Minimization and Generation

Intensification reduces inputs and increases throughput

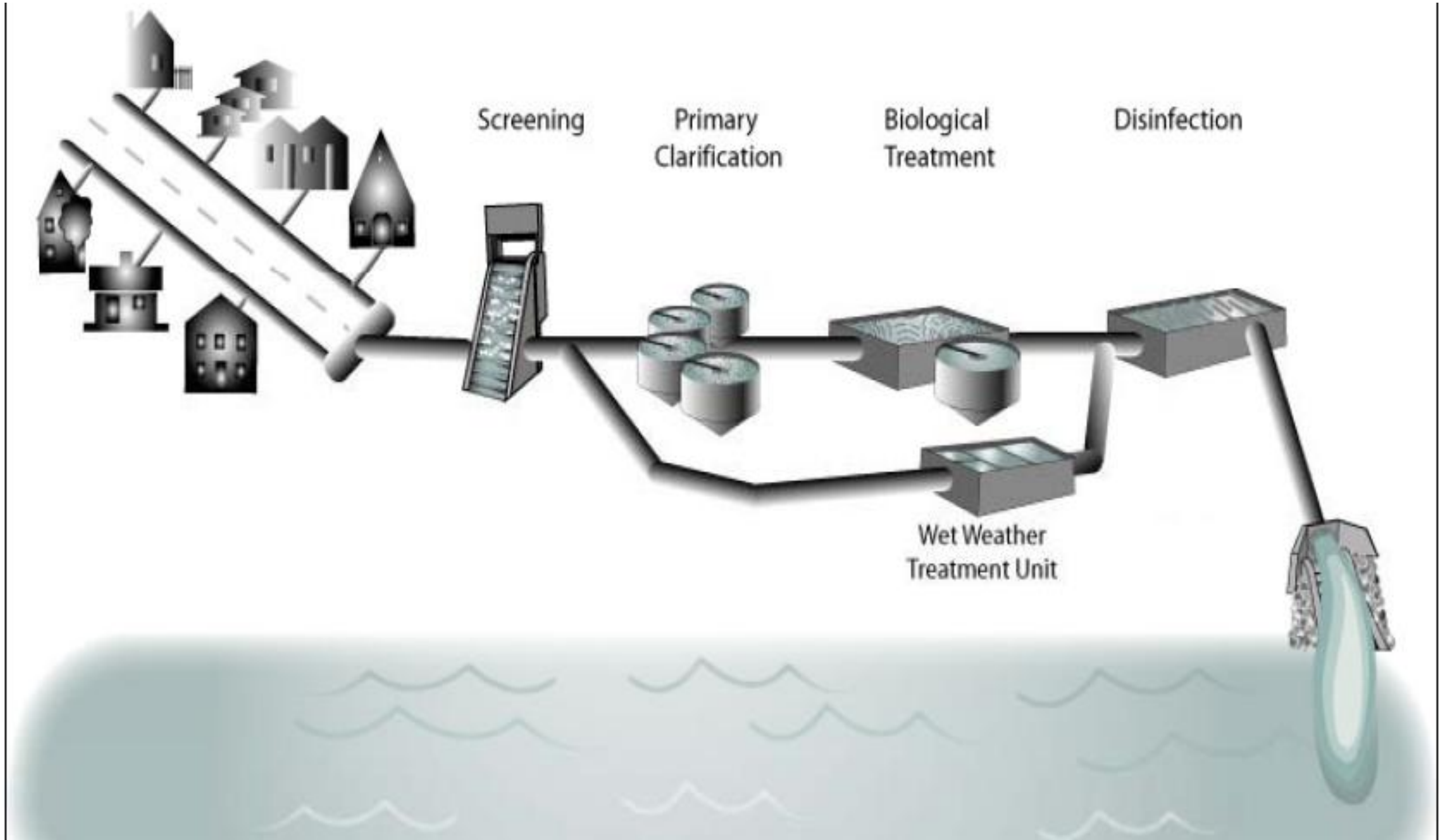
Types of Intensification Technologies

- Filtration
- Chemical Addition
- Biological
- Filtration + Biological

Objective – Increase Capacity



Background diagram from: U.S. EPA, Sanitary Sewer Overflows and Peak Flows Listening Session, 2010



Background diagram from: U.S. EPA, Sanitary Sewer Overflows and Peak Flows Listening Session, June 30, 2010

Settling Process and Technology Alternatives

Settling-Based	Filtration-Based	Flotation-Based
1. **Conventional Settling** -Rectangular, Circular, Square - RTB, Vertical Shaft	1. **Shallow Granular Media**	1. **Conventional Floatables Removal** -Skimmers, Scum baffles
2. **Vortex (Swirl Concentrator)**	2. **Deep Granular Media** HRF	
3. **Lamella Settler**	3. **Microscreens, Woven Media** -Salsnes Filter, Eco MAT®Filter, Hydrotech Discfilter, SuperDisc™, Forty-X™ Disc, Quantum™ Disk	
4. **Chemically Enhanced Settling** a. Conventional Basin b. Sequencing Batch - e.g. ClearCove Flatline EPT	4. **Floating Media** -MetaWater High Speed Filter, BKT BBF-F	2. **Dissolved Air Flotation (DAF)**
c. Lamella Settler HRC	5. **Pile Cloth Media** -AquaPrime™, infini-D™, Five Star™	3. **Polymer-aided DAF** -Various suppliers
d. Solids Contact / Recirculation - e.g. DensaDeg®, CONTRAFAST®	6. **Compressible Media** -Fuzzy Filter™, FlexFilter™, FiltraFast™	
e. Ballasted Flocculation - Microsand (e.g. ACTIFLO®, RapiSand™, Densadeg XRC™) - Magnetite (e.g CoMag™)	7. **Fixed-Film Contact** -Biological Aerated Filter (BAF), BioFlexFilter™	4. **Biocontact + DAF** -Captivator®
5. **Suspended Growth Contact** -BIOACTIFLO™, BioMag™, Bio-CES		

Primary Removal Equivalent*

High-Rate Treatment (HRT)

Enhanced HRT

*If pre-coagulation/flocculation, HRT → EHRT (in some cases)

HRC = High-Rate Clarification; HRF = High-Rate Filtration

Conventional Technology – Gravity Settling

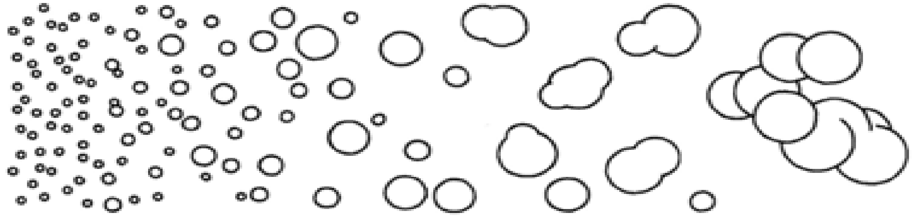
- 10 States Standards: Up to 2,000 gpdsf (1.4 gpmsf)

Organic wastewater solids settle slowly, if at all

Enhancing Settling

Gravimetric

Particle Conditioning



Surface Charge Neutralization

Coagulation Co-precipitation

Flocculation Adsorption

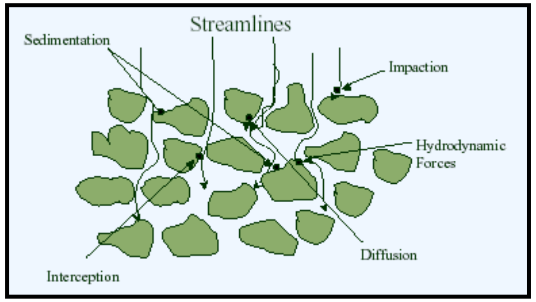
Flotation

Sedimentation

Filtration

Sieving (Surface)

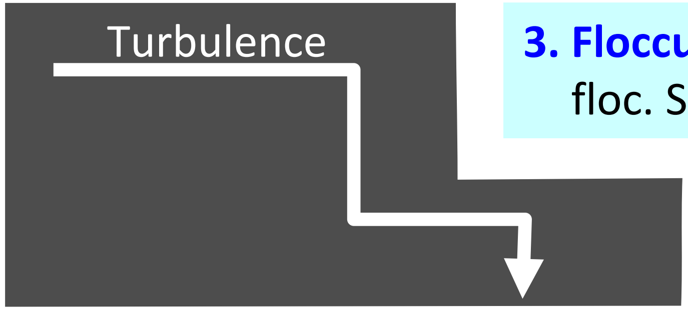
Adsorption (Depth)



Chemically Enhanced Settling (CES)

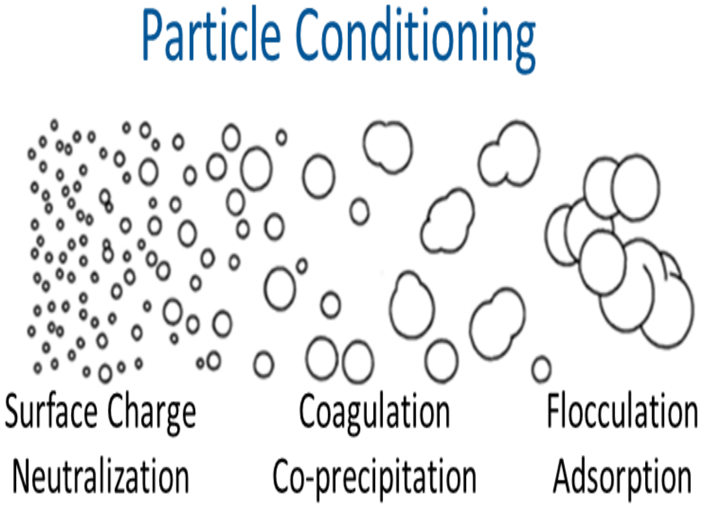
1. Coagulant Addition. Rapid mix. Add coagulant, e.g. Ferric, Alum, ACH

2. Flocculant Addition. Rapid mix. Add anionic polymer. If Step 1 & 3 are ideal, then optional (rare in municipal wastewater).



