Biologically Enhanced Primary Treatment

Ohio WEA 2018

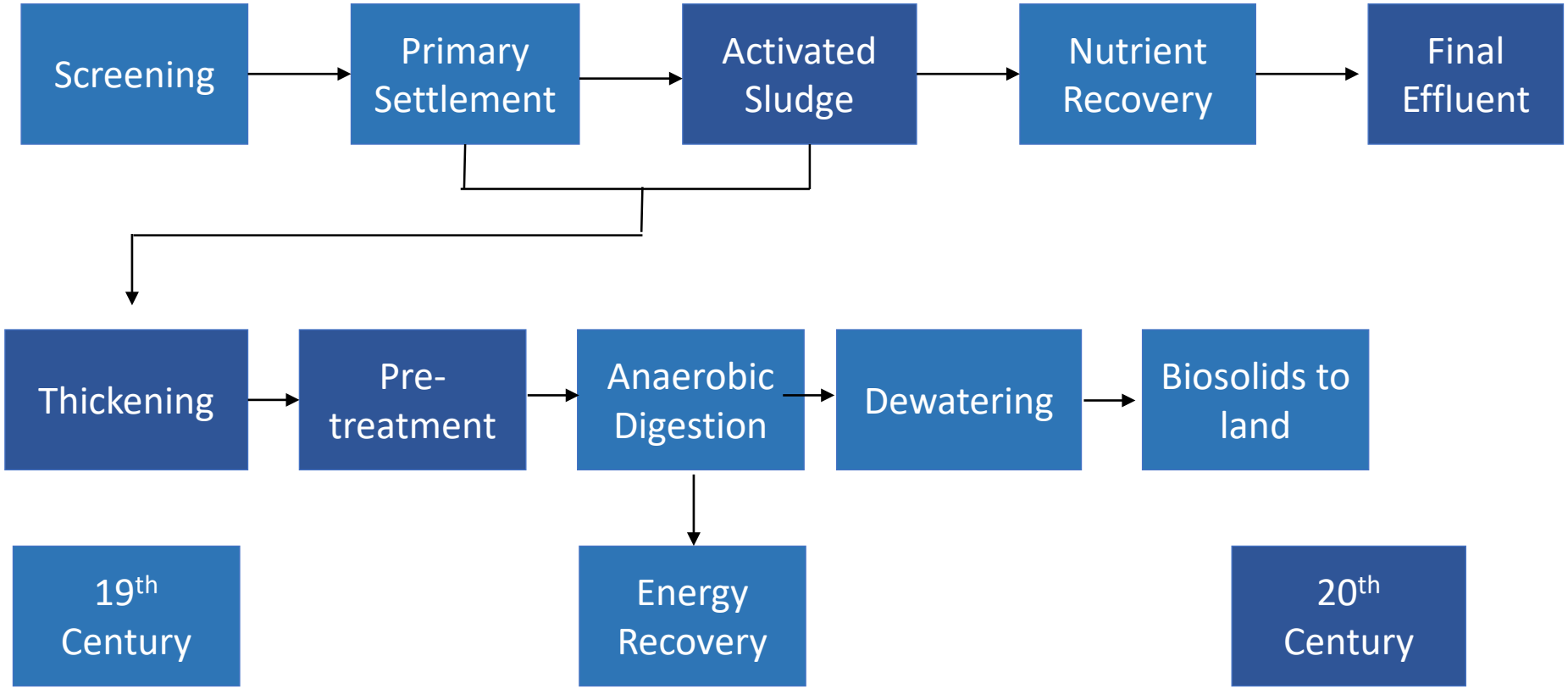
TRANSFORMING WATER. ENRICHING LIFE.

Columbus, OH Fun Facts

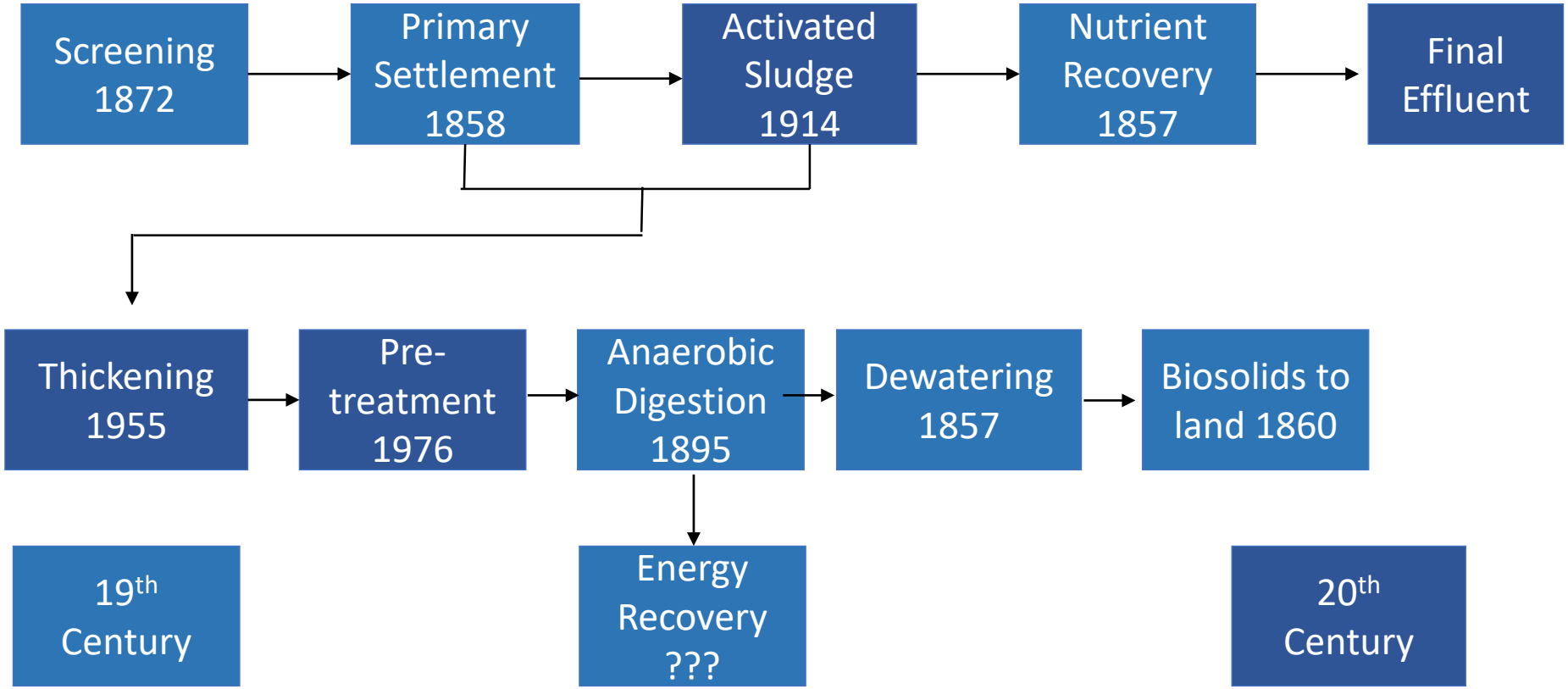
- 50% of the American population lives within how many miles of Columbus?…
- 500 miles
- Columbus was the very first site of this type of school in the nation……..
- Junior High, Graham Expeditionary School in Indianola which is a charter school today.
- Columbus was the site of the world's first water filtration facility designed by Clearance and Charles Hoover. Same design and treatment protocols are still in use today.

