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PARTRAC
MARINE DATA EXPERTISE

Innovative Tools for Rapid Site Characterization and Post-Remedial Monitoring of Contaminated Aquatic Sediments

Dr Matt Wright – Principal Consultant

4th December 2019

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25 YEARS OF ESTCP
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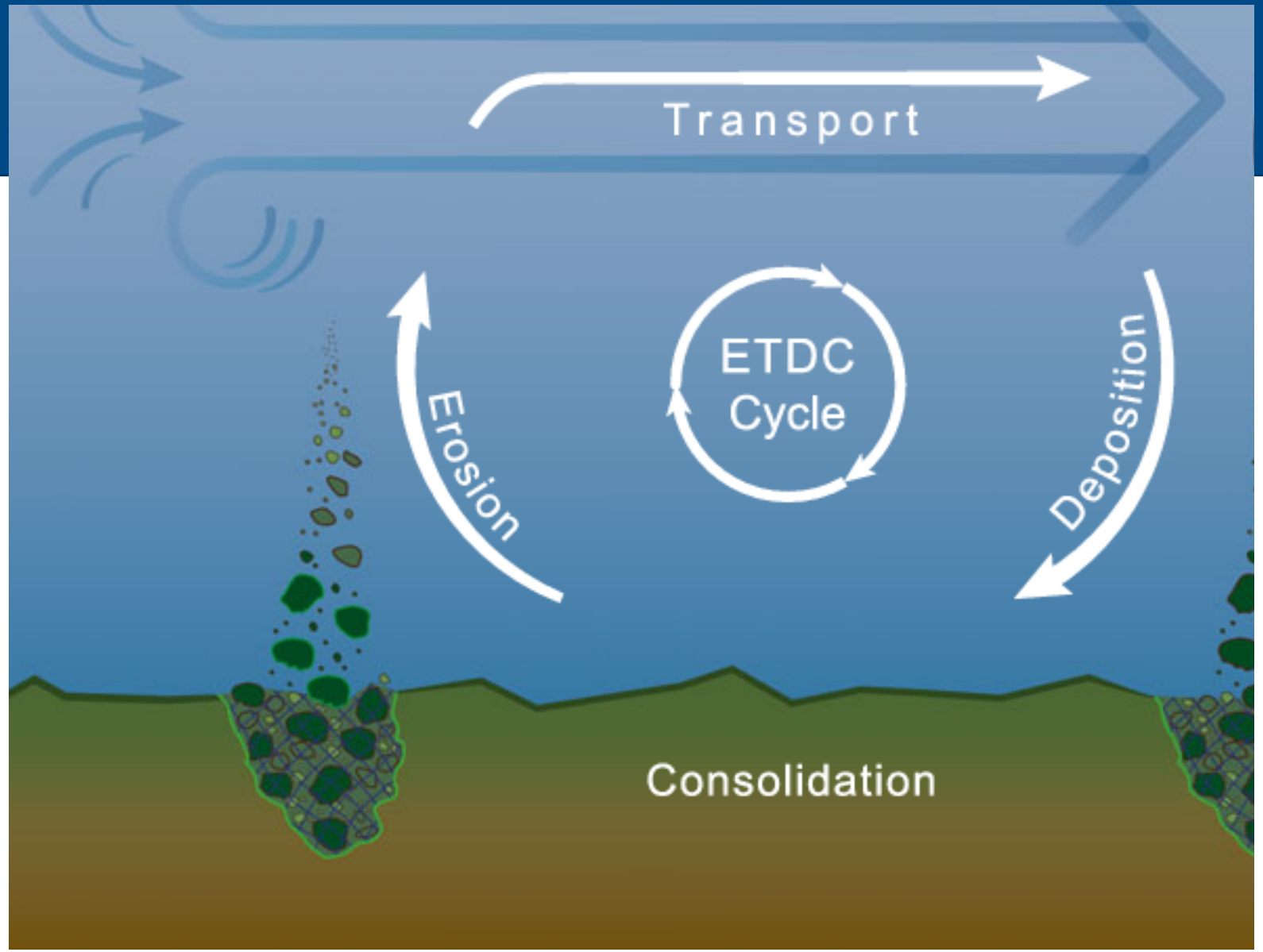
2019 | Enhancing DoD's Mission Effectiveness



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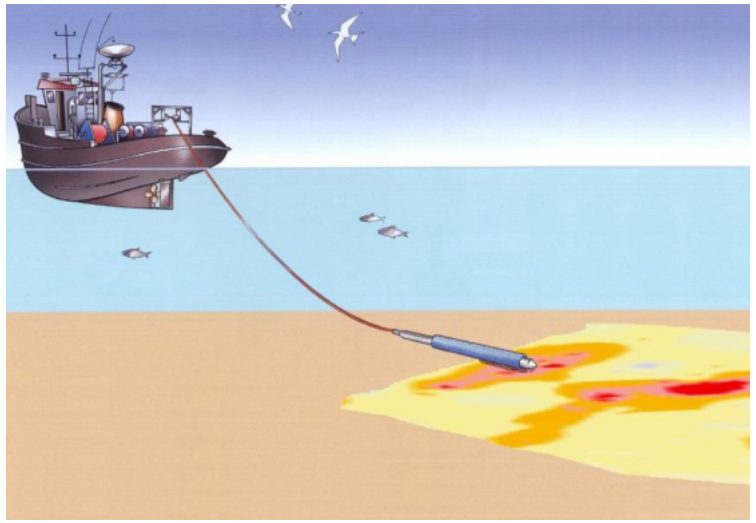
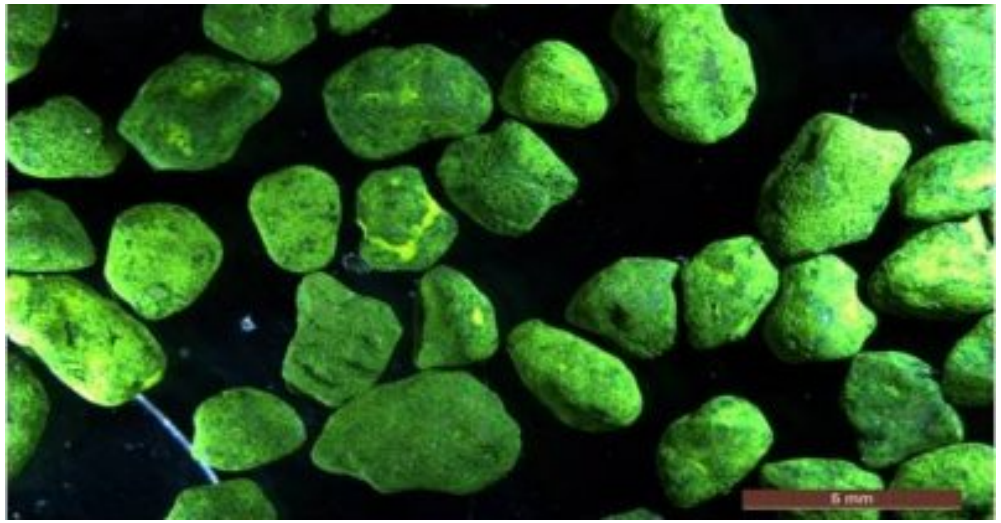
Innovative Tools for (Rapid) Site Characterization and Post-Remedial Monitoring of Sediments



1) Towed sensor



2) Sediment tracers

3) Benthic Flumes & CSM

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ESTCP Project ER19-B2-5014 (2019-Present)

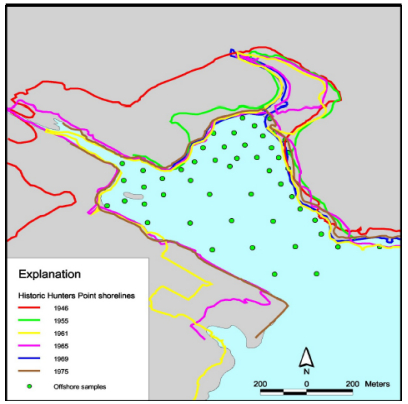
NON-INVASIVE TOOL FOR RAPID SITE CHARACTERIZATION AND POST REMEDIAL MONITORING OF AQUATIC SEDIMENTS

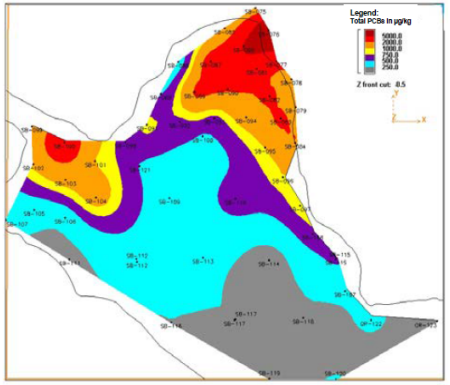
- Contamination of aquatic sediments is a **significant and ongoing liability** for the DoD - $Billions
- Current approach to management and monitoring involves **invasive, labor intensive (costly/time consuming)** methods to quantify and map Contaminants of Concern (CoCs)
- At present no means exist for **rapid *in situ* mapping and monitoring** of CoCs
  - Non-effective remediation/remediation monitoring
  - Hot spots not mapped
  - Incomplete insight into sediment/contaminant properties and processes (e.g. conceptual site models)
  - Removal and storage/processing of non-contaminated sediments at disposal sites

Present vs Proposed Approach

Example of present approach

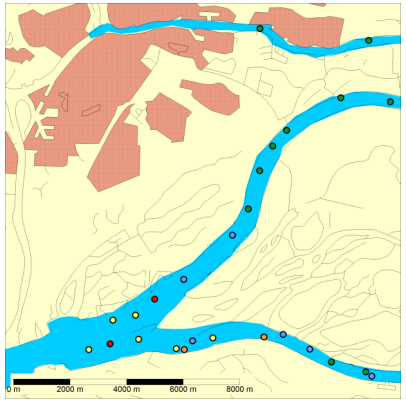
- 44 sediment samples
- ~200 samples / km^2
- Map produced by interpolation
  - highly influenced by point measurements
  - potential hot spots missed

