Scour monitoring around offshore jackets and gravity based foundations

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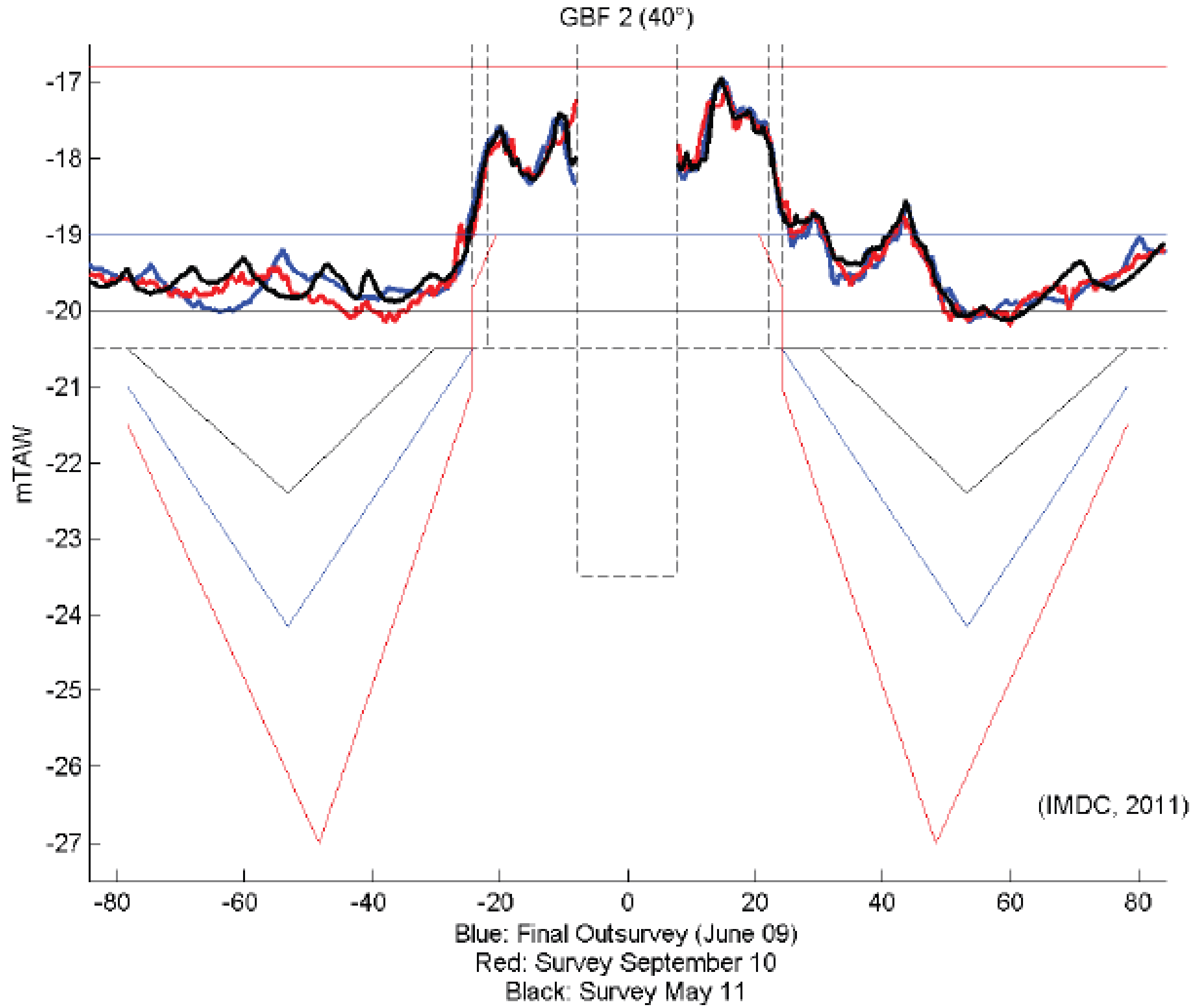
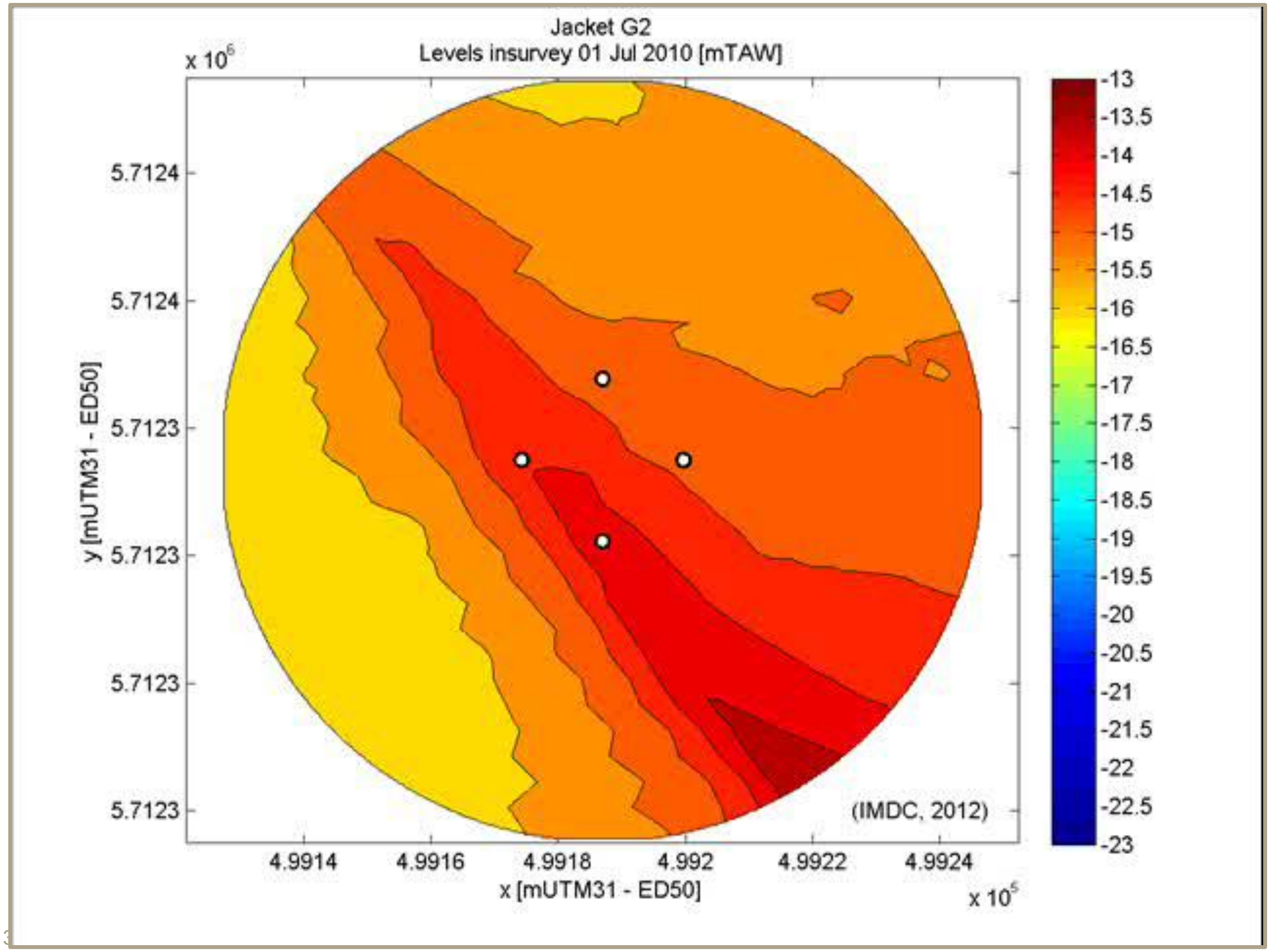
IMDC
International Marine & Dredging Consultants

