THAR BE DRAGONS

and how Goldilocks and the Quokkas can help fighting the fear

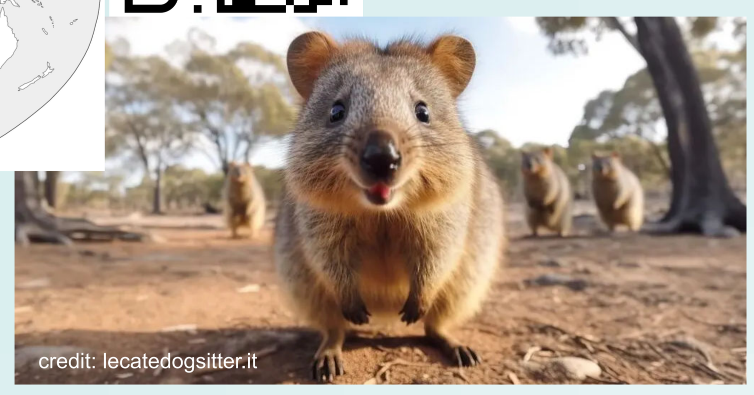
AURORA Offshore Engineering

Lessons from delivering engineering solutions to over 12 GW and 1,100 km of global offshore renewables cables that can benefit offshore wind and wave industry in both established and emerging markets.

Out of a global grid-connected total of around 63 GW of offshore wind projects, Aurora Offshore Engineering AOE have been very fortunate to have had the chance to assist in solving really difficult design and integrity problems for the subsea cables market covering installation of over 1,100 km and 12 GW of projects across the globe. Each of these projects has required ingenuity and creativity to solve problems that in most cases should have been avoided at the concept / FEED stage. Globally, cables cost the offshore renewables industry about 9% of CAPEX but represent over 80% of insurance claims. As more offshore renewables projects are executed, the goal of this presentation is to share global lessons learnt to help the renewables industry avoid the dragons lurking undersea for the unwise and unwary.

Offshore cables industry requires different / novel approaches that differentiate

- Cables on erodible seabeds
- Cables on hard rocky seabeds
- Design of secondary stabilisation methods: e.g. rock bags
- Prediction of marine growth settlement and hydrodynamic properties
- Metocean reanalysis and the importance of cable specific design criteria
- HVDC hydrodynamics
- Survey and AGAIN the importance of cable specific design criteria
- Goldilocks and the impossibility of conservative assumptions



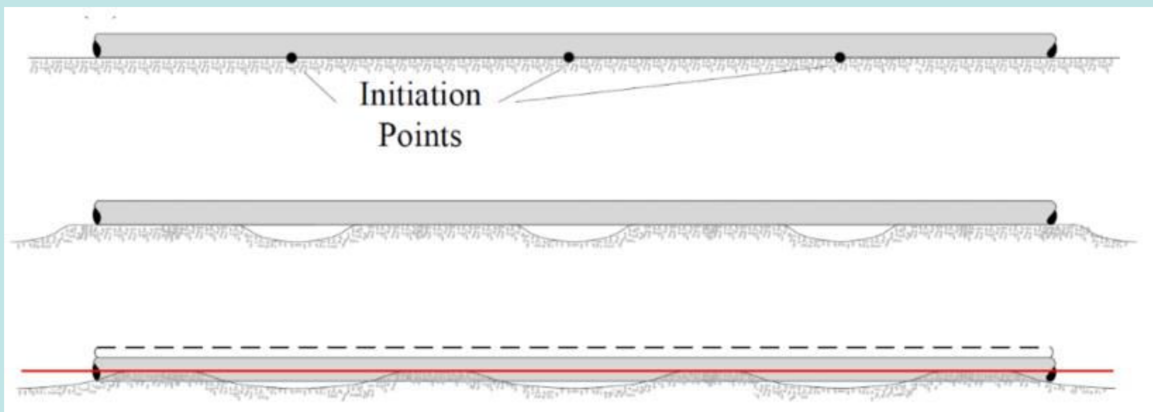
The quokka is a small macropod about the size of a domestic cat. It is the only member of the genus Setonix. Like other marsupials in the macropod family (such as kangaroos and wallabies), the quokka is herbivorous and mainly nocturnal.
The quokka's range is a small area of southwestern Australia. They inhabit some smaller islands off the coast of Western Australia, particularly Rottnest Island just off Perth.
They look a lot like "Rodents of unusual size" hence the Dutch name for "Rats Nest" = Rottnest Island

The cable is not laying on a smooth surface

Cables can be laid on erodible seabeds or on rocky seabeds, either or the surfaces are far from being smooth, uniform and constant in time.
Cables interact with the seabed in manners which are incredibly more complex than the Coulomb friction model with a constant coefficient... 0.6?