EVOQUA WATER TECHNOLOGIES

The Wastewater Treatment Plant of Today



The Wastewater Treatment Plant of Today



Wastewater Treatment Evolution Timeline

1846 Liming

1854 Activated Carbon

1857 Filter press dewatering

1858 Primary settlement, electricity

1859 Thermal drying

1863 Freezing

1867 Struvite precipitation

1871 Ammonium recovery

1872 Screening and thermal drying

1880s Interest in anaerobic digestion

1887 Anaerobic sand filter

1895 Septic tanks

1914 Activated Sludge

1965s Thermal hydrolysis

1970s Upflow Anaerobic

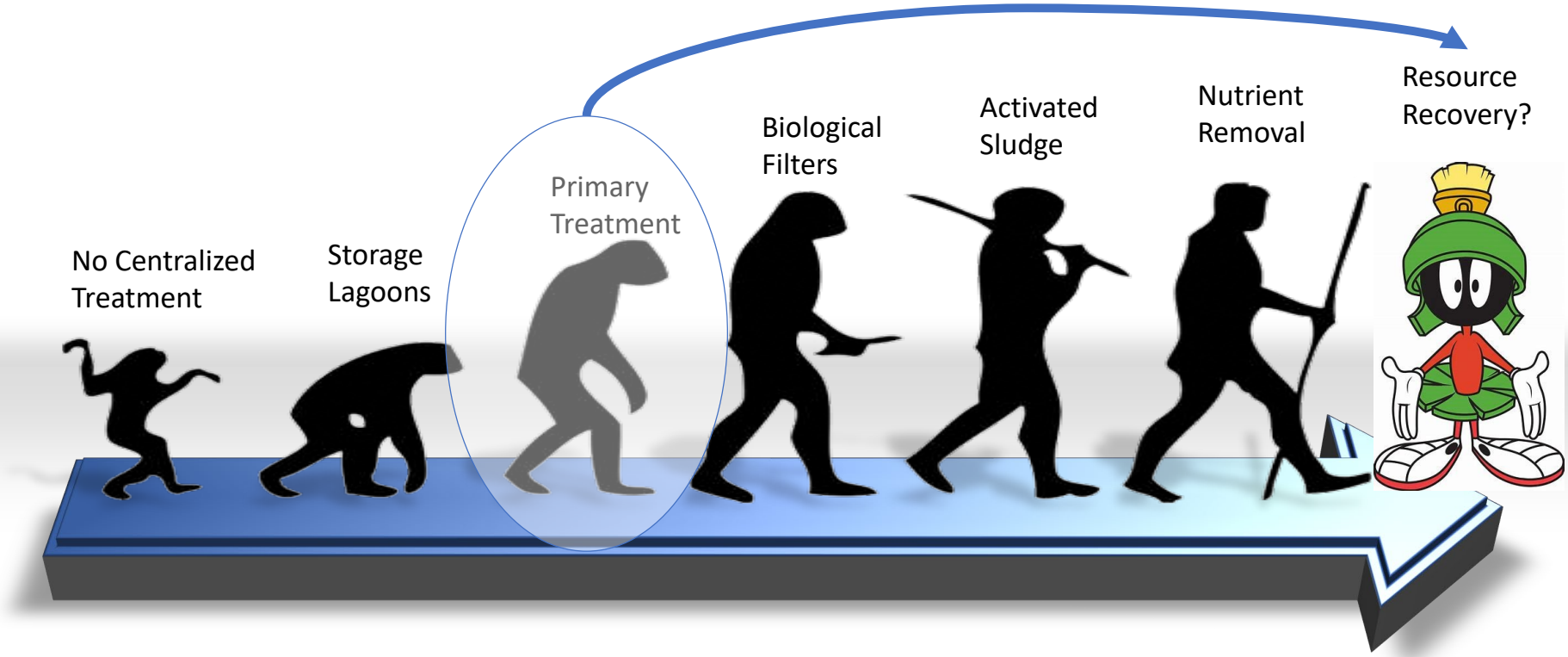
1980 Anaerobic fluidized bed

1990s MBR

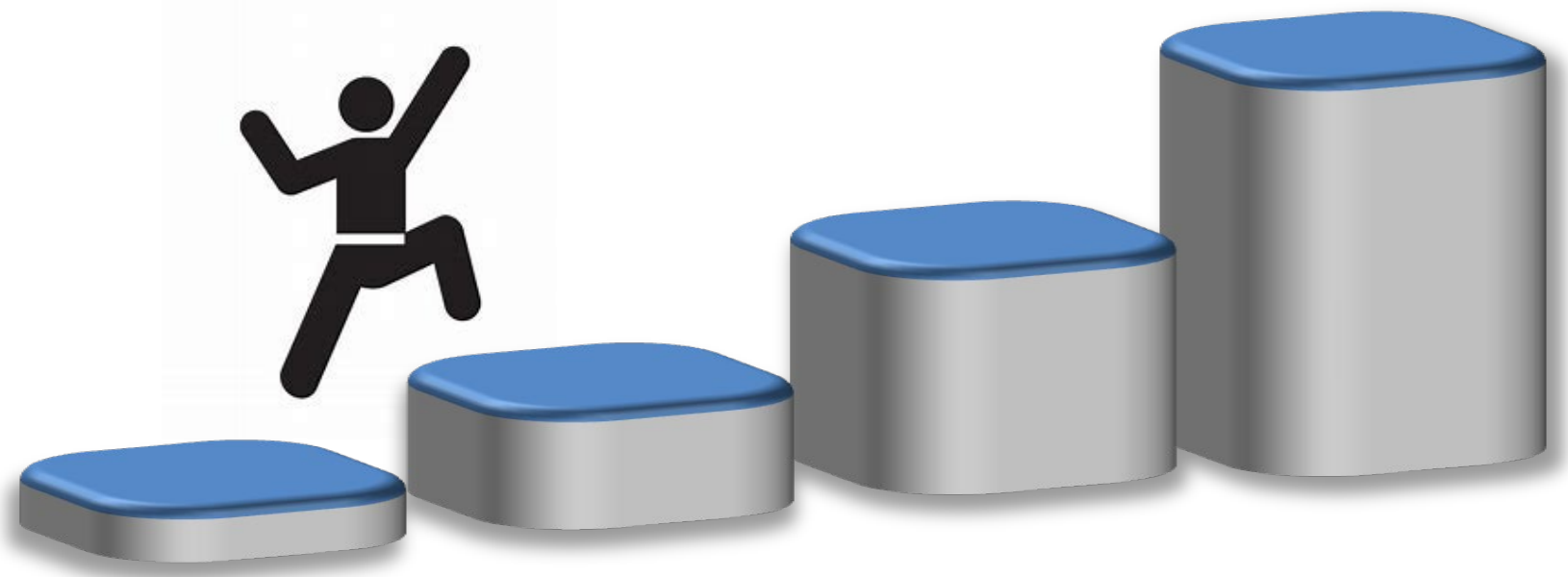
Issues With Use of Technology Designed to Meet 19th Century Drivers

- We rely on activated sludge and variants
- Produces secondary sludge which doesn't digest well
- We still design digestion facilities which are sub-optimal
- Current best practices is to build new plants which already need pre-treatment bolt-on to improve performance
- They are not designed for modern drivers

Industry Evolution



Advanced Primary Treatment Evolution



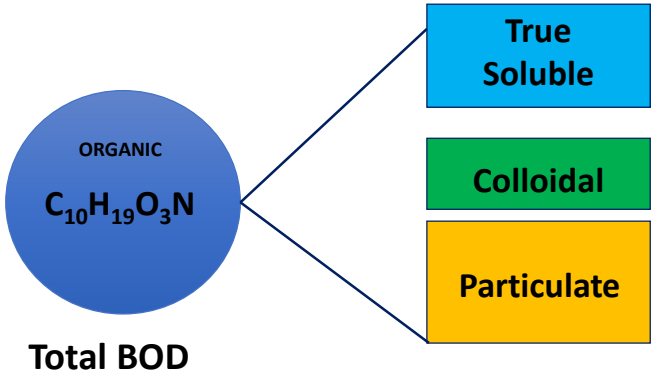
Chemically-Enhanced Sedimentation

Mechanically Enhanced Separation

Ballast Enhanced Sedimentation

Biologically Enhanced Treatment

CARBON (BOD) EXPLAINED



Typical domestic BOD fraction:

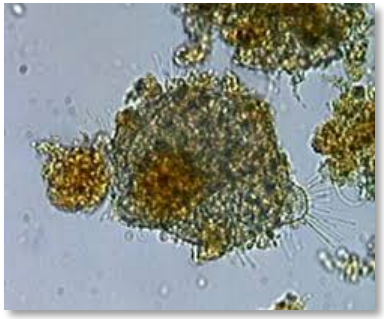
- 55% sBOD
  - 31% ffBOD
  - 24% sBOD
- 45% pBOD

(Guellil, et. al. 2001)

Key Mechanisms: Biosorption & Bioflocculation

True Soluble	Uptake
Colloidal	Coagulation
Particulate	Enmeshment

Total BOD
Raw WW



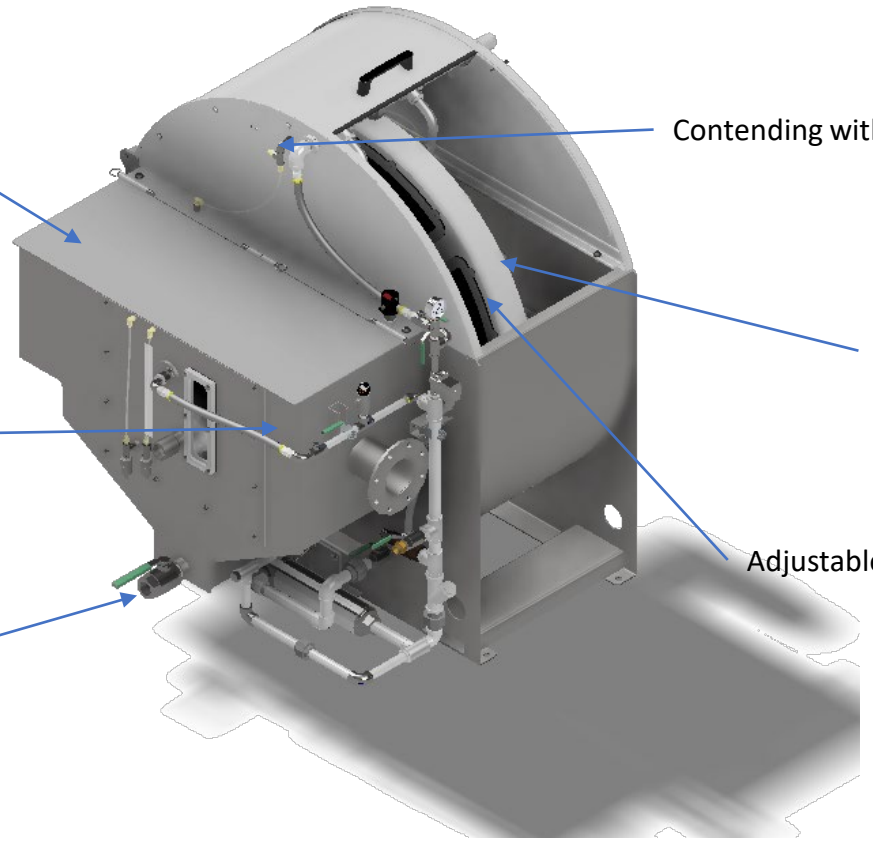
Biological floc (WAS)

- Microorganisms
- Biopolymers (EPS)

