Transport and Reactivity of Contaminated Estuarine Sediments: Results from a High Capacity Flume

Plymouth Team *: Fay Couceiro, Andrew Turner, Geoff Millward*

Cardiff Team *: William Rauen, Binliang Lin, Roger Falconer*

Environment Agency: *Peter D Jones*

Funded by the Engineering & Physical Sciences Research Council

The Mersey Estuary

<u>Mersey River Flow</u>

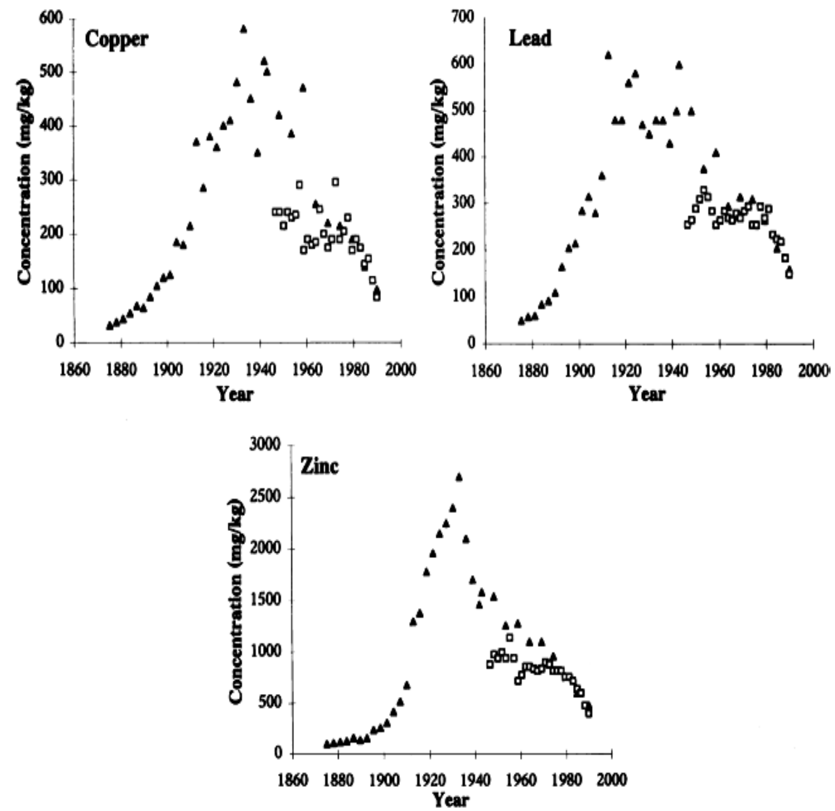
20 to 40 $m^3 s^{-1}$

<u>Tidal range</u>

3.5 to 10.5 m

Liverpool Bay

Impact of Industrial Activity



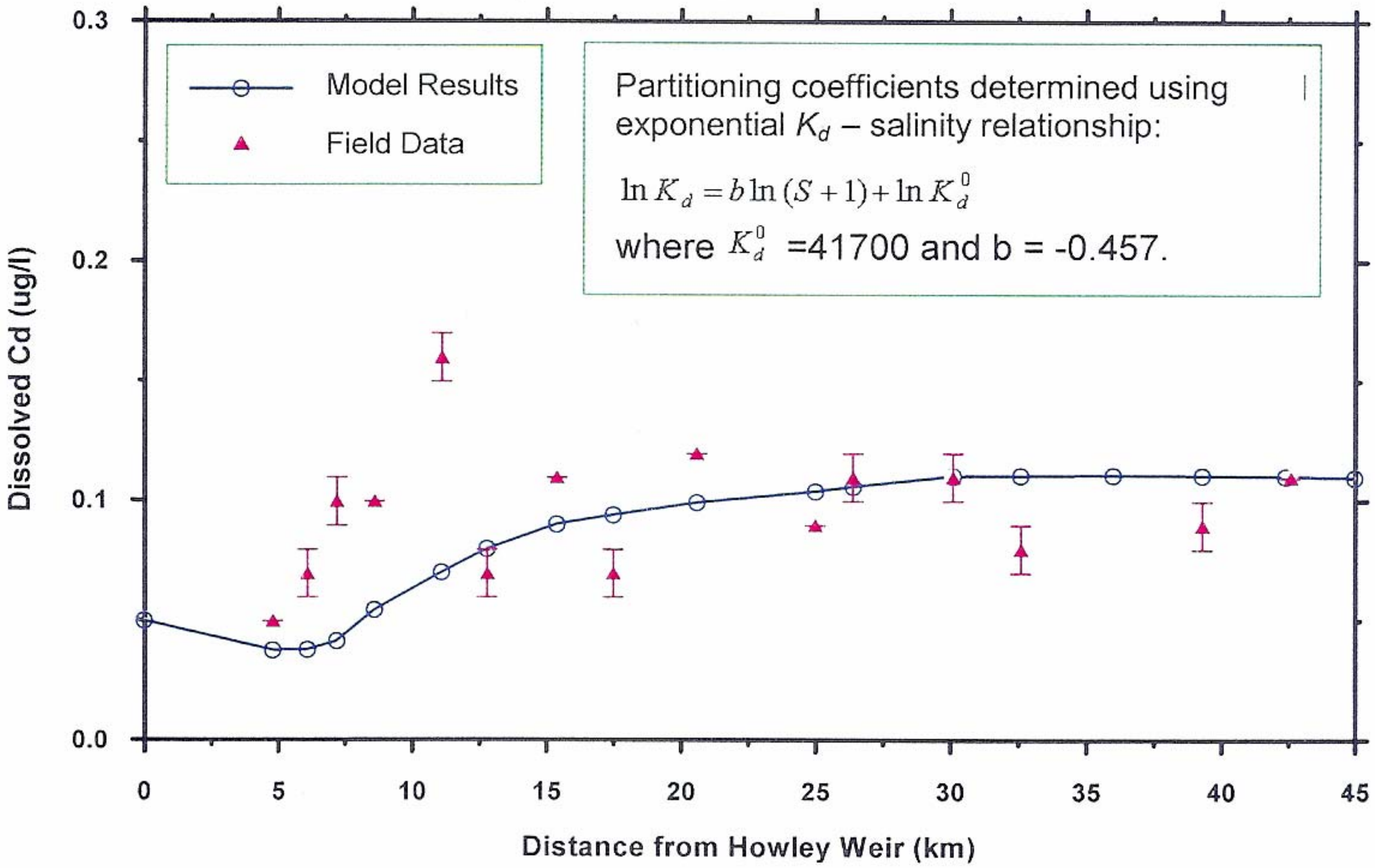
Cu, Pb & Zn & geochronology in a 1 m core in the Mersey Estuary (Fox et al., 1999)

