OVIVO
Bringing water to life

Aerobic Digestion Processes with Membrane Thickening is SOS

Bryen Woo, PE

OWEA Conference 2010

12/13/2010

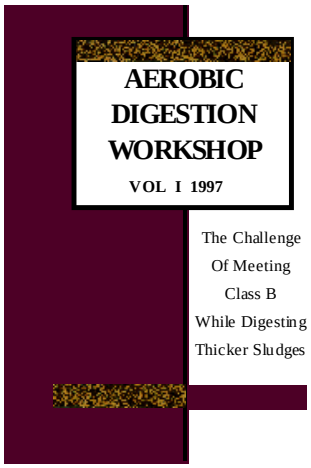
SOS = Sustainable Operating Solution

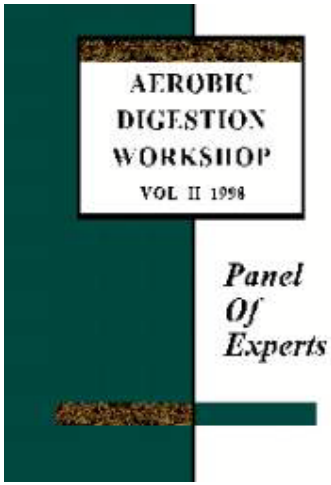
An aerobic digestion process with membrane thickening is SOS, **S**ustainable **O**perating **S**olution. This SOS makes people stress free and happy!

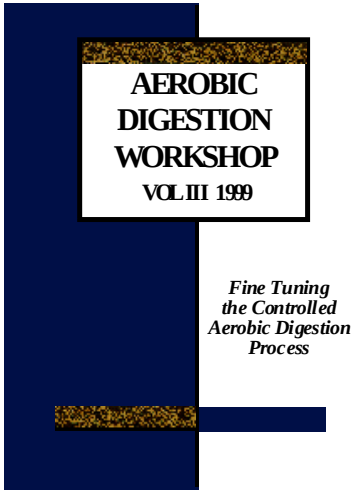
Without membrane thickening an aerobic digestion process can be this SOS!

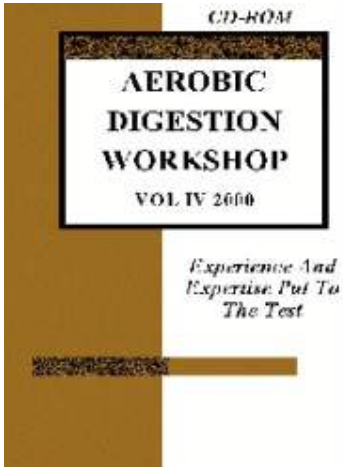
Digestion Expertise

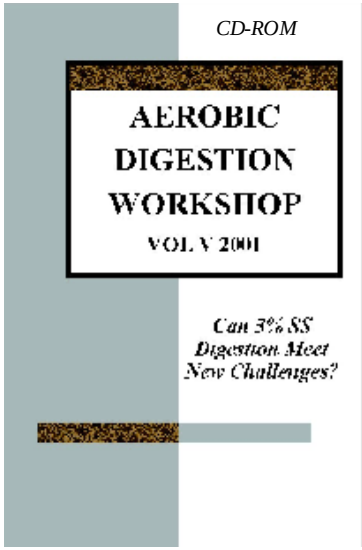
WEFTEC 1997 - 2001











… recognized as the industry leader in aerobic digestion and thickening at high solids concentrations

Digestion Expertise

Manual of Practice No. 11 Operation of Municipal WWTP

Volume III:

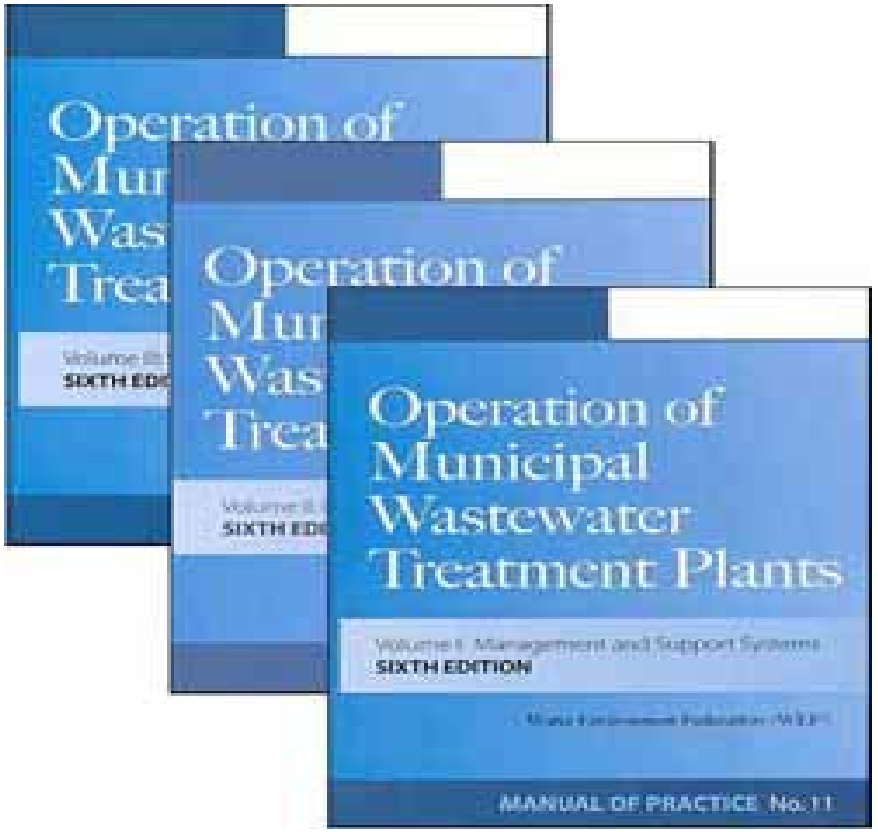
Solids Processes

Chapter 31:

Aerobic Digestion

Author:

Elena Bailey



Digestion Expertise

MOP No. 8 5th Ed., 2009 Design of Municipal WWTPs

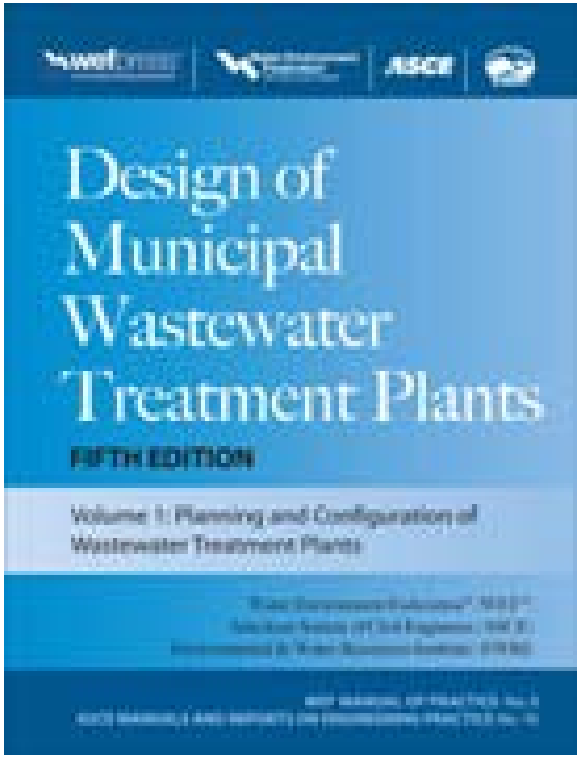
Volume III:

Solids Processing and Management

Chapter 25: Stabilization

Section 3 : Aerobic Digestion

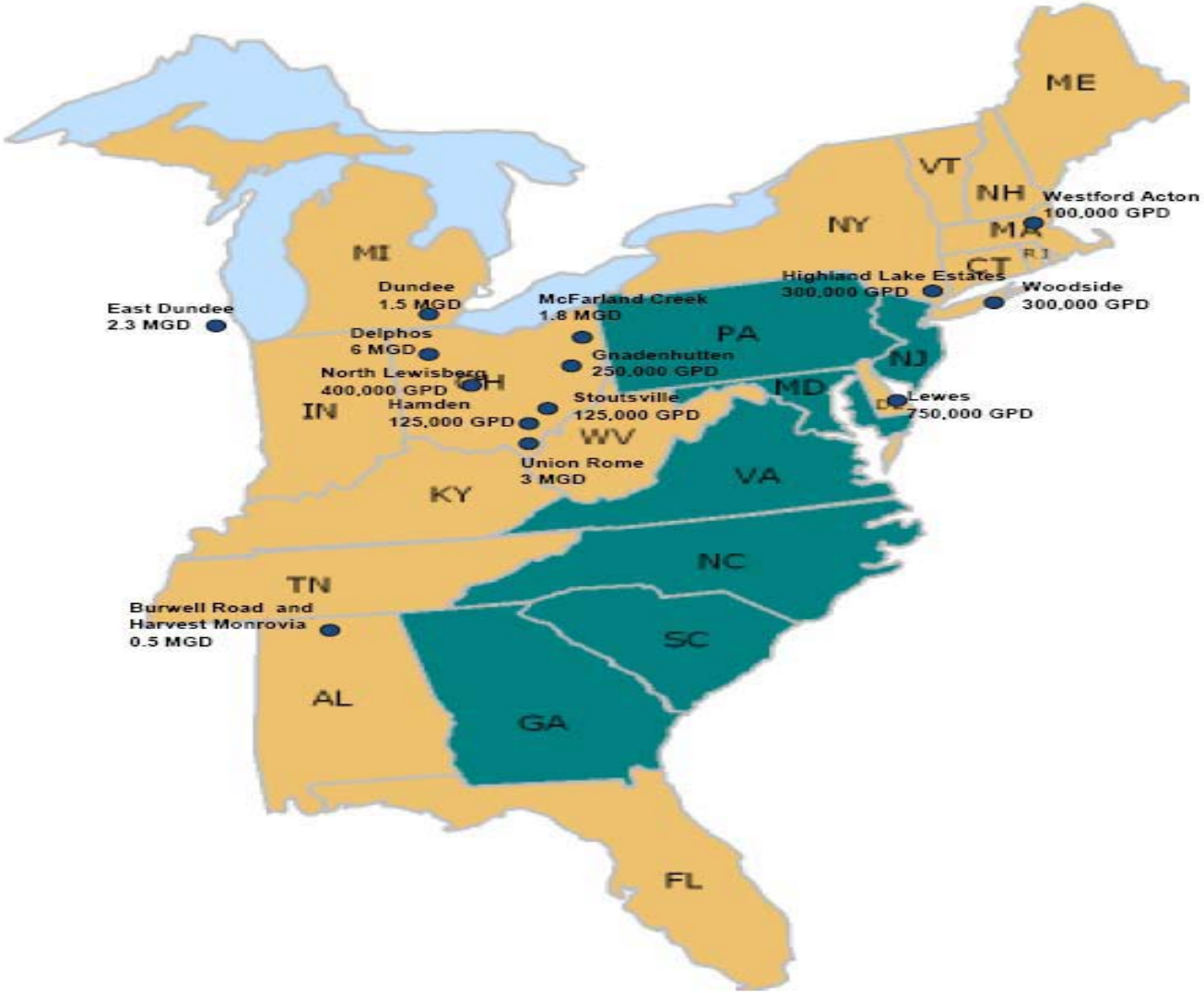
Author: Miguel Vera



Membrane Thickening Installations

Date	Plant	City	State	Liquid Process	MBT/ PAD-K
Jun-04	Dundee WWTP	Dundee	MI	MBR	PAD-K
Jun-04	Arlington WWTP	Arlington	WA	SBR	MBT
Jul-04	Troy WWTP	Troy	MO	MBR	PAD-K
Aug-04	McFarland Creek WWTP	Chagrin Falls	OH	MBR	PAD-K
Nov-04	Gnadenhutten WWTP	Gnadenhutten	OH	MBR	PAD-K
Apr-05	Delphos WWTP	Delphos	OH	MBR	Stormmaster
Apr-05	Cottonwood WWTP	Manor	TX	MBR	PAD-K
Aug-05	Lewes WWTP	Lewes	DE	MBR	MBT
Nov-05	East Dundee WWTP	East Dundee	IL	CAS	PAD-K
Apr-06	Yakama IN Casino	Toppenish	WA	MBR	PAD-K
May-06	Woodside STP	Yaphank	NY	CAS	PAD-K
May-06	Stoutsville WWTP	Stoutsville	OH	MBR	MBT
Jun-06	North Lewisberg WWTP	North Lewisberg	OH	MBR	MBT
Jul-06	Harvest Monrovia	Hunstville	AL	MBR	MBT
Jul-06	Bob's Creek WWTP	Lincoln County	MO	MBR	PAD-K
Aug-06	Hamden WWTP	Hamden	OH	MBR	MBT
Aug-06	Shelton WWTP	Shelton	WA	MBR	MBT
Sep-06	Lake of the Pines WWTP	Auburn	CA	MBR	PAD-K
Nov-06	Concrete WWTP	Concrete	WA	MBR	PAD-K
Dec-06	Providence Estates	O'Fallon	MO	MBR	PAD-K
Feb-07	Westford-Acton WWTP	Acton	MA	MBR	MBT
Apr-07	Winlock WWTP	Winlock	WA	MBR	PAD-K
Jun-07	Burwell Road WWTP	Hunstville	AL	MBR	MBT
Jun-07	Highland Lake Estates WWTP	Monroe	NY	MBR	MBT
Apr-08	Alpine WWTP	Alpine	WY	MBR	PAD-K
Jul-08	Union Rome WWTP	Union Rome	OH	MBR	PAD-K
Oct-09	C'oeur d'Alene Casino	C'oeur d'Alene	ID	MBR	PAD-K
Dec-09	Cayce WWTP	Cayce	SC	OX	PAD-K
Nov-10	Davie WWTP	Davie	FL	MBR	PAD-K

