

SEDIMENT PLUME MONITORING AND MODELLING FOR IMPACT ANALYSIS



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DHI A/S



Agenda

Brief Introduction to DHI

Sediment Plume Monitoring:

Strategy

Methods

Preliminary results

“DHI is engaged as specialist environmental consultant for



*to **measure** and **model** the **sediment plume** activities for accurate assessment of the environmental impact generated by deep-sea mining”*

DHI Water & Environment

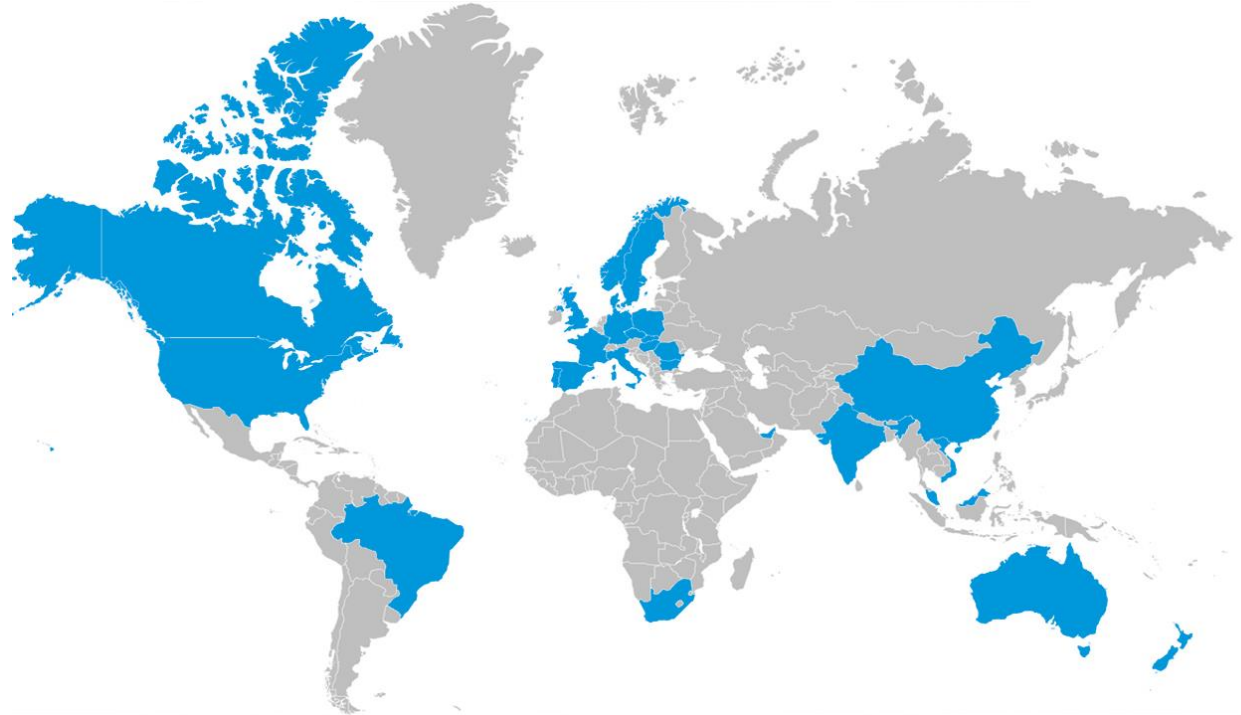


We are independent,
research-based and
not-for-profit



MIKE Powered by DHI
The most advanced water
modelling tools

THE ACADEMY by DHI
Training and knowledge
sharing



DHI is an independent, not for profit, research and consultancy organization and a world leader in consulting services and research in water environments

Supporting sustainable development is in our DNA



Our Knowledge Background:

DHI is a global expert in environmental impact assessment of dredging activities driving best practice such as PIANC 108 2010 endorsed by UNEP and high-profile projects such as Case No 12 at the International Tribunal for the Law of the Sea in addition to some of the worlds largest and most complex dredging projects.

The solutions to environmental impact assessment of the dredging industry developed over the past 50 years are **directly applicable to deep sea mining.**



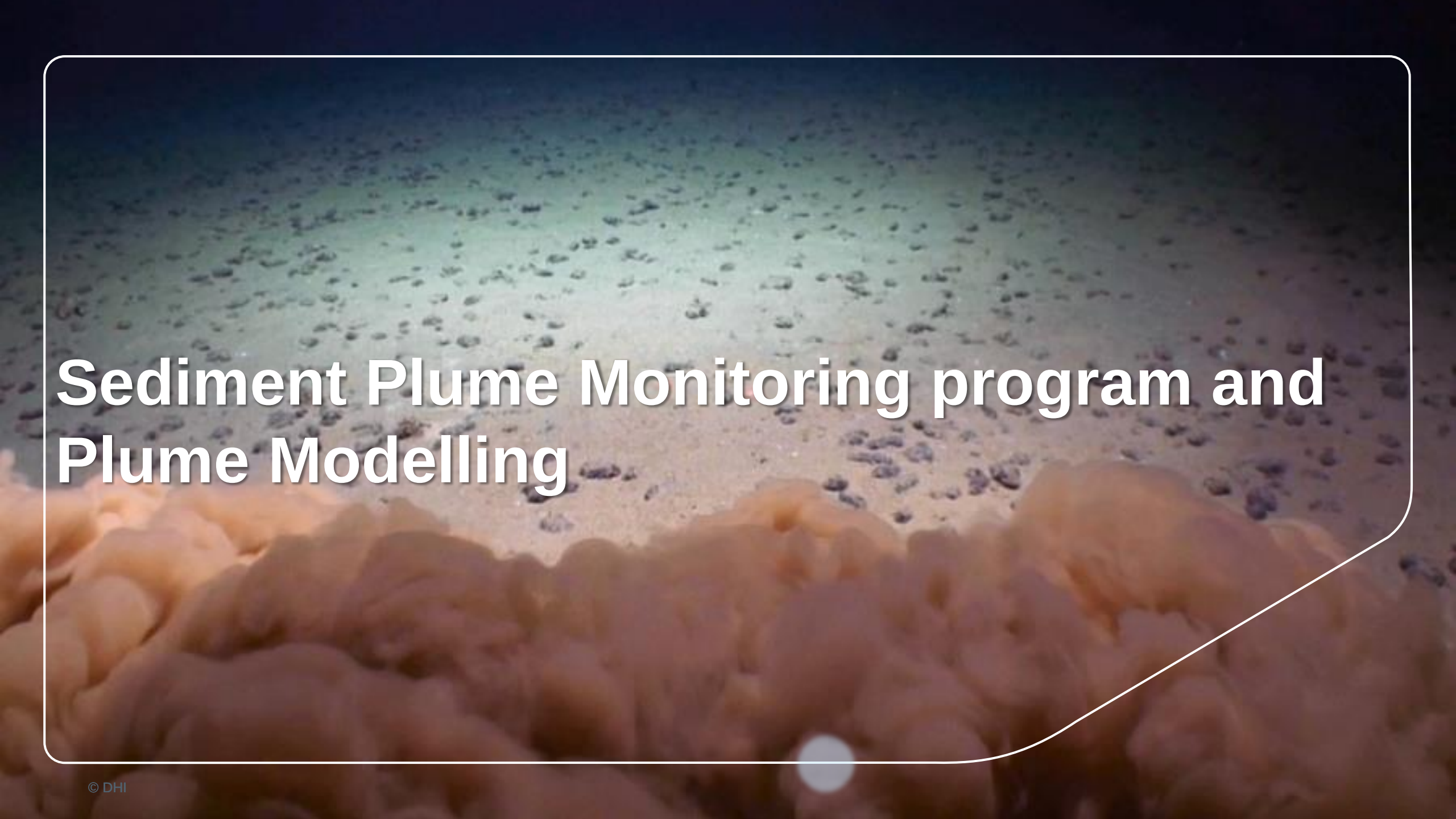
Images

<http://www.seanews.com.tr/malaysia-s-port-of-tanjung-pelepas-sets-aside-funds-for-more-cranes-in-2016/157017/>

<http://ifonlysingaporeans.blogspot.com/2015/06/pasir-panjang-terminals-35b-expansion.html>

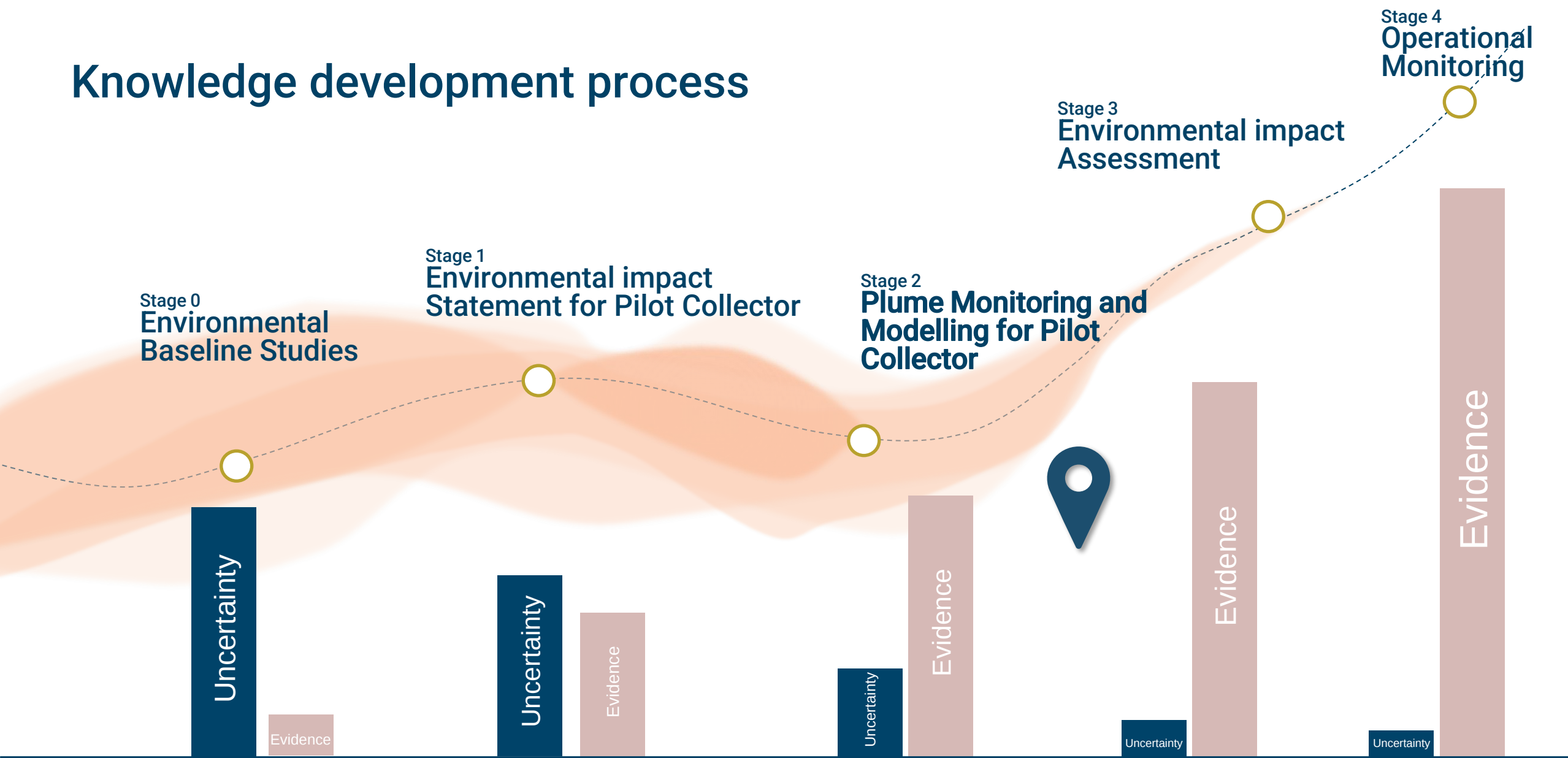
<https://archerrecruitment.com/news/we-are-not-done-building-singapore-yet-lawrence-wong>

<https://sgx.i3investor.com/blogs/singaporestockmarketnews/16764.jsp>

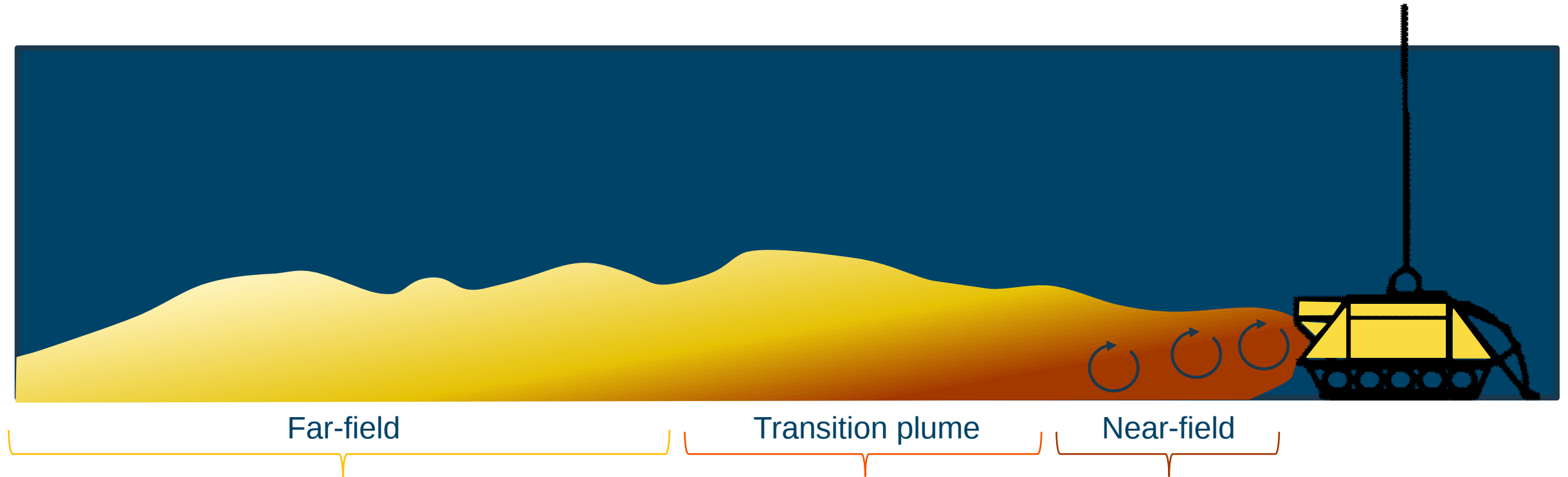
An underwater photograph showing a sediment plume. In the foreground, there are large, rounded, brownish-orange sediment mounds. Above them, a lighter, more diffuse plume of sediment extends towards the background, where the water is a deep blue. The overall scene is dimly lit, typical of an underwater environment.