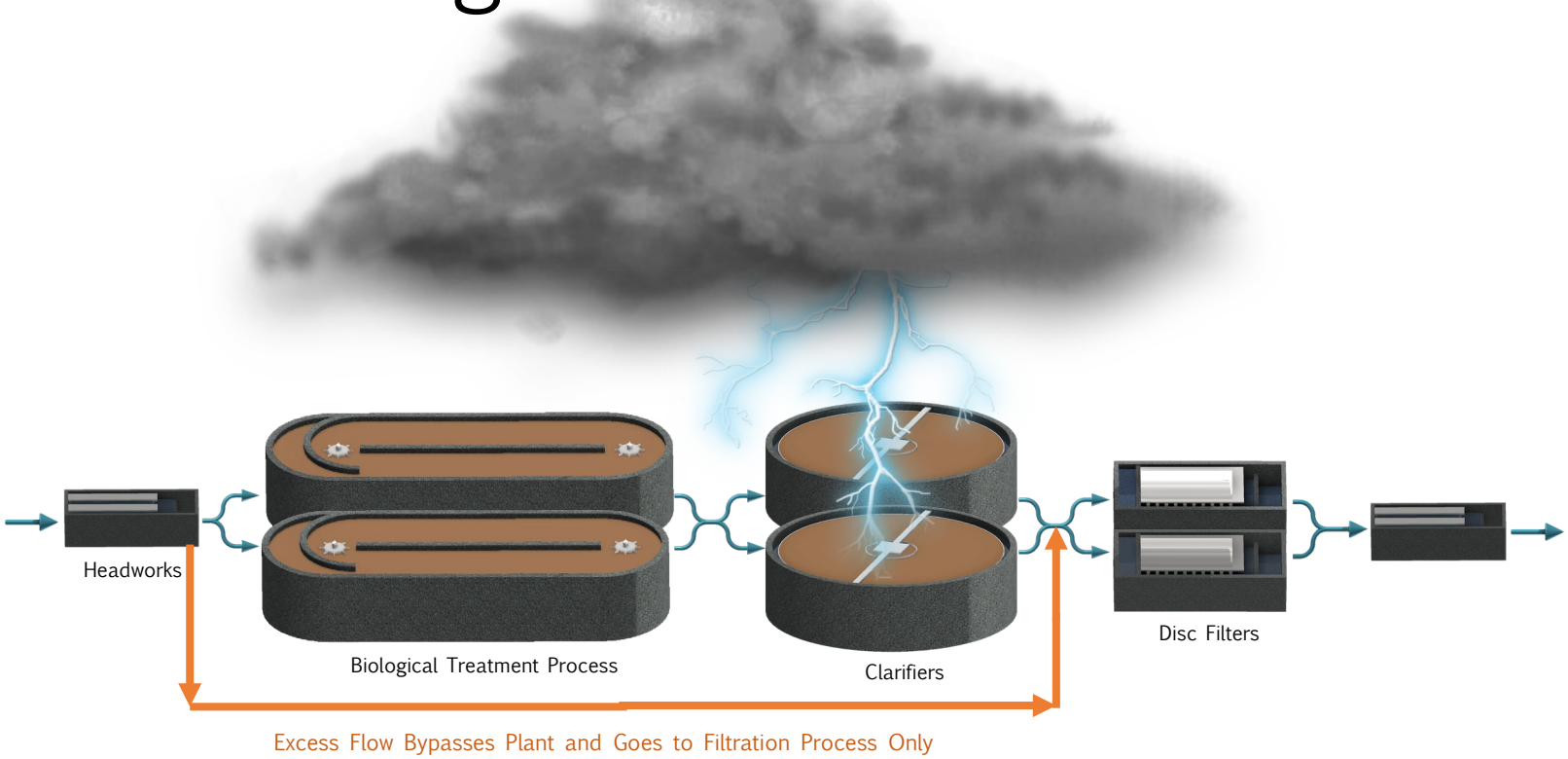
Contact Tank: Short HRT and Mild Aeration

PRIMARY TREATMENT	BOD FRACTION REMOVED	REMOVAL MECHANISM
Conventional **Primary Clarification**	✓ Particulate/settleable	Sedimentation.
Chemically Enhanced **Primary Clarification**	✓ Particulate/settleable ✓ Colloidal	Sedimentation with chemical coagulation and flocculation.
Mechanically Enhanced **Microscreens & Filters**	✓ Particulate larger than filtering media	Physical barrier. Mechanical separation.
Ballast Enhanced **Primary Clarification**	✓ Particulate/settleable ✓ Colloidal	Sedimentation with chemical coagulation, flocculation, and ballast.
Biologically Enhanced **"A" Stage of A/B Process**	✓ Particulate ✓ Colloidal ✓ Soluble	Biosorption, bioflocculation, and sedimentation.
Biologically Enhanced **Captivator®**	✓ Particulate ✓ Colloidal ✓ Soluble	Biosorption, bioflocculation, and flotation.

Key Requirements of a Primary Filter

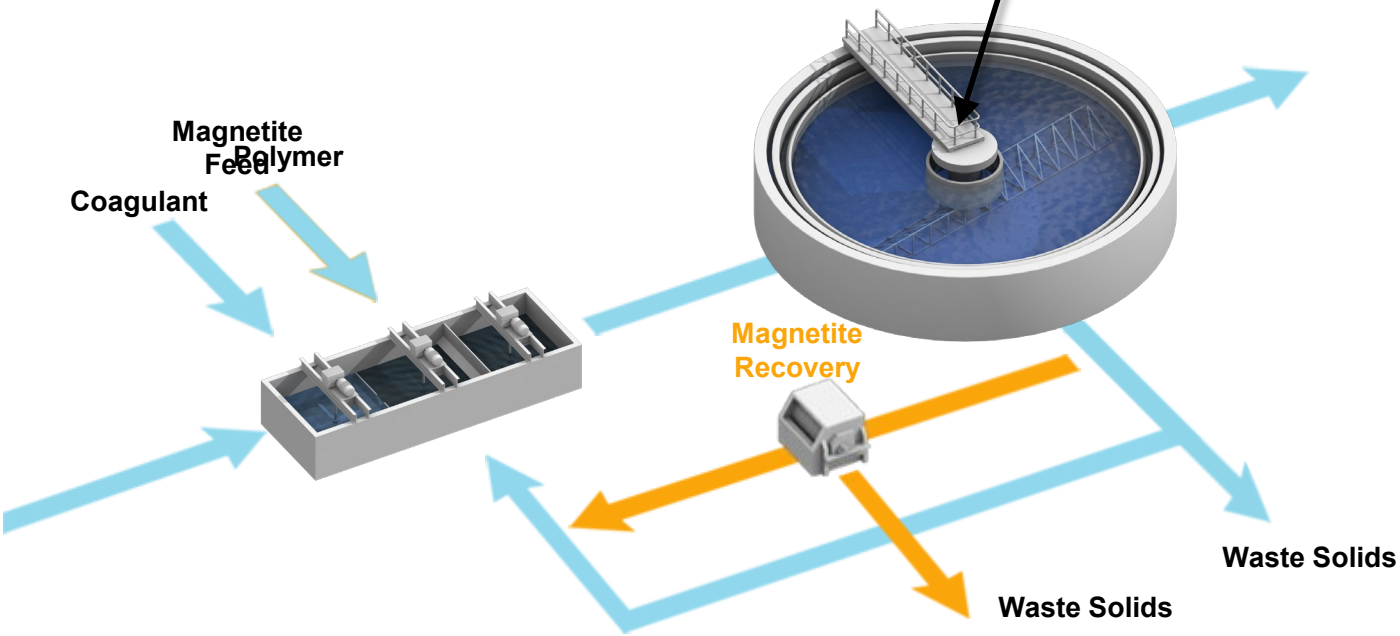


CSO Design Scenario



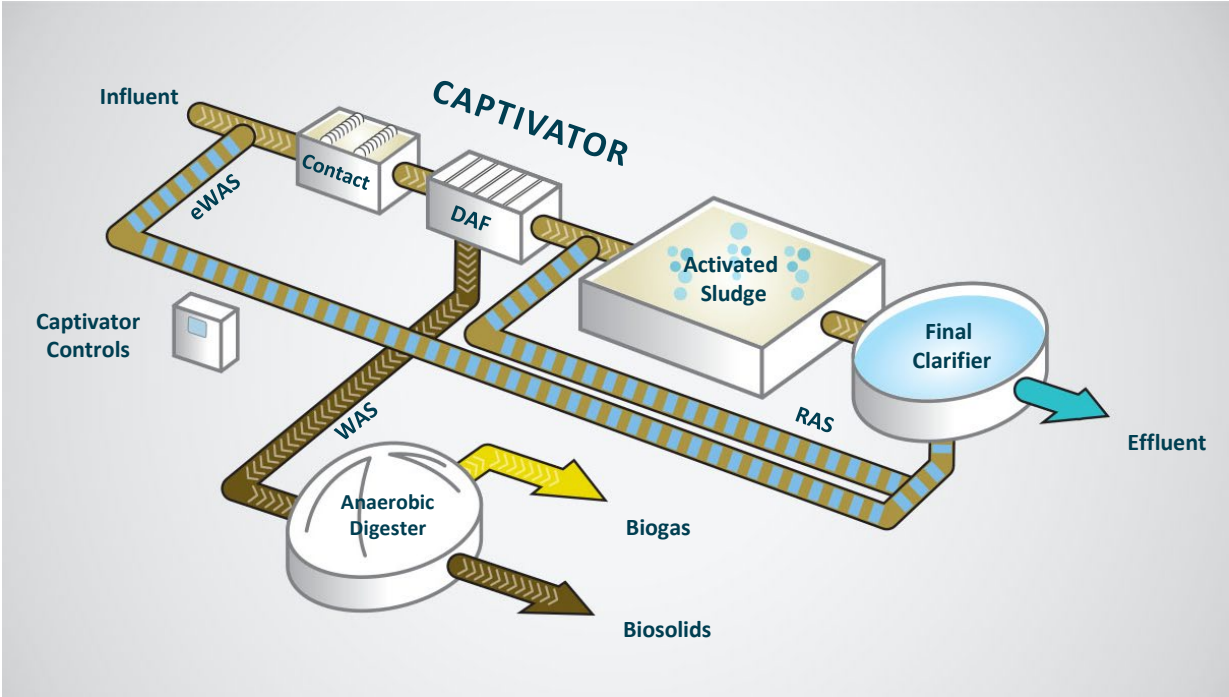
Ballasted Sedimentation CoMag® Process Flow Diagram

- Clarifiers 80-90% smaller
  - Increase capacity up to 10X
  - Superior solids removal



- Optimize chemical use
- Promote solids-contact

Biological Enhanced Primary Treatment Captivator



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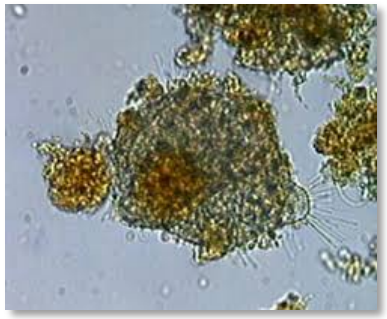
True Soluble — Uptake

Colloidal — Coagulation

Particulate — Enmeshment

Total BOD
Raw WW



Biological floc (WAS)

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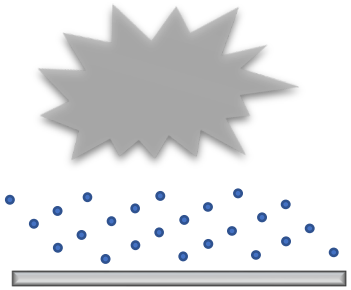


Contact Tank: Short HRT and Mild Aeration

DAF: Flotation

Why DAF?

