INSTITUTE OF PARTICLE SCIENCE & ENGINEERING

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"Novel characterisation of flocculated dispersions using acoustic backscatter systems"

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EPSRC Engineering and Physical Sciences Research Council

Sellafield Ltd

Motivation – Pile Fuel Storage Pond

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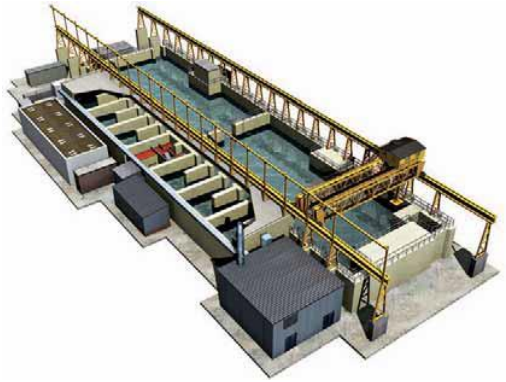

- Spent fuel from the first Windscale pile reactors has been stored in the PFSP for > 50 years.
- Corrosion of the waste material and additional organic matter has resulted in a significant build up of sludge.
- Sludge recovery is on-going as part of a decommissioning programme with settlement in a corral prior to removal for ultimate encapsulation.

Motivation – Aims of Acoustic Characterisation

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First Generation Magnox Storage Pond - Sellafield

Water Treatment Thickener

- **Analysis of settling front and concentration profiles in small-scale test settling suspensions.**
- **Acquire data for modelling prediction and *In situ* monitoring of sludges to optimise processing, transport and separation.**
- **Applications in water treatment & minerals thickeners**
- **Can observe changes in visually opaque suspensions**

Advanced acoustic backscatter array

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- Ultrasound Array Research Platform (UARP)

○ High resolution concentration & interfaces from backscatter echo strength.

○ Up to **sixteen** **1.5 – 2.5** MHz transducer heads aid depth penetration.

Specification	UARP
Maximum Output Voltage	5 Level ± 100V, ± 50V, GNS
Transmit Frequency	0.5 MHz to 15 MHz
Number of channels	16 per module (Max: 256)
Raw data transfer to computer	PCI Express Gen 3 (Max : 64Gbps)
Analog Digital Converter	AFE5807 (Max 80MSPS)
Mechanical aspects	Communications via PCIe Dedicated Clock and Synchronisation signals.

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Full Scale In situ monitoring

Advanced acoustic backscatter array

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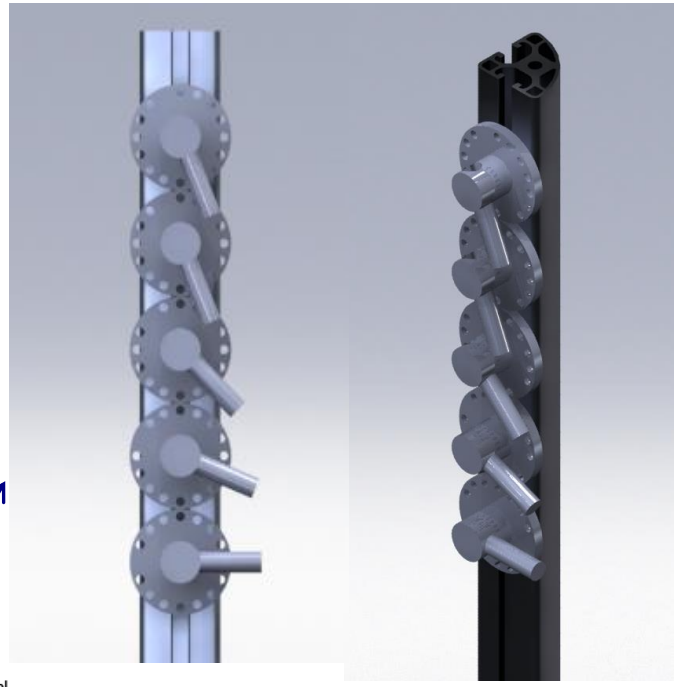
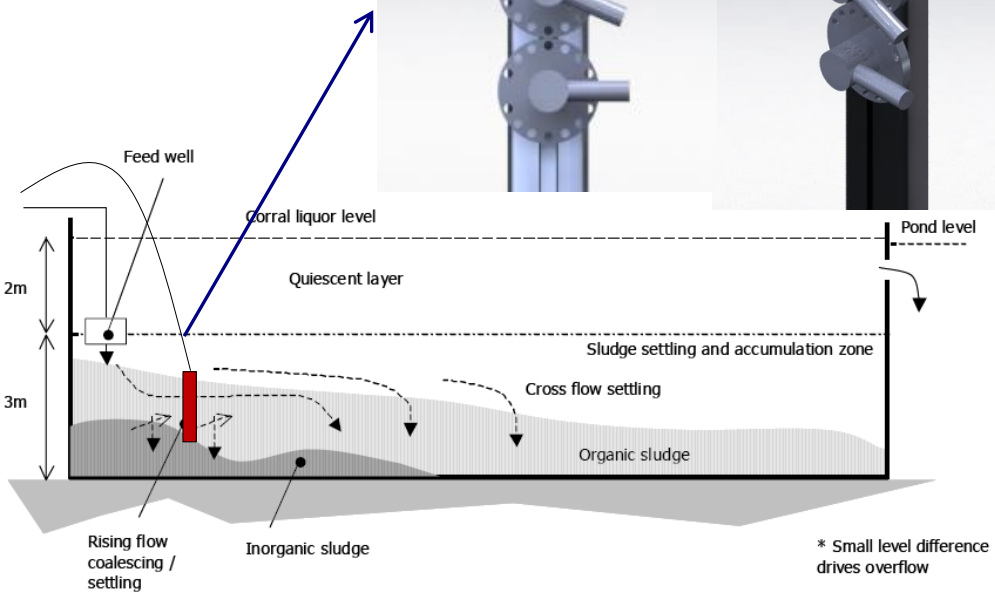
- Acoustic Backscatter Array (ABA)
  - Single probe array
    - Multiple Frequency (2 – 2.5 MHz).
  - Can vary depth from 1 – 10 metres.