Installations Near Ohio (Northeast US)



Why Use Aerobic Digestion with Membrane Thickening?

Benefits of Membrane Thickening

1. **Improved thickening**
   - **Thickening of WAS without using polymer.**
     - Reduced chemicals and disposal cost.
   - **Thickening of WAS to 3% solids (5% with a dual step) independent of settling characteristics in a single step.**
   - **Less sludge volume to handle or dispose.**
2. **Reduced operator attendance.**
   - **No Set-up or clean up time**
   - **No constant attendance while thickening**

Why Use Aerobic Digestion with Membrane Thickening?

Benefits of Membrane Thickening

3. **Reduced Footprint**

   - **Smaller tanks + No chemical storage = Less concrete and less air requirements resulting in less energy/electrical usage**

     - Ideal for rehabs and small plants.

     -Could use existing overloaded aerobic digesters - SHT

4. **Produces a High Quality Permeate when used with an Aerated Digester(s) or SHT**

   - **Reduces Total N (NH_3/NO_3) and P in the permeate. Substantial release of these nutrients in liquid stream going back to the head of the plant compromises the performance of the BNR activated sludge process.**
   - **Permeate can be combined with effluent without reducing quality.**
   - **Sludge for disposal has reduced Total N as well.**

Why Use Aerobic Digestion with Membrane Thickening?

Benefits of Membrane Thickening

Membrane Thickening Processes reduces capital costs associated with the construction of additional tanks

Design	% Solids	Required Design SRT (Days)	Required Volume (gallons)	Concrete Required to Build Tanks (cubic yd)	Concrete Costs ($600/yd^3)	Design Air (scfm)
Decant	1.75	60	2,055,480	1,333	$800,000	8,240
P.A.D-K	**3.0**	**42**	**699,440**	**638**	**$385,000**	**2,800**

P.A.D-K Process will reduces energy costs

Design	Total Brake HP Demand for Blowers	Convert Energy Usage in Kilowatts	Annual Energy Costs ($0.06/KWH)
Decant	333 hp	249 kW	$131,000
P.A.D-K	**113 hp**	**85 kW**	**$45,000**

Based on 3.0 MGD Class B Aerobic Digestion Facility Design

The P.A.D®-K Process

P.A.D®-K stands for Pre-Thickened Aerobic Digester using a Kubota Flat Plate Membrane

Ideal for:

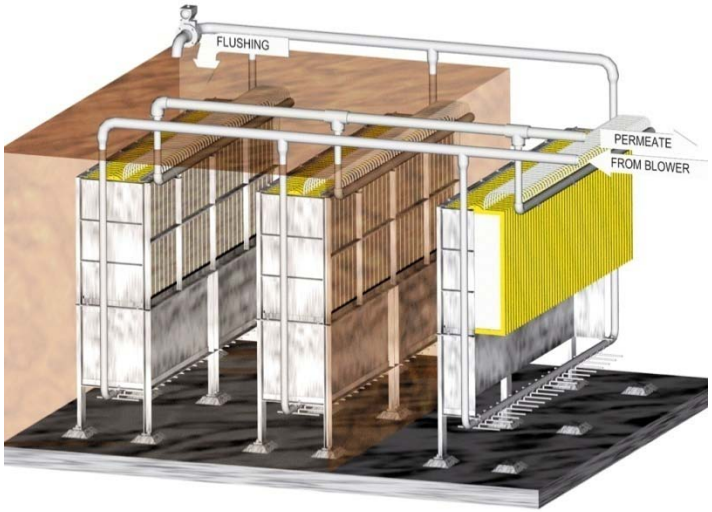
MBR WWTPs

Decentralized facilities or Reduced operations staff

Class B Applications

How Does Membrane Thickening Work?

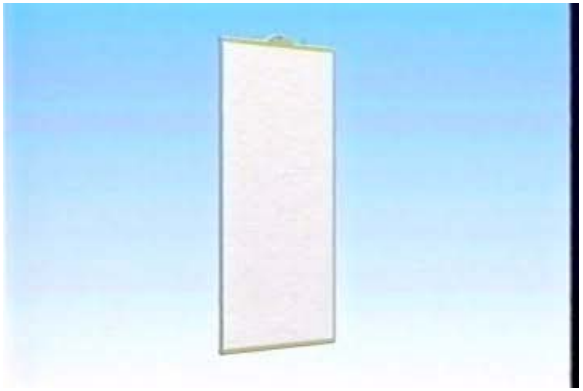
How Does Sludge Get Thickened With a Membrane?

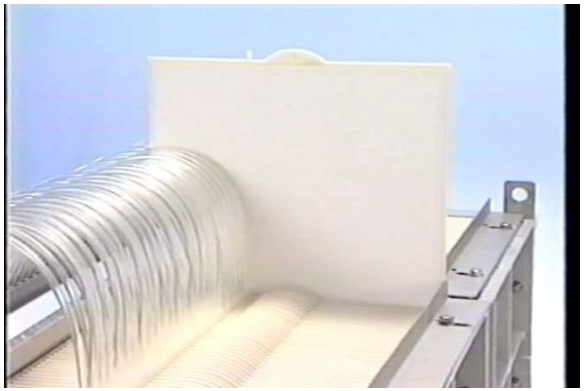


- **An MBT submerged membrane unit is used to create a physical barrier across which to extract clear water from sludge**
- **Air diffuser incorporated in lower part of cassette**

Membrane Thickener Facts

Membrane Thickener

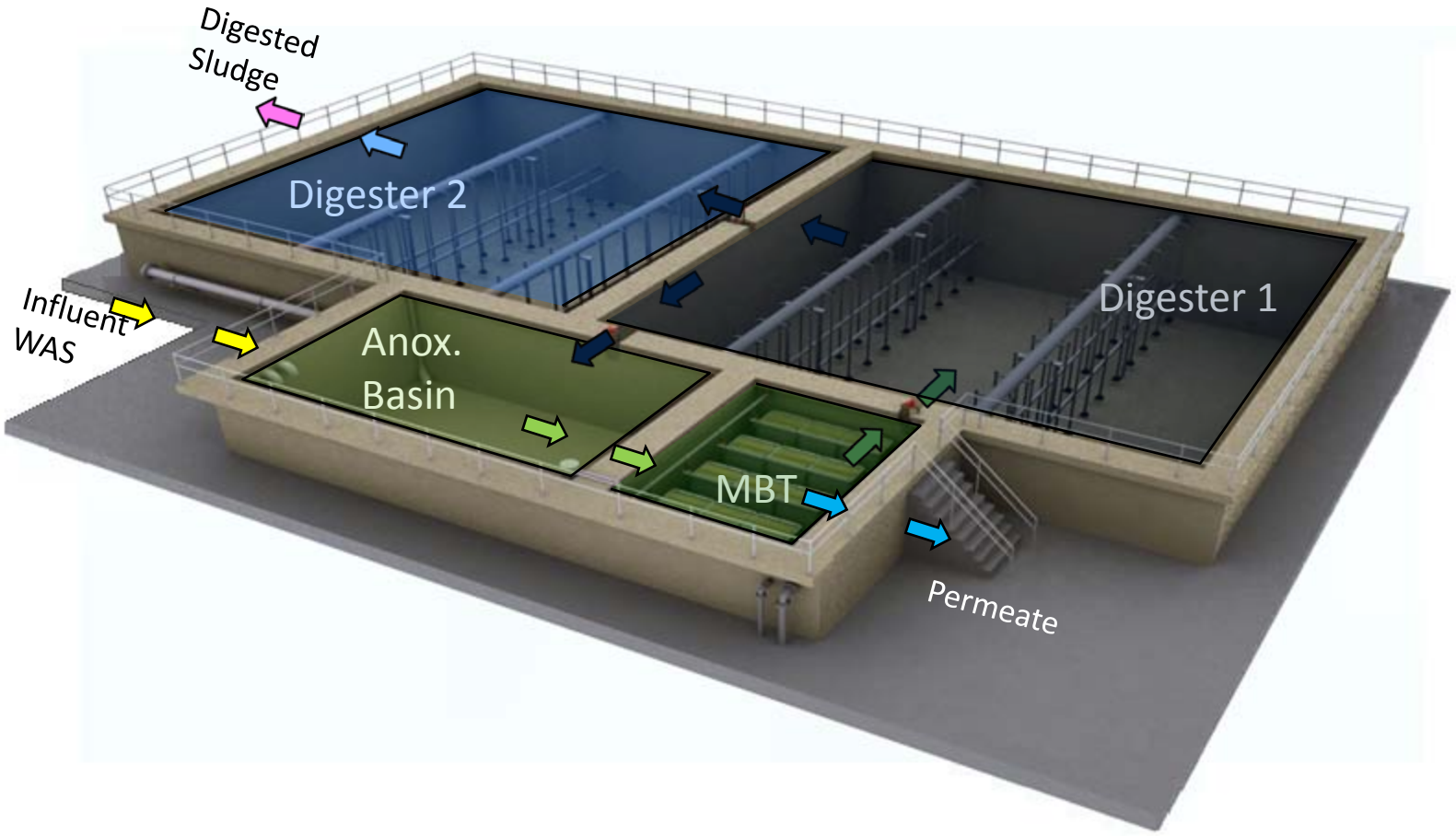




Kubota Membrane Thickener Facts:

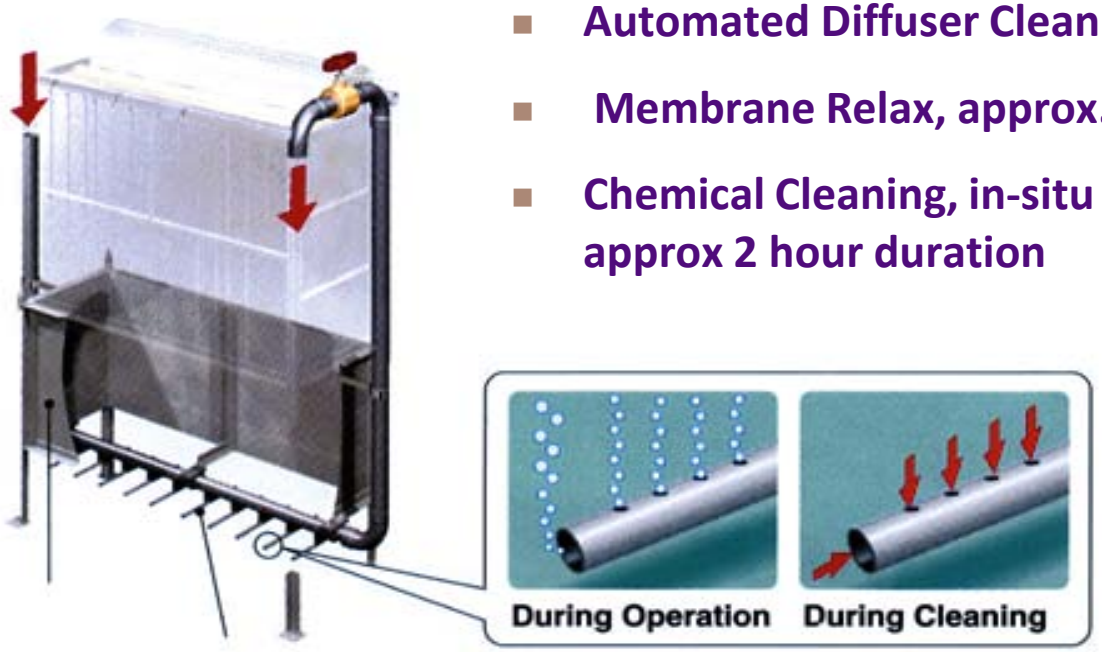
- **PE membrane ultrasonically welded to ABS plate Air diffuser incorporated in lower part of cassette**
- **Nominal pore size 0.4 micron, effective pore size 0.1 micron**
- **Effective filtration area 8.6 ft^2 per cartridge**
- **MBT Design flux 5 gfd @ 20° C**
- **MBT Cross flow velocity is 2.25 ft / sec**

The P.A.D®-K Process



Minimum Maintenance Of Membrane Thickener Requirements

Maintenance



- **Automated Diffuser Cleaning, approx. 30 min/day**
- **Membrane Relax, approx. 1min/10min**
- **Chemical Cleaning, in-situ clean every 6 months, approx 2 hour duration**

NO NEED TO DRAIN TANKS OR TAKE OUT OF SERVICE FOR CHEMICAL CLEANING!

Aerobic Digestion Chemistry

Aerobic Digestion is a biological process similar to Activated Sludge.

Activated Sludge = Growth

Aerobic Digestion = Decay

Process control is required to maintain healthy biomass

Aerobic Digestion Chemistry

1. Digestion:

$C_5H_7NO_2 + 5O_2 = 4CO_2 + H_2O + (NH_4HCO_3)$

Biomass — Ammonium Carbonate

2. Nitrification:

$NH_4^+ + 2O_2 = H_2O + 2H^+ + NO_3^-$

Ammonia — Acid — Nitrate

3. Digestion with Nitrification:

$C_5H_7NO_2 + 7O_2 = 5CO_2 + 3H_2O + HNO_3$

Biomass — Nitric Acid

Aerobic Digestion Chemistry

4. Digestion with Nitrification:

$C_5H_7NO_2 + 7O_2 = 5CO_2 + 3H_2O + HNO_3$

Biomass — Nitric Acid

5. Denitrification:

$C_5H_7NO_2 + 4NO_3^- + H_2O = NH_4^+ + 5HCO_3^- + 2N_2$

Biomass — Nitrate — Ammonia — Alkalinity — N Gas

6. Complete Nitrification / Denitrification:

$C_5H_7NO_2 + 5.75O_2 = 5CO_2 + 3.5H_2O + 0.5N_2$

Biomass — N Gas

Aerobic Digestion Chemistry

18% Oxygen Savings:

3. Digestion with Nitrification:

$$C_5H_7NO_2 + 7O_2 = 5CO_2 + 3H_2O + HNO_3$$

Versus

6. Complete Nitrification / Denitrification:

$$C_5H_7NO_2 + 5.75O_2 = 5CO_2 + 3.5H_2O + 0.5N_2$$

Aerobic Digestion Chemistry

pH Cycle:

1. Digestion: (pH UP)

$$C_5H_7NO_2 + 5O_2 = 4CO_2 + H_2O + NH_4^+ + HCO_3^-$$

2. Nitrification: (pH DOWN)

$$NH_4^+ + 2O_2 = H_2O + 2H^+ + NO_3^-$$

4. Denitrification: (pH UP)

$$C_5H_7NO_2 + 4NO_3^- + H_2O = NH_4^+ + 5HCO_3^- + 2N_2$$

Case Studies of Aerobic Digestion Processes with Membrane Thickening

Miyazaki WWTP, Japan

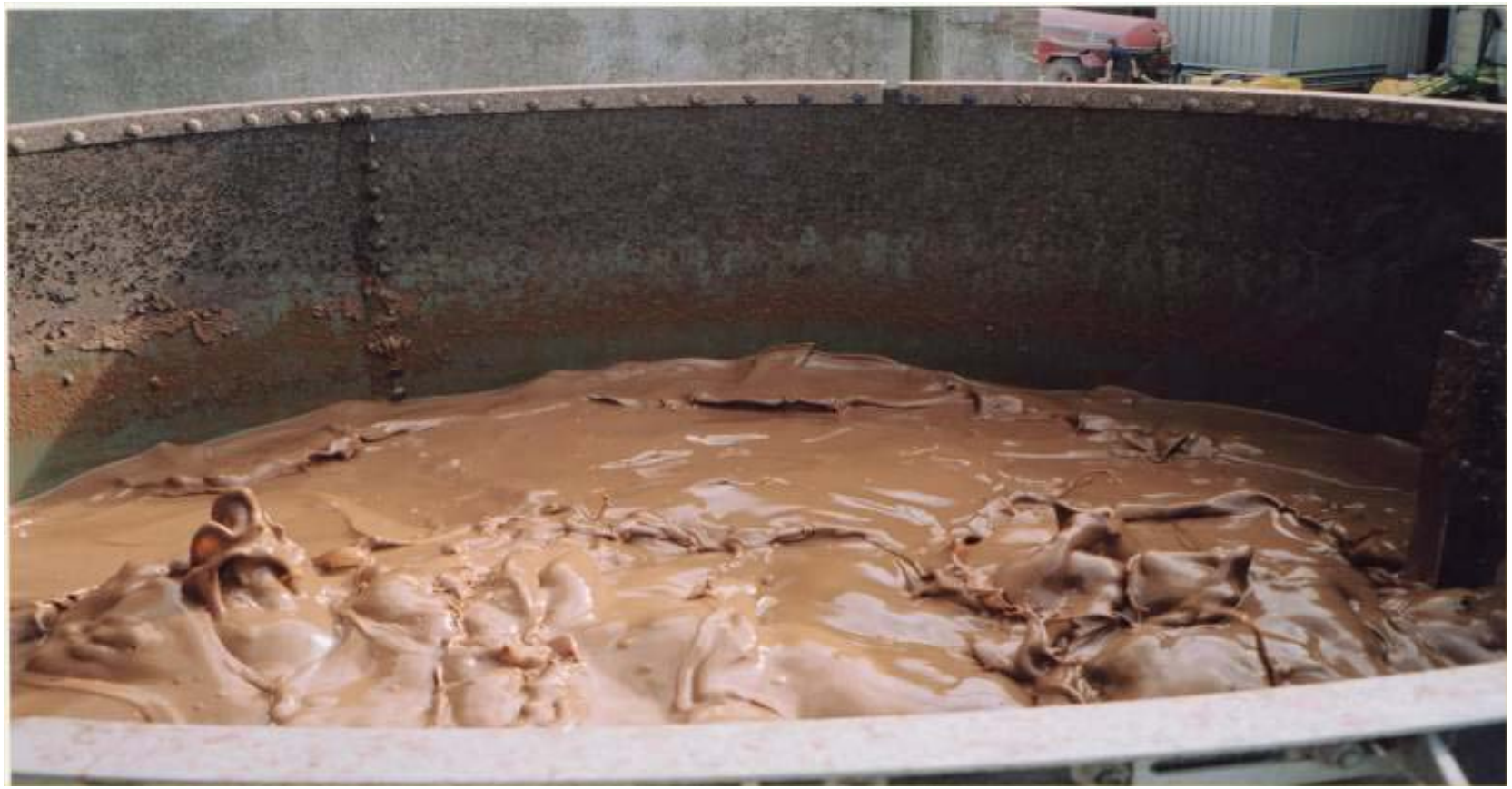
Oldest Installation using Membrane Thickener in the World (Since 1999)

Miyazaki WWTP, Japan

Commissioned:	**1999 (11 years)**
Waste Type:	**Municipal**
Liquid Process:	**SBR**
MBT Size:	**300 plates**
MBT Flux:	**5.3 gfd**
Air Scour:	**0.35 scfm/plate**
Solids Conc.:	**3.1%**
Chemical Cleaning:	**4 / year**
Diffuser Cleaning:	**30 min /day**

Minch Malt WWTP, Athy, Ireland

Oldest Ovivo Installation

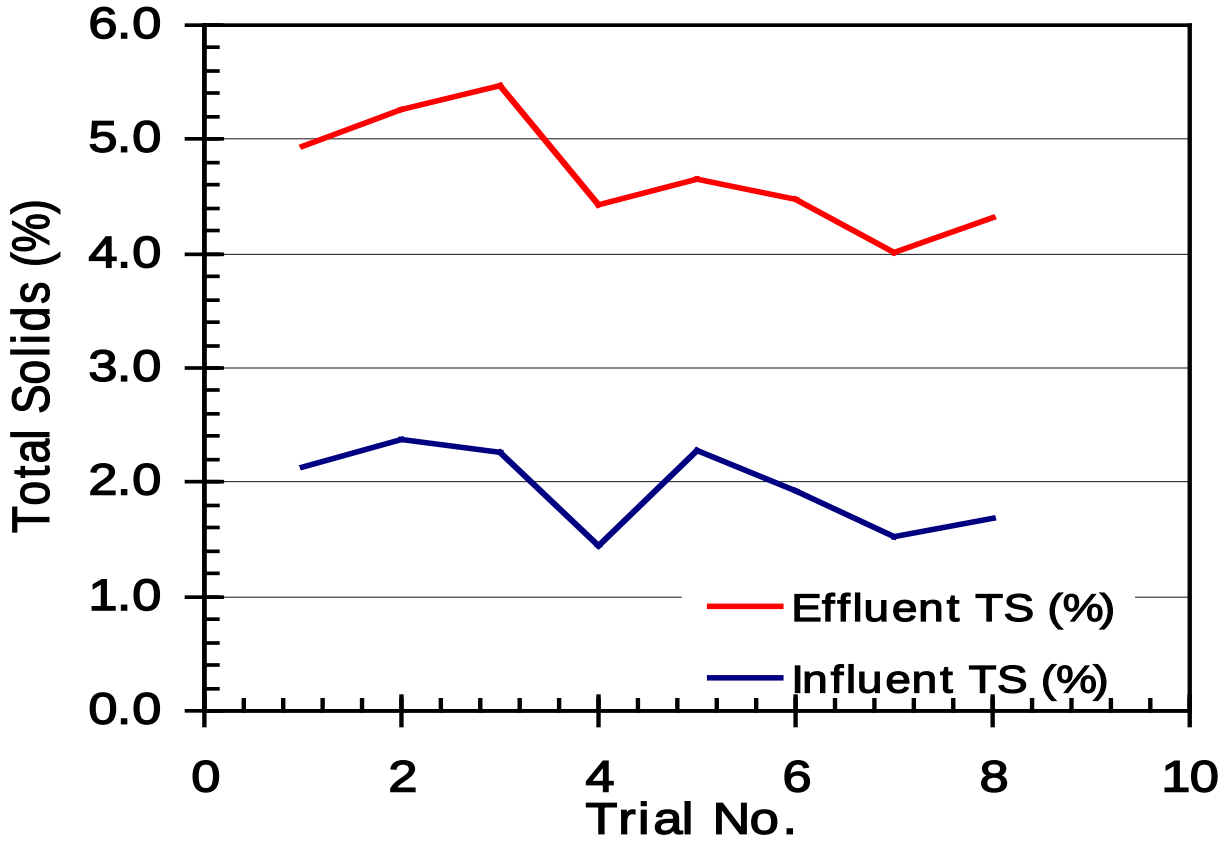


High Solids Concentration: 45,000 mg/L
Using Membrane Thickener (Since 2001)

