New limits for the sand extraction on the Belgian part of the North Sea?

Koen Degrendele[*1], Marc Roche[1] & Helga Vandenreyken[1]*

[*]*Presenting author: Koen.Degrendele@economie.fgov.be*

[1]*FPS Economy, S.M.E.s, Self-employed and Energy, Directorate-General Quality and Safety, Continental Shelf Service, Koning Albert II-laan 16, 1000 Brussel, Belgium*

Introduction

Responding to the central question of this 2017 study day for sand extraction "Is marine sand a rare resource?" is not an easy task. It requires a scientific evaluation of the resources available for sand extraction, and based on this evaluation, a prognosis of how long the sand industry can continue its activities at the present rate. Under the current legislation, the sand reserve can be calculated by simply multiplying the total area where extraction is allowed with the maximum extraction depth. Compared to this reserve evaluation, the scientific evaluation of the available sand resource is a complex assignment, requiring knowledge of the structure and nature of the seabed. The latest attempt to produce a global and useful knowledge base of the sediments on the entire Belgian part of the North Sea is made in the framework of the Tiles project (Van Lancker et al., this volume). This article focusses on the ongoing project to combine legal restrictions, scientific criteria, and practical issues to define new limits for the extraction. Based on these well-considered limits an analysis can be made of the durability of the sediment extraction, and a prognosis of the future prospects for the sector becomes realistic.

At this moment, the limit for extraction is laid down in legislation at 5 meters below a reference area defined by the Continental Shelf Service (Law of 13 June 1969 on exploration and exploitation of the non-living resources of the territorial sea and the continental shelf, amended By the laws of 20 January 1999 and 22 April 1999). To date, this is a detailed seabed terrain model of the extraction areas, measured during extensive MBES surveys in the first half of the previous decade (in this report, this surface will be referred to as the BAS surface). Based on this limit, three areas in Zone 2 (KBMA, KBMB and BRMC), where the extraction led to a deepening of more than 5 meters, were closed. Currently, this limit is approached on some areas within Zone 1 (TBMAB) and 4 (HBMC), which in a medium term can lead more closures.

This legal constraint does not take into account the nature and structure of the seabed and the resulting differences in the extraction impact. In addition, the sustainable character of the exploitation is compromised. The sub-regions of the extraction areas with the highest quantities of the most requested quality of sand (medium to coarse sand) are closed irrespective of the still available volumes on site, while areas with economically less interesting quality of sediment (fine sand) remain open.

To address these problems, the Continental Shelf Service started a project to determine a new reference surface based on scientific and legal criteria. The purpose of this new surface is to limit the impact of extraction in the most sensitive areas of sediment and habitat and to increase economic sustainability by taking into account the available volumes and quality of sand. The introduction and application of these criteria will require a more proactive management of the sector's activities, and a closer cooperation and exchange of information between government and industry.

Procedure and assumptions

When designing the new surface, a number of considerations are taken into account:

1. In the preparation of the Marine Spatial Planning Plan (MRP) in 2014, the control zones where sand extraction was authorized were adapted: the Gootebank (then zone 1b) and the ecologically valuable gullies between the Kwintebank, the BuitenRatel and the Oostdyck inside zone 2 are no longer available for extraction (Figure 1). Only the sandy areas on the sandbanks themselves remain and the Sierra Ventana, as a source of recycled material. These are the areas that have the lowest ecological value. Furthermore, Control Zone 2 now falls completely within the newly demarcated habitat directive area (Figure 1). Within zone 2, the extracted volumes should now decrease by 2% annually to preserve and protect the habitats present in the western part of the Belgian part of the North Sea.