Sediment Plume Monitoring program and Plume Modelling

Knowledge development process



Sketch of Plume – Hydraulic conditions

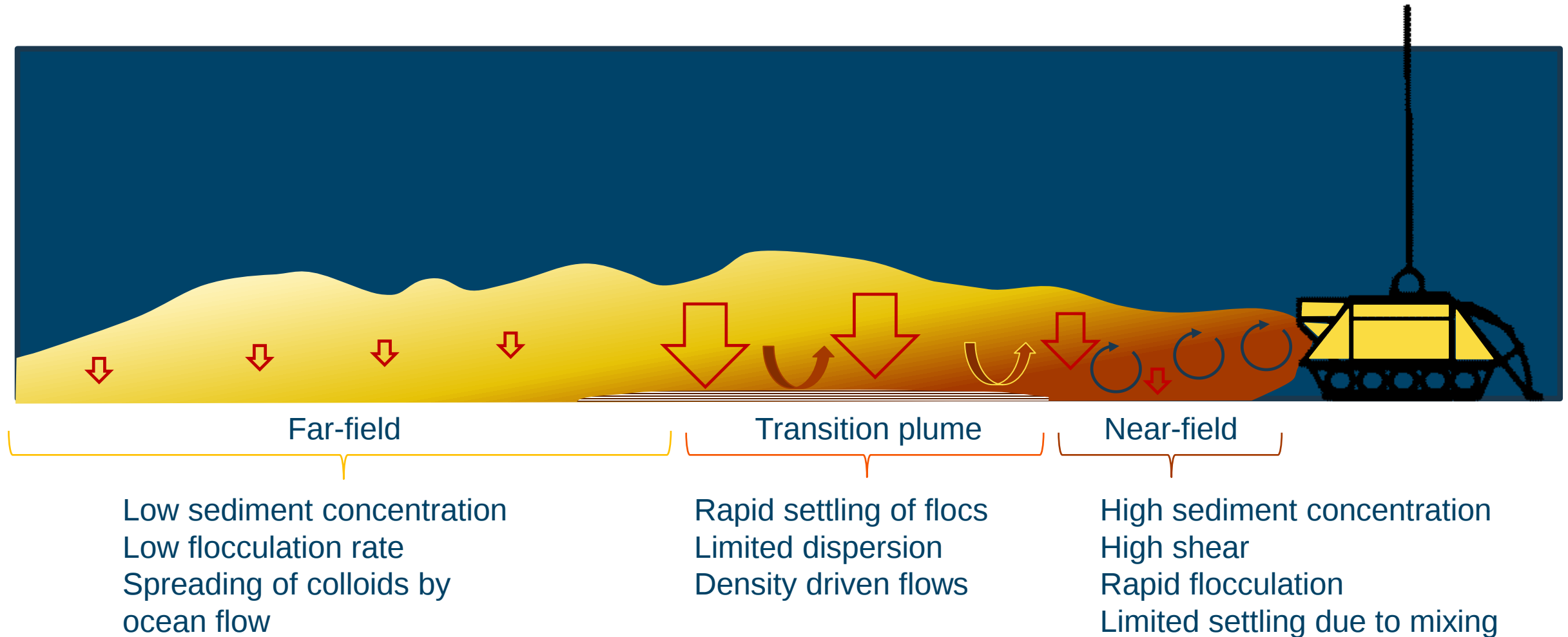


Laminar flow
Shear rate $\sim 0.1 \text{ G}$
200 m +

Transitional flow
Shear rate $\sim 1 \text{ G}$
20-200 m

Turbulent flow
Shear rate $\sim 2-10 \text{ G}$
10-20 m

Sketch of Plume – The Sediments

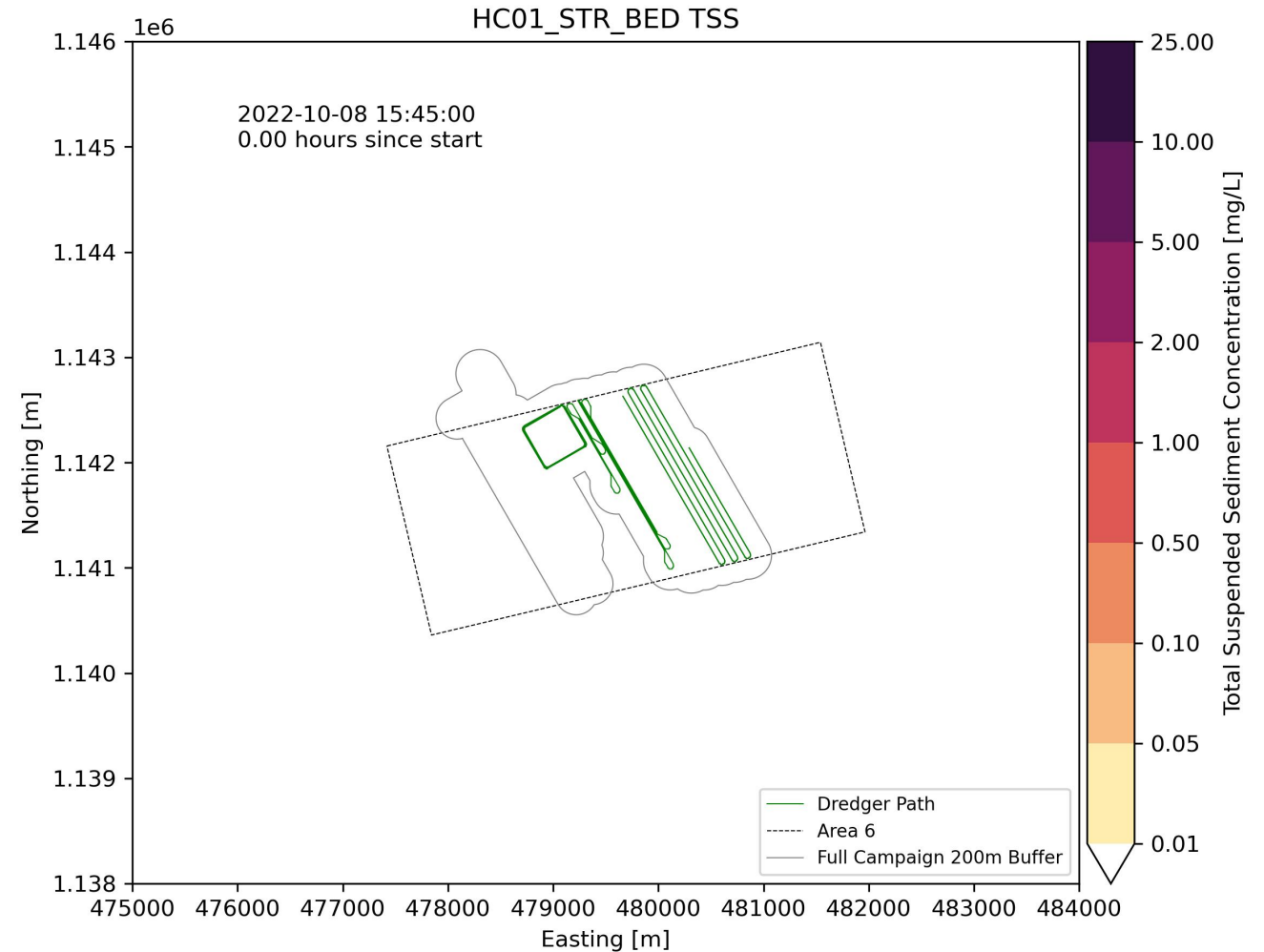


Plume monitoring and modelling

Monitoring yield **instantaneous data** of conditions **in points and transects**. With physically based models, data are **integrated and aggregated over time and space**.

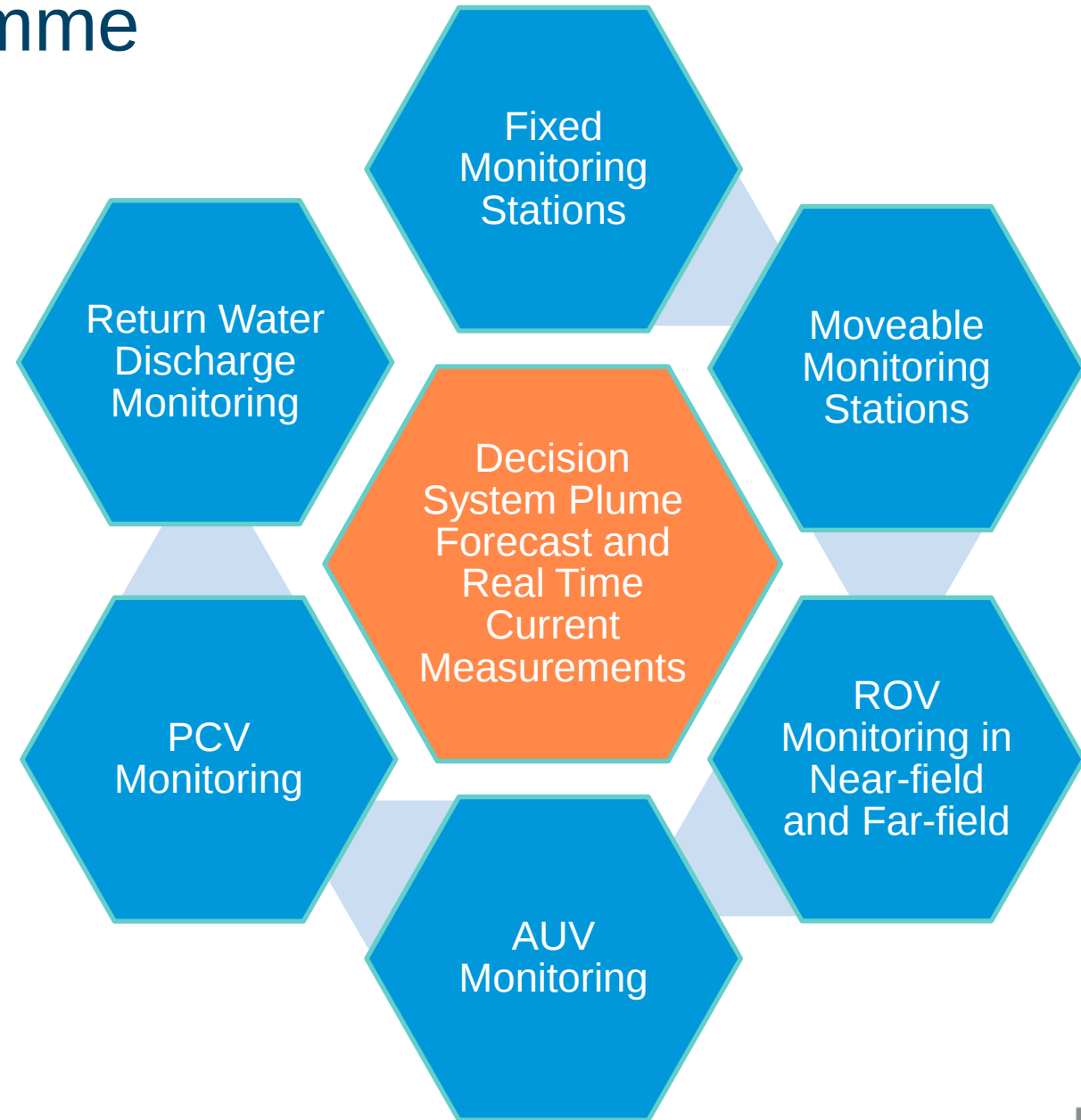
Monitoring data are fused into numerical models providing 3D assessment of:

- The **concentration of sediment** in water and;
- The **sediment deposition** (area and depth).



Plume Monitoring Programme

A monitoring strategy using detailed near real-time modelling guided the monitoring programme. This allowed effective use of all assets and enabled characterization of mid-water and benthic plumes.