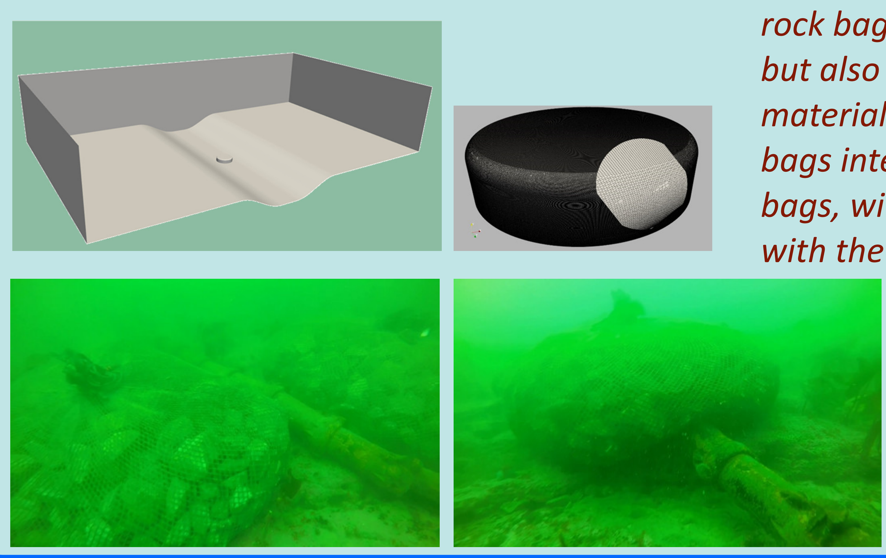
The seabed is not stable

This means that the cable embedment due to scour initiation, propagation and cable lowering evolves in complex manners on erodible or liquefiable seabeds subjected to hydrodynamic loads.
The evolution of cable embedment begins as soon as the cable is laid.



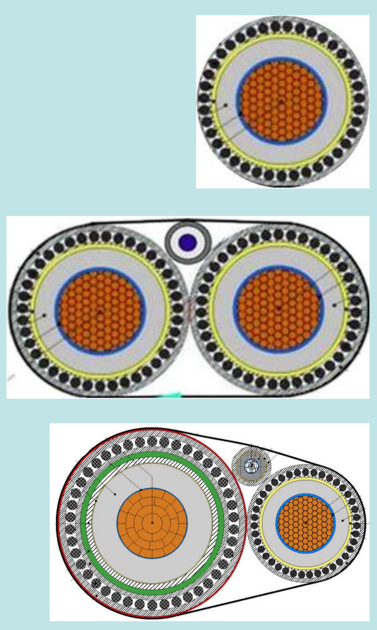
Rock bags are not solid objects hockey puck shaped on a smooth surface

Under hydrodynamic loads rock bags do not just slide but also roll, the filling material is rearranged, bags interact with other bags, with the cable and with the seabed



Some cables are not circular cylindrical objects

As the offshore renewables industry evolve and countries increase their inter-connectivity so do the requirements for power transmission. High Voltage Direct Current (HVDC) submarine cables are becoming more complex and it is often required to lay cable bundles. The hydrodynamic properties of a cable bundle in complex flow conditions: waves, currents, tides and vessel motions are different from a circular cylinder. This impacts both the installation loads and their behaviour on the seabed.

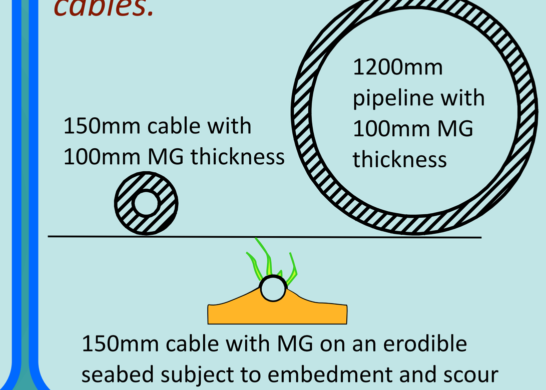


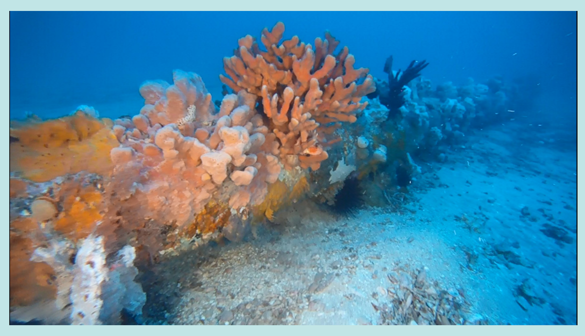
Cable protection systems (CPS) can roll

Field experience and surveys have shown instances in which CPS system roll back and forth. This impacts the loads and fatigue on the cable, total displacement and the type of abrasion of the protection system. Field experience and surveys have shown instances in which CPS system roll back and forth.