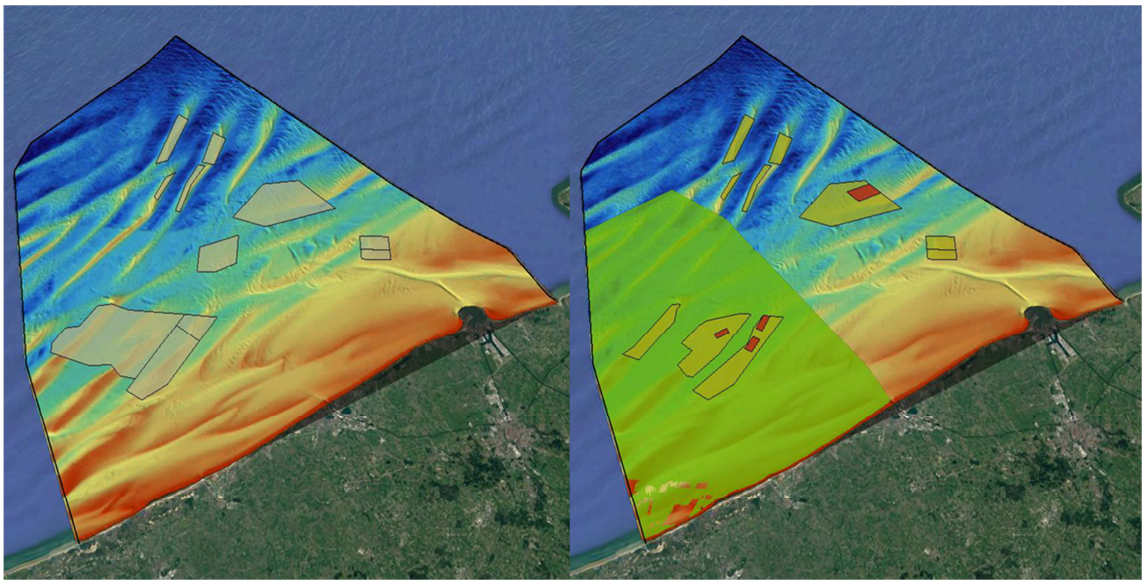

Figure1: Changes in the definition of the control zones for sand extraction in the Marine Spatial Plan (MSP). On the left the situation before (the control zones are marked in brown), on the right the situation since the implementation of the MSP. The control zones are indicated in yellow, the subareas closed for extraction in red and the habitat directive area in green.

On the basis of these recent measures and the conclusions of the biological monitoring by ILVO (De Backer et al., this volume), no new spatial restriction is introduced in this project. Thus, the current boundary of the zones is used in the further calculation of the new reference area.

2. To protect the integrity of the seabed as much as possible, the extraction should be limited to the top homogeneous package of sediments. Within this layer, the sand quality remains more or less constant. Further extraction down to the underlying layers, would change the nature of the sediments at the surface of the seabed and, consequently, the quality of the available sand. Under the European Marine Framework Framework Directive (MSFD) and its implementation in Belgian law (Royal Decree of 23 June 2010), Member States are obliged to maintain the integrity of their seabed to a maximum. This criterion therefore fully meets this specification of the directive.

To determine this limit, a complete and detailed geological (seismic) mapping of the Belgian part of the North Sea (BPNS) is required. With the collaboration of the SeArch and Tiles projects, the most recent and accurate modeled seismic surfaces are implemented: Top Paleocene (Upper Paleocene), Top Pleistocene and Top U4 (Figure 2). The presence and thickness of these geological layers vary throughout the Belgian part of the North

Sea. For this study, the lower limit of the homogeneous Holocene package is important, less the nature and age of the underlying layer. Therefore, a new surface area is defined by the Continental Shelf Service: SDS (Shallowest Discordant Surface). For each point of the new grid the corresponding value from the shallowest seismic surface (Figure 2) is selected. The result is a surface for the entire BPNS with the depth of the first found heterogeneity in the seabed composition.

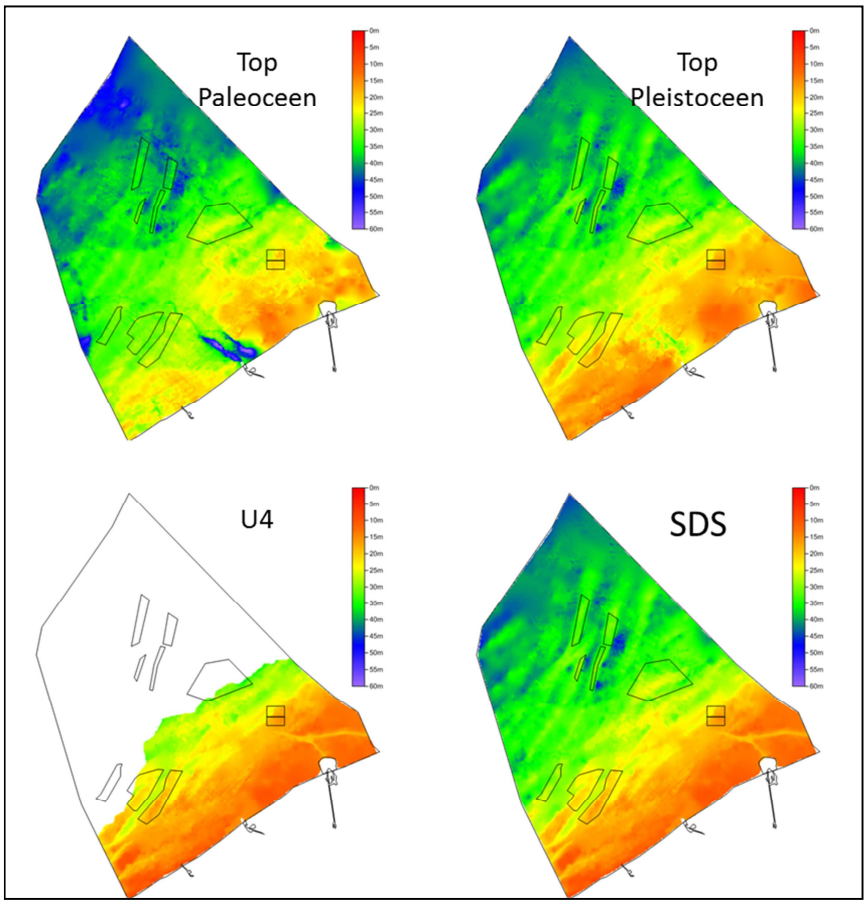

Figure2: The different seismic surfaces (courtesy ofSeArch and Tiles projects) and the resulting SDS.