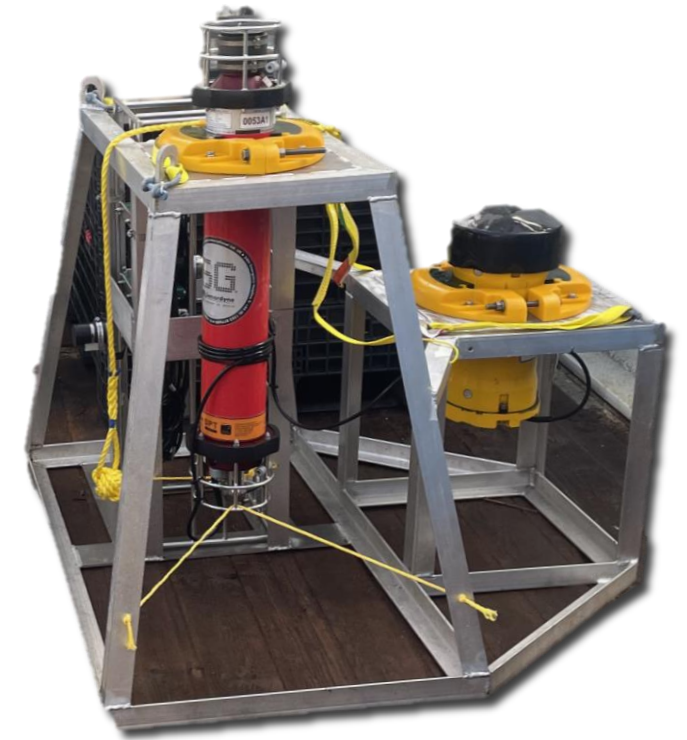
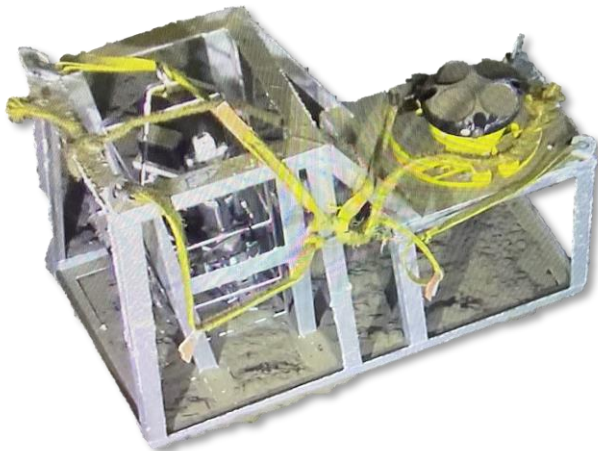


Instrumentation - Static



Fixed Turbidity Stations

- ADCPs 300 kHz or 600 kHz
- Optical Backscatter Sensor (OBS)
- Transmissometer



Fixed Current & Turbidity Stations

- ADCPs 600 kHz
- Optical Backscatter Sensor (OBS)
- Transmissometer
- Acoustic Modem

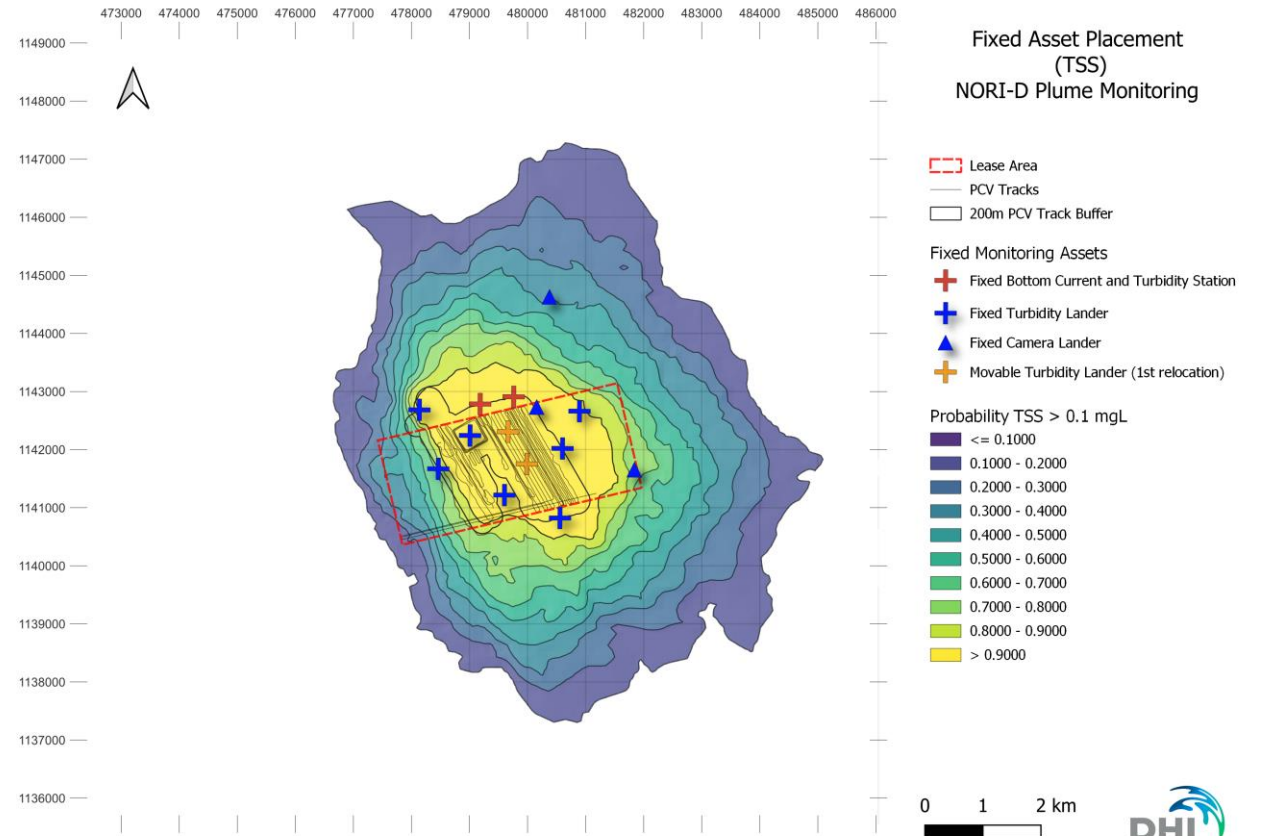
TSS Exceedance Probability

Results from stochastic model ensemble runs using sequences of historical currents

Collector vehicle source term is “as-planned”

Exceedance probability for TSS >0.1mg/L used to plan asset placement for Turbidity Landers

TSS threshold of 0.1mg/L based on instrument theoretical detection limits



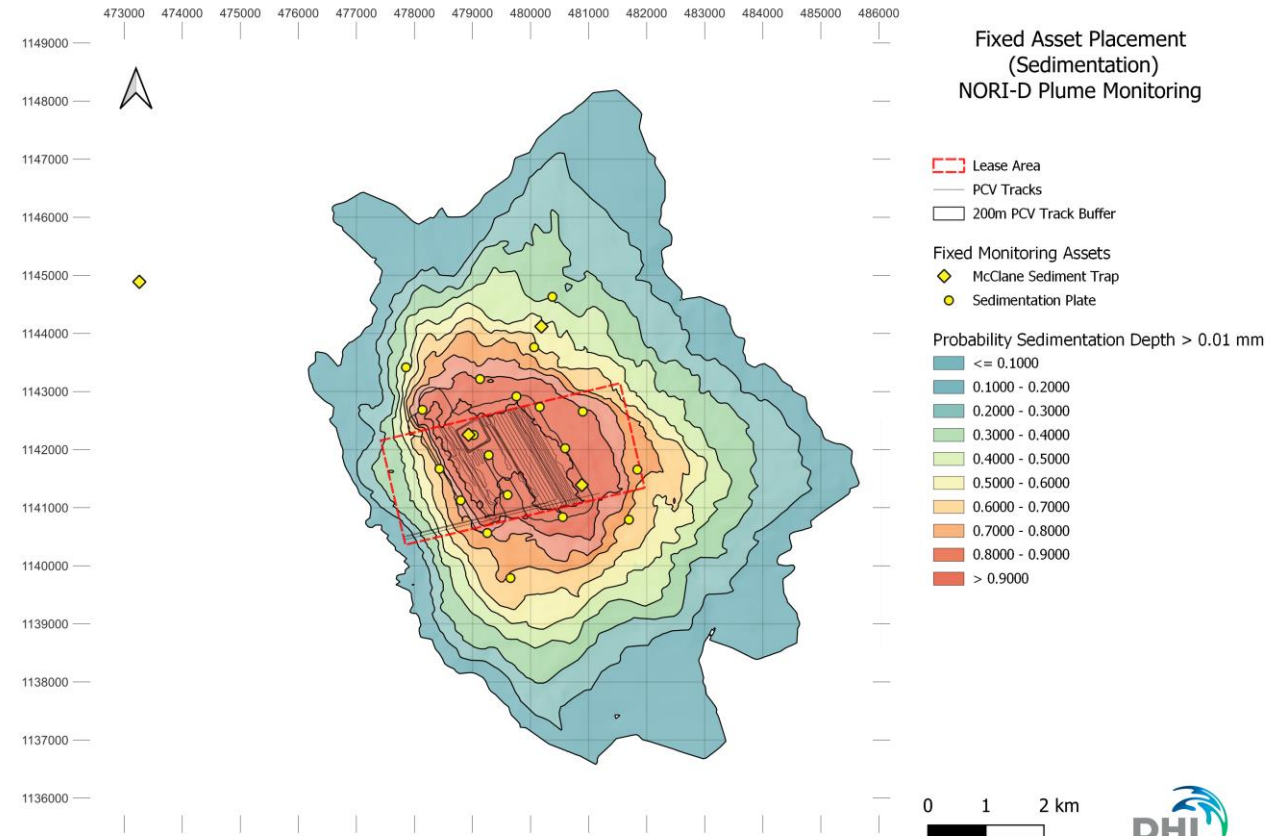
Sedimentation Exceedance Probability

Results from stochastic model ensemble runs using sequences of historical currents

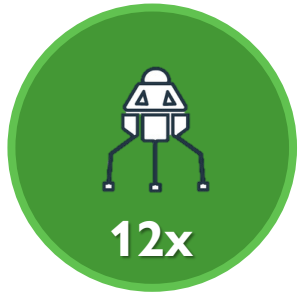
Collector vehicle source term is “as-planned”

Exceedance probability for sedimentation depth $>0.01\text{mm}$ used to plan asset placement for sediment traps and plates.

Sedimentation threshold of 0.01mm based on instrument theoretical detection limits

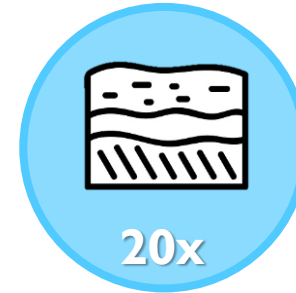


Fixed Monitoring Assets



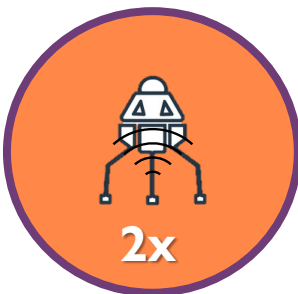
Fixed Turbidity Stations

- **19k** hours ADCP data
- **18k** hours OBS data



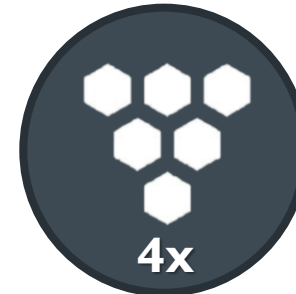
Sediment Accretion Traps

- Deployment duration ~60 days



Near Real-Time Current & Turbidity Stations

- **16k** hours ADCP data
- **16k** hours OBS data

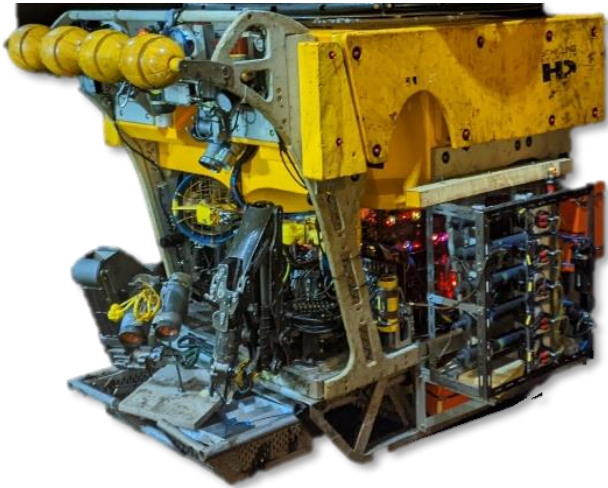


McLane Sediment Traps

- **84** 0.5L samples
- Deployment duration ~60 days

Instrumentation – Vehicle Mounted

Remotely Operated Vehicles (ROVs)



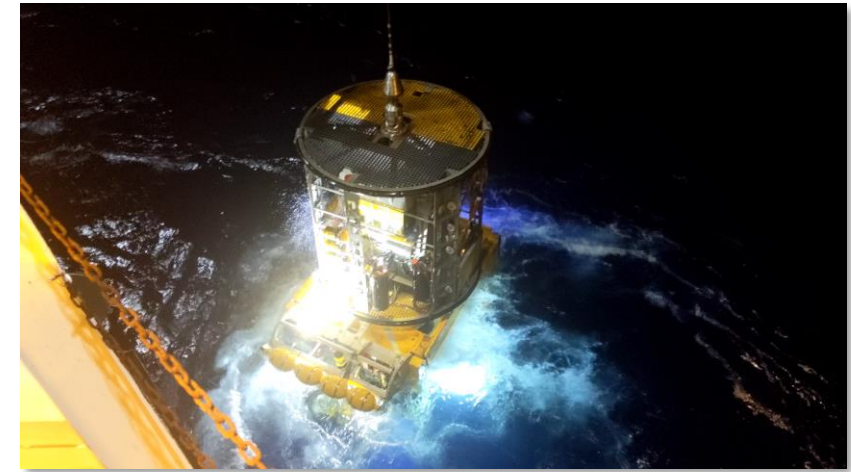
Schilling HD ROV

Monitoring Equipment

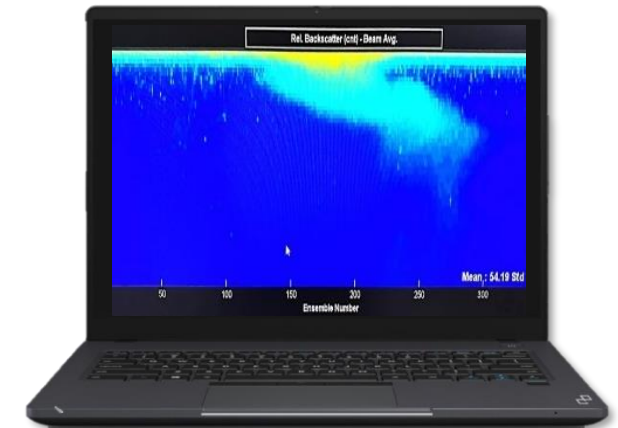
- Niskin Water Sampler
- 600 kHz ADCP
- CTD w/ OBS and Transmissometer
- Video Camera