Full Scale In situ monitoring

Method to estimate attenuation constant of particles

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1. Relationship between received voltage to suspension properties

$$V = \frac{k_s k_t}{\psi r} M^{1/2} e^{-2r\alpha}$$

2. Expression for attenuation with distance due to particles

$$\alpha_s = \frac{1}{r}\int_0^r \xi(r)\, M(r)\mathrm{d}r \;\rightarrow \xi M$$

3. **Define $G = \ln(\psi r V)$**

$$\frac{\mathrm{d}}{\mathrm{d}r}[\ln(\psi r V)] = -2\left(\alpha_w + \xi_h M\right)$$

4. Differentiate w.r.t. r and M to find ξ → scattering cross-section, χ

$$\frac{\mathrm{d}}{\mathrm{d}M}\left[\frac{\mathrm{d}}{\mathrm{d}r}[\ln(\psi r V)]\right] = -2\xi_h$$

5. Substitute into first equation to find k_s → form function, f

Rice et al. *J. Acoust. Soc. Am,* **2014**, 80, 156-169.

Acoustic Calibration – 3 steps

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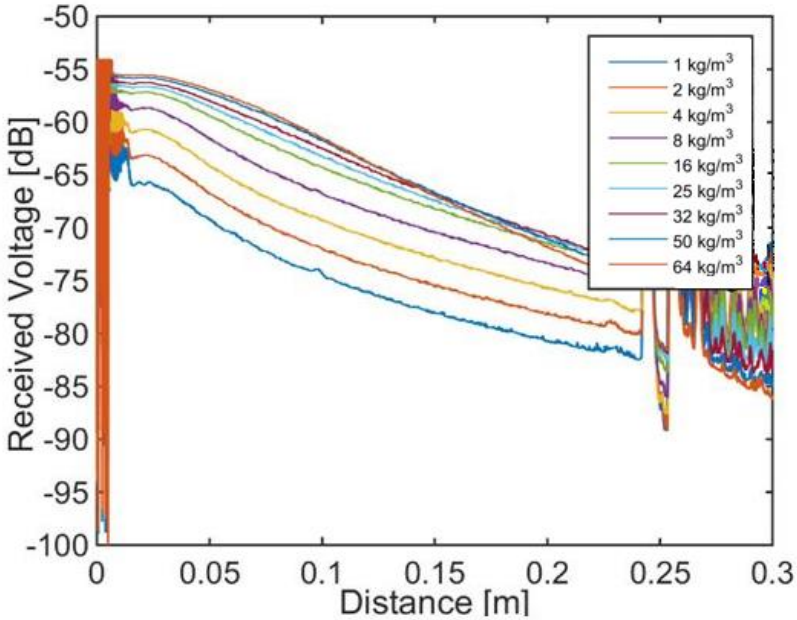
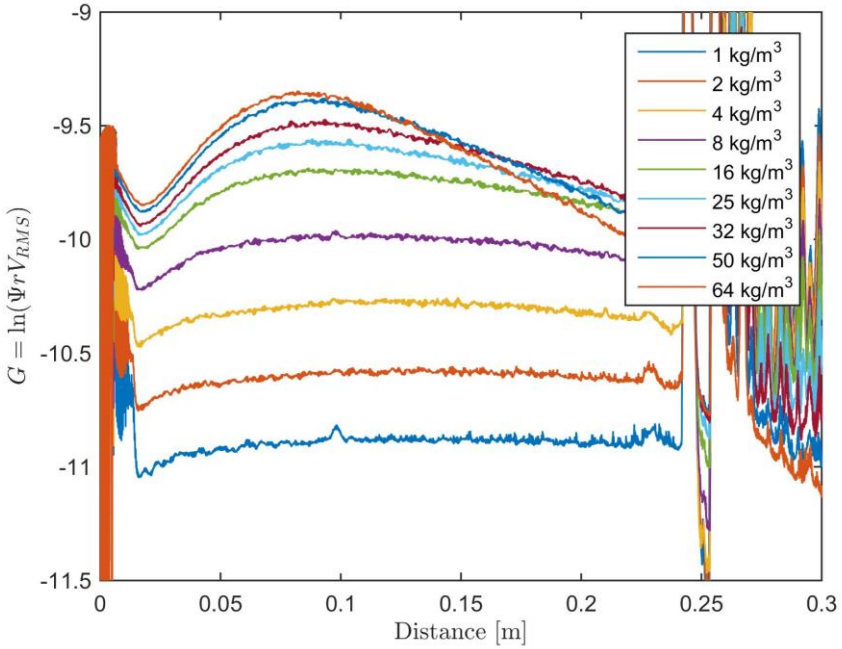
1. Measure received voltage



