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What you can't see in your Digesters can Hurt You... (or at least your Plant's Performance)



John L. Willis, Ph.D.,
P.E., BCPE, WEF Fellow
770.361.6431
JWillis@BrcwnCald.com

With acknowledgements (for prior efforts) to:

Peter Planelli and Lou Carfo (former NYC DEP);
Taft McNeal (Nashville Metro); and Perry Schaffer,
Gary Newman, Steve Krugel, Tom Chapman,
Chris Muller, Dante Fiorino, and Nancy Andrews (BC)

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Summary Agenda

- Digester Low-specific Gravity Stratification
- How do we know it's happening?
- What to do about it?
- Floating Cover Fugitive Methane
- Storage Tank Fugitive Methane
- Conclusions

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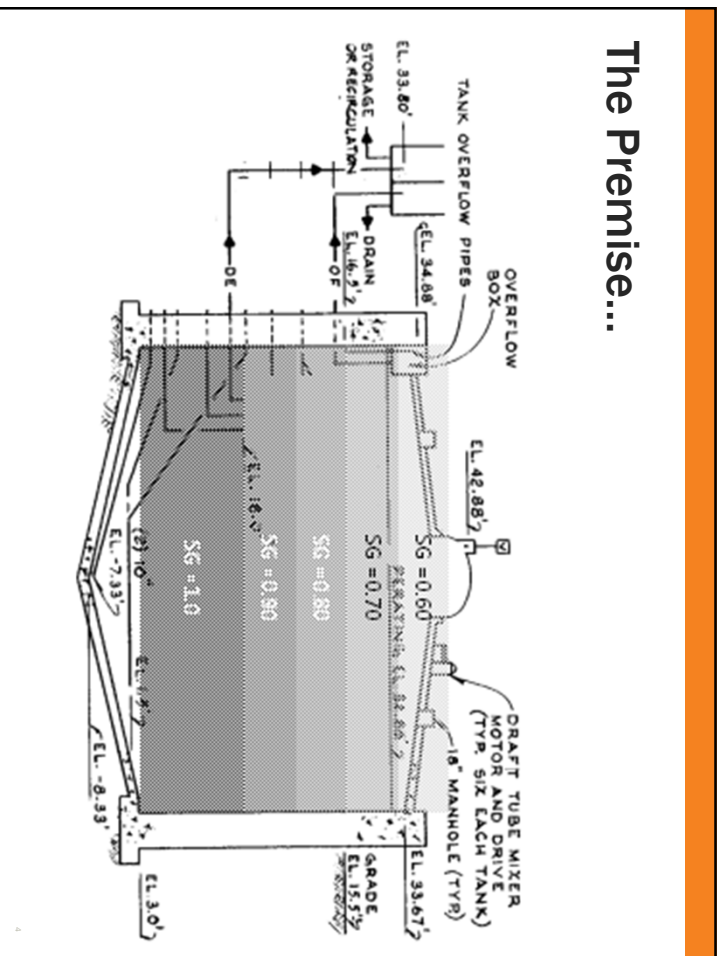
Digester Low-specific Gravity Stratification

Date or speaker or subtitle

Brown and Caldwell

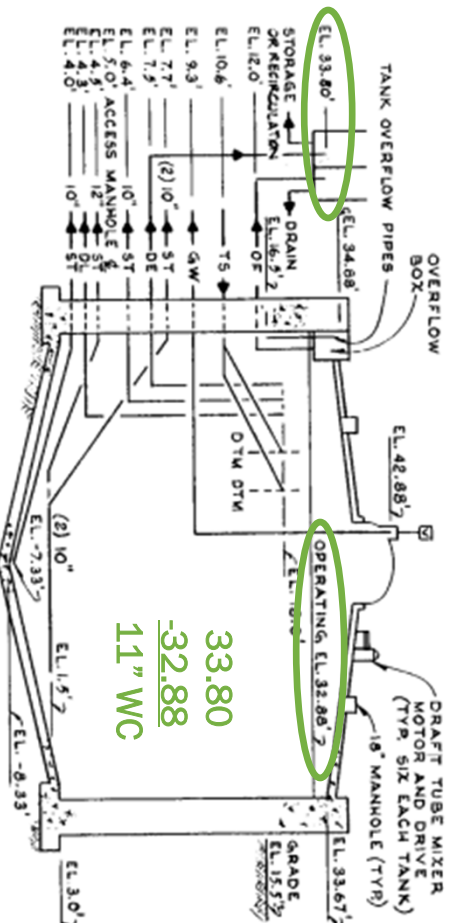
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The Premise...