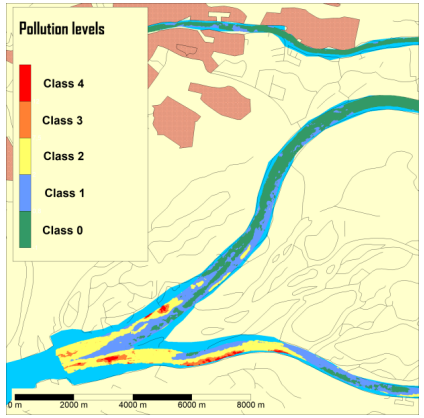




Example of proposed approach

- 27 samples
- ~2 samples / km^2
- Reduced sampling
- Highly detailed map
  - Realistic representation of contaminant distribution





Technical Objectives

- **Main objective**: to demonstrate that the technology has significant scientific, cost and HSE benefits in the mapping, monitoring and management of CoCs (PCBs, PAHs, heavy metals) in aquatic sediments compared with existing techniques and methods

  - **Demonstrate** the technology at suitable DoD-led sites
  - **Compare** the technology with existing contaminant sampling methods and outcomes
  - **Obtain** sufficient good quality data to undertake meaningful cost and safety benefit and scientific data analyses to prove the new technology
  - **Develop** guidance and design protocols to support technology transition in a wider DoD context

Technology Description

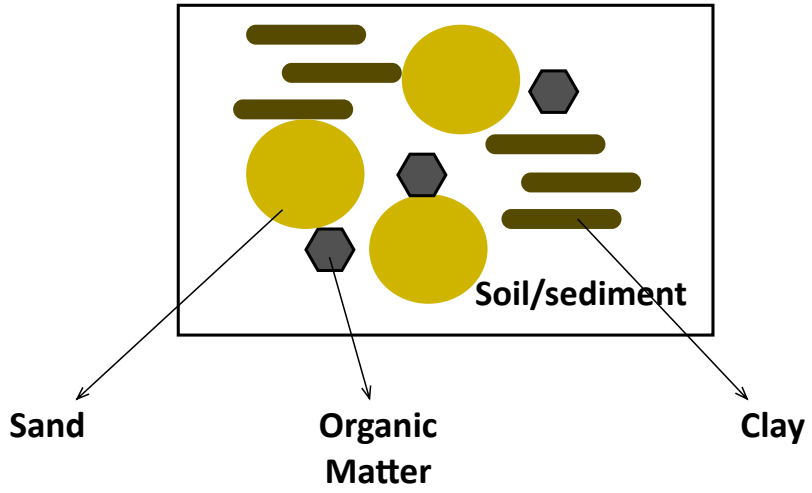
- The technology uses a specially adapted **gamma spectrometer** to provide rapid site characterization and mapping of CoCs in aquatic sediments

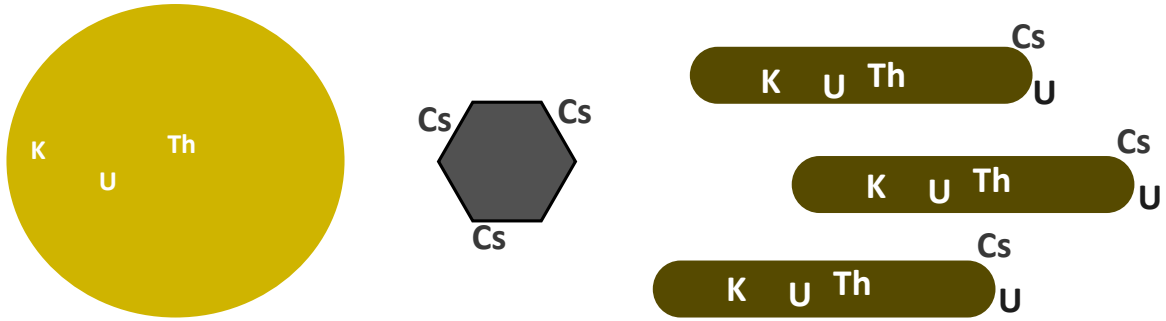
- The technique makes use of the **known adsorption properties** of CoCs with clay minerals, and has been used successfully to map CoCs in ports, rivers and estuaries in Europe for the past 10 years

- The method is **innovative** - it provides rapid, quasi real-time mapping of CoCs through the use of naturally (or artificially) occurring radionuclides in sediments that are a proxy for a particular contaminant or contaminants

Sediments as proxy for contaminants

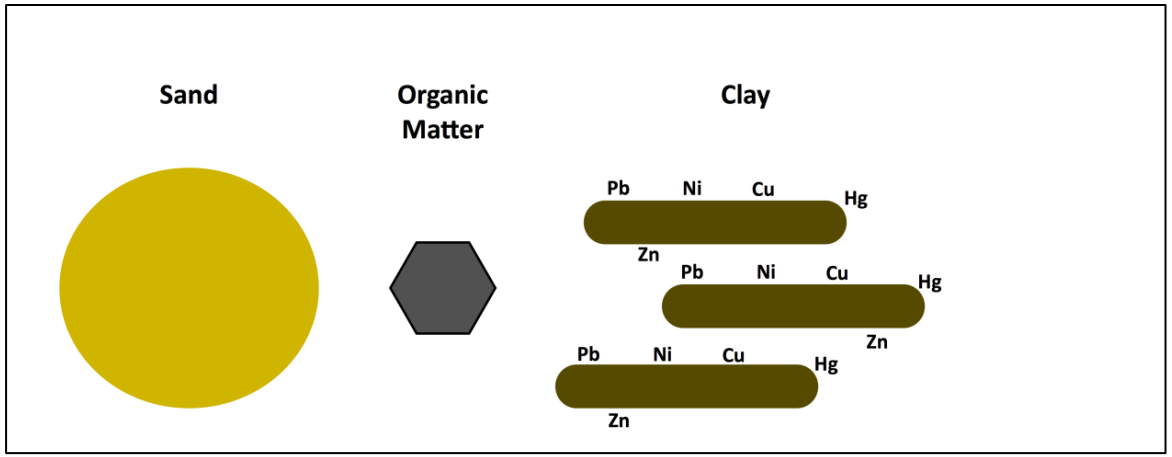
- ^{40}K, ^{238}U, ^{232}Th enriched in clay particles
- ^{137}Cs binds to organic matter
- Depends on provenance
- Determination of regionally dependent “fingerprint”

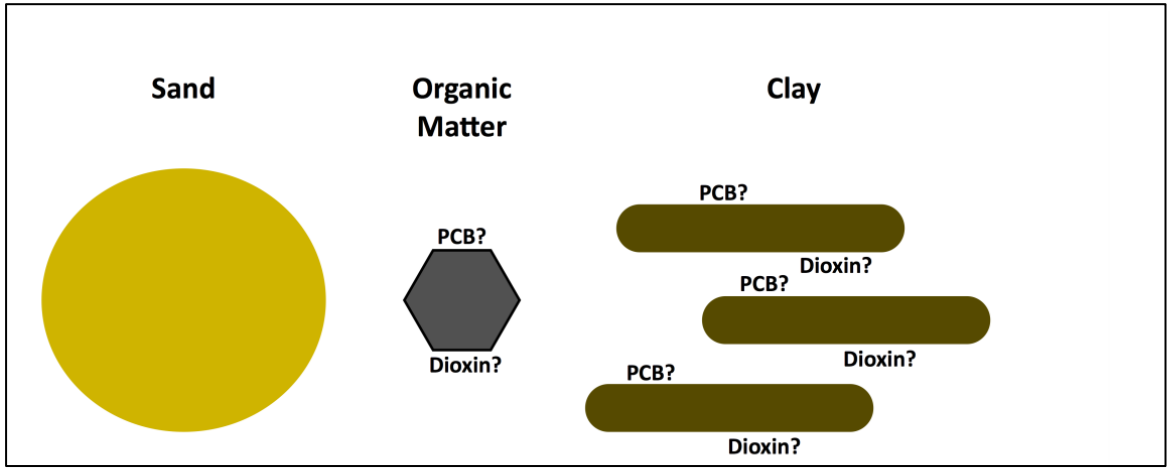




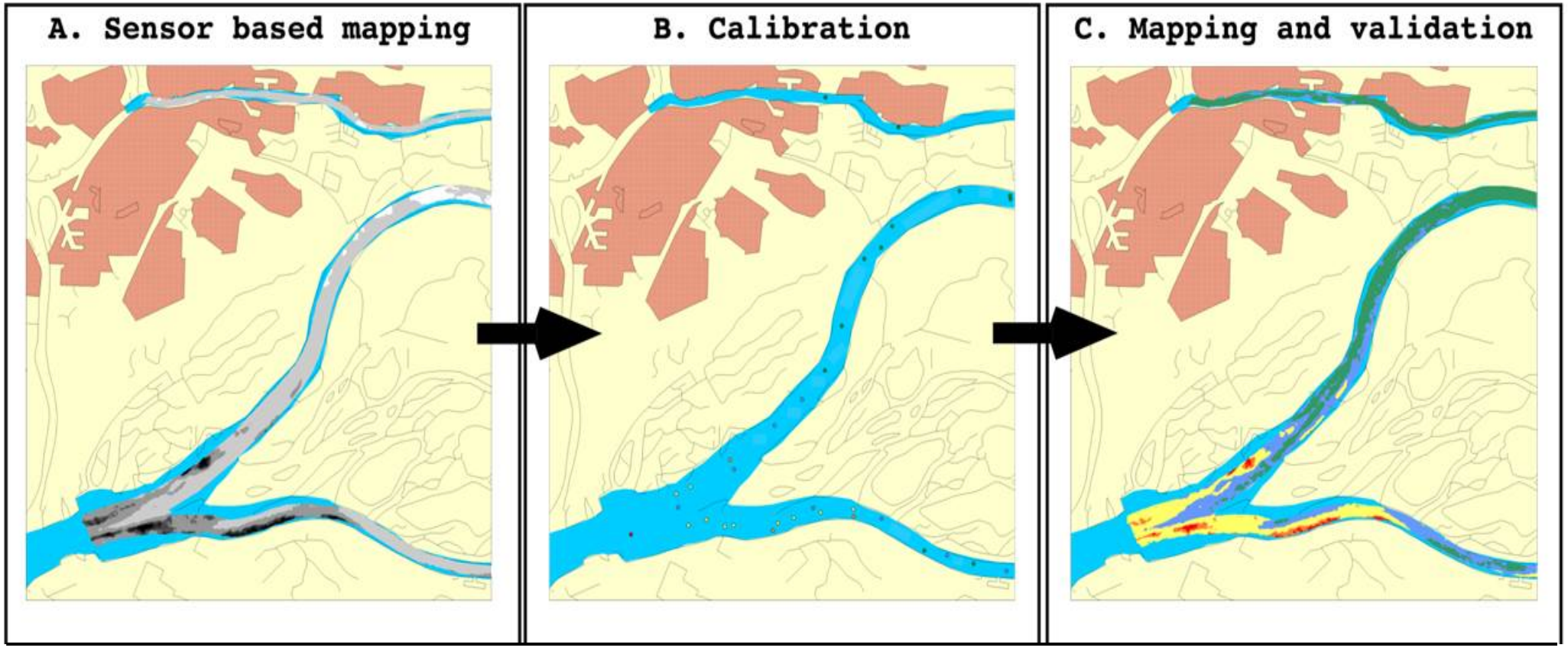
Contaminants

- Clay and Organic Matter (OM) have high cation exchange capacity
- Contaminants are bound to clay and OM particles
- Clay (and therefore ^{40}K, ^{238}U, ^{232}Th) is a proxy of contaminant levels
- Local calibration with samples needed





