Ecosystem-based design rules for marine sand extraction sites

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Background

The demand for marine sand in the Netherlands and globally is still rising. The Dutch authorities promote sand extraction depths over 2 m for sand extraction projects over 10 million m^3 of sand, to decrease the surface area of impact. The ecological effects of deep sand extraction, however, are still largely unknown.

Objective

- Develop generic ecosystem-based design (EBD) rules for borrow pits

Methods

We studied 3 Dutch sand extraction case studies, 1: common shallow sand extraction (2 m), an 8-m deepened Euromaasgeul turn channel and 3: the 20 m deep Maasvlakte 2 borrow pit (short-term effects) (**Fig. 1**). We collated data on: animals living in and on the sediment (in- and epifauna), demersal fish and sediment and hydrodynamic characteristics

For intercomparison between case studies, we used tide-averaged bed shear stress (τ) as a generic proxy for environmental changes and related ecological effects. τ is the amount of force exerted by water on the seabed and plays a role in sand transport, the formation of bedforms, and sedimentation or erosion of the seabed and can be influenced by extraction depth which influences depth-averaged flow velocity magnitude (U). τ can be estimated using a two-dimensional quadratic friction law.

$$\tau = \frac{\rho_{seawater} * \ g * |U|^2}{C^2}$$

(Chézy factor (C): 65: reference and 2 m, 80: 8 - 20 m and 110 m½/s)

Results

Ecological response to different extraction depths can be summarized as:

Extraction depth	Infauna [2]	Epifauna [2]	Demersal fish [3]	Sediment [2]	Shear stress (T, N m^{-2})
Reference	11.7 g AFDW m^{-2}	2.6 g WW m^{-2}	20.9 kg/ha	290 µm, low mud and SOM	0.5
2	No	-	-	Mud: 0.5%< SOM [3]	0.41
8	*, biomass 2x [2]	*, biomass 6 x	-	Grain size: factor 2 decrease and mud 23,1% [2]	0.17
20	*,4x	*,12x	*, 20x	Grain size: factor 2 decrease and mud 22,3%	0.08
24	*,7x	*, 67x	ns, 1.5x	Smaller grain size and mud 13,8%	0.04

*: significant different species composition, ns: not significant, -: not measured, x: factor increase of biomass, SOM: sediment organic matter

Tide-averaged bed shear stress decreased asymptotically from 0.50 to 0.04 N m^{-2} in borrow pits in 20 m deep water with a depth-averaged flow velocity magnitude (U) of 0.65 and extraction depths up to 24 m (**Fig. 2**).

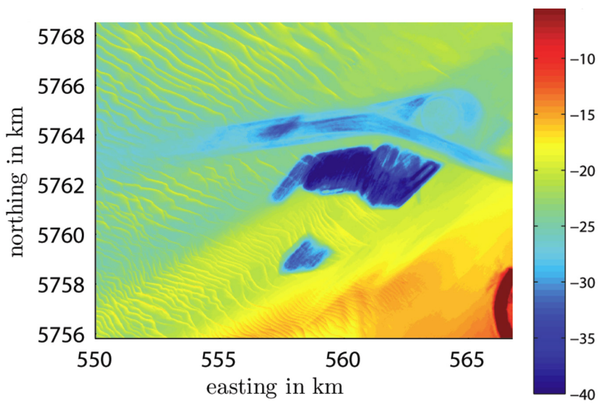

Fig. 1: MV2 borrow pit with Euromaasgeul

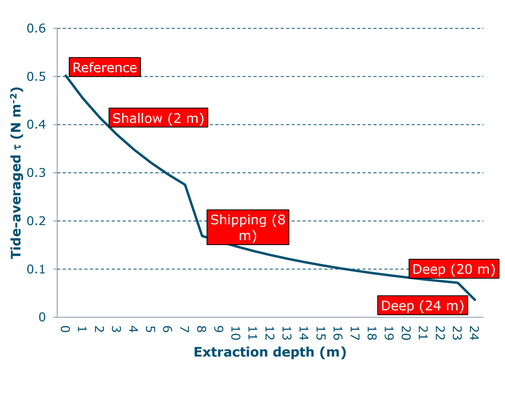

Fig. 2: Bed shear stress and extraction depth at a flow velocity of 0.65 m s^{-1}

Generic EBD rules

We calculated extraction depths needed to reach τ values of the case studies and related ecological effects for areas with other flow velocities (0.7, 0.75 and 0.8 m s^{-1}) and initial water depths (15, 25, 30, 35 and 40 m) (**Fig. 3**).