Sometimes, long-term measurements can become a bit boring…



... but other times you can not wait to see the result!



Scour monitoring around offshore jackets and GBFs

- The C-Power wind farm
- Phase 1: the GBFs
  - Monitoring 2009 - 2012
- Phase 2: the jackets
  - The foundations
  - Installation
  - Predicted scour pits
  - Actual scour pits
- Conclusions

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The C-Power wind farm

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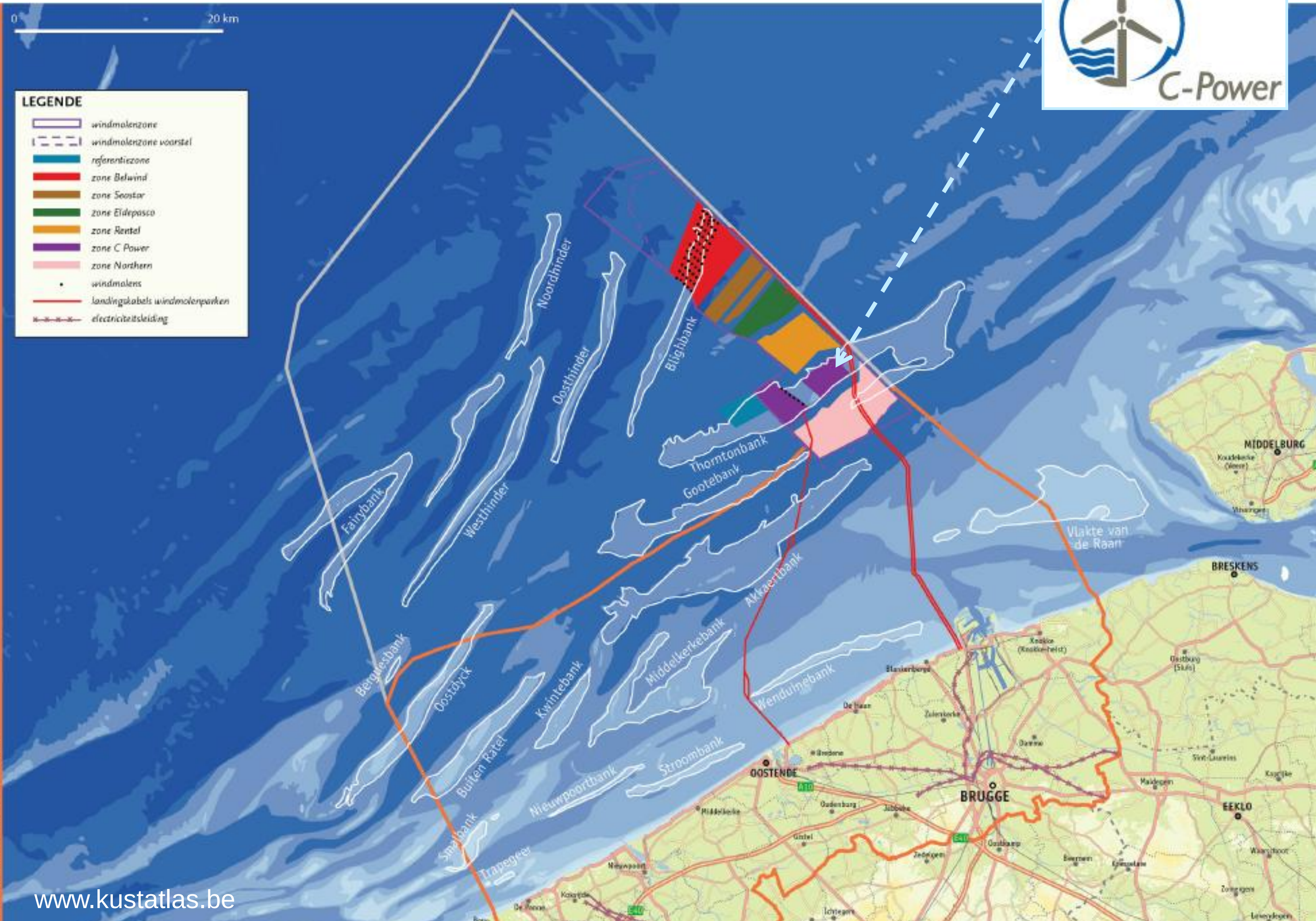
The C-Power wind farm