3-stage process



- Field mapping
- Sediment variability assessment

- Selective sampling
- Calibration

- Mapping
- Validation

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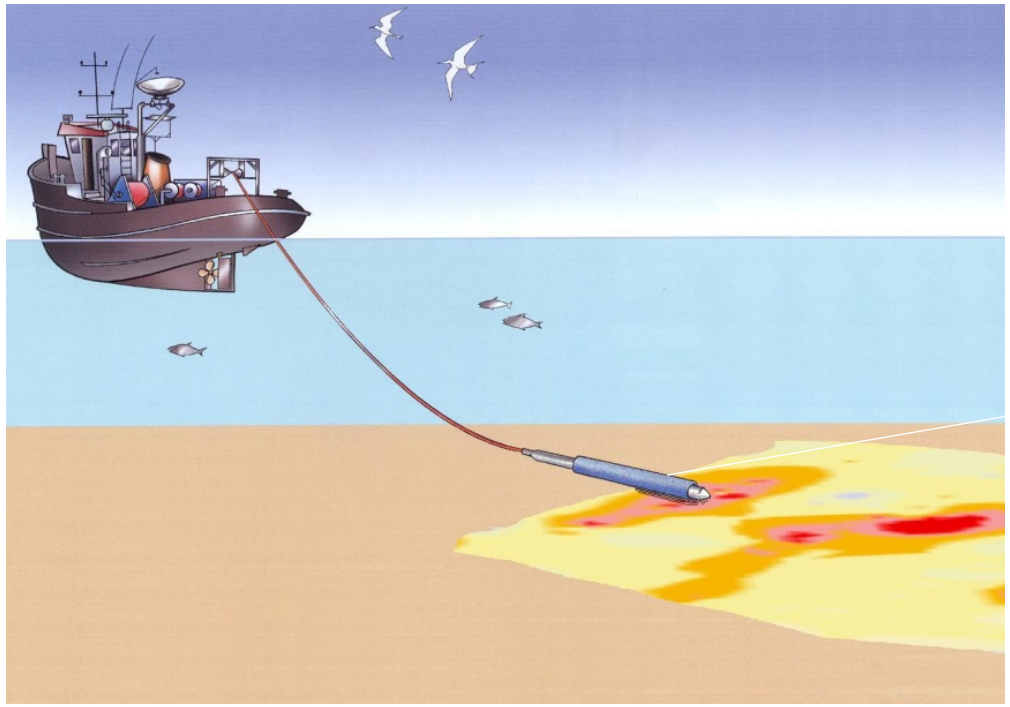
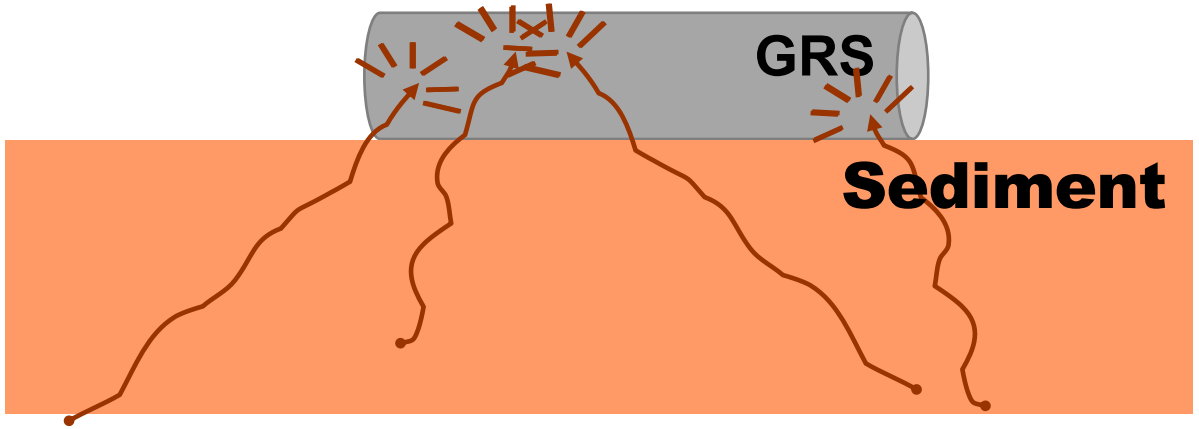
Mapping

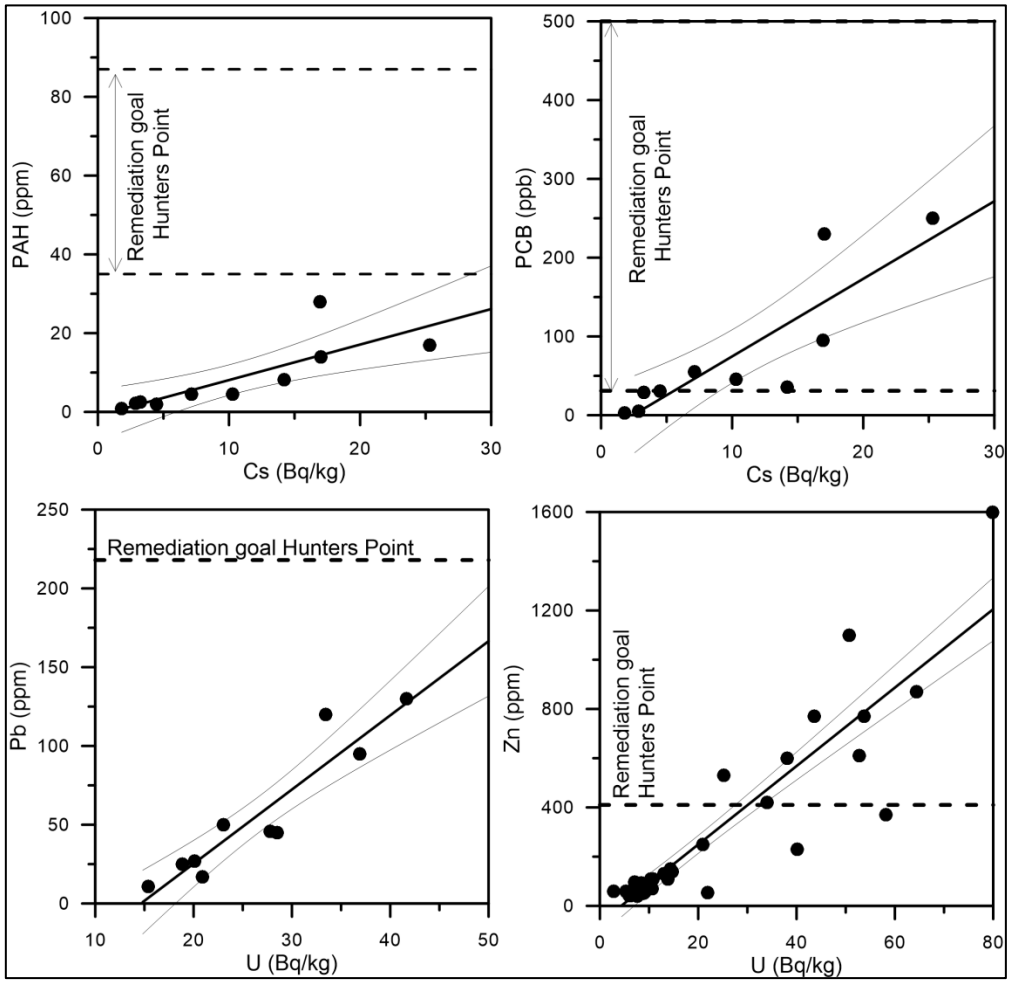




- A passive gamma spectrometer provides a continuous measure of background radiation
- Spectral information is recorded and analyzed to concentrations
- Result: maps of radio-emitting geochemical trace elements (^{40}K, ^{238}U, ^{232}Th, ^{137}Cs)

Calibration

- Sediment samples collected for calibration
  - Measure radionuclide concentration (laboratory)
  - Measure contaminant concentrations (laboratory)
- Site-specific calibration model
  - Convert field measurements to conaminant maps