Positioning

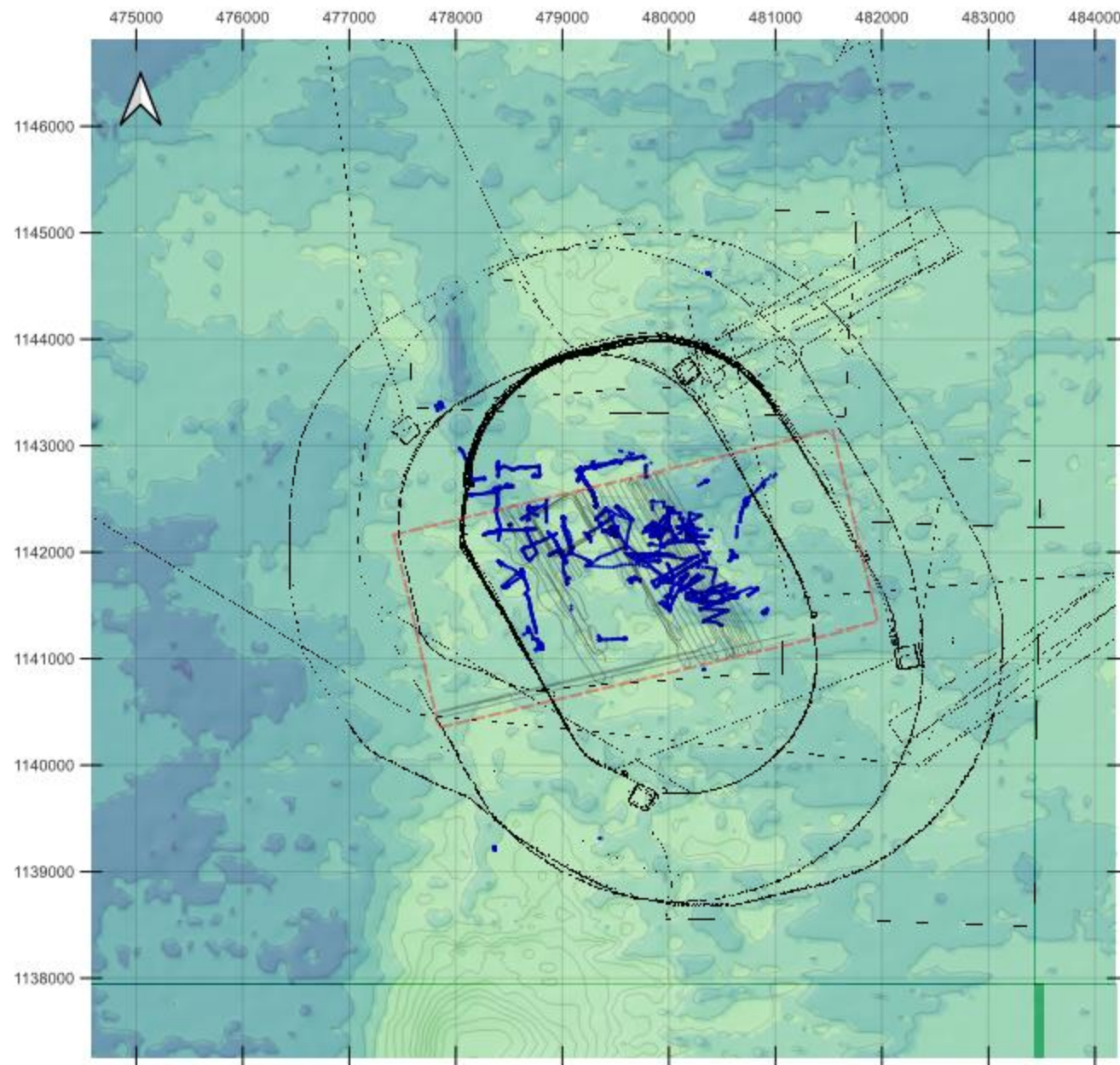
- Hydroacoustic Aided Inertial Navigation (HAIN)



ROV Recovery



Aqua Vision ViSea DAS



Mobile Asset Location Summary NORI-D Sediment Plume Monitoring Campaign

- Lease Area
- PCV Tracks
- AUV Tracks
- Far-Field ROV Tracks (Benthic)

Depth (meters above MSL)

- ≤ -4340
- 4340
- 4330
- 4320
- 4310
- 4300
- 4290
- > -4280

0 1 2 km



Mobile Monitoring Assets



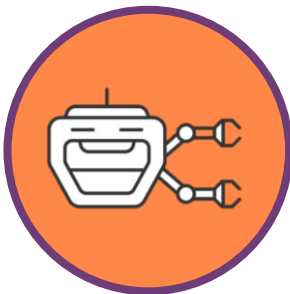
AUV

- **553** hours OBS and MBES transect data



Hidden Gem

- **115** Riser Intake Samples
- **120** Riser Return Samples
- **16k** hours PCV ADCP data



Far-Field ROV

- **132** 1L water sample taken
- **251** hours ADCP and OBS transect data

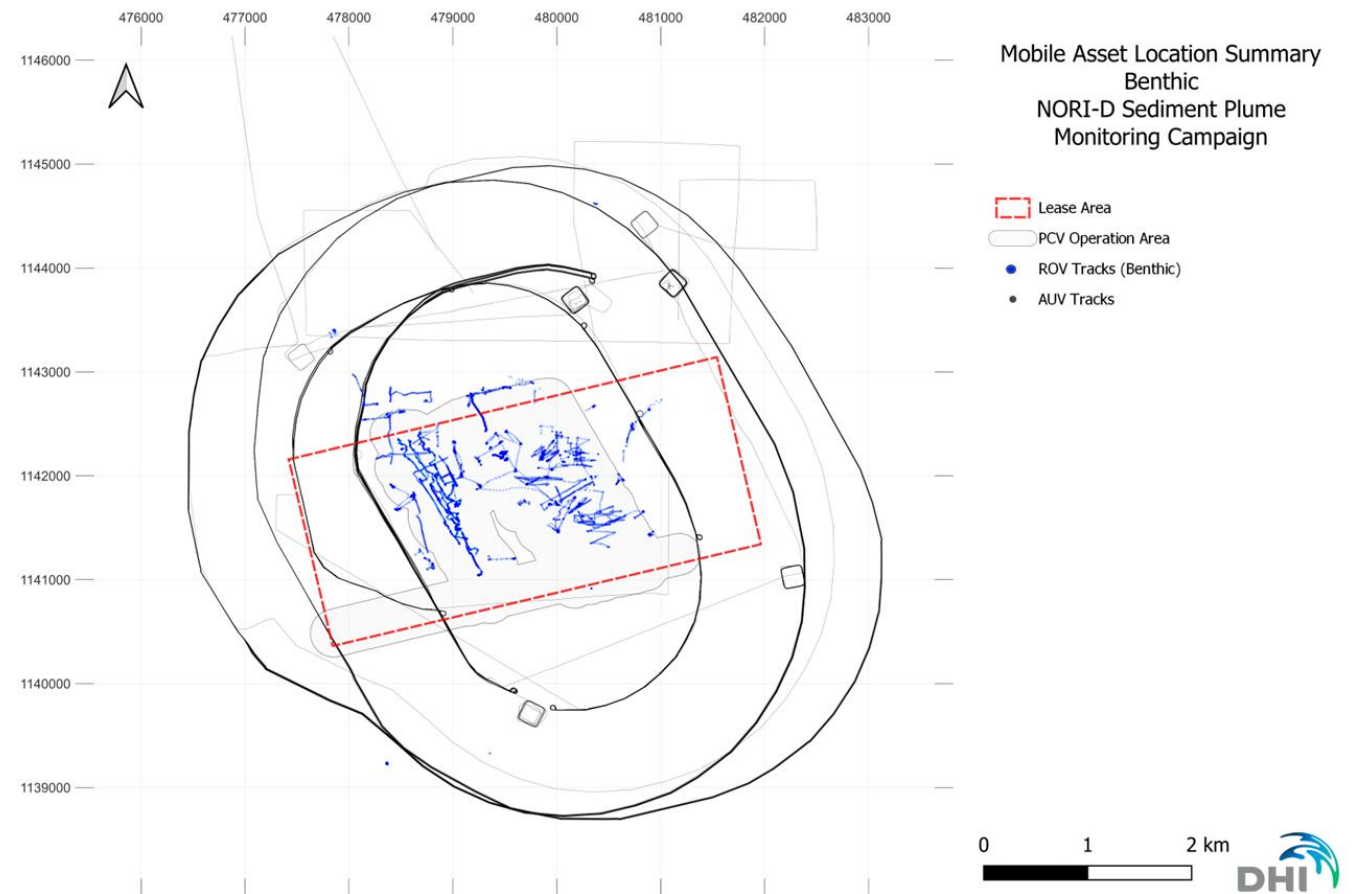


Near-Field ROV

- **142** 1L water sample taken
- **504** hours ADCP and OBS transect data

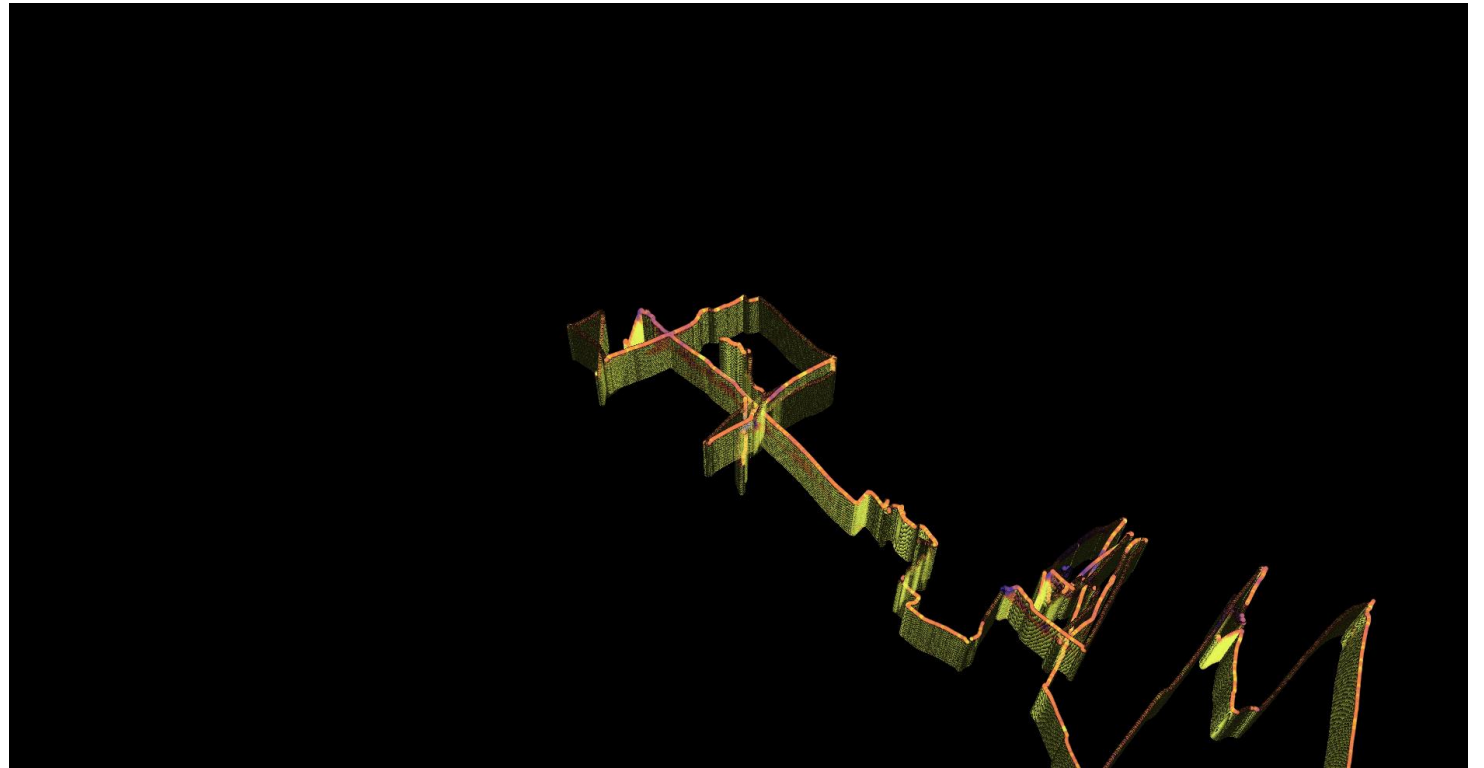
Mobile Monitoring Platform Position Data

- AUV04 and AUV11 position data shown as black
- Near-field and Far-field ROV data shown as blue
- ROV transects can be seen (straight lines)
- The boxes in the AUV data are when the AUV is in holding pattern