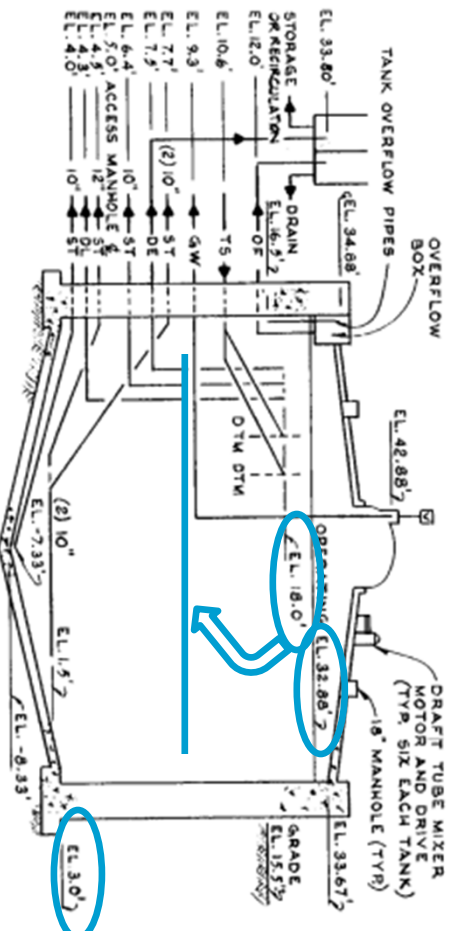
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AND these are everywhere, BTW...



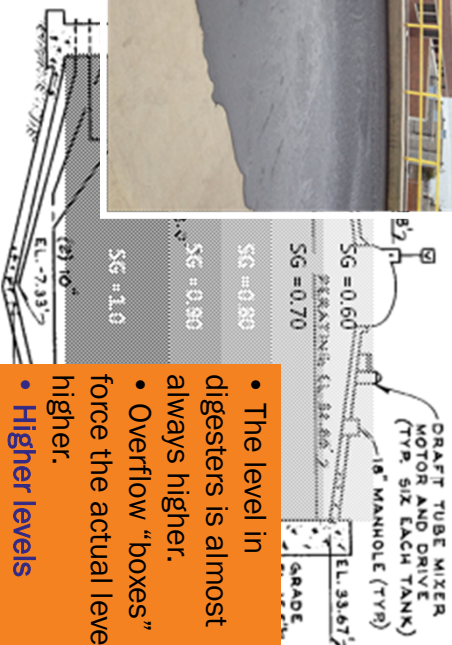
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Just to Note: Draw-off is actually here:



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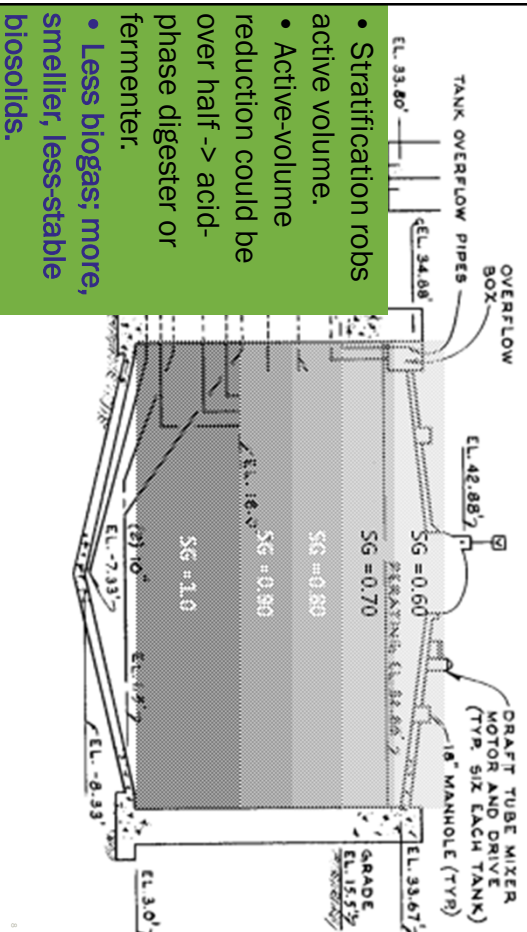
What does this cause???



- The level in digesters is almost always higher.
- Overflow "boxes" force the actual level higher.
- Higher levels create foaming episodes.

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What does this cause???



- Stratification robs active volume.
- Active-volume reduction could be over half -> acid-phase digester or fermenter.
- Less biogas; more, smellier, less-stable biosolids.

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What does this cause???