The Upper Mersey Estuary

Metal	Concentration, µg g^{-1}
Cu	35 ± 6
Ni	58 ± 5
Pb	540 ± 81
Zn	330 ± 45

Metal concentrations in surface sediments from the upper Mersey (Martino et al., 2002)

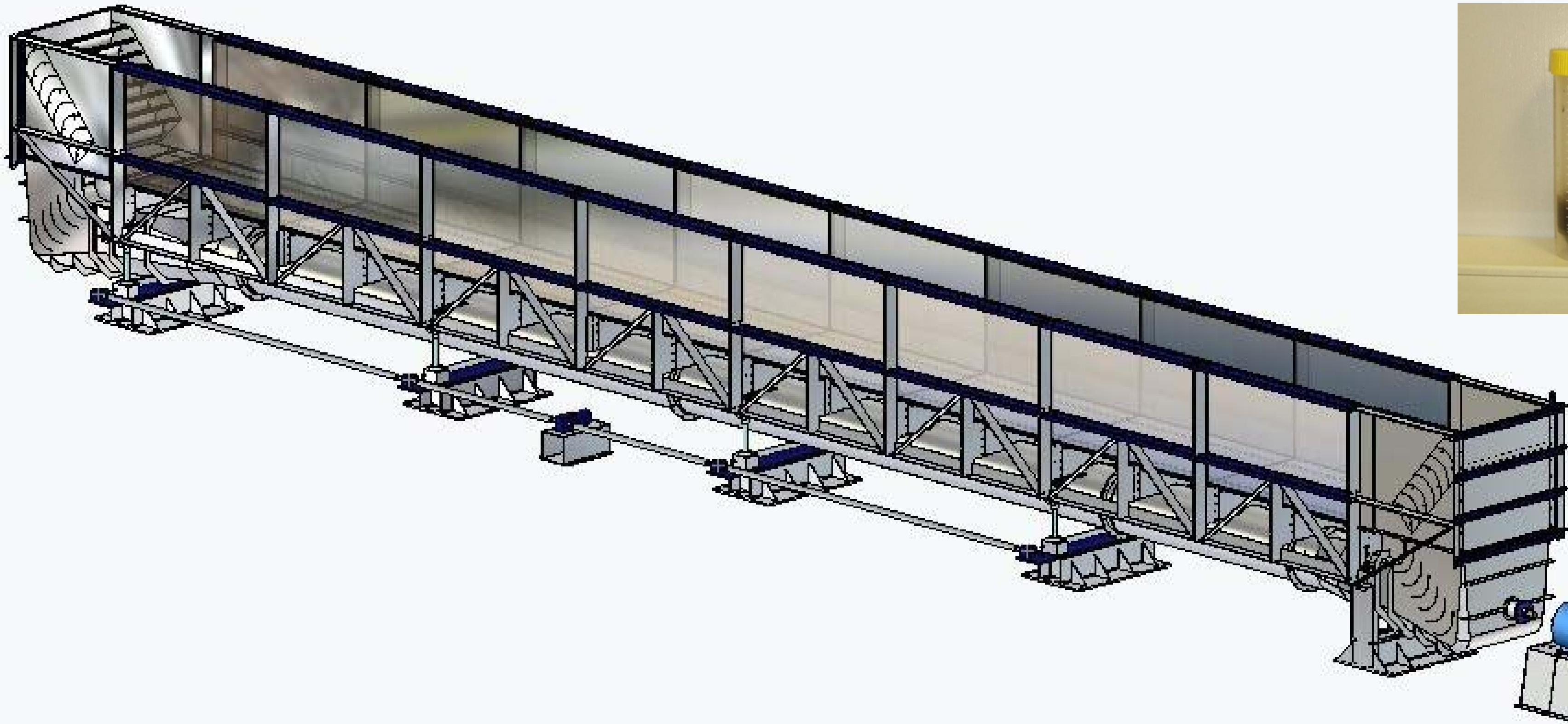
Modelling Metal Distributions in the Mersey Estuary (Wu et al., 2005)



Aims

- To conduct flume experiments using chemical tracers to track the mobility of estuarine sediments and the partitioning of Ni;
- To monitor the hydrodynamics and geochemistry concurrently during flume experiments;
- To integrate sediment-dynamics with geochemistry;
- To develop *generic* models for predicting metal transport and behaviour in estuaries.