2. Convert to 'G' Function $\underline{G = \ln(\psi r V)}$

Should give linear slope wrt. distance



Acoustic Calibration – 3 steps

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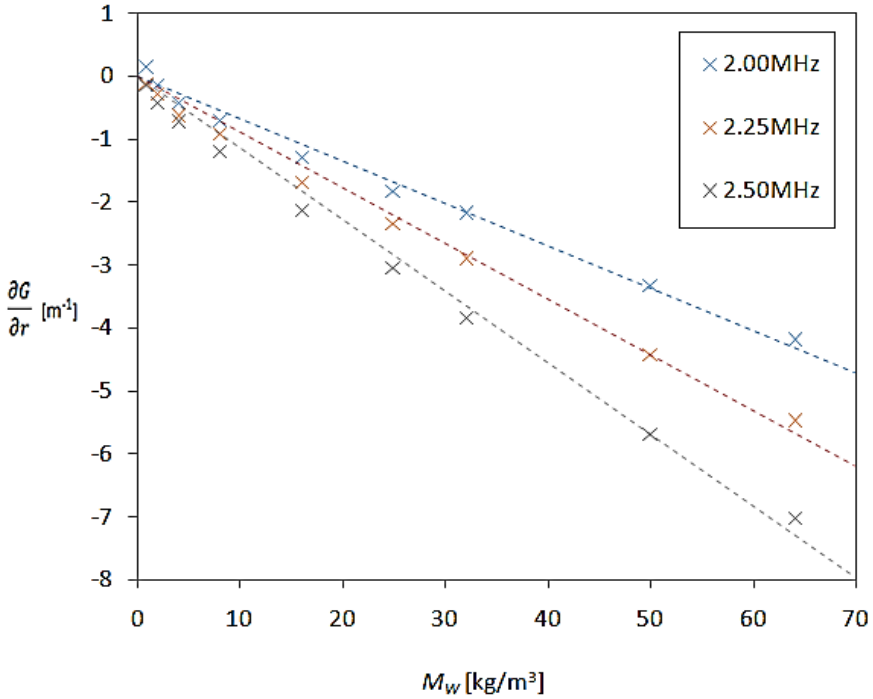
3. Plot dG/dr wrt. Concentration

Linear calibration wrt. Concentration

Frequency dependent (i.e. can check multiple frequencies for same measurement)

Measure G in real settling systems, estimate conc. based on G slope



Large-scale trials

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Large-scale trials

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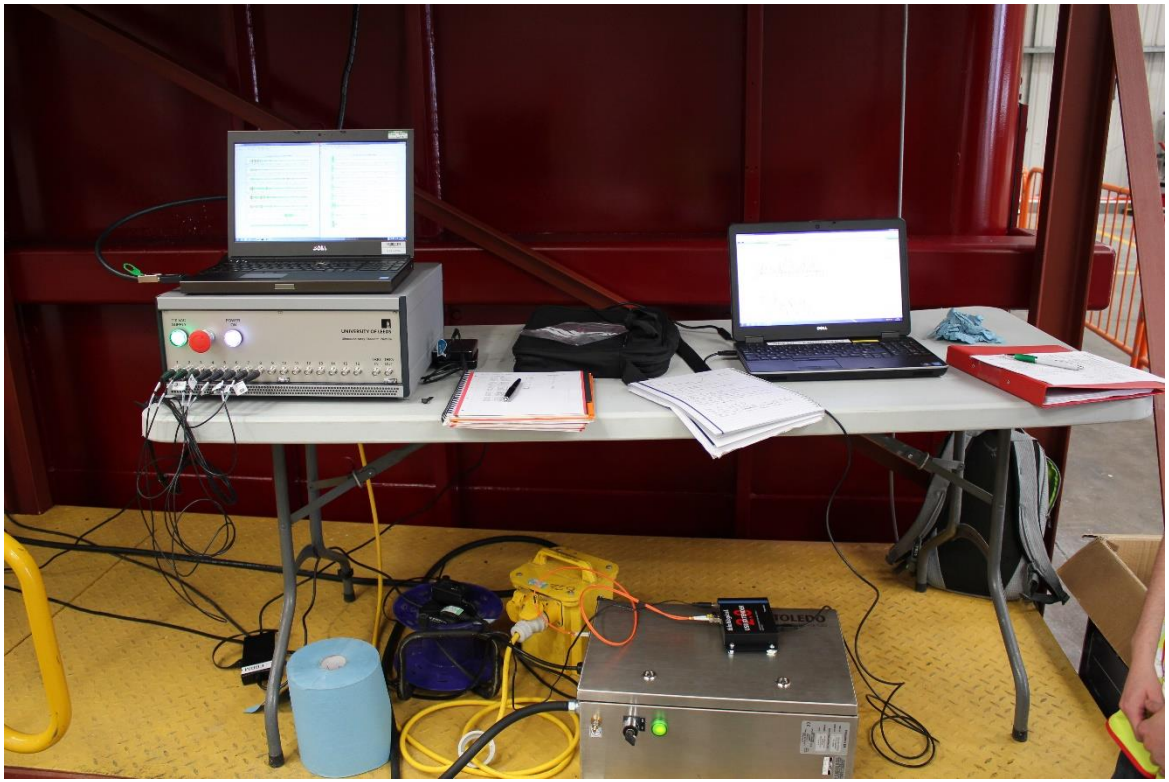