3. Flocculation. Low turbulence. Build and “sweep” floc. Solids contact and ballasting options.

4. Settling. Non-turbulent quiescent zone. Separate solids. Lamella options.

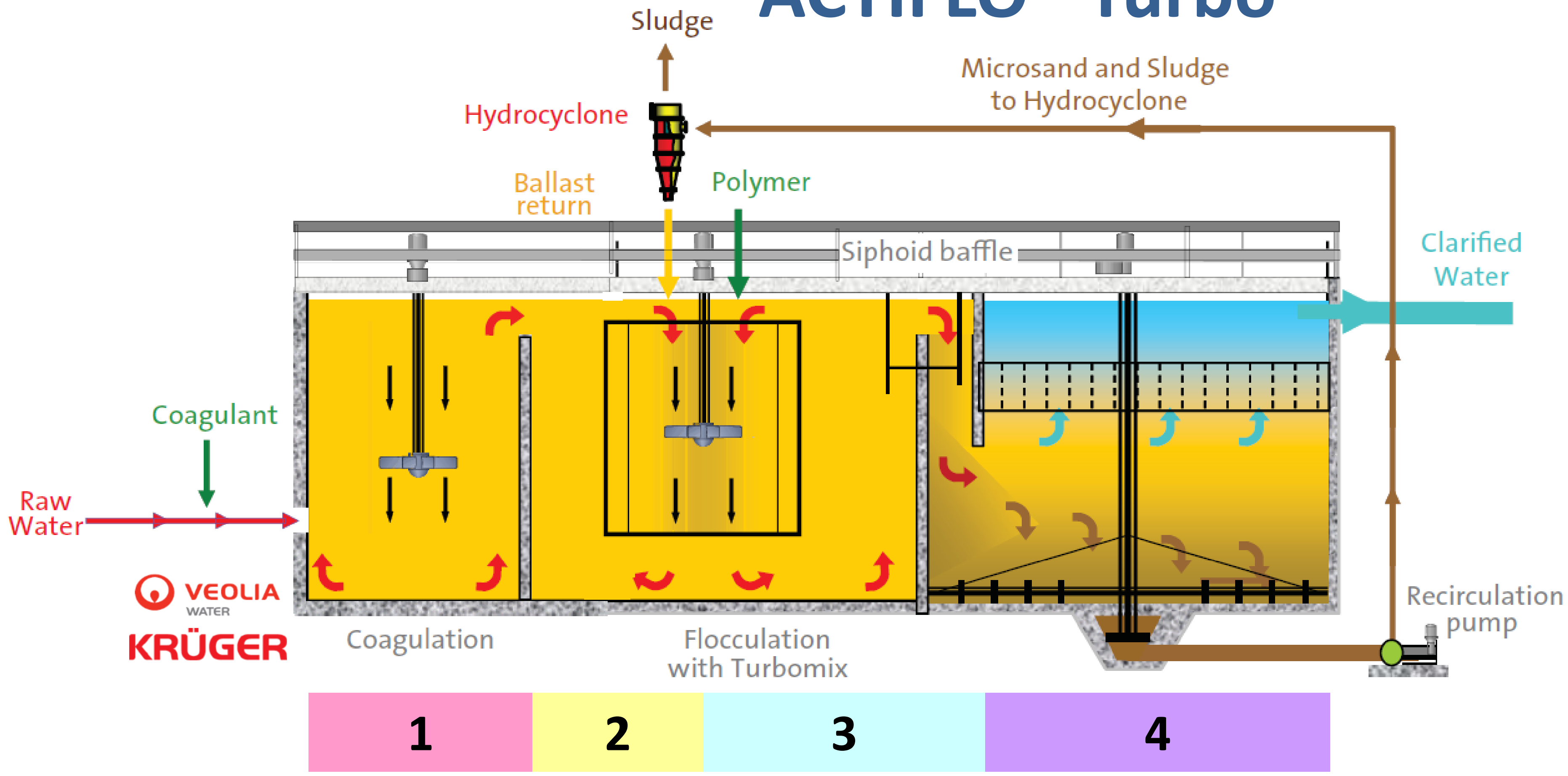


Conventional settling involves steps 3 and 4

HRC – Ballasted Flocculation

40 to 60 gpmsf

ACTIFLO® Turbo



HRC Example - Ballasted Flocculation

River Road Park and Wet-Weather Treatment Facility

Salem, Oregon

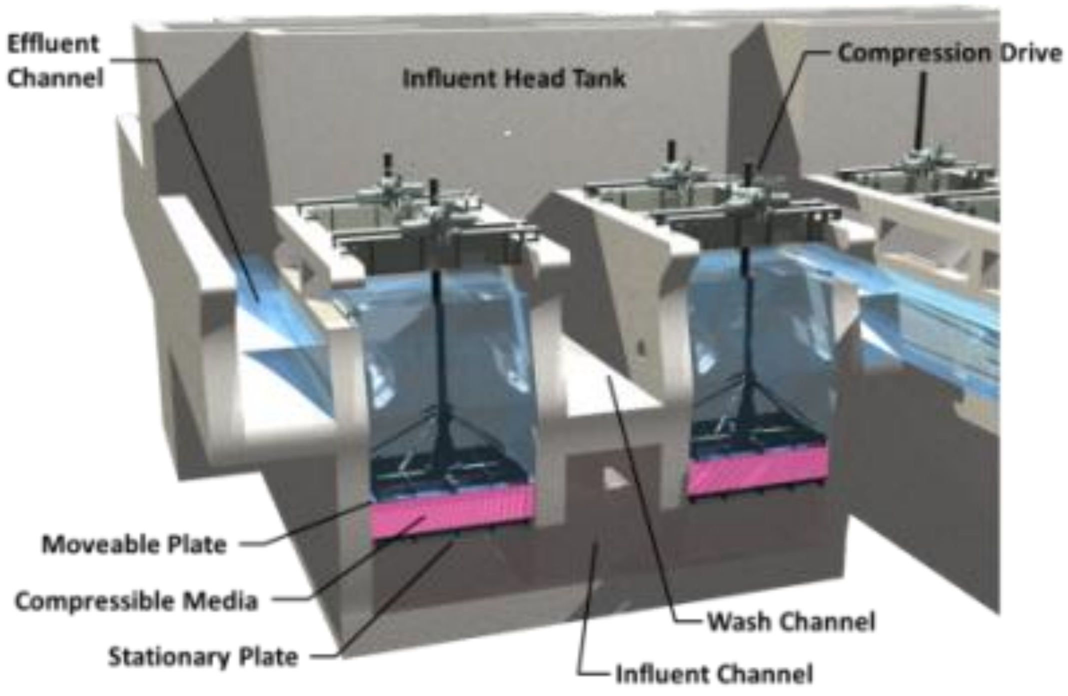
- Driver - Capacity
- 50-mgd treatment
  - Fine screens
  - Ballasted flocculation
  - Aluminum Chlorohydrate coagulant, polymer and sand storage/feed
  - UV disinfection
- ~$30.5M (2004)
- Watershed based NPDES permit with Willow Lake WPCF shares mass load

HRC Example

- 232-mgd treatment
- 130 ft x 270 ft
- ~$67M (2006)
- Cl_2 disinfectant
- $NaHSO_3$ dechlorination

HRF – Compressible Media

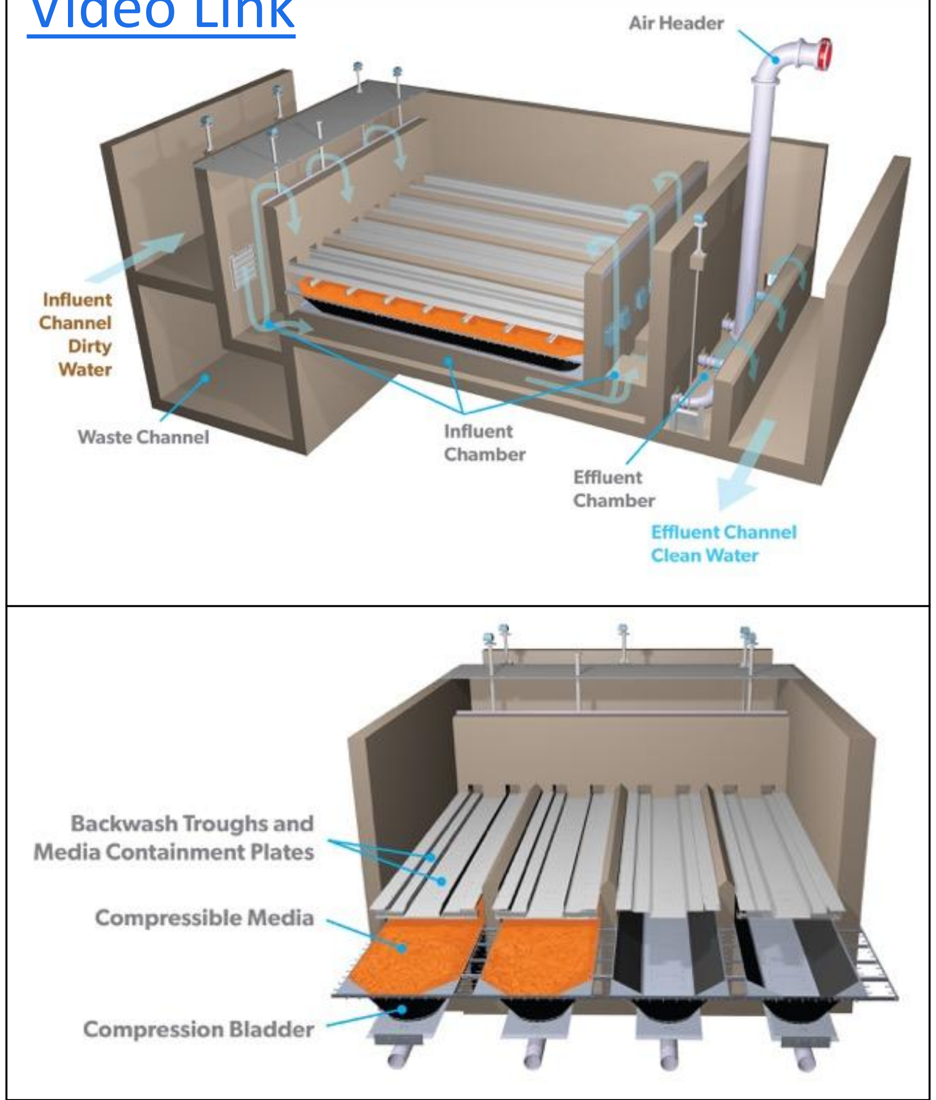
Up to 12 gpmsf



Schreiber Fuzzy Filter™

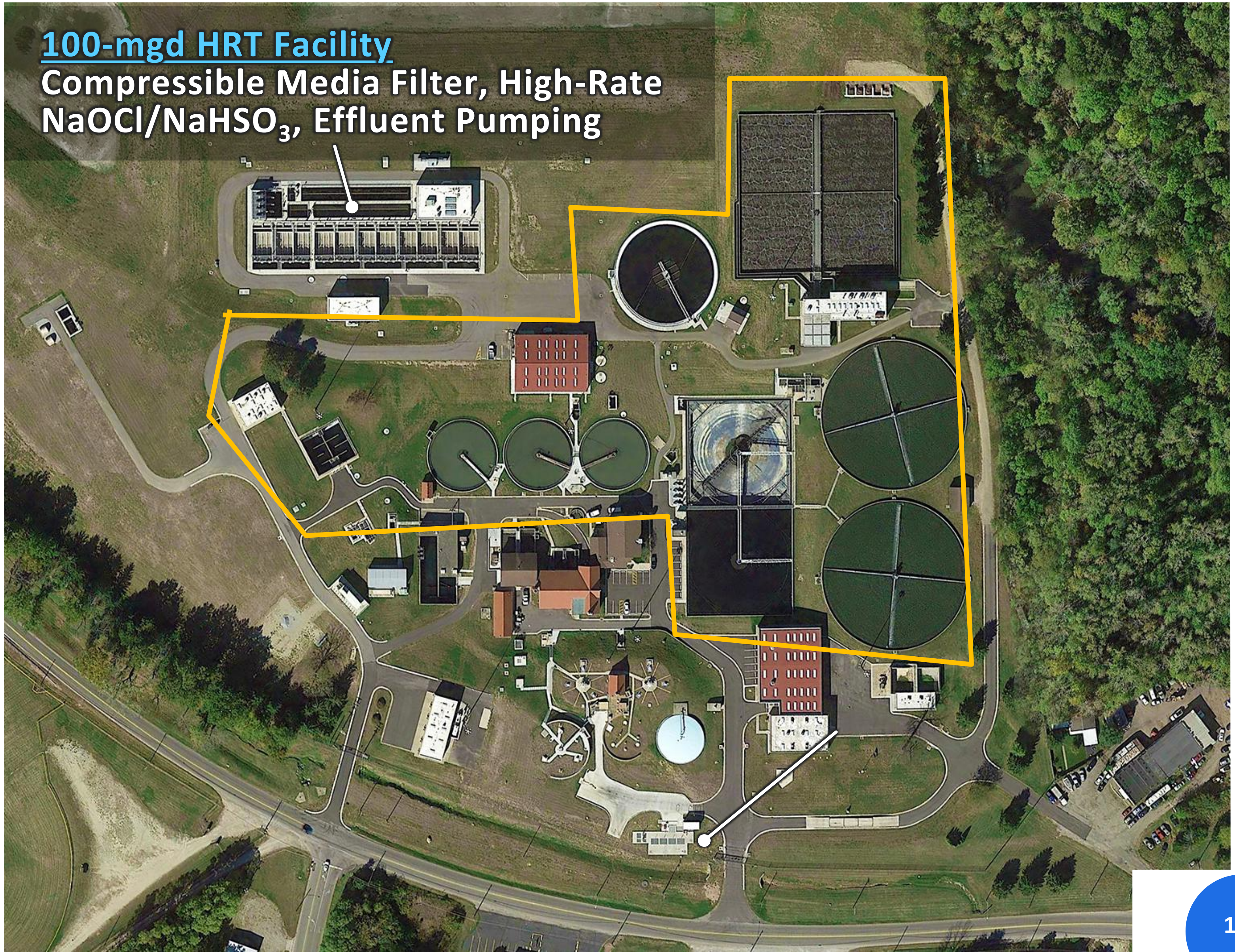
WesTech/WWETCO FlexFilter™

[Video Link]

