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

NORI
NAURU OCEAN RESOURCES INC.

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

DHI

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

UN environment
United Nations Environment Programme

6 CLEAN WATER AND SANITATION

7 AFFORDABLE AND CLEAN ENERGY

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

13 CLIMATE ACTION

14 LIFE BELOW WATER

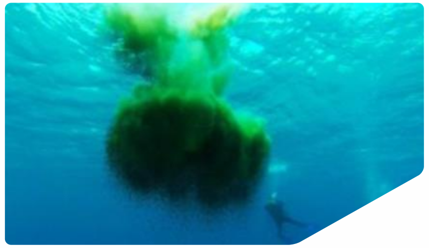
Deep domain knowledge delivered through expert advisory services

+

Advanced digital technologies used on projects and available for purchase

=

Culture of innovation enables new ways to mitigate water-related climate change risks to society and ecosystems



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Our Knowledge Background:

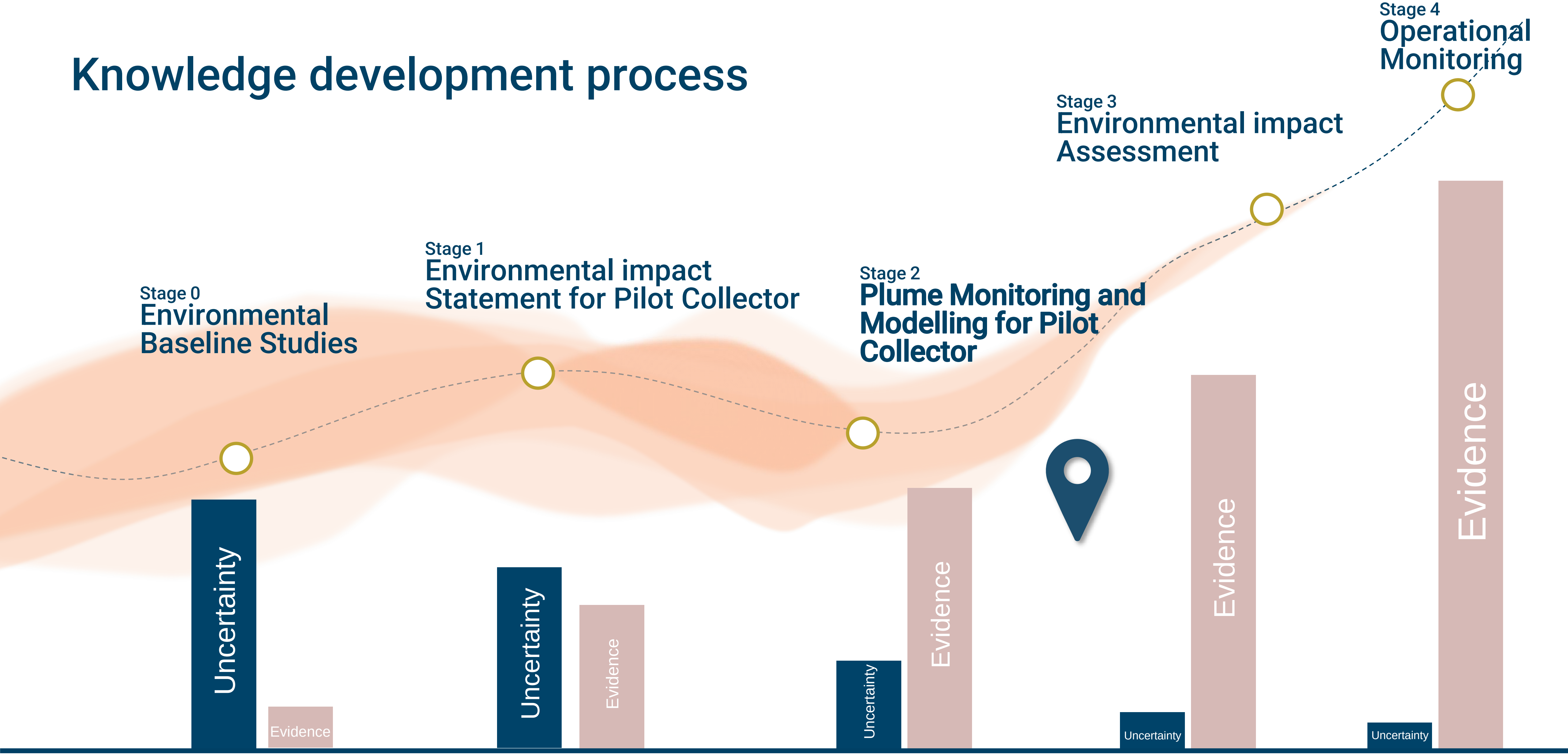
DHI is a global expert in environmental impact assessment of dredging activities driving best practice such as PIANC 108 2010 endorsed by UNEP and high-profile projects such as Case No 12 at the International Tribunal for the Law of the Sea in addition to some of the worlds largest and most complex dredging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

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

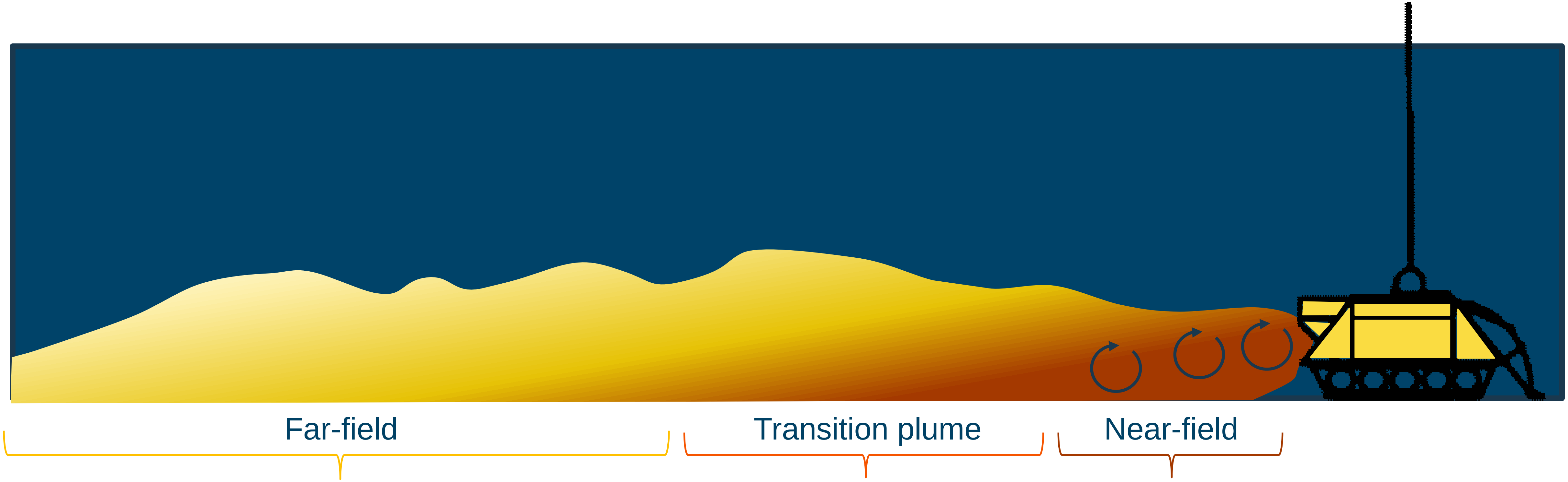
Images
http://www.seanews.com.tr/malaysia-s-port-of-tanjung-pelepas-sets-aside-funds-for-more-cranes-in-2016/157017/
http://ifonlysingaporeans.blogspot.com/2015/06/pasir-panjang-terminals-35b-expansion.html
https://archerrecruitment.com/news/we-are-not-done-building-singapore-yet-lawrence-wong
https://sgx.i3investor.com/blogs/singaporestockmarketnews/16764.jsp

Sediment Plume Monitoring program and Plume Modelling

Knowledge development process



Sketch of Plume – Hydraulic conditions

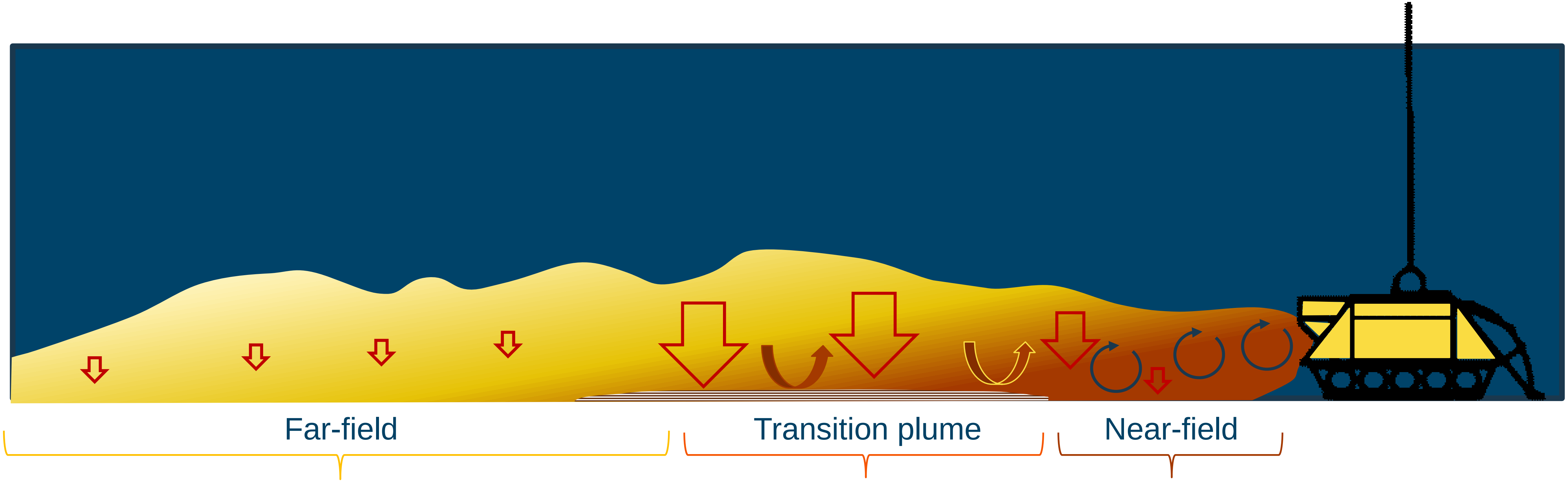


Laminar flow
Shear rate ~ 0.1 G
200 m +

Transitional flow
Shear rate ~ 1 G
20-200 m

Turbolent flow
Shear rate ~ 2-10 G
10-20 m

Sketch of Plume – The Sediments



Low sediment concentration
Low flocculation rate
Spreading of colloids by
ocean flow

