Practical and Achievable Monitoring of Dredging: from “Dredging for Sustainable Infrastructure”……& Beyond……!
1. Does monitoring matter for dredging, who cares, why?

2. Delivering **practical, achievable** & fit for purpose monitoring:
   
   o Key principles for designing monitoring for dredging
   
   o Why not losing sight of the science is essential for practical and achievable monitoring
   
   o What is commonplace in modern monitoring of dredging; and
   
   o What is likely to constitute practical and achievable monitoring of dredging in the near future.
Does monitoring matter for dredging?

- **YES**

Who does it matter to?

- Regulators, Developers, Contractors, Other Stakeholders

Why does it matter, what is it relevant to?

- Quantifying impact, assessing licence compliance, managing the works, calibrating/validating model predictions
Types of Monitoring

- **Initiation**
  - Desk Study
  - Site Investigation

- **Planning & Design**
  - Baseline Monitoring informs Modelling, Front-End Design, EIA, & Surveillance & Compliance Monitoring

- **Construction**
  - Surveillance Monitoring (includes Adaptive Monitoring if any)
  - Compliance Monitoring
    - Surveillance Monitoring assesses change relative to baseline & relative to thresholds agreed to manage the works
    - Compliance Monitoring provides measurements for assessment against environmental requirements in licences, permissions and contracts

- **Operation & Maintenance**

From: *Dredging for Sustainable Infrastructure*, CEDA/IADC, 2018
Practical, achievable & fit for purpose monitoring for dredging
Key **design principles**, for delivering practical, achievable & fit for purpose monitoring are:

1. Monitoring should be proportionate to the scale of the dredging and the significance of the potential changes to the environment

2. Design must be undertaken by suitably qualified and experienced individuals and maintain a project-scale perspective

3. Monitoring must have clearly identified and recorded objectives which are agreed Regulators, the Project Owner and Contractors in advance

from: Lee et al., in press; and *Dredging for Sustainable Infrastructure*, CEDA/IADC, 2018
**Key design principles**, for delivering practical, achievable & fit for purpose monitoring are:

4. Baseline monitoring (in combination of with existing data and desk studies) must be capable of defining the natural variability of the key environmental parameters and resources.

5. The statistical / mathematical analysis to be applied to monitoring results in order to analyse them and detect change must be taken into account in the monitoring design.

6. Measurements for baseline monitoring, surveillance monitoring and compliance monitoring must all be carried out in a sufficiently consistent way to allow direct inter-comparison of the data.
Key design principles, for delivering practical, achievable & fit for purpose monitoring are:

7. Monitoring should be efficient i.e. equipment levels, study durations and numbers of monitoring sites should not exceed those needed in order to meet the monitoring objectives, and multiple usage of datasets should be planned where possible. [5% rule]

8. Procedures for judging whether monitoring effort should be increased, decreased or stopped should be agreed by all relevant parties (and documented) well in advance of dredging commencing.

from: Lee et al., in press; and Dredging for Sustainable Infrastructure, CEDA/IADC, 2018
Key **design principles**, for delivering practical, achievable & fit for purpose monitoring are:

9. Monitoring techniques specified must be robust (reliable, tried and tested) and practical (realistic to implement) if they are a key part of the monitoring design.

10. The way that data is managed and used can be as important as the data itself. Monitoring design should include provisions for: data quality assurance; collection and storage of metadata; data security; data transmission; data presentation/reporting; and data storage/archiving.

from: Lee et al., in press; and *Dredging for Sustainable Infrastructure*, CEDA/IADC, 2018
Don’t lose sight of the science amid everything else, it really matters!
What are the sources, magnitudes and combined consequences of monitoring errors – do they matter?

Key monitoring techniques are:

- water sampling and lab analysis (TSS); and
- the use of turbidity sensors (e.g. OBSs) for measuring suspended sediment concentration (SSC)
• Laboratory Analysis
  • Different methods exist e.g. those of ISO, APHA and ASTM.
  • Errors can arise from:
    • Lack of consistency in terms of the method used e.g. drying temperatures.
    • Salinity effects (crystallisation of salt on filters) – inadequate washing
    • Filter ‘overloading’

• Order of potential error: 15% (see for example AAPH, 1995 and Neukermans et al., 2012)
• Sample Transfer & Sub-sampling for Lab Analysis
  • See for example Glysson et al. (2000) – USGS
  • Order of potential error: 10%

• Pump Sampler Intake Orientation & Flow Speed (more relevant for sand size material)
  • See for example Bosman et al., 1987
  • Order of potential error: 20%
Errors – Water Sampling

- Collision or Interaction of Sampling Device with the Bed
  - Order 100s of mg/l (based on experience – this effect can be seen in real-time data displays)

- Artificial Elevation of Concentration via Vessel
  - Order 10mg/l (based on experience)
• Example Application
  • Assume 10mg/l baseline, 20mg/l caution, 30mg/l stop