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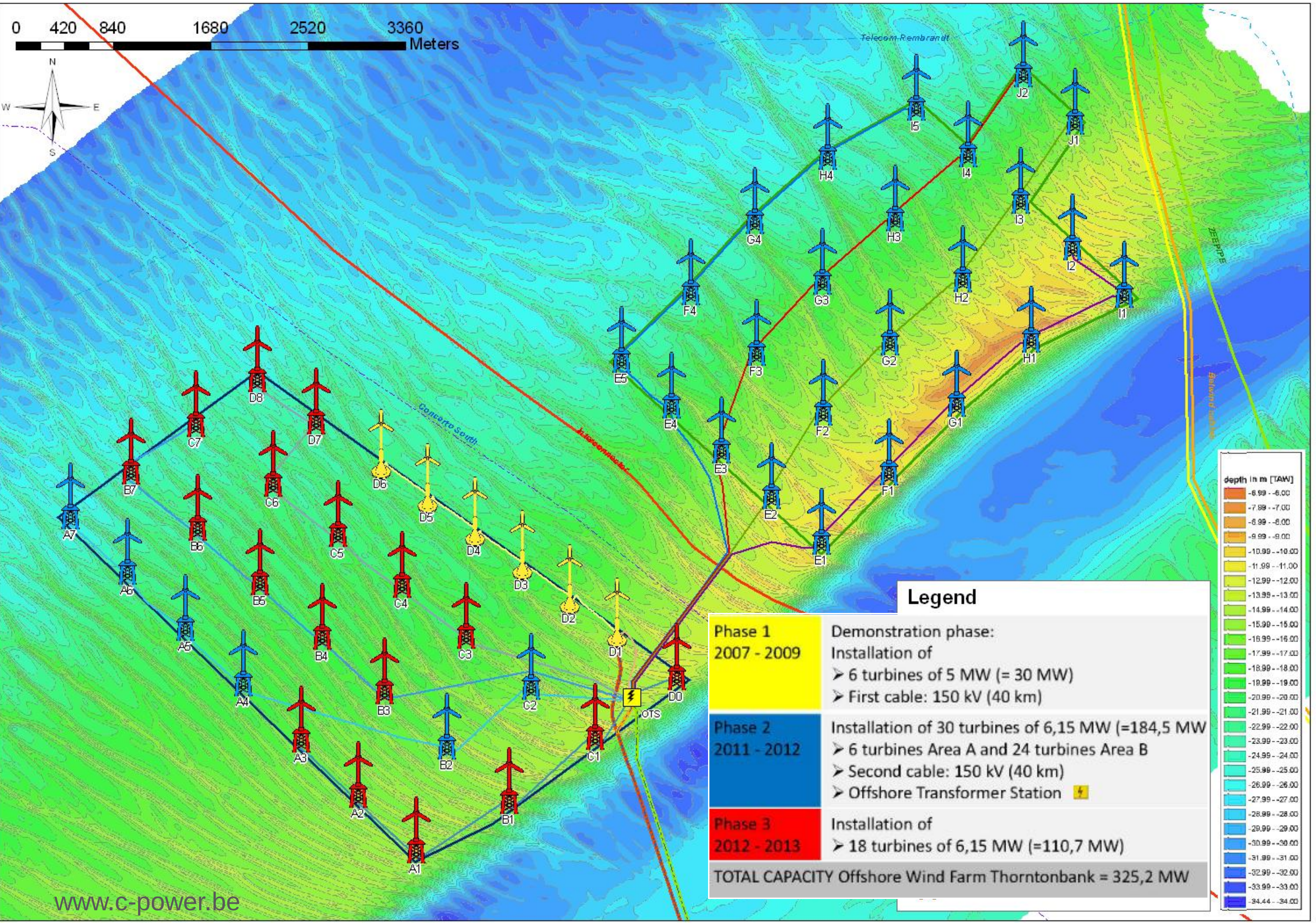
The C-Power wind farm



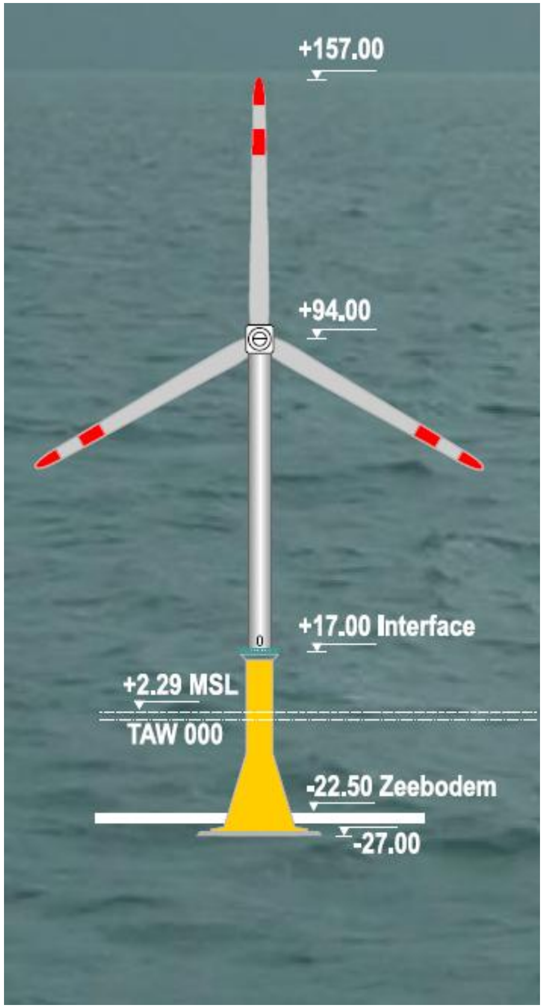
The C-Power wind farm

Involvement of IMDC

- Owners engineer
- Design basis + scour & scour protection
- Supervision of the works
- Monitoring program

G. Dewaele → C-Power
J. De Winter, W. Goossens → supervision
A. Bolle, P. Haerens → design issues

Phase 1: Gravity based foundations (GBFs)



The GBF is a concrete cylindrical/conical structure, held in place by its own gravity.