Rapid settling of flocs
Limited dispersion
Density driven flows

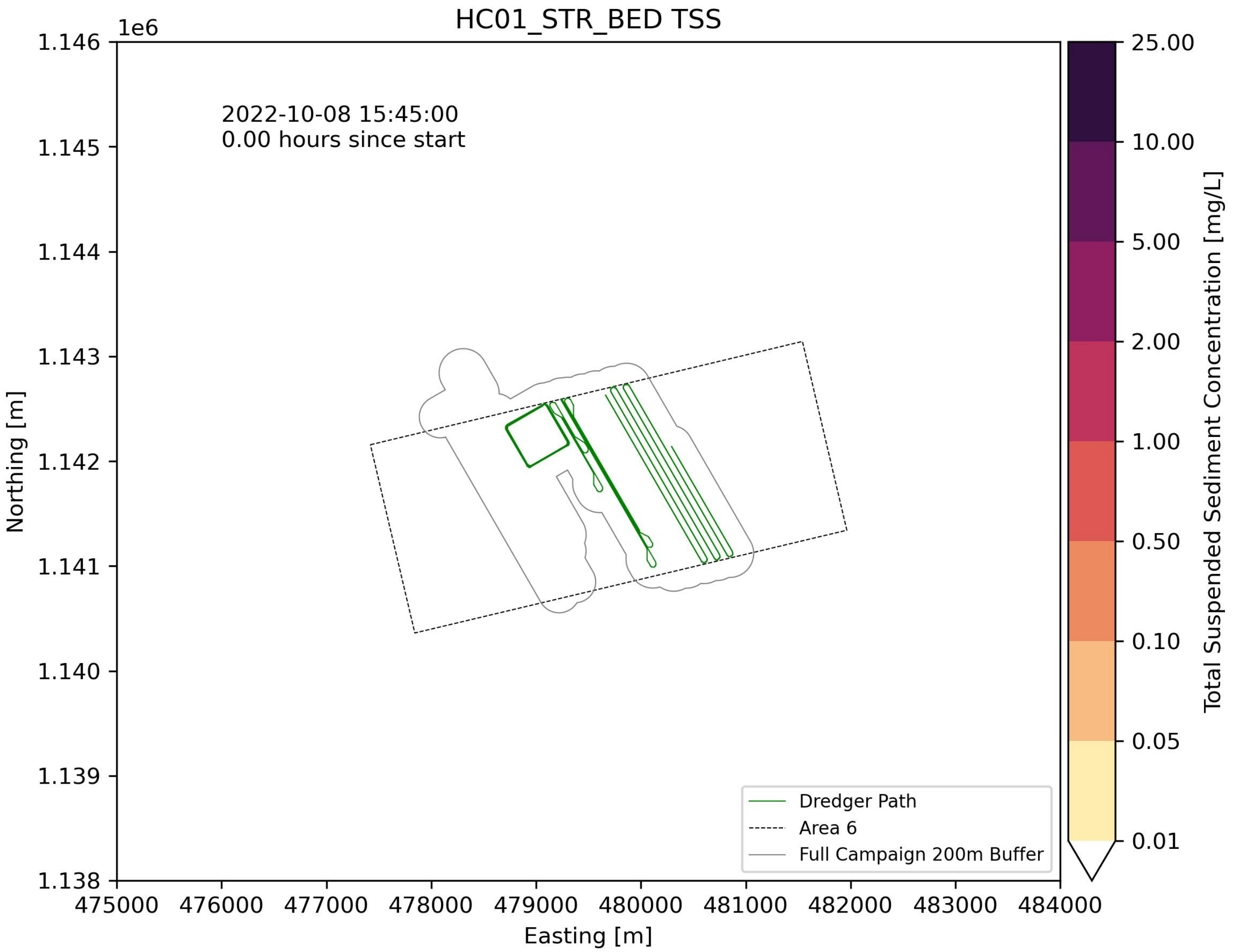
High sediment concentration
High shear
Rapid flocculation
Limited settling due to mixing

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**.

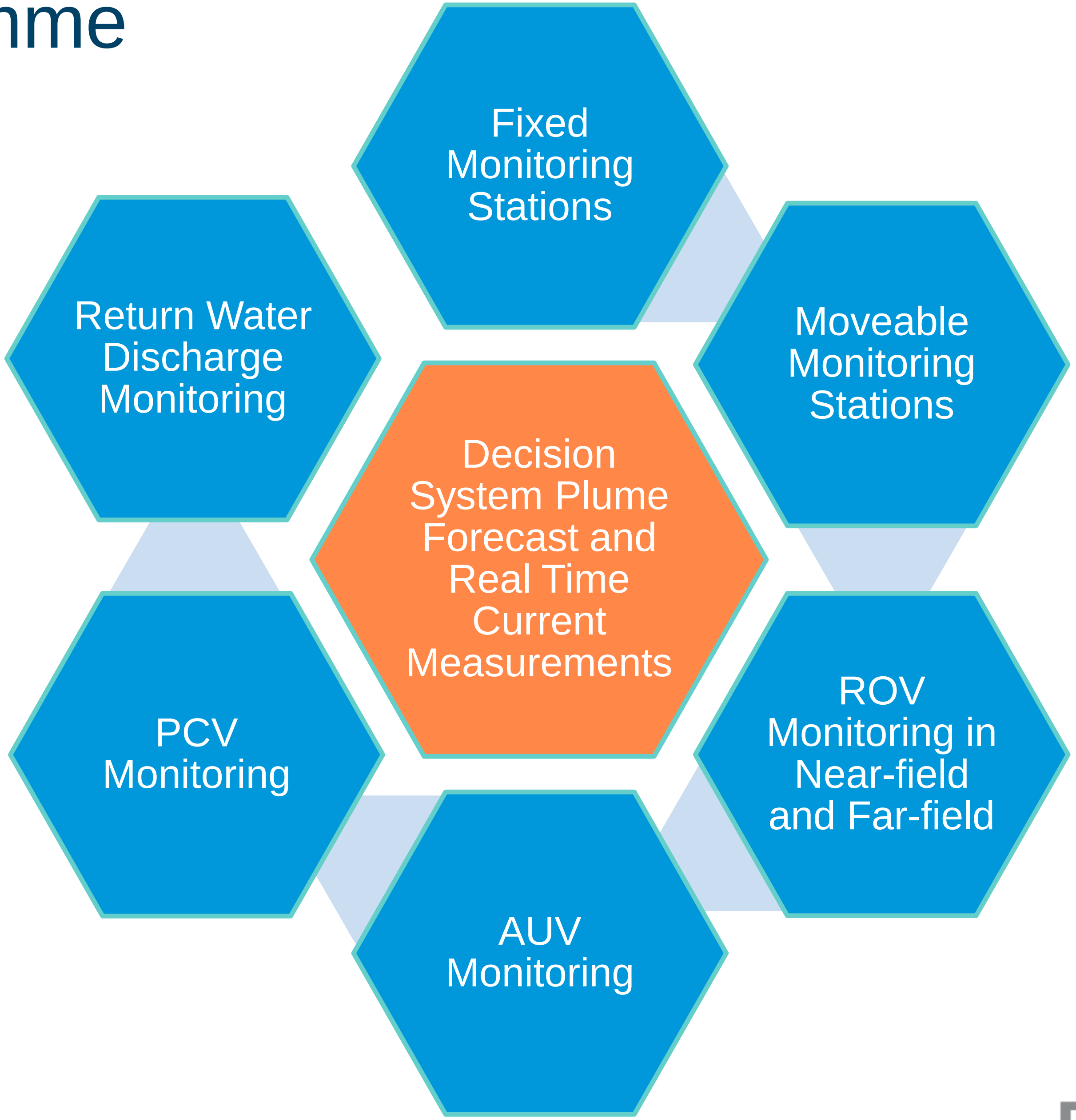
Monitoring data are fused into numerical models providing 3D assessment of:

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

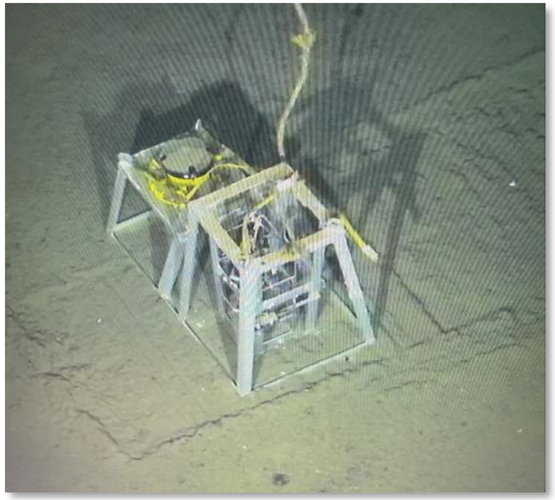


Plume Monitoring Programme

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.

