5^{th} YP Com – Wind, Blue & Green energy

Environmental monitoring:

Hydrodynamics, seabed mobility, scouring & scour protection

IMDC

International Marine & Dredging Consultants

Hydrodynamics, seabed mobility, scouring & scour protection - **Index**

IMDC EXPERTISE IN WATER

Hydrodynamics, seabed mobility, scouring & scour protection - **Index**

Introduction

Design seabed level (DSBL) and reference seabed level (RSBL)

Effects of foundations on the seabed

- Scouring
- Scour protection

Design optimisations, physical modelling and in-situ measurements

Conclusions

Hydrodynamics, seabed mobility, scouring & scour protection - **Introduction**

Design of offshore is different than for onshore foundations

- Interaction between hydrodynamic forces (i.e. tide, waves & currents) and the seabed results in an dynamic environment;
- Translated into the following phenomena to deal with:
  - Mobile seabed, different seabed features;
  - Scour and scour protection;
  - Limited/difficult access;
- Even more complex due to:
  - Different types of foundations;
  - Lack of experience & scientific background;
  - Lack of in-situ observations and measurements
  - Standards not always in line with in-situ observations;
  - Limitations during construction and maintenance.

Focus on definition of design seabed level, including reference seabed level and effect of scour or scour protection and related monitoring

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Hydrodynamics, seabed mobility, scouring & scour protection - **Introduction – Seabed mobility**

- Mobility is depending on:
  - Receptor:
    - the soil (e.g. rock, sand, clay,…);
    - the bed forms;
  - Hydrodynamic forces: water level, wave action, currents & storms;
  - Anthropogenic influence (e.g. ship propeller actions, presence of foundations, spuds,…).
- Influences the design seabed levels
- Sandy seabed mobility is comparable with dune mobility in the Sahara

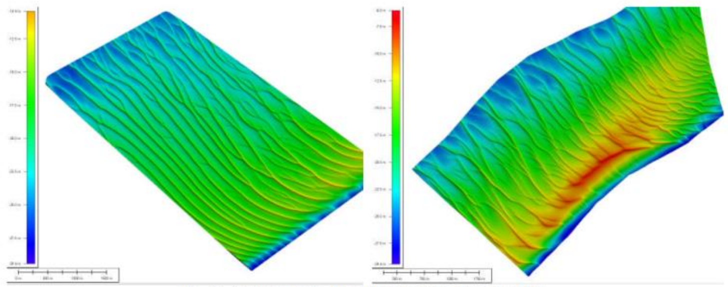


Fig. 5 – General seabed morphology Sub Area A and B

	Ripples	Small dunes	Medium dunes	Large dunes	Very large dunes
Amplitude (m)	<0.075	0.075 – 0.4	0.4 – 0.75	0.75 – 5	>5
Wavelength (m)	<0.6	0.6 – 5	5 – 10	10 – 100	>100

Hydrodynamics, seabed mobility, scouring & scour protection - **Introduction – Scouring**

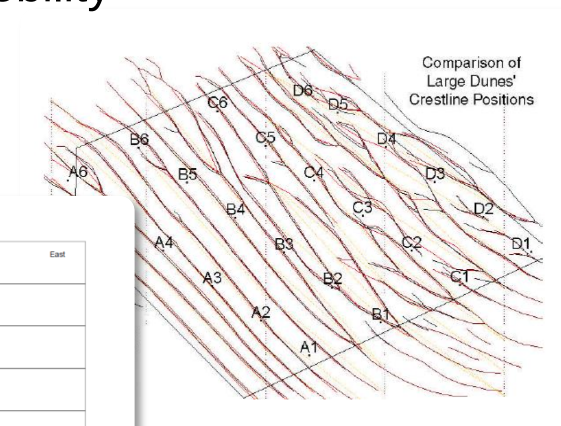
- Scour in different sizes & environments
- Scour leads to instability of structures:
  - ULS (failure);
  - FLS (fatigue);
- Appropriate counter measures are needed;
- Understanding the process is essential to provide adequate solutions

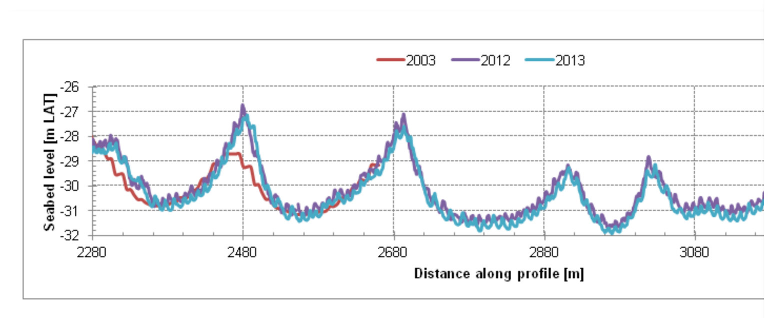
Hydrodynamics, seabed mobility, scouring & scour protection - **Index**

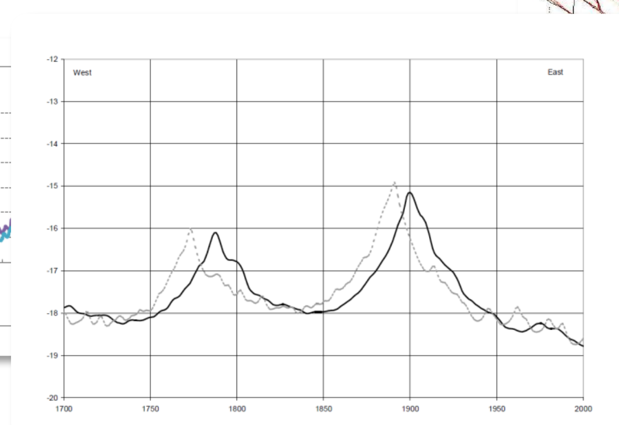
Hydrodynamics, seabed mobility, scouring & scour protection - **Design Seabed Level**

- DSBL is one of the main design parameters for foundation calculations
- On land easy to define & to maintain, offshore much more complex & function of:
  - Seabed characteristics & hydrodynamics (see introduction);
  - Foundation type, load case & lifetime;

- **Measurements are essential**:
  - To avoid over conservatism!
  - To define natural erosion
  - To define natural seabed mobility







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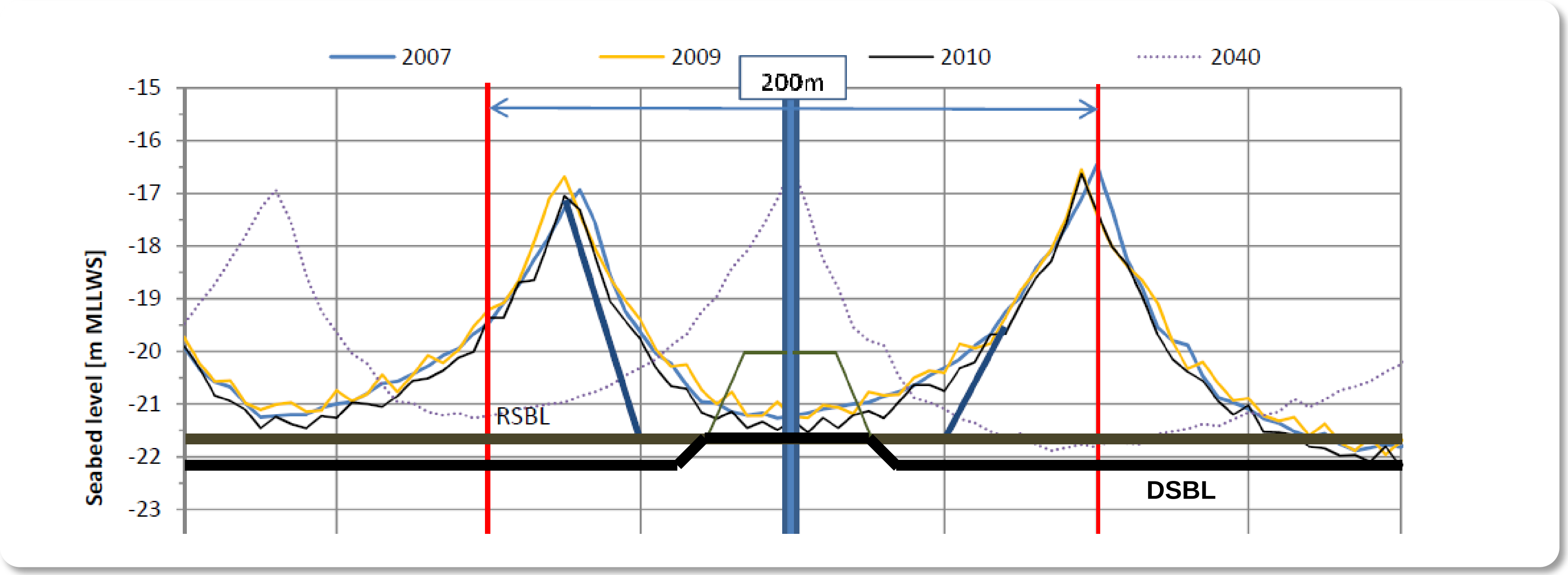
Hydrodynamics, seabed mobility, scouring & scour protection - **Design Seabed Level**