Hydraulically efficient

- **5X** smaller footprint than primary clarifiers
- Rapid transport of solids to digester

Thickener (coflotation)

- **4-6%** solids without chemicals
- **NO** need for additional thickeners

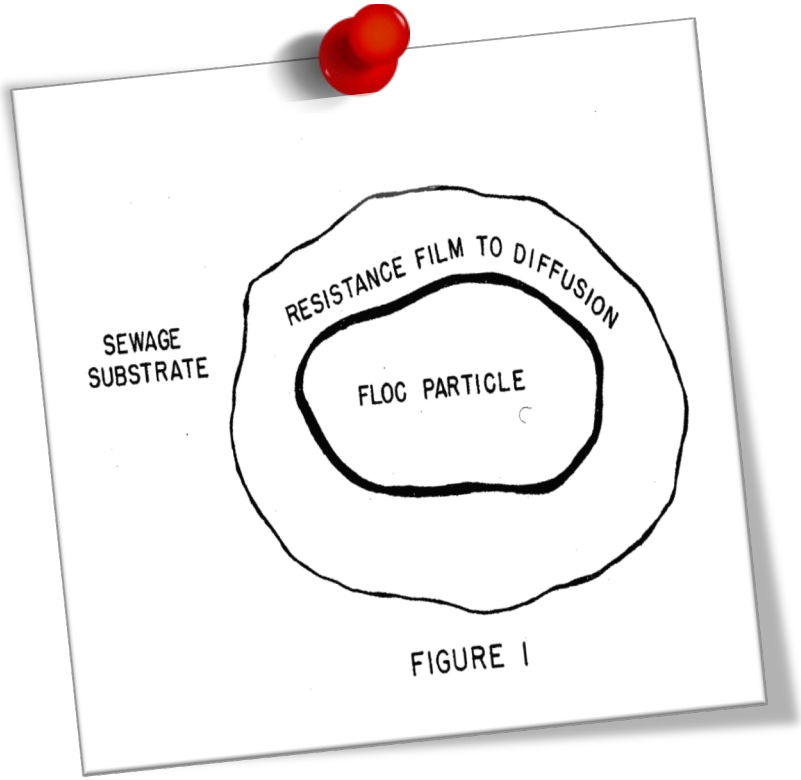
Additional benefits

- Grit separation (settleable)
- FOG removal (floatable)

Knowledge Growth Timeline

1953	1993	1996-2010	2012-13	2014
Katz Biosorption Study	DAFT Coflotation, Renton, WA	Pilot Studies Bethlehem & Oconomowoc	Pilot Study Singapore R&D Study	Full-Scale Agua Nueva WRF (32 MGD)

Katz Study (1953)



Key Points:

- One of the first studies on biosorption mechanisms, tested sludge from four WWTP's in WI
- Relationships were similar across the plants studied, and repeatable
- Evaluated contact time, with and without aeration (60 min w/ aeration)
- Developed isotherm to predict removal
- Sludge concentration plays a role

Renton, WA Plant Study (1993)

A DISCUSSION OF THE ADVANTAGES OF CO-THICKENING OF PRIMARY AND SECONDARY SLUDGES IN DISSOLVED AIR FLOTATION THICKENERS

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Abstract

Dissolved air flotation thickeners (DAFTS) are commonly used to thicken waste activated sludge; however, their use for co-thickening primary and waste activated sludges is not commonly practiced. This paper describes the results of a full-scale DAFT co-thickening operation. Soluble BOD reduction across the DAFTS is approximately 80% while soluble COD reduction is approximately 60%. This represents a reduction in BOD loading to the activated sludge facilities of approximately 4%. In addition, substantial amounts of fine grit is removed from the primary sludge during the flotation process. Thus, DAFT co-thickening of primary and secondary sludges can significantly reduce secondary organic loading while concurrently reducing the amount of grit being discharged to the digesters. It also eliminates the need to independently thicken primary sludge. These impacts lead to reductions in secondary operating costs as well as reduced operating costs associated with digester cleaning and thickening of primary sludge.

Keywords

Dissolved Air Flotation Thickening, Soluble BOD Removal, Solids Thickening, Grit Removal

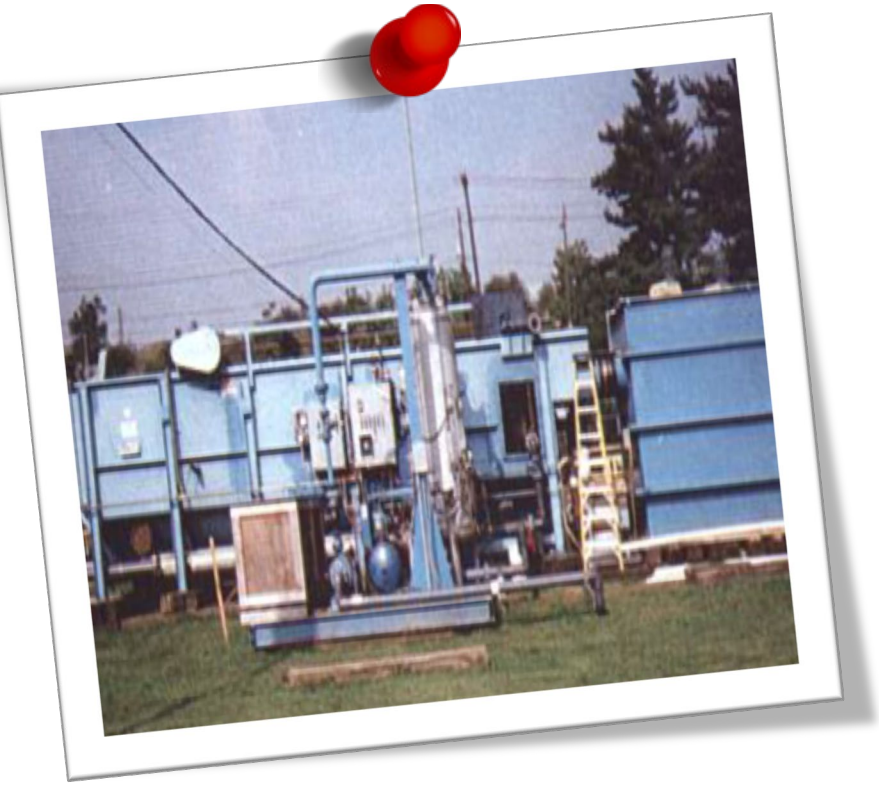
Introduction

The East Division Reclamation Plant (EDRP) of King County's Department of Metropolitan Services (Metro), which was formerly known as the Municipality of Metropolitan Seattle's Renton Treatment Plant, is a secondary activated sludge treatment plant, which was originally constructed in the early 1960's. The original plant design, which was described by Uhte (1964), did not include solids processing; all EDRP solids were pumped to Metro's West Point facility for treatment. The EDRP was expanded in 1972 to increase its liquid stream capacity from 1.05 m^3/s (24 mgd) to 1.58 m^3/s (36 mgd); however, solid stream processing was again not included. A second expansion, completed between 1985 and 1988, doubled the secondary capacity to 3.15 m^3/s (72 mgd) and constructed solids handling facilities for the first time. The solid stream processing facilities included thickening, anaerobic digestion and belt filter press dewatering.

Key Points:

- 80% soluble BOD removal was observed, less returned in side streams versus gravity thickeners
- Co-flotation produces higher %TS conc.
- Grit removal in DAF [24,000 lb (10,900 kg) during two-day storm event]
- Digesters were "relatively free of accumulated grit"

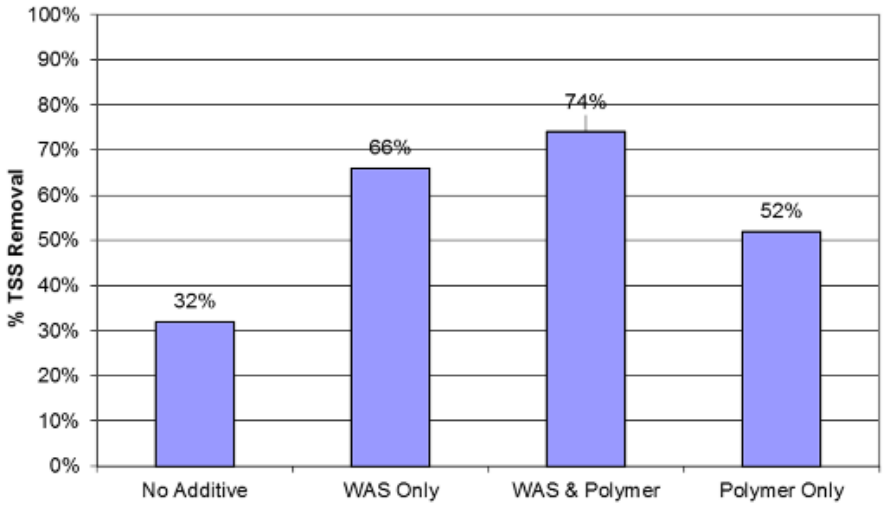
Bethlehem, PA Pilot Study (1996)