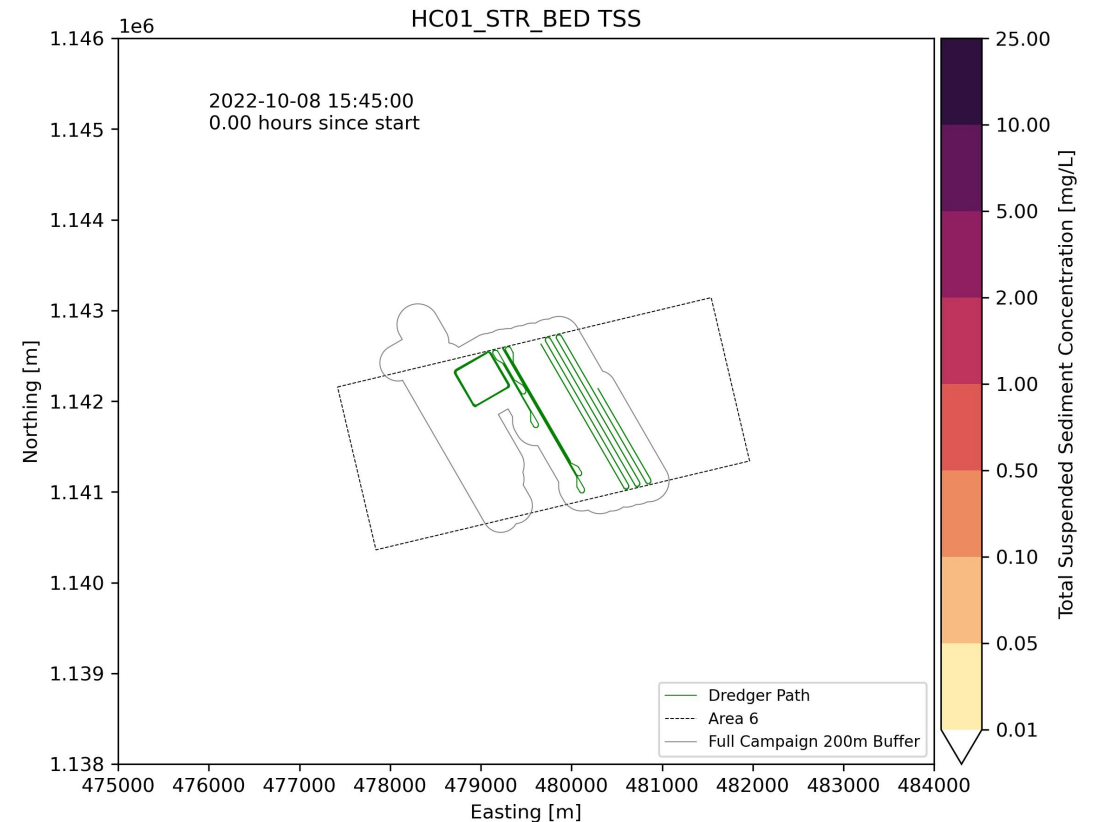
Example of ROV ADCP Data (Far Field)

- Data collected during **mid-water plume** monitoring
- Test- PR2B
- Span of transect (end to end) – 790m
- Total length along path is >2.7km
- Data collected over course of ~8 hours



Results of Plume Monitoring

- Comprehensive data has been acquired from both benthic and mid-water plumes allowing
- Detailed description dispersion and spreading of plumes
- Detailed quantification of sediment concentration in water and sedimentation



Animation showing sediment concentration 0-1 m above sea bed

Key Preliminary Modelling Results



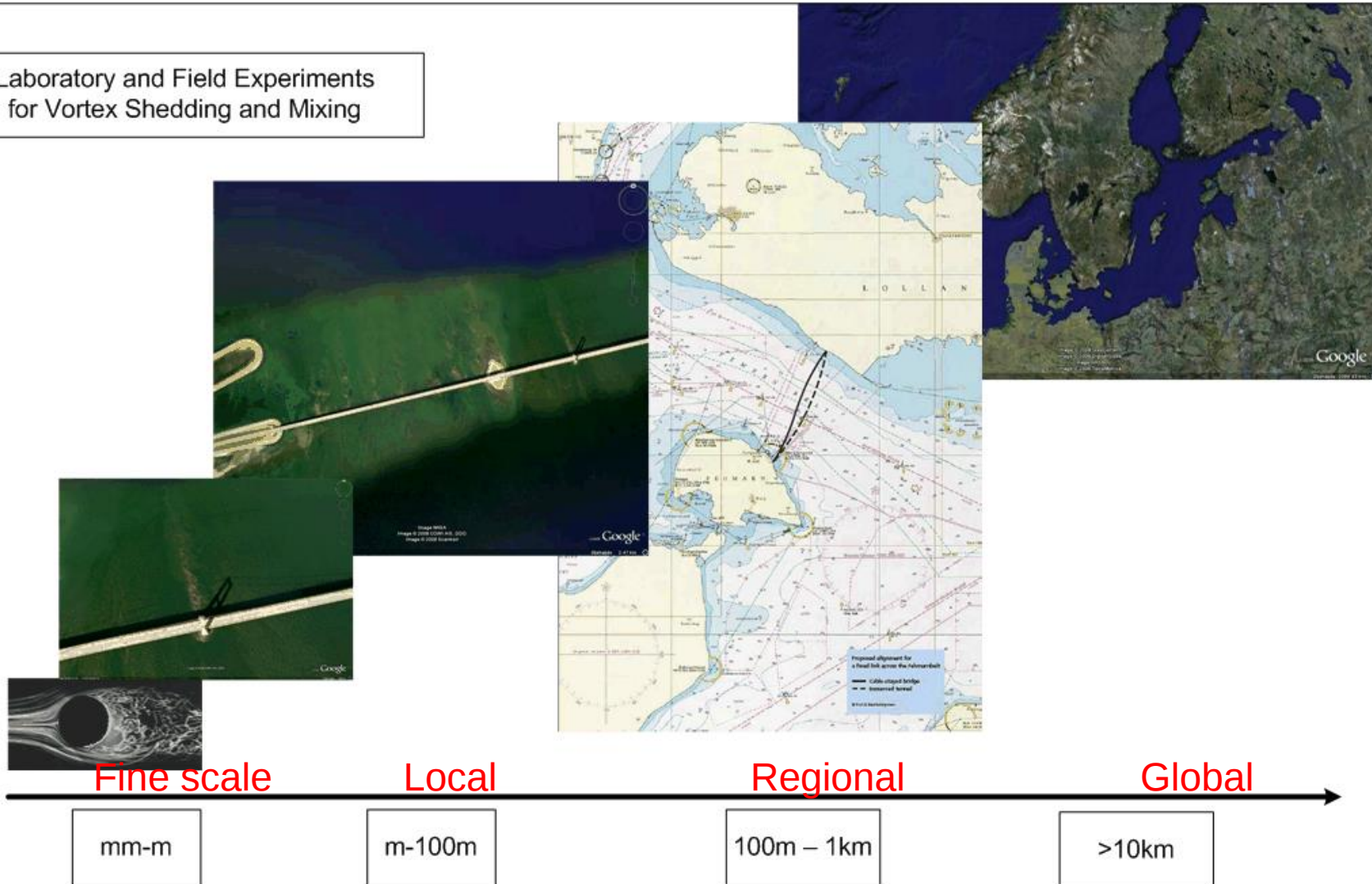
Multi Scale Models – Multi Scale Forecasts

NS3 - MIKE 3 Near Field Model

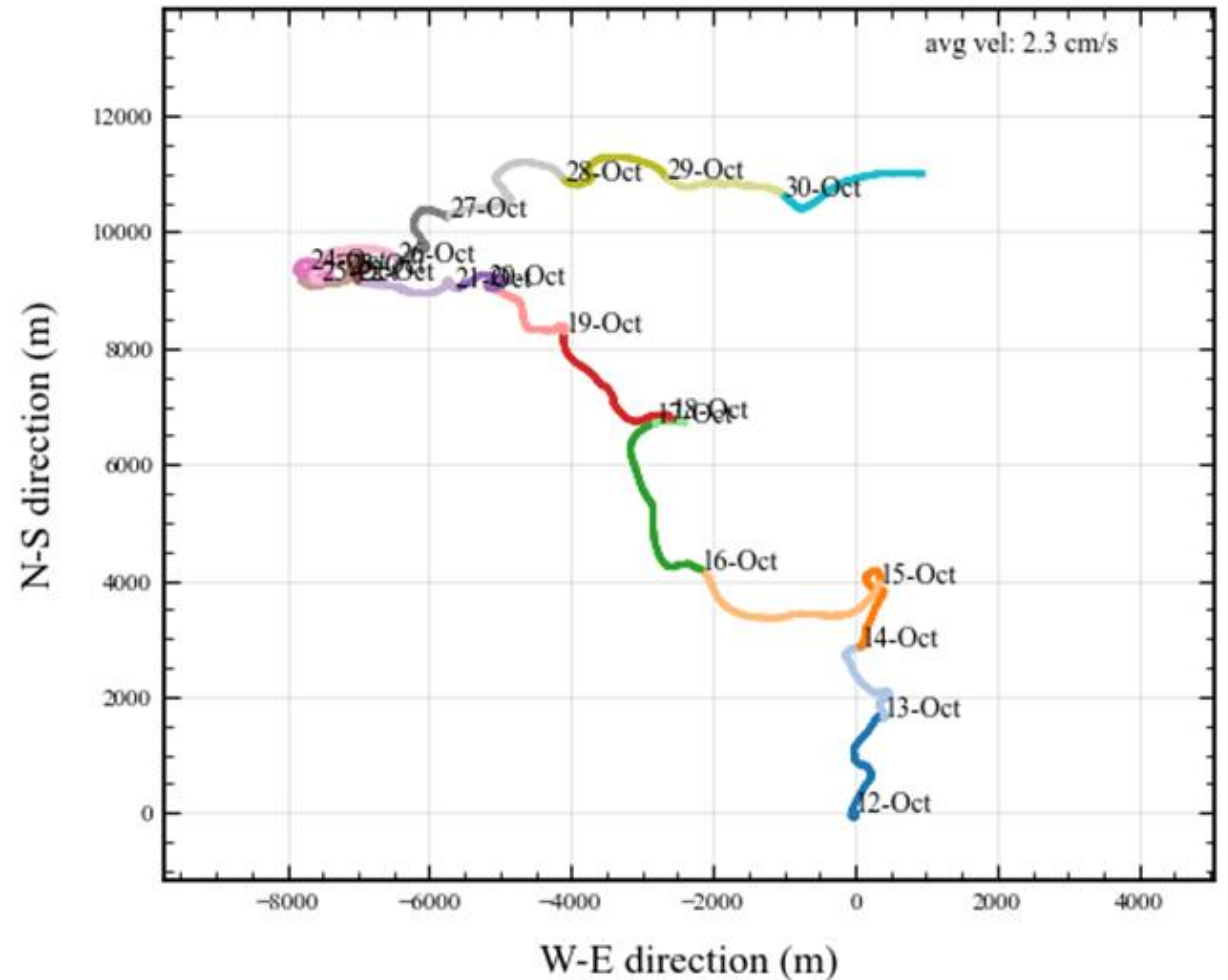
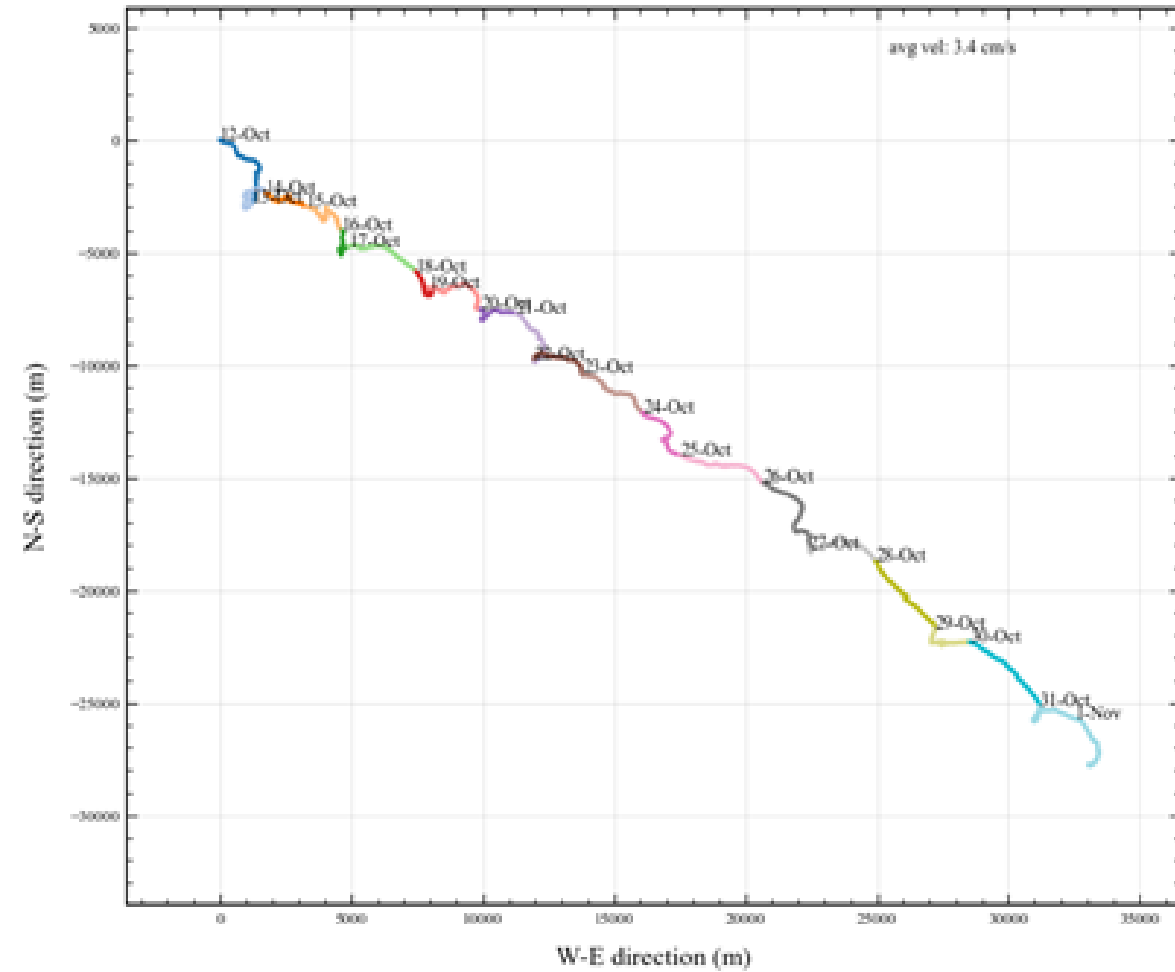
MIKE 3 and GETM Local Models