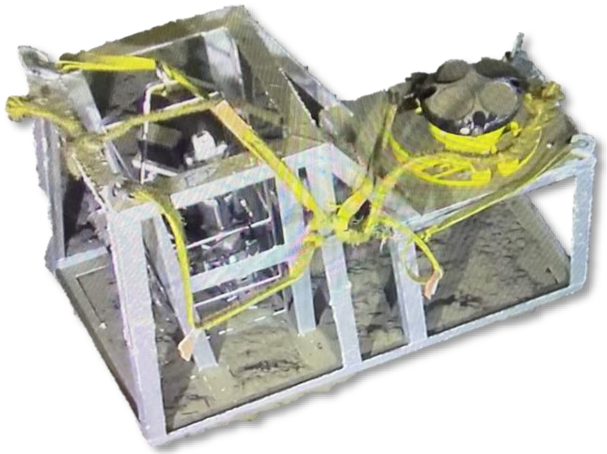


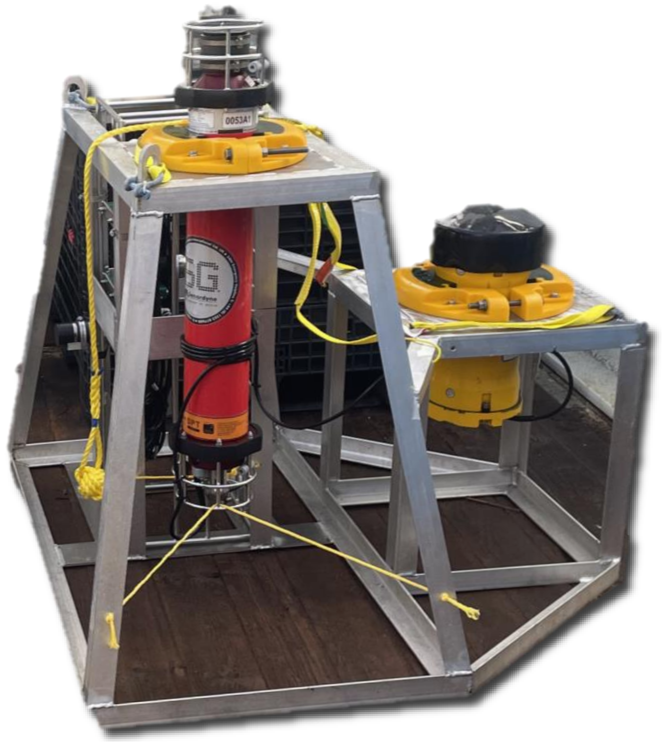
Instrumentation - Static



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

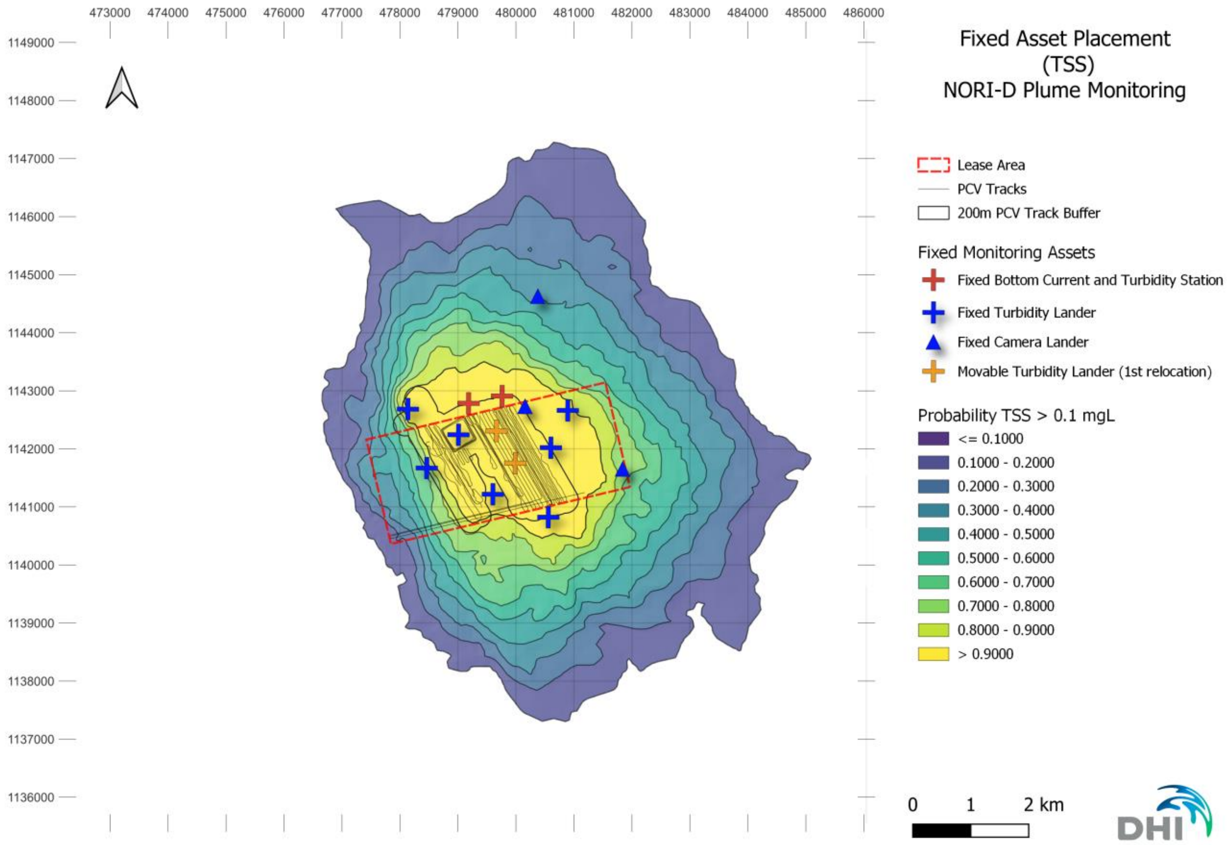
TSS Exceedance Probability

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



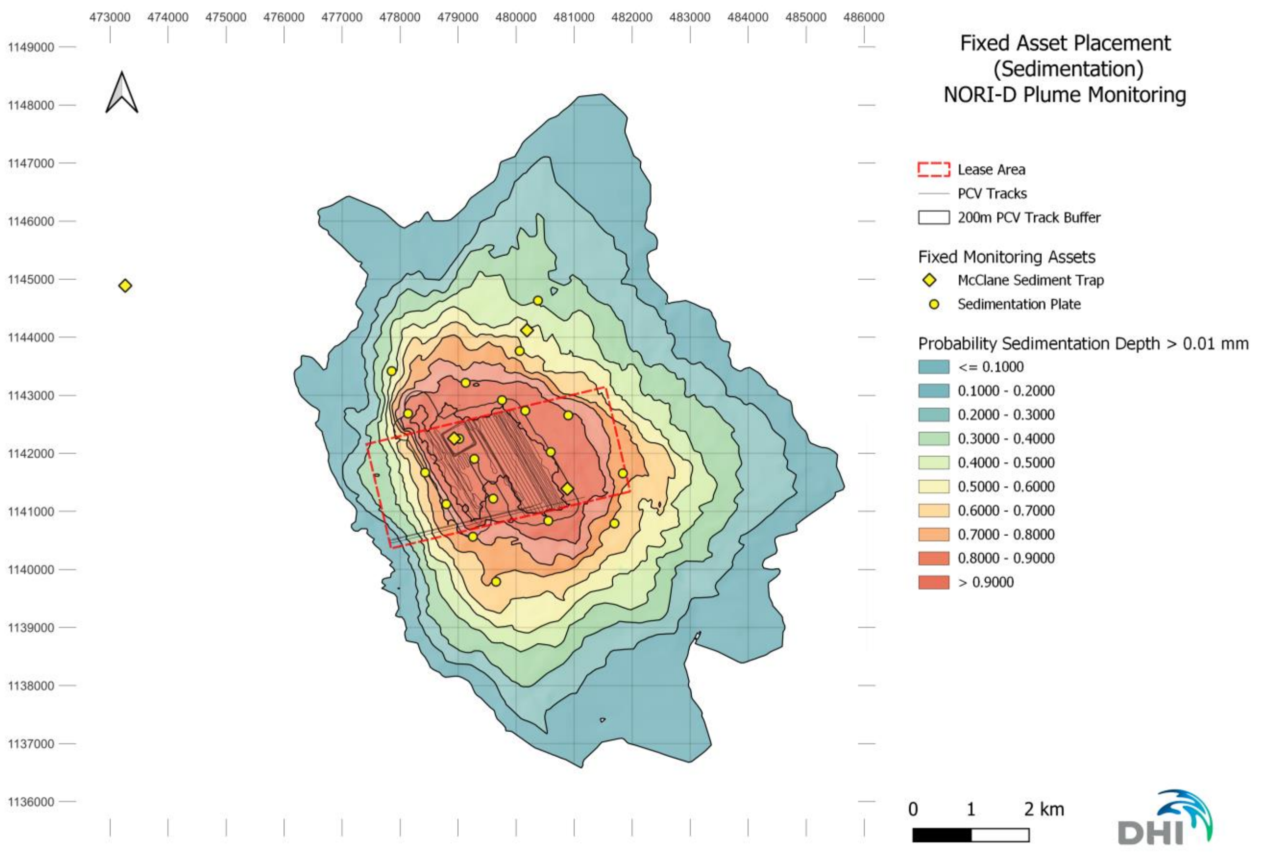
Sedimentation Exceedance Probability

Results from stochastic model ensemble runs using sequences of historical currents

Collector vehicle source term is “as-planned”

Exceedance probability for sedimentation depth >0.01mm used to plan asset placement for sediment traps and plates.

Sedimentation threshold of 0.01mm based on instrument theoretical detection limits



Fixed Monitoring Assets

12x

Fixed Turbidity Stations

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

20x

Sediment Accretion Traps

- Deployment duration ~60 days

2x

Near Real-Time Current & Turbidity Stations

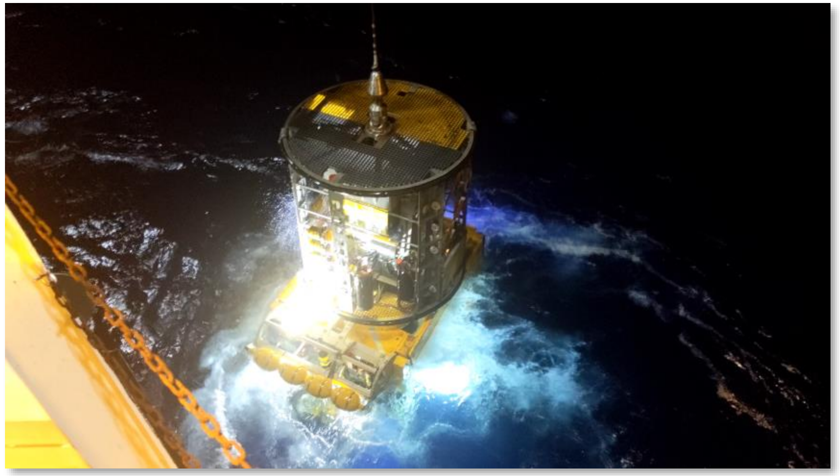
- **16k** hours ADCP data
- **16k** hours OBS data

4x

McLane Sediment Traps

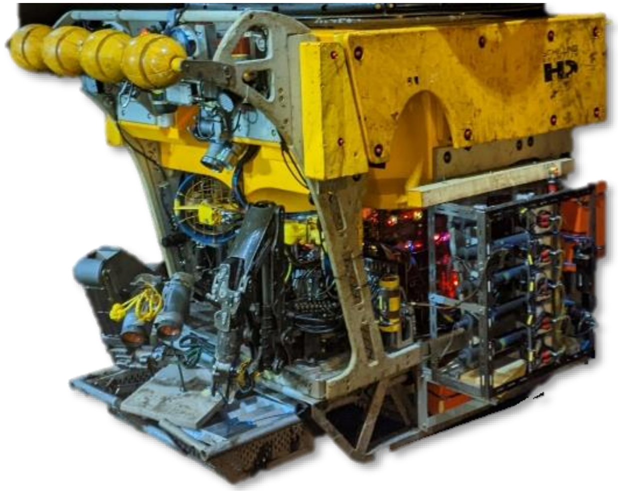
- **84** 0.5L samples
- Deployment duration ~60 days

Instrumentation – Vehicle Mounted



ROV Recovery

Remotely Operated Vehicles (ROVs)



Schilling HD ROV

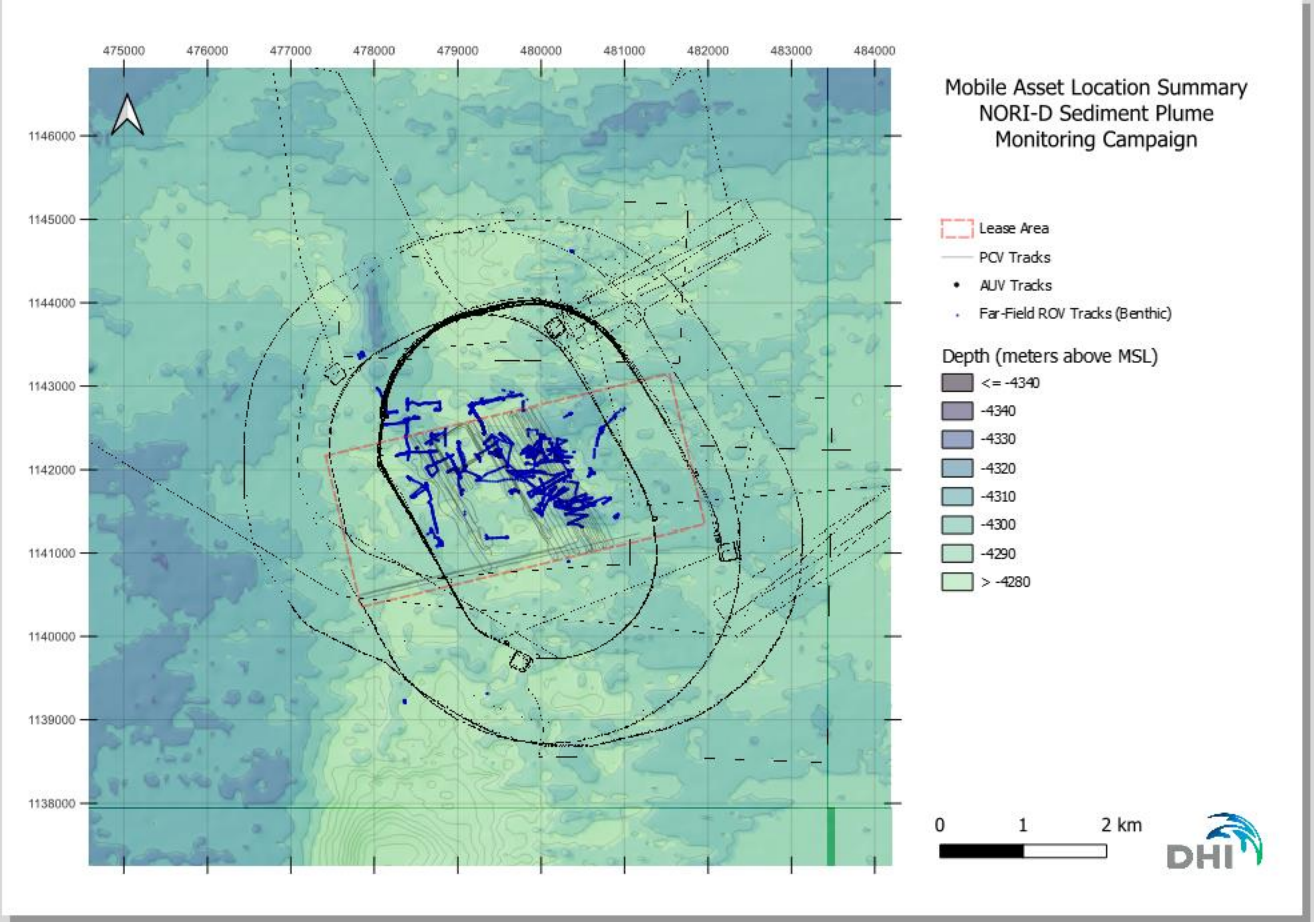
Monitoring Equipment

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

Positioning

- Hydroacoustic Aided Inertial Navigation (HAIN)

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
475000
476000
477000
478000
479000
480000
481000
482000
483000
484000
1146000
1145000
1144000
1143000
1142000
1141000
1140000
1139000
1138000
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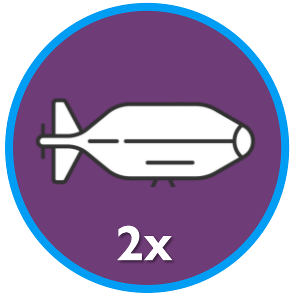
Mobile Monitoring Assets