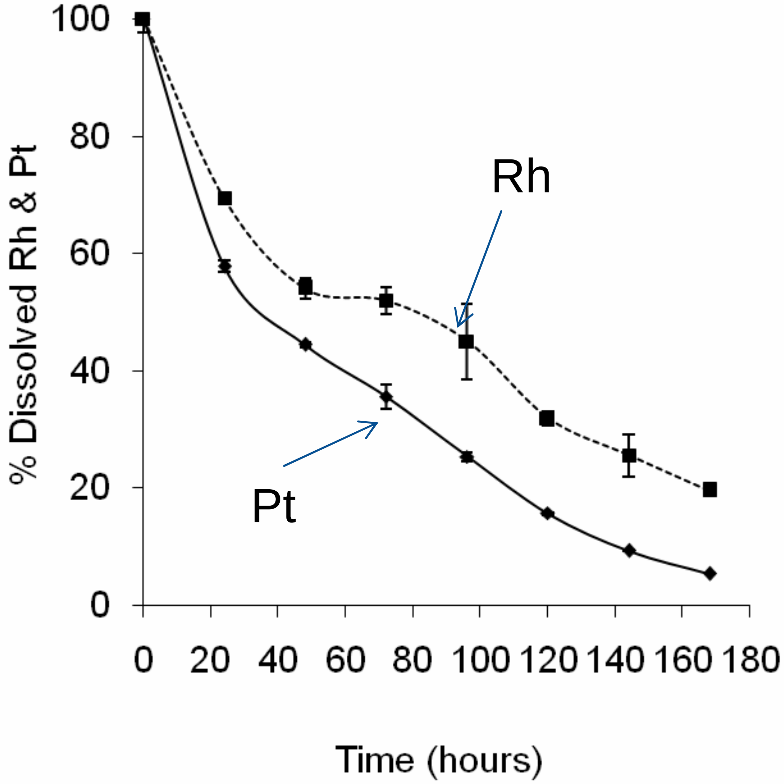
High Capacity Flume and Model Funnel-Shaped Estuary



Characteristics of Flume Sediments

Parameter	Sediment Type	
	Mersey Estuary Fine Sand	Commercial Fine Sand
Grain Size	d_{50} = 130 µm	d_{50} = 130 µm
Surface Area, $m^2 g^{-1}$	1.3	0.08
Total Carbon, %	0.35	<0.05
Total Fe, %	0.8	0.03

Labelling Sediment using Bucket Chemistry !

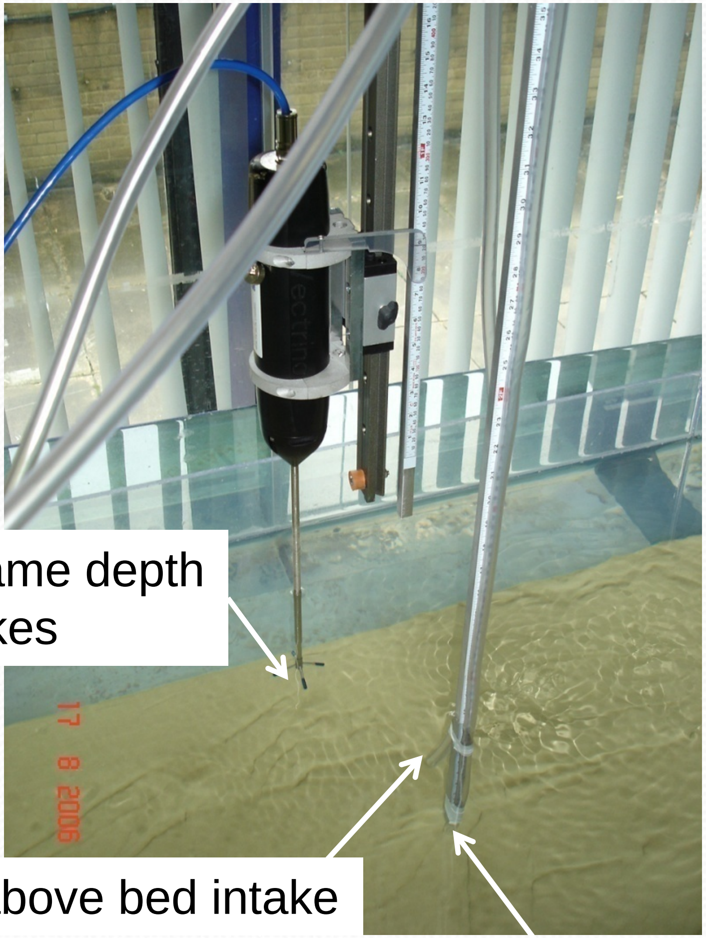


Wet sieve 10 kg sediment with d_{50} = 130 µm

Incubate with Rh and Pt to give 400 µg/g; Ni 200 µg/g

(Couceiro et al., 2007)