MIKE 3 and MOM Regional Models

Laboratory and Field Experiments
for Vortex Shedding and Mixing

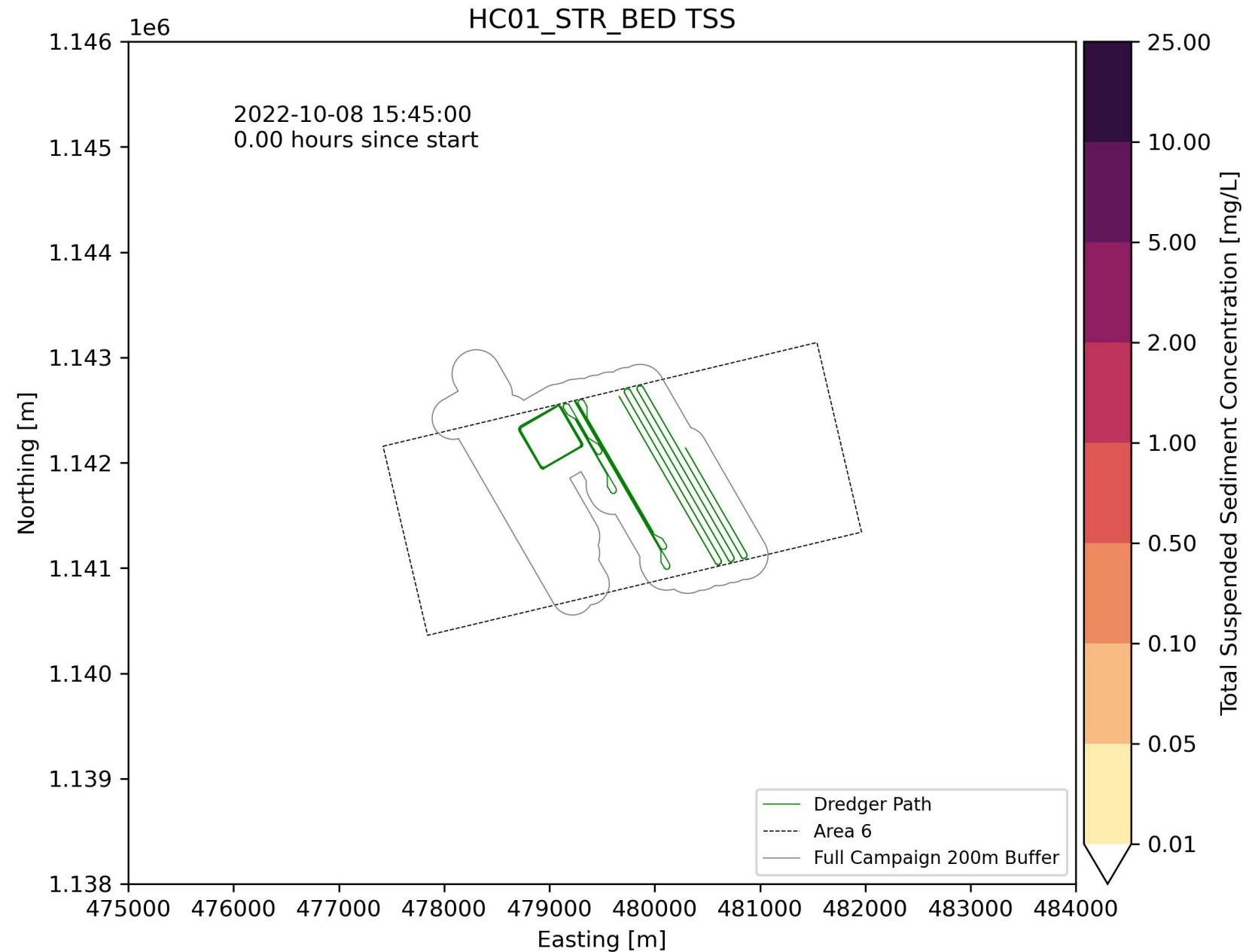


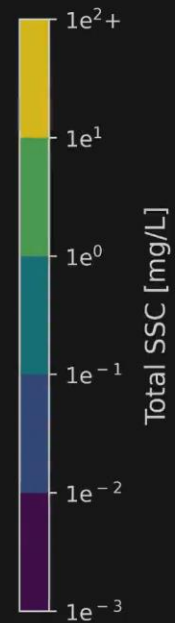
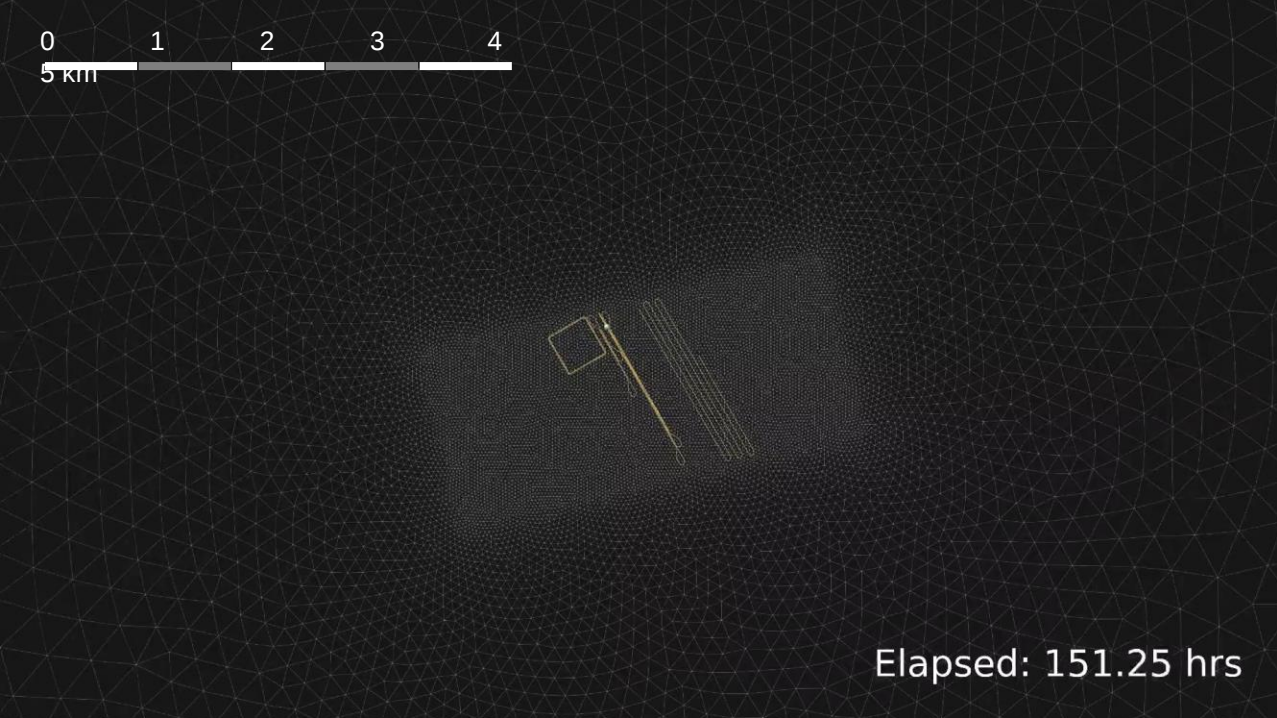
Progressive vector plot during campaign



Animation

Simulation of
entire
campaign

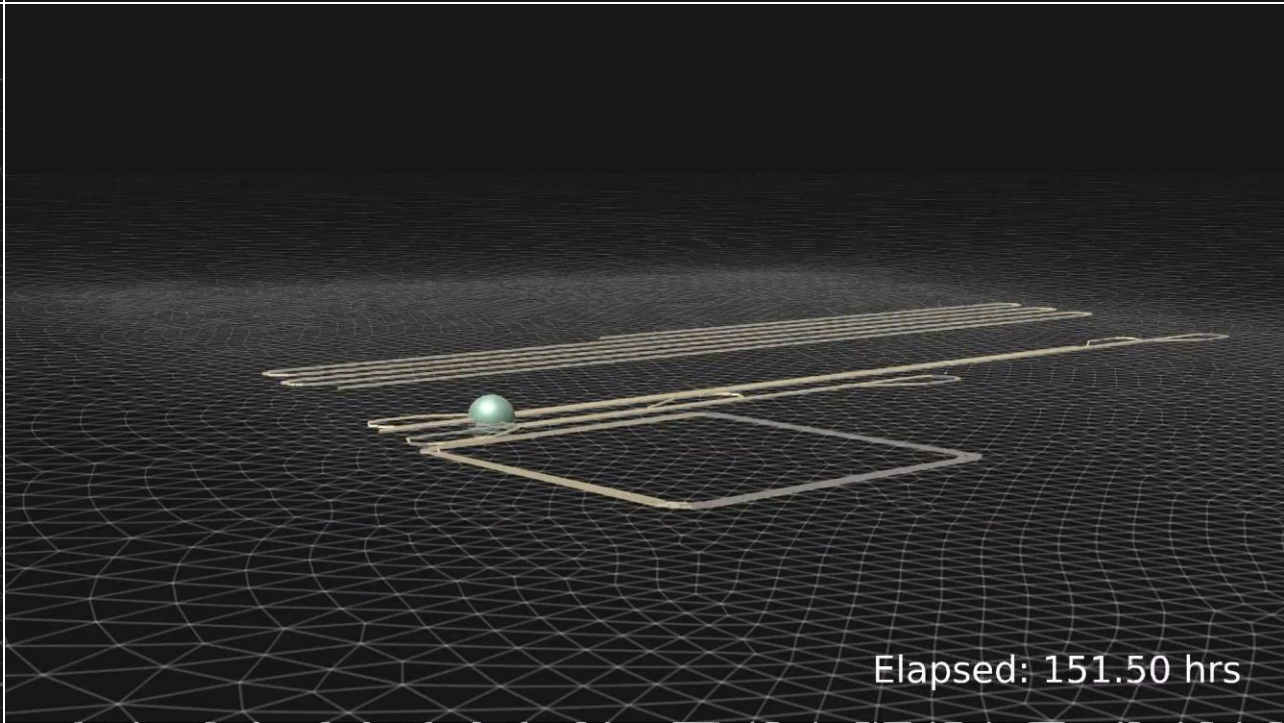
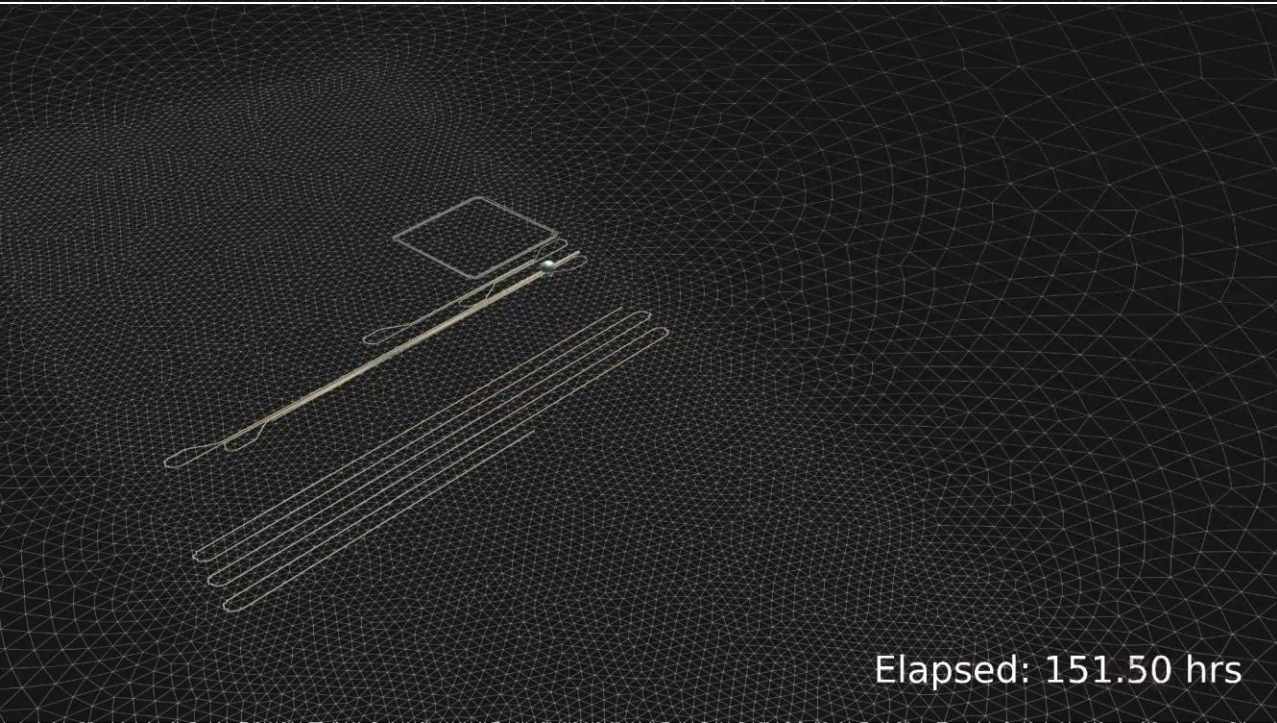