Mitch Malt WWTP, Athy, Ireland

Commissioned:	**2001 (9 years)**
Waste Type:	**Industrial**
Liquid Process:	**MBR**
MBT Size:	**150 plates**
MBT Flux:	**3.9-9.6 gfd**
Air Scour:	**0.49 scfm/plate**
Solids Conc.:	**4%-5.5%**
Chemical Cleaning:	**2 / year**
Diffuser Cleaning:	**30 min / day**

Minch Malt WWTP, Athy, Ireland



Influent Flow – 11,900 gpd

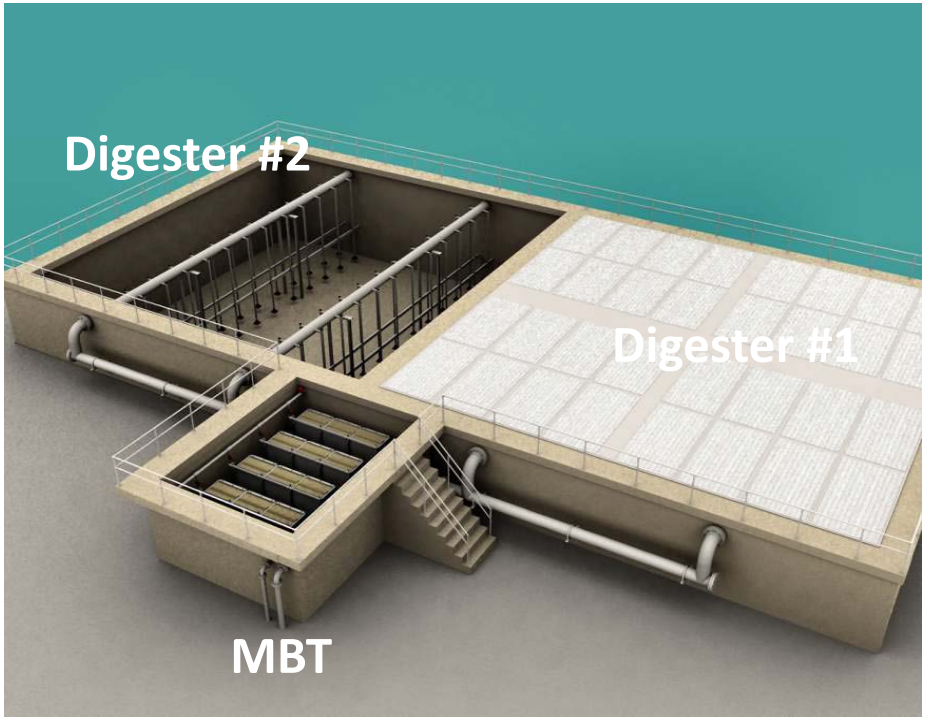
Dundee WWTP, Michigan

MBR and PAD®-K

Dundee WWTP, Michigan

Commissioned:	**2005**
Liquid Process:	**MBR (1.2 MGD)**
MBT Size:	**800 plates**
MBT Flux:	**4.5 gfd Design at 4.5 degrees C**
Air Scour:	**0.35 scfm/plate**
Solid Conc.:	**3%-5.25%**
Chemical Cleaning:	**2-3 / year (scheduled)**
Diffuser Cleaning:	**30-45 min / day**

Dundee WWTP, Michigan



Engineer: Arcadis

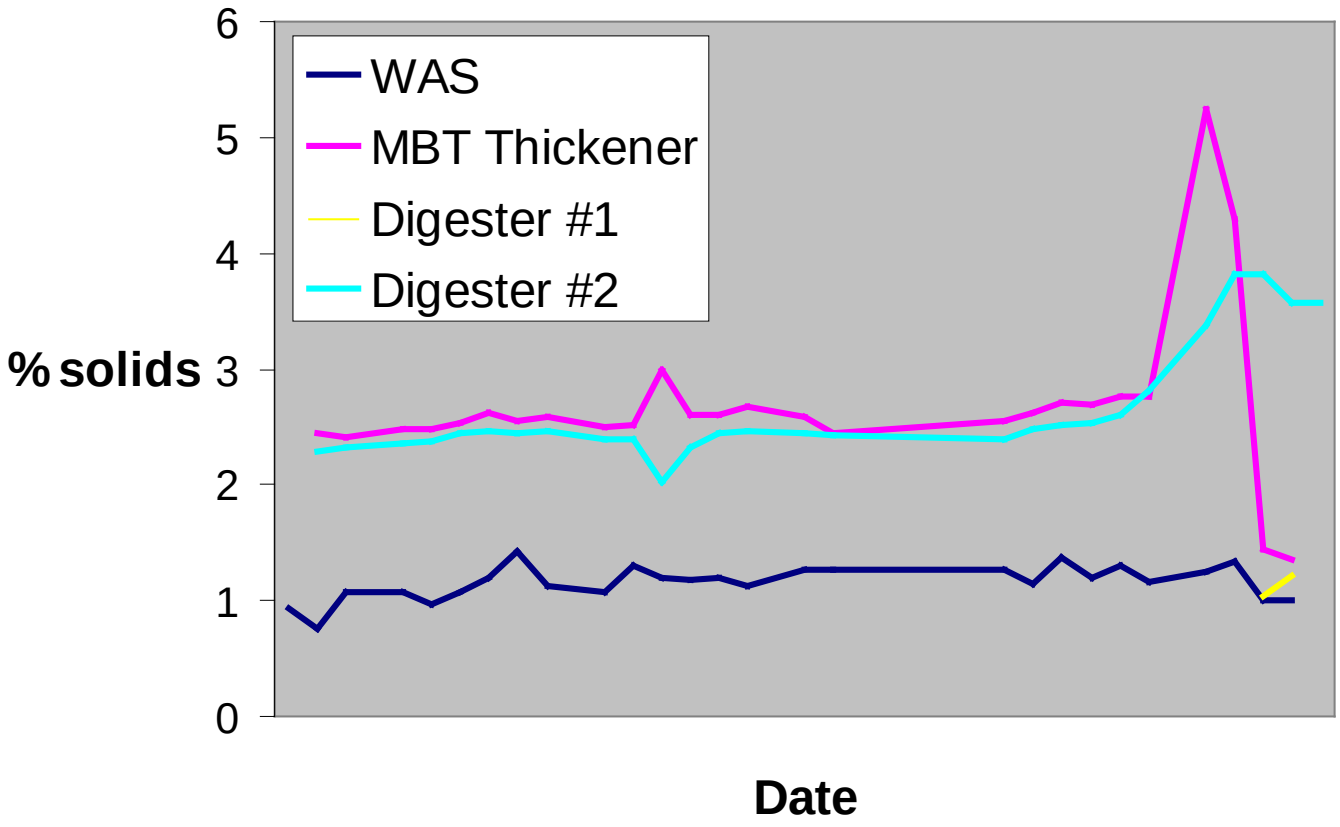
History:

- Objective was to reduce the hauling to 2 times per year. Tanks are designed to store 180 days at 3% solids.
- Operator friendly when compared to other systems.
- Enviroquip's Aerobic Digestion experience rated higher when evaluated against other vendors/technologies.

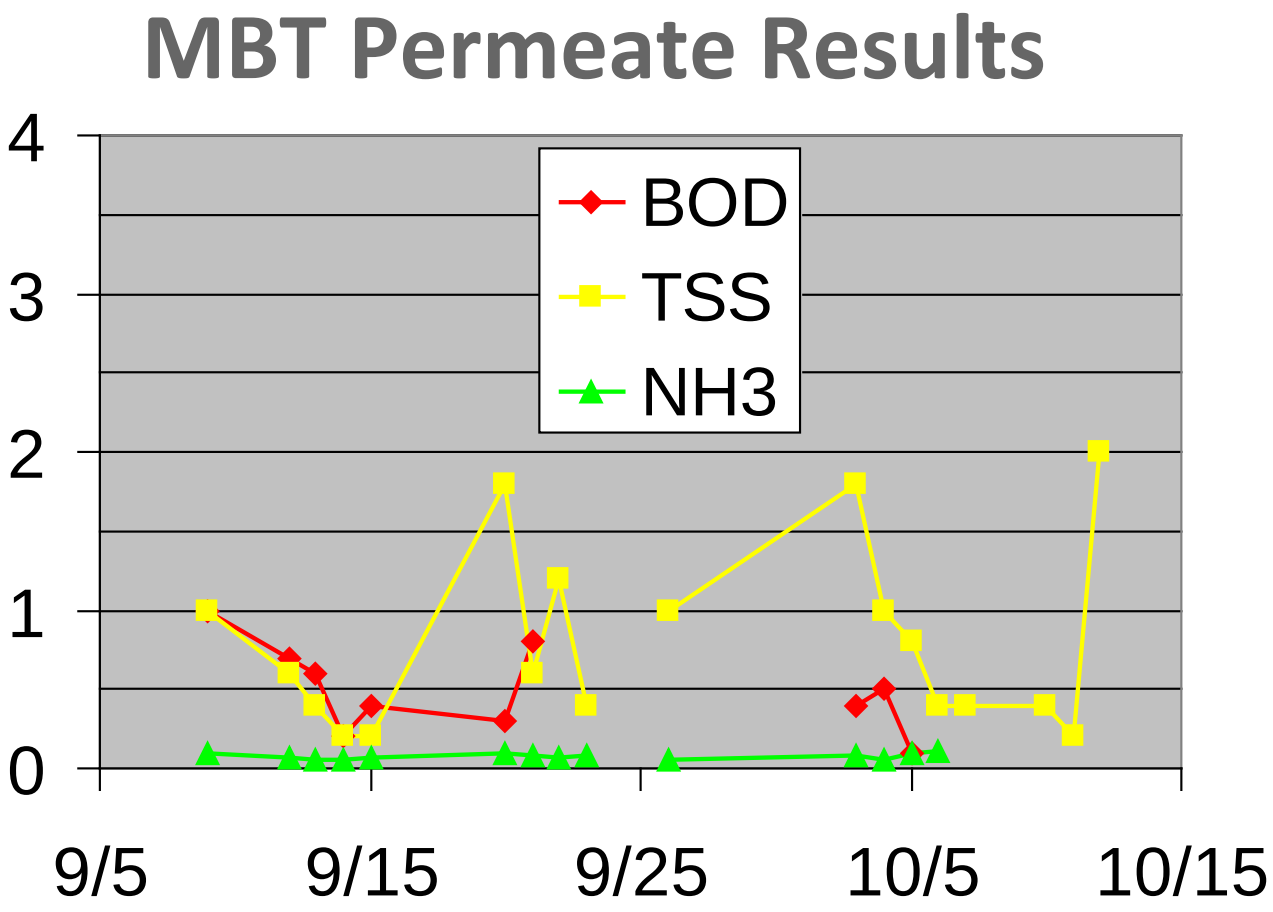
Dundee WWTP, Michigan

Thickening Performance

Sep & Oct 2005 Operation



Dundee WWTP, Michigan



January 2007 to June 2008 Data

Sustainable Permeate Quality

before it's blended with MBR effluent

BOD:	**1.12 mg/l**
TSS:	**2.00 mg/l**
NH_3-N:	**0.22 mg/l**
NO_3-N:	**0.03 mg/l**
TP:	**1.09 mg/l ***

*BioP MBR upstream

Dundee WWTP, Michigan Sludge Hauling Cost Summary

Years	Gallons Hauled	Dry Tons	Yearly Cost
2004 (0.6 MGD SBR)	248,885 – Belt 943,200 – Truck 1,192,100 - Total	22.67 – Belt 99.39 – Truck 122.06 - Total	$16,850 – Belt $30,088 – Truck **$46,938 - Total**
2005 (1.2 MGD MBR) MBT operational for 2nd half of year only	572,400 – Belt 432,000 – MBT 1,004,400 - Total	55.62 – Belt 47.55 – MBT 103.17 - Total	$39,135 – Belt $14,623 – MBT **$53,758 – Total**
2006	**887,400 - MBT**	**130.48 – MBT***	**$32,739 - MBT**

Belt press was needed for years 2003 -05 due to lack of storage space.