DSBL in **3 steps**:

- Step **1** - Definition of the RSBL - natural evolution
- Step **2** - Estimation the effect of presence of foundation
- Step **3** - DSBL = RSBL – effect of the foundation



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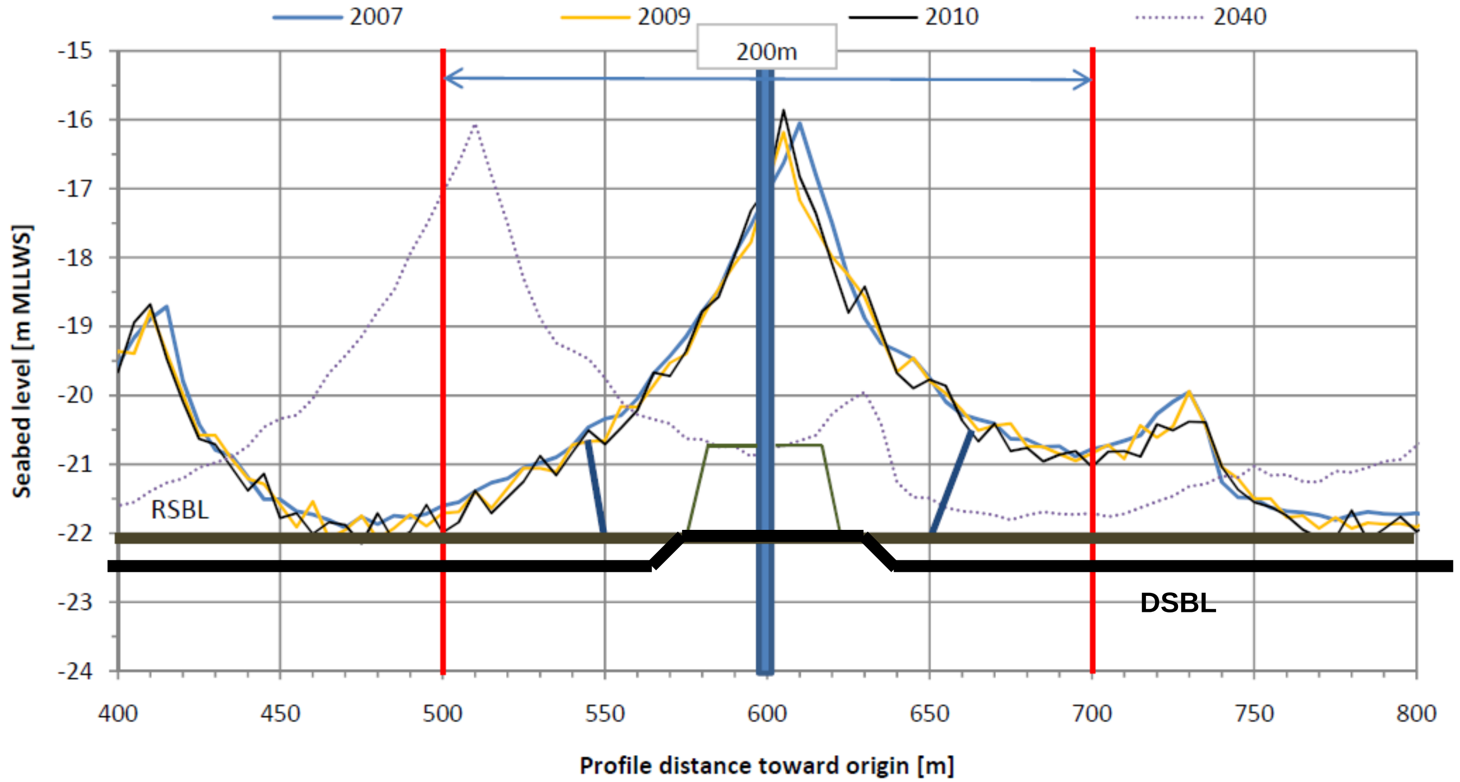
Hydrodynamics, seabed mobility, scouring & scour protection - **Reference Seabed Level**

Is defined as the minimum seabed level that can be guaranteed during the lifetime of the foundation, considering the mobility of the seabed and **natural** erosion and/or accretion.

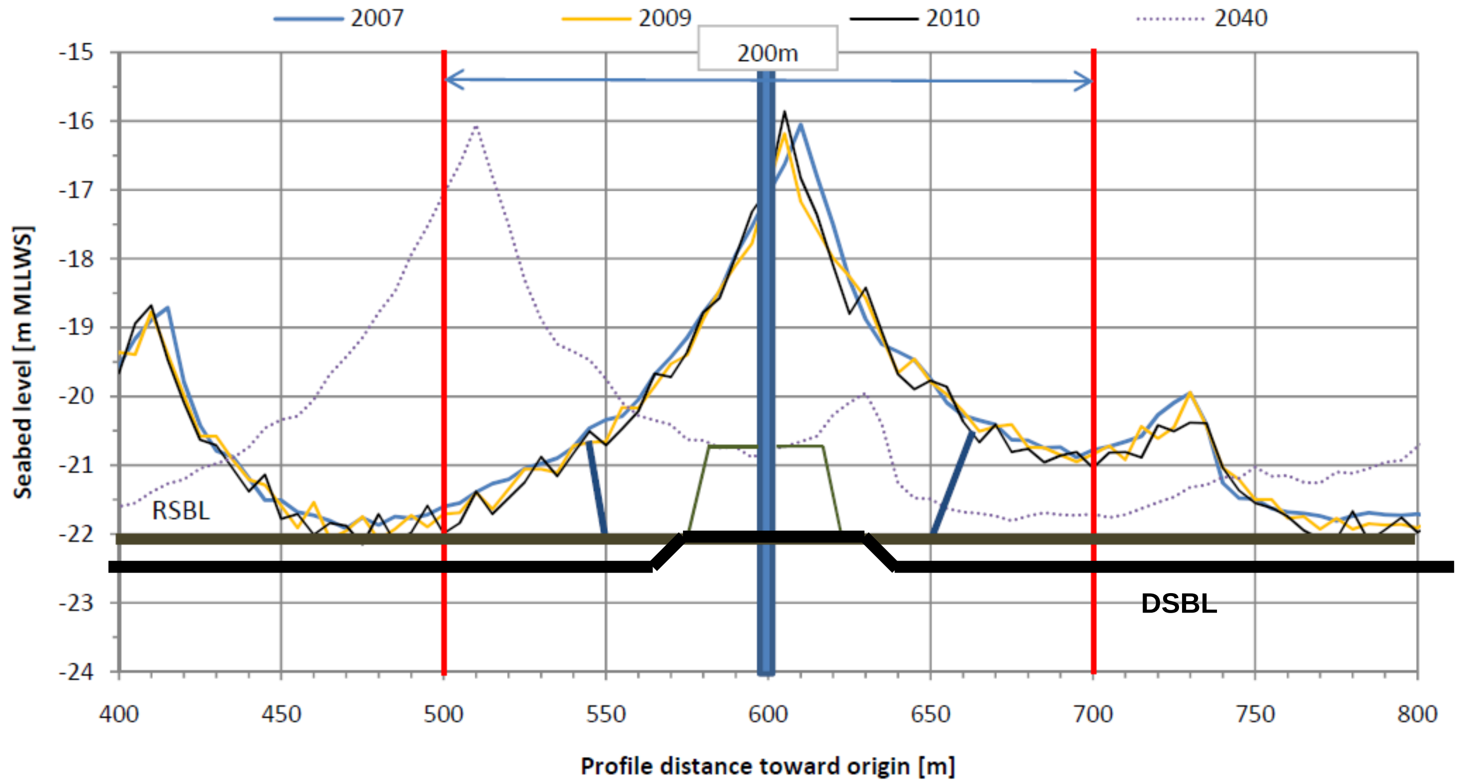
RSBL = minSBL (mLAT) in a (circular) area around the foundations – global erosion trend (m)



Hydrodynamics, seabed mobility, scouring & scour protection - **Reference Seabed Level**

The minSBL is based on historical data, analysis and literature review & is defined by: **Dune mobility rate** (xm/yr), **global erosion trend** (xm/yr) and **dune length**