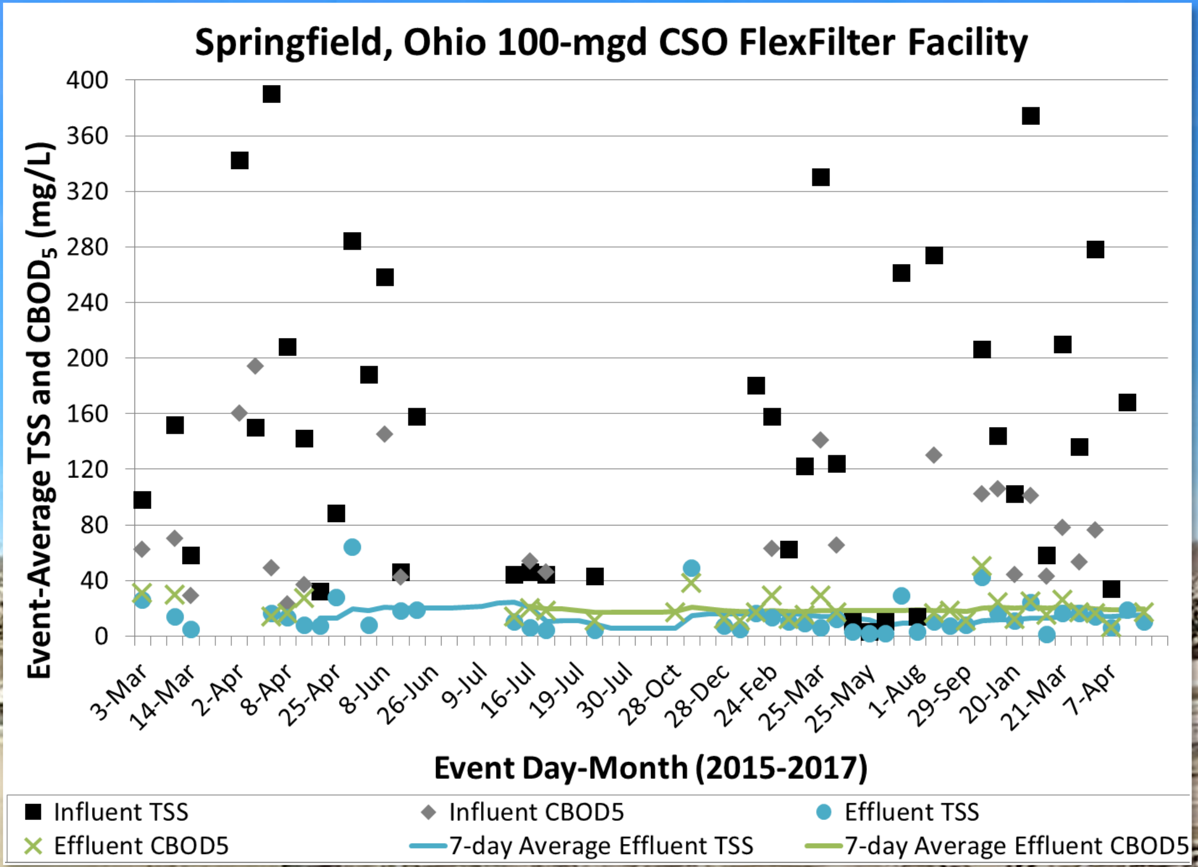


Compressible Media Filter – Springfield, Ohio

Driver: Capacity



Compressible Media Filter – Performance Results

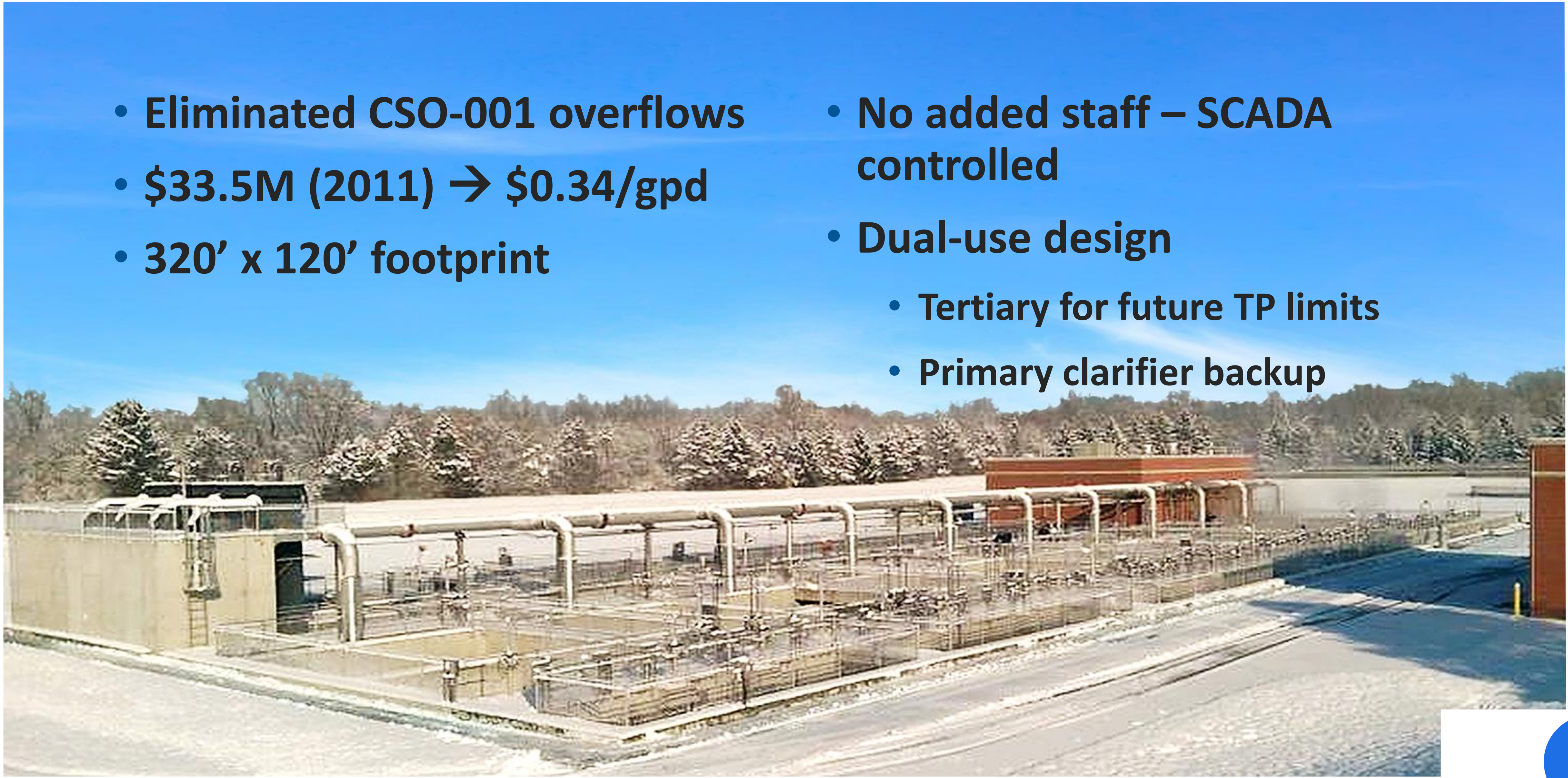


Effluent Average*		
TSS	mg/L	14
$CBOD_5$	mg/L	20
NH_3-N	mg/L	2.3
TP	mg/L	0.4
DO	mg/L	8.7
TRC**	mg/L	0.02
E. Coli	#/100 mL	56

* 63 events Mar 2015 – May 2017

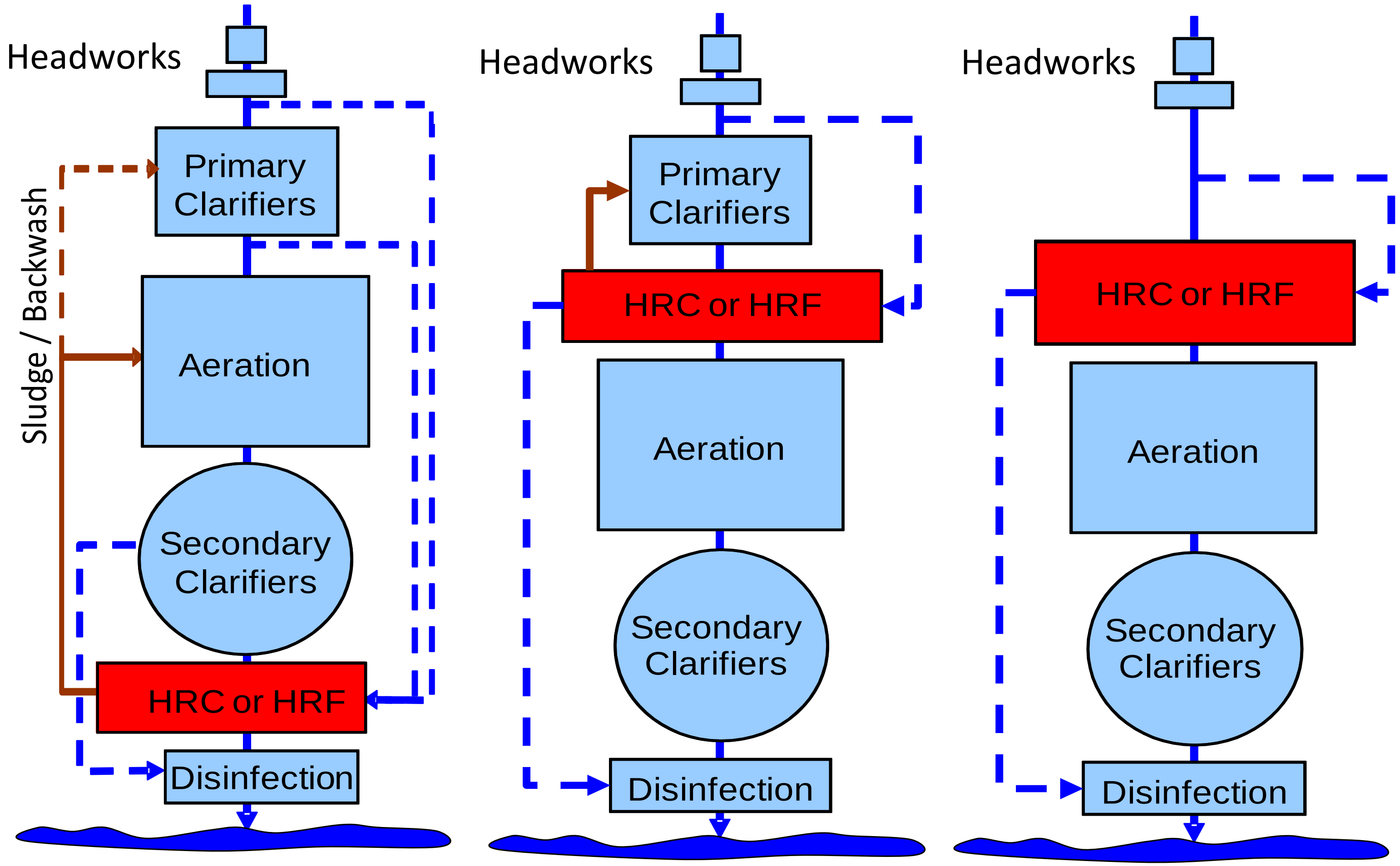
** NaOCl dose < 4 mg/L (avg)