Marine growth is not a uniform 100mm thickness of rigid impermeable material

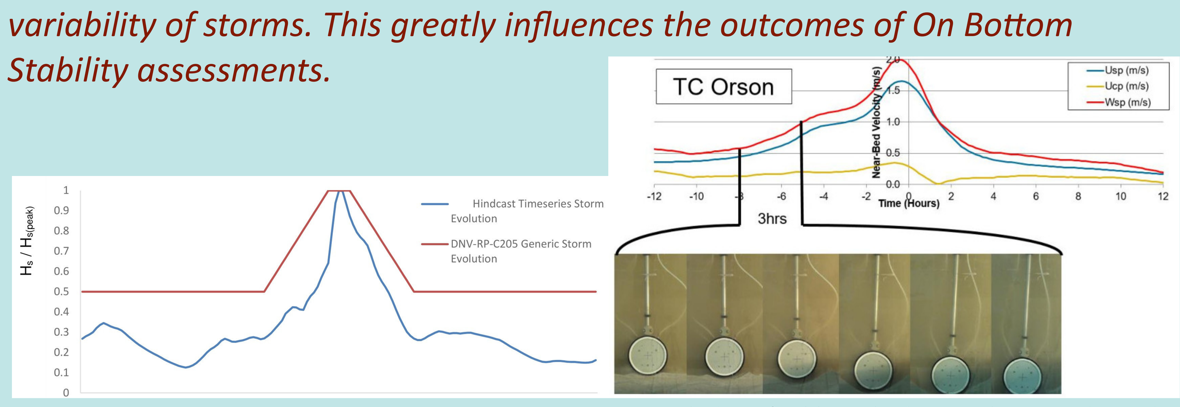
Marine life does not grow uniformly around the perimeter of the cable, nor is made of a homogeneous and impermeable material. Most marine growth is not vegetable but animals which choose where to settle.
Better understanding leads to better assessment of the hydrodynamic loads on cables.





Not all storm evolutions or ambient conditions are the same

The evolution of storms from their inception and through their peaks are site specific and very different from proposed standardised profiles. Cable embedment on erodible seabeds is influenced by temporal and spatial variability of storms. This greatly influences the outcomes of On Bottom Stability assessments.

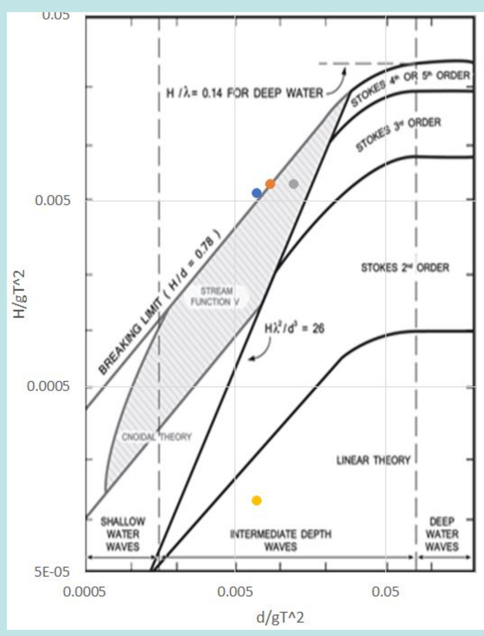


evolution of cable embedment whose maximum is reached well before the peak of the storm

Waves can break and that affects the near bed on-bottom velocity

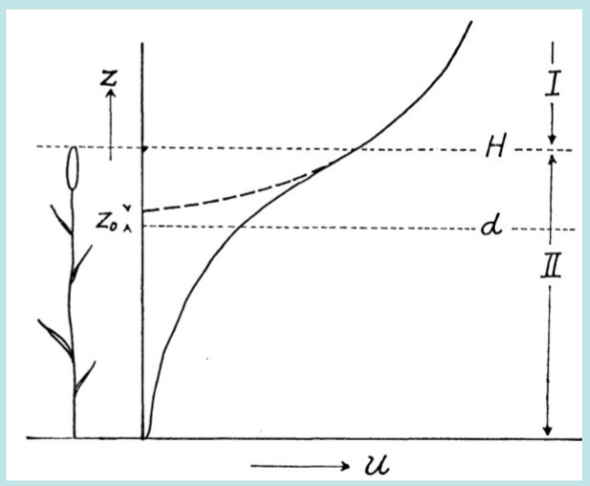
Offshore wind farms are installed in relatively shallow water locations where higher waves break. Wave breaking affects the near bed flow velocity and the stability of the cable. In case of breaking waves higher order methods are required to calculate the on-bottom flow velocity accurately.