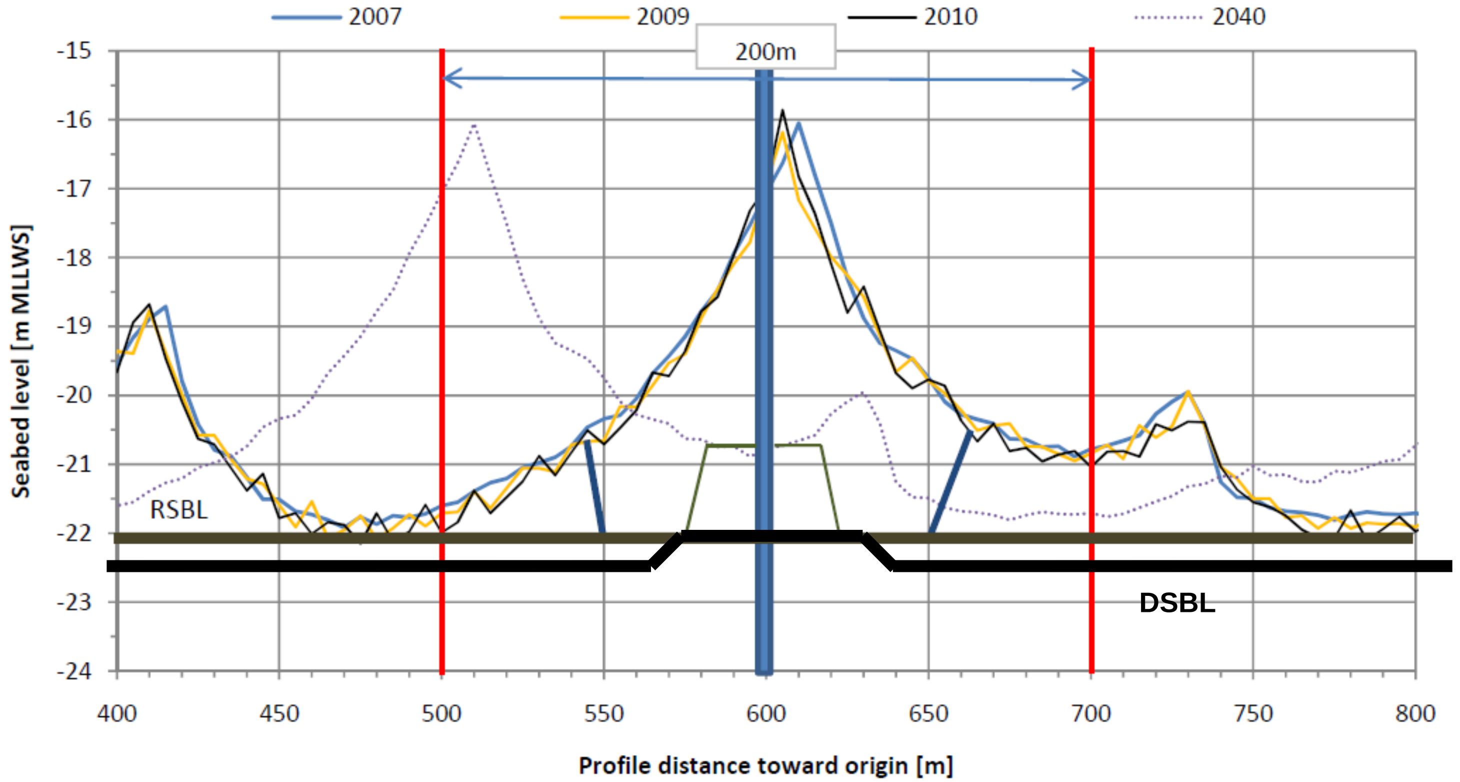
=> defining the radius R of the circular area to base minSBL on



Hydrodynamics, seabed mobility, scouring & scour protection - **Reference Seabed Level**

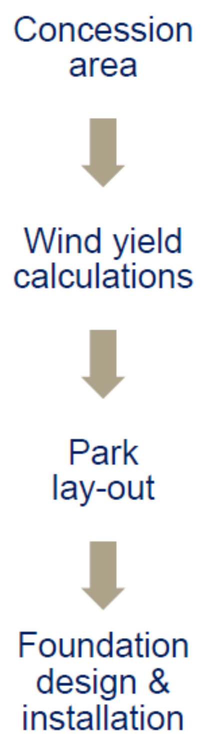
- RSBL is different for each foundation position
- The more data available, the more accurate, the less conservative the DSBL is

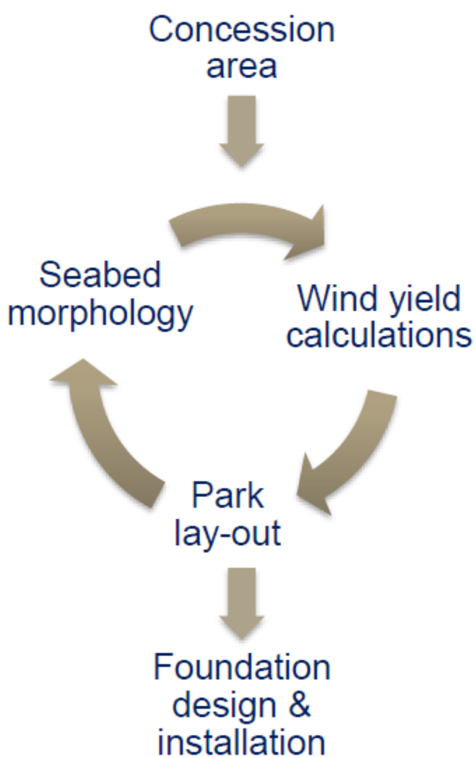
=> measurements are key aspects



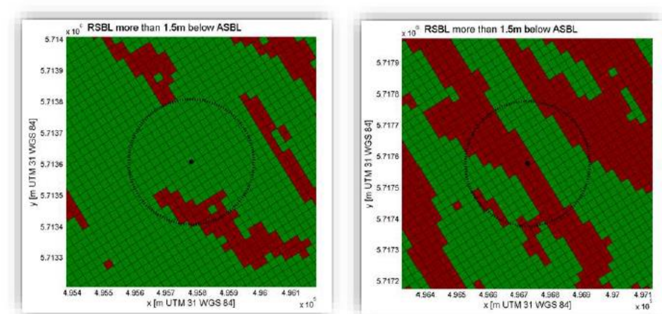
Hydrodynamics, seabed mobility, scouring & scour protection - **Design**

Lay-out optimisations in view of optimized DSBL





Grid averaged calculation of ASBL - RSBL



↦ cells with ASBL-RSBL
>1.5 m : red
<1.5 m : green

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Hydrodynamics, seabed mobility, scouring & scour protection - **Index**

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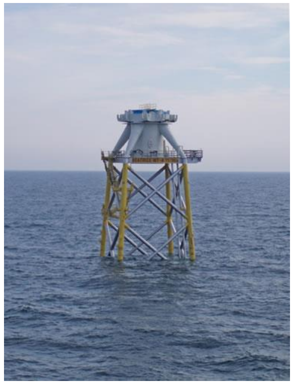
Hydrodynamics, seabed mobility, scouring & scour protection - **Effects of foundations**

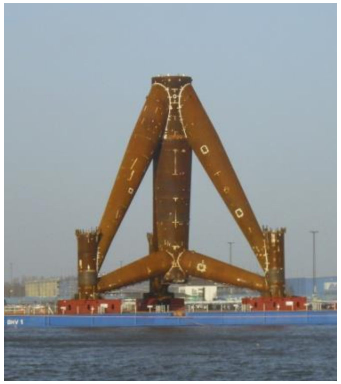
A large range of different **foundation types**:

- Monopile, jacket, GBF, suction bucket, tripod,…
- All different influences on the seabed;
- All different dynamic behavior;

Every type of foundation can introduce disturbance of the seabed

= scour assessment is needed





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Hydrodynamics, seabed mobility, scouring & scour protection - **Effects of foundations**