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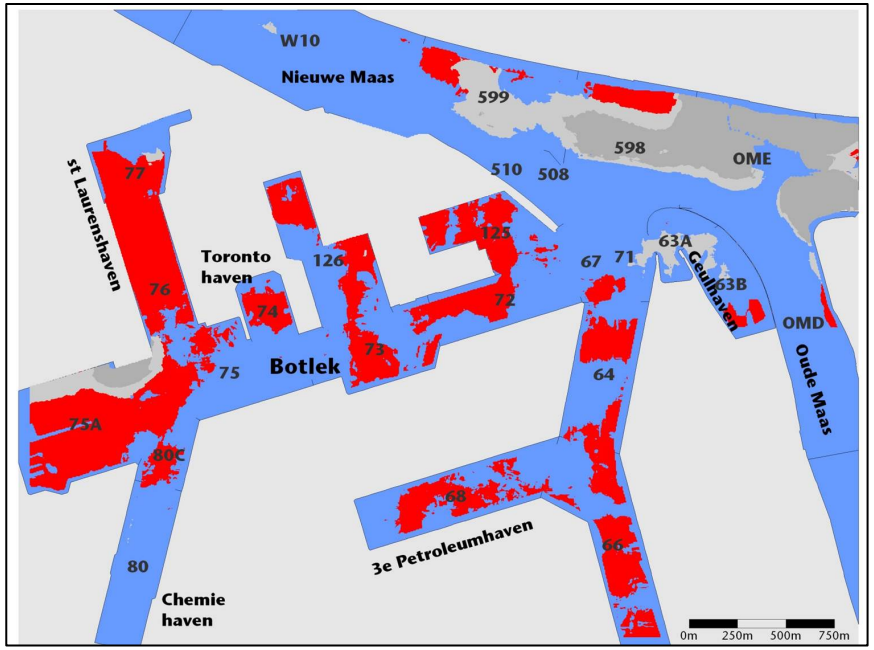
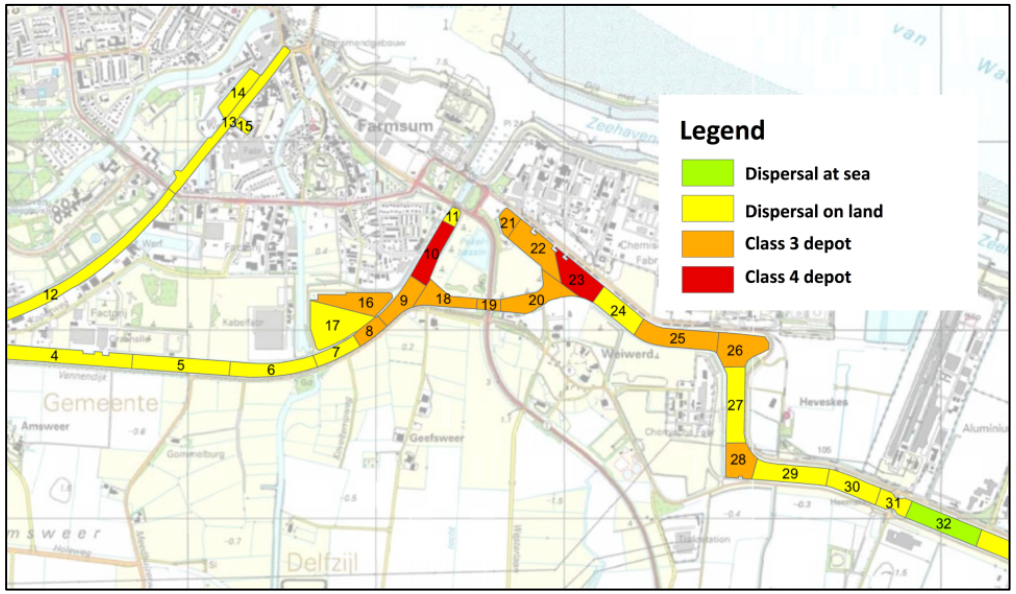
Results Example



Detailed distribution map of contaminants

- Dioxin concentrations above remediation level shown in **RED**
- Increased concentrations of phosphogypsum shown in **GRAY**



Zonation map

for disposal actions

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ESTCP Project: ER-201214

Demonstration of Fluorescent Magnetic Particles for Linking Sources to Sediments at DoD Sites (2012 -2018)

- Joint Project led by Dr Jim Leather at SPAWAR
- Co-PI – Dr Kevin Black, Technical Director (Partrac Limited)

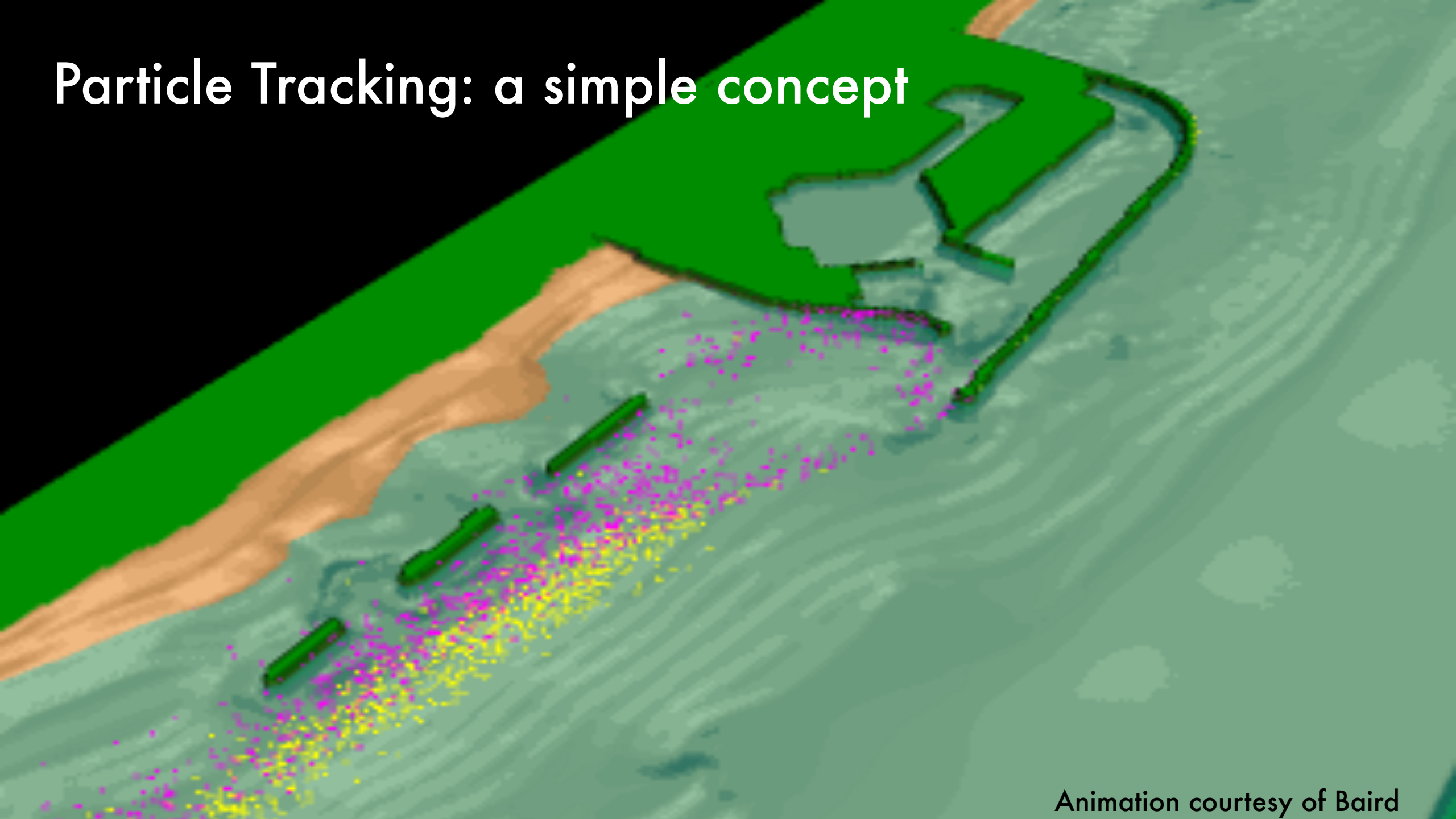
Particle Tracking (Sediment Tracing)

- Particle tracking is a practical technique used to determine the source-sink relationships (transport pathways), the depositional footprint and rates of sediment transport through the environment.
- It uses natural and artificial sediment that has been ‘tagged’ or ‘marked’ with an identifiable signature. These are called **tracers**.

Why is it useful?

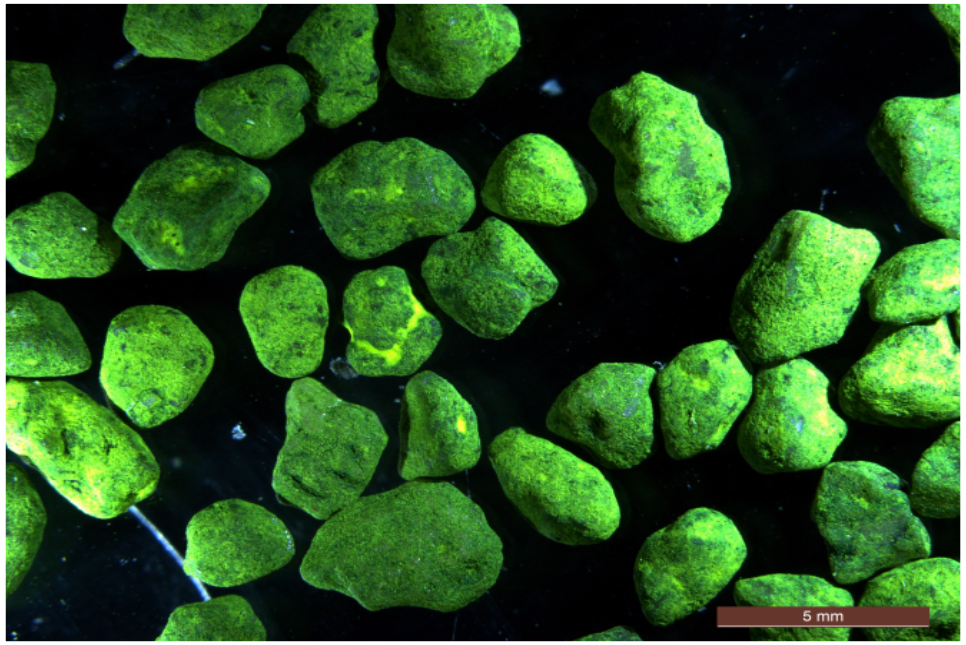
- Improve the understanding of sediment transport processes
- Evaluate management and mitigation techniques
- Develop and validate sediment transport models

Particle Tracking: a simple concept



Animation courtesy of Baird

Partrac's Dual Signature Tracer



Fluorescent and magnetic tracer particles

A 30cm (1ft) long bar magnet saturated with tracer particles

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Demonstration Project

Project consisted of two field campaigns to:

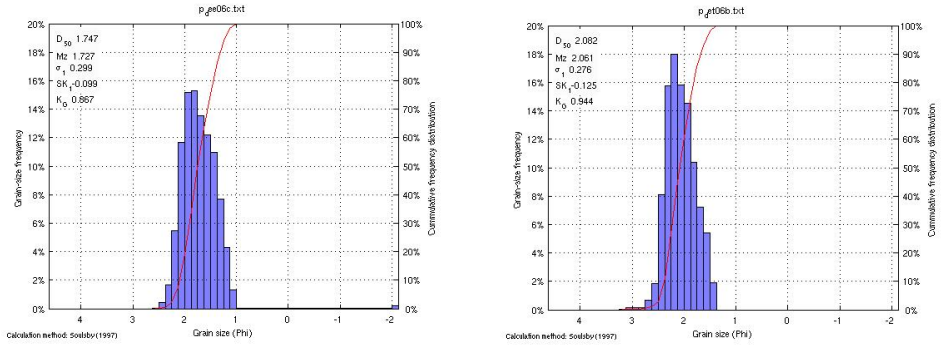
1. Quantitatively track and map the depositional footprint of particles released from typical DoD discharges into adjacent aquatic environments.