Static scour protection has been placed:

- details in Bolle et al. 2009 & 2010

Operation and Maintenance program:

- discussed previously in IMDC (2010) and Whitehouse et al. (2011)
- multi-beam surveys at least every 6 months
- comparison with monitoring lines: alarm, intervention and danger line

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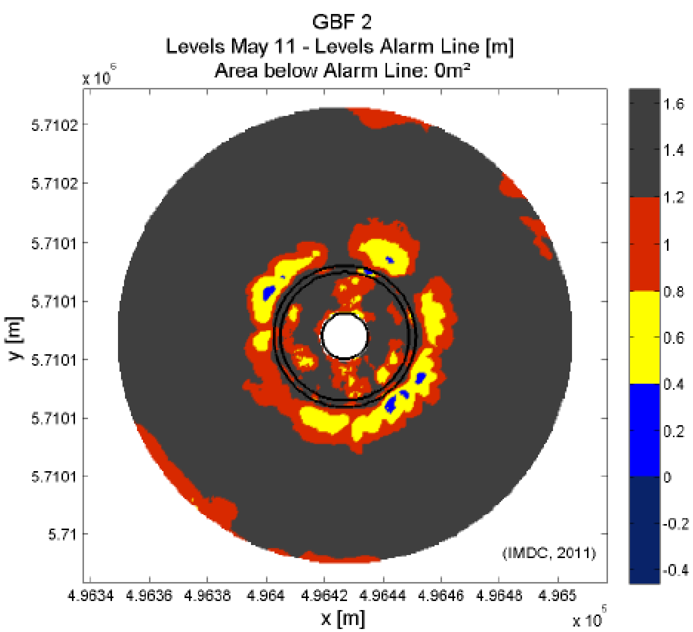
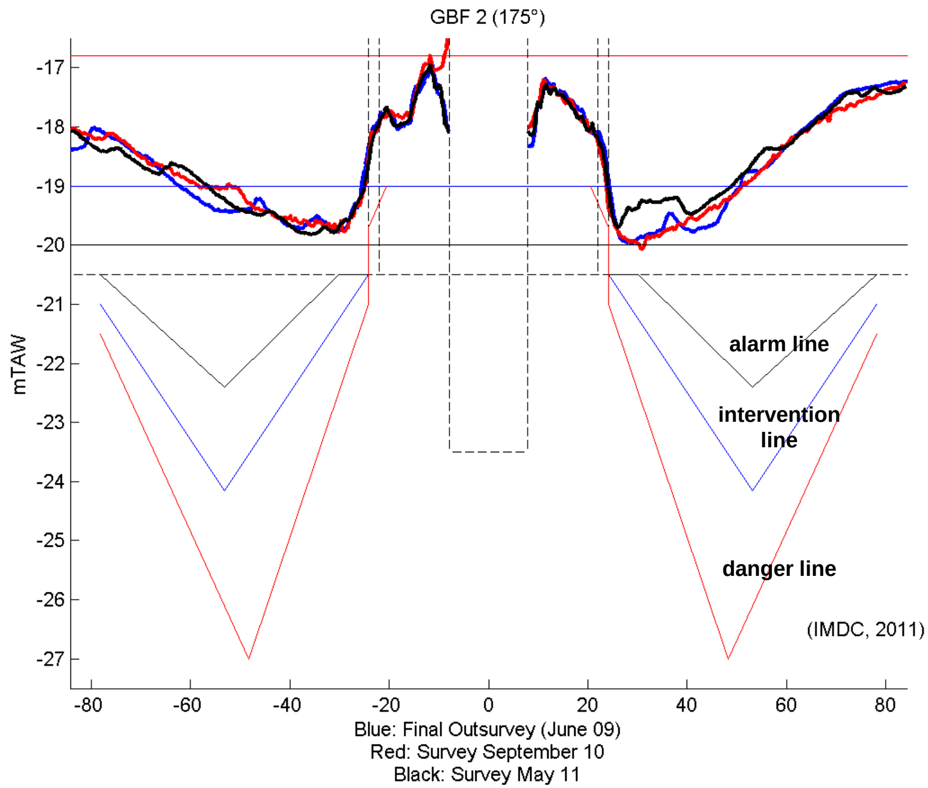
Phase 1: Gravity based foundations (GBFs)