Two design options

Design with scour allowance

=> estimate needed as input for DSBL

Design with scour protection

to avoid scouring
=> design needed as input for DSBL

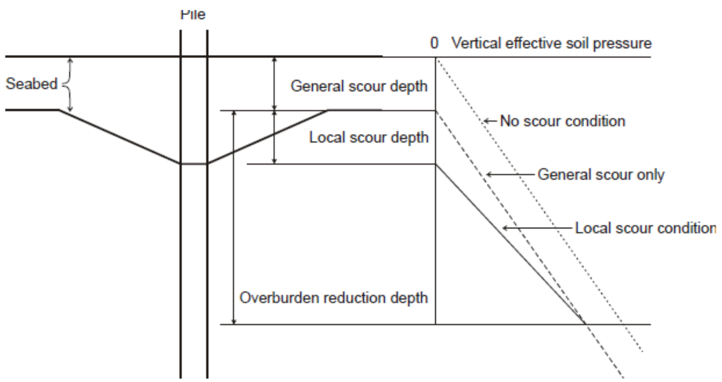
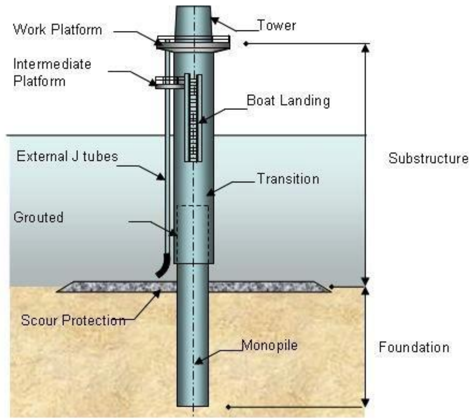
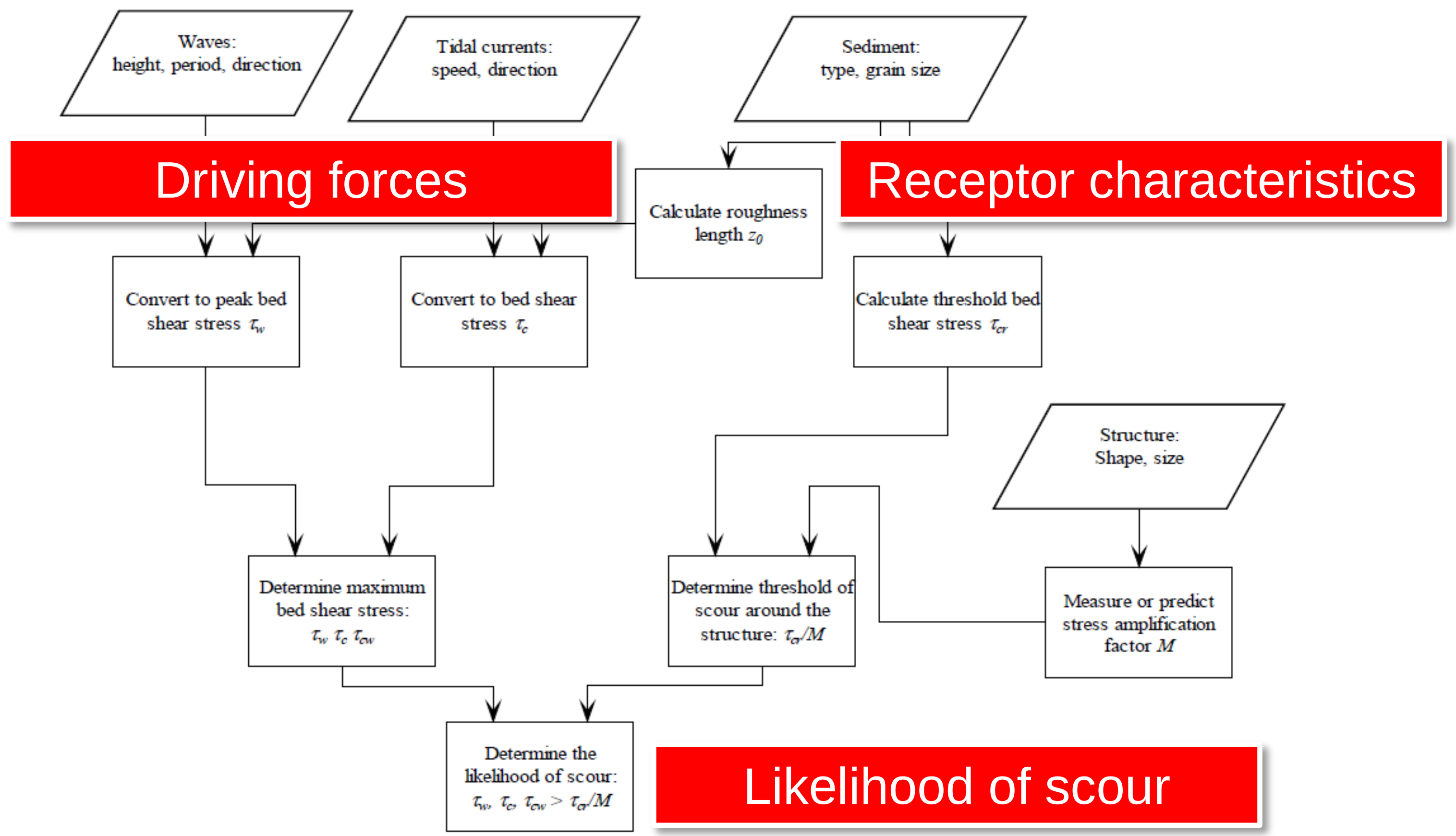


Figure 8. Overburden reduction depth determination for global and local scour



Hydrodynamics, seabed mobility, scouring & scour protection - **Scouring**

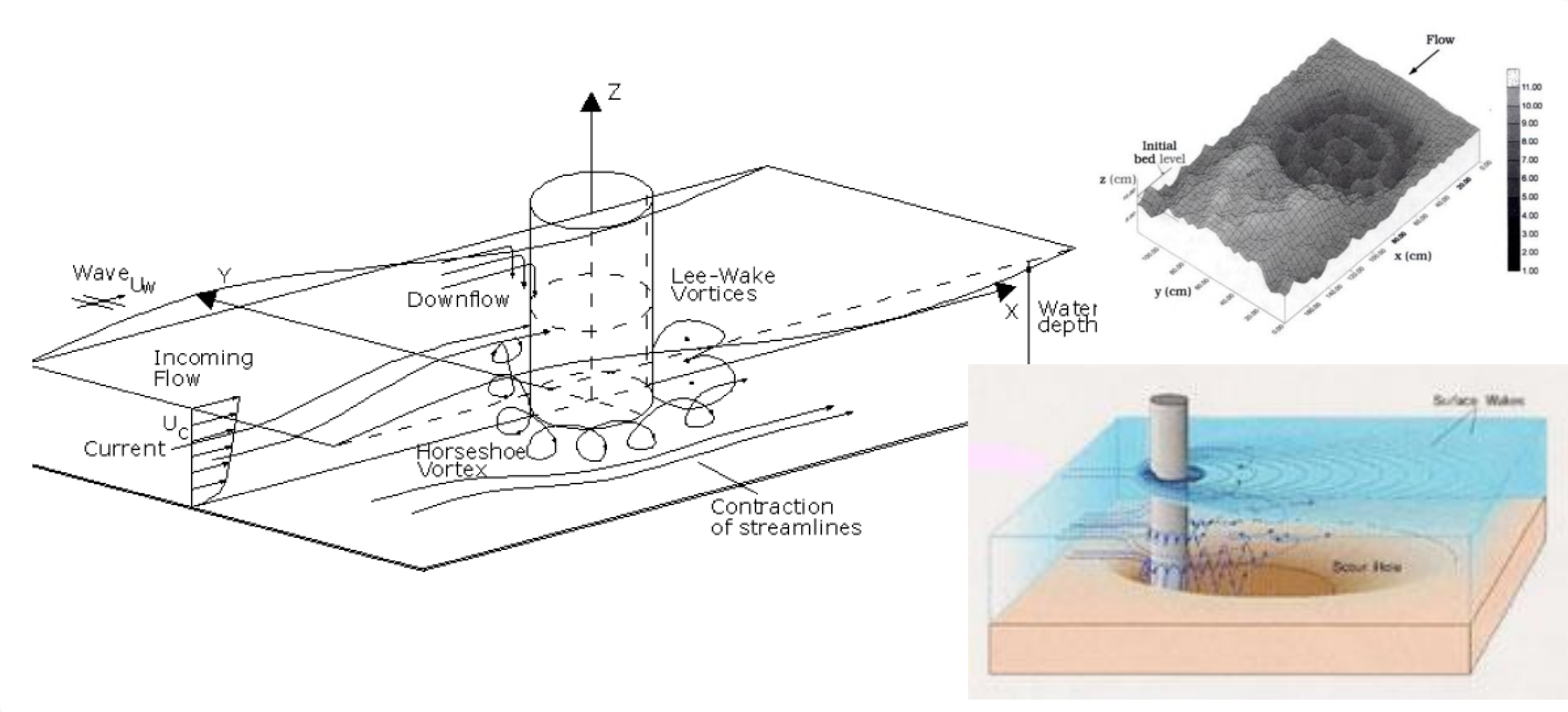
Scour assessment – based on the shear stress approach (after Whitehouse, 1998):



Hydrodynamics, seabed mobility, scouring & scour protection - **Scouring**

Scouring = effect of currents and waves on seabed level & introduced by flows: down-flow, lee wake vortices, contraction of streamlines, horseshoe vortex;

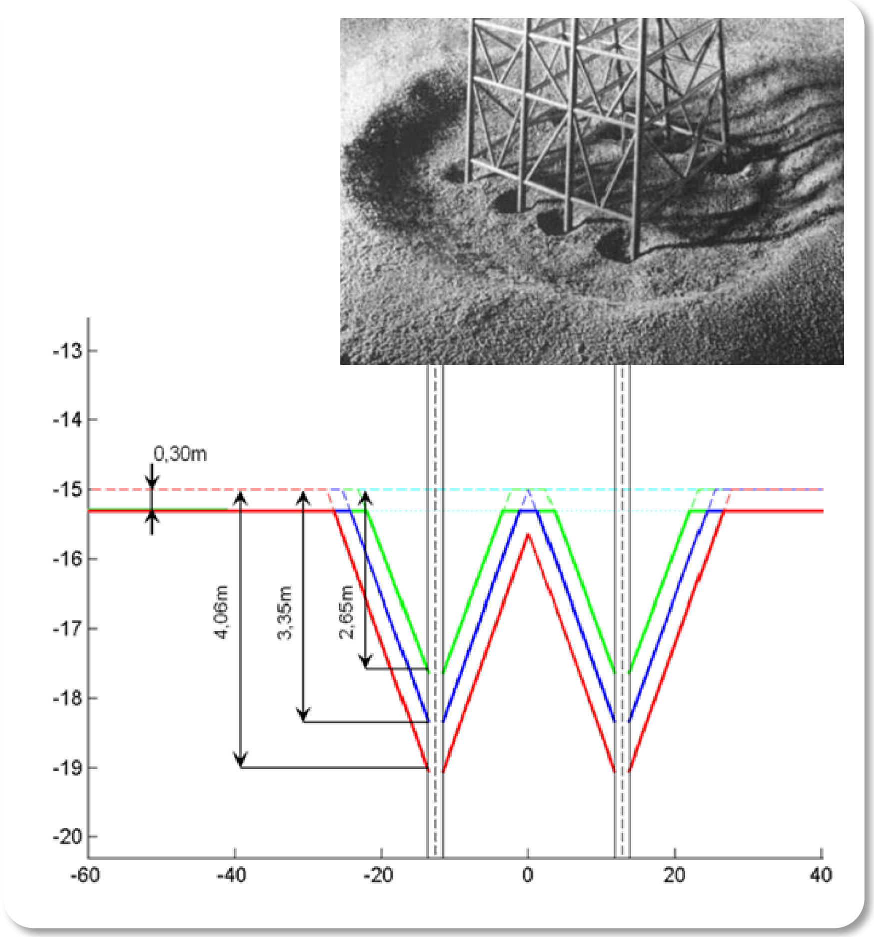
Result = scour pit => effect on dynamic, FLS and ULS behavior foundation