Water Sampling Along the Axis of the Flume

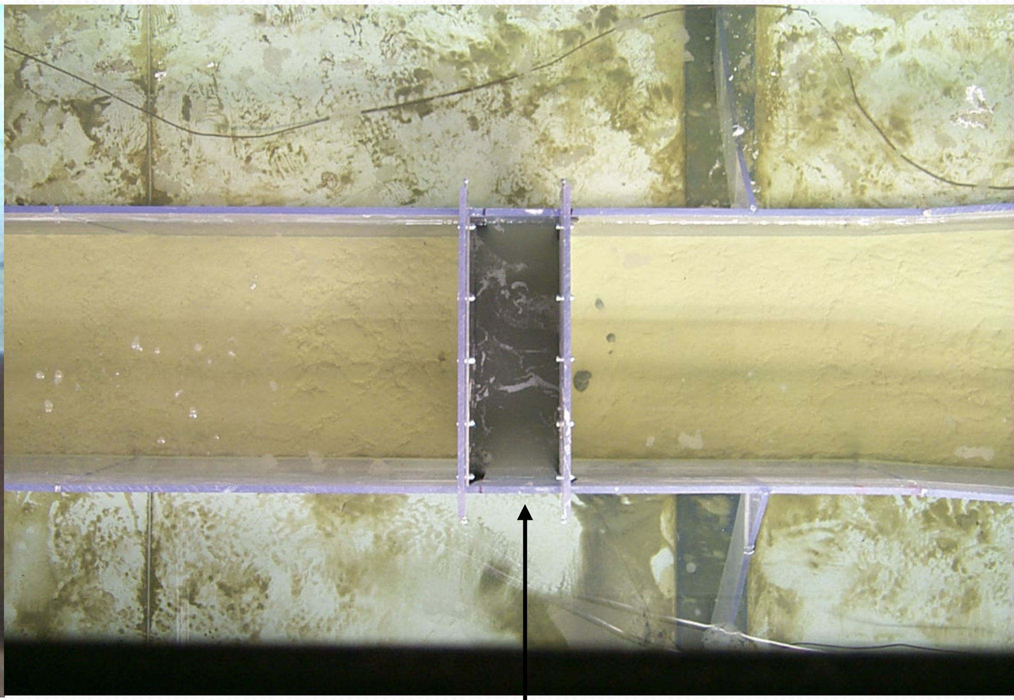


ADV same depth as intakes

40% above bed intake

Near bed intake