Observations

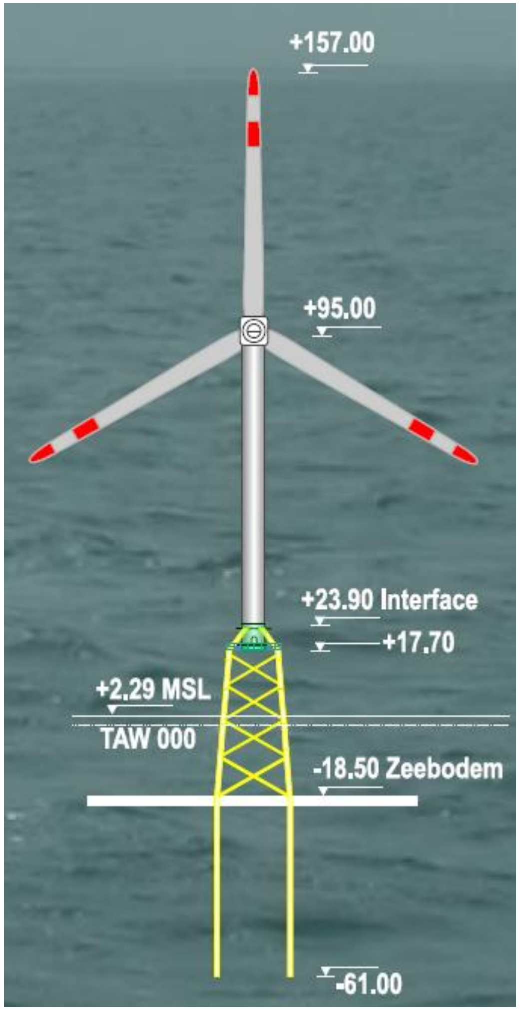
- Armour layer is stable
- No damage observed
- No significant edge scour
- No interventions needed
- Monitoring continues





Phase 2: Jacket foundations

1. The foundations



The jacket foundation is a steel structure with four legs connected to each other with braces.

The legs are grouted to pinpiles, which are driven into the sea soil.

The main advantages compared to GBFs:

- serial production: faster fabrication & better quality control
- easier logistics: less harbour space & marine preparation works needed
- only 2 types of installation vessels are required: pre-piling & jacket installation
- more cost-effective (steel price evolution!)
- easier decommissioning

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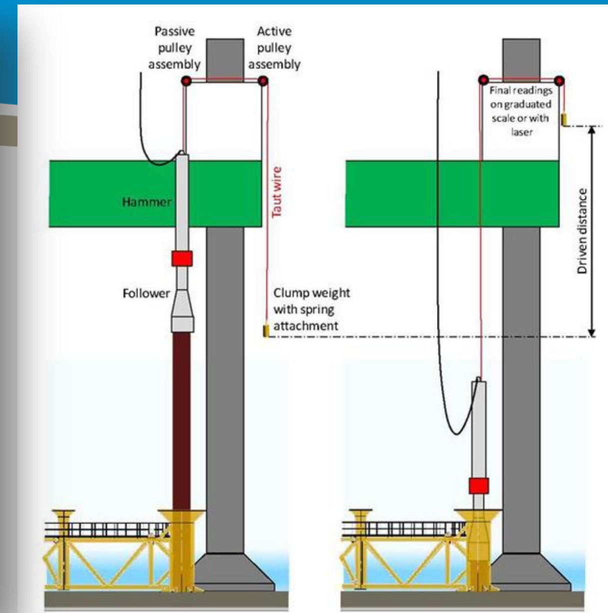
Phase 2: Jacket foundations

2. The installation



Phase 2: Jacket foundations

3. The predicted scour pits

global scour depth

- $S_G = 0.37 \times D_{calc}$
- based on a 2x2 pile group (Sumer and Fredsoe, 2002)
- D_{calc} = pile diameter incl. marine growth (DNV, 2007)

global scour extent

- radius $r_G = S_G / \tan \alpha$
- with α = equal to $\varphi/2$ and φ = the friction angle of the soil [°]

No global scour if the distance between the pile centres is more than $6 \times D_{calc}$ (Breusers, 1972 and Hirai and Kurata, 1982)

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Phase 2: Jacket foundations

3. The predicted scour pits

local scour depth S_L

- expected value $S_{L,e} = 1.3 \times D_{calc}$ (DNV, 2007)
- maximum value $S_{L,m} = 2 \times D_{calc}$ (Sumer et al., 2002)

local scour extent r_L

- expected radius $r_{L,D} = ½\, D_{calc} + S_{L,e} / \tan \alpha$
- maximum radius $r_{L,D} = ½\, D_{calc} + S_{L,m} / \tan \alpha$

with $\alpha_{downstr} = 0.5 * \alpha_{upstr}$

- applied all around the piles (Hoffmans and Verheij, 2007)
- inclined members and secondary structures increase the turbulence

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Phase 2: Jacket foundations

3. The predicted scour pits

total scour depth

- expected total scour depth $S_{T,e} = S_G + S_{L,e} = 2.6m$
- maximum total scour depth $S_{T,m} = S_G + S_{L,m} = 4.1m$

total scour extent

- expected radius $r_{T,e} = ½\ D_{calc} + S_{T,e} / \tan\alpha = 9.4m$
- maximum radius $r_{T,m} = ½\ D_{calc} + S_{T,m} / \tan\alpha = 13.9m$

→ In this case the total scour depth and extent equals the local values, since no global scour has been found.