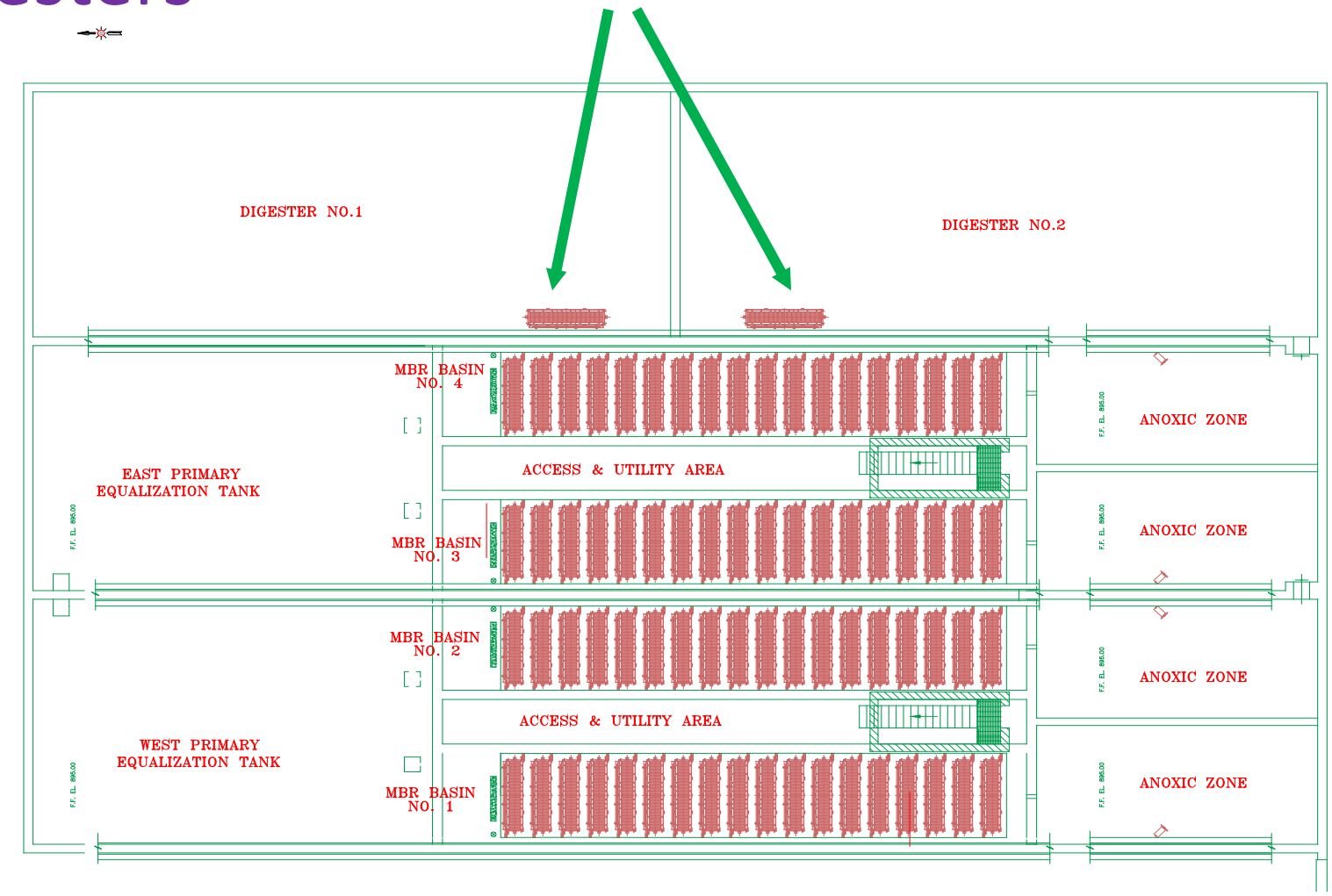
Sludge Hauling costs for first full year of operation of MBT in 2006 was $32,739 which is cheaper than the last 5 years

*** Sludge Production minimized due to N/DN**

McFarland Creek WWTP, Ohio
Engineer: CT Consultants

MBR and Two Stage PAD®-K

SMUs Installed Directly in Digesters



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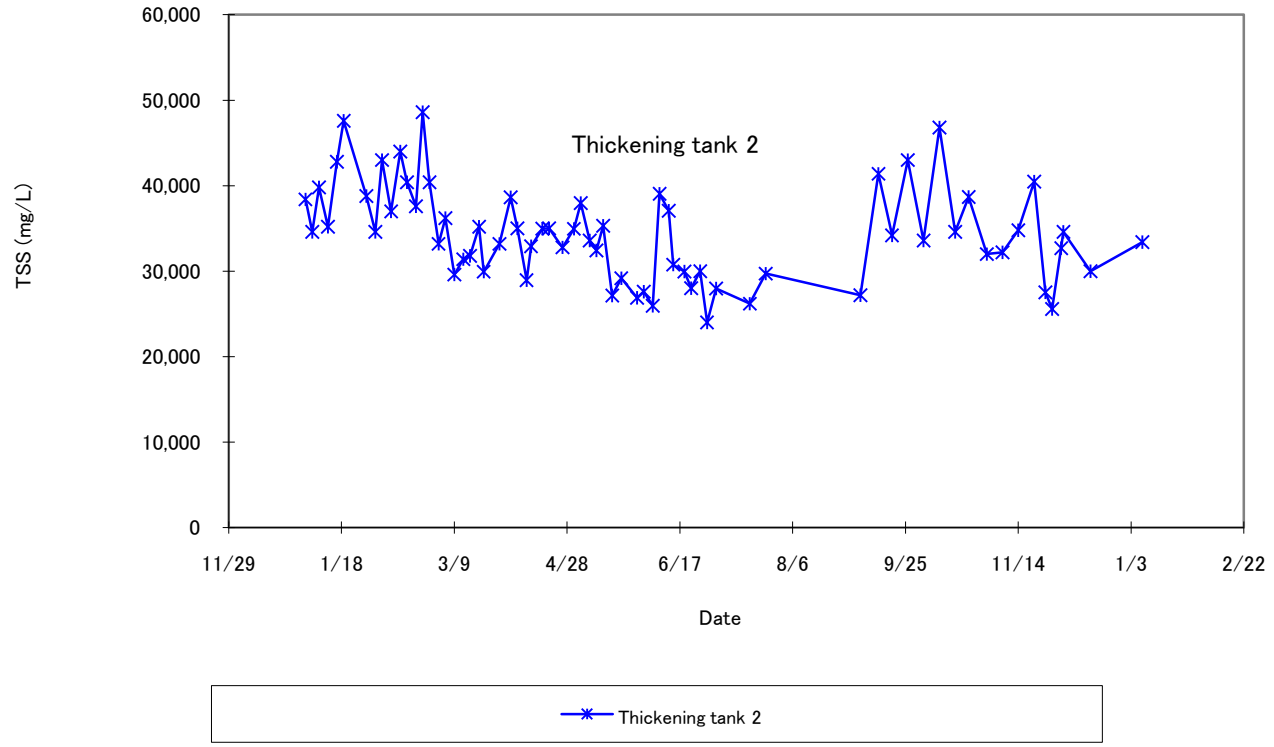
McFarland Creek WWTP, Ohio

Commissioned:	**2005 (5 years)**
Waste Type:	**Municipal**
Liquid Process:	**MBR (1.8 MGD)**
MBT Size:	**400 plates**
Air Scour:	**0.53 scfm/plate**
Solids Conc.:	**3.5%-5.5%**
Diffuser Cleaning:	**30 min / day**

McFarland Creek WWTP, Ohio



Membrane thickening at McFarland Creek WWTP was able to thicken up to 5% solids.

McFarland Creek WWTP BFP Results

Annual BFP run time w/o PAD®-K	8,736 hours
Annual BFP run time with PAD®-K	3,744 hours
Reduction BFP run time	57.14%

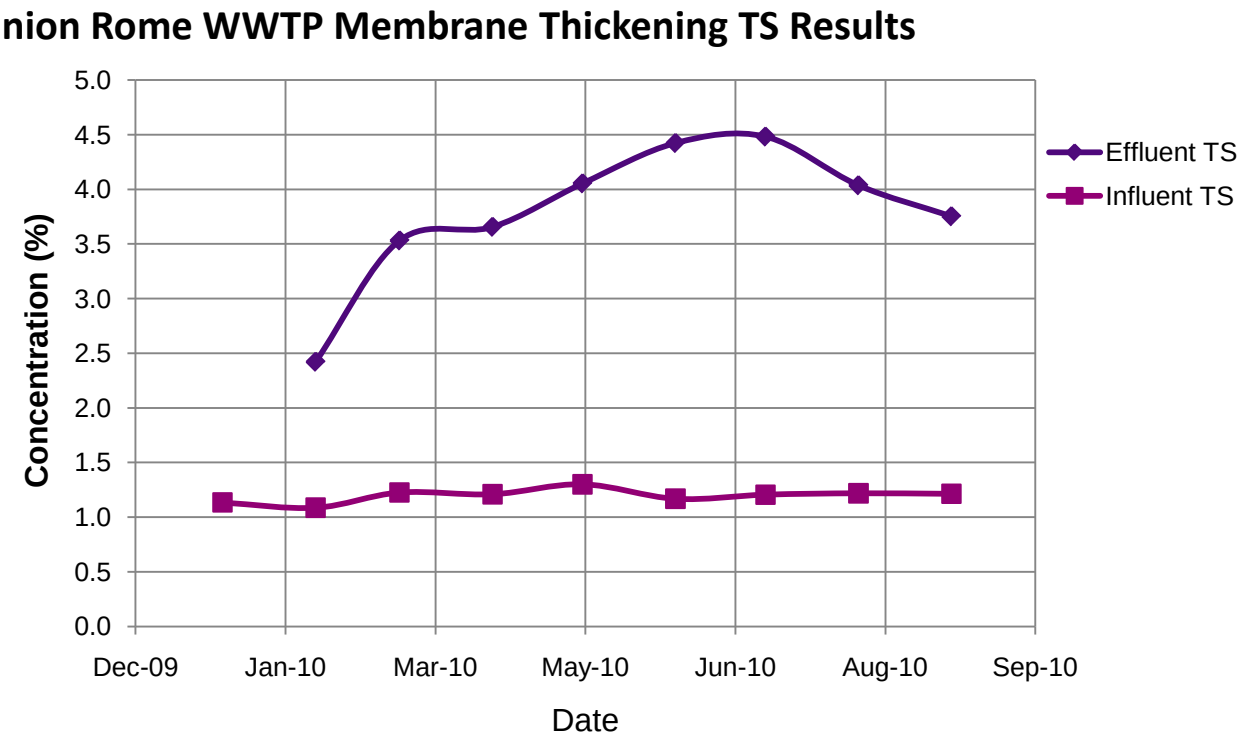
Union Rome WWTP, Ohio
Engineer: CT Consultants

MBR and PAD®-K

Union Rome WWTP, Ohio

Commissioned:	**2010**
Waste Type:	**Municipal**
Liquid Process:	**MBR**
MBT Size:	**1,000 plates**
Air Scour:	**0.53 scfm/plate**
Solids Conc.:	**3.5%-4.5%**
Diffuser Cleaning:	**30 min / day**

Union Rome WWTP, Ohio



The TS concentration was MORE THAN TRIPLED by thickening with membranes at Union Rome WWTP.