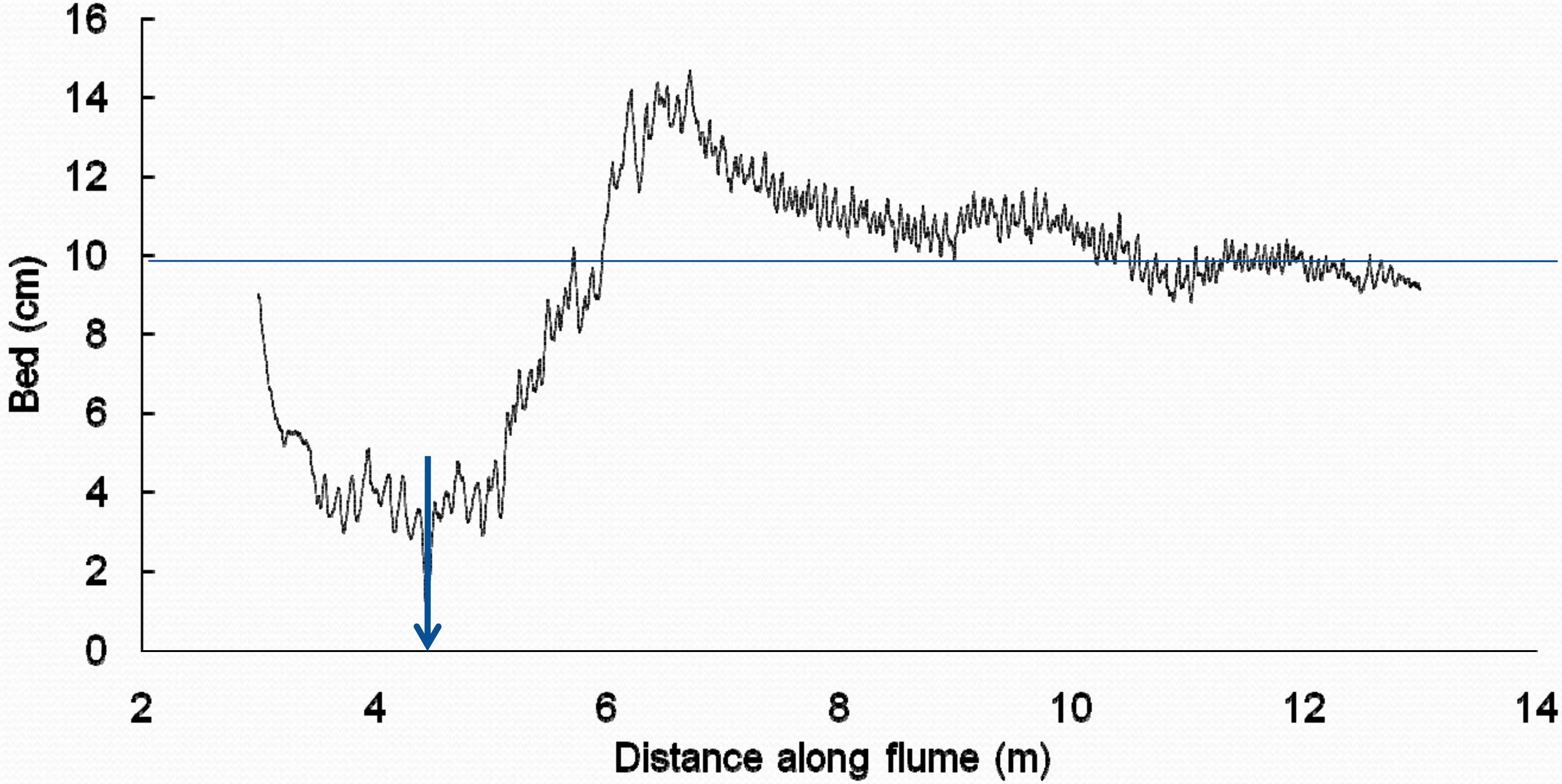
Plug of Labelled Sediment



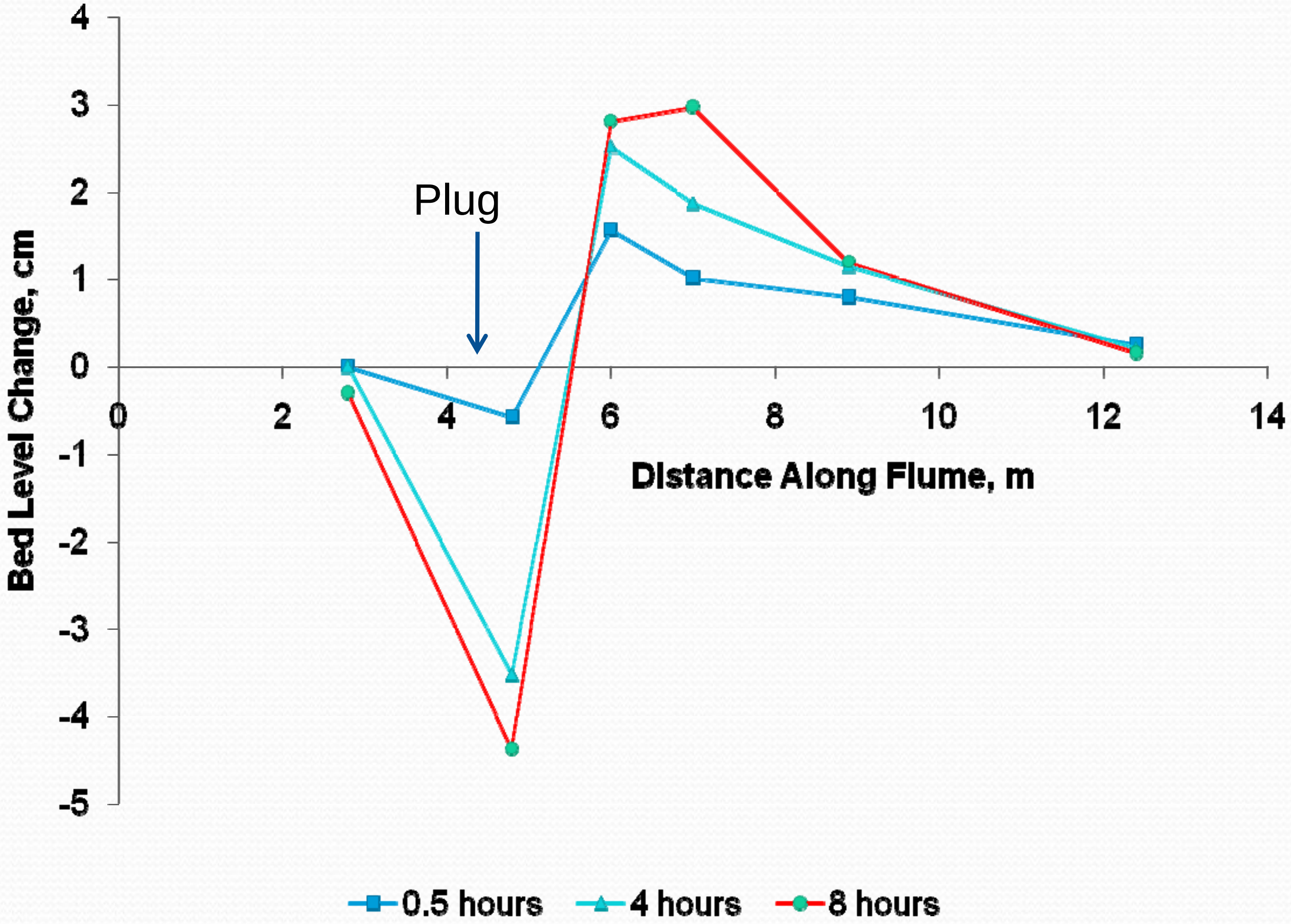
Plug labelled with tracer Pt & Rh.
Exchangeable Ni