The SDS becomes the absolute lower limit for the exploitation in the new reference. Taking into account the inaccuracy and possible error on seismic measurements and their interpretation, an additional buffer of 1m was added to this surface. The extraction is thus limited to a depth of 1 meter above the SDS.

3. Based on the role played by the sand banks in the protection of the Belgian coast, the maximum preservation of the morphology of the banks is introduced as a precaution. The impact of the banks' partial disappearance on coastal erosion has already been studied (Verwaest & Verelst, 2006), but the potential impact of a deepening up to the level of the new reference surface will be re-examined by the Directorate Natural Environment (OD Nature) of the Royal Belgian Institute of Natural Sciences. Within this project, maintaining the basic form of the sand banks is therefore an important criterion. However, maintaining only the basic form of the sandbank, opens up the important volume of sand in the sand dunes, the mobile part of the bank, for exploitation.

The modeling of the basic form of the various sandbanks within the control zones is an important challenge. The Continental Shelf Service approach passes by a filtering of the sandbank bathymetric data (BAS) based on the slope and local depth difference eliminating the measurement points of the grid located on the sand dunes.

With the remaining bathymetric points, a new grid is computed using an inverse distance weighted algorithm resulting in a basic form model which defines tangentially quite well the base of the dune pattern of the bank. in 2016, in collaboration with the Continental Shelf Service, researchers from ENSTA Bretagne and IMT Atlantique Télécom Bretagne have develop specific algorithms to approach the “osculatory – envelop surface” of a sandbank as closely as possible on the base of its bathymetric model (Debese & Jacq, 2016). In this contribution, the basic form of the sandbanks within the control zones (ECOS) are based on a mixed approach, merging the Continental Shelf Service approach with an intermediate osculatory model from ENSTA (Figures 3 and 4).

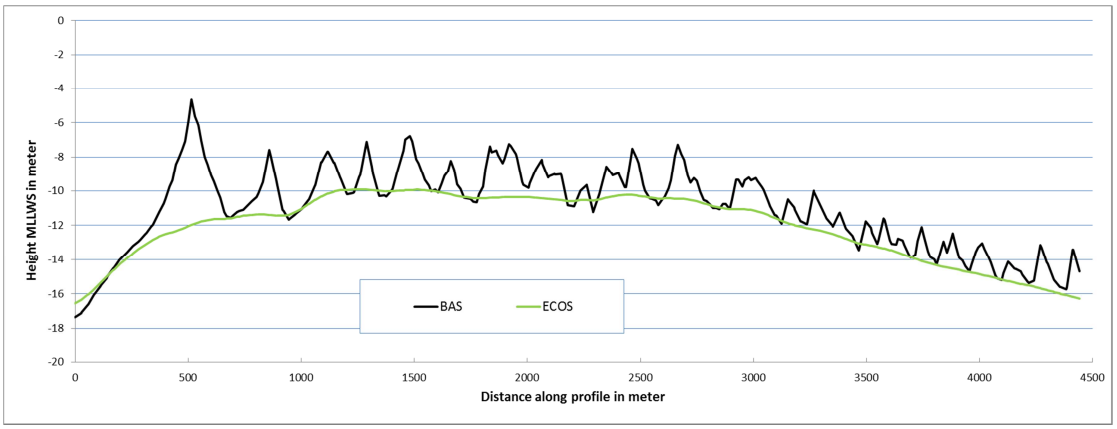

Figure 3: Cross section along profile AB (see figure 4) through BAS and ECOS surfaces for the Oostdyck. Depth in meter MLLWS.