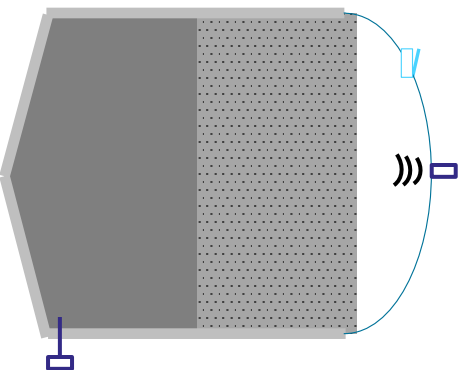


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How do we know it's
happening?

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OWASA (Chapel Hill, NC) Measurements

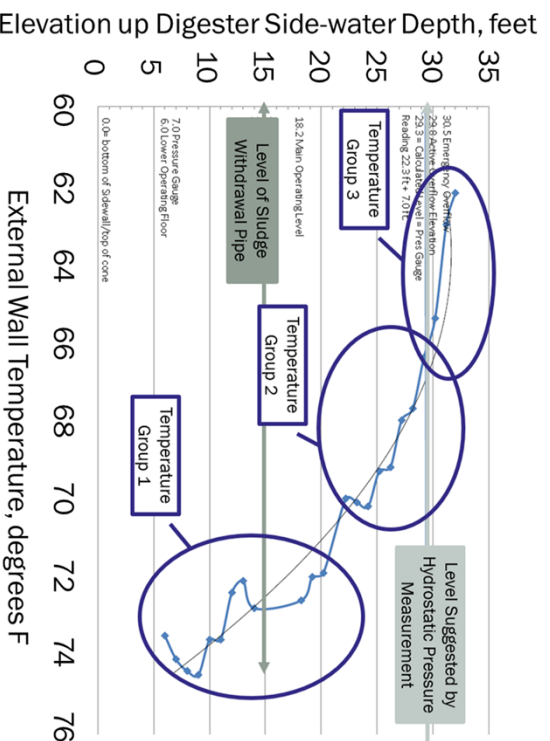


	1 st Stage	2 nd Stage	3 rd Stage
Pressure (ft WC)	22.6	19.3	15.8
Radar Surface (ft WC)	30.4	23.3	19.0
Difference (ft)	7.8	4.0	3.2
Specific Gravity	74.5%	82.6%	83.2%

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Tallman Island External Wall Temperature



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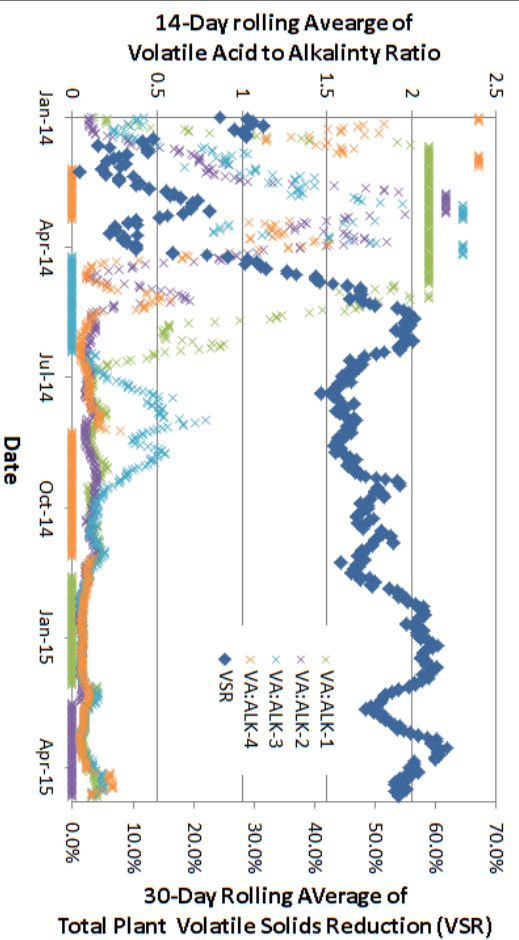
Owls Head Conversion Performance

Cautioned that
surface wasting
 was **NOT** the only
 digester
 enhancement



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Owls Head Conversion Performance

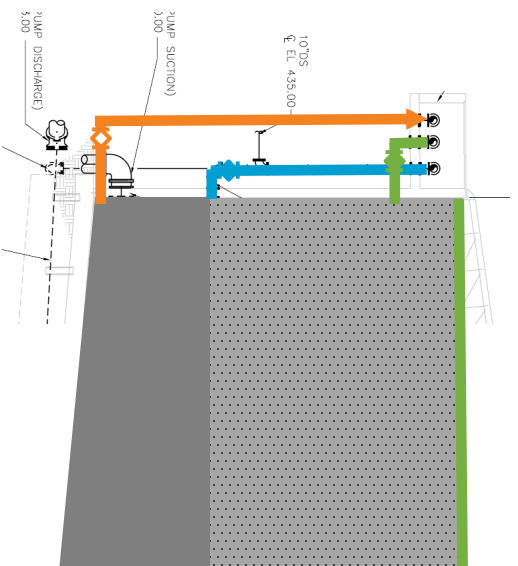


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What can we do about it??