Springfield, Ohio – Project Successes

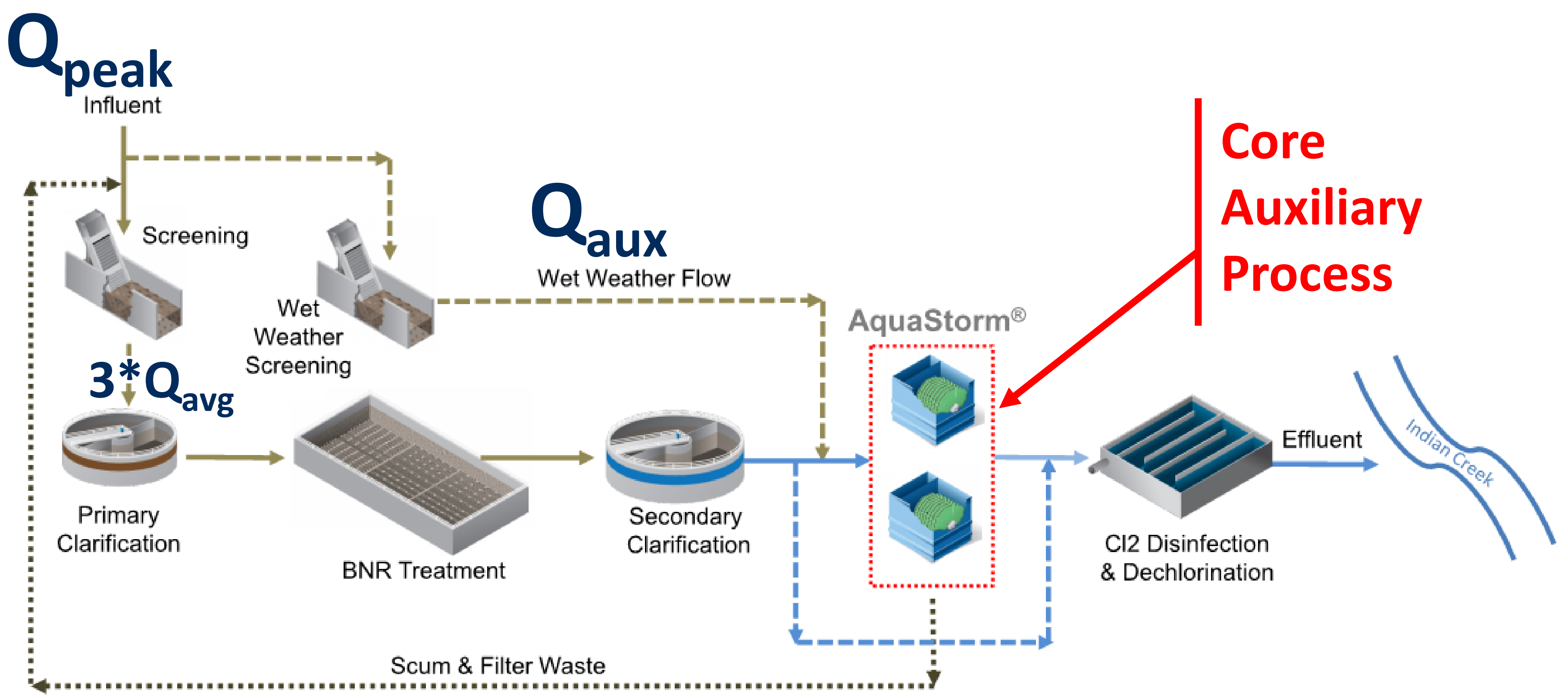


- Eliminated CSO-001 overflows
- \$33.5M (2011) → \$0.34/gpd
- 320’ x 120’ footprint
- No added staff – SCADA controlled
- Dual-use design
  - Tertiary for future TP limits
  - Primary clarifier backup

Dual-Use Auxiliary Facilities



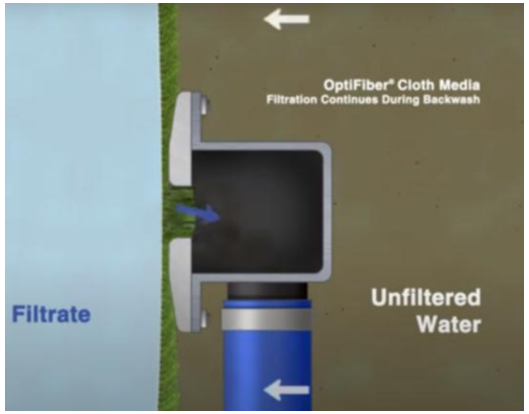
More WRRF benefit from capital investment than just infrequent wet weather



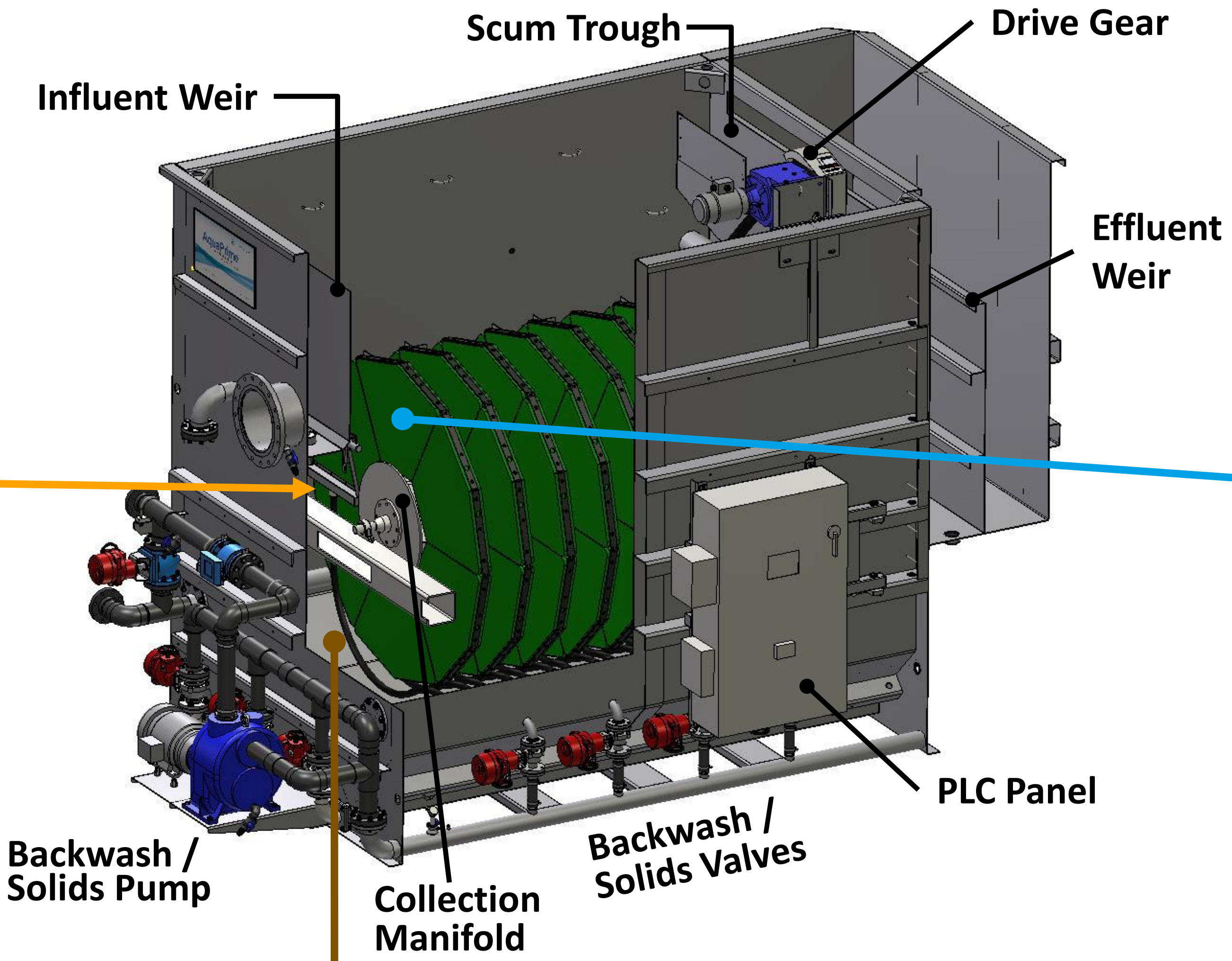
Q_{peak}
Influent
Screening
Wet Weather Screening
$3*Q_{avg}$
Q_{aux}
Wet Weather Flow
AquaStorm®
Core Auxiliary Process
Primary Clarification
BNR Treatment
Secondary Clarification
Cl2 Disinfection & Dechlorination
Effluent
Indian Creek
Scum & Filter Waste

Pile Cloth Disk Filter

- Backwash shoes vacuum pile cloth
- Drive gear turns the disks during backwash
- Filtration continues during backwash



Settled solids removed intermittently from tank bottom hoppers



- Gravity filter through pile cloth disks
- Removable segments for ease of maintenance

OptiFiber PF-14®

Images courtesy Aqua-Aerobic Systems

Adapted for enhanced primary and auxiliary wet-weather applications

- **NPDES permit with no objections from U.S. EPA**

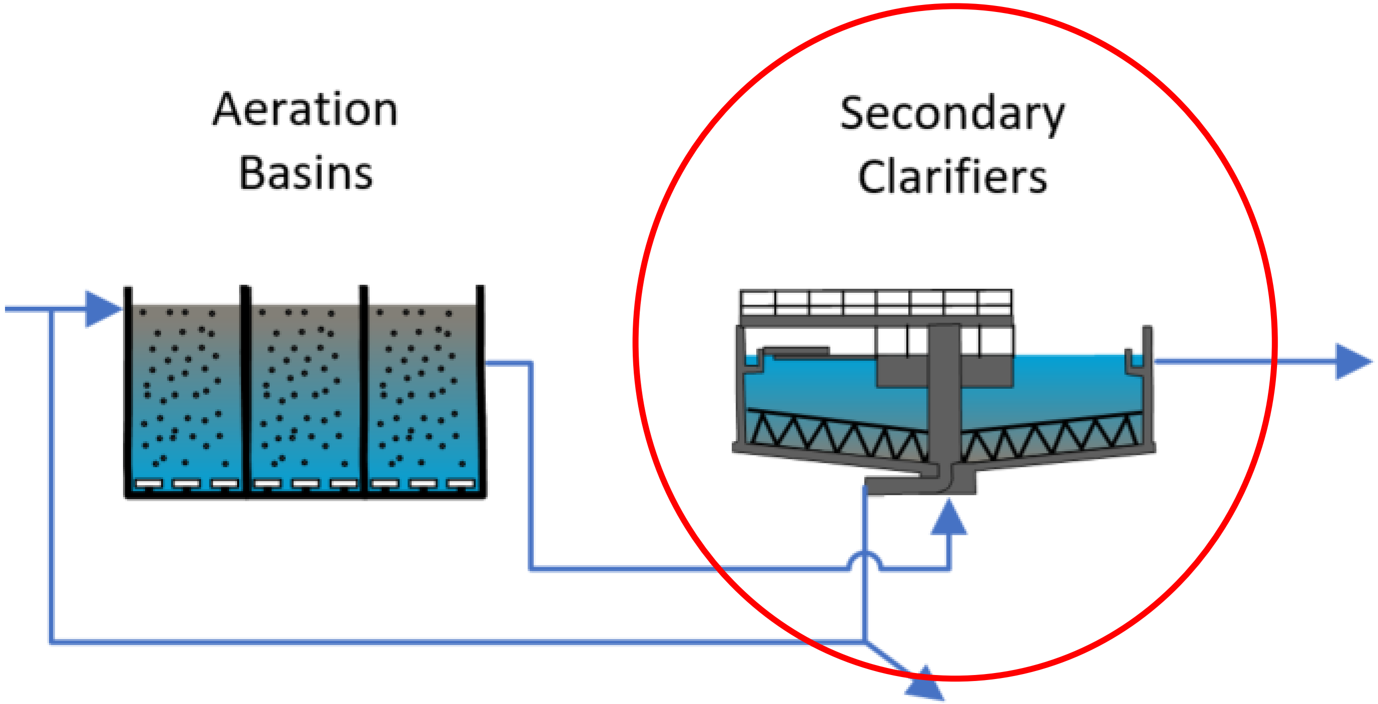
- **BNR + filter up to 57 mgd**
  <u>+ Auxiliary filter up to 115 mgd</u>
  Peak WWTF capacity = 172 mgd

- **115-mgd filters + 172-mgd disinfection (hypo/bisulfite)**
  - **$23MM → $0.20/gpd (2018)**

Questions so far?