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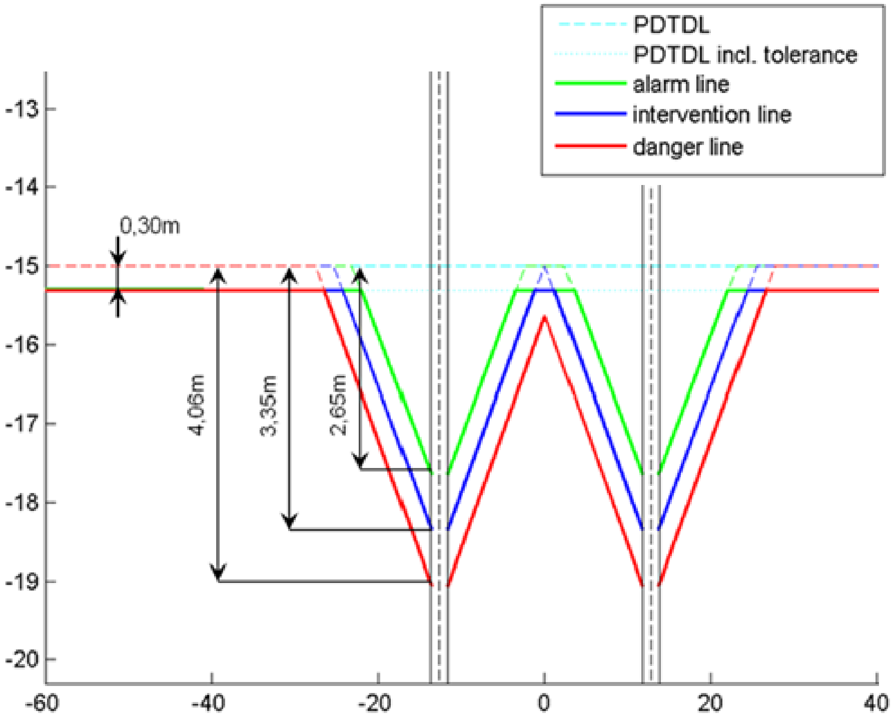
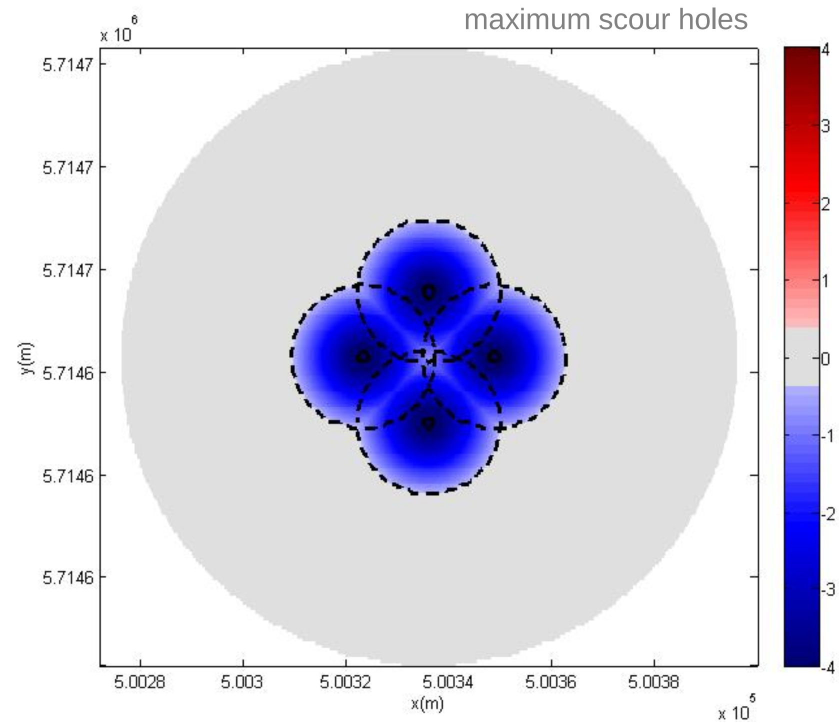
Phase 2: Jacket foundations

3. The predicted scour pits





RSBL = Reference Seabed Level or the lowest expected level over the lifetime, without structures
PDTDL = Pile Design Tolerance Dredging level or the lowest value of RSBL & dredged level
alarm = expected scour depth
danger = maximum scour depth

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Phase 2: Jacket foundations

4. The actual scour pits

Available measurements

- Multi-beam surveys: from 6 up to 16 datasets per jacket
  - before dredging: August 2010 – March 2011
  - after dredging: March – April 2011
  - after pre-piling: June – September 2011
  - during cable installation: October – December 2011
  - during the first winter: December 2011 – February 2012
  - spring and summer 2012
- Hydrodynamic data
  - from the Flemish banks monitoring network

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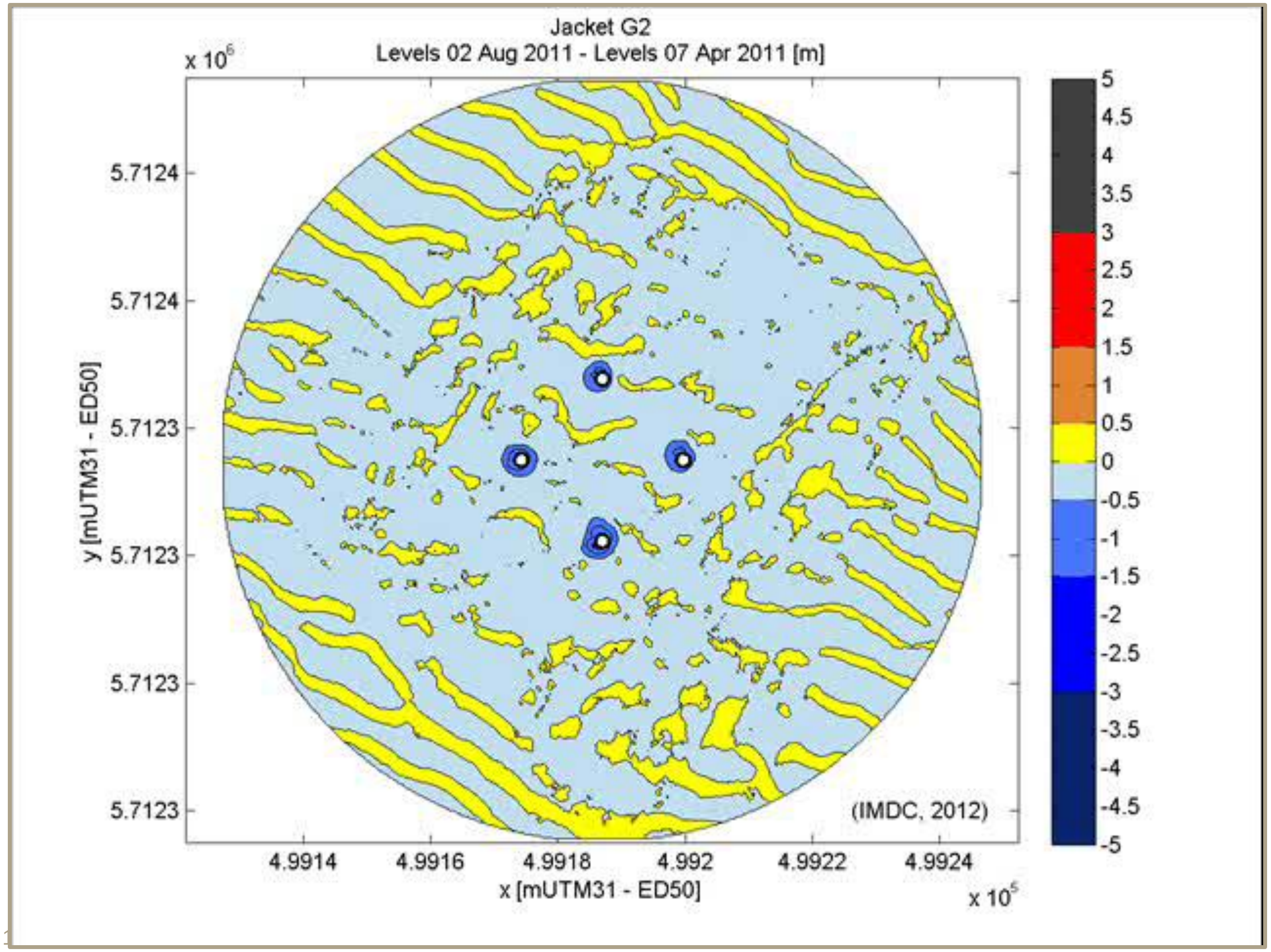
Phase 2: Jacket foundations