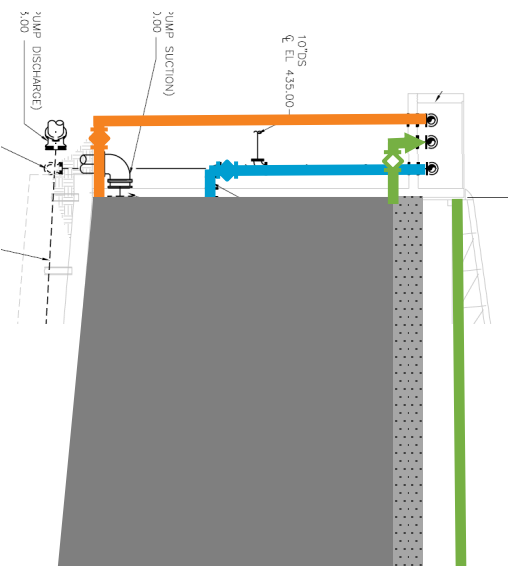
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For some Tanks, the “Fix” is **FREE**



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Solution at Owls Head

Add surface-wasting
“extension piping”
during your next
digester outage

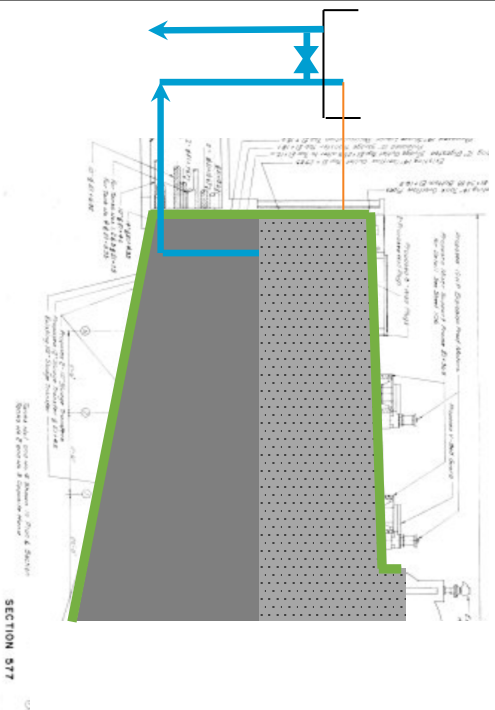


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Brown and Caldwell

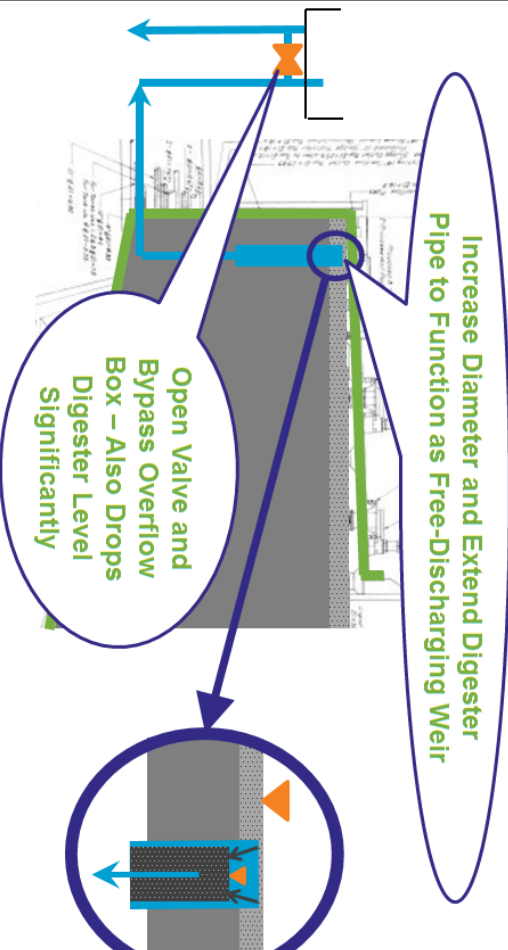
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Hunts Point