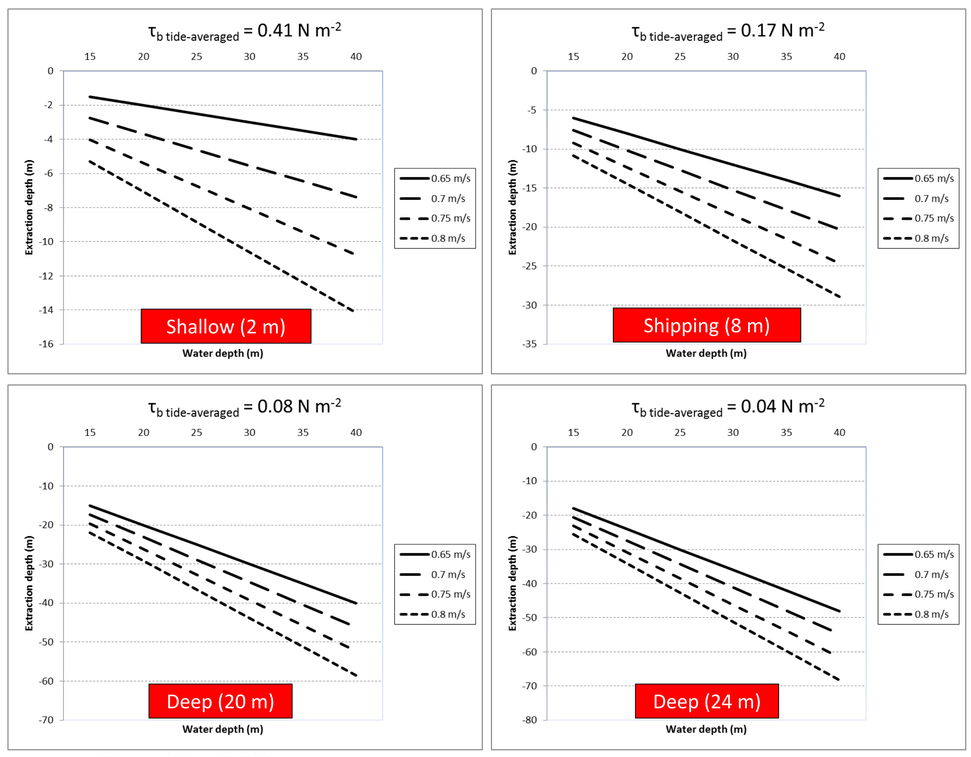

Fig. 3: EBD graphs with required extraction depths

Conclusions

- At higher flow velocity and initial water depth, higher extraction depths can be applied to reach desired tide-averaged bed shear stresses (τ) and related ecological effects (**Fig. 3**)[1,5].
- In borrow pits with a decrease in τ < 0.09 N m^{-2}, return to initial conditions is expected to occur within 4-6 year [van Dalfsen et al. 2000].
- When the decrease in τ is < 0.33 N m^{-2} enhanced species richness, biomass and increase of white furrow shell is expected [5].
- When τ becomes < 0.08 N m^{-2}, an increasing abundance of brittle stars and higher chance for detrimental effects is expected [5].
- Ecosystem-based sandbars significantly changed sediment and fauna.
- Determining the effects of intermediate extraction depths and medium and long-term effects and oxygen and sedimentation measurements in MV2 borrow pit are recommended [4,5]

References

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