Video of Flume Experiment

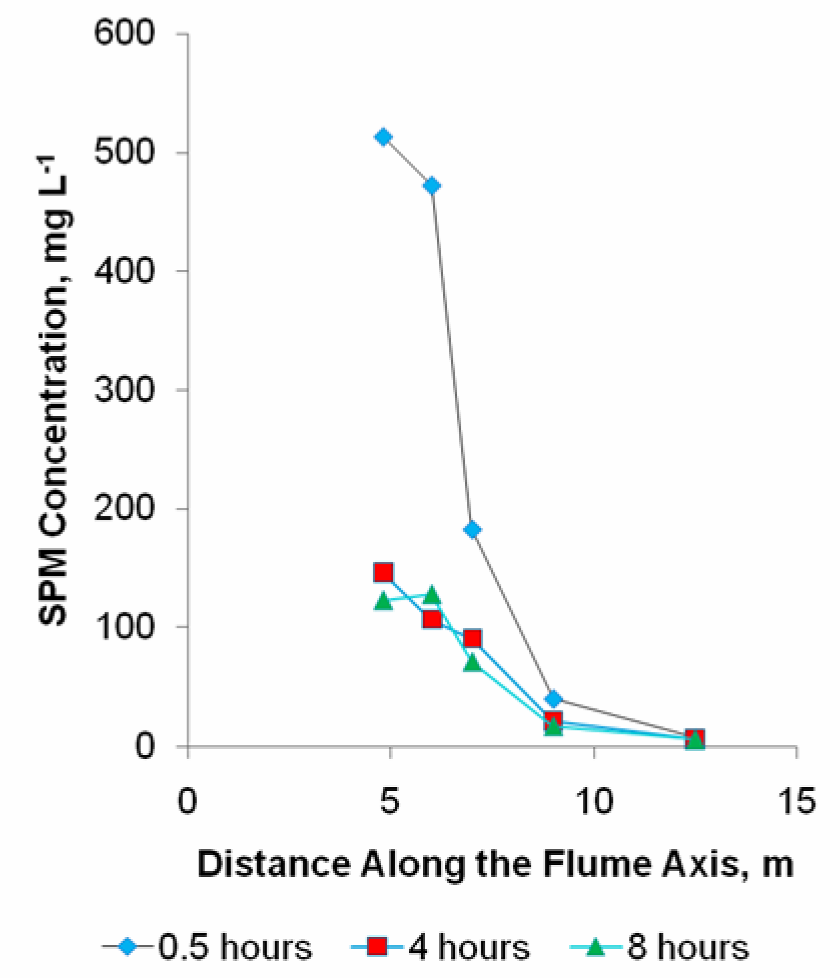
Bed Morphology After 8 Hours

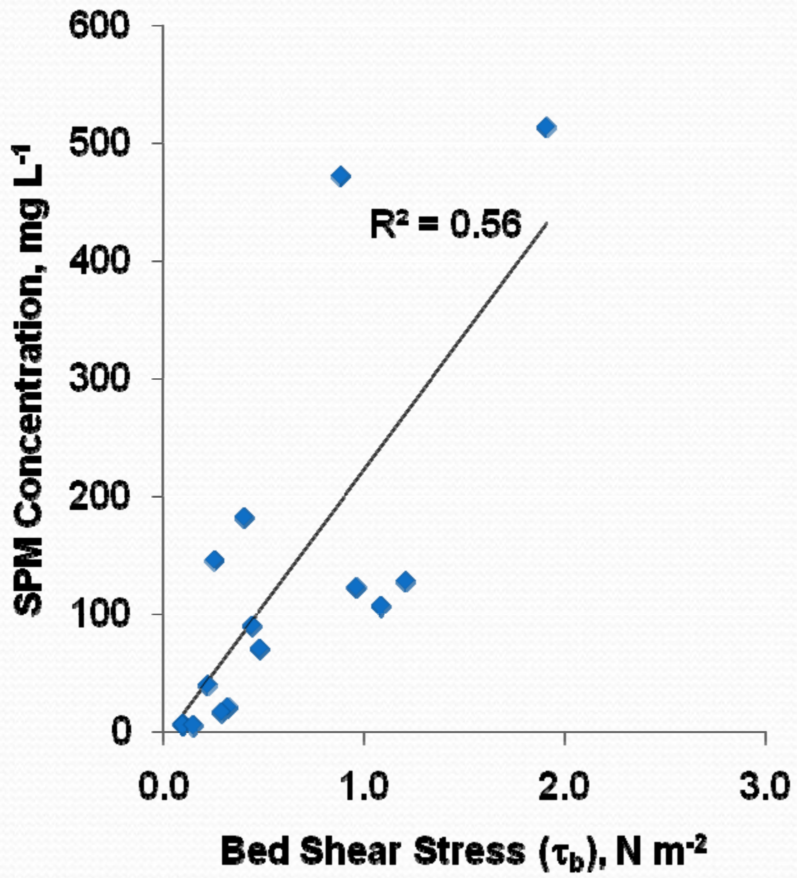


Evolution of Bed Morphology & Bathymetric Feedback



Near Bed Concentrations of SPM

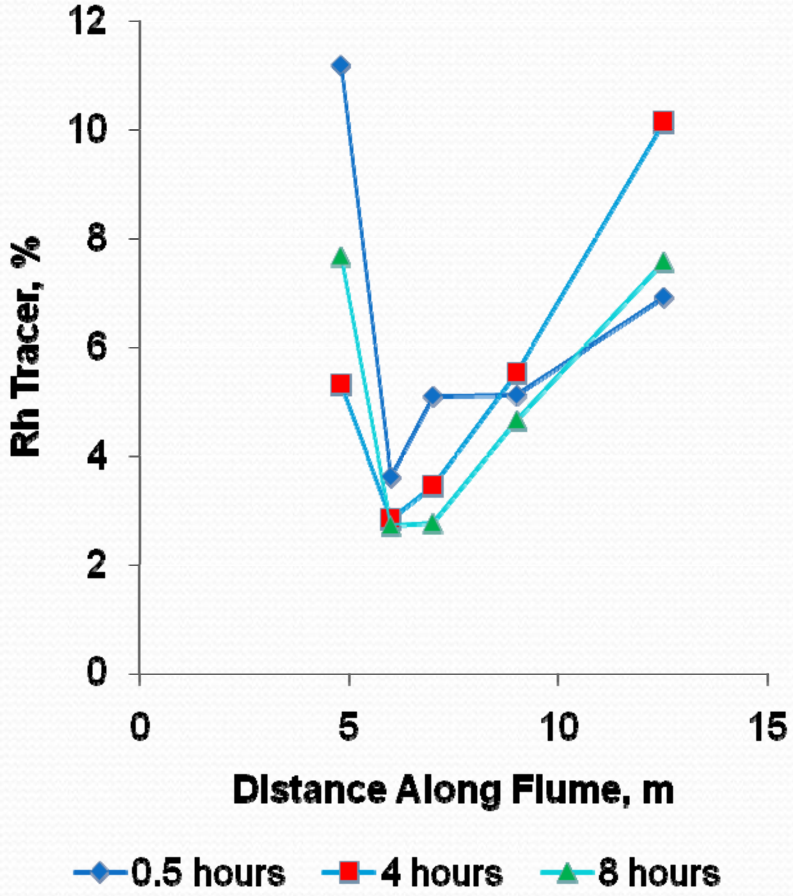


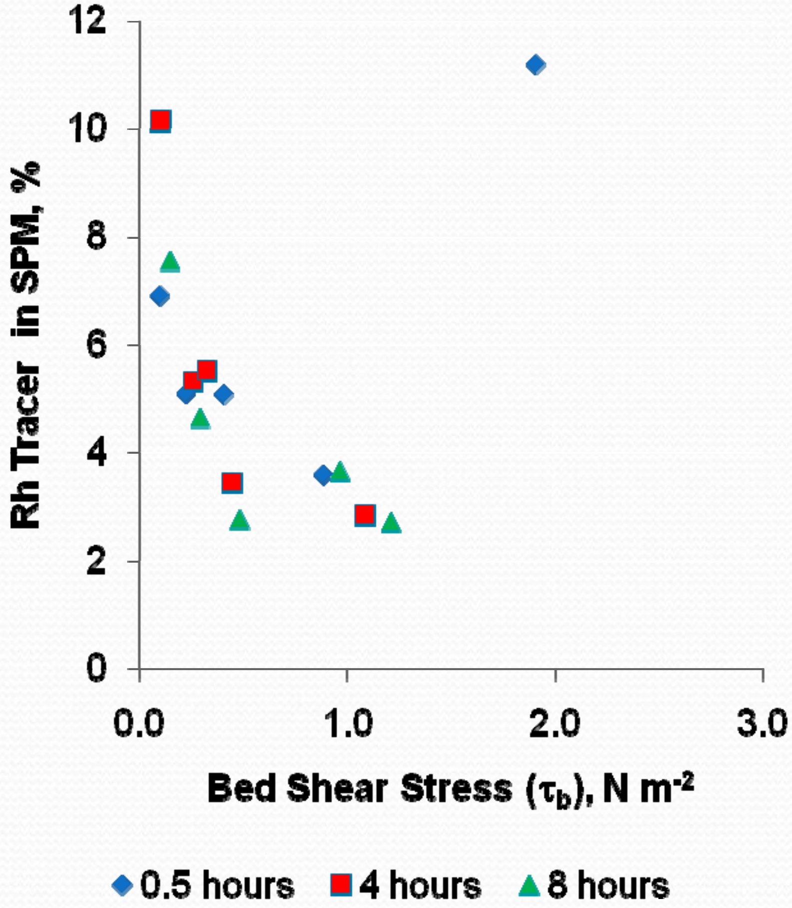


$\tau_b \propto (w)^2$

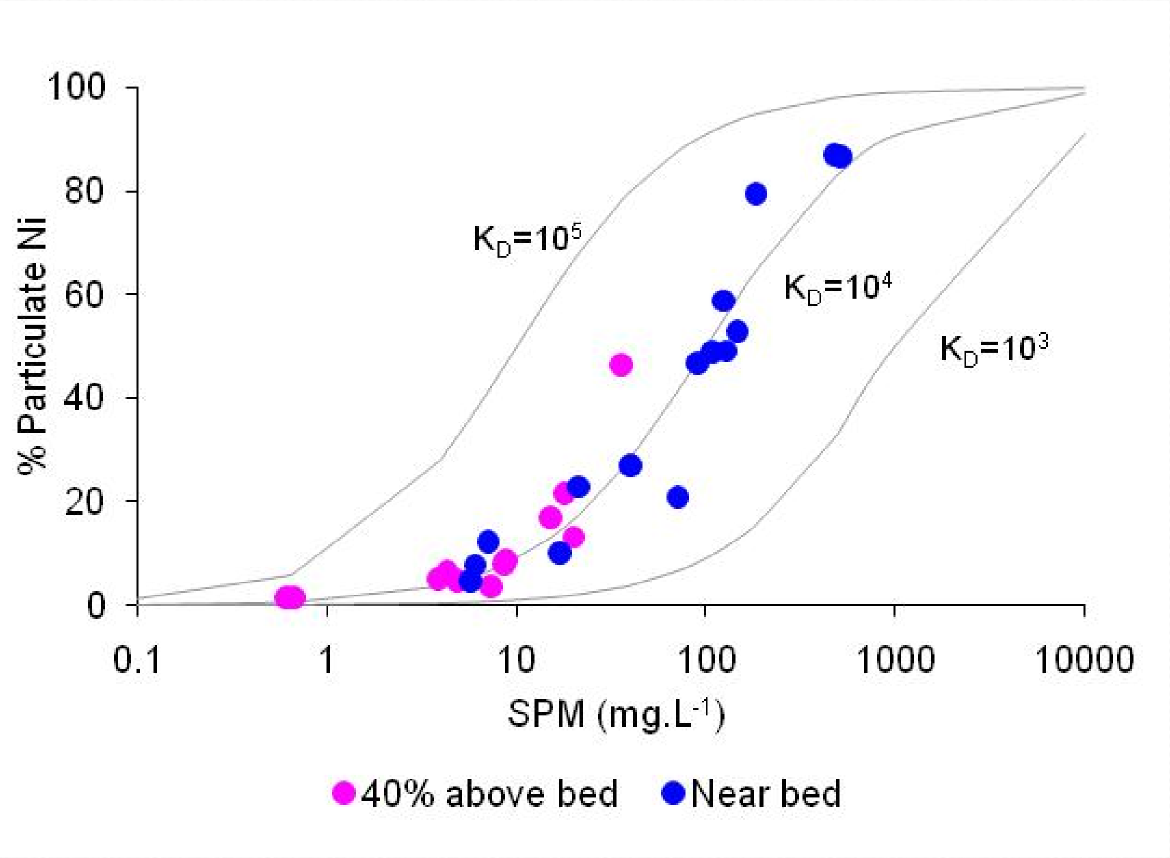
where w=RMS vertical velocity from ADV

Rhodium Tracer in SPM Near Bed