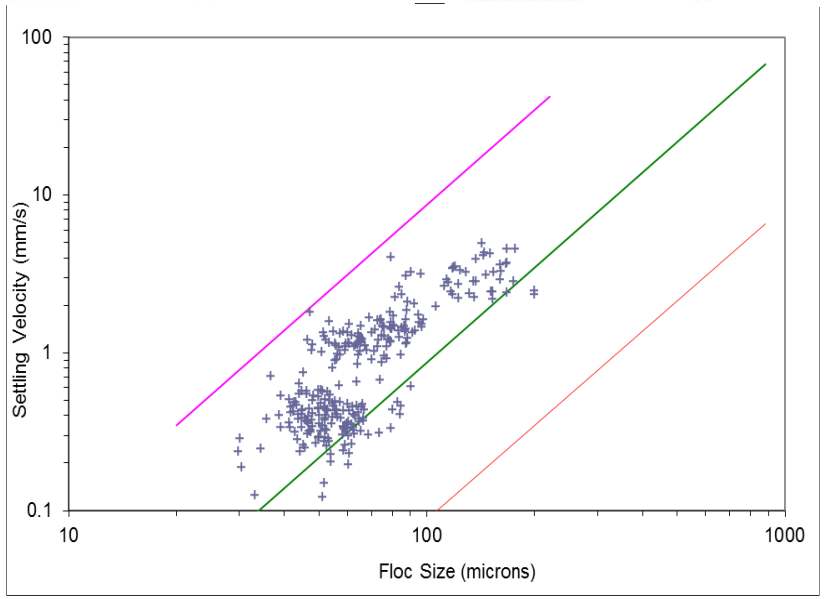
2. Assess the loss of amendment material from an activated carbon cap and potential for recontamination from an adjacent upland site.

Effective Tracer Design

Active sediment tracers must:

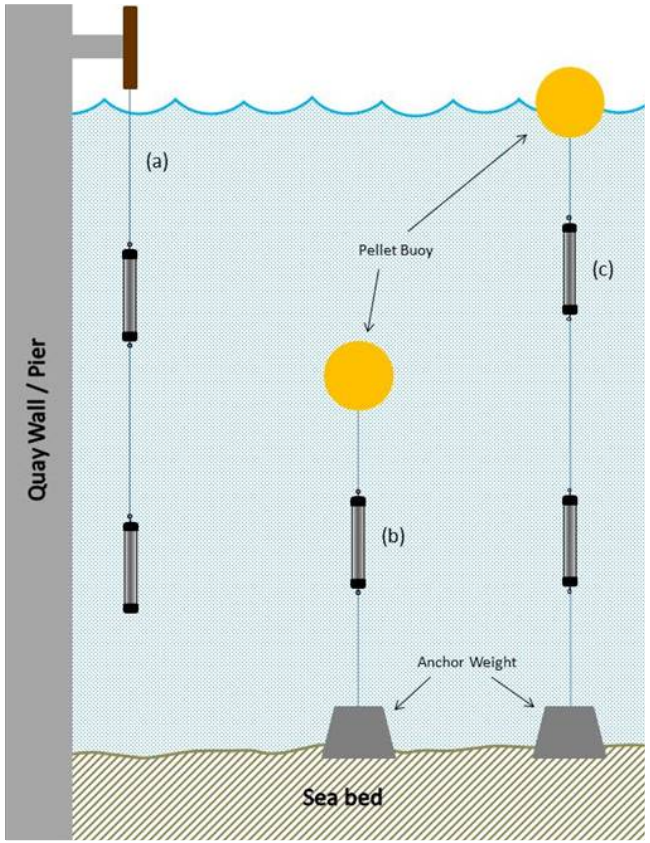
- Closely match the hydraulic properties of the native sediment or material of interest.
- Remain identifiable within the native sediment load over appropriate temporal scales.
- Not impact the transporting system in any manner.

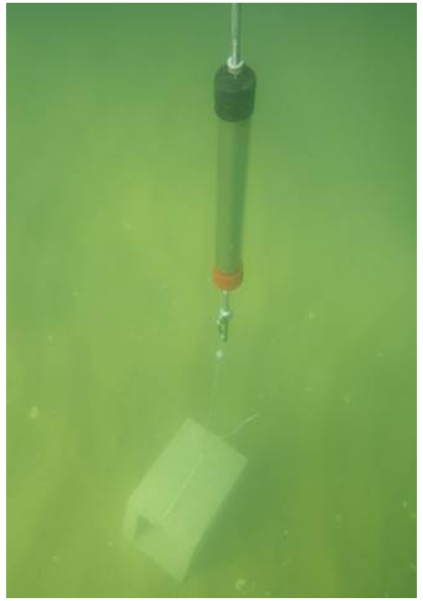


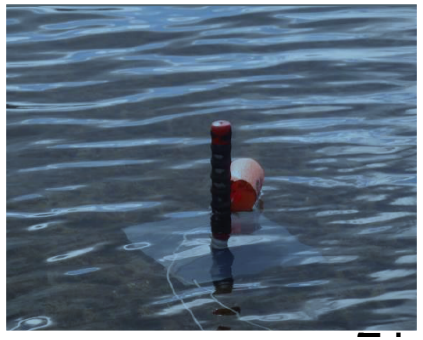


Novel Sampling– a multi-tool approach

Exploiting the magnetic and fluorescent signatures







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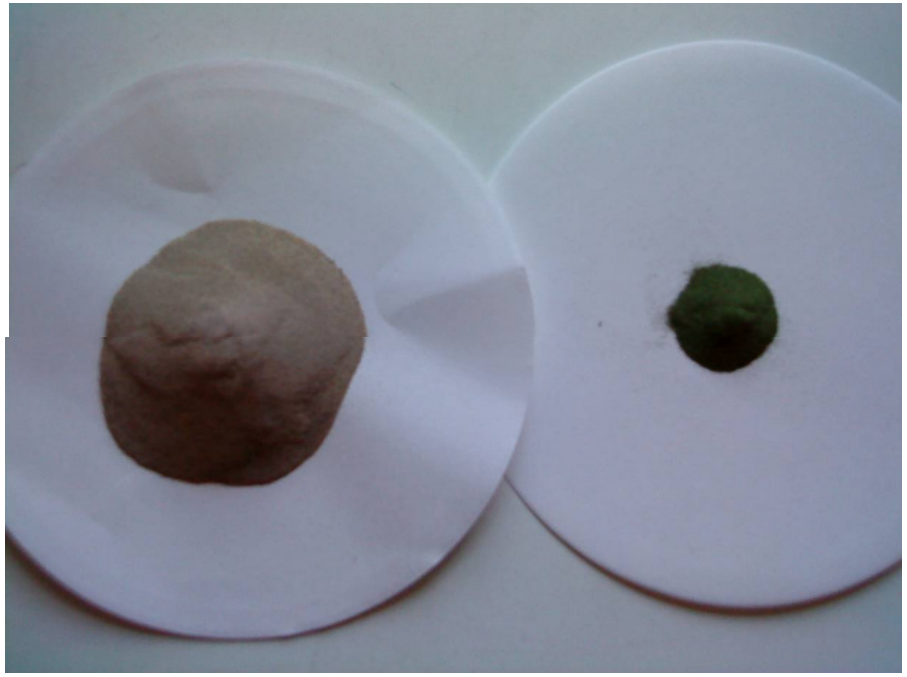
A Robust and Rapid Analytical Approach

Magnetic separation



Spectrofluorometric technique

0.982 g

- The aim of tracer enumeration is to determine the dry tracer mass
- Optimal approach: Non – resource intensive methodology

Methodological Framework

1. Background Survey
2. Design / Select Tracer(s)
   - Match the Tracer to the Native Sediment
3. Tracer Introduction to the Environment
4. Sampling
5. Tracer Enumeration
6. Analysis of Results

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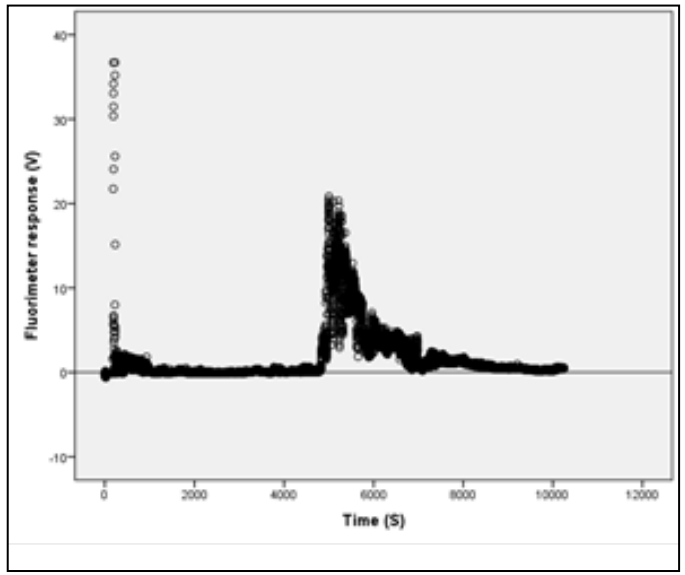
Assessing the Spatio-Temporal Distribution of DoD Discharges