Hydrodynamics, seabed mobility, scouring & scour protection - **Scouring**

Design with scour allowing needs:

- Estimation of scour pit dimensions:
  - Global scour = structural level
  - Local scour (extent and depth)
- Definition of design lines
- Definition of monitoring program:
  - Alarm line
  - Intervention line
  - Danger line



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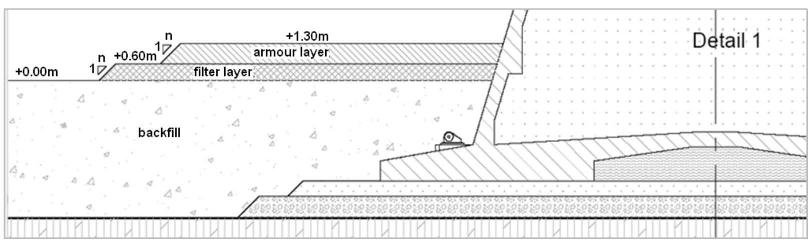
Hydrodynamics, seabed mobility, scouring & scour protection - **Scour protection**

Different solutions for scour protection : different types

- **Classic** multi-layer rock dump
- **Innovative** alternatives

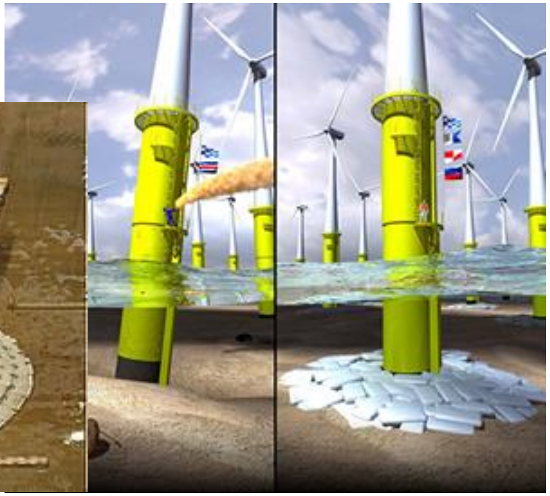
Classic rock dump



Alternatives

Geobags

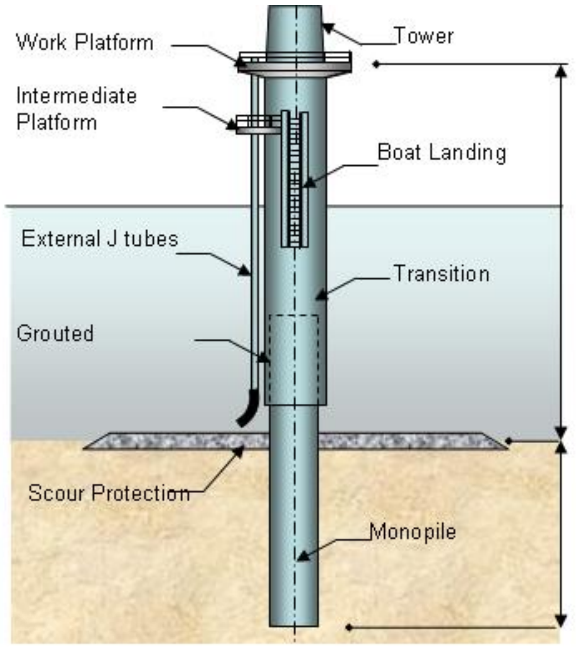
Geo-textiles

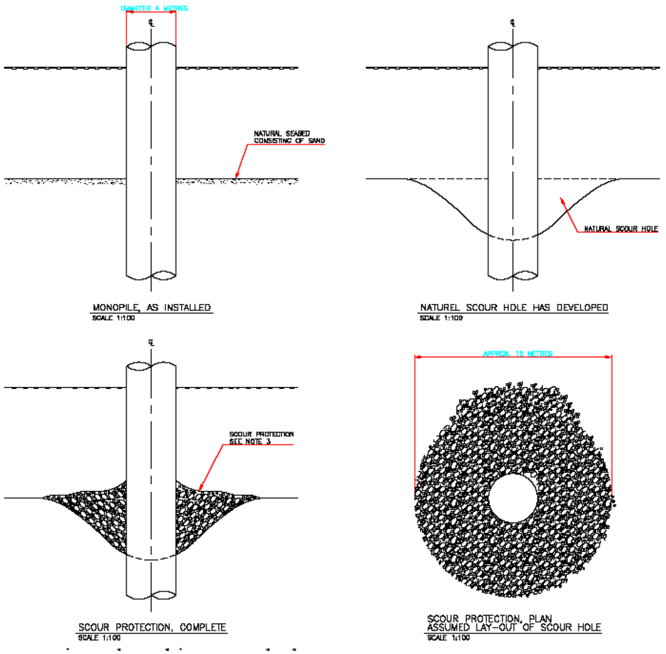


Hydrodynamics, seabed mobility, scouring & scour protection - **Scour protection**

Different solutions for scour protection : different design approaches

- Static scour protection (e.g. C-Power - GBF)
- Dynamic scour protection (Northwind – monopiles)
- Post installed scour protection/dynamic scour protection (Belwind – monopiles)

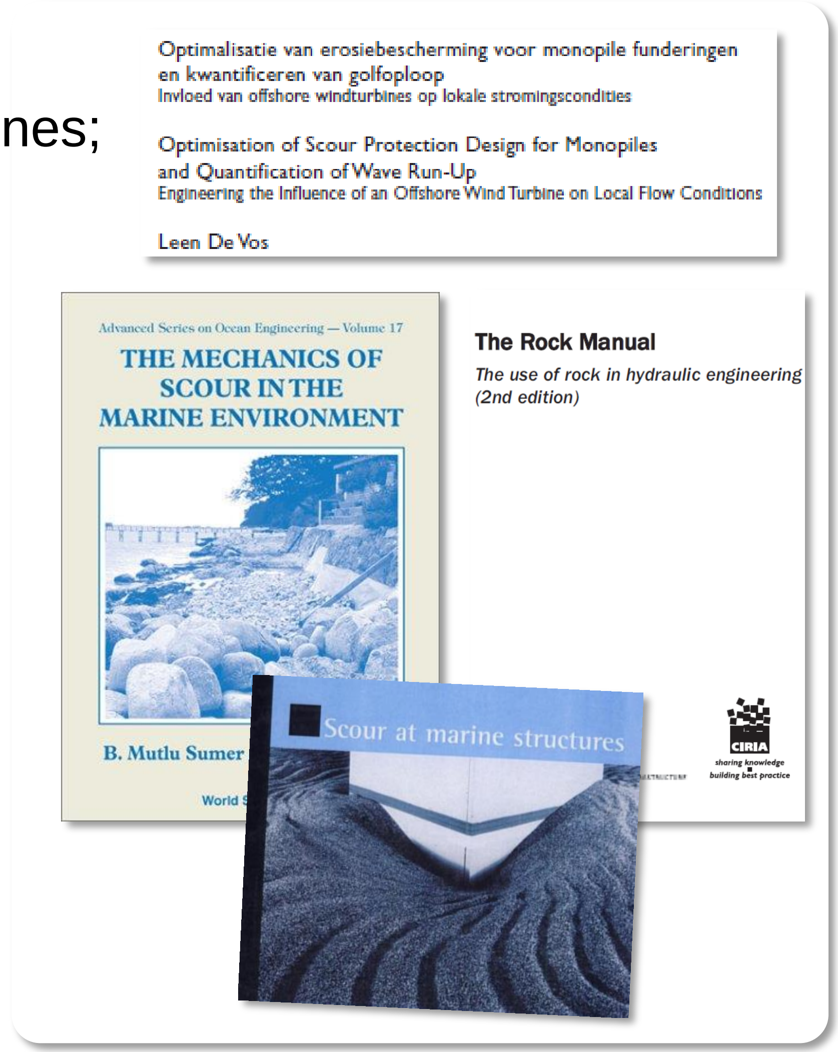




Hydrodynamics, seabed mobility, scouring & scour protection - **Scour protection**

Design of scour protection:

- No available standards nor guidelines;
- Engineering judgment based on:
  - Scientific research at universities
  - Physical model results
  - Standard reference works:
    - Sumur and Fredsoe
    - R. Whitehouse
    - PhD L. De Vos (Ugent)
    - Shields parameter (1936)
- Physical model test results & **in-situ measurements** are very important



Hydrodynamics, seabed mobility, scouring & scour protection - **Index**

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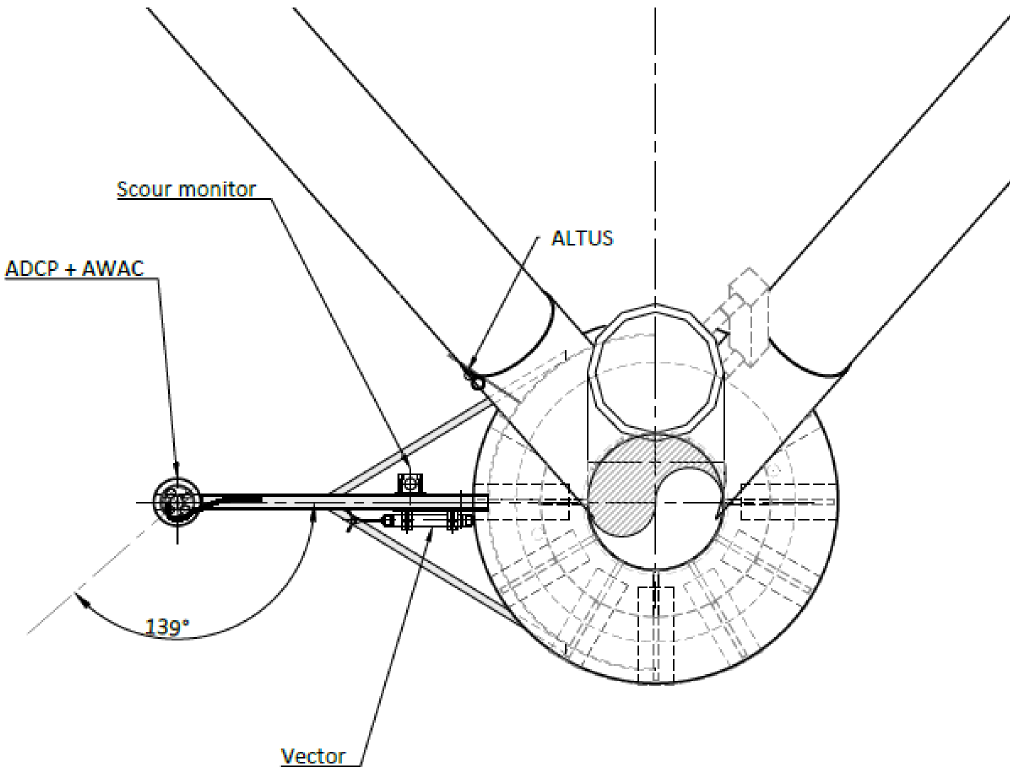
Hydrodynamics, seabed mobility, scouring & scour protection - **Design optimisations**

Design optimisation needed:

- Less conservative approach
- Shallower water
  => larger stones
  => other solutions
- For proven installation technique
  => design is to be optimised to allow use of these techniques
- Scour pit development to be measured and scour pit estimation to be improved



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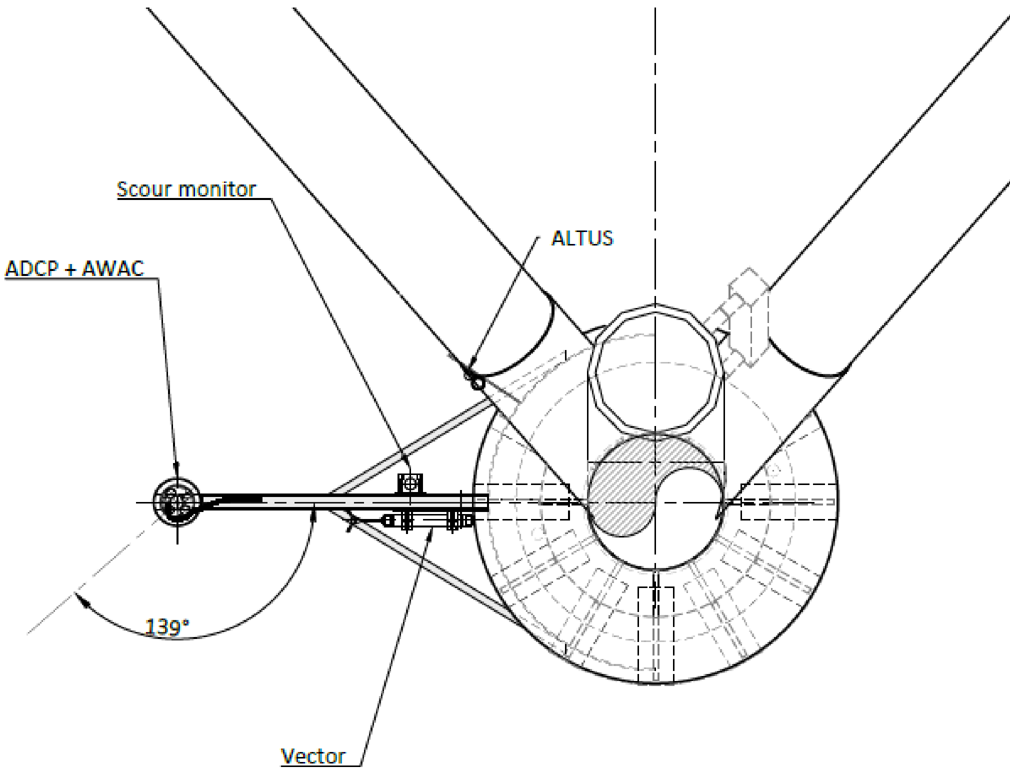
Hydrodynamics, seabed mobility, scouring & scour protection - **Design optimisations**

Initiatives

- Fundamental research MARINET FP7
- Scour development measurements at C-Power ongoing
- Monitoring dynamic behavior of the foundation



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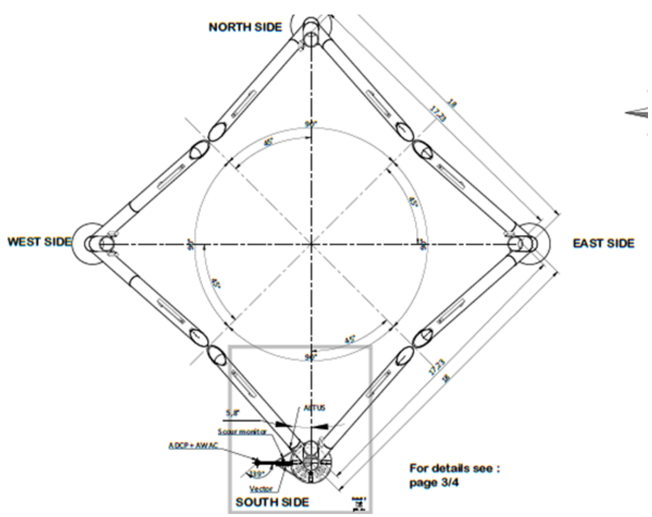
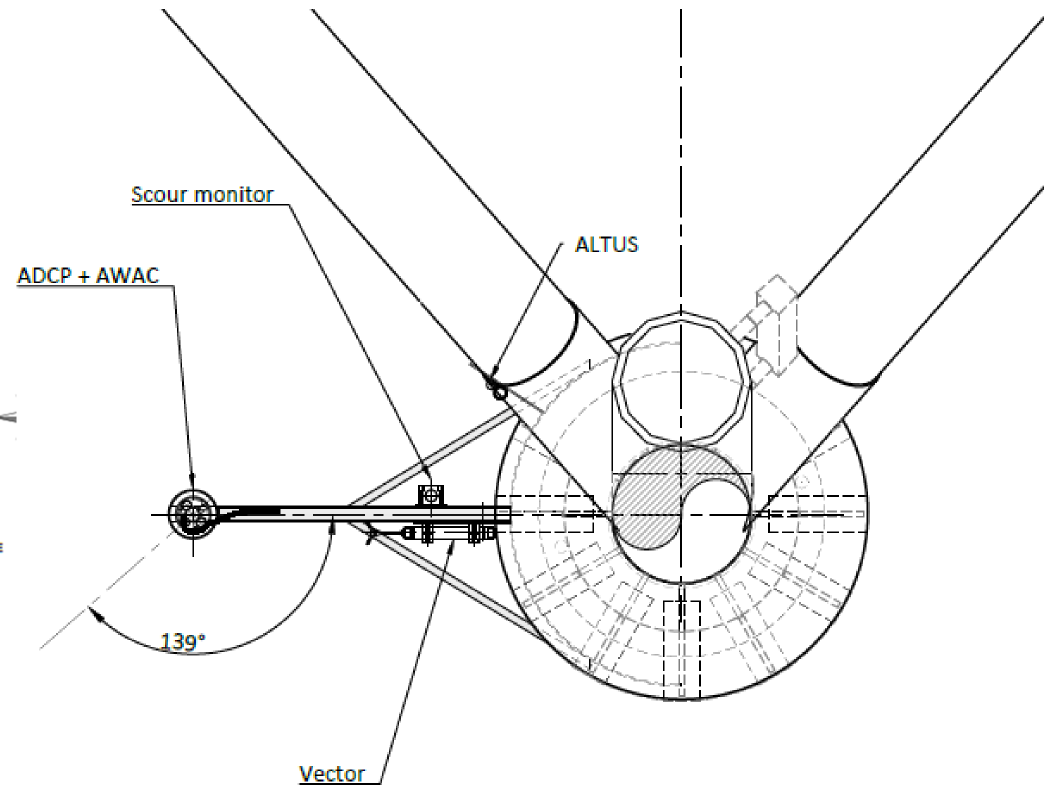
Hydrodynamics, seabed mobility, scouring & scour protection - **Design optimisations**

Measurement campaign: **5 different devices** are placed on a frame to monitor the scour development and the hydrodynamic parameters:

- **A scour monitor**
- **ADCP** (Acoustic Doppler Current Profiler)
- **AWAC** (Acoustic Wave and Current Profiler)
- **Altus**
- **Vector probe**





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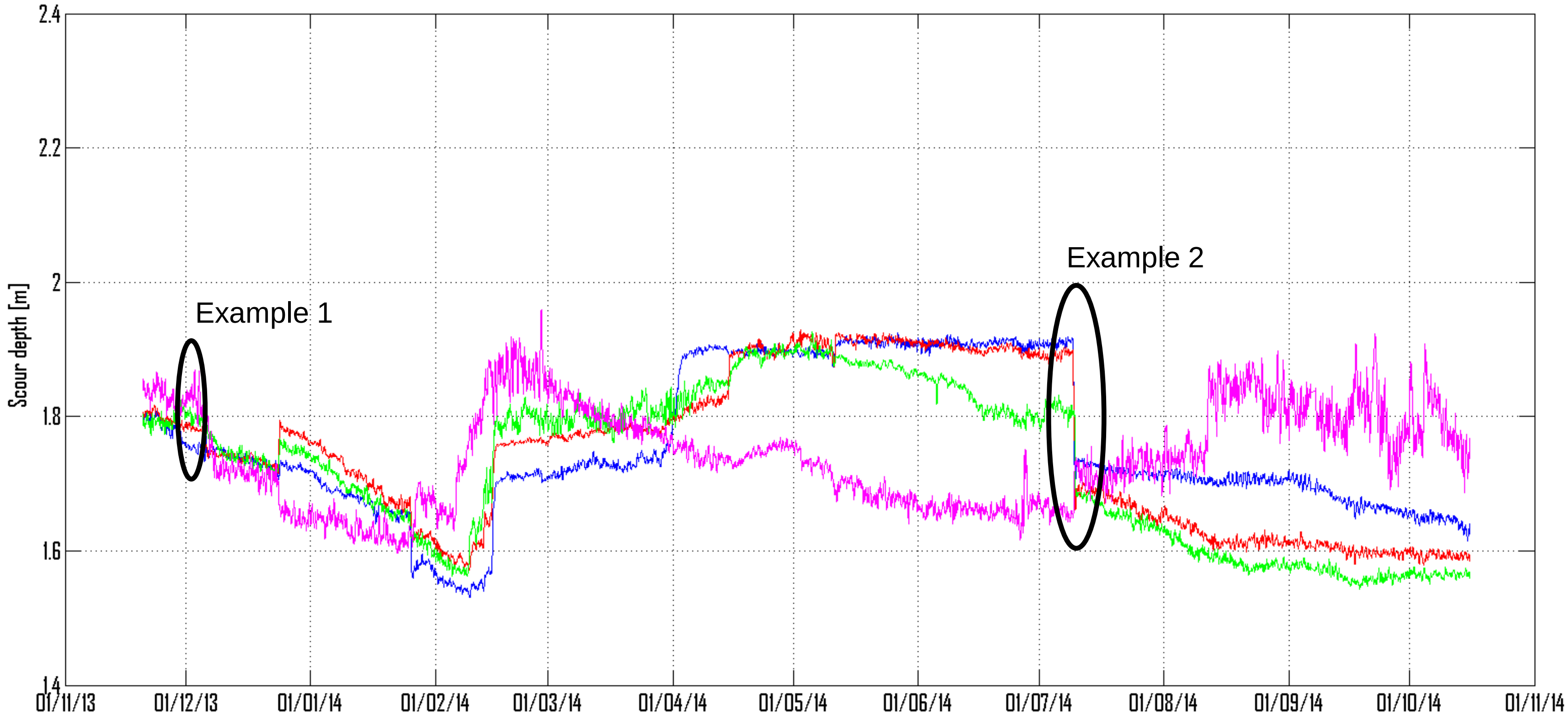
Hydrodynamics, seabed mobility, scouring & scour protection - **Real-time monitoring results**

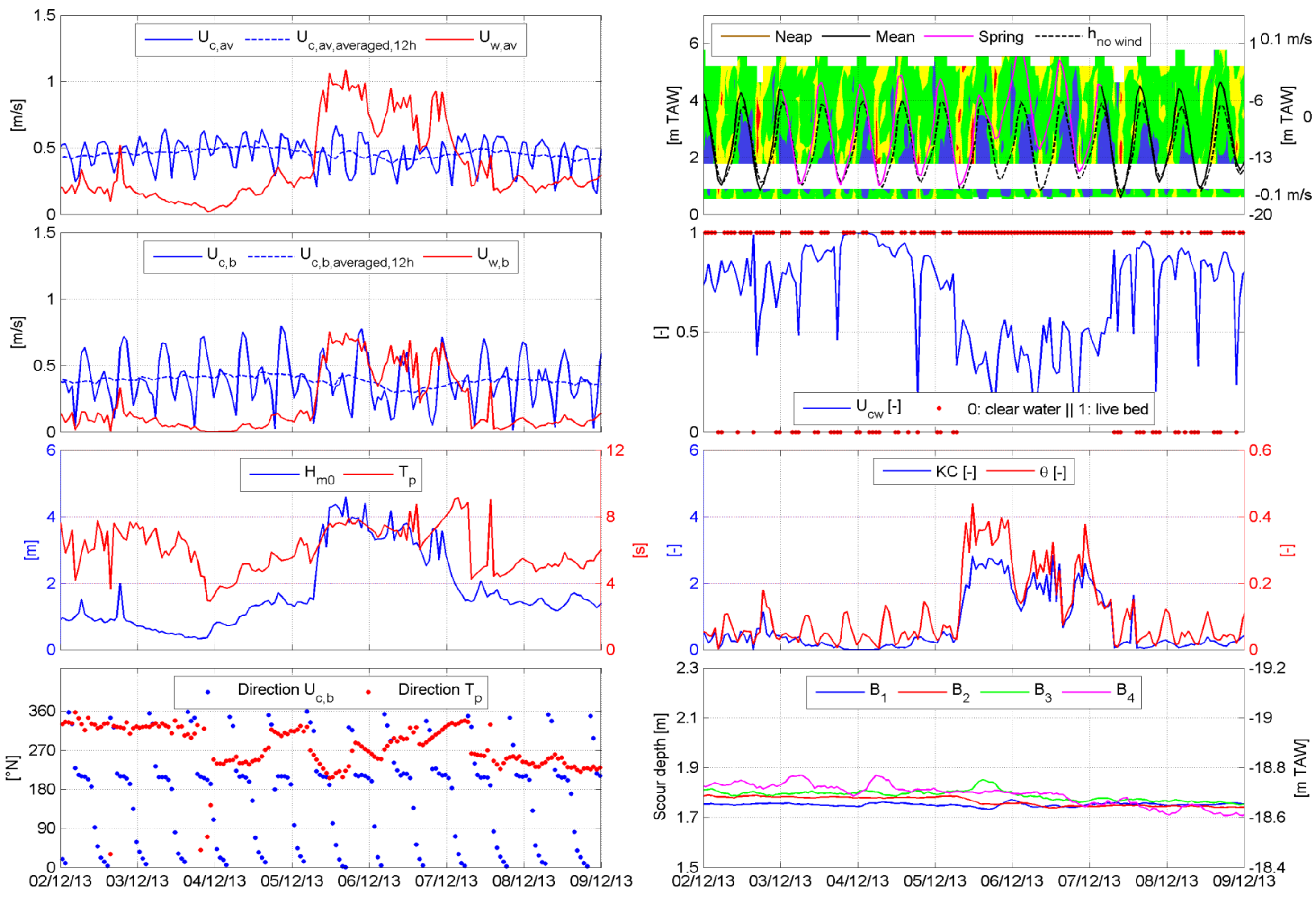
Scour depth measured by the **4 beams of the scour monitor** in function of time for the entire measurement campaign.



Red line = beam 1, green line = beam 2, blue line = beam 3, magenta line = beam 4.

Hydrodynamics, seabed mobility, scouring & scour protection - **Influence of storm conditions**

Example 1: storm Xaver 5 & 6 December 2013 (Sinterklaas storm)



H_{m0} > 4 m
Dir_w ~ 300° N

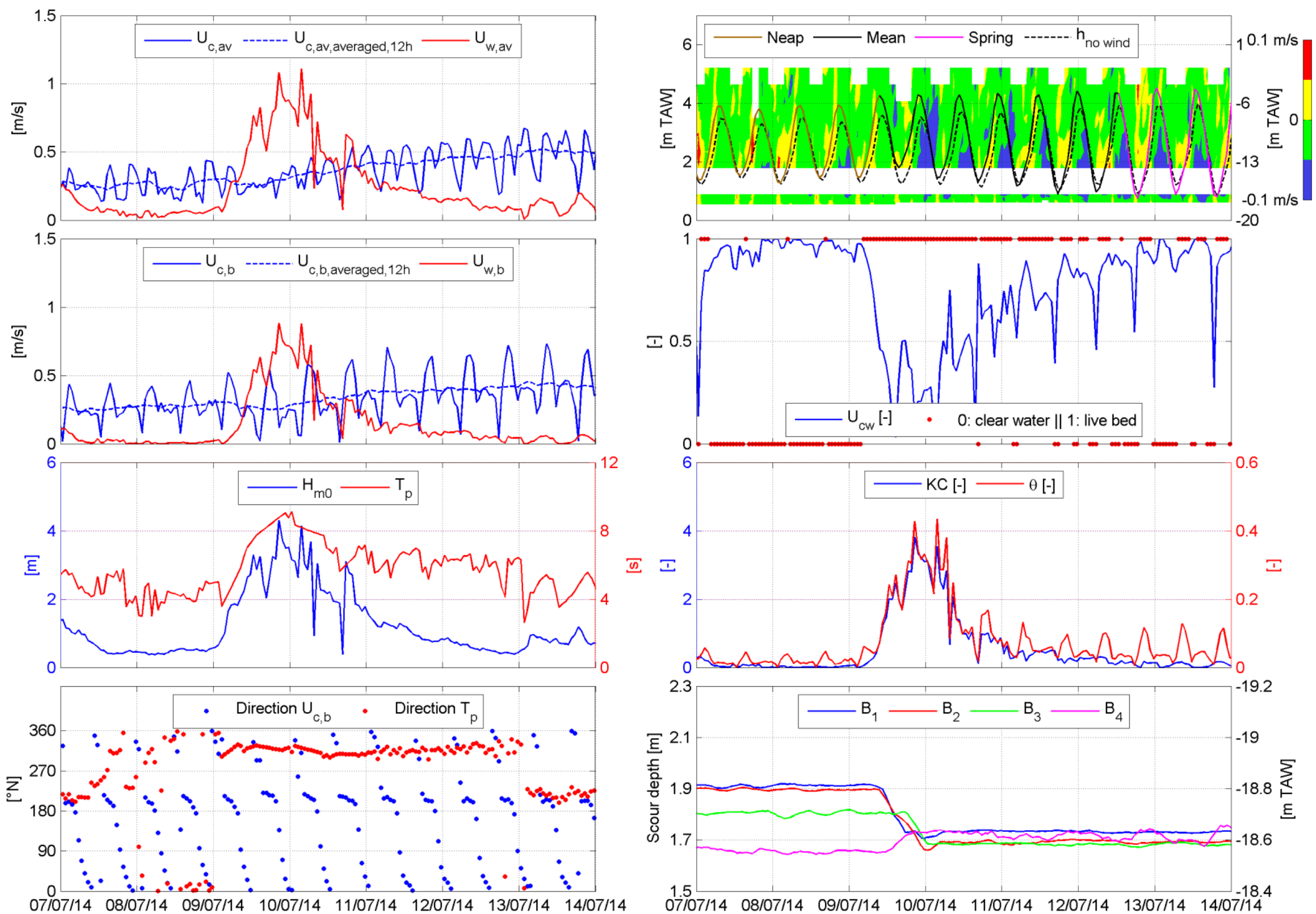
Spring tide
Large water level set up (~1.5 m)

U_{w_b} = 0.6 à 0.7 m/s
U_{c_b} = max 0.6 m/s

No large changes in scour depth were recorded. A small gradual accretion is measured.

Hydrodynamics, seabed mobility, scouring & scour protection - **Influence of storm conditions**

Example 2: Storm on 9 & 10 July 2014



H_{m0} > 4 m
Dir_w ~ 300° N

Mean tide
Slight water level set up (~0.5 m)

U_{w_b} = 0.8 à 0.9 m/s
U_{c_b} = max 0.6 m/s

Approx. 0.20 m of accretion was measured by beam 1 and 2. Beam 3 measured ~0.10 m of accretion. Beam 4 measured ~0.10 m erosion.

Hydrodynamics, seabed mobility, scouring & scour protection - **Influence of storm conditions**

- Calm hydrodynamic conditions tend not to lead to significant changes in the scour pit.
- Sudden changes in scour depth (both erosion and accretion) are recorded when the wave climate is agitated.
- Accretion is mostly measured during storms with a wave direction larger than 230°N. Erosion on the other hand was mostly measured during storms with a wave direction lower than 230°.
- Not one single parameter but **a combination of hydrodynamic parameters determines whether erosion/accretion occurs**.

IMDC EXPERTISE IN WATER

Hydrodynamics, seabed mobility, scouring & scour protection - **Index**

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Hydrodynamics, seabed mobility, scouring & scour protection - **Conclusions**

Seabed mobility is an important factor for design

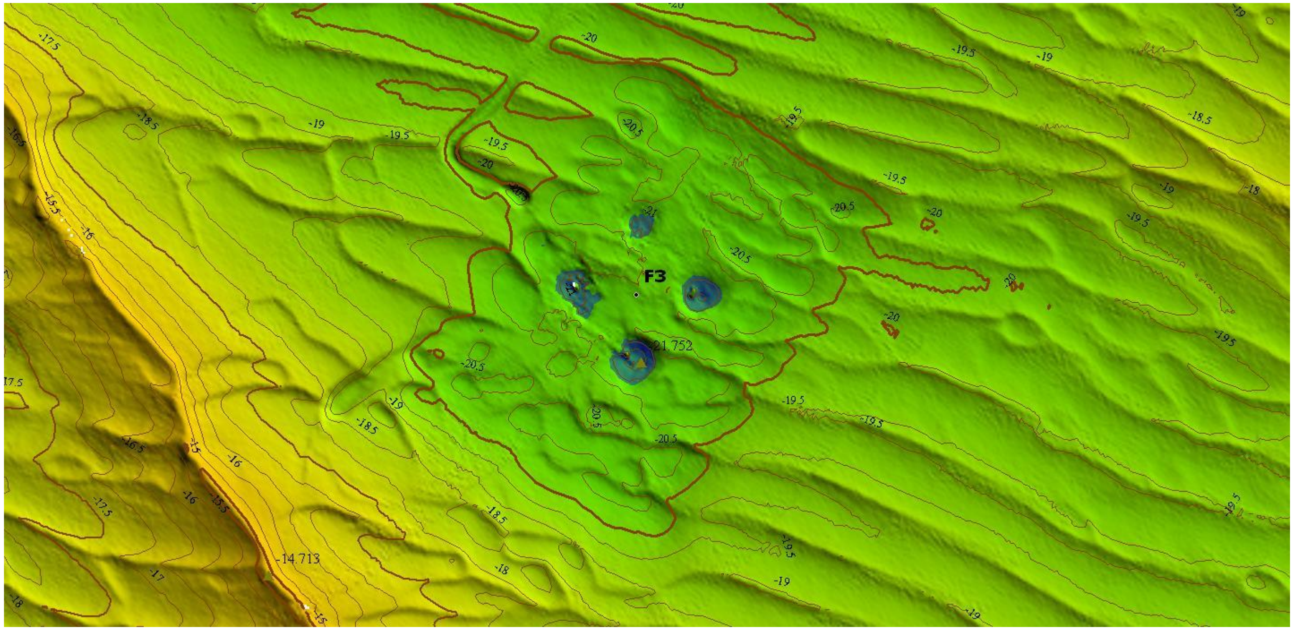
- Definition of DSBL is depending on natural seabed mobility, the presence of any structure & the application of scour protection;
- Without a defined scour protection system **and** monitoring program a good structural design is **not** possible;
- Multiple offshore seabed **measurement** are needed;
- Every project needs different approach;

Scouring and scour protection

- Phenomena is known, but lack of any standards or guideline to perform designs;
- Scour allowance versus scour protection needs to be investigated for each project
- Fundamental research needed
- In-situ **measurements** will provide better understanding of real life behavior

5th YP Com - Environmental monitoring

Thank you for your attention!



Contacts:

piet.haerens@imdc.be