January 2010 to October 2010 Data

Sustainable Permeate Quality

after it's blended with MBR effluent

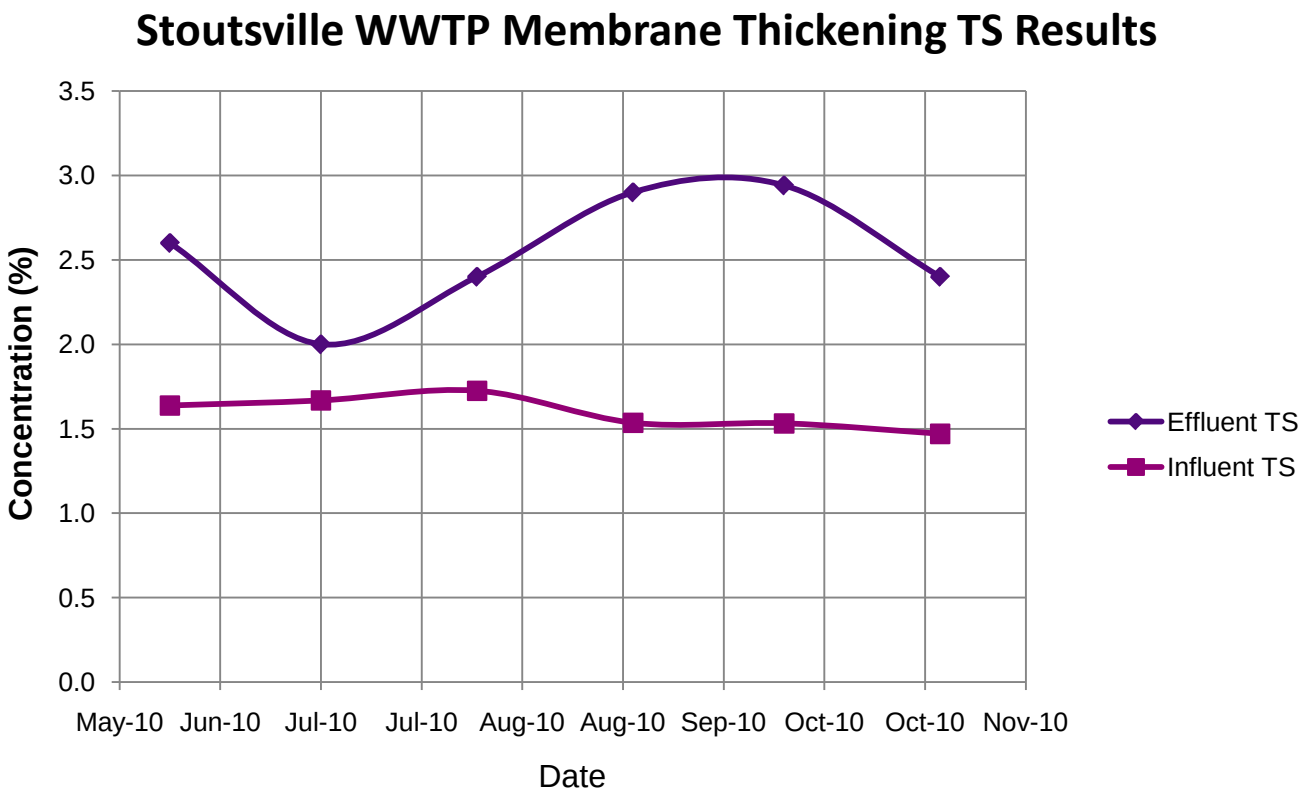
BOD:	**<1.0 mg/l**
TSS:	**<1.0 mg/l**
NH_3-N:	**<0.1 mg/l**
TP:	**<5.0 mg/l ***

*No BioP in the Liquid Process Upstream

Stoutsville WWTP, Ohio
Engineer: R.D. Zande

Commissioned:	**2006 (4 years)**
Plant Size:	**50,000 GPD**
Liquid Process:	**MBR**
MBT Size:	**50 plates**
Air Scour:	**0.53 scfm/plate**
Solids Conc.:	**2.5%-4.0%**
Chemical Cleaning:	**4 / year**
Goal:	**Reduce Sludge Hauling Trips**

Stoutsville WWTP, Ohio



Stoutsville WWTP Results

Avg. Annual Hauling Volume w/o MBT	208,000 gal.
Avg. Annual Hauling Trips w/o MBT	26
Avg. Annual Hauling Volume with MBT	136,000 gal.
Avg. Annual Hauling Trips w/o MBT	17
Reduction of sludge being hauled	34.61%
Reduction of hauling trips	34.61%

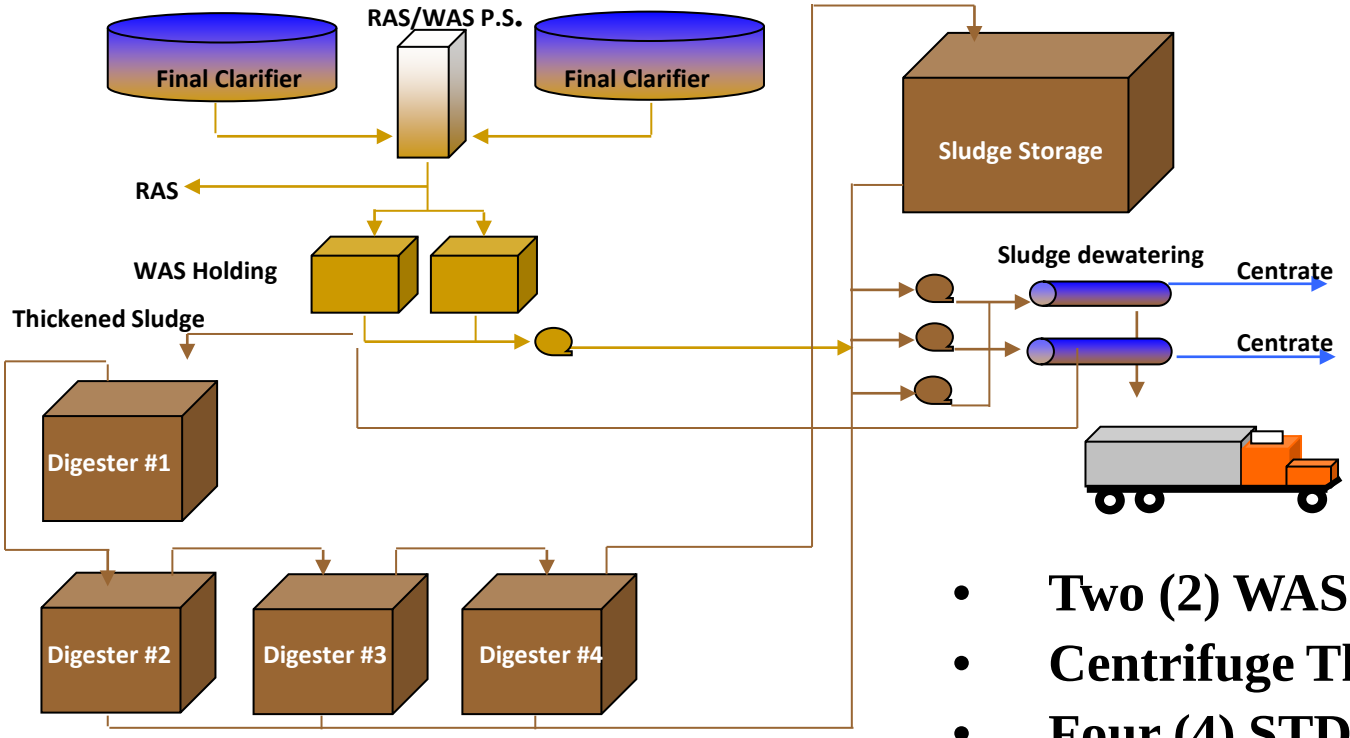
Case Studies of Membrane Thickening following Conventional Activated Sludge Processes

First Installation in 2005

East Dundee, IL Project Background
Engineer: Trotter and Associates

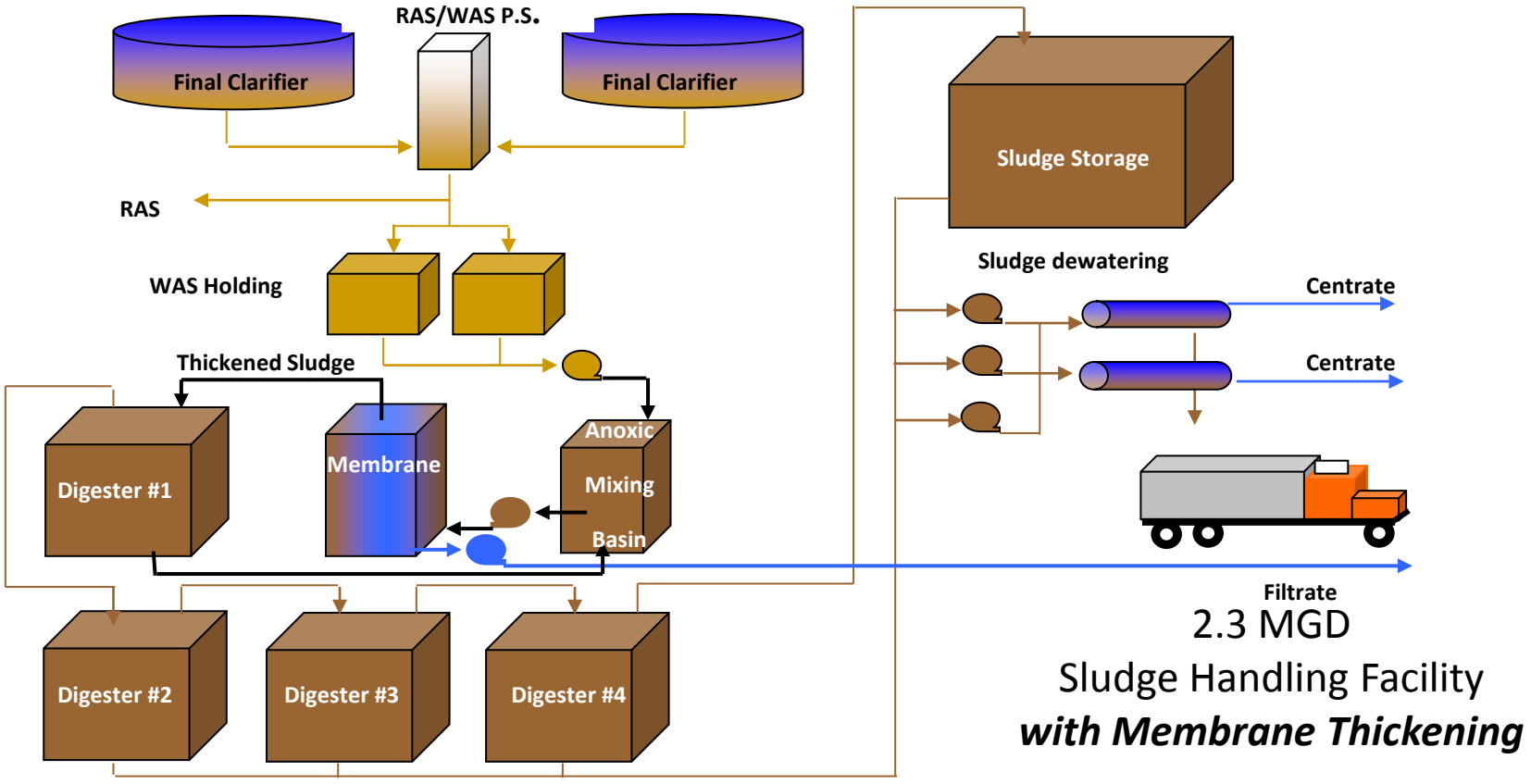
- **1.15 MGD Oxidation Ditch Extended Aeration Facility - 1998**
- **2.30 MGD expansion to include Membrane Thickening- 2003**

East Dundee, IL Sludge Handling



- **Two (2) WAS Holding Tanks**
- **Centrifuge Thickening**
- **Four (4) STD Aerobic Digesters**
- **Sludge Holding Tank**
- **Centrifuge Dewatering**

East Dundee, IL Expansion



2.3 MGD

Sludge Handling Facility

with Membrane Thickening

Also added Fine Screen on top of Anoxic Tank

East Dundee WWTP, Illinois Expansion

Issues and Solutions after Carrousel MD Installation

1. Centrifuges Relied on for Double Duty
   - **Install Dedicated Membrane Thickening System**
2. Fine Bubble Diffuser System could not handle 4% solids
   - **Replace Fine Bubble Membranes w/ Medium Bubble**
3. Increased Solids Loading Due the Expansion & BNR
   - **Operate at Higher Temperature**
4. Digestion Facility Being Operated in Batch Mode
   - **Reconfigure for Continuous Process**