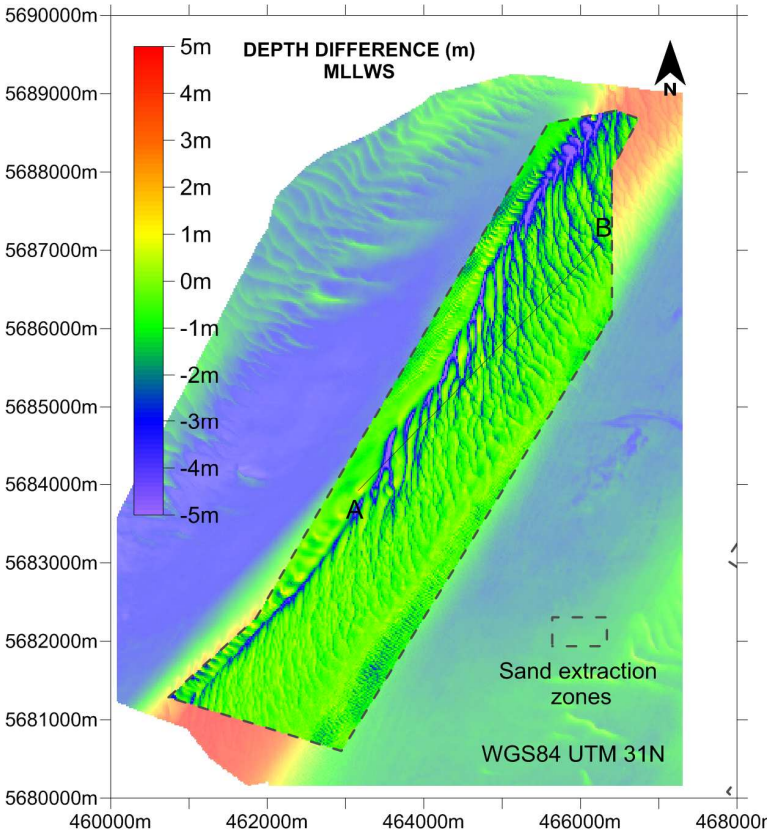

Figure 4: Depth difference between bathymetry (BAS) and basic form (ECOS) of the Oostdyck (sector 2od). A-B: profile from figure 3.

Improved modeling of the sandbanks basic forms by taking into account the latest generation of ENSTA models is under way. The new reference area will approach this resulting ECOS model for the different banks and control zones as closely as possible, taking into account economic sustainability.

Development of scenarios

Based on the SDS area (criterion 2) and the detailed bathymetric model of the control zones (BAS) or the modeled bank form (ECOS), a number of scenarios are elaborated (Figure 5). The total reserve of homogeneous Holocene material (BAS minus SDS) and dynamic sediments, or the volume of the sandwaves (BAS minus ECOS), are calculated and compared with the current legal reserve and reserves in the various scenarios. By limiting ourselves to the current control zones, all scenarios are assumed to meet the first criterion, namely minimizing environmental impact.

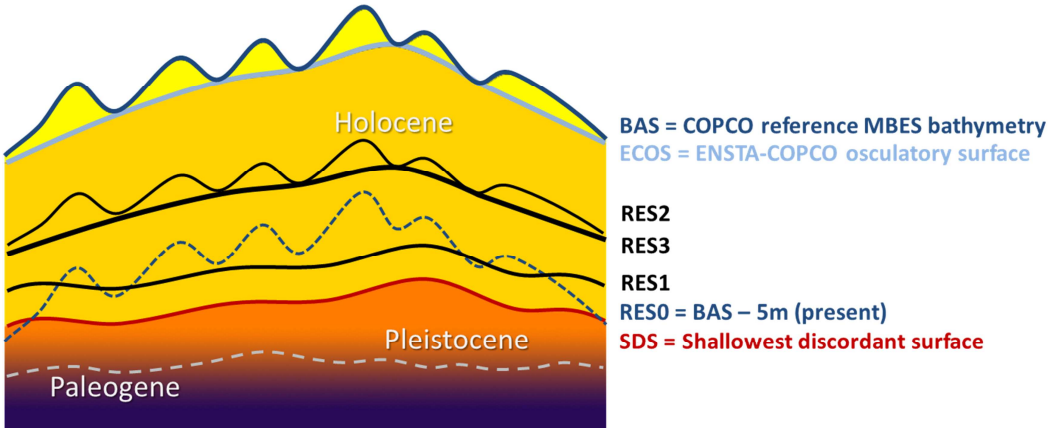

Figure 5: Overview of the different scenarios by means of a schematic cross section of a sandbank.

1. The base scenario (RES0) is the current situation with a reference area that is 5m below the bathymetric model. The nature of the sediment present is not taken into account, allowing in principle the extraction to go deeper than the upper homogeneous package (lower than SDS).

RES0 = BAS – 5m

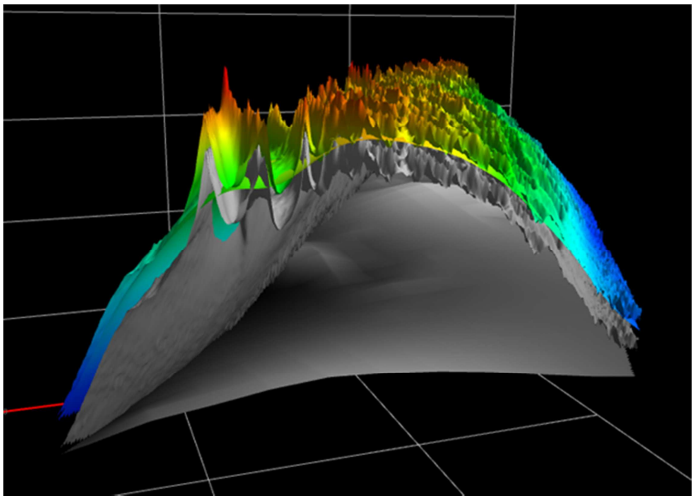

Figure 6: 3D-cross section of the Oostdyck with RES0 in grey (BAS-5m).