<table>
<thead>
<tr>
<th>Error Source</th>
<th>Estimated Minimum</th>
<th>Estimated Maximum</th>
<th>Estimate for Our Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory Analysis</td>
<td>2mg/l</td>
<td>30%</td>
<td>2mg/l</td>
</tr>
<tr>
<td>Transfer / Sub-sampling</td>
<td>0</td>
<td>50%</td>
<td>0mg/l</td>
</tr>
<tr>
<td>Pump Sampling</td>
<td>0</td>
<td>90%</td>
<td>-2mg/l</td>
</tr>
<tr>
<td>Vessel disturbance</td>
<td>0</td>
<td>20 mg/l</td>
<td>5mg/l</td>
</tr>
<tr>
<td>Instrument disturbance</td>
<td>0</td>
<td>200mg/l</td>
<td>2mg/l</td>
</tr>
</tbody>
</table>
- Reporting in Turbidity Units without Calibration to mg/l
- Order 100% (have done tests on this at HR Wallingford)

<table>
<thead>
<tr>
<th>Sample</th>
<th>% &lt;63um</th>
<th>% Shell</th>
<th>Slope (m)</th>
<th>R²</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>36</td>
<td>0.1</td>
<td>2.35</td>
<td>0.995</td>
<td>135</td>
</tr>
<tr>
<td>B</td>
<td>15</td>
<td>0.1</td>
<td>3.61</td>
<td>0.999</td>
<td>261</td>
</tr>
<tr>
<td>C</td>
<td>5</td>
<td>6.7</td>
<td>5.4</td>
<td>0.997</td>
<td>440</td>
</tr>
</tbody>
</table>
• Calibration Methodology
  • Laboratory sensor calibration versus in-situ (field) calibration
  • Order 100% (although examples of errors around 1000% do exist)
• Sensor Range & Resolution
  • Sensors exceeding their full scale is not uncommon and can be difficult to spot.

• Order 100s – 1000s of mg/l
• Biofouling of Instruments
  • This is very common, instrument selection is important, as they have different degrees of resistance to fouling, also need to service the instrument at an appropriate frequency. Detecting early fouling can be difficult.

• Order 0 – FSR e.g. 4000 mg/l
• Interference from Bubbles
  • Measured concentrations may be twice the actual concentrations (VBKO, 2003) (may be caused by waves, motion of the survey vessel, overflow, propellers etc)

• Order 0 - 100s of mg/l
### Example Application
- Assume 10mg/l baseline, 20mg/l caution, 30mg/l stop

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<th>Estimated Maximum</th>
<th>Estimate for Our Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>No calibration to mg/l</td>
<td>5%</td>
<td>500%</td>
<td>10mg/l (NTU baseline?)</td>
</tr>
<tr>
<td>Poor calibration methodology (lab)</td>
<td>0</td>
<td>1000%</td>
<td>10mg/l</td>
</tr>
<tr>
<td>Insufficient sensor range</td>
<td>0</td>
<td>4000mg/l</td>
<td>0mg/l</td>
</tr>
<tr>
<td>Biofouling of instruments</td>
<td>0</td>
<td>4000mg/l</td>
<td>2mg/l</td>
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<td>200mg/l</td>
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What does modern monitoring of dredging often include?
Mobile monitoring around working plant

- Direction of tide
- Vessel-mounted ADCP (distance from dredger varies)
- Measurements beyond the margin of the plume
- Measurements within the plume
- Plume extents
- Measurements in the estuary well clear of the dredger at a location unlikely to be affected

Transducer immersion depth (typically about 1m)
Blank after transmit (length varies)
Effective measurement interval
Water sampler & turbidity sensor

94% (typical)
6% (typical)
Mobile monitoring around working plant
Stationary monitoring around works

Surface Marker Buoy
Fitted with equipment for data transmission

Kevlar Cable
For data transmission and lifting

Mooring Riser

Clump Weight

Instrumented Bed Frame

Buoy receives data via data cable

Database
allows Internet access (100% redundancy on server)

Transmission of data by multi-provider GPRS Modem

Any authorised computer

Interactive data display

http://www.alphecca.co.uk/artemis/login.jsp
Sensitive receptor monitoring
Bathymetry monitoring
Practical & achievable monitoring in the near future?
Autonomous / remotely controlled systems are gaining traction

- aerial (LiDAR, photogrammetry, visible/NIR spectrum)
- water surface (bathymetry, water quality)
- soon underwater (swarms of AUVs mapping plumes)

Why?

- Lower cost
- Logistically simpler
- Faster
- Reduced H&S risk
Measure once, use data for multiple purposes

- ADCPs – currents, depth, sediment plumes
- MBES - depth, sediment plumes, seabed characterisation
Thank you for your attention – questions?