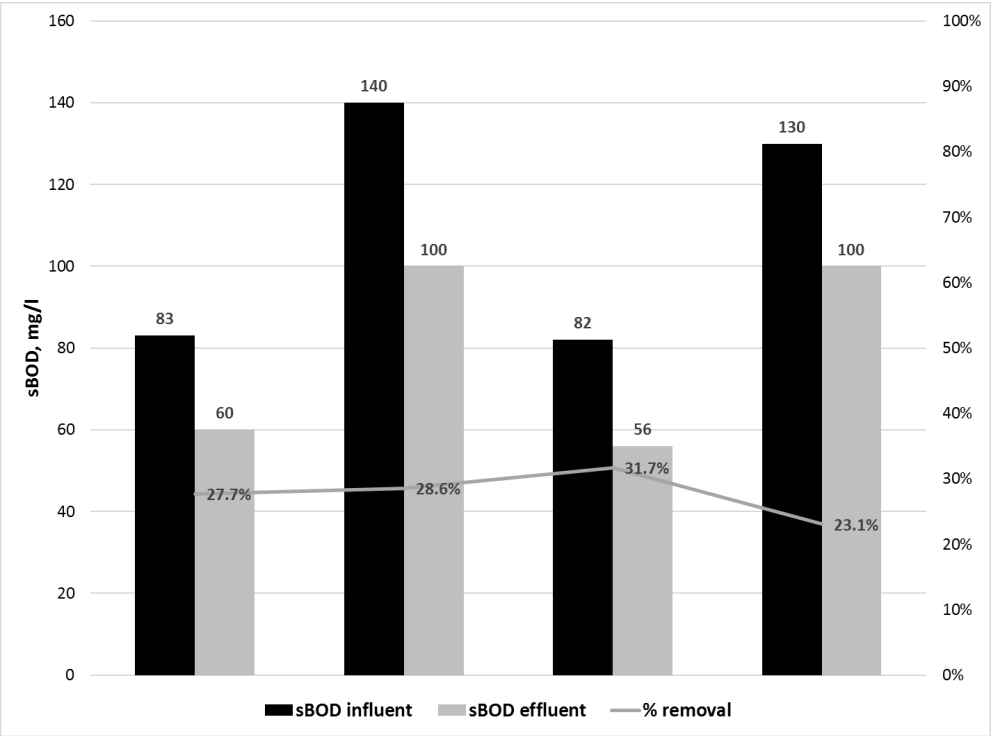


Key Points:

- First Evoqua pilot
- Tested 5000 gpd/sf (8.5 m/hr) loading w/ 10-min contact tank
- Evaluated TSS & BOD removal with and without polymer (74% vs 66% TSS)
- 23-32% sBOD removal observed (colloidal & truly soluble)
- Co-flotation in primary DAF measured, with and without polymer (4-7%DS)

TSS removal results from bench scale study





"sBOD" removal from Pilot

Oconomowoc, WI Pilot Study (2010)

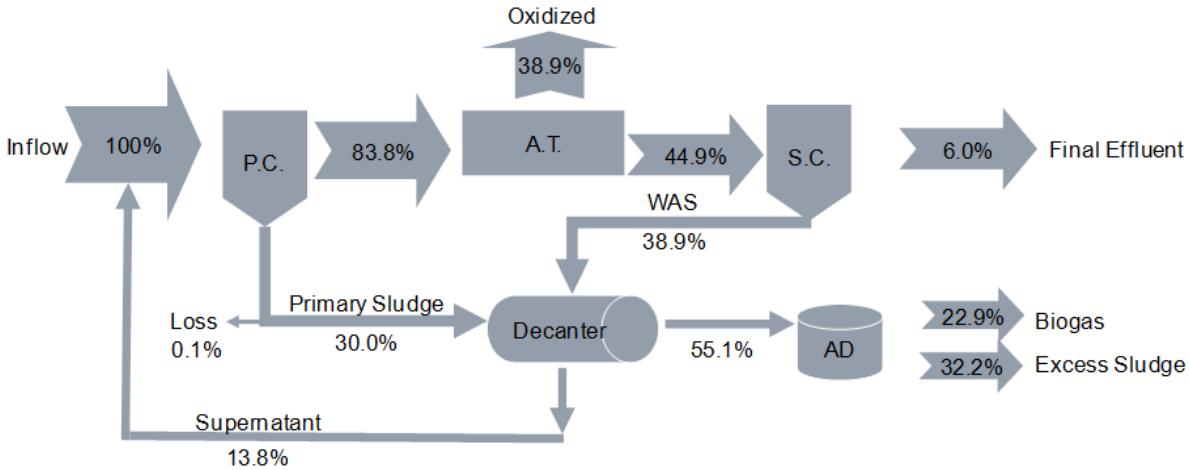
Key Points:

- Testing conducted with Jacobs/CH2M in advance of Agua Nueva project
- Evaluated TSS & BOD removal with and without polymer & coagulant (73-90% TSS)
- Ability to achieve consistent float concentration at desired conc (2-3% DS)
- Peak flow testing conducted w/o chemical (69%)

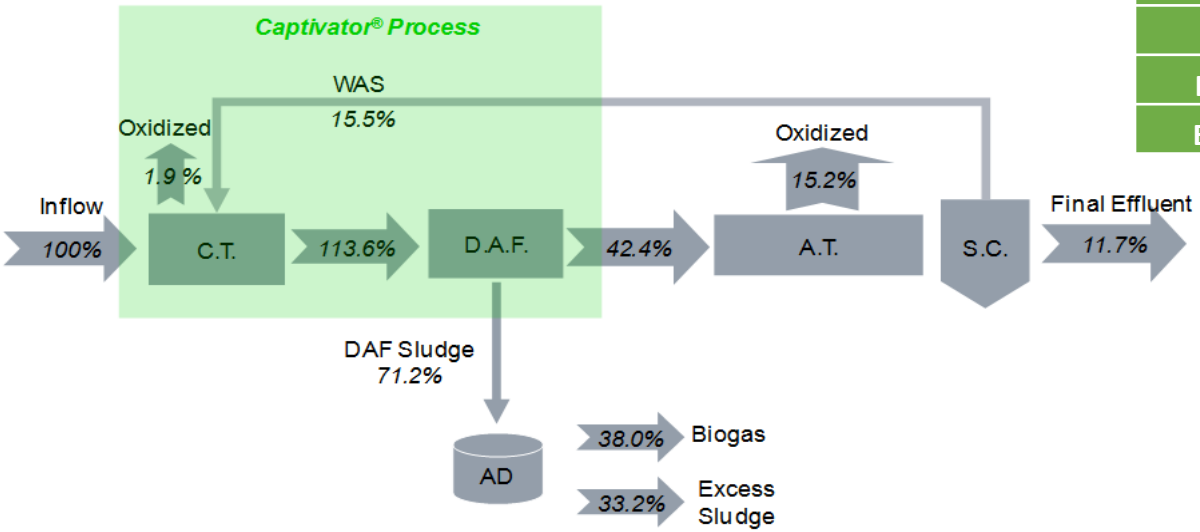
Singapore R&D Pilot Study (2012-13)

Key Points:

- 37-gpm (200 cmd) micro plant constructed
- Baseline run and compared against two different modes of BEPT operation
- Complete mass balance performed
- 40-min contact tank
- Biogas production measured for first time (8.4 cmd vs 11 cmd→31% increase)



COD balance
CAS



	CAS	Captivator System
Oxidized	39%	17%
Biogas	23%	38%
Final Effluent	6%	12%
Excess Sludge	32%	33%

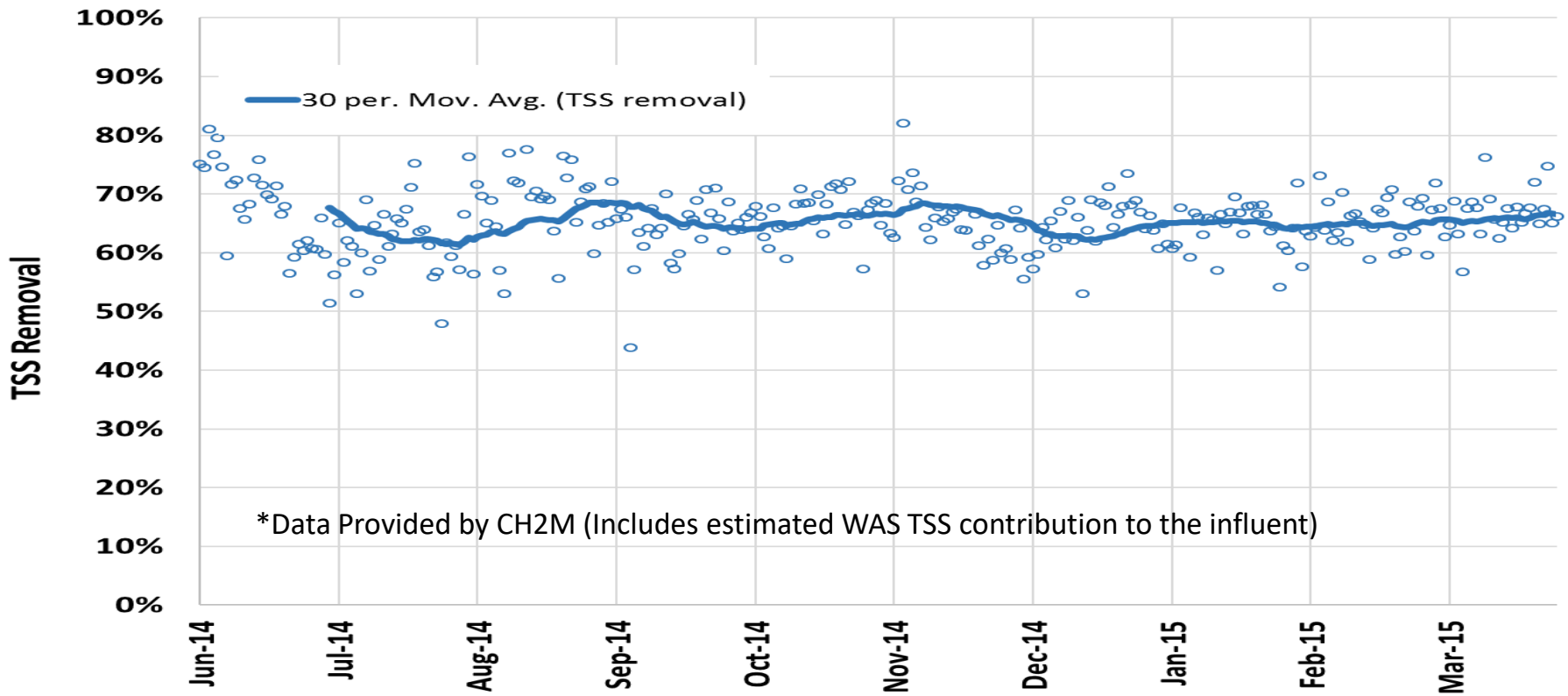
COD balance
Captivator System

Agua Nueva WRF (2014)