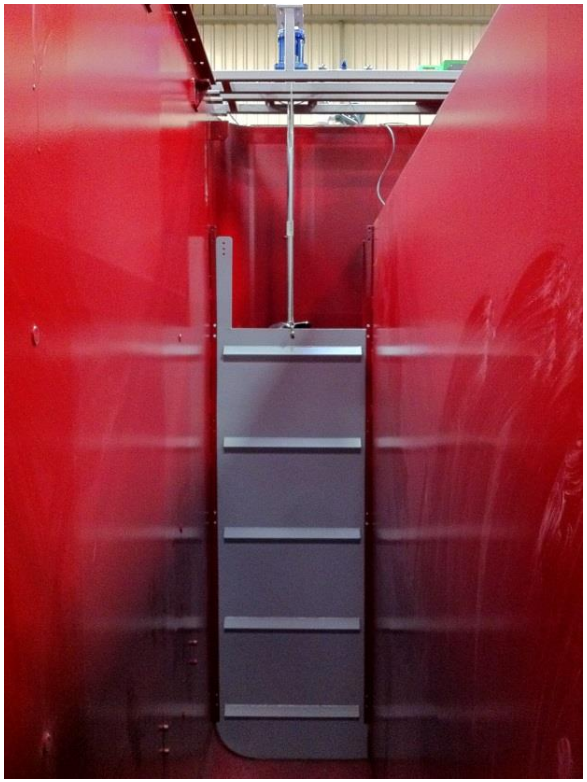

Large-scale trials

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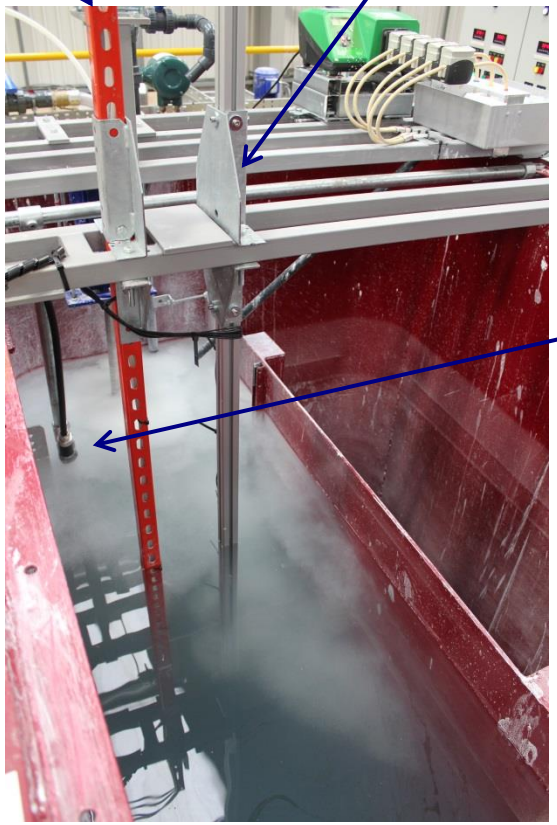
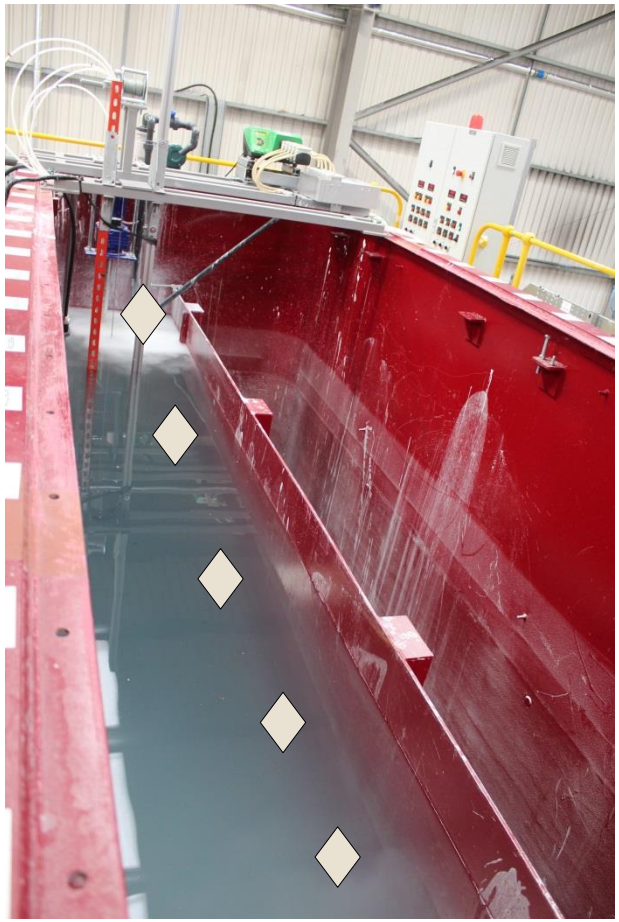
Comparison 5 point samples