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

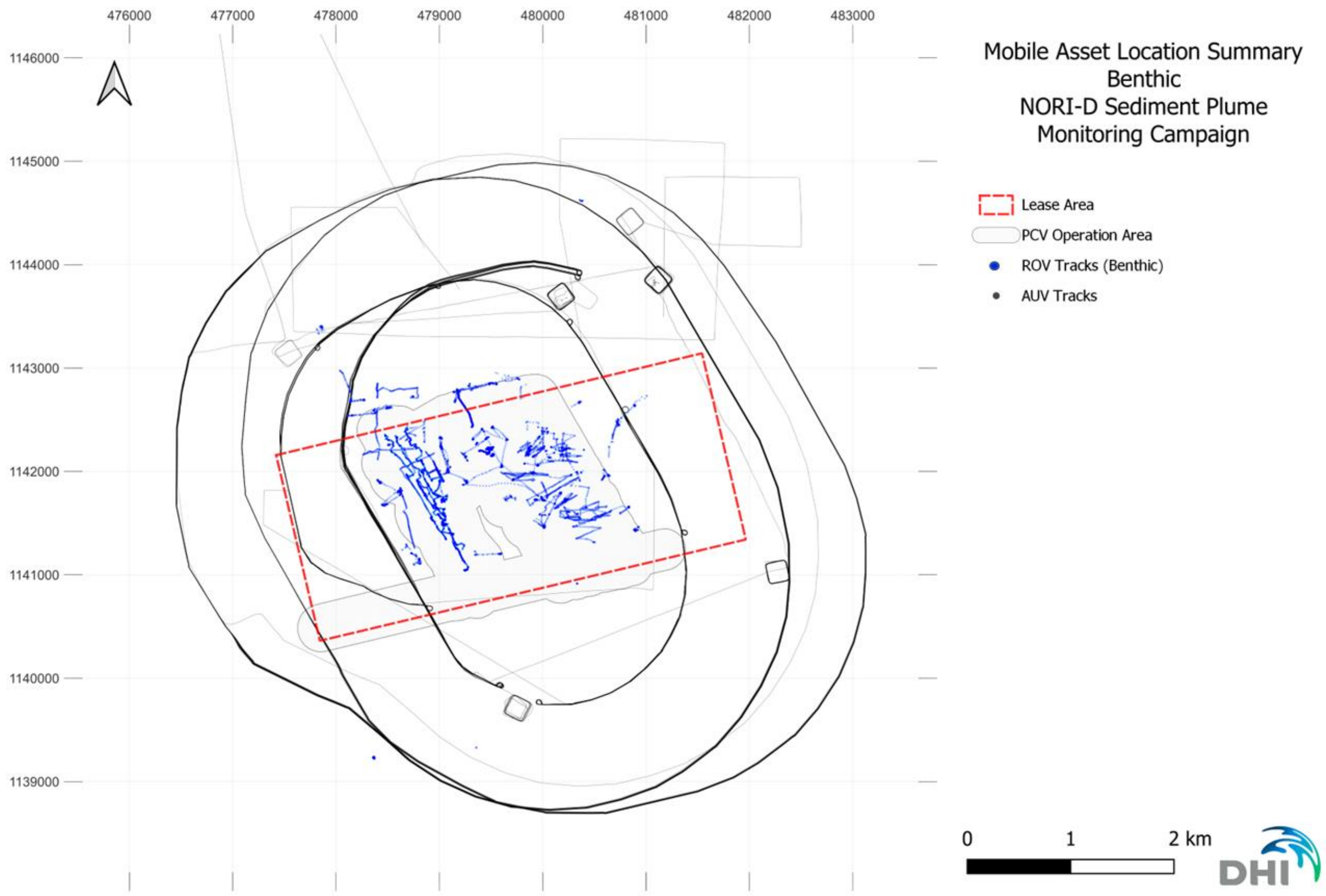
- **132** 1L water sample taken
- **251** hours ADCP and OBS transect data

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



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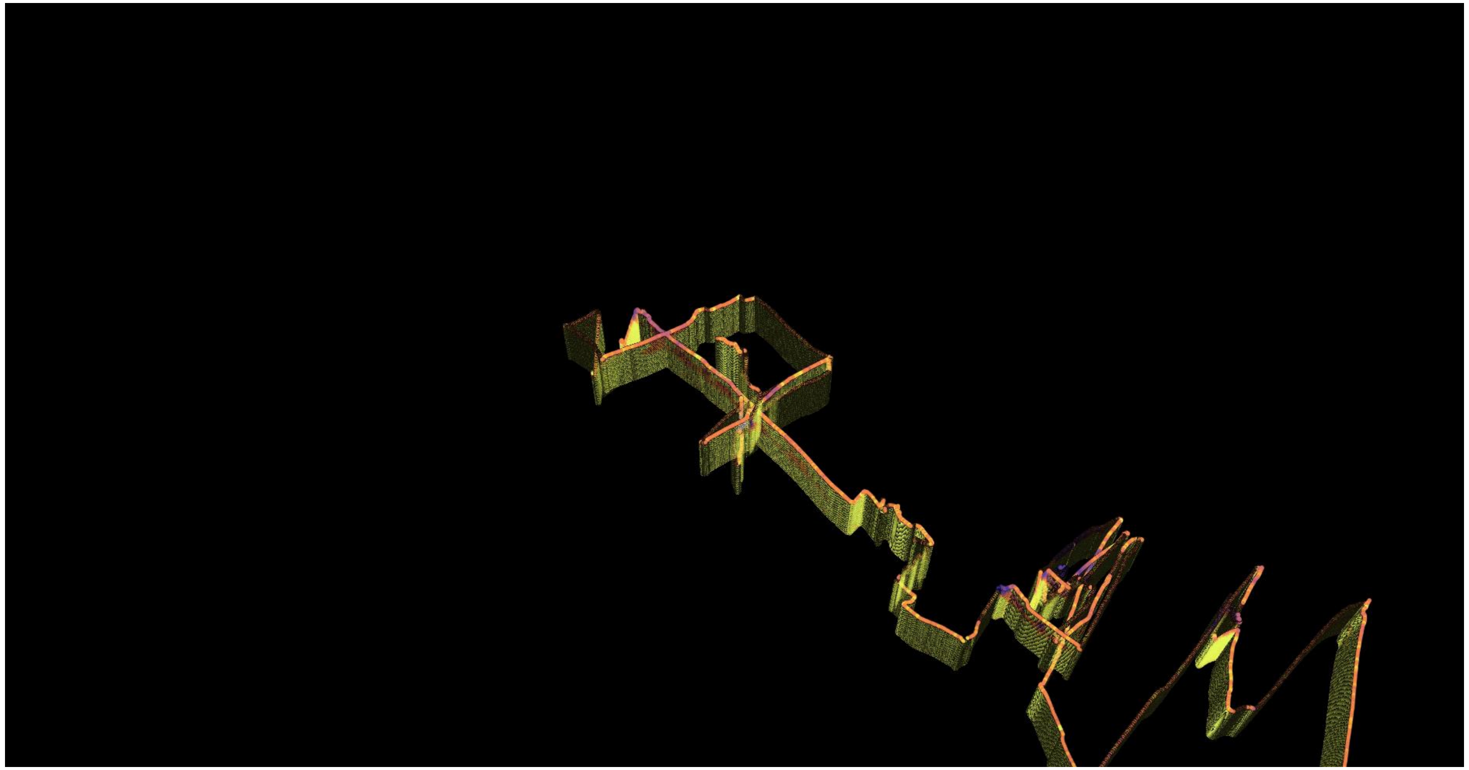
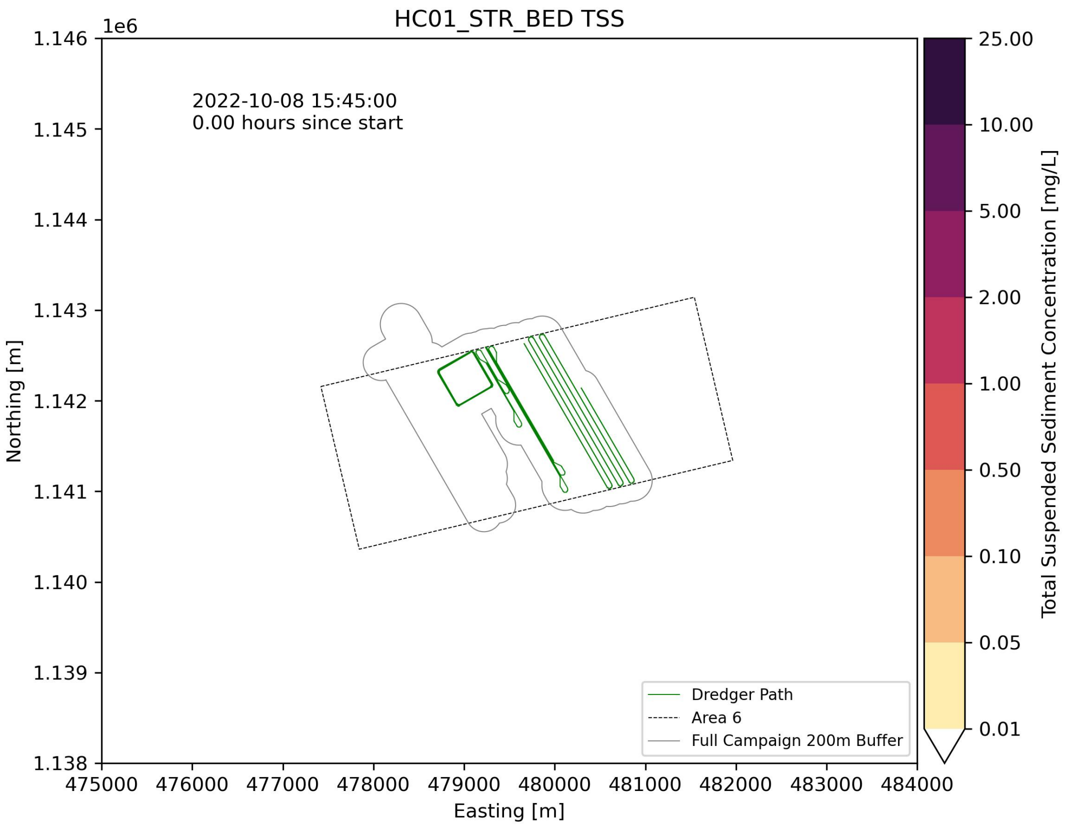
Example of ROV ADCP Data (Far Field)

- 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



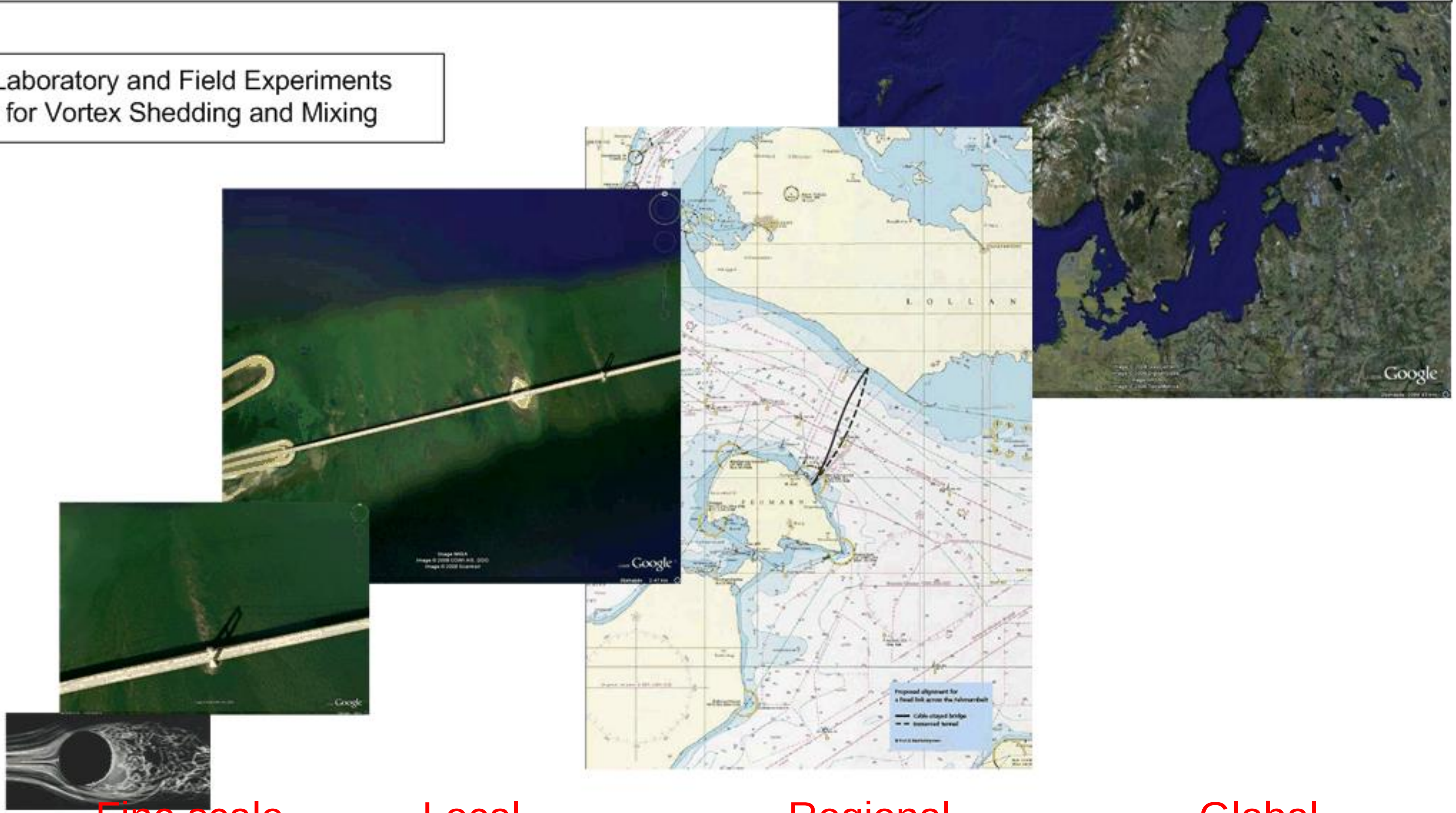
Animation showing sediment concentration 0-1 m above sea bed

