Generation and release of sediments by hydraulic dredging
Dredging Science Node Plan - Task 2.1

Literature review:

Generation and release of sediment by hydraulic dredging

- Trailing suction hopper dredger (TSHD)
- Cutter suction dredger (CSD)
Acknowledgments

- Woodside, Chevron, BHP and WAMSI partners for funding this research
- Mr Ian LeProvost (ECA)
- Dredging practitioners and consultants who provided survey responses
- Dr Saima Aijaz (Swinburne University of Technology) for technical review
Context

Far-field dredge plume model used in EIA

- sediment release (multiple sources, processes & plumes)
- sediment retention (deposited)
- sediment export (in suspension)

- horizontal mass flux (kg/s)
- settling rates
- vertical distribution

Adapted from Jones et al. (in prep.)
Scope of literature review

- break up of soil or rock material → fine particles
- sources / mechanisms of sediment release from dredgers
- near-field plume behaviour
- sediment source for the far-field dredge plume

- horizontal mass flux (kg/s)
- settling characteristics
- vertical distribution
Where does material break up occur?
Material break up mechanisms

- mechanical breakage where dredge head excavates the bed
- particle-particle collisions (e.g. in pipelines and pumps)
- particle impacts with pipe and pump surfaces
- erosion or abrasion by flow around fragments & grains

Costaras et al. (2011), Barber et al. (2012)
Break up of material by cutting

- Material break up by cutting
  - Cutting tool: rock chips
  - Water: crushed rock, intact rock

- Rock break up
  - Fracture
  - Source: Verhoef (1997)

- Clay break up
  - 1 plastic
  - 2 shear planes
  - 3 cracks
  - 4 fragments
  - 5 chips
  - Source: Van der Schrieck (2009)

Sources:
- IADC
- GLDD
- Verhoef (1997)
- Van der Schrieck (2009)
Break up of material by hydraulic transport (1)

High strength materials may be broken by destructive impacts in pumps

Source: IADC
Break up of material by hydraulic transport (2)

In-pipe material attrition depends on:

- material properties
- particle size distribution
- flow velocity and duration
- physics of flow regimes
- particle impacts and interactions

Flow regimes - horizontal pipeline

Adapted from Abulnaga (2002). See also Barber et al. (2012)
Break up of material by hydraulic transport (3)

<table>
<thead>
<tr>
<th>Material Strength</th>
<th>Overall level of attrition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weak</td>
<td>Increases with time of transport in pipelines</td>
</tr>
<tr>
<td>Strong</td>
<td>Mainly occurs during passage through pumps</td>
</tr>
</tbody>
</table>
Break up of material - testing

Attrition tests

- Standardised drum tests - developed for construction industries
- Do not reproduce physics of the material breakdown during dredging operations
- Can give anomalous results (Ngan-Tillard 2009)
- How to calibrate the test parameters?
- How to scale up the test results?
- Need full-scale attrition data at various points along the dredging production line

1 – test material
2 – steel balls
3 – water

Source: Ngan-Tillard et al. (2009)
Also refer to Barber et al. (2012)
Release mechanisms, mass rates and size characteristics are different for each source
Sediment release by TSHD

- coarse & fine particles
- near-bed release
- propeller clearance
- bed PSD

- fine particles
- high SSC
- negatively buoyant mixture
- elevated release

- hopper inputs & processes
- hopper
- overflow pipe
- pump
- propeller jet
- drag arm
- drag head
- bed shear stress & erodibility
Density-driven hopper processes

Input mixture density: 1325 kg m$^{-3}$

Overflow mixture density: 1075 kg m$^{-3}$

Sea water density: 1025 kg m$^{-3}$

Source: Van Rhee (2002)
Near-field plume behaviour

| Released material |  
|-------------------|---|
| • Settles and deposits within the near-field  
| • Exported (in suspension) from the near-field |

Factors that promote deposition:
• Dynamic plume from the overflow descends to the sea bed  
• Coarse primary particles settle rapidly  
• Clumping or flocculation of cohesive material increases the settling rate

Factors that promote suspended sediment export:
• Dynamic plume is mixed by strong cross-flow  
• Dynamic plume is mixed due to interactions with the TSHD
Simulated TSHD overflow plume ...

Normal dredging speed, front-mounted overflow pipe

… being mixed into surface waters

Base case

Base case + propeller + pulsed discharge

Source: De Wit (2015)
Conclusion

To make predictions of the sediment source for the far-field dredge plume requires understanding of:

- material break down by dredging processes and the evolution of the particle size and settling characteristics of dredged material
- sediment release from the dredger
- near-field plume behaviour and the export of suspended sediments from the near-field.

The literature review has summarised available information on these topics, including measurement techniques and protocols, empirical data, process understanding and predictive modelling. The review has identified relevant matters where knowledge remains limited.
Thank you