Vertical 8 probe array



FBRM Probe

5 lateral locations along channel measured



Large-scale trials: raw data

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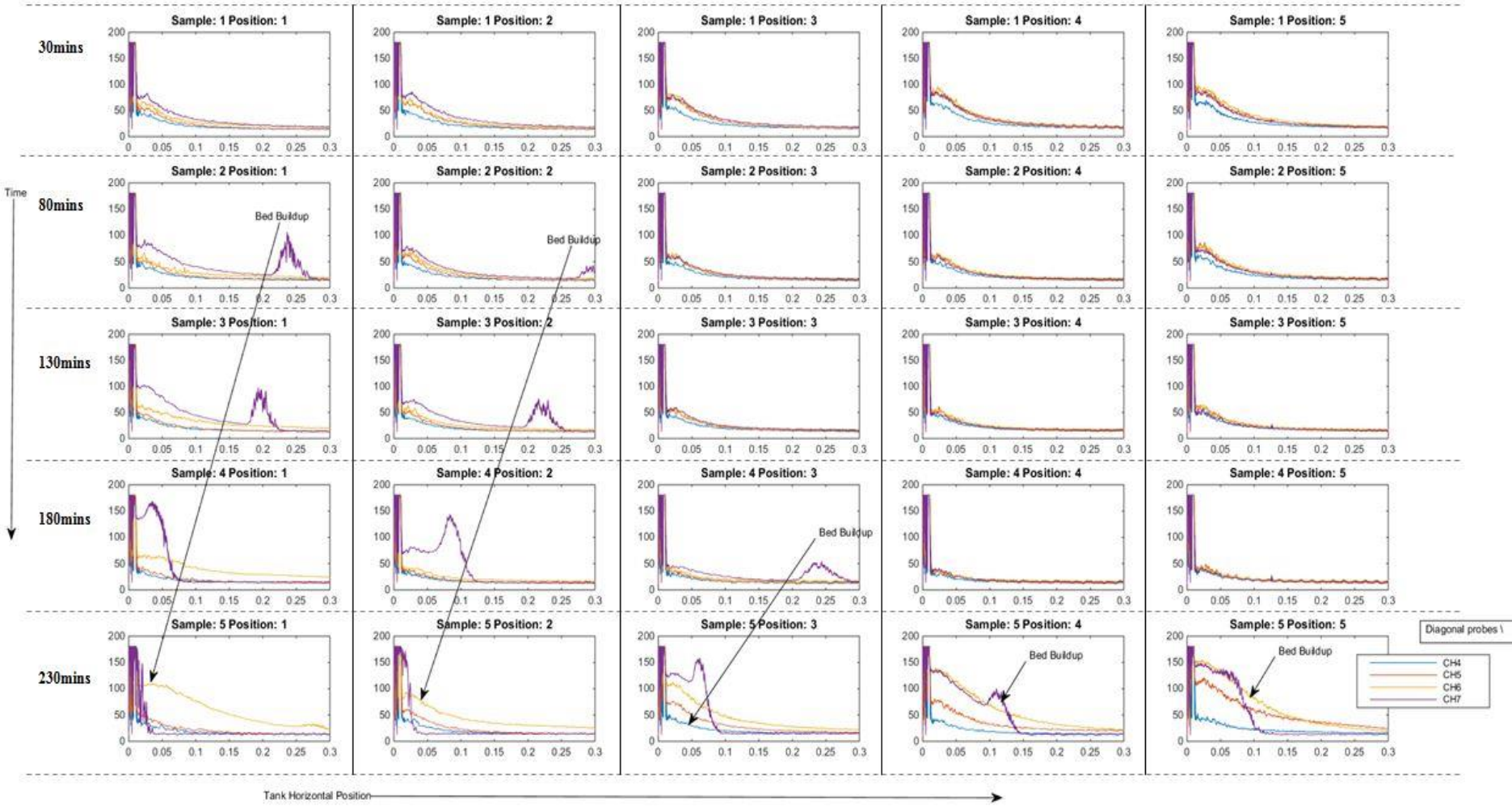
Raw acoustic data (G Values still to be determined…ongoing)