4. The actual scour pits

Evolution from dredging level



Phase 2: Jacket foundations

4. The actual scour pits

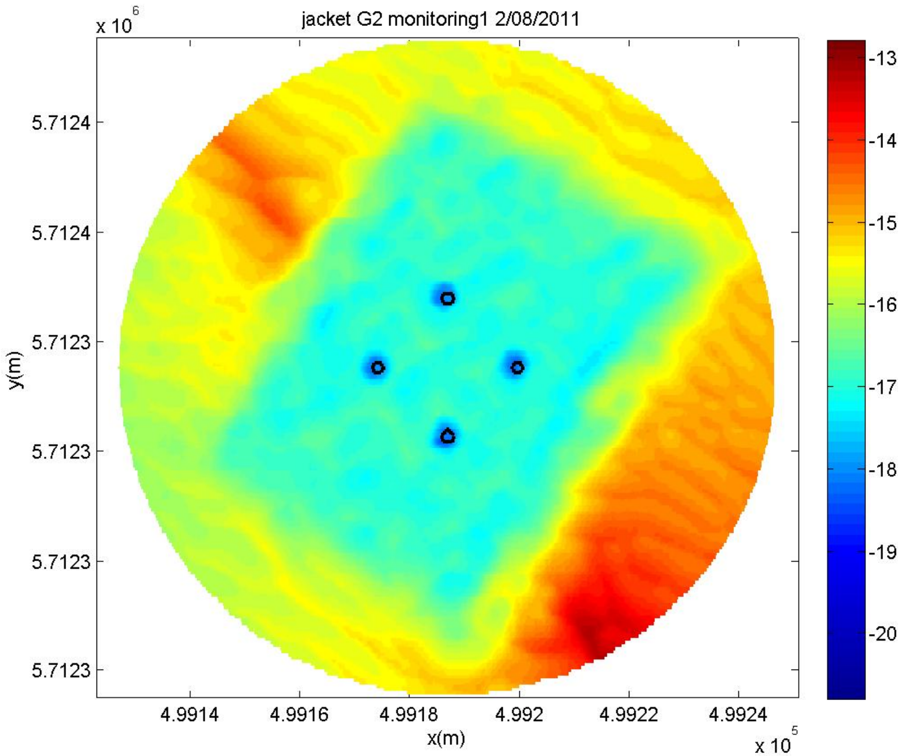
2.5 months after pre-piling, before jacket installation

distinct circular scour holes

- S_{av} = 1.3m (0.65D)
- S_{max} = 2.4m (1.2D)
- fully developed scour after 1 month
  (DNV, 2007; Sumer and Fredsoe, 2002)

4 piles only , pile-stick-up = 1.5m

- effect of the pile height
  (DHI & Snamprogretti,1992)
- S_{exp} = 0.9m (0.45D vs. 0.65D)
- S_{max} = 1.4m (0.7D vs. 1.2D)
- lower than the observed values!



Phase 2: Jacket foundations

4. The actual scour pits

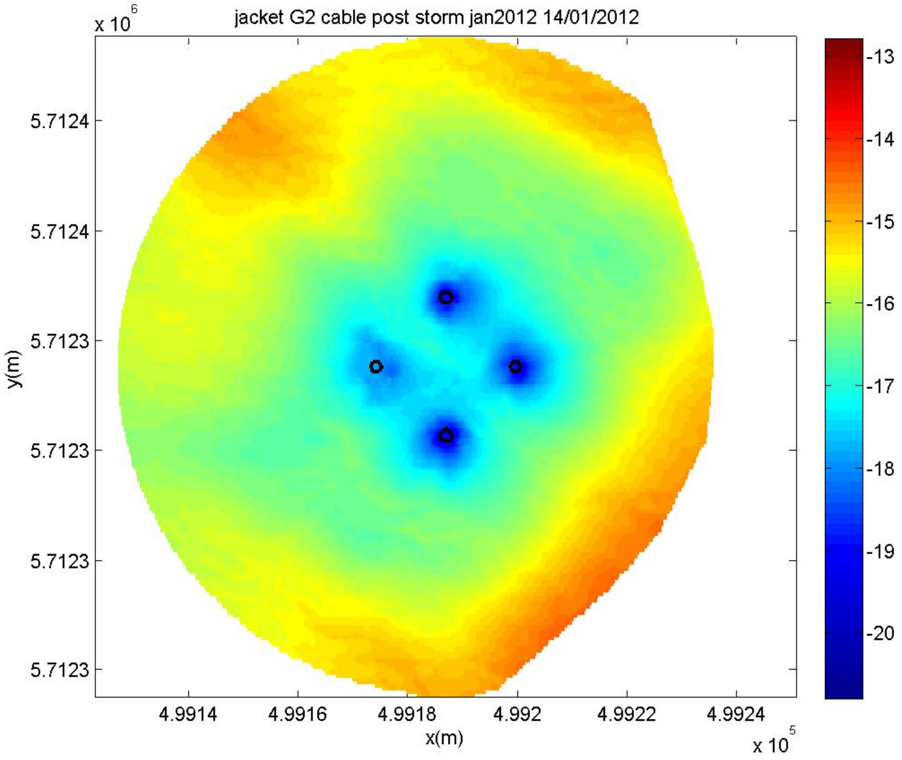
After jacket installation: October 2011 – February 2012