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

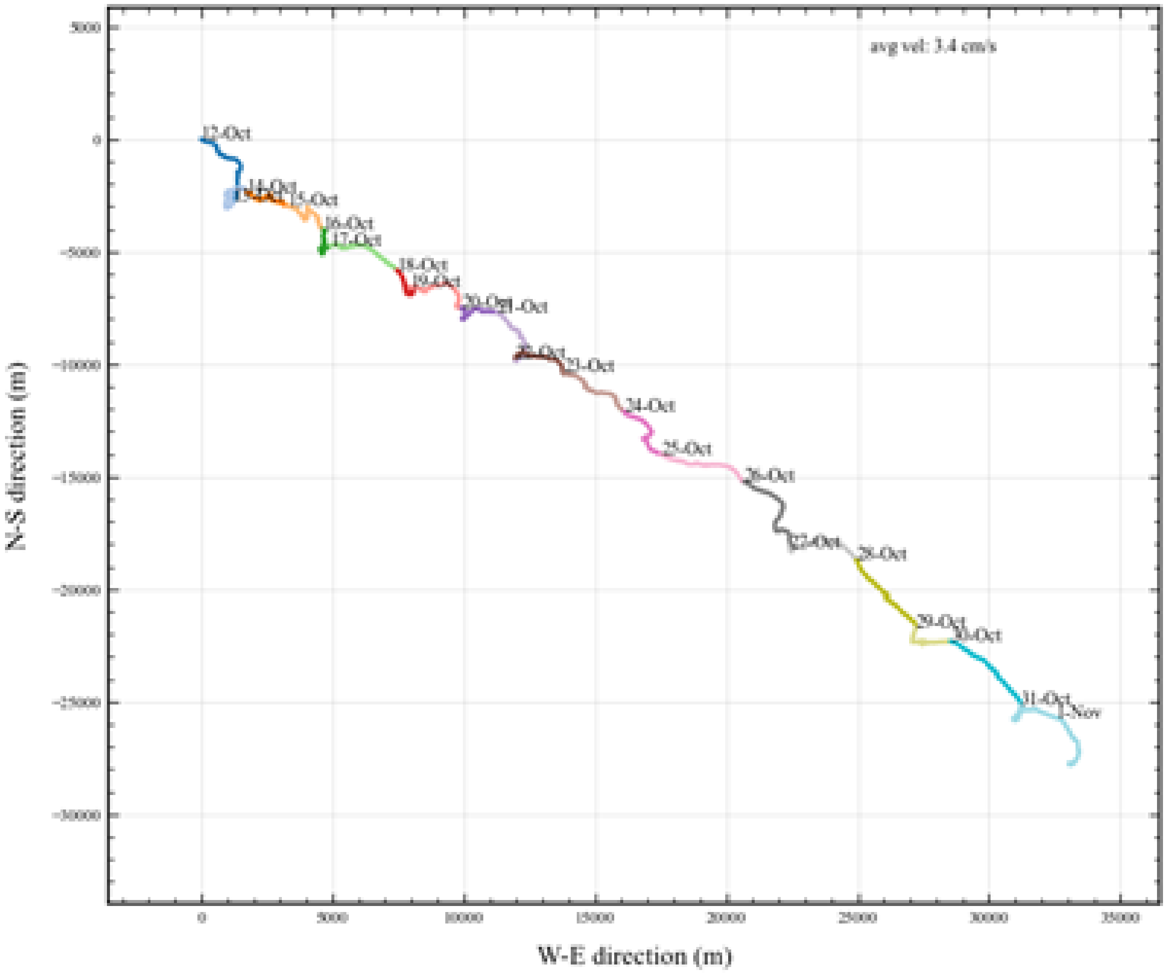
Laboratory and Field Experiments for Vortex Shedding and Mixing