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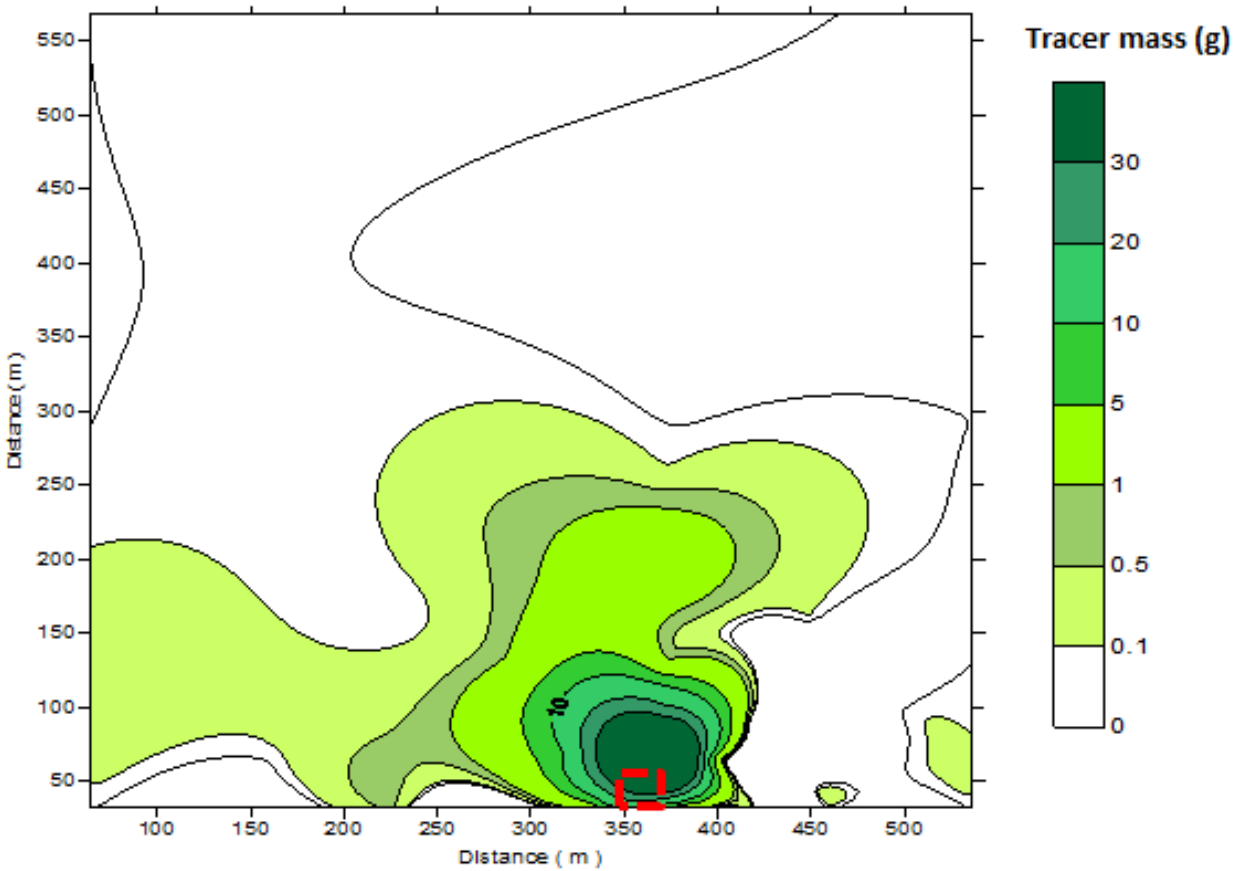
Mapping the plume



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Discharge zone

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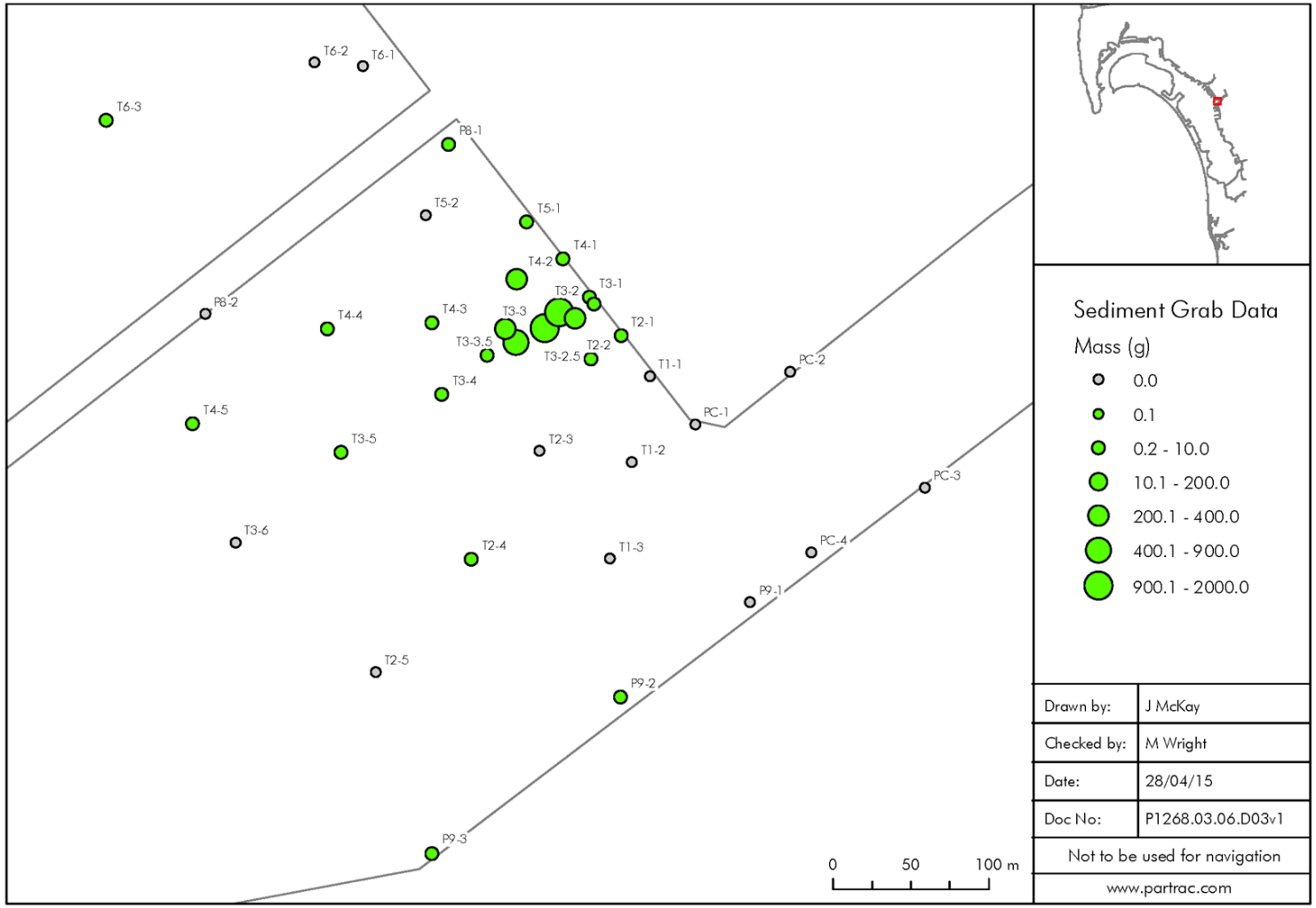
Mapping the depositional footprint



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Assessing the distribution of amendment material following deployment at an activated carbon cap

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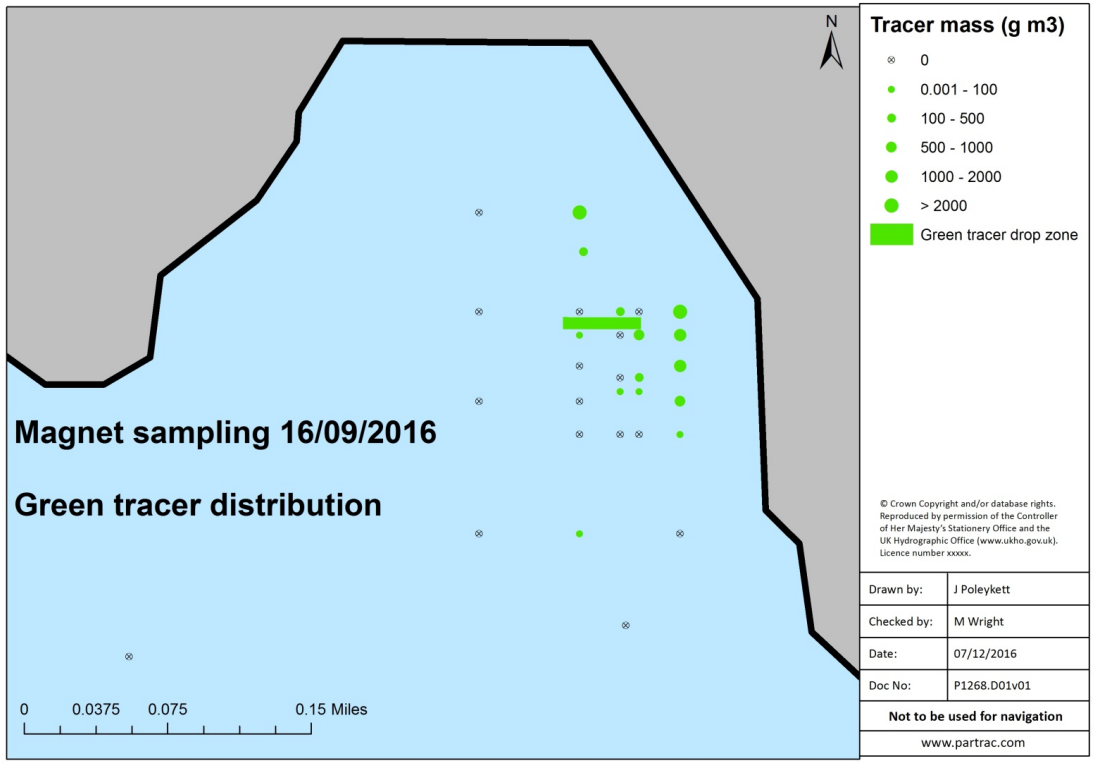
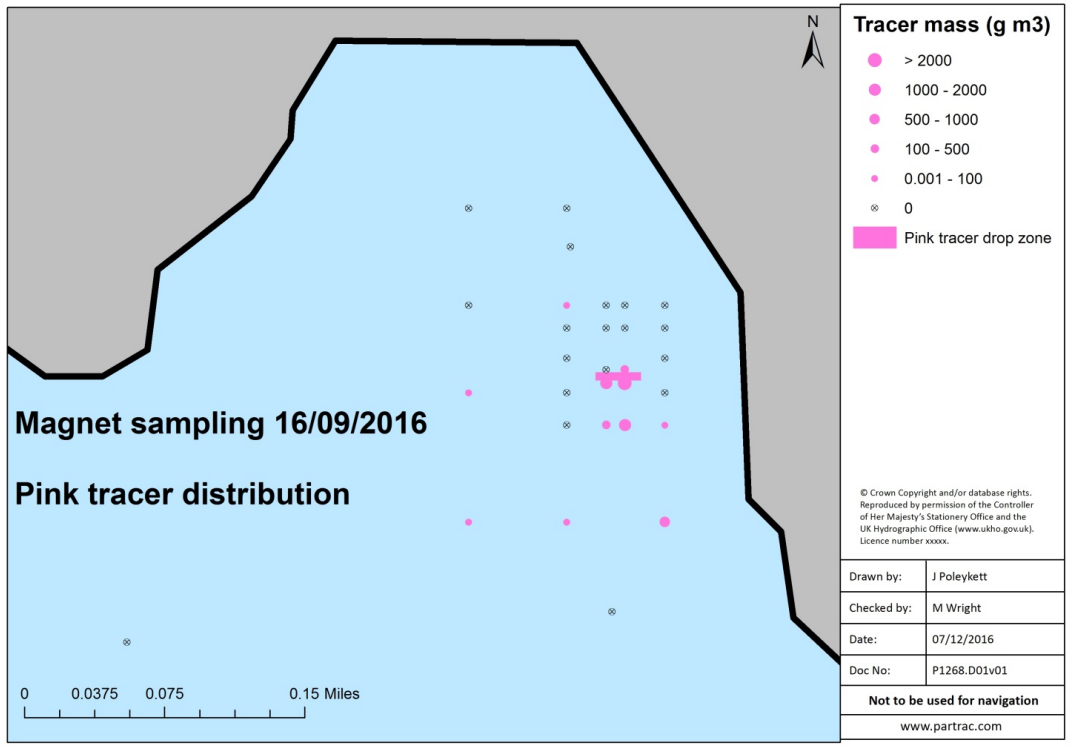
Spatial distribution of material