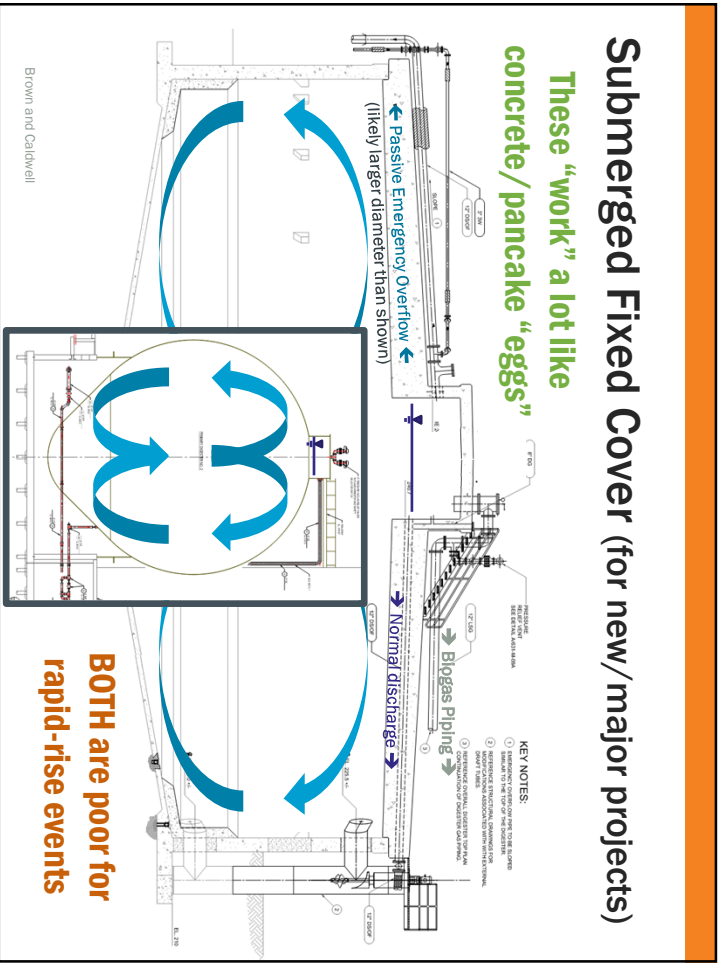


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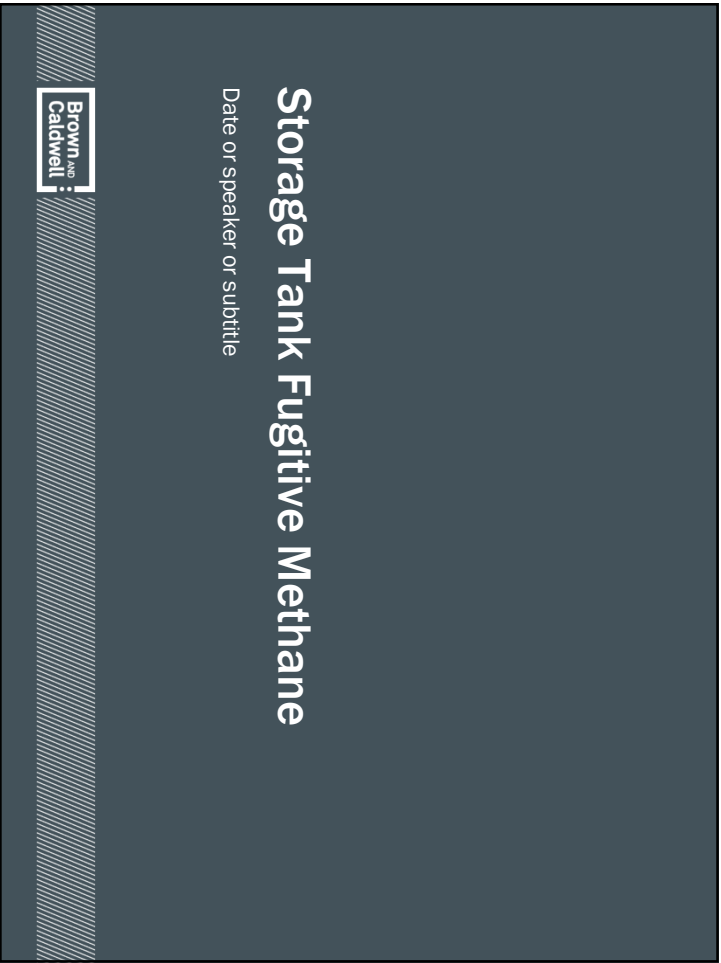
Hunts Point Concept is Pipe and Valve



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We are learning more each day...