Objectives: Increase Capacity, Improve performance, Nutrient Removal

Activated Sludge Process



Secondary Clarifier (settling step) is the weak link

Extended Aeration Activated Sludge (EAAS)

- Very common for facilities < 5 MGD
- Advantages
  - No primary settling
  - Low loading rates
  - Sludge is more stabilized and there is less of it
- Disadvantages
  - Large tanks
  - High energy input

Intensifying Activated Sludge Facilities – Sludge Densification

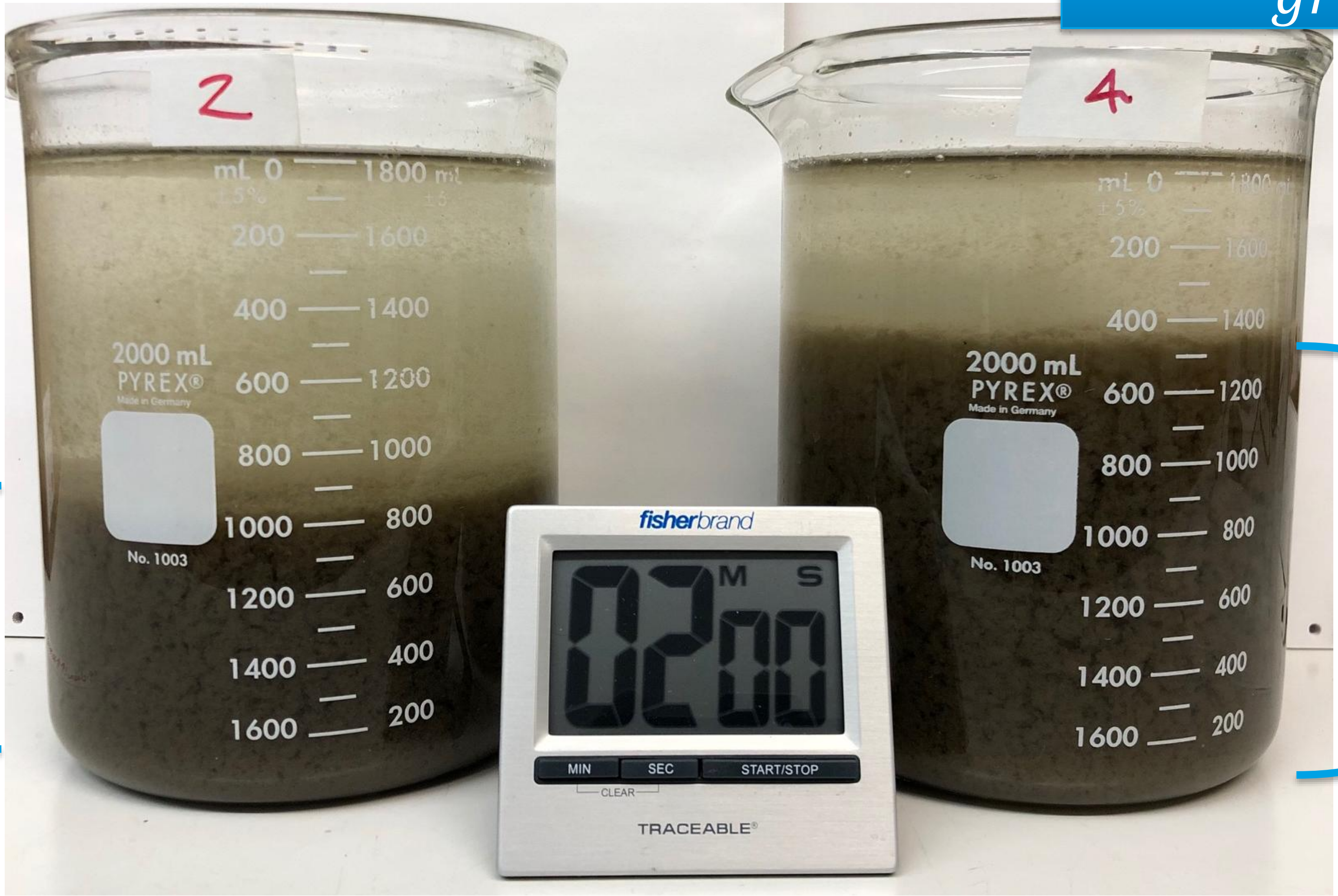
Technology for Enhancing Settleability – Sludge Densification

- Two Factors
  - Biological Selection
  - Physical Selection

Sludge Volume Index (SVI)

$$SVI: \frac{solids\ volume}{gram\ solids}$$

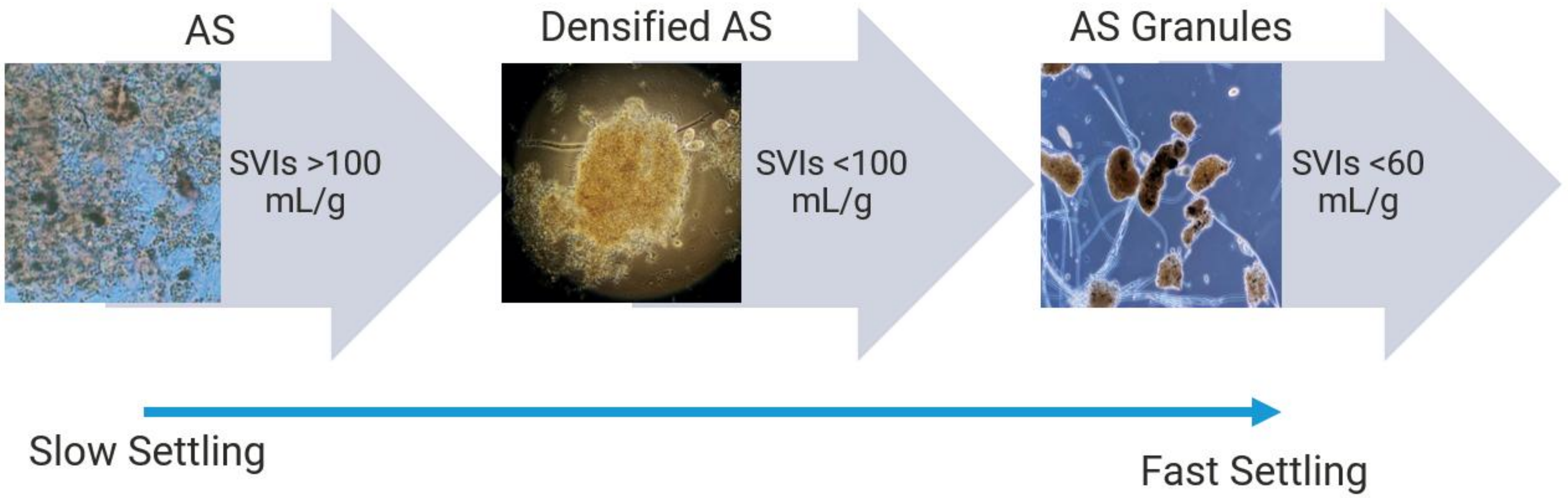
Low SVI or "Good" settling sludge.



High SVI or "Poor" settling sludge.

Overview of Densification

Settling Implications



Overview of densification - Implications for Nutrient Removal

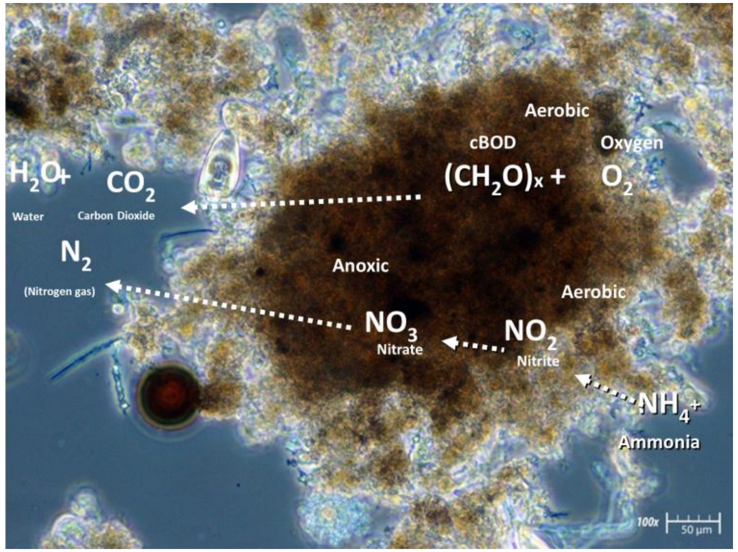
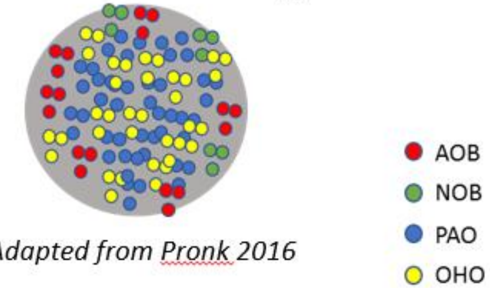


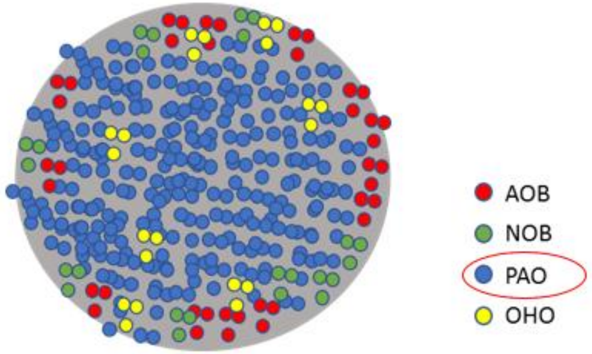
Image courtesy of Paul Klopping

Smaller granule: more heterogeneous



Adapted from Pronk 2016

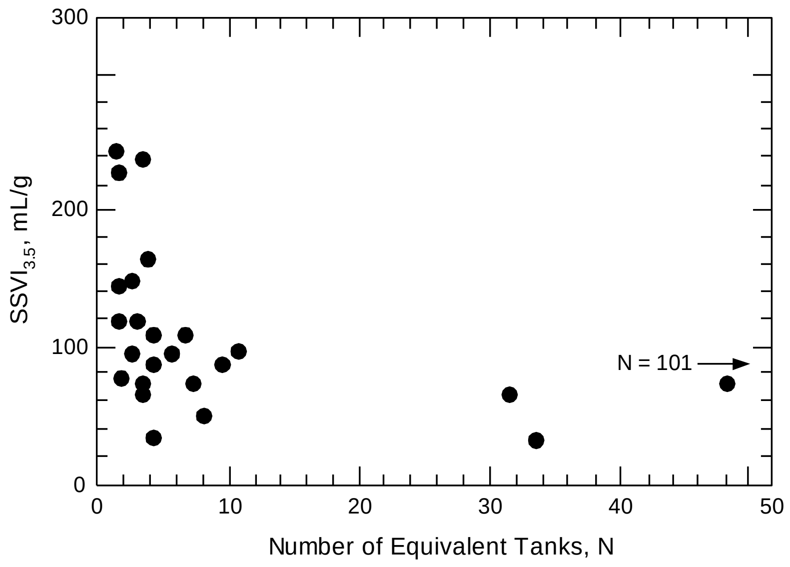
Larger granule: more stratification



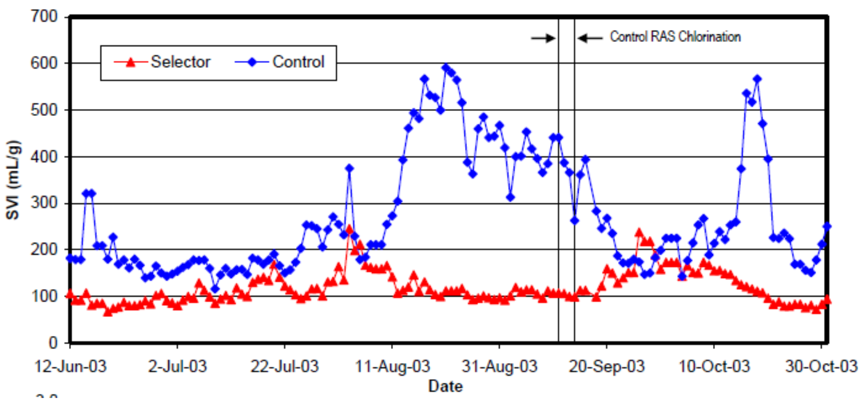
Adapted from Pronk 2016

Mass transfer results in unique stratification of microbial ecology within the granules

Biological Selection – Right Food for the Right Bugs at the Right Time



From E. J. Tomlinson and B. Chambers, The effect of longitudinal mixing on the settleability of activated sludge. Technical Report TR 122, Water Research Centre, Stevenage, England, 1978. Reprinted by permission of the Water Research Centre.)



From Gray et al (2006) Develop and Demonstrate Fundamental Basis for Selectors to Improve Activated Sludge Settleability

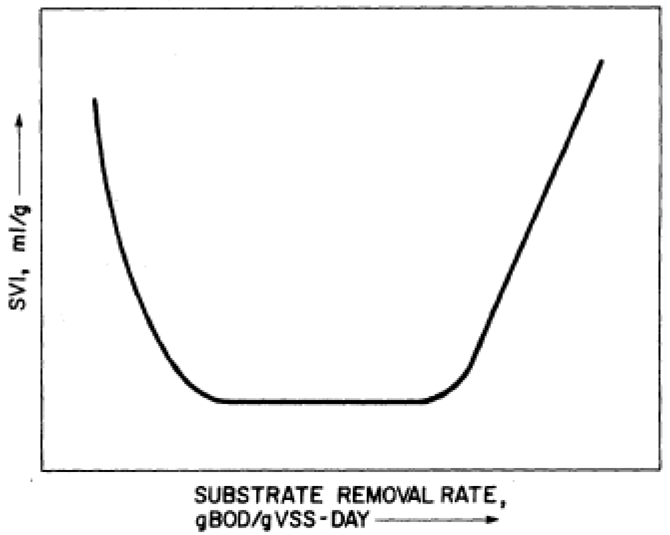


FIGURE 15. Effect of substrate removal rate on sludge volume index.