Main Conclusions of the Demonstration Project

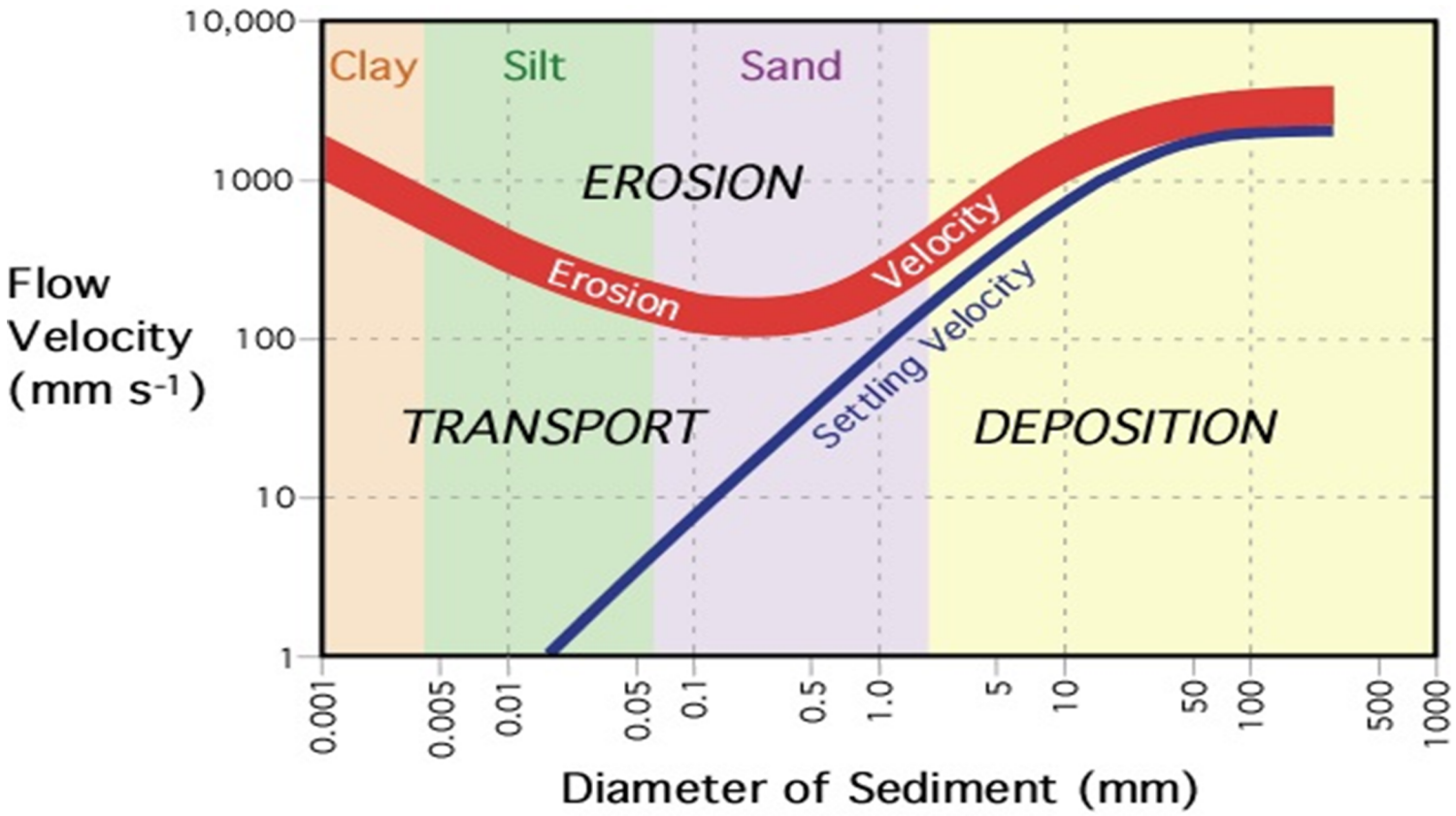
- The demonstration of a robust, commercially available, sediment tracer.

- The tracer successfully met all required performance objectives - The Technology is now ‘proven’ as a tool for the DOD.

- A robust tracer applied within a defined methodological framework provides a useful ‘tool in the box of tricks’ for understanding and mapping sediment transport pathways and assessing sediment transport dynamics.

Benthic Flumes

Tools to Determine In Situ Erodibility of Sub-aquatic Sediments



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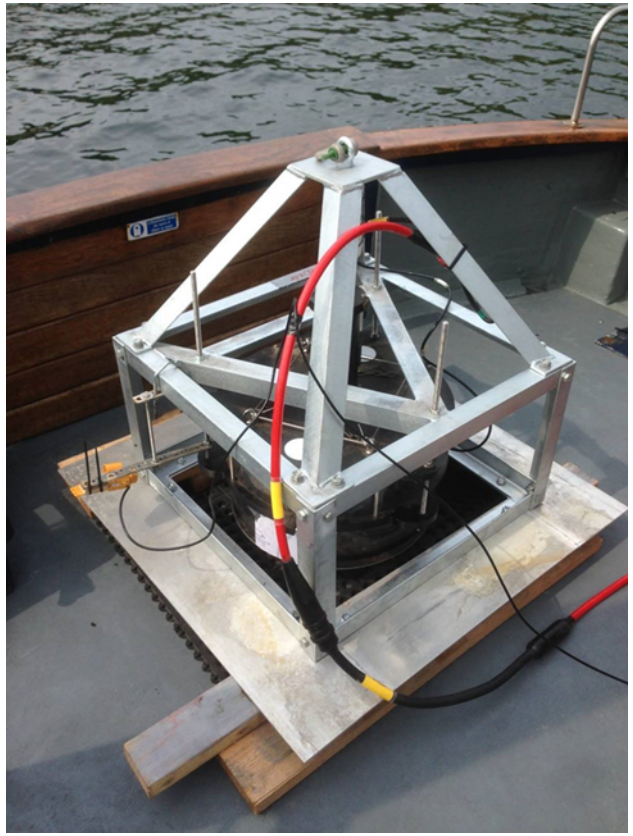
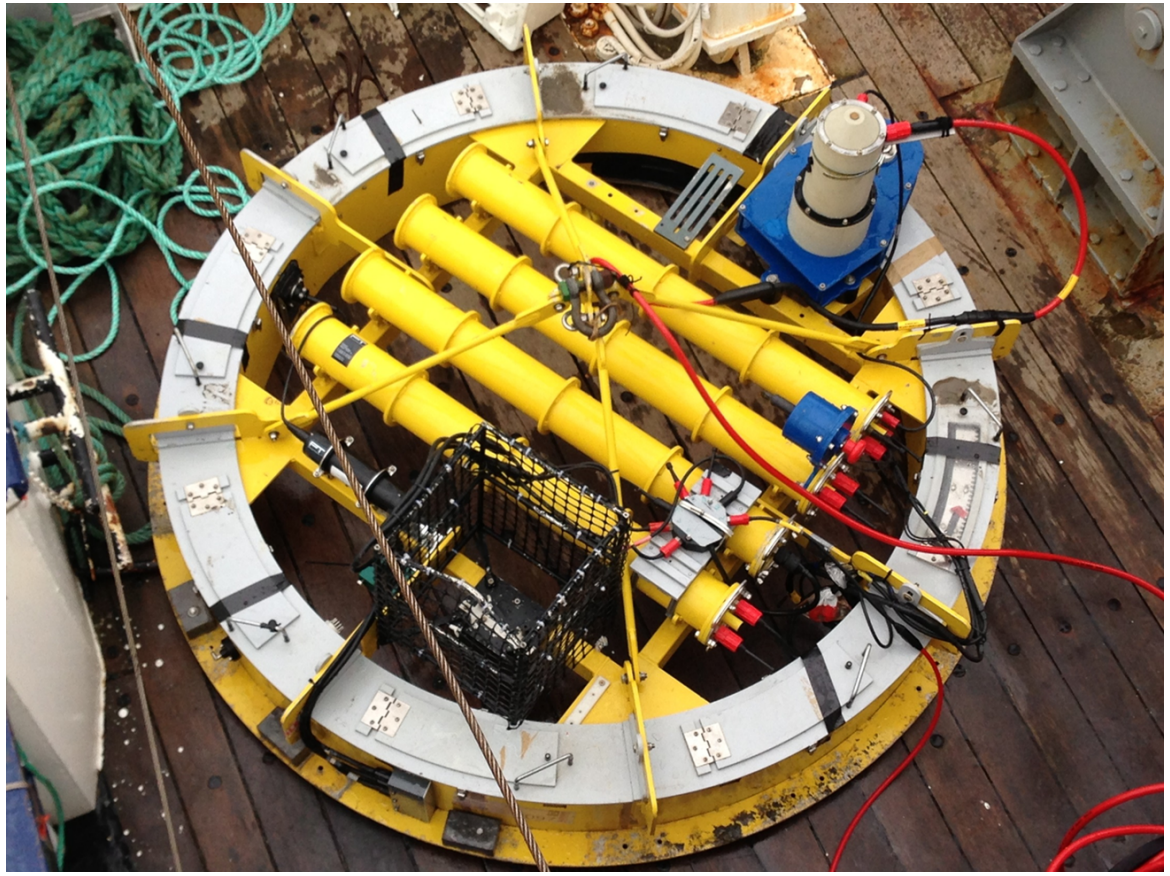
Benthic Flumes