Two Case Studies (from one WRRF)

- Did you know that:
 - A. Digested Biosolids Storage Tanks can also Emit CH_4 ?
 - B. Floating Digester Covers can Emit CH_4 ?

Brown and Caldwell

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Storage Tanks: Method #1 Volatile Solids Reduction in Storage as Digester Gas

- Seasonal liquid biosolids storage (with 6 to 9 months hold times)
- 64%VS biosolids fed to storage land applied with 56%VS
- VSR in storage of 26 to 30%
- Above totals and 16 cf-biogas/#VSR and 56%- CH_4 in biogas

→ 105 kg- CH_4 /hour based on VSR



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Storage Tanks: Method #2 Foul Air Mass-Flux Rates

- 4 Tanks: each ventilated at $\sim 7,000$ cfm to odor control:
- Three of Four averaged 155 ppmV-CH₄
- For 1.4 kg-CH₄/hr from each tank = 4.2 kg-CH₄/hr from all three
- Fourth Tank (most recently fed and mixed) averaged 1,790 ppmV-CH₄
- For 18 kg-CH₄/hr from each tank (ranging from 14 to 25 kg-CH₄/hr)

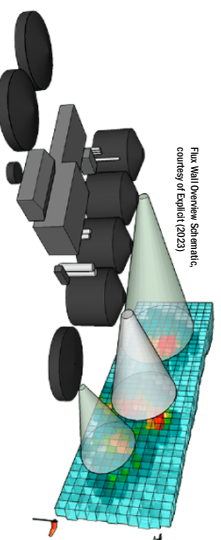
→ Apparent total was **22 kg-CH₄/hour** from all four

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Storage Tanks: Method #3 Hired 3rd Party for Drone Flux Walls

- Hired Explicit Aps (from Denmark) to fly the site...
- Drone flies and measures CH₄ and wind (direction and speed) to build a “flux wall”
- Multiple flux walls (3 to 6 are needed for an accurate “read”)
- Can also measure N₂O



Brown and Chikwell

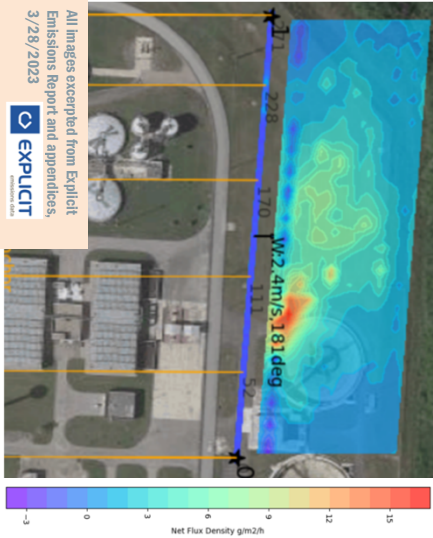
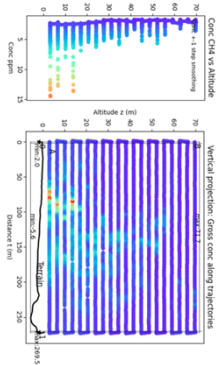
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Storage Tanks: Method #3
2nd Drone Flux Wall

- Storage-Run#1: 34.4 kg-CH₄/hour
- Storage-Run#2: 30.4 kg-CH₄/hour

→ 32.4±2.9 kg-CH₄/hour



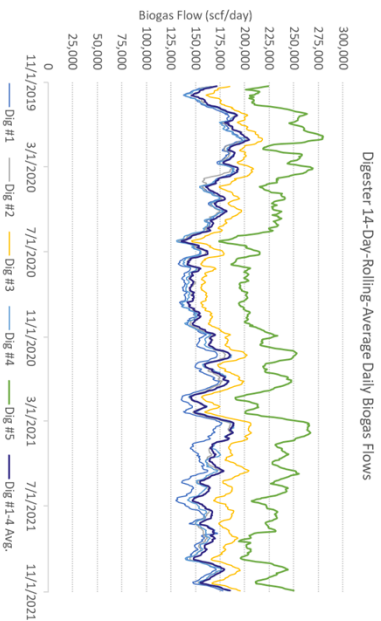
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Floating Cover Fugitive Methane
Date or speaker or subtitle



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Floating Covers: Method #1
14-Day Rolling-Average Biogas from 5 Digesters