Case Study

Arlington, WA

1.68 MGD SBR Facility (2004)

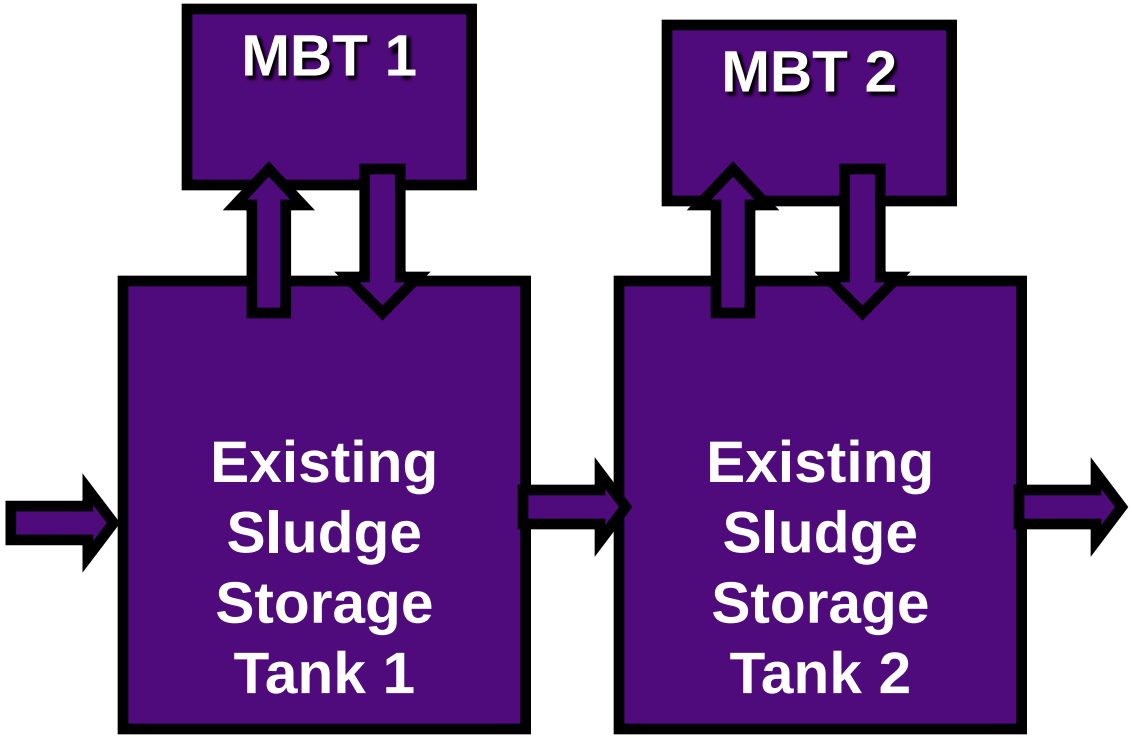
(4000 to 6000 mg/l feed)

Evaluation of Short-Term Methods

for Handling Solids

By Kennedy/Jenks Consultants

Arlington WWTP, Washington



Arlington WWTP, Washington

Table 2: Comparison of Sludge Thickening Alternatives

Parameter	Gravity	Dissolved Air Flotation	Centrifugal	Gravity Belt	Rotary Drum	Membrane
Operation	Continuous	Continuous or Intermittent	Intermittent	Intermittent	Intermittent	Continuous
Continuous Monitoring Required?	No	No	Yes	Yes	Yes	No
Typical Thickened Solids Concentration	2-3%	3-4% (up to 5% with polymer)	4-6%	4-7%	3-9%	2-3%
Typical Solids Capture Efficiency	Up to 99%	85-95% (up to 99% with polymer)	95-99%	95-98%	93-99%	100%
Performance with WAS	Fair	Fair to Good	Good	Good	Variable	Fair to Good
Estimated Eqpt. Space Requirements[a]	36' Diameter	9.5' x 32'	4'x14'	9' x 20'	15' x 6'	13'x14'
Operational Costs	Low	High	High	Medium	Medium	Low
Odor Control	Odor potential unless covered	Odor potential unless enclosed in building	Enclosed process and in building	Odor potential unless enclosed in building	Odor potential unless enclosed in building	Limited odor potential due to continual aeration
Budgetary Equipment Cost[a]	$205,000 (uncovered tank)	$290,000	$305,000	$100,000	$125,000	$230,000
Installation	In-tank	Building space optional	Building space required	Building space required	Building space required	Skid mounted
Polymer Required?	No	Optional	No	Yes	Yes	No
Capacity (gpm)	70 - 100	70	200	300	250	70
Equalization Needed?	No	Yes	Yes	Maybe	Yes	Yes
Ease of Operation/ Maintenance	Simple	Moderate	Complex	Moderate	Moderate	Simple to Moderate

Source: Report by Kennedy-Jenks Consultants

Arlington WWTP, Washington

Table 4: 20-Year Life Cycle Cost Comparison

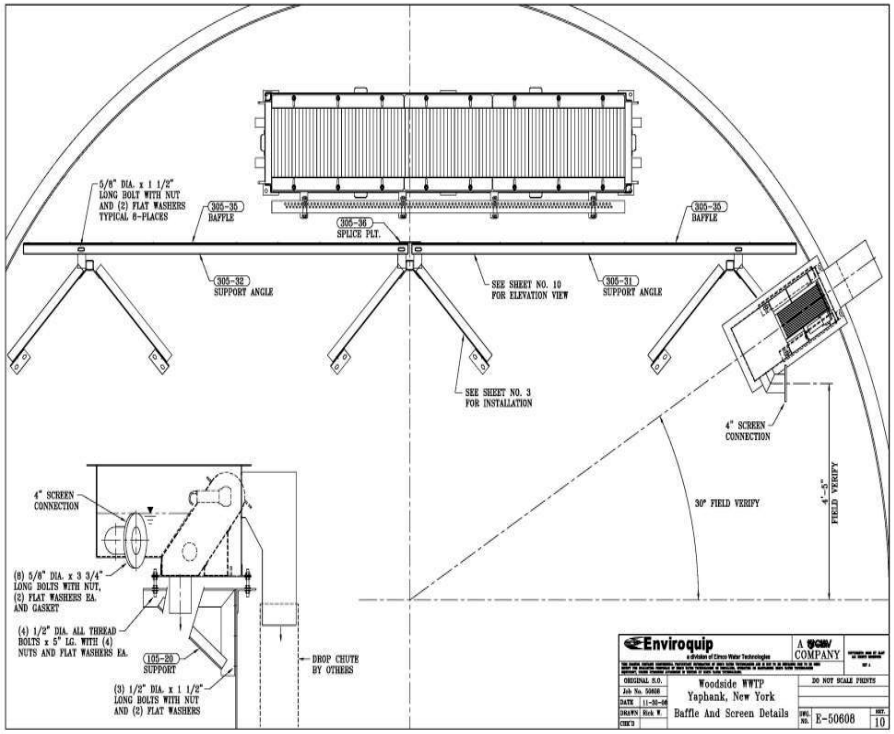
Parameter	Units	Gravity Belt Thickener	Membrane Thickener
Design Parameters			
Target Thickened Sludge Concentration	%	4	3
Design WAS Flow	gpd	103,000	103,000
Design Solids Loading	lbs/day	4,100	4,100
Labor Cost			
Weekly Labor	hrs/week	18	7
Labor Rate	$/hr	$40.00	$40.00
Annual Labor Cost	$	$37,400	$14,600
Power Cost			
Power Requirement	HP	12	20
Daily Runtime	hrs/day	8	24
Power Use	kWh/day	72	358
Power Cost	$/kWh	$0.07	$0.07
Annual Power Cost	$	$1,800	$9,100
Polymer Cost			
Polymer Use	lbs/dry ton	5	0
Polymer Cost	$/lb	$2.00	$2.00
Annual Polymer Cost	$	$7,500	$0
Maintenance Cost			
Annual Equipment Maintenance Cost	$	$2,000	$4,300
Annual Membrane Replacement Cost	$	$0	$1,600
Total Annual Maintenance Cost	$	$2,000	$5,900
Annual O&M Cost Estimate		$48,700	$29,600
Capital Cost Estimate		$839,000	$1,115,000
20-year Life Cycle Cost		$1,813,000	$1,707,000

Note:All costs are in 2005 dollars.

vs. actual 14 lbs/ DT or $13,500 more per year
or $270,000 more @ 20 Yr life cycle cost

Source: Report by Kennedy-Jenks Consultants

Woodside WWTP, New York
Biological Process: Concentric Circular Plant
GOAL: Reduce number of sludge hauling trips



Less gallons to haul per year:

Sludge hauling reduction 625,783 gal.

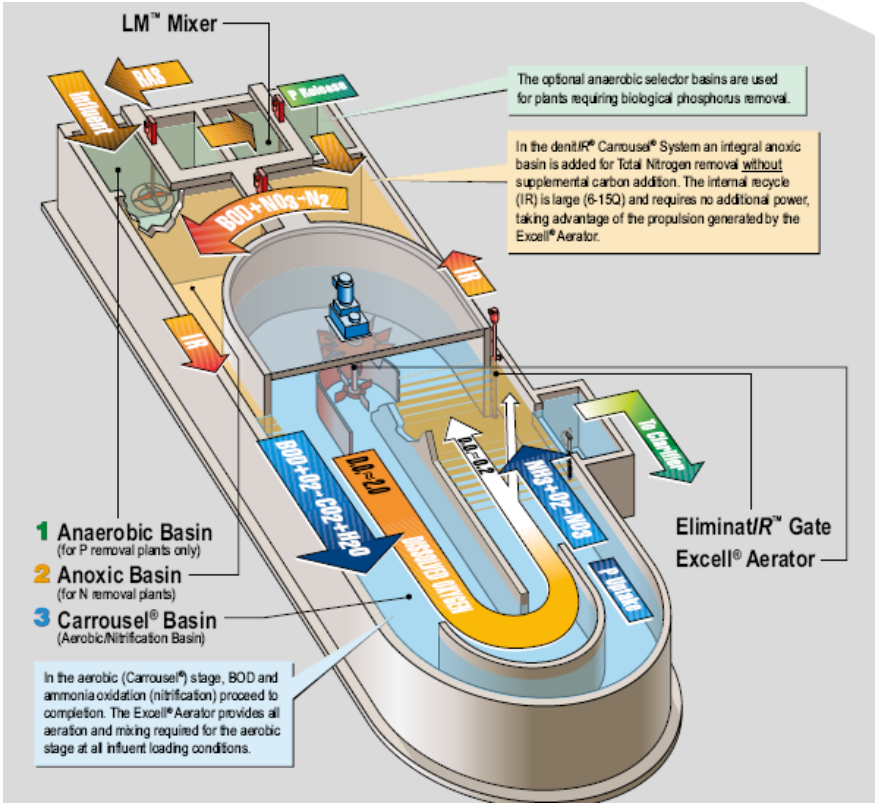
Savings per year $59,449

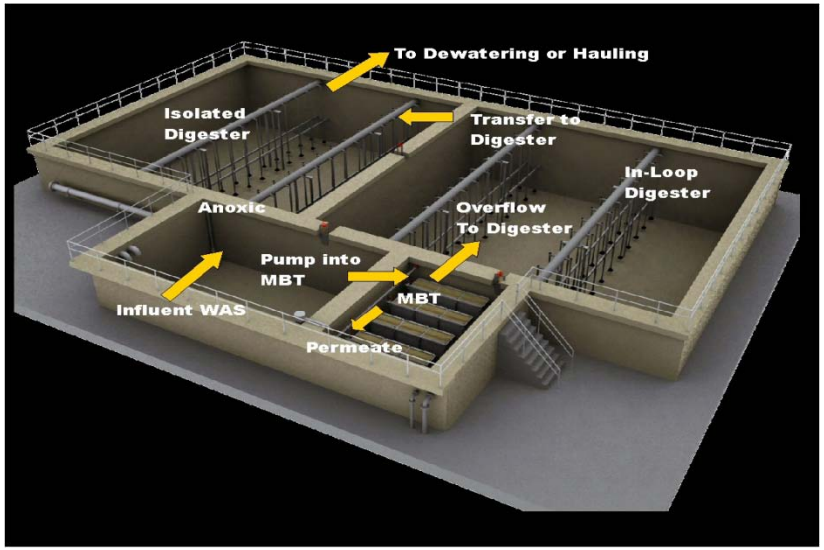
ROI of 2.57 years based solely on hauling