2. The maximum scenario in volume (RES1) does not take into account criterion 3 (retention of the bank form). The reference here becomes the SDS surface so that we remain sedimentary in the same homogeneous package. An additional 1m buffer is provided to capture the inaccuracies of the seismic models.

RES1 = SDS + 1m

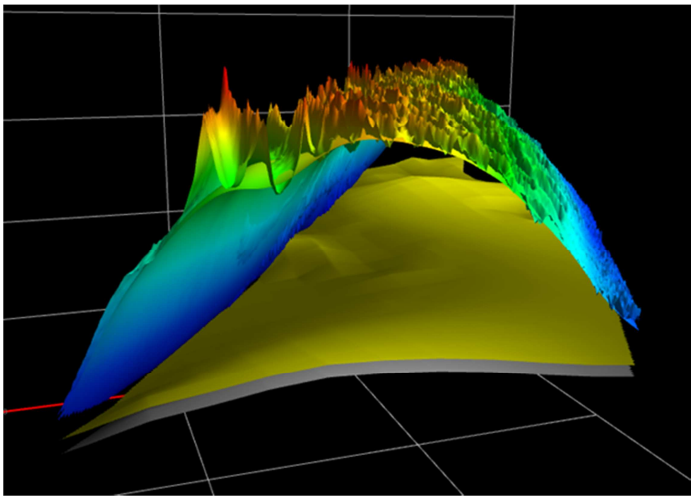

Figure7: 3D cross section of the Oostdyckwith RES1 in yellow (RES1 = SDS + 1m).

For Zone 3 (Sierra Ventana) only this scenario has been withheld. Both BAS and ECOS are useless because of the specific nature of this area: the alternation of dumping and extraction results in a constantly changing seabed. Thus, the only possible scientific criterion is to maintain a similar sediment type at the seabed surface.

3. The second new scenario takes into account the conservation of the bank form (criterion 3). The new reference area is located halfway between SDS and Bathymetry (BAS), but remains at least 1m above SDS. In this option, the morphology of the bank is partially maintained.

RES2 = (SDS + BAS)/2 with RES2 ≥RES1

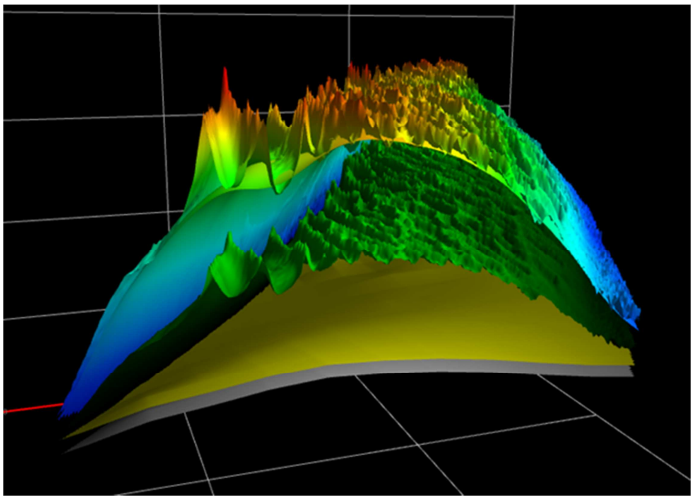

Figure 8: 3D cross section of the Oostdyck with RES2 in green (RES2 = (SDS + BAS)/2 with RES2 ≥ RES1).

4. By replacing the detailed bathymetric model of the control zones with the modeled bank shape, the volume in the sand dunes (dynamic volume) is added to the total available volume. The new reference area is thus halfway between SDS and ECOS. AS in the previous scenario, the morphology is partially maintained.

RES3 = (SDS + ECOS)/2 with RES3≥RES1

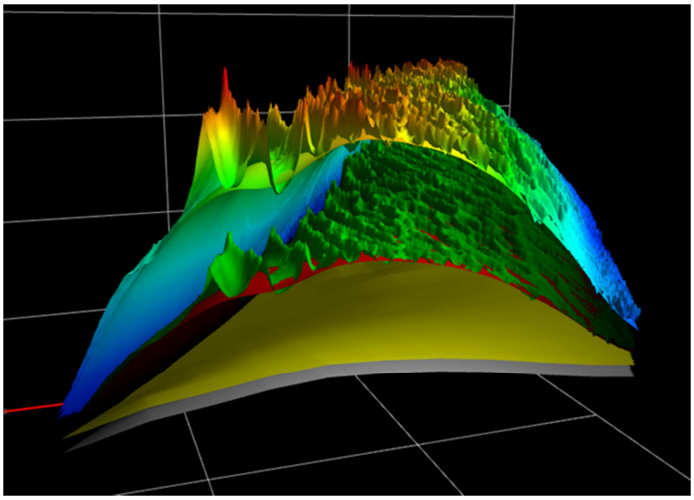

Figure9: 3D cross section of the Oostdyck with RES3 in red (RES3 = (SDS + ECOS)/2 with RES2 ≥ RES1).