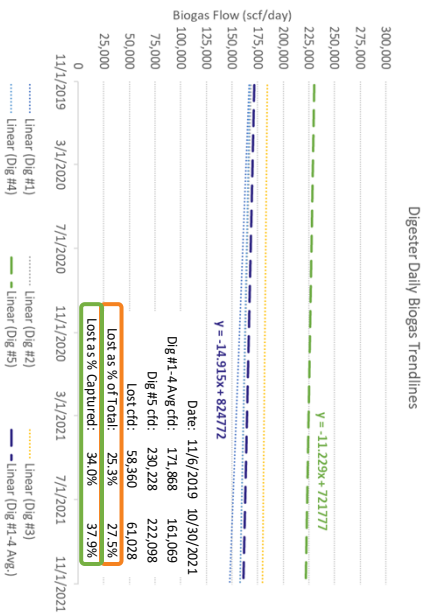


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Floating Covers: Method #1
Best Fit / Linear Trends

This represents:

- ~1/4 of produced CH_4 may be lost
- Could get >1/3rd more re-nergy
- 28 kg- CH_4 /hour from each;
x4 digesters
→ 112 kg- CH_4 /hour (total)



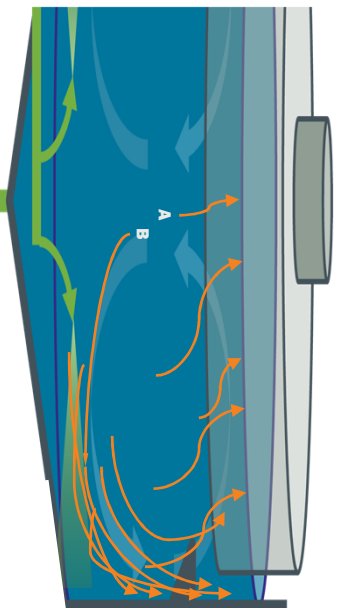
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Floating Covers: Method #1(b)
Visual Evidence from Annular Gap Video



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Floating Covers:
What We Think is Happening



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Floating Covers: Method #2 Flux Hood Testing

- Measured time to fill a known-volume bag
- Fill times ranged from 3 to 40 minutes
- Then scaled the measured rate to the entire annular-space area =
 - 80 to 2,000 cfh
 - 2,000 to 48,000 cfd

* but not at highest bubbling locations

→ **1 to 23 kg-CH₄/hour**



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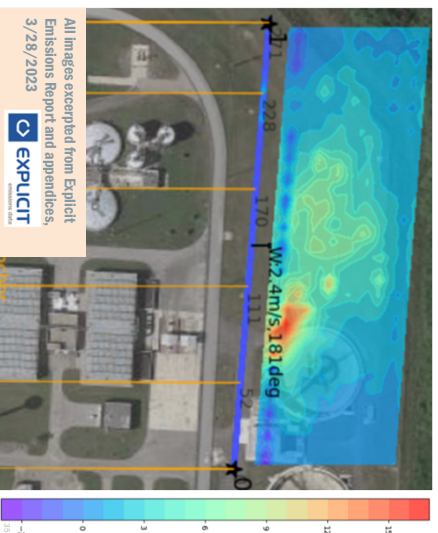
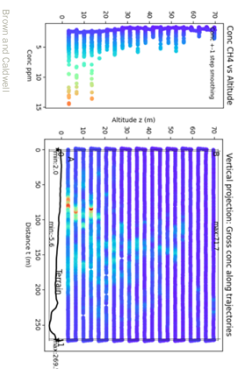


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Floating Covers: Method #3 8 Drone Flux Walls

Multiple runs with varied parsing between digesters and storage tanks, resulted in estimate of:

→ **$36.7 \pm 8.8 \text{ kg-CH}_4/\text{hour}$**



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We are learning more each day...

Two Case Studies (from one WRRF)

• Did you know that:

- A. Digested Biosolids Storage Tanks can also Emit CH_4 ?
 1. Estimated **$105 \text{ kg-CH}_4/\text{hr}$** by Volatile Solids Reduction
 2. Measured **$22 \text{ kg-CH}_4/\text{hr}$** with Foul-air Duct CH_4 Meter
 3. Measured **$32 \text{ kg-CH}_4/\text{hr}$** with Drones
- B. Floating Digester Covers can Emit CH_4 ?
 1. Measured **$112 \text{ kg-CH}_4/\text{hr}$** by Different Biogas Flow Meters
 2. Measured **$<23 \text{ kg-CH}_4/\text{hr}$** with Flux Hoods
 3. Measured **$37 \text{ kg-CH}_4/\text{hr}$** with Drones

These examples showcase how different your determinations can be, depending on how and when you collect your measurements

Brown and Cartmell

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Conclusions

But first, an aside...