Wave breaking affects the near bed flow velocity and the stability of the cable.



The cable is not in a uniform flow but subject to boundary layer flow

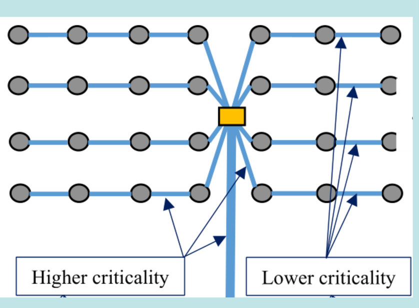
A cable is smaller than a pipeline. This means it is located deeper into the wave and current induced near-bed flow boundary layer, where flow and loading is reduced, and it has a size that is comparable to the undulations of a rocky seabed. It has been shown these affect both the load and resistance to movement and the outcome of the as-laid stability on erodible seabeds as well as the stability on rocky seabeds.



Takeda 1996: boundary layer schematics

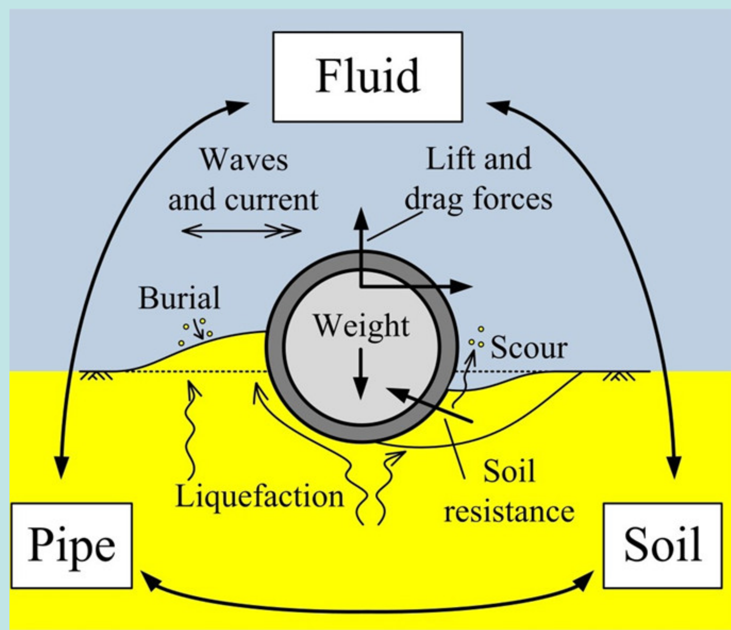
The consequences of an electrical cable failure are not the same as of an hydrocarbon pipeline failure

Offshore renewables industry has drawn substantially on prior design guidance and recommended practices from O&G. Including extension of existing DNV-RP-F109 for OBS of subsea power cables. The focus of O&G design is to avoid loss of containment catastrophic events. In contrast, the mechanical failure of subsea power cables in an offshore wind farm represents a purely economic consequence. The inherited factors of safety are therefore entirely inappropriate. A more relevant approach to quantitatively consider the lifetime product is to quantitatively consider the lifetime design risk through an assessment of the relative net present value (NPV) of different options.



Due to the tri-partite interaction between the soil, the cable and the flow
Goldilocks cannot make any a priori conservative assumption on the stability of the cable

Instead all possible combinations of soil types, cable initial embedment, combinations of wave and current induced velocities, storm time evolution, ambient environmental events including tidal phases, etc. have to be tested in order to assess their influence on the cable on bottom stability.
Some cables are stable as they are laid, some others require time at ambient (non storm) conditions before becoming stable, others may (or may not) become stable during a storm... which return period storm? It needs to be tested!



The pipe-soil-fluid interaction triangle

Small essential bibliography.
Get in touch with the Team at aurora-oe.com We will be happy to provide full bibliography references of all the subjects of this poster

T. Griffiths et al., "Pipeline and Cable Stability: Updated State of the Art," OMAE2018-77736.
J. Jorgensen et al., "Application of Stablepipe Method C Assessment to Determine On-Bottom Stability of a Cable Crossing in north Sea Mobile Seabed Conditions" OMAE2023-102329
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BSI (in press) "Marine energy — On bottom stability of cables on rocky seabeds — Guideline" BS 10009.

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scan for references