Large-scale trials: raw data

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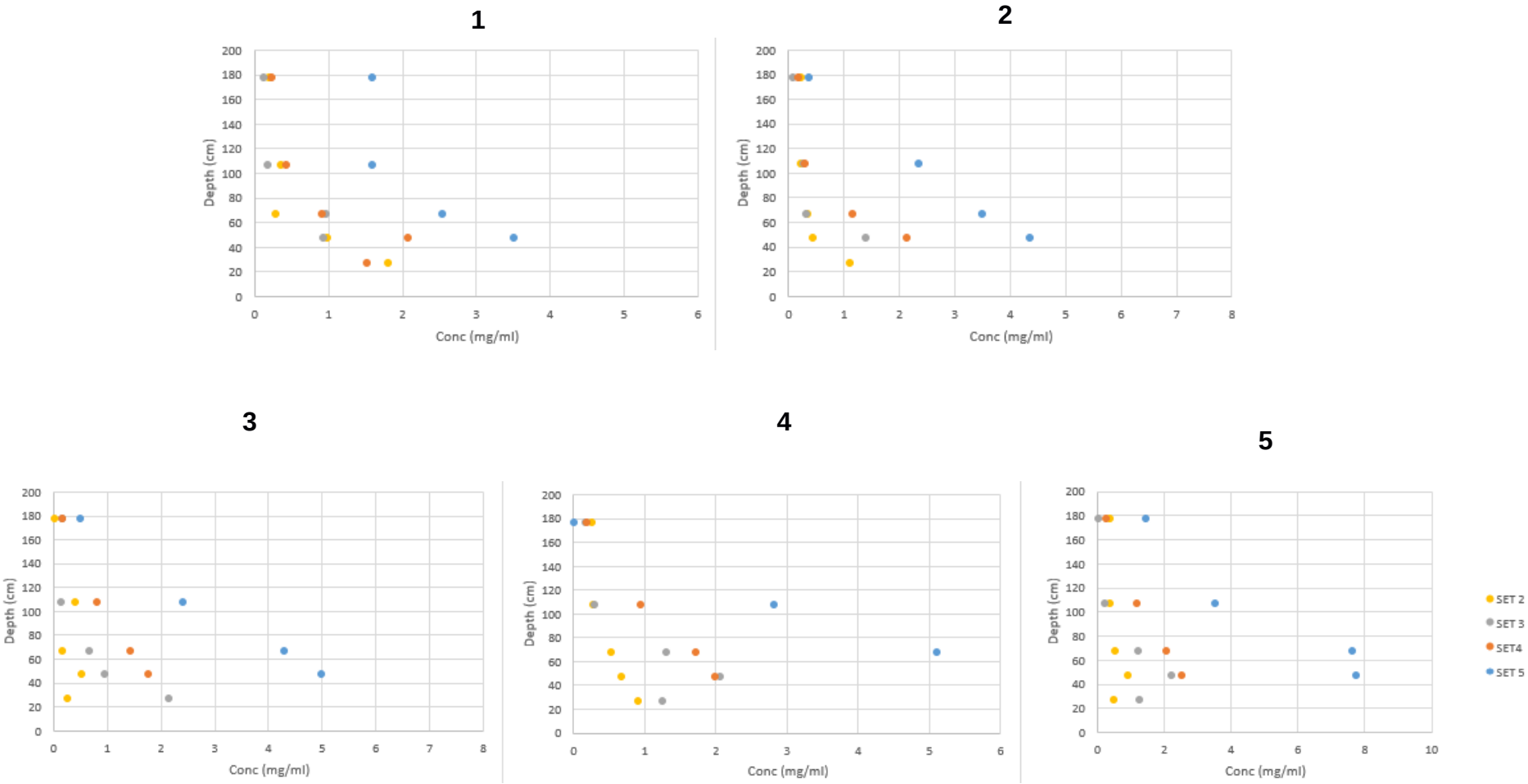

Large-scale trials: raw data

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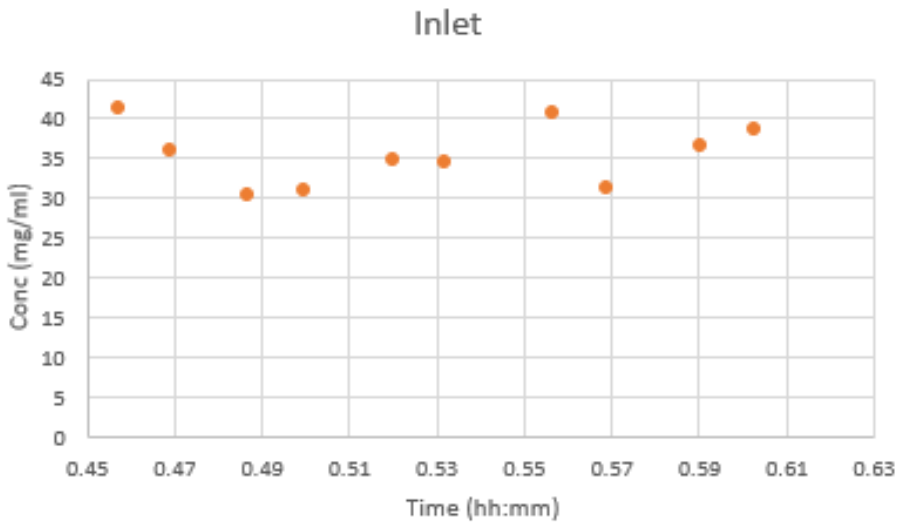