From Sezgin et al (1978) A Unified theory of activated sludge bulking, Journal of Water Pollution Control Federation 50(2)

1. Plug Flow Conditions

2. Anaerobic/Anoxic feed

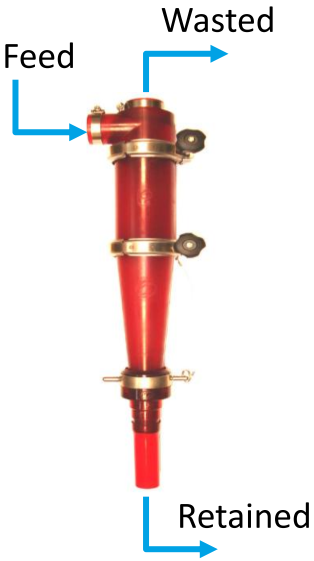
3. Loading rate matters

Design Approaches for Physical Selection

Surface Wasting

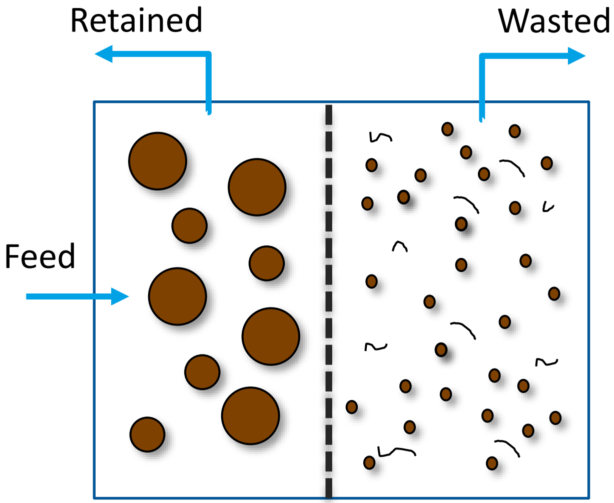
Removing lighter material and deselection of filaments and foam

Hydrocyclones



Deselection of floc/filaments and retention of larger better settling material

Screens or sieves



Floc/filament deselection and retention of larger particles

Surface Wasting

- Wasting from surface of aeration tank
- Last (aerobic) zone just before clarification
- Less dense flocs are removed and more dense flocs are retained

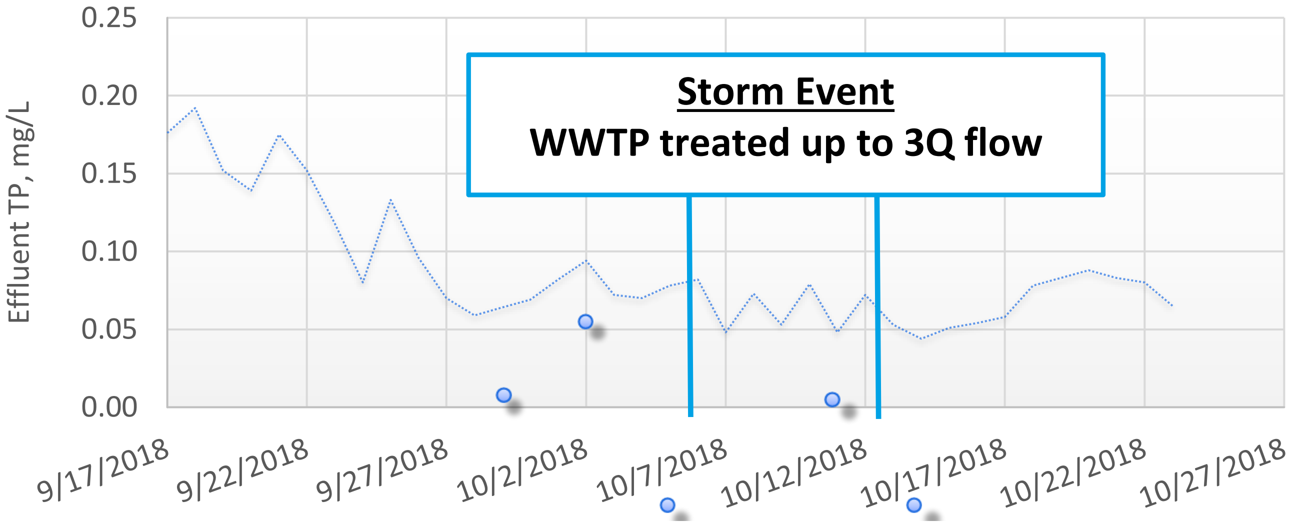
Wakarusa WWTP | Lawrence, Kansas

2.5-mgd ADF | 12.5-mgd PDF (7.5-mgd AS + 5-MG EQ)

1. Screening and Grit Removal
2. 5-MG Equalization Basin
3. BNR Splitter Box
4. ML Fermenter, Anaerobic Bio-selector, Anoxic Basins
5. SND Oxidation Ditch
6. Secondary Clarifiers
7. UV Disinfection
8. Thickening / Dewatering
9. Aerobic WAS/TWAS Storage / Digesters

Wakarusa WWTP (Lawrence, Kansas)

- **Drivers: P and N removal; Peak Flow Management**
- **No filter, no chemicals**
- **Average TP <0.2 mg/L, NO_3-N <8 mg/L**
- **No upset during 3Q wet-weather event**



Questions so far?

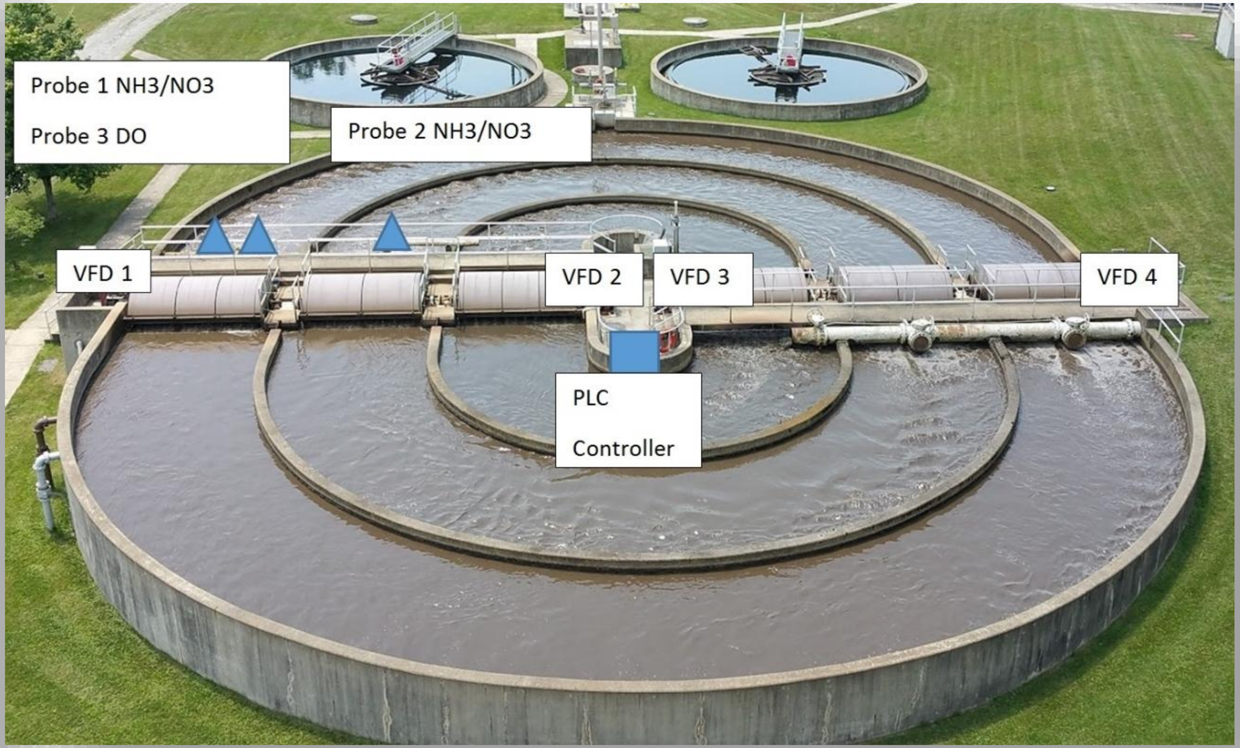
Intensifying Extended Aeration Facilities - Aeration

Technology for Aeration Intensification

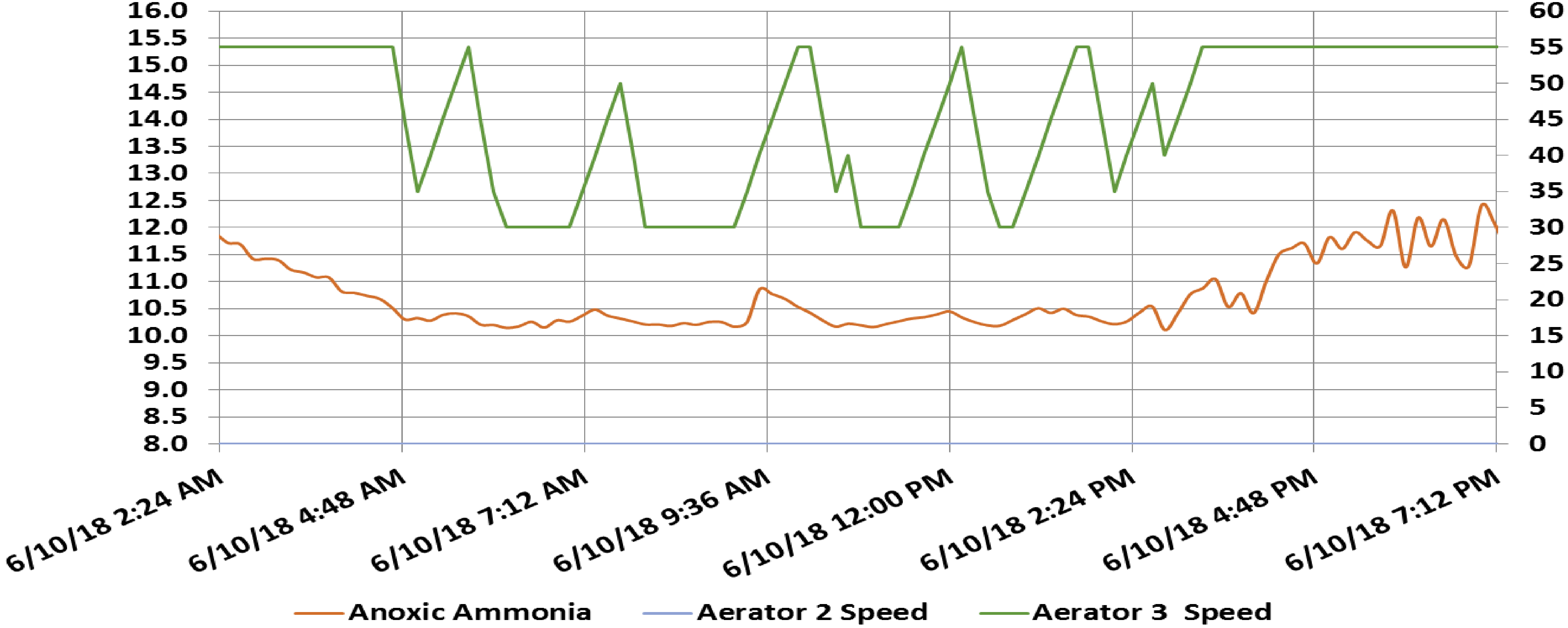
- Ammonia Based Aeration Control (ABAC)
- Membrane Aerated Bioreactor (MABR)