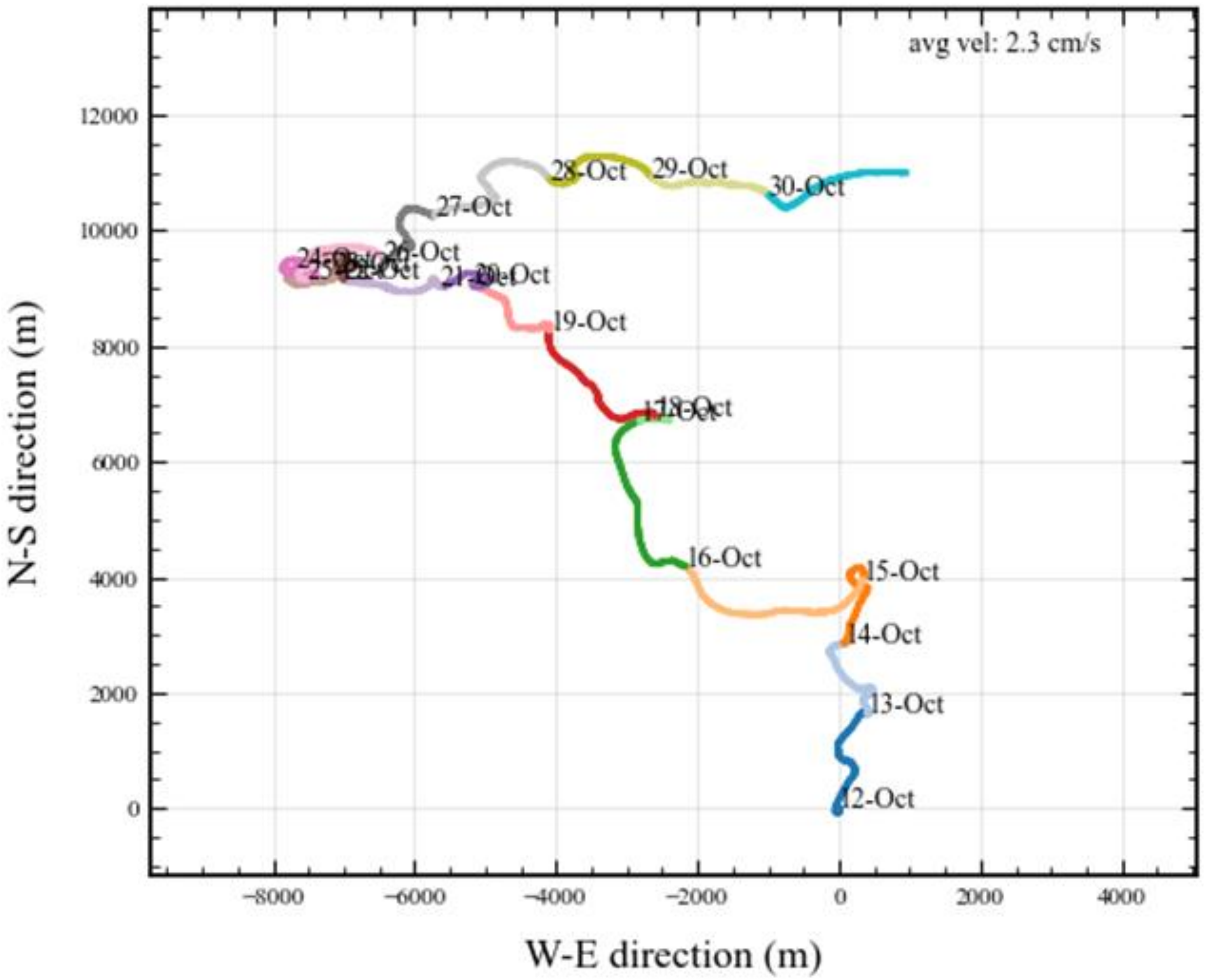


Fine scale — Local — Regional — Global

mm-m | m-100m | 100m – 1km | >10km

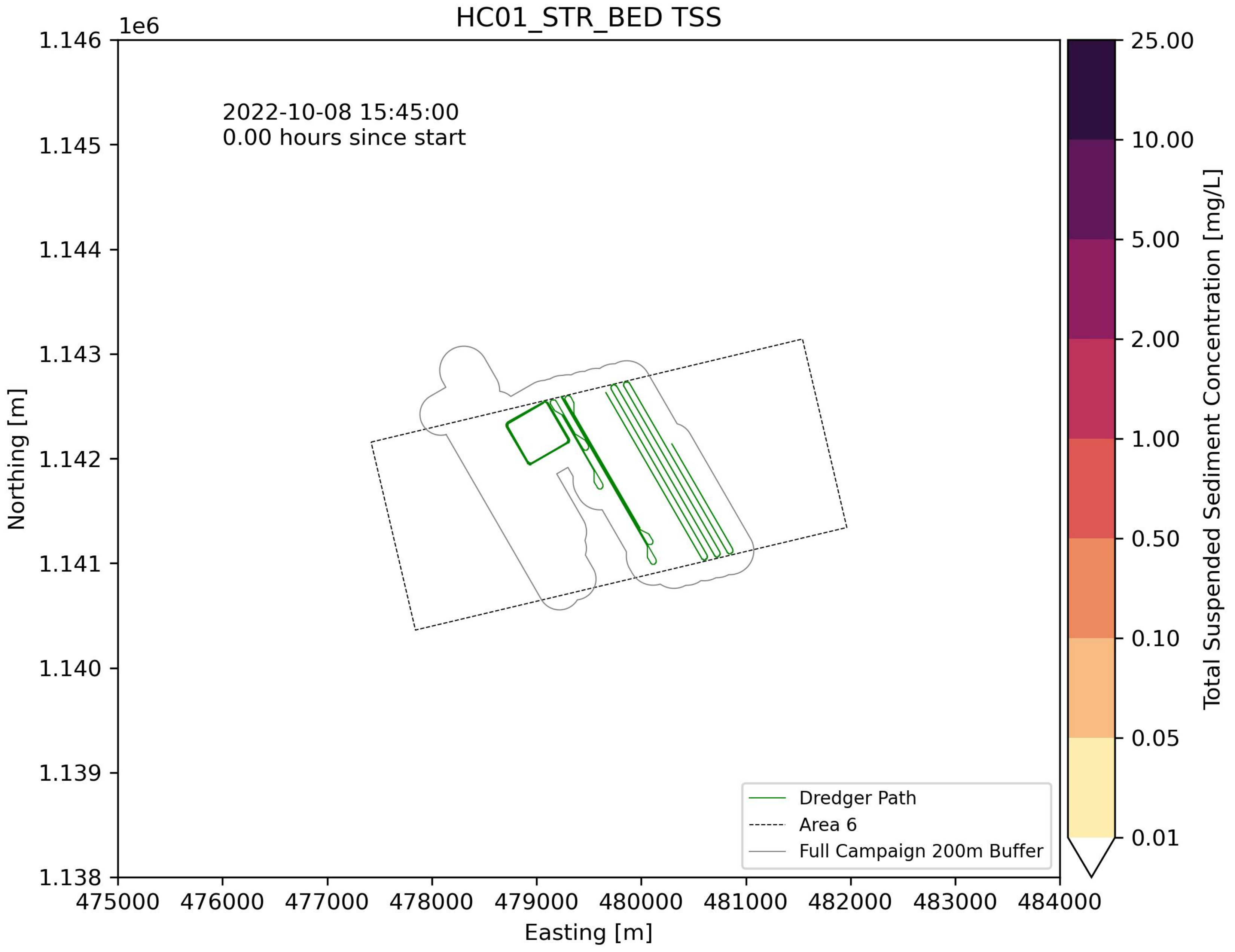
Progressive vector plot during campaign

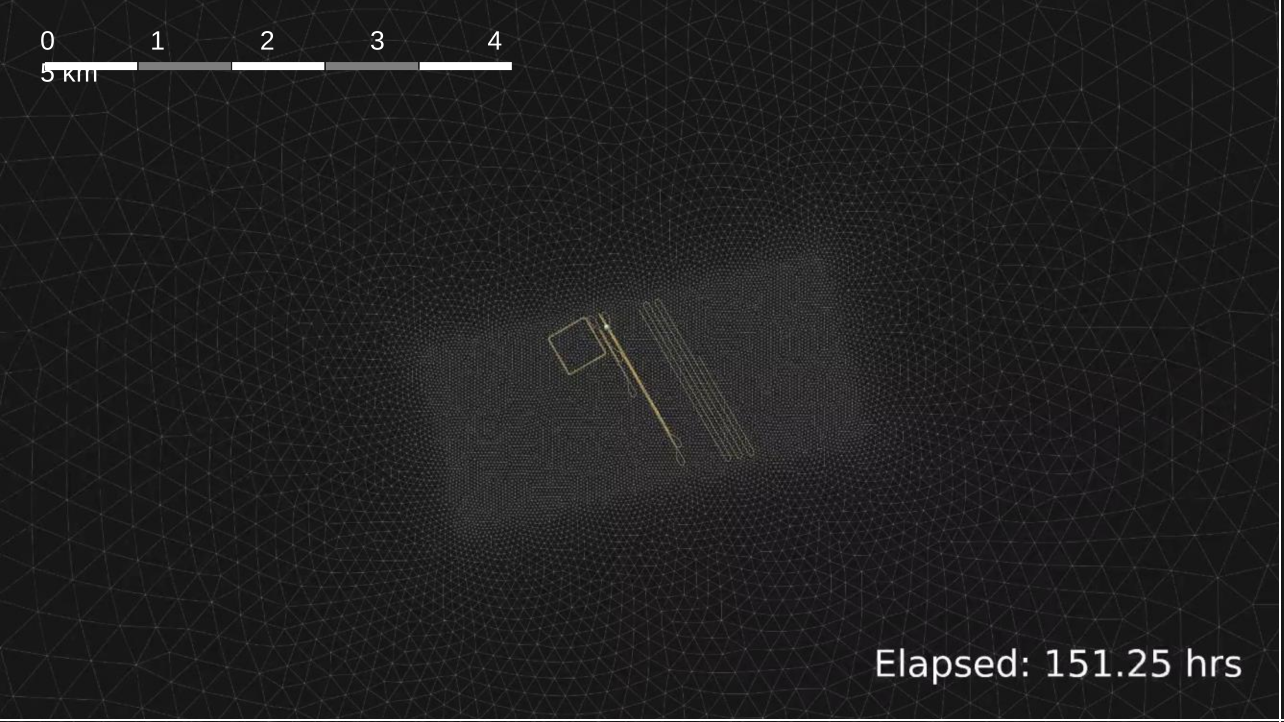


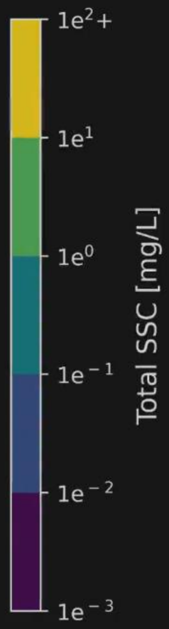


Animation

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]

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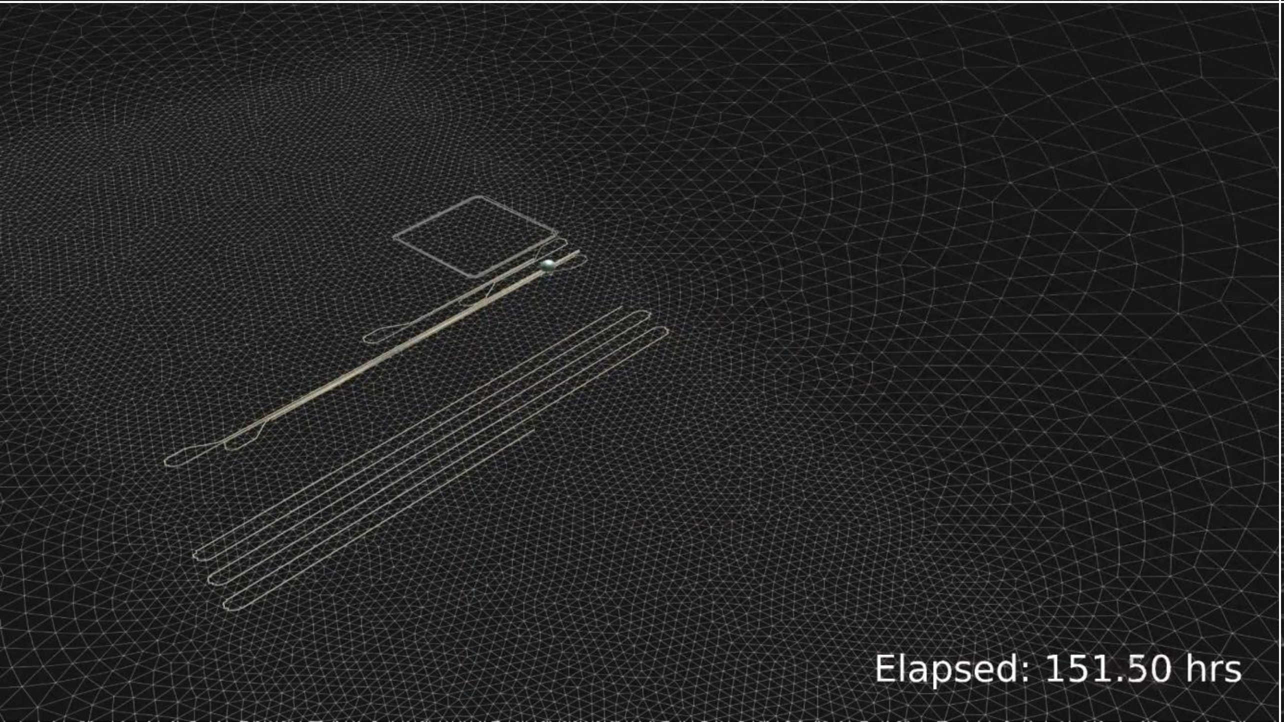
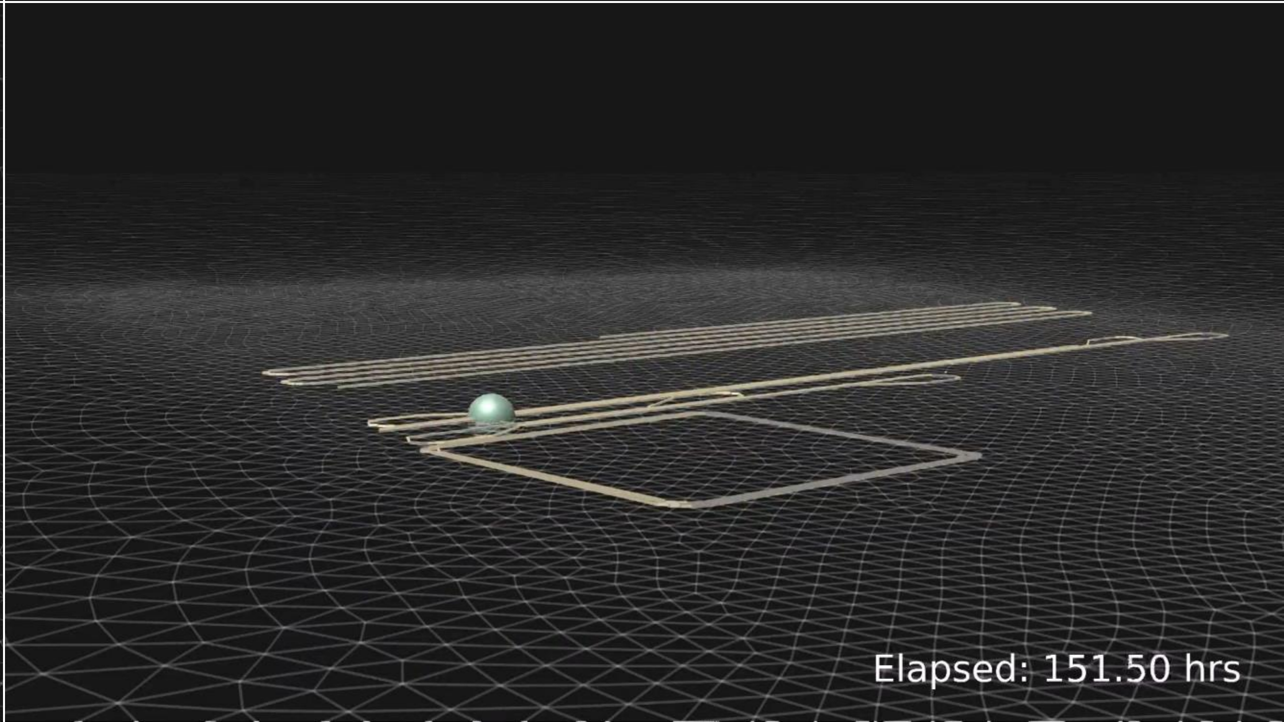
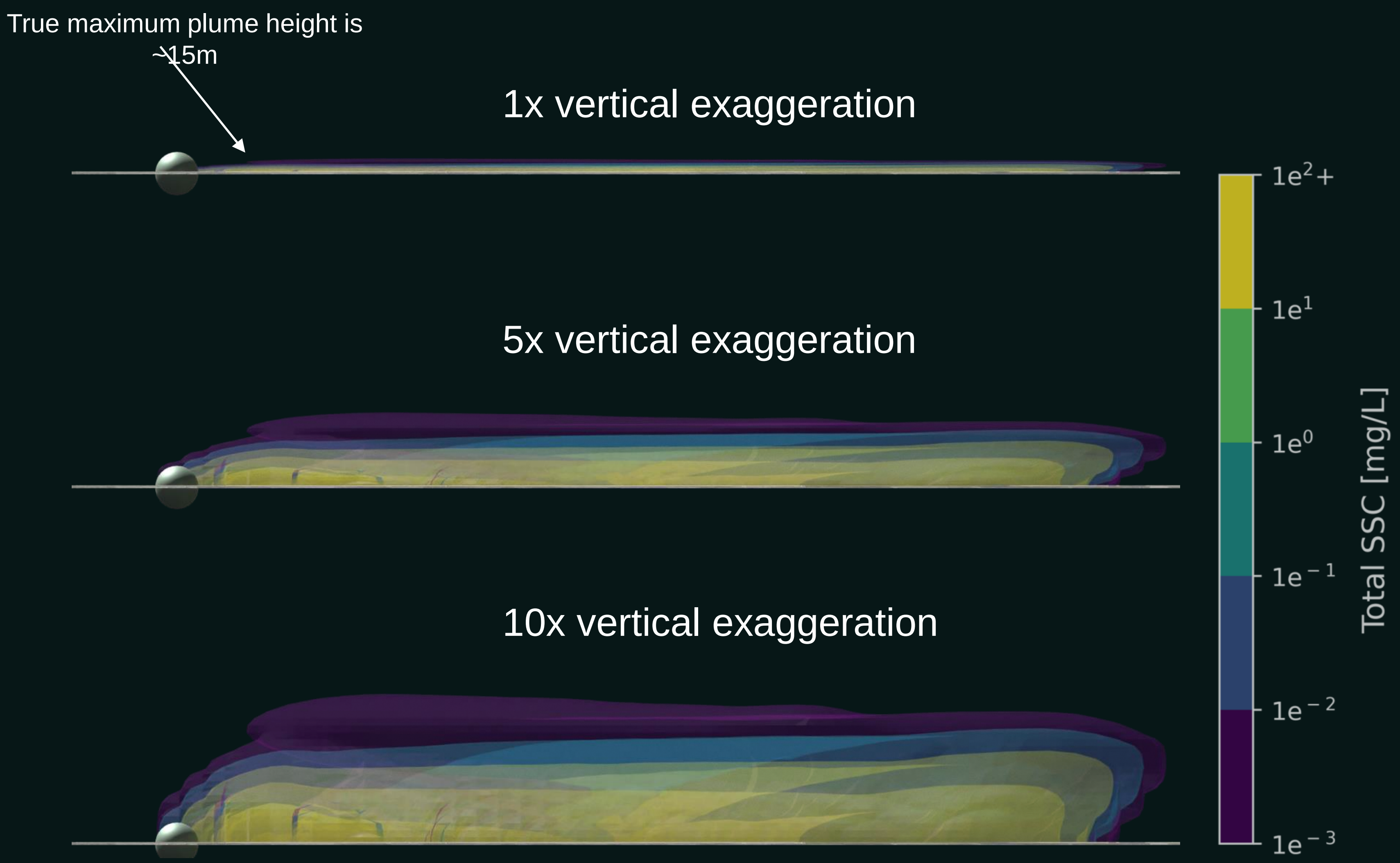