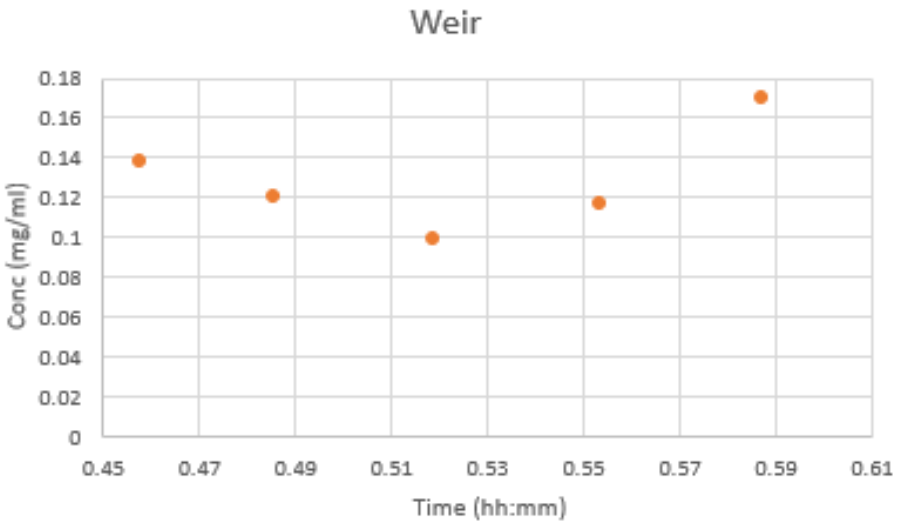

Large-scale trials: raw data

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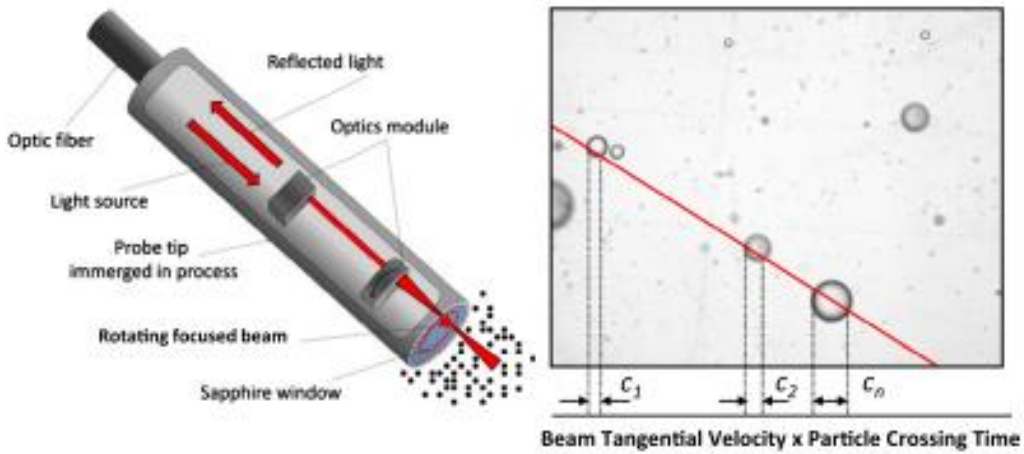
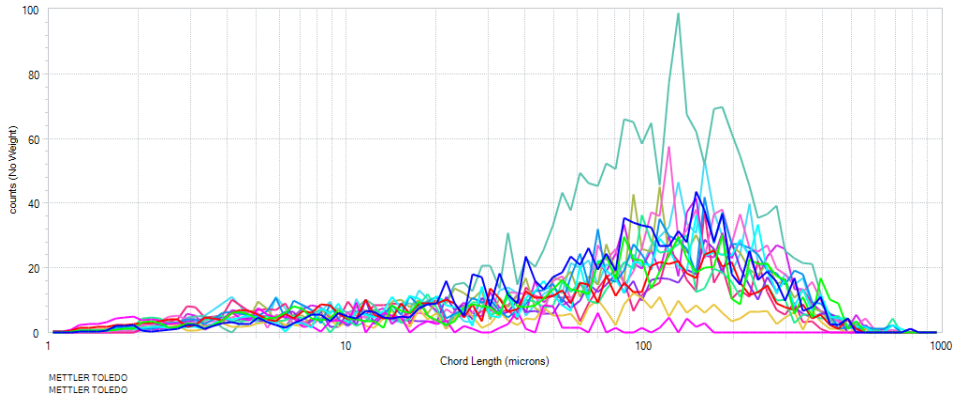
S. Less, R. Vilagines / Fuel xxx (2013) xxx–xxx