Further scenarios where the volume of the bank (criterion 3) is more maintained, will not be considered for the moment, as this would significantly reduce available volumes and endanger economic sustainability. For the various proposals, the volumes available for extraction can be estimated.

SECTORS	Holocene reserve BAS-SDS	Dynamic volume BAS-EOS	Legal volume BAS-RES0	Scenario 1 BAS-RES1	Scenario 2 BAS-RES2	Scenario 3 BAS-RES3			
S1	224	72	392	166	104	125			+
S2	485	56	430	412	210	259			+/-
S3	61		83	46					-
S4	393	42	228	349	195	215			--
TOTAL	1164	170	1133	973	508	599			

Table 2.Comparison of the available volumes for extraction associated with the scenarios with the current available legal volume: red = strong decrease, orange = decrease, yellow = stable, green = increase. Volumes in $10^6 m^3$.

In zone 1, each new scenario strongly reduces the available volume (Figure 10 and Table 2). This is the consequence of the shallow location of the SDS. Extraction seems only possible in the eastern part of this zone. In the western part, the Holocene material has already largely disappeared or is not present.

In zone 2 there are big differences between the three sandbanks present (Figure 11). At the Kwintebank and Buiten Ratel there is a clear decrease in the operable volume. Only on the southern and eastern part of the Buiten Ratel the available layer remains comparable to the current situation in each scenario. This loss is partially compensated by the greater volume available on the Oostdyck.

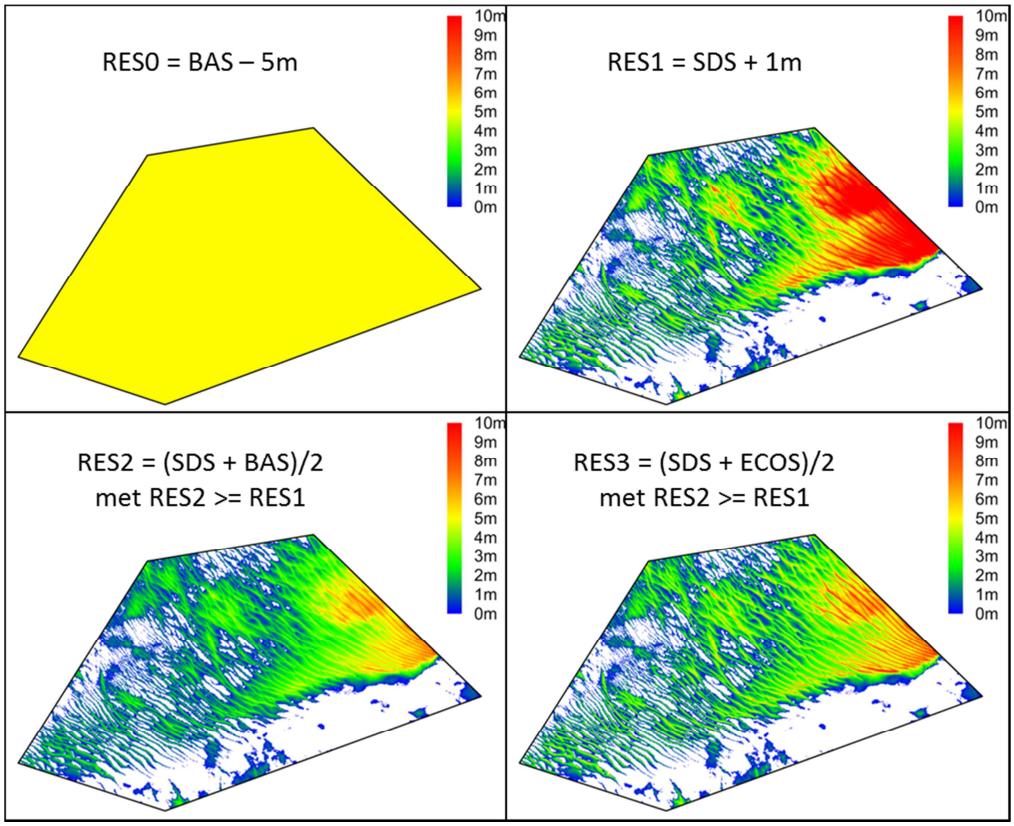

Figure10. Comparison of the thickness of the available layer of sediment in zone 1 on the basis of the different scenarios.