Hindcast Simulation

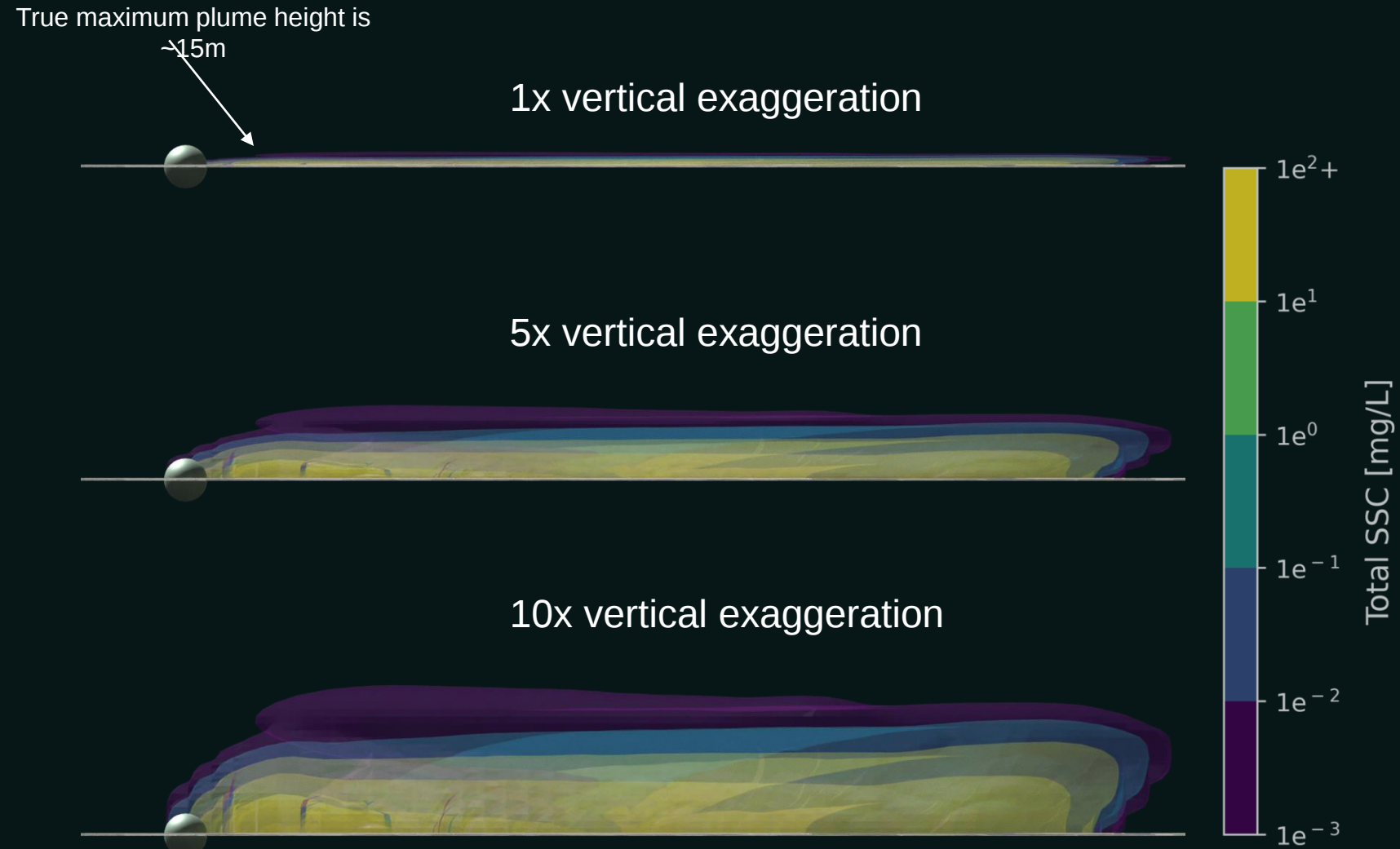
STR 1.1 – PR.2

- Preliminary model
- Vertical exaggeration of 10x
- Based on planned dredging operations
- Iso-surfaces of Total SSC [mg/L]



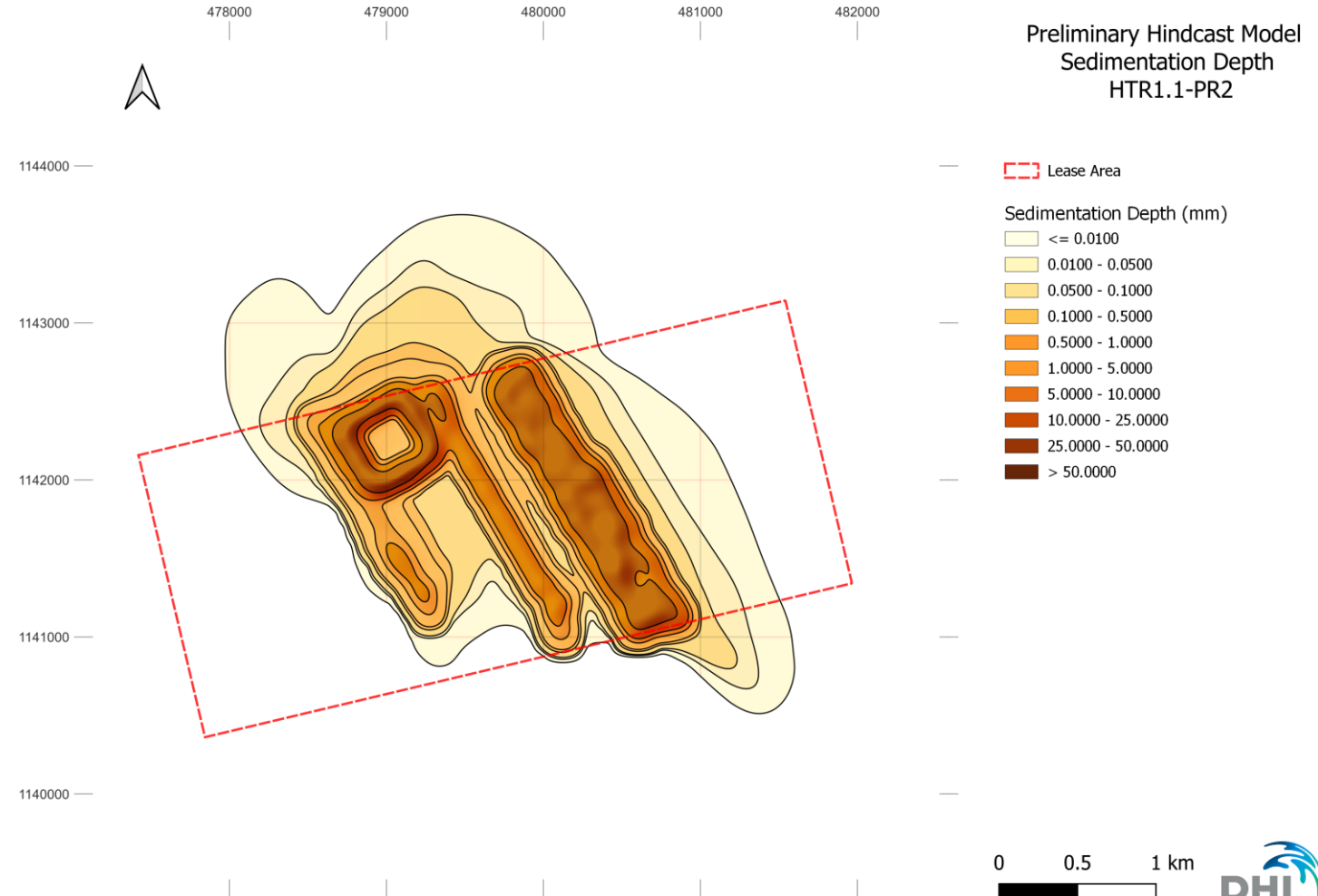
Hindcast Simulation STR 1.1 – PR.2

- Reaches approximately 15m above seabed (depending on contour)
- Sediment concentrations perceptible to the eye generally $< 5\text{m}$
- Vertical exaggeration applied to depict structure of the plume



Total sedimentation depth during pilot test (12/10-6/11)

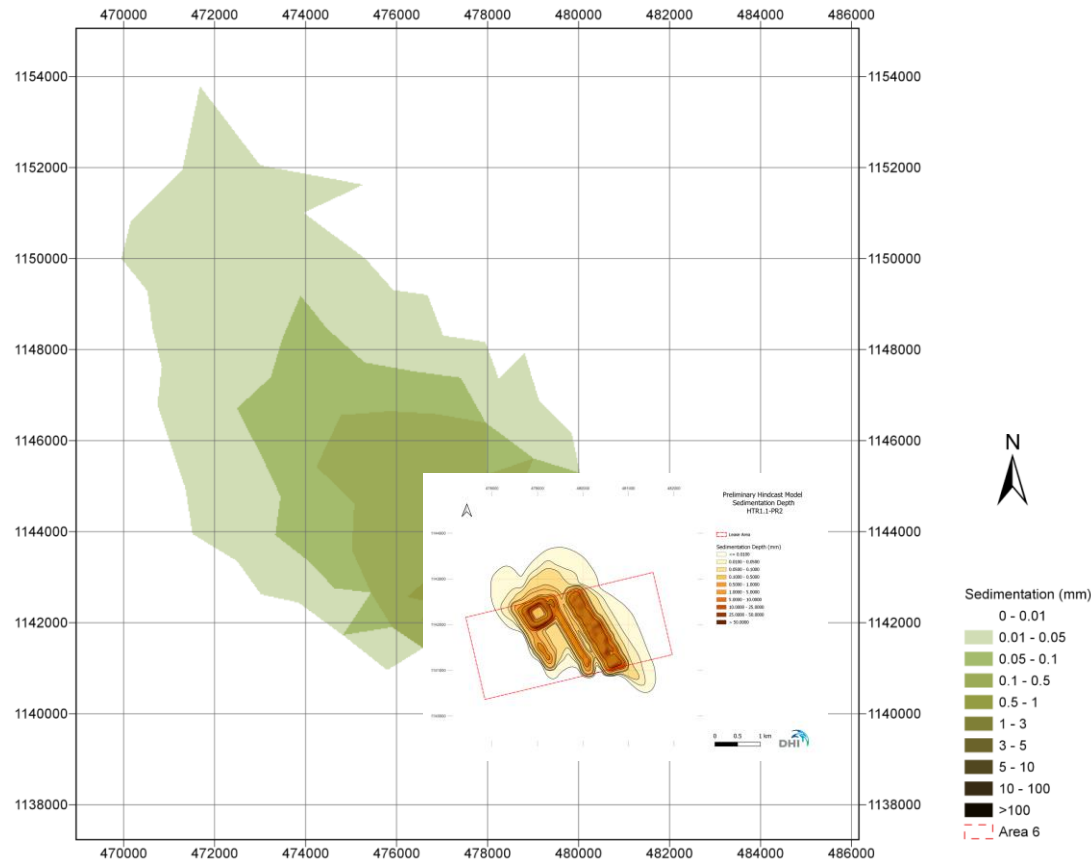
The total sedimentation depth is calculated from measurements and sediment plume modelling.



Comparison of ESIA and realized pilot collector test plume

Why is the sediment transport so small?

- Cut-depth lower than assumed
- Volume of resuspended sediments significantly lower than assumed
- Sediment aggregation is fast leading to fast settling
- Currents lower than assumed



Thank you!