Hindcast Simulation

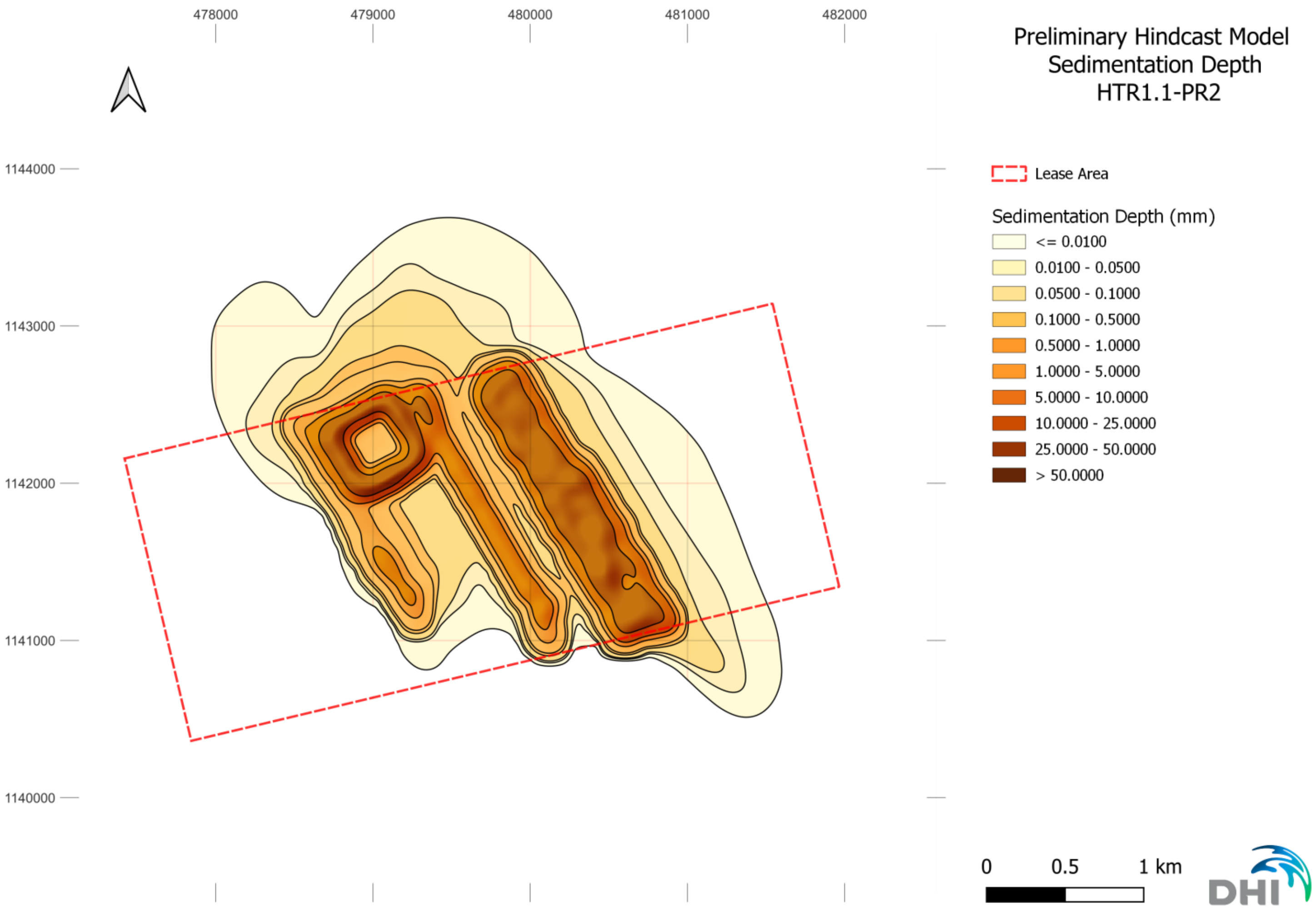
STR 1.1 – PR.2

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

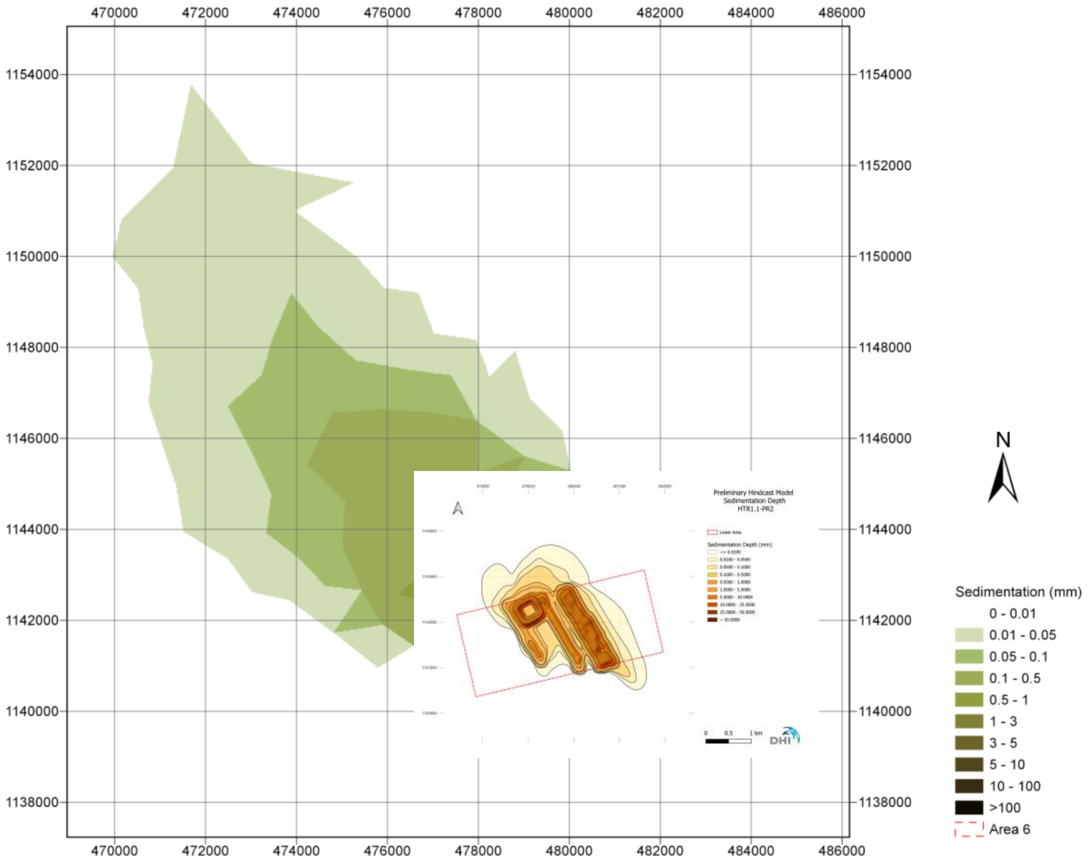


Total sedimentation depth during pilot test (12/10-6/11)

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 resuspeded sediments significanlty lower than assumed
- Sediment aggregation is fast leading to fast settling
- Currents lower than assumed

Thank you!

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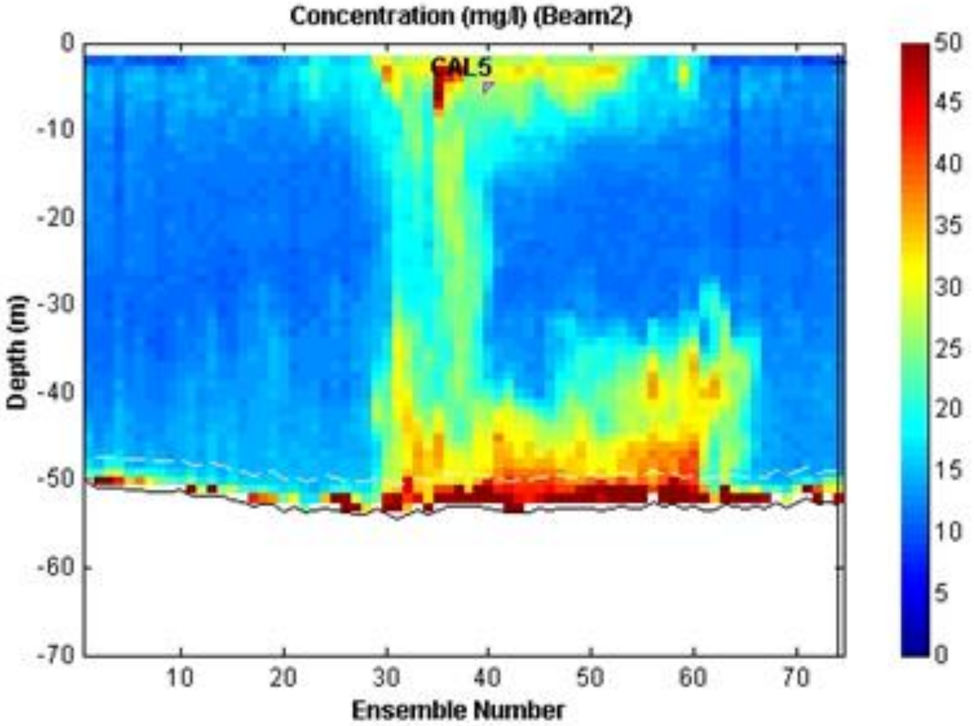
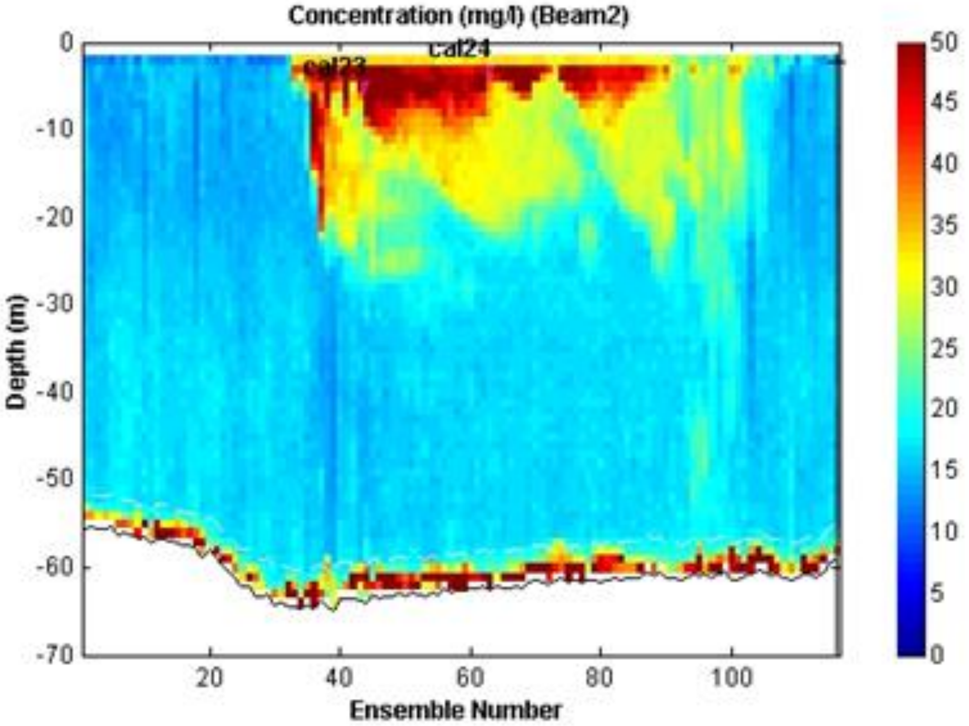
Backup slides