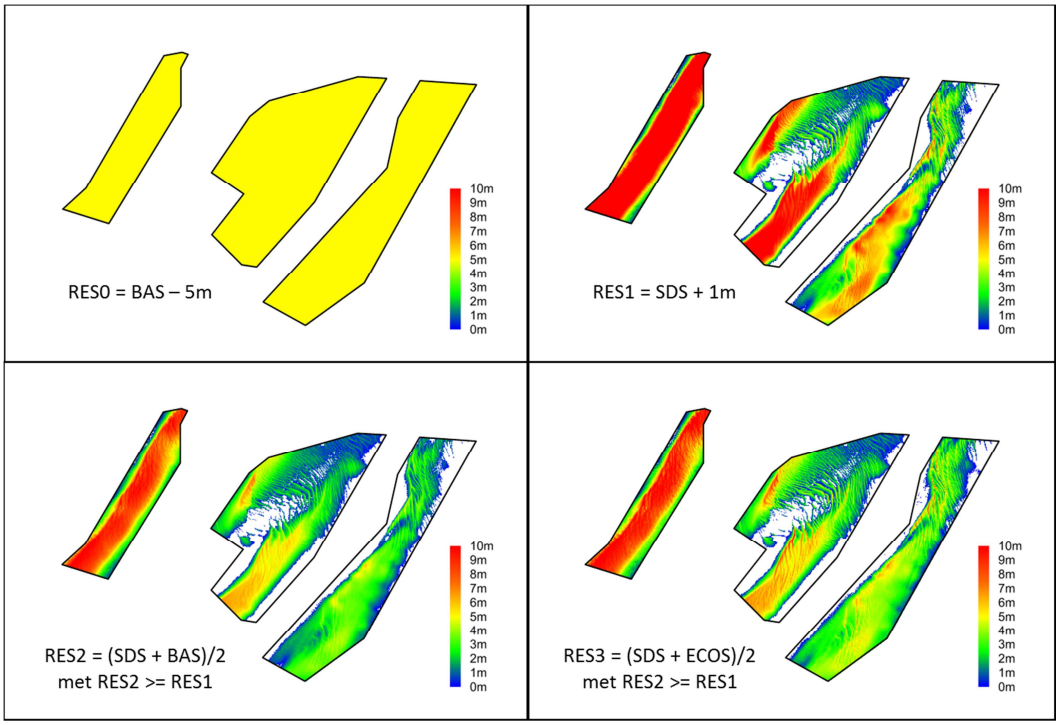

Figure 11.Comparison of the thickness of the available layer of sediment in zone 2 on the basis of the different scenarios.

At the Hinder banks, the total volume decreases less (Table 2 and Figure 12). In scenario 1, which amounts to almost the entire sandbanks in the 4 sub-areas, there is even a strong increase. For scenarios where the form of banking endures a bit more, the volume concentrates on the central upper sections of the banks, with a thickness of up to 10m.

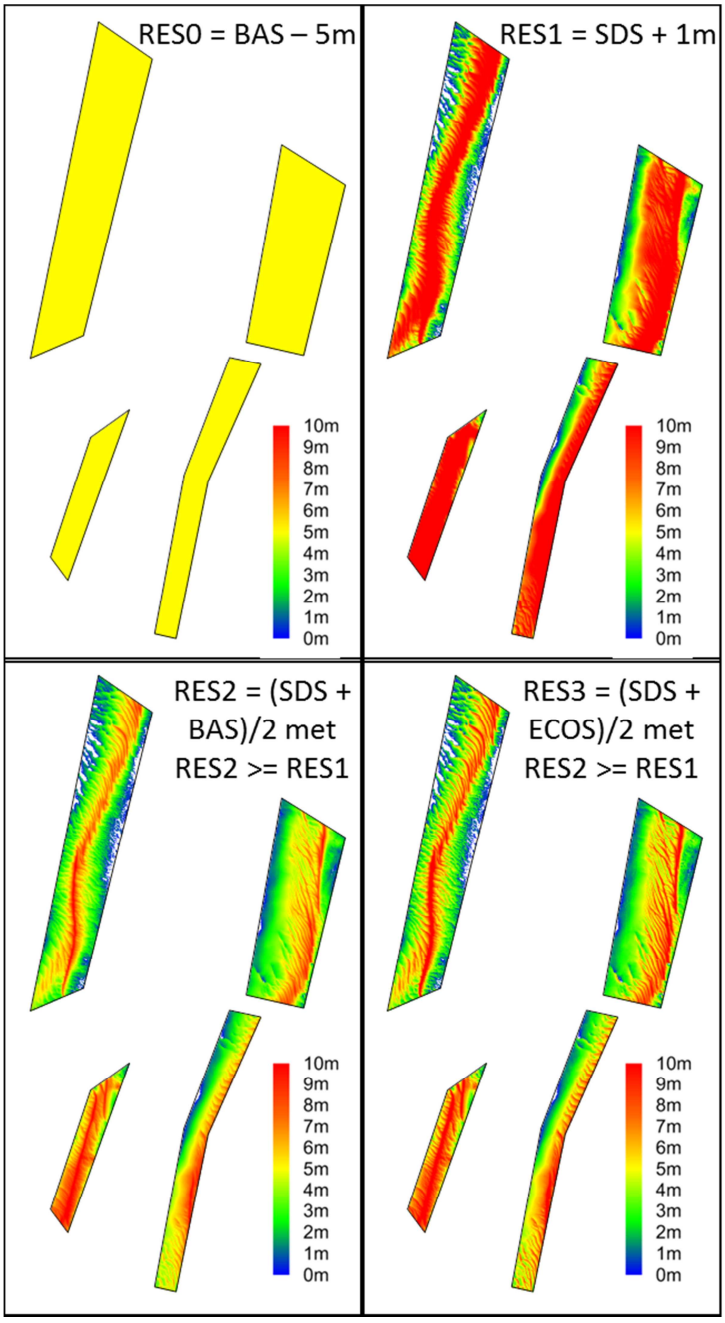

Figure 12.Comparison of the thickness of the available layer of sediment in zone 4 on the basis of the different scenarios.