D [50] (um)	319-342	298-319	298-319	298-319	298-319	298-319	298-319	298-319	298-319	298-319	298-319	298-319	298-319	298-319	298-319
Time (mins)	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30



Large-scale trials: bed track

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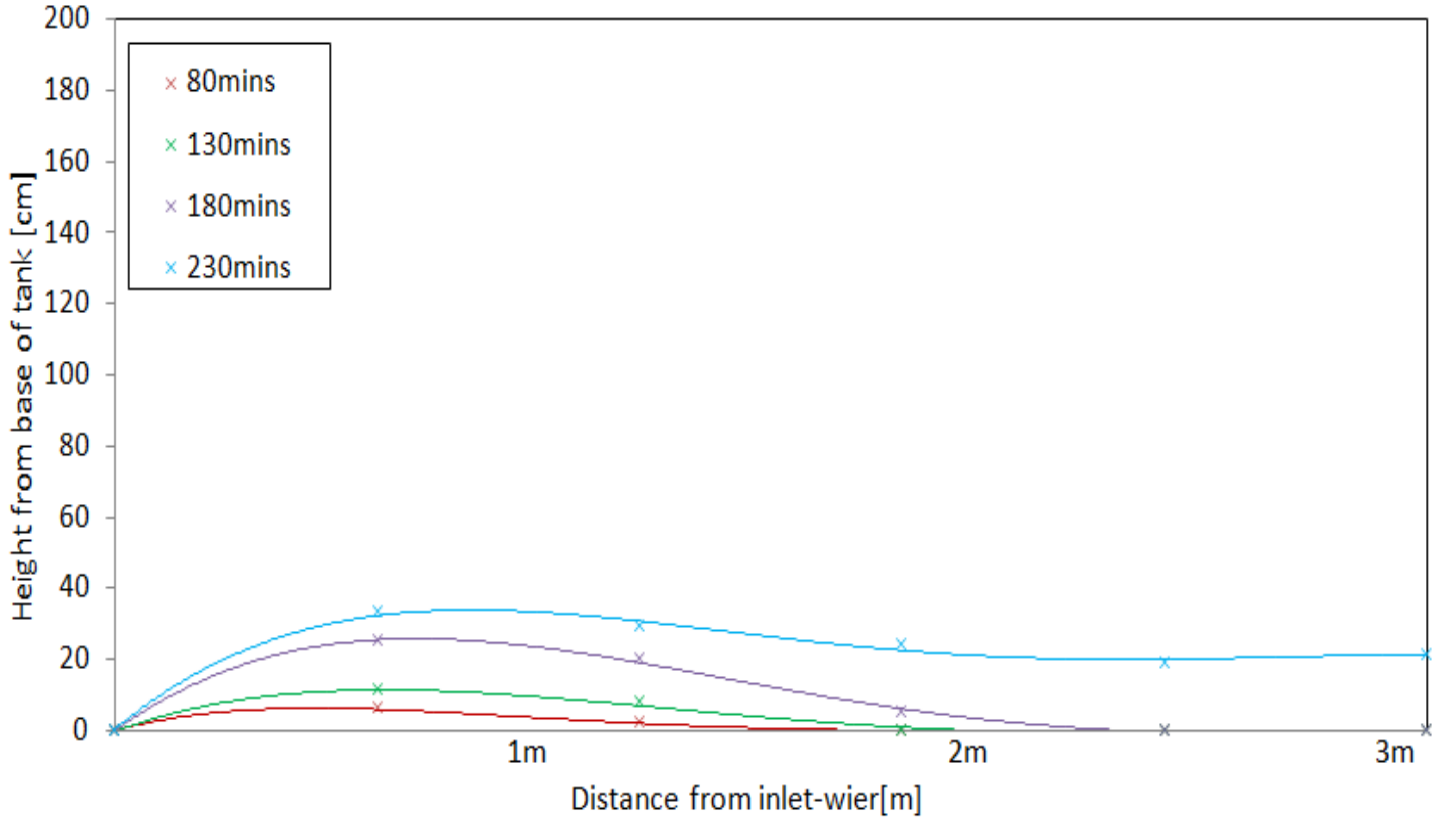

Small Scale Settling Tests

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- Small scale settling column will be used to find at what shear rates floccs break up
- Will then be converted to continuous gravity settler to avoid shear using a peristaltic pump

Conclusions & Future work

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- Acoustic backscatter data collected in a large scale thickener for flocculated and non-flocculated systems for which G parameter and concentration profiles can be produced (ongoing).

- Sampling and FBRM data taken at large scale trial can be compared to acoustic data to determine constants within the model and more accurately take account of the Particle Size Distribution.

- Small scale acoustic and FBRM data will be collected in a continuous gravity settler under different shear regimes and various degrees of flocculation

- Further settling data will be collected on a large scale settler at the University of Melbourne

- Active trials to take place in Summer 2016

Thank you for listening!