Examples of plume transects

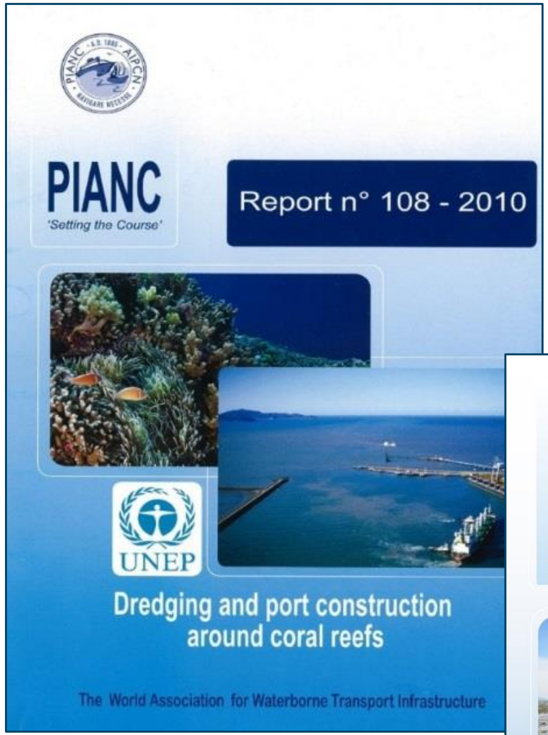




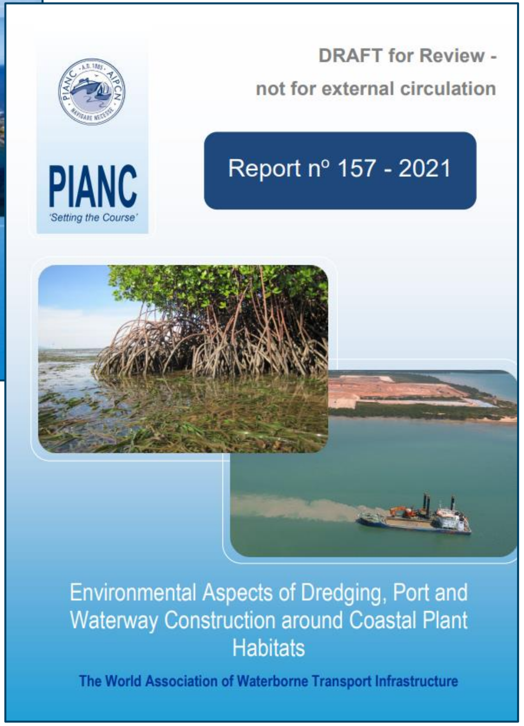
Plume resulting

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.'

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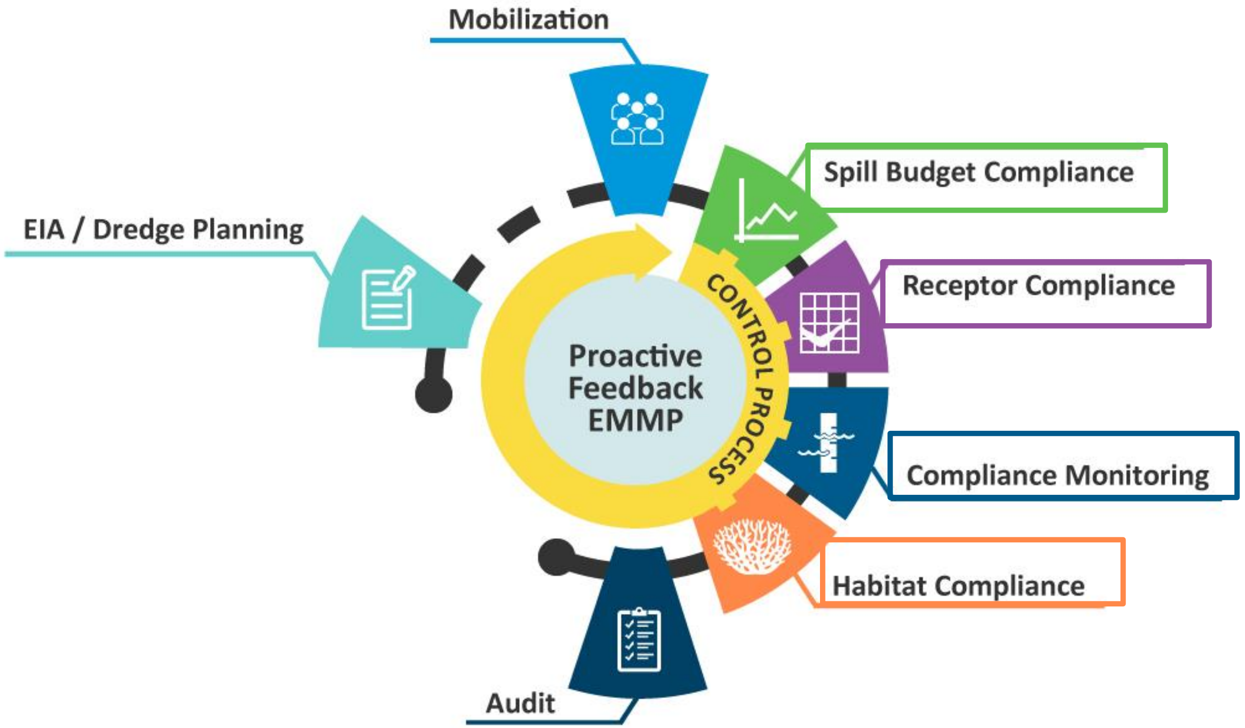
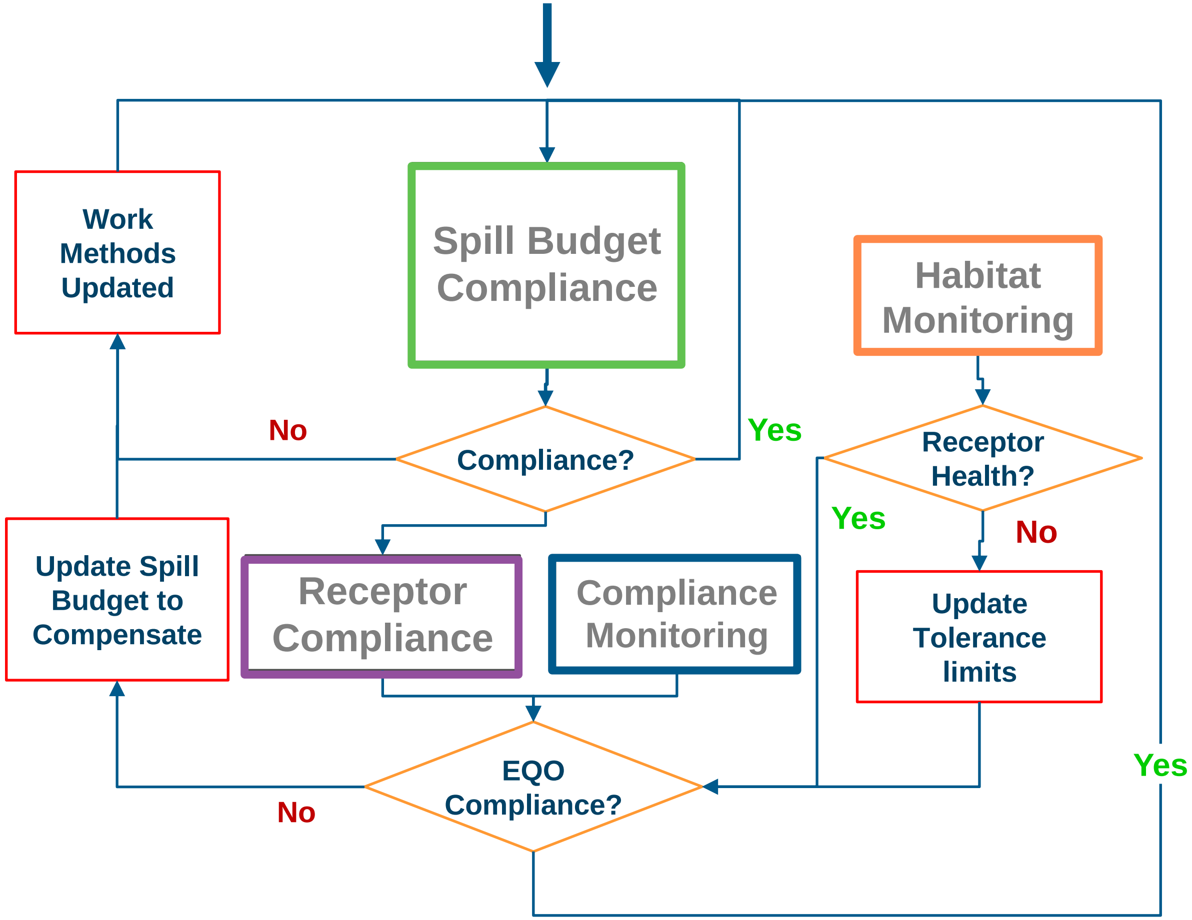
Feedback EMMP: Components & Control Process

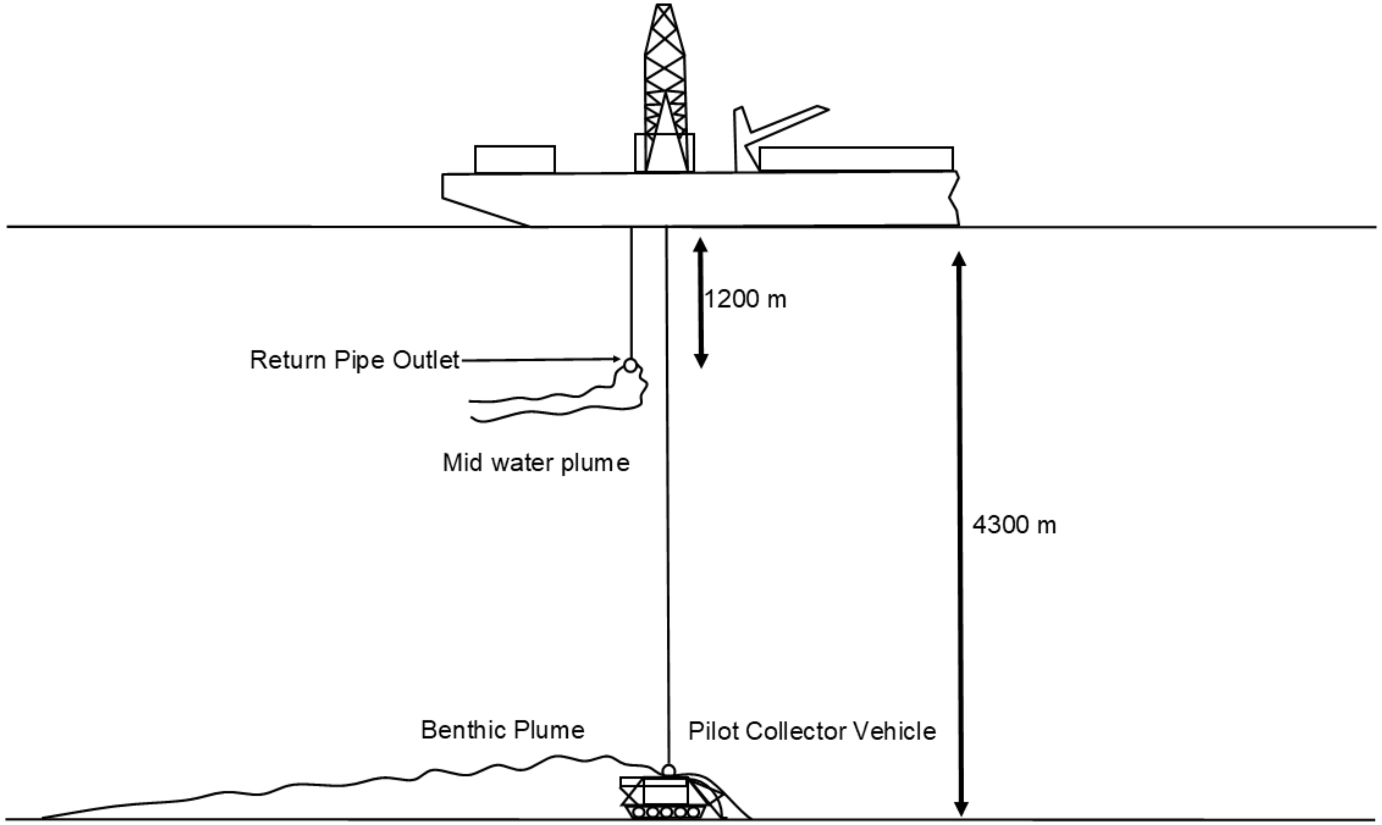




Feedback EMMP- Managing and Mitigating Impacts

The challenges

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




E
S140
S
DCC 0.00
KP 0.0000
East 479163.
North 1141267
4044'
18694'
80
4200
20
40
60
4272.8
80
4300
20
40
60
Allseas


Alt: 0.6
W
NW 323
N
21/10/2022
21:25:46
N: 1141941.3
E: 480339.4
1200
20
40
1247.72
60
80

Plume monitoring