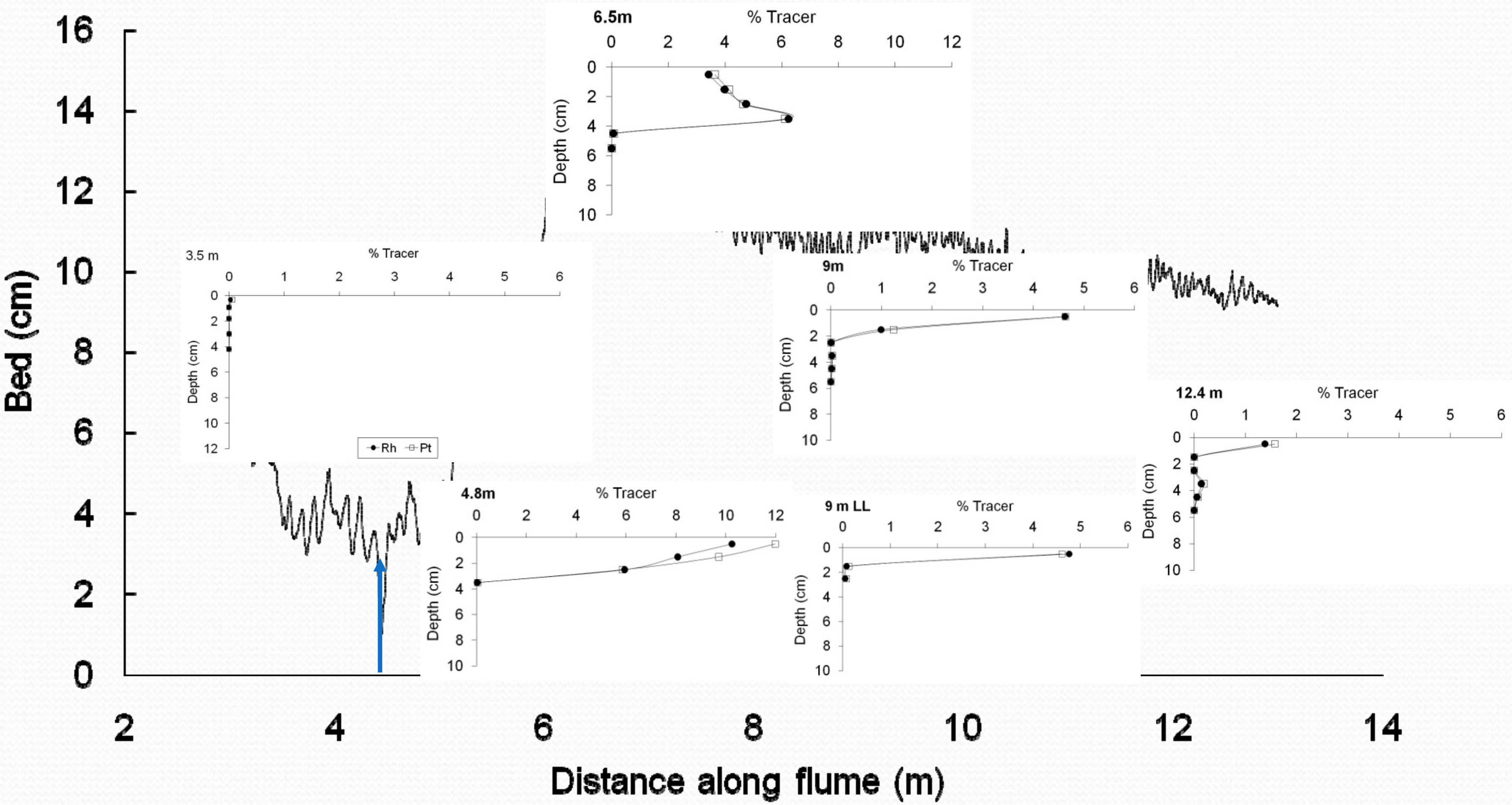




Partitioning of Ni with SPM



Tracers in Sediment Cores



CONCLUSIONS

- The SPM concentrations and the amount of labelled sediment depend on the bed stress in a complex manner because of “bathymetric feedback”;

- The K_Ds for exchangeable Ni were independent of the concentration of SPM and were of the order 10^4 L kg^{-1};

- The labelled sediments were mixed to various depths depending on distance from the source.

- Integration of hydrodynamics and geochemistry is on-going.

Sediment Mixing

Using Fick's Law:-

$$M = -D * \left\{ \frac{dC}{dx} \right\}$$

D = Mixing Coefficient ($cm^2\ s^{-1}$)

M = Mixing Rate ($\mu g\ cm^{-2}\ s^{-1}$)

$\left\{ \frac{dC}{dx} \right\}$ = Concentration Gradient ($\mu g\ cm^{-4}$)

$D \sim 10^{-3}\ cm^2\ s^{-1}$

Typical Mixing Coefficients for Estuarine Sediments $D \sim 10^{-7}\ cm^2\ s^{-1}$