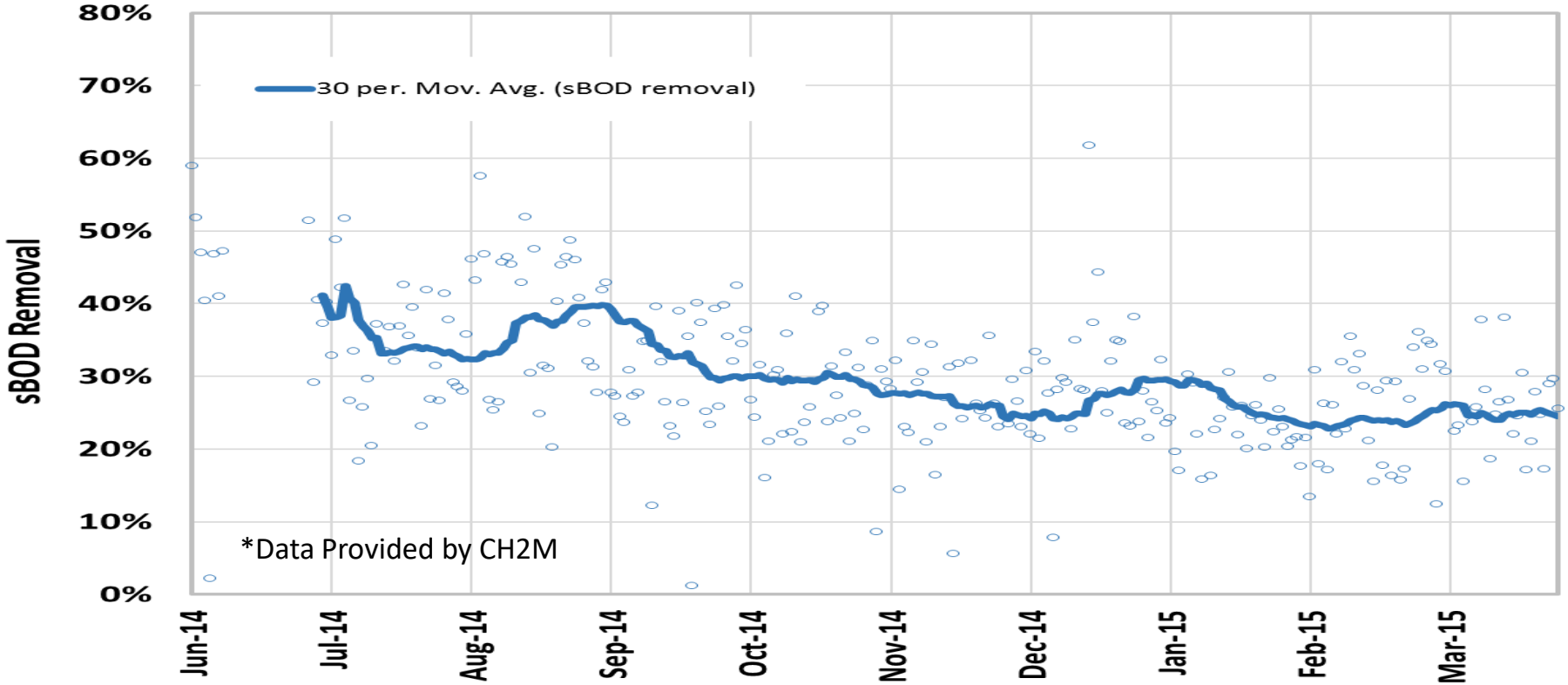
Key Points:

- Award winning 32 MGD (121 MLD) facility in Tucson
- Scalping plant (no digesters)
- Combined grit removal, primary DAF, sludge thickening, and FOG removal in a single unit process
- 65% TSS & 25-30% sBOD removal
- Float consistently maintained ~2%
- Add supplemental carbon as needed

Agua Nueva – DAF TSS Removal



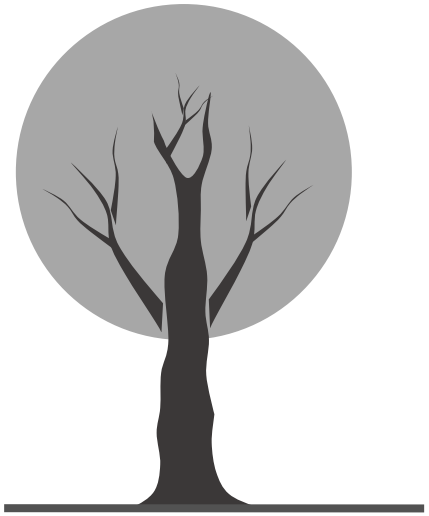
Agua Nueva – DAF sBOD Removal



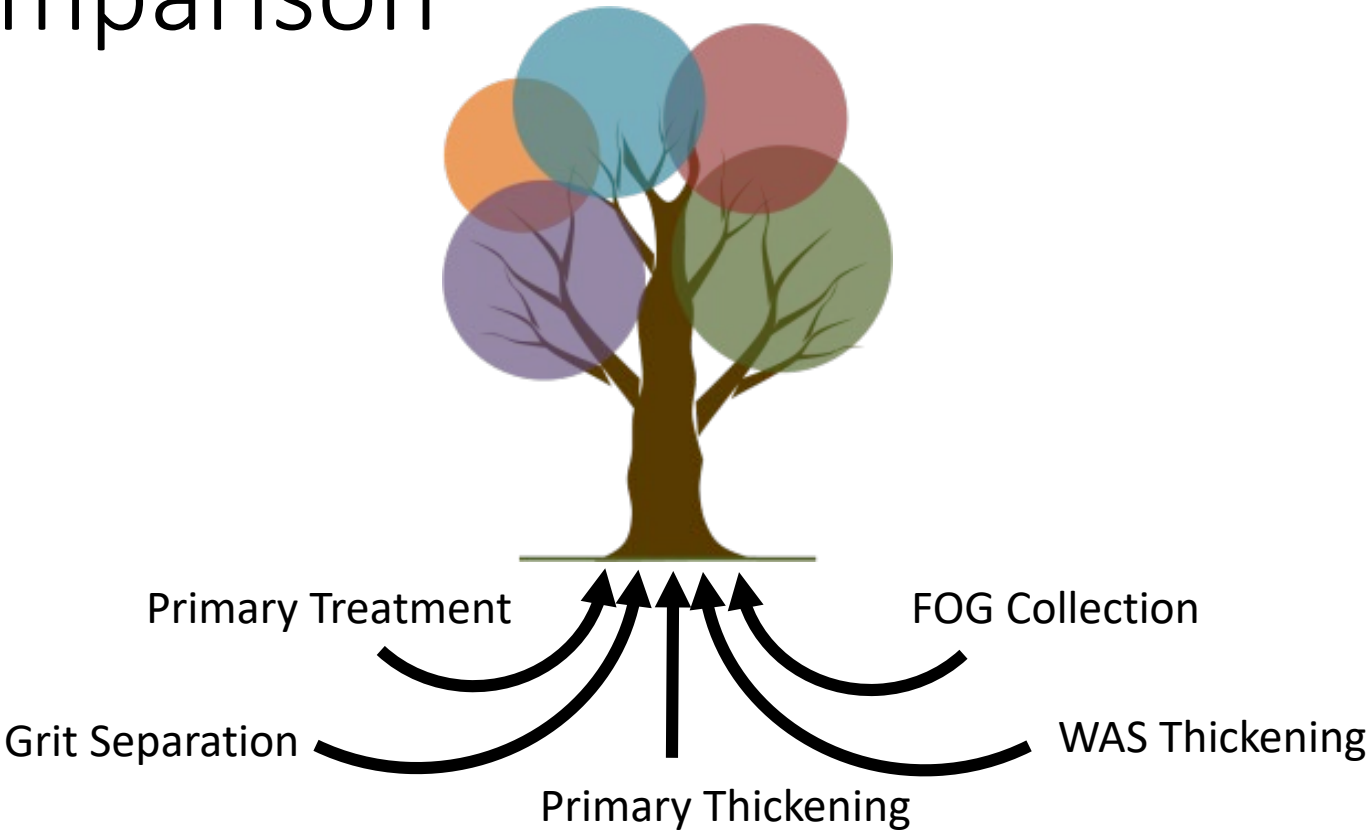
We Learned…

- Aerated contact tank promotes biosorption & bioflocculation, need some HRT and good mixing
- Ability to handle peak flows, but need min A:S for effective removal
- Result is high functioning primary clarifier in small footprint
- Ability to reliably co-thicken w/o polymer in DAF
- Grit separation occurs
- FOG collection in float
- Supplemental carbon may be needed for Nutrients