Dr. Ole Larsen

DHI

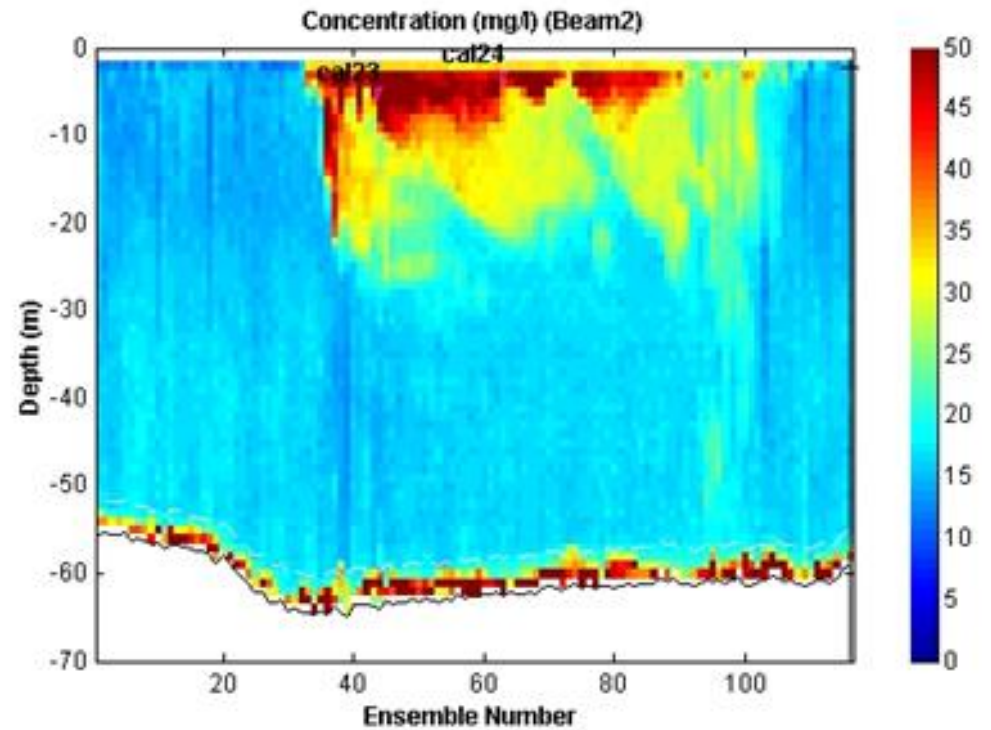
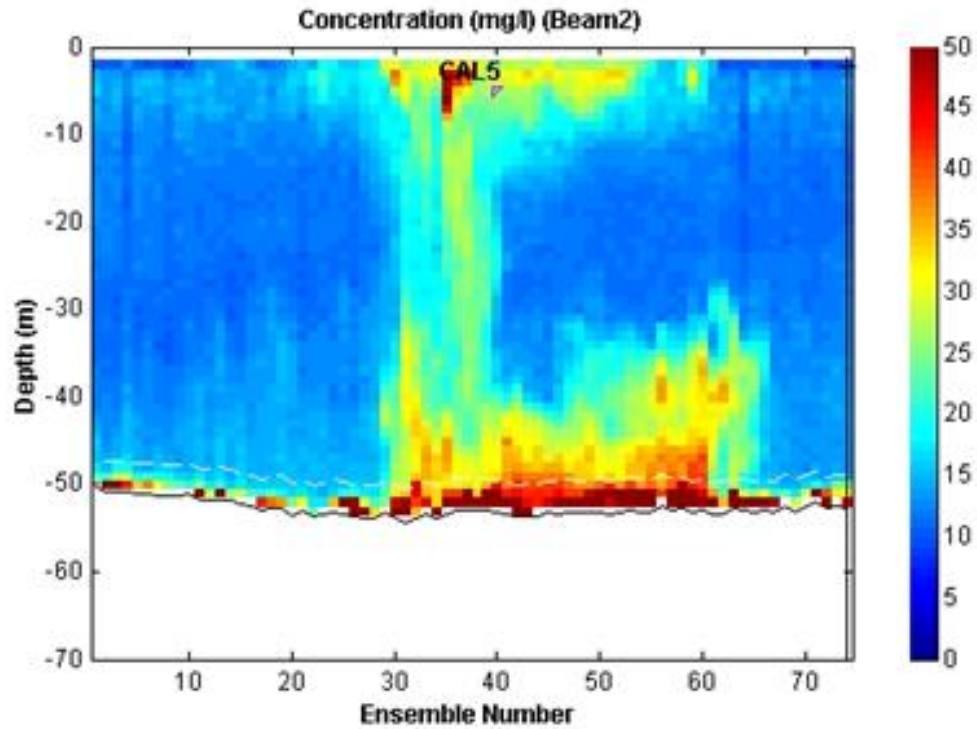
ola@dhigroup.com

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Backup slides

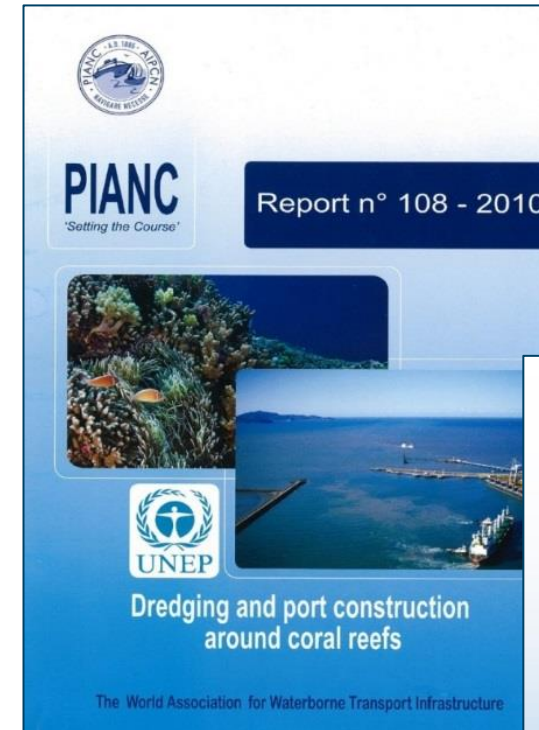
Examples of plume transects



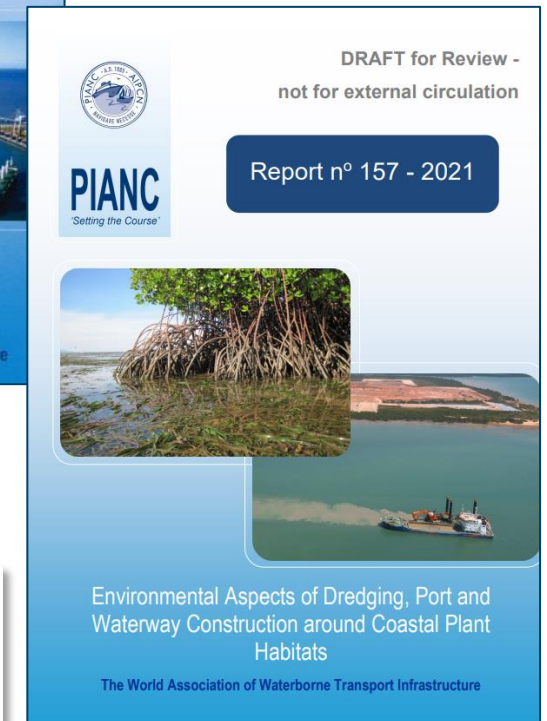
Plume resulting

Origins of Feedback EMMP

- IADC Workshops on Dredging and Reclamation [Environmental Impact and Management Session]
 - PIANC Report No. 108-2010
 - PIANC Report No. 157-2021 (in print)
- Approach endorsed / recognized by
 - WODCON XVIII (2007) (Best Practice)
 - UNEP, and
 - IFC's Environmental, Health, and Safety Guidelines for Ports, Harbors, and Terminals www.ifc.org/ehsguidelines



Available from
www.PIANC.org

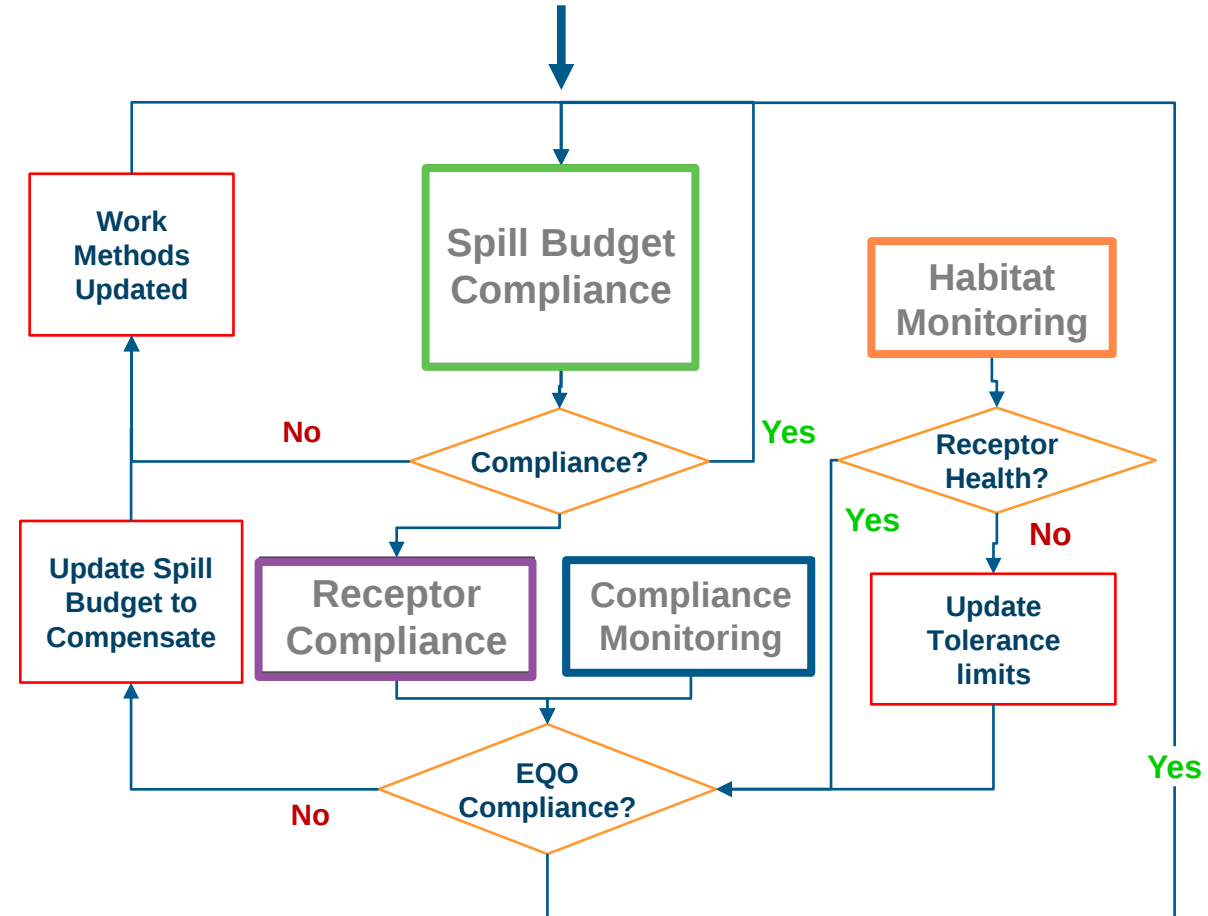


In Print

Taken from PIANC 108:

'...experience shows that by adopting sound planning, impact assessment, monitoring and management practices, large benefits can be achieved in terms of avoiding or minimizing adverse effects on the coral reef environment from dredging and port construction.'

Feedback EMMP: Components & Control Process

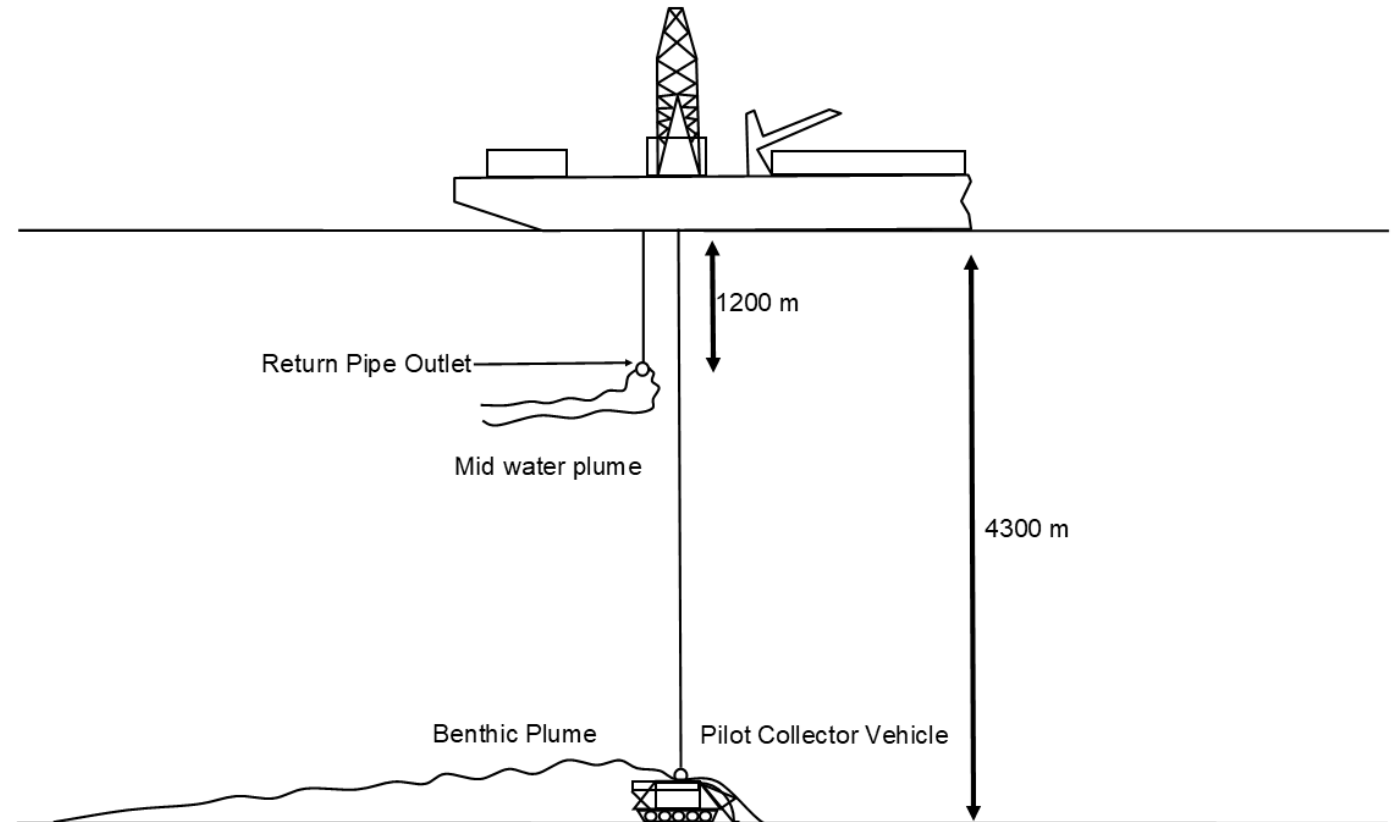


Feedback EMMP- Managing and Mitigating Impacts



The challenges

- Plumes are transported with ocean currents
- Plumes spread due to dispersion
- Plumes settle and may smother benthic environments





Plume monitoring