Ammonia-Based Aeration Control

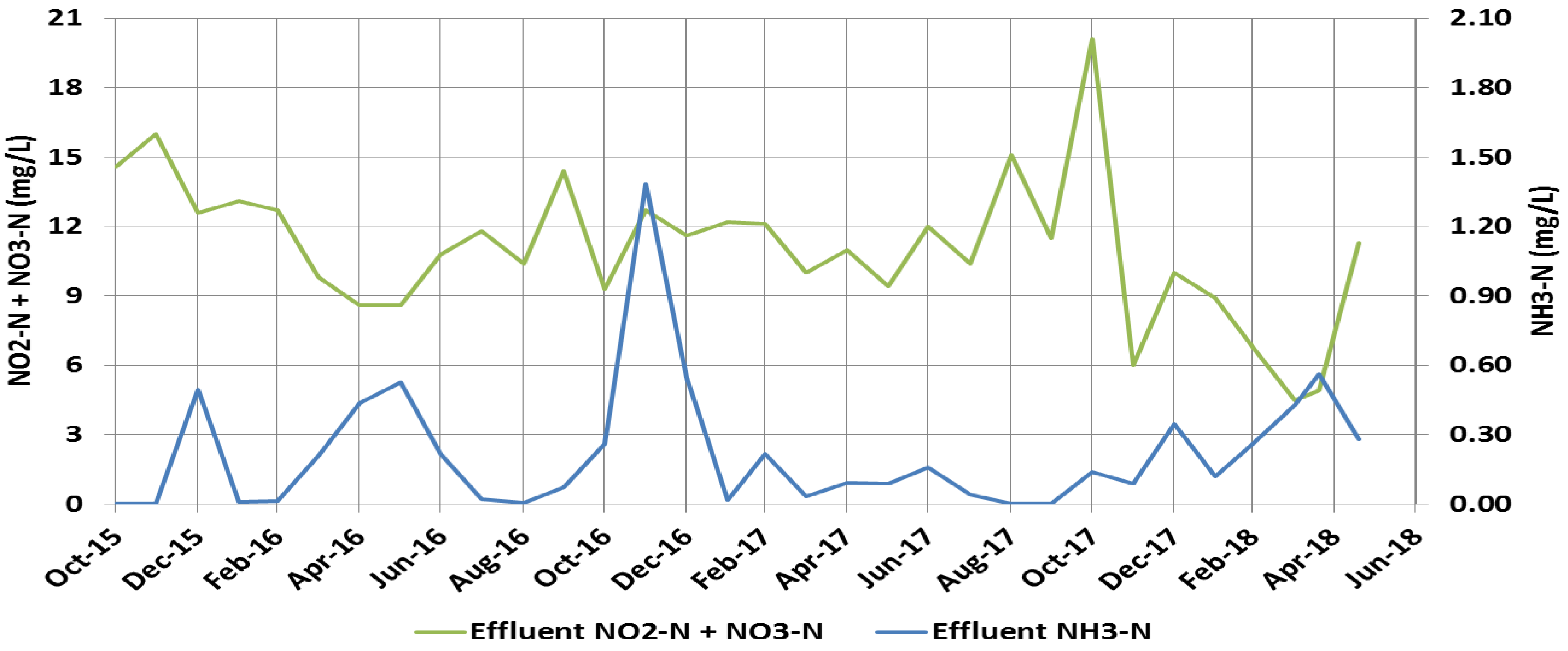
- Control of aeration with ammonia as control variable



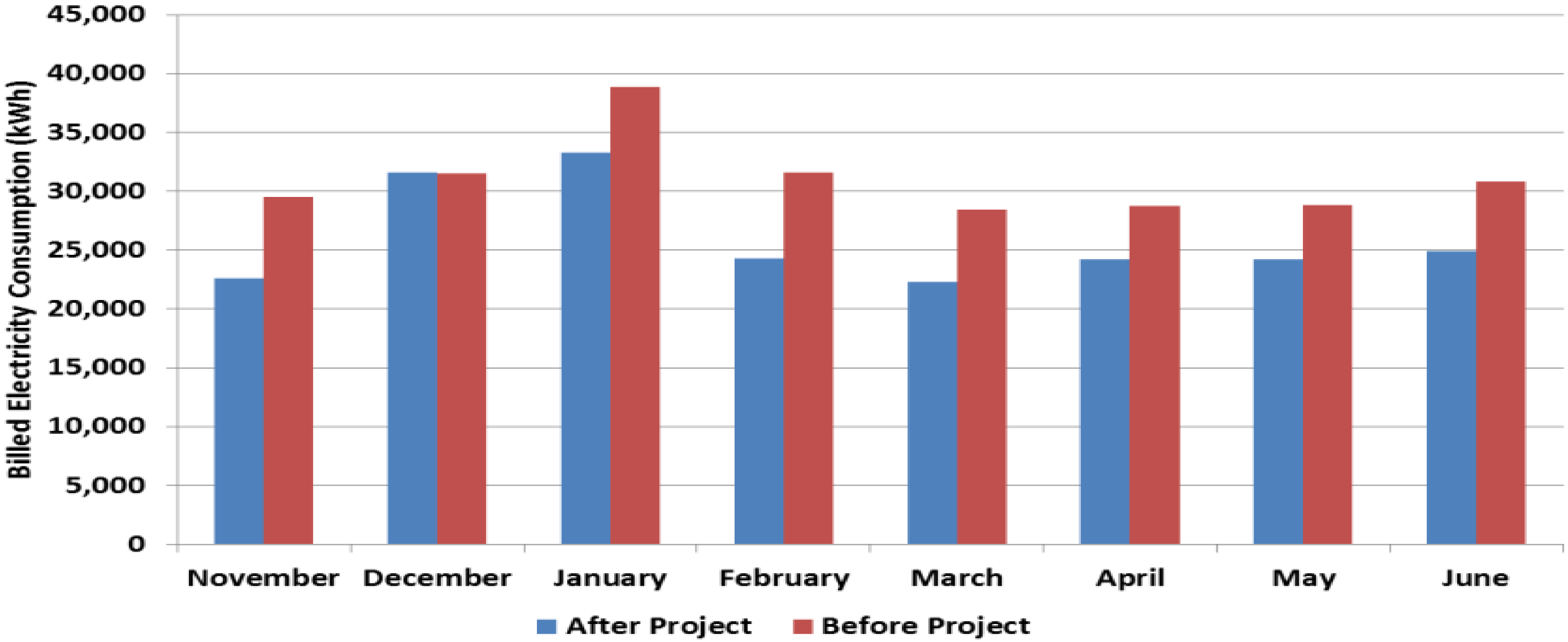
Daily Operation



Final Effluent (Outfall 001)

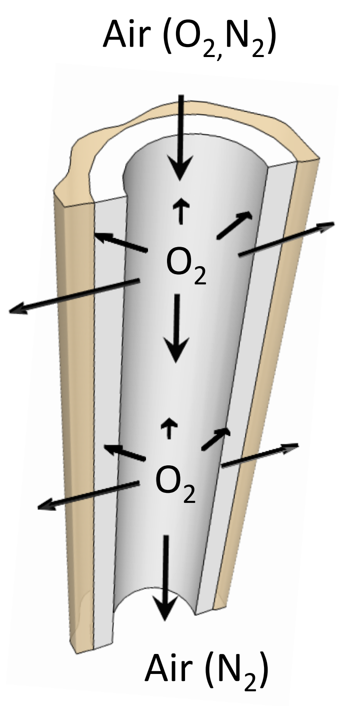


Energy Usage Reduction



Membrane Aerated Bioreactor (MABR)

- Air is fed into membrane
- Membrane acts as diffuser
- Biofilm grows on membrane
- High oxygen transfer efficiency

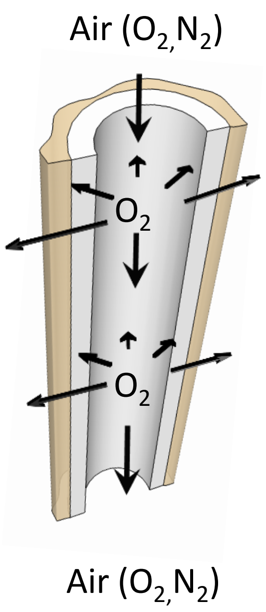


The MABR supports biofilm growth on oxygen-supplying membranes.

MEMBRANES

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

AIR DELIVERY



Flow-through mode

SUBSTRATE

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

"Breathing" Biofilms!

Membrane Aerated Bioreactor (MABR)

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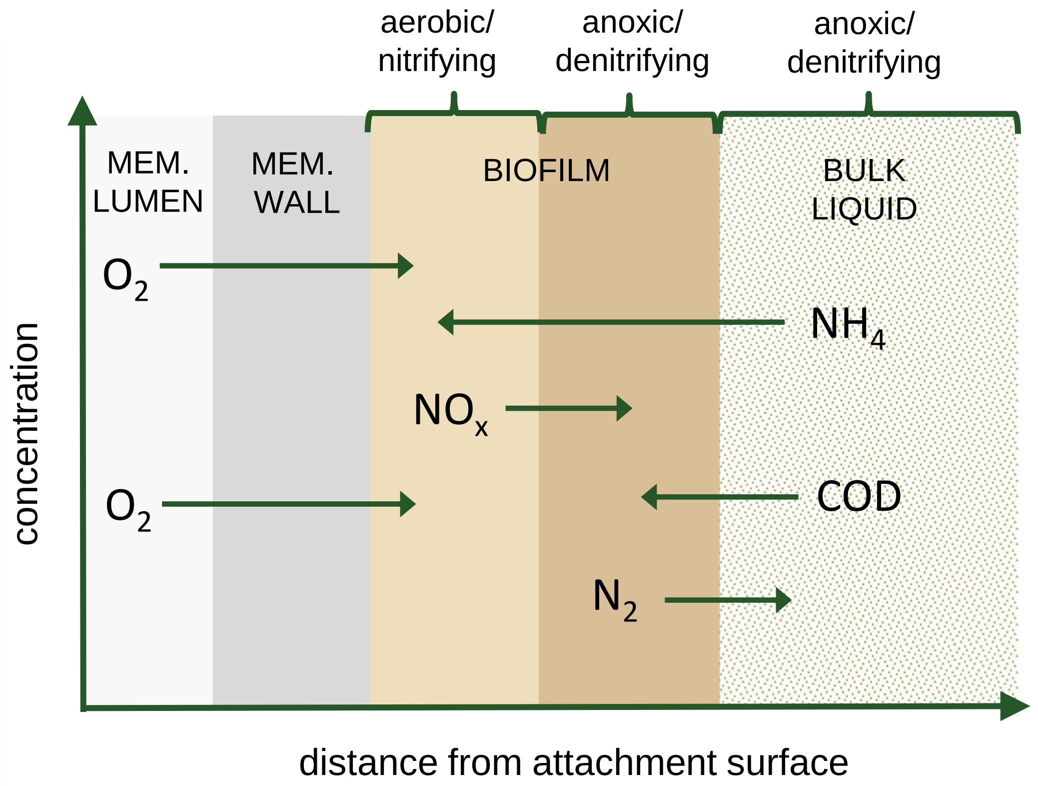
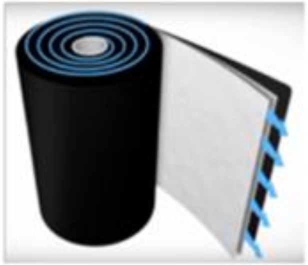
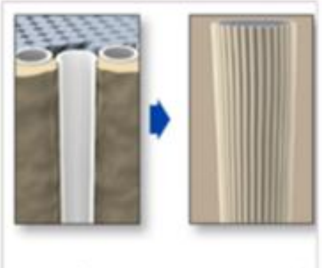