Brown and Caldwell

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Caution Against Digester CFD modeling as NOT REAL Data

Digester CFD models usually rely on assumptions that are known-to-be-inaccurate :

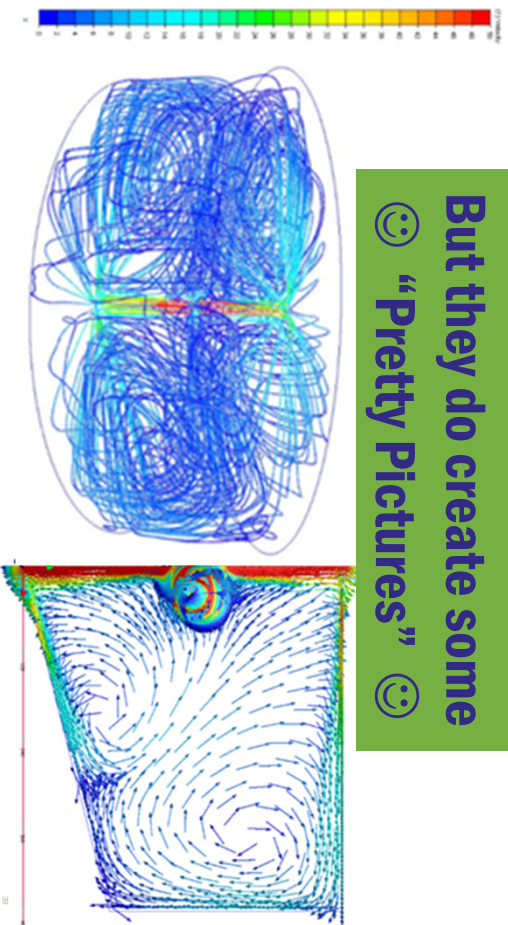
- **That tank contents are uniform and Newtonian.** Most will commonly assume higher viscosity that water.
- **Contents are uniform density.** Cannot account for dense particles (like grit) and lighter solids or liquids (like grease); OR the very things mixing is supposed to solve.
- **Not accounting for gas-phase or gas production.**
- **Models cannot truly be calibrated.** Nobody has measured full-scale sludge velocity vectors in active digesters.

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Caution Against Digester CFD modeling as NOT REAL Data

But they do create some
☺ “Pretty Pictures” ☺



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Caution Against Digester CFD modeling as NOT REAL Data

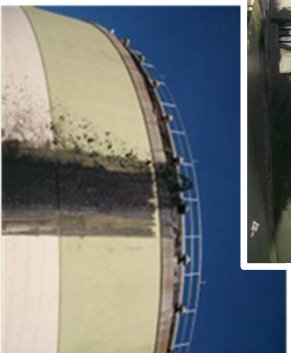
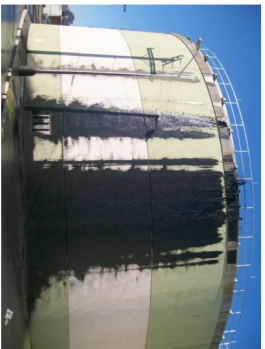
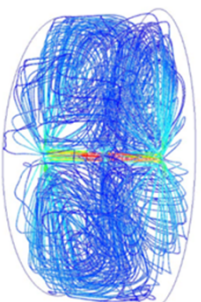
But they do create some
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Just say “NO” to
☺ “Pretty Pictures” ☺



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CFD-Model for Nashville's Digesters predicted a "Clean Bill of Health"

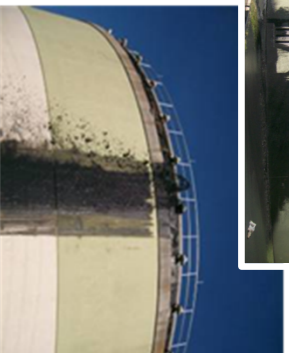
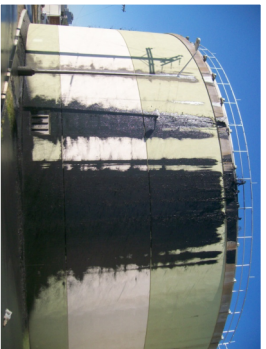


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CFD-Model for Nashville's Digesters predicted a "Clean Bill of Health"

**And these are NOT
☹️ "Pretty Pictures" ☹️**



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Conclusions

1. Lots of volume is lost from digester upper reaches
2. Methane (and other GHGs) production / emission from WRRFs is very poorly understood
 - And measuring at one time / one way may not get you the complete answer
 - **Contact me if *you* want to join WW GHG research**
3. We should think even-harder about the things we cannot see (that we believe we understand)



Brown and Caldwell

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QUESTIONS?

it's about connecting



John Willis, P.E., BCEE
(770) 361-6431
JWillis@BrwnCald.com



essential ingredients®

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