In general, a shift of available volumes to the Oostdyck, the eastern part of the Thorntonbank and the Hinderbanken is observed in all three scenarios.

Selection and impact of scenarios

Based on the comparison, scenario 3 was selected as the ideal compromise between the criteria. For zone 3 scenario 1 was selected, based on the specific regulation for this area. However, the Belgian implementation of the MSFD provides an additional restriction: the resulting bottom shear stress change has to remain inside a 10% interval (see Vandeneynde et al, this volume). The third scenarios was evaluated and all area's except sector 2od (Oostdyck) complied with this condition. On the Oostdyck the impact on the seabed would exceed this threshold. The scenario was adapted to fulfill the requirements with the maximum of volume. If the surface from scenario 3 (RES3) is raised by 4m, it would comply with the MSFD specification (see Vandeneynde et al, this volume). The impact on the available volume amounts to 58 10^6m^3 (more than half of the volume in scenario 3), resulting in an important drop in the overall available sediment reserve.

The different volumes are listed more detailed (per sector) in Table 3. The available volumes for the present situation (legal volume) and for the new reference surface are corrected for the extracted quantities of sand in the period 2003-2016 (-EMS) and the area currently closed for extraction: KBMA, KBMB, BRMC and the reference area in zone 1 (-EMS -CLOSED). Zone 3 (Sierra Ventana) is included in the table, but since the model for this zone is based on recent bathymetric data, no corrections are applied (these uncorrected values are in italic).The biggest drop in available volume is situated in zones 1 and 2. On the Thorntonbank the volume would drop from 337 10^6m^3 to 87 10^6m^3, or 74%. On zone 2 this amounts in a decrease from 390 $10^6m^3$to 178 10^6m^3, or 54%. Considering the reopening of the closed areas in both zones, would reduce the decline in zone 1 to 64% (to 120 10^6m^3) and in zone 2 to 52% (to 187 10^6m^3).

SECTOR	Legal Volume RES0	Legal Volume RES0 -EMS -CLOSED	New Volume	New Volume RES -EMS	New Volume RES - EMS -CLOSED
S1a	392	337	125	120	87
S2kb	163	140	66	61	53
S2br	187	173	85	77	76
S2od	79	77	51	50	50
S3	83	*83*	46	*46*	*46*
S4a	96	96	79	79	79
S4b	69	69	62	62	62
S4c	42	38	41	37	37
S4d	22	22	33	33	33
TOTAL	**1133**	**1033**	**587**	**564**	**522**

Table 3. Comparison of the available volumes for extraction per sector associated with the preferred scenario with the current available legal volume. Volumes in 10^6m^3.

All these values represent the maximum volume that is available inside the limits of the sectors. How much of these volumes are really extractable is not easy to define. The spatial distribution is fragmented, not evenly distributed over the area as in the present situation (RES0). Especially in zone 1 (figure 10) this will largely reduce the extractable quantities. Furthermore, the sand is not extracted up to the border of the area. Doing so would result in infractions on the regulation (overpassing the limit of the zone) and cause direct impact on the seabed outside the allowed extraction areas. In case the impact exceeds the new limit, the impacted areas will be closed, as in the present situation. This doesn't result in closed areas where 100% of the legally accessible volume was extracted. In the closed area on the Buiten Ratel (BRMC), the average deepening is only 2.5 m, although it exceeds the 5m limit for a large part.

Based on the listed arguments and the experience up to now, an extraction of 50% of the available volume seems realistic. This would amount to a total of 260 10^6m^3, or a possible 80 years extraction at the present rate (3 10^6m^3/year). However, this doesn't take into account a further rise in the extraction figures or extra volumes

for special projects (for coastal defense or offshore construction), which would decrease the forecast, and the replenishment of the available volume on zone 3, which could increase the forecast slightly.

Conclusions

The economic sustainability of the sand extraction can be augmented by ensuring the long-term availability of available stocks of economically valuable aggregates. Based on the demarcation of the control zones and the 5m limit, we can calculate the total available stock of sediments for extraction, but this does not take into account technical constraints (e.g. impossibility to extract the full volume without direct impact on the surrounding area) and the suitability of the sediments for extraction. For this latter, extensive knowledge of the sediment present is required, both on the surface of the seabed and in the subsoil.

The Tiles project (Van Lancker et al, this volume) attempts to formulate an answer to this important question. Based on the preliminary results, a 3-dimensional mapping (by means of voxels), in cooperation with Ghent University and OD Nature, of the sediments in the different control zones has been made (see Figure 13). In this case, the third scenario (halfway between SDS and the model of the bank – ECOS) is always used as the lower limit.