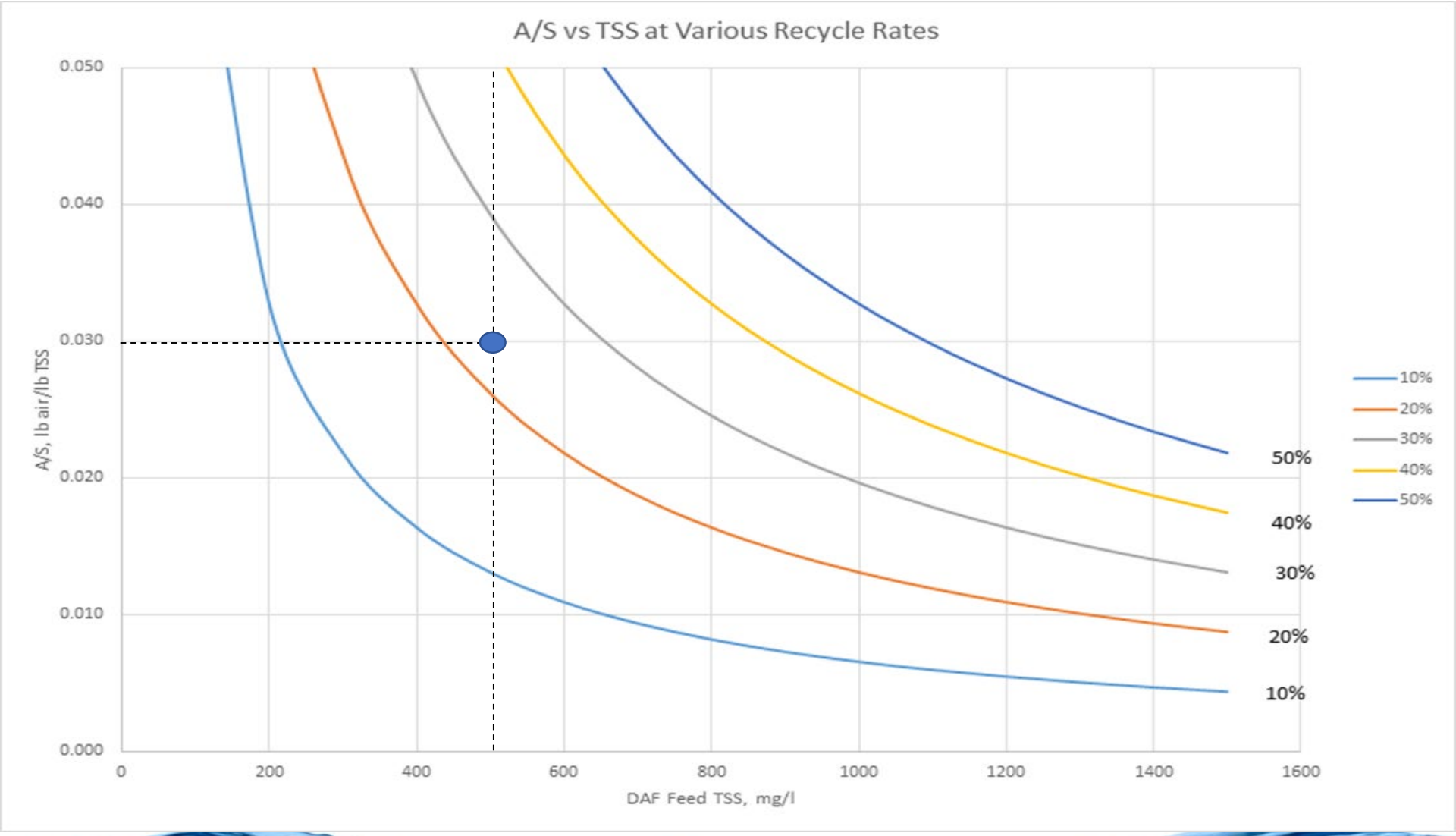
Value Comparison

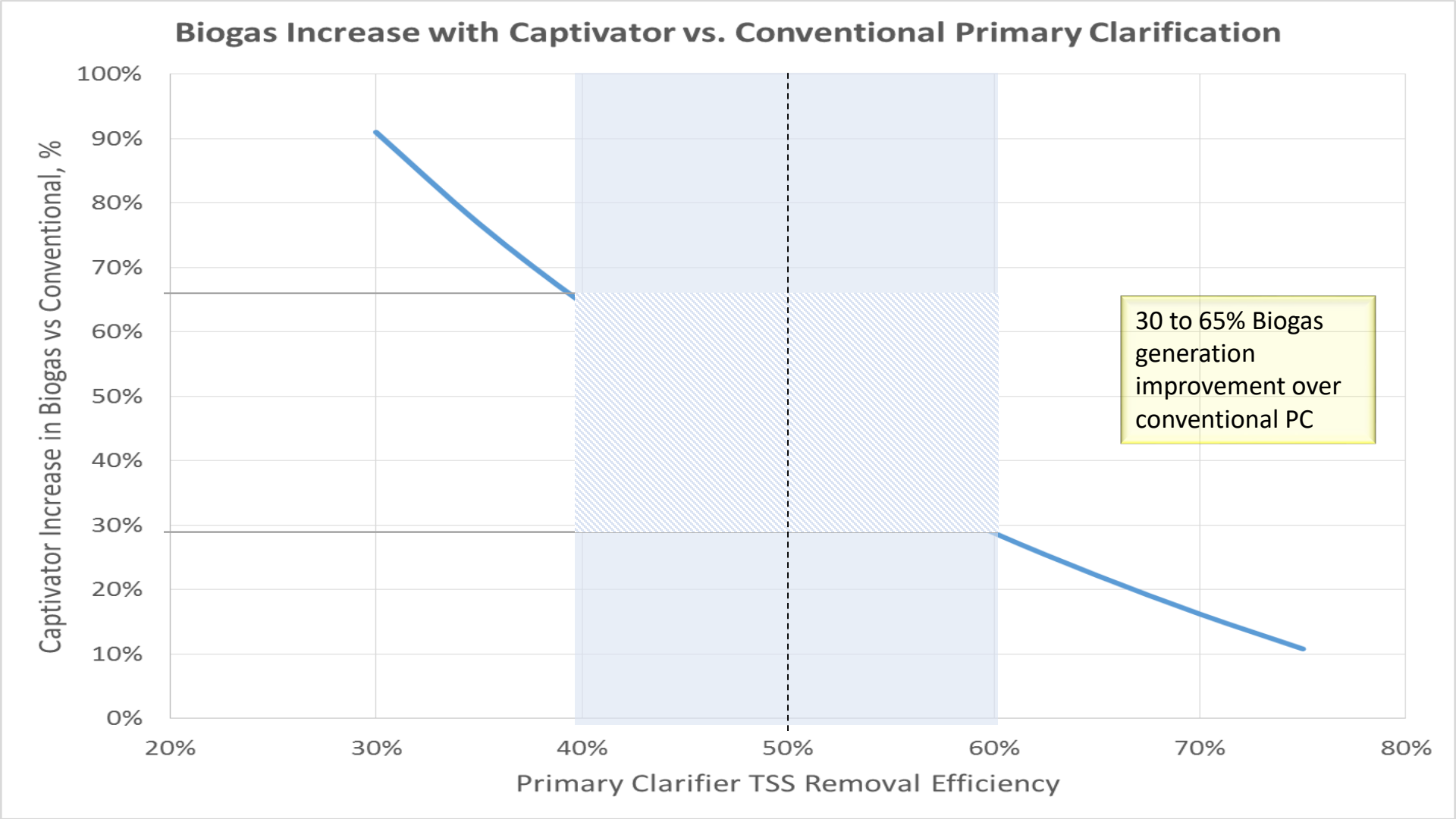


Primary Treatment
(TSS & BOD removal)

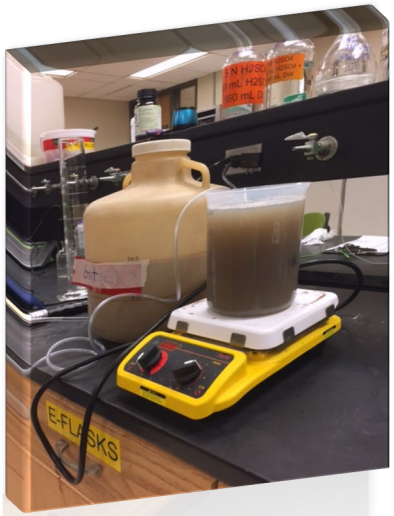


PARAMETER	VALUE	UNITS
Contact time	10-40	minutes
DAF Air:Solids	ADF > 0.03 PDF > 0.02	mass basis
DAF Surface Overflow Rate (SOR)	ADF < 5000 (8.5) PDF < 10,000 (17)	gpd/sf (m/hr)
DAF Solids Loading Rate (SLR)	ADF < 20 (98) PDF < 30 (147)	ppd/sf (kg/m2-d)
Removal Efficiency (w/o chem) **BOD5** **TSS**	 50-55% 65-75%	
DAF Float (w/o polymer)	4-6%	dry solids