Carrousel MD :

Carrousel Biological Process Followed by Membrane Thickening Digestion

Carrousel + **Membrane Digestion**

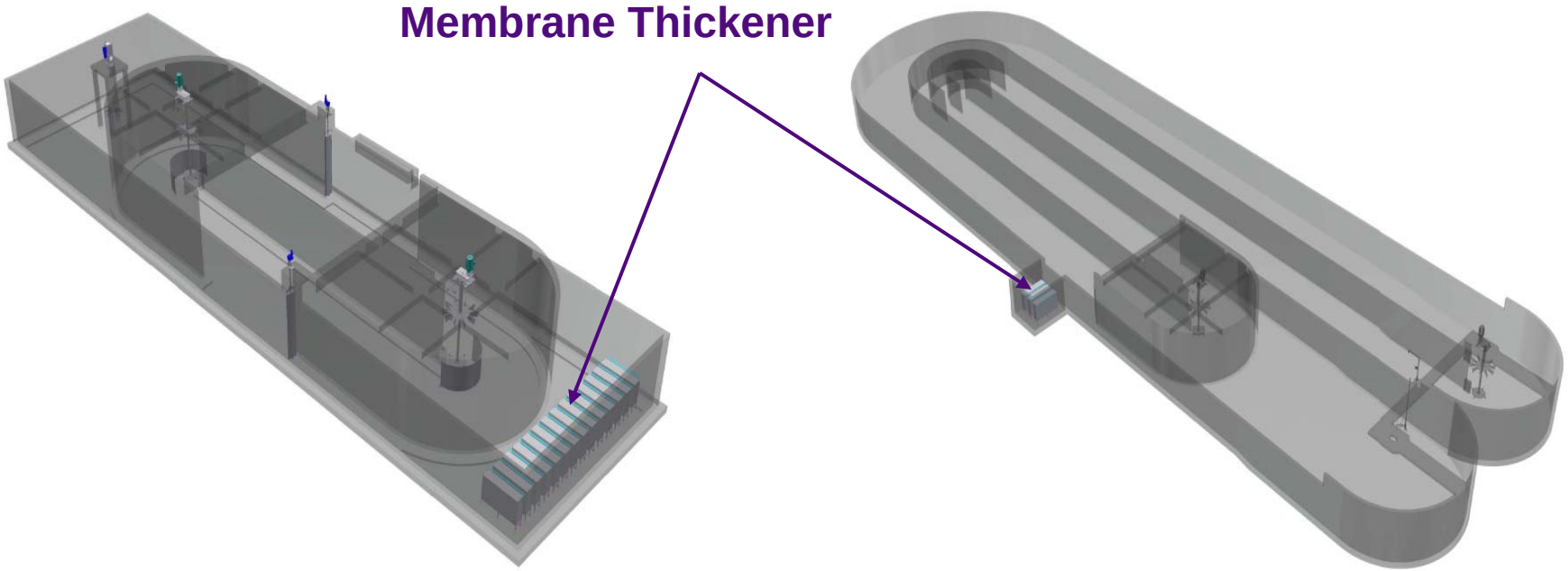




Carrousel MD :

Carrousel Biological Process Followed by Membrane Thickening Digestion

Conversion of Existing Carrousel with 2 Ditches



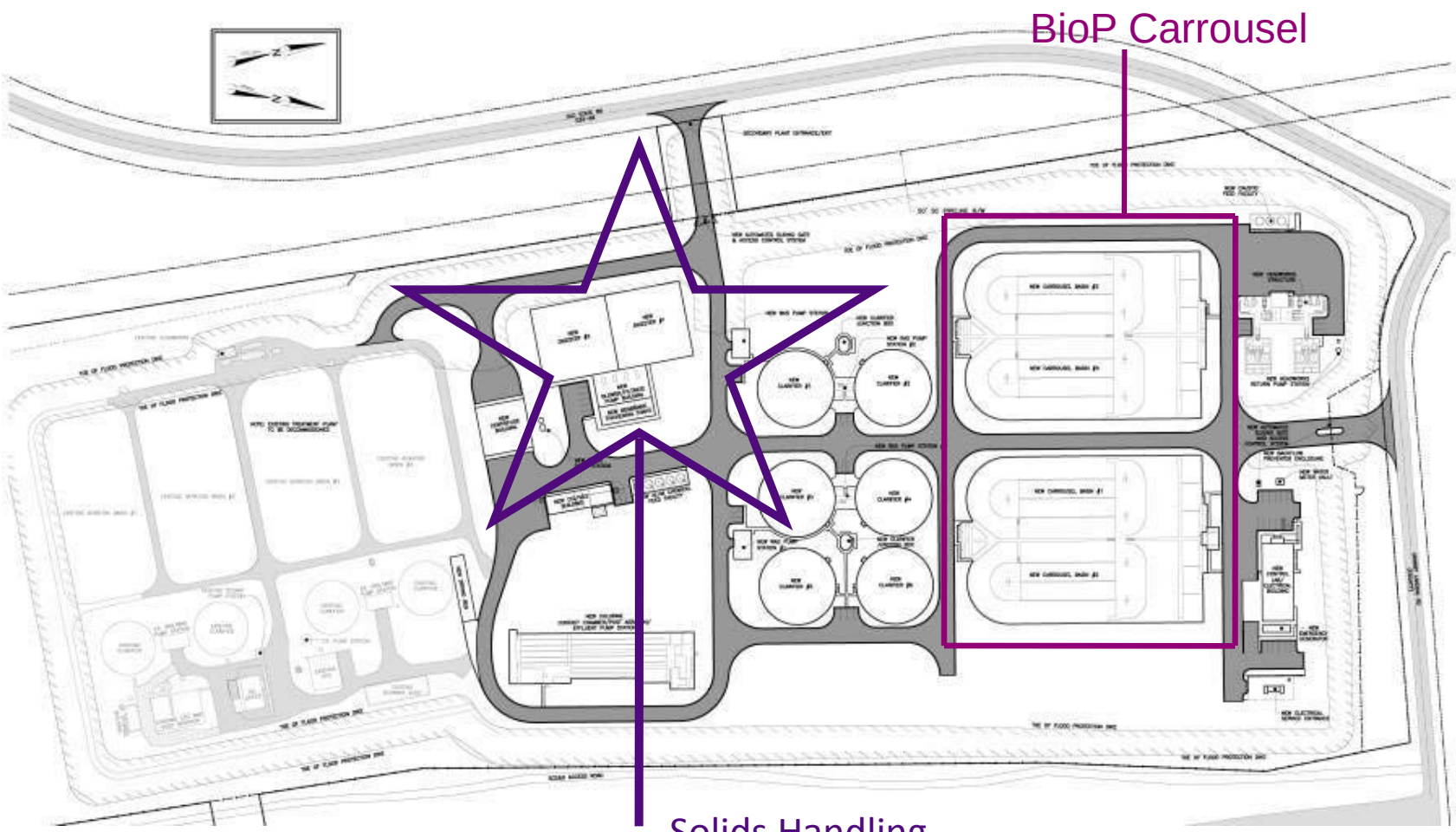
Cayce WWTP, South Carolina
Engineer: American Engineering Consultants

Carrousel MD: Coming To A Theatre Near You

Current Site
8 MGD Cap.
To be expanded to 25 MGD

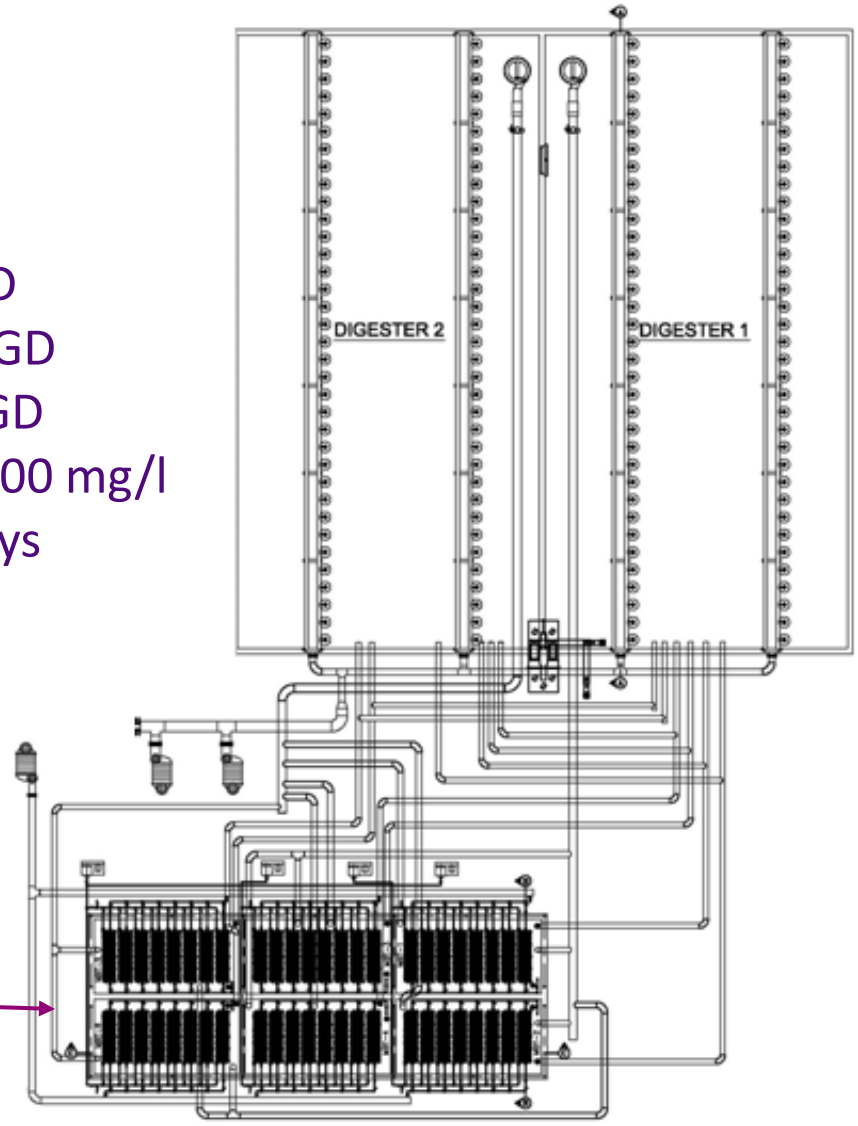
Carrousel MD selected to protect BioP Carrousel Ditch

Cayce WWTP, South Carolina Layout at 25 MGD



Cayce WWTP, South Carolina Carrousel MD

Start-up Plant Flow=	8 MGD
Intermediate Plant Flow=	12 MGD
Design Influent Plant Flow=	25 MGD
WAS concentration=	<10,000 mg/l
Design digestion SRT=	20 days



Membrane modules in Series

Cayce WWTP, South Carolina Carrousel MD

Benefits:

- **Eliminated Construction of a thickener building**
- **Reduced number and size of digesters by operating at 4% TS**
- **Provided flexibility for a gradual flow increase.**
- **Reduced O&M costs by eliminating use of polymer for thickening**
- **Reduced O&M costs due to lesser aeration / energy needs.**
- **Reduced O&M costs due to lesser supervision needs.**
- **Safeguard high quality BioP Carrousel effluent**

Conclusions

- **Aerobic digestion processes using membrane thickening offer superior thickening performance without the use of polymer compared to other technologies**

- **Membrane thickening processes require very minimal operator attention**

- **Permeate produced from membrane thickening processes contain very low nutrient levels and can be sent to disinfection or to the head of the plant without compromising the performance of upstream BNR activated sludge processes.**

- **Membrane thickening processes feature many financial benefits such as savings on hauling cost, operating cost, energy costs, and ideal for retrofits eliminating cost of building new tanks.**

Aerobic Digestion using Membrane Thickening is SOS,

Sustainable Operating Solution

Questions

ANY QUESTIONS?

Thank You

THAT'S ALL FOLKS!