MABR – VENDOR DESCRIPTIONS

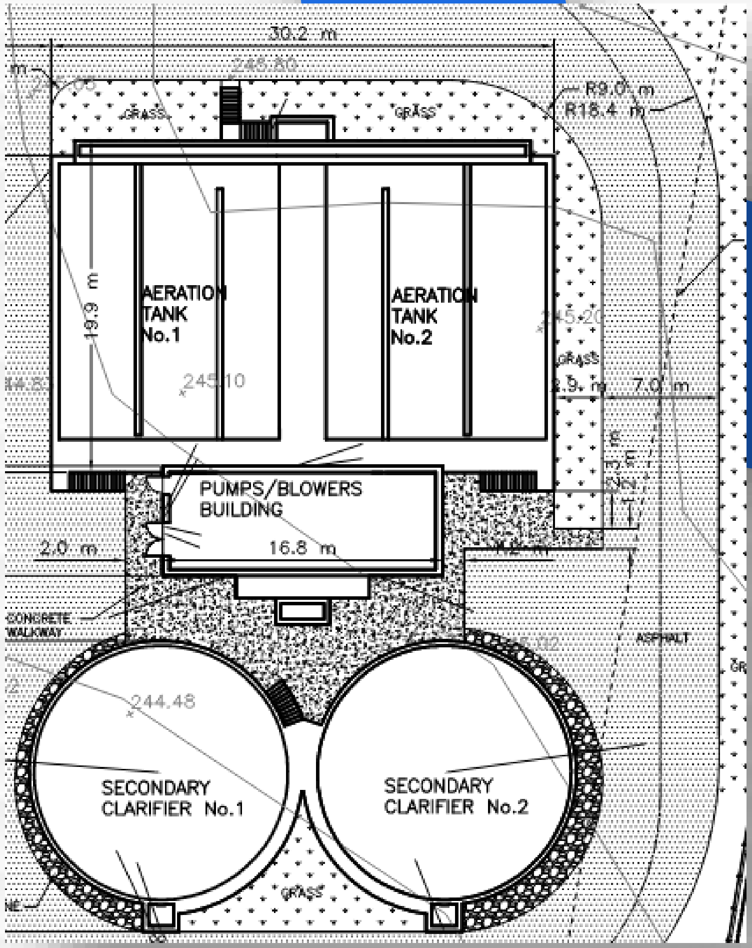
Technology Provider	System Configuration		Typical Applications	Current Facilities
fluence 	Spiral-wound Modules Mixing via Bubble Pulses		Decentralized Treatment, Remote or Developing Areas New Steel Modules Allow for Aeration Basin Retrofit	20+ Installations in China 5 MGD Installation in May'an Zvi
VEOLIA ZeeLung™ 	Hollow Fiber Membranes ZeeLeed™ Modules within Cassettes Mixing & Scour via Aeration Grid		Retrofitting Existing Aeration Basins	3.6 MGD WWTP (Yorkville, IL) 2.3 MGD WWTP Anoxic Zone (Schilde, Belgium) Multiple Pilot Scale Applications Including Black & Veatch Pilot in Hayward, CA
OXYMEM SMART AERATION 	Hollow Fiber Membranes offered in Cassette, Package, or Standalone Options Biofilm control via air scour		Retrofit Existing Aeration Basins Food, Beverage, and Dairy Applications	Three Full Scale Installations in the UK

DRIVERS

1. Limited footprint available
2. Sustainability: lower energy usage and greenhouse gas emissions
3. Intensify existing activated sludge basins without new construction
4. Easy and modular expandability for future growth

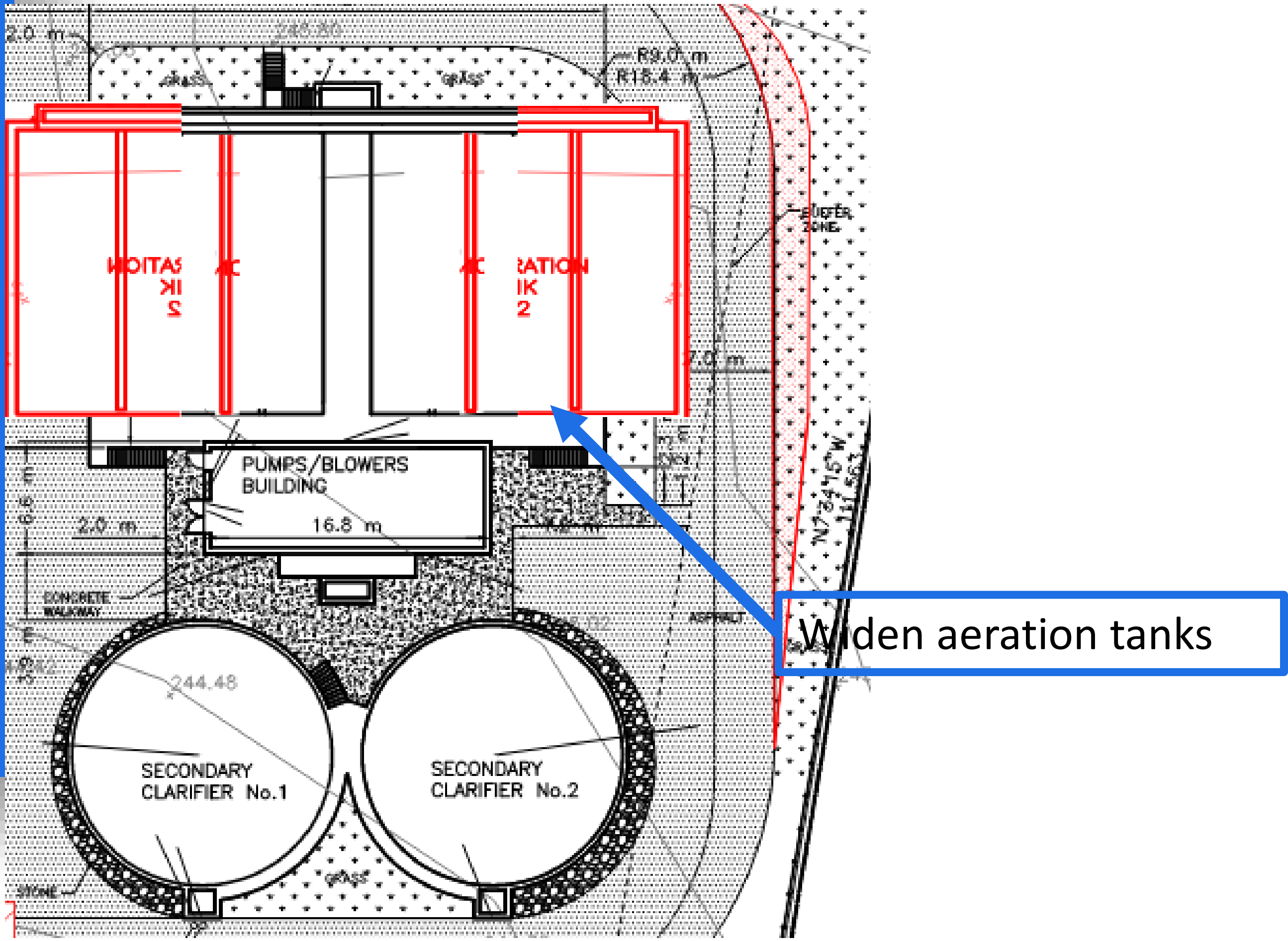
EAAS System Expansion from 0.75 MGD to 1.0 MGD

Clarifier Capacity Adequate for Future Peak Flows and Loads



Expand Existing Aeration Tanks

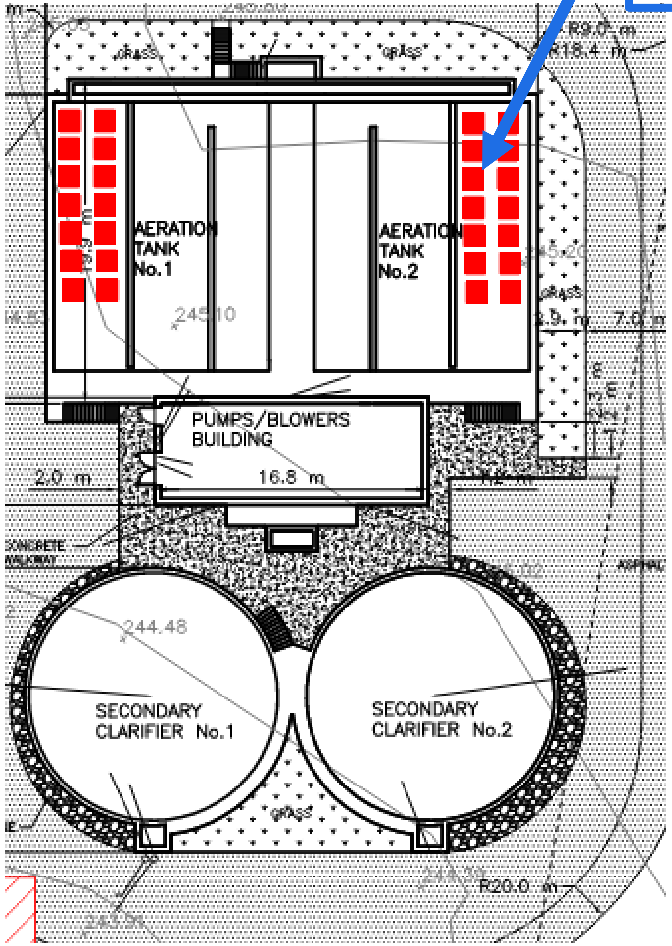
- Same Process
- Larger Tanks
- Larger Aeration Blowers
- Expanded Air Distribution System



Intensity EAAS Process with MABR Technology

- No Additional Tankage
- Small Additional Blower System
- Installed in Anoxic Selector Zone
- Air Distribution System Removed from MABR Zone
- New Mixers

Convert existing tankage to process intensification (ex. MABR modules)

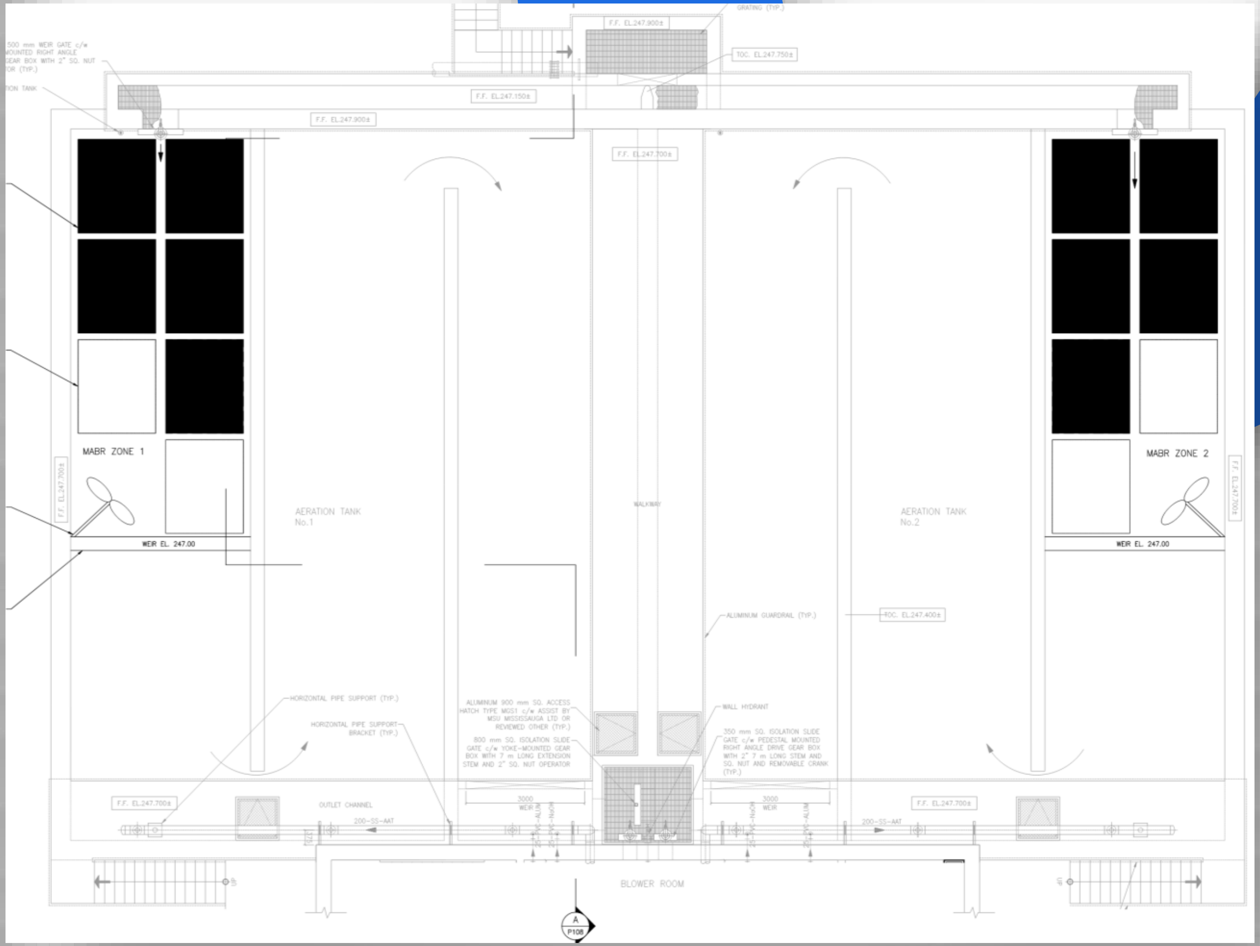


10 MABR Cassettes (Expandable to 14)

2 x Anoxic Zones (20% of AT volume)

2 Submersible Mixers

Submerged Baffle



Thank You

Contact Us

+1 614 428 2728
smithr@bv.com

Intensification Objectives

- Increase capacity
- Removal of a new pollutant
- Improve effluent quality
- Reduce chemical / energy demand
- Reduce waste