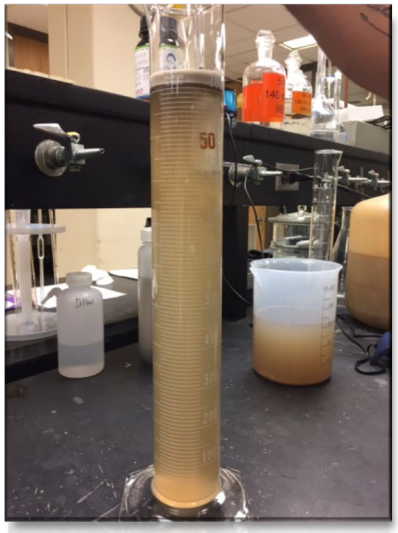




Captivator® Bench Testing



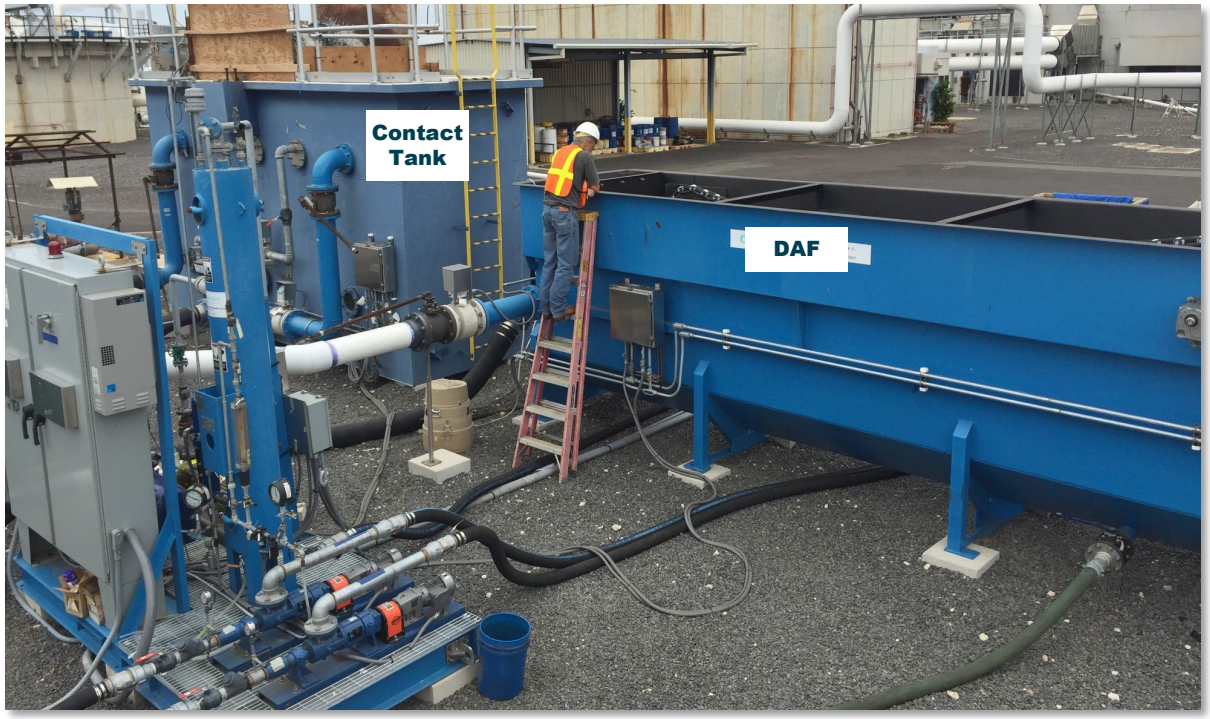
Contact Tank Simulation



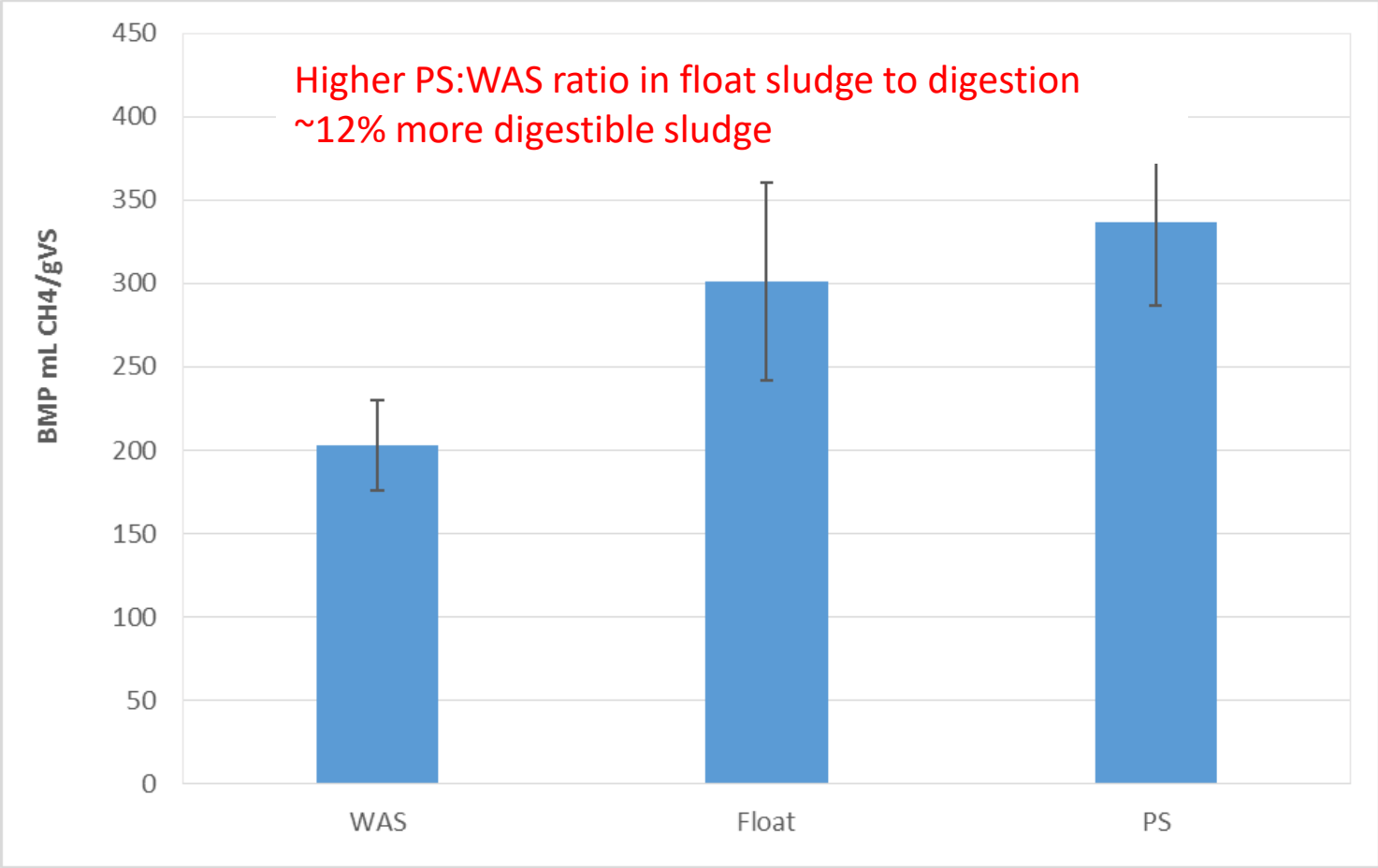
DAF Simulation

Pressurized System

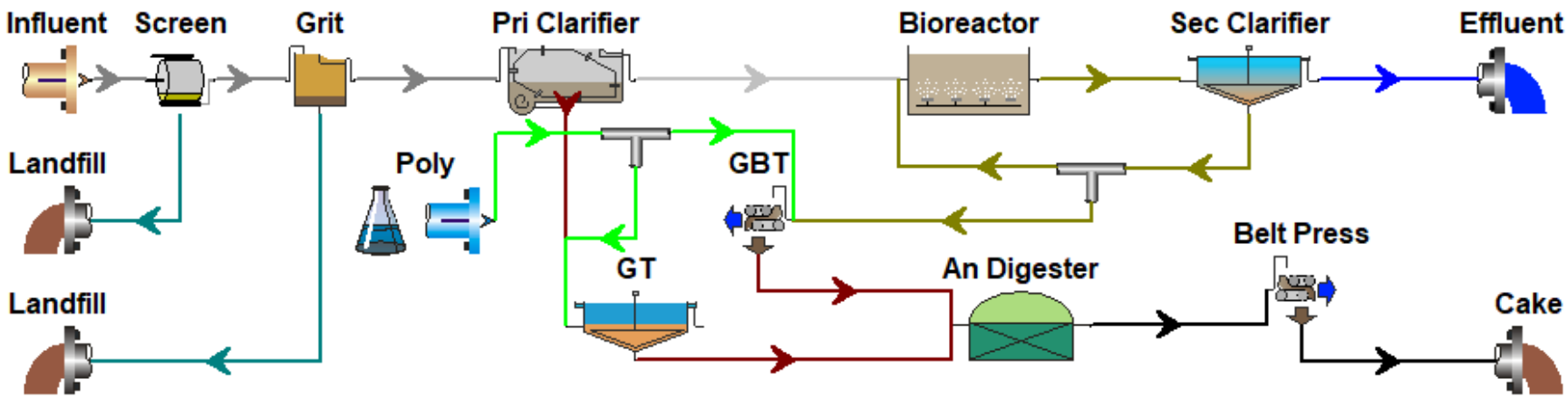
Captivator Demonstration Pilot Unit (0.3 MGD)



Captivator Pilot – BMP test



System Impacts from Advanced Primary Treatment



FEATURES	CHEMICALLY ENHANCED	MECHANICALLY ENHANCED	BALLAST ENHANCED SEDIMENTATION	BIOLOGICALLY ENHANCED (FLOTATION)
Enhanced Carbon Diversion	✓	✓	✓	✓
Compact Footprint	X	✓	✓	✓
Co-thickening w/o Chemical	X	X	X	✓
Grit Separation	X	?	X	✓
FOG Capture	X	X	X	✓

When to Consider APT Process?

Applications:

- Plant Expansions
- Desire To Reduce Energy Demand
- Desire To Eliminate Thickening / Polymer (Captivator® Only)
- Plants Undergoing Biosolids / Energy Recovery Upgrades

Good Candidates:

- Have Digesters / Energy Recovery
- CEPT Facilities
- Converting From Fixed Film Or Pure Oxygen To Activated Sludge
- High Energy Costs (>$0.08 KW/H)
- Grit Issues (Captivator® Only)
- FOG Issues (Captivator® Only)

References & Suggestions for Additional Reading

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WATER TECHNOLOGIES

TRANSFORMING WATER. ENRICHING LIFE.