- Practical, easily deployed
- Avoid necessity to collect sample (cf. disturbance)
- Removes regulatory risks for contam. sediments
- Semi-mature technology
- 6-8 deployments / day
- Tool to inform Conceptual Site Model development



Voyager I

Voyager II



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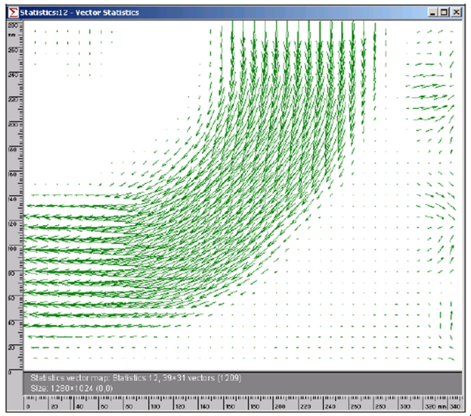
Measuring Sediment Resuspension

Deployed in the Florida Everglades for the SFWMD

- Suitable up to depths 40 m
- Lightweight and field portable
- Erosion runs take approx. 90 minutes
- Turbidity sensor calibrated by collecting simultaneous water samples
- Can also measure deposition rate / settling velocity
- Can impose erosion – sedimentation – erosion etc cycles



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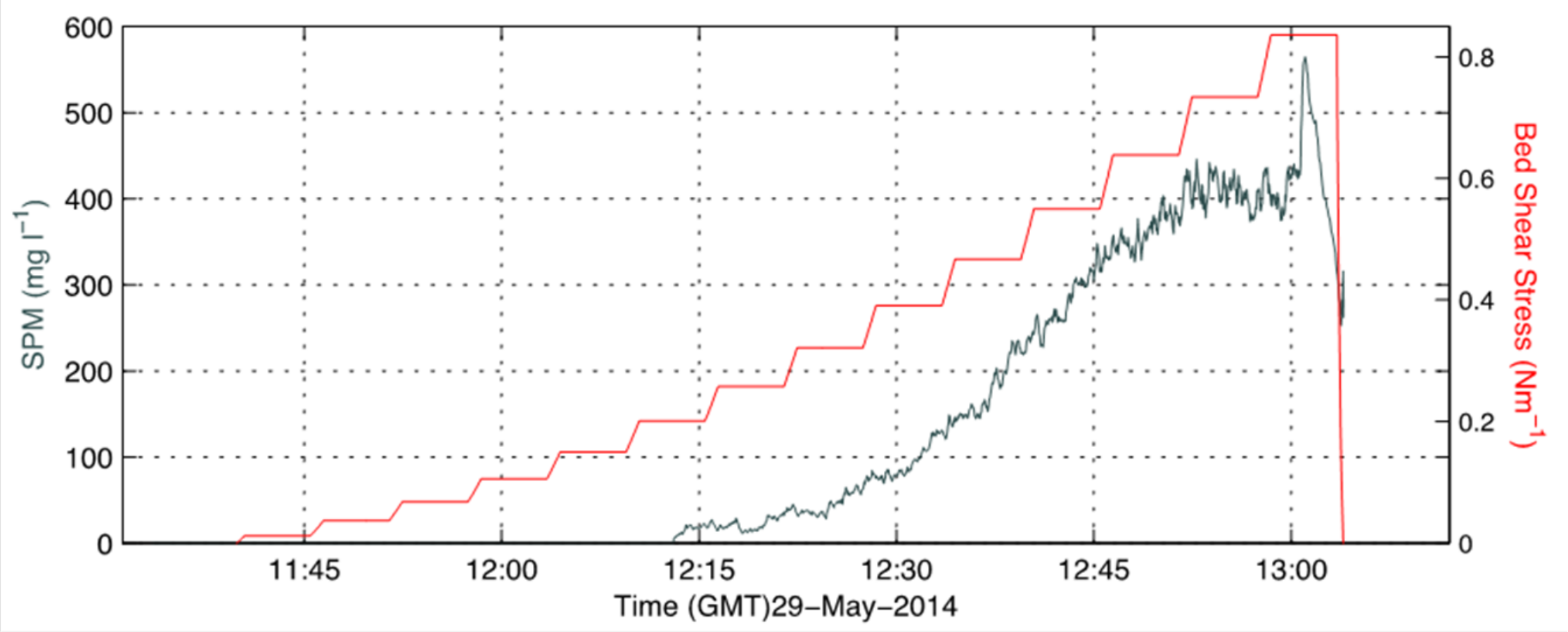
Aquaculture Site, Scotland, UK



Critical shear stress for motion τ_{0crit} and seabed resuspension rate ε

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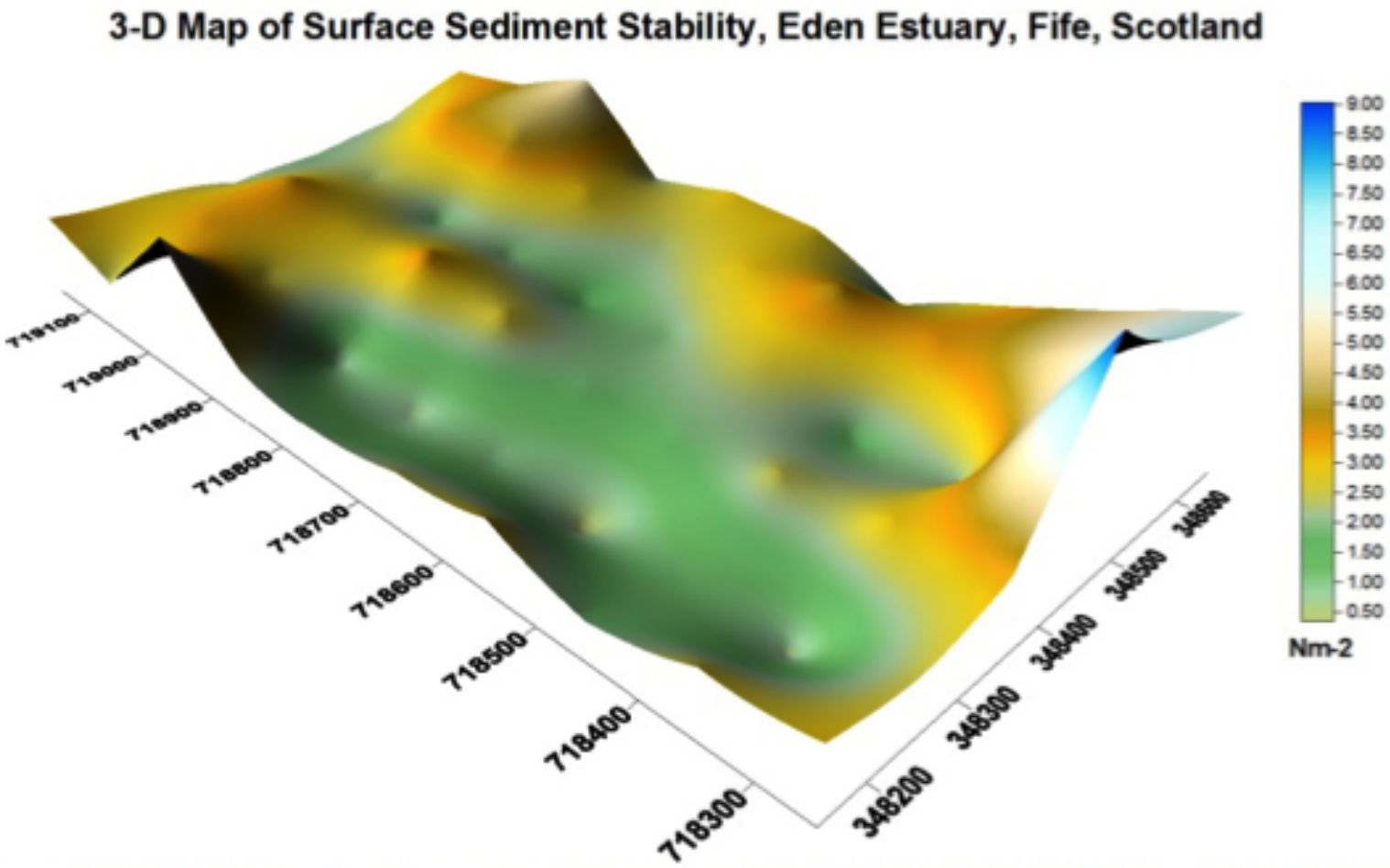
Cohesive Strength Meter

- Measures the surface erodibility of marine, fluvial and terrestrial sediments
- Capable of conducting up to 100 tests per run and with up to 80 predefined test routines
- Internationally recognised as the leading device for the rapid in situ measurement of sediment erosion

A World First ?



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