Observed scour:

- The depth increases instantly
  - S_{av} = 1.4 to 1.9m (0.7 – 0.95D)
  - $S_{max, av}$ = 1.7 to 2.7m (0.85 – 1.35D)
- The width increases during time

Predicted scour depths:

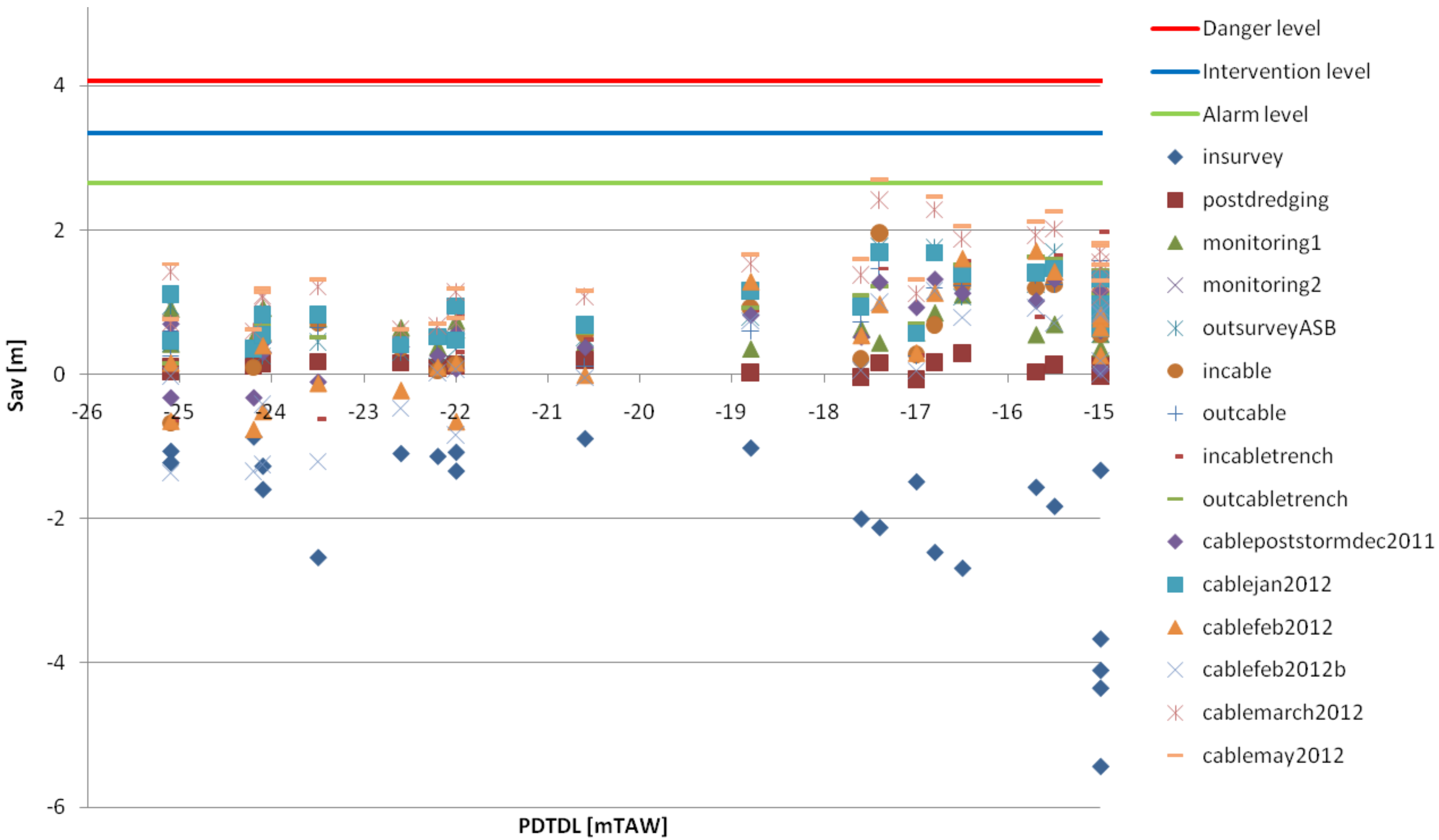
- S_{exp} = 2.6m
- S_{max} = 4.1m



Phase 2: Jacket foundations

4. The actual scour pits

Observed scour depths



Conclusions

GBFs: the monitoring went on the last years, and no damage of the scour protection was observed.

Jacket foundations: comparison theoretical & observed scour

- Design made for the maximum expected scour for a pile group
- The observed scour pits are close to the theoretically expected scour (or alarm level)
- Observed scour is somewhat deeper than the (average) values from literature

Monitoring continues.

Recommendations

- Be careful when applying formulas (also DNV guideline)
- Continue monitoring & compare with data from other sites
- Combine observations with hydrodynamic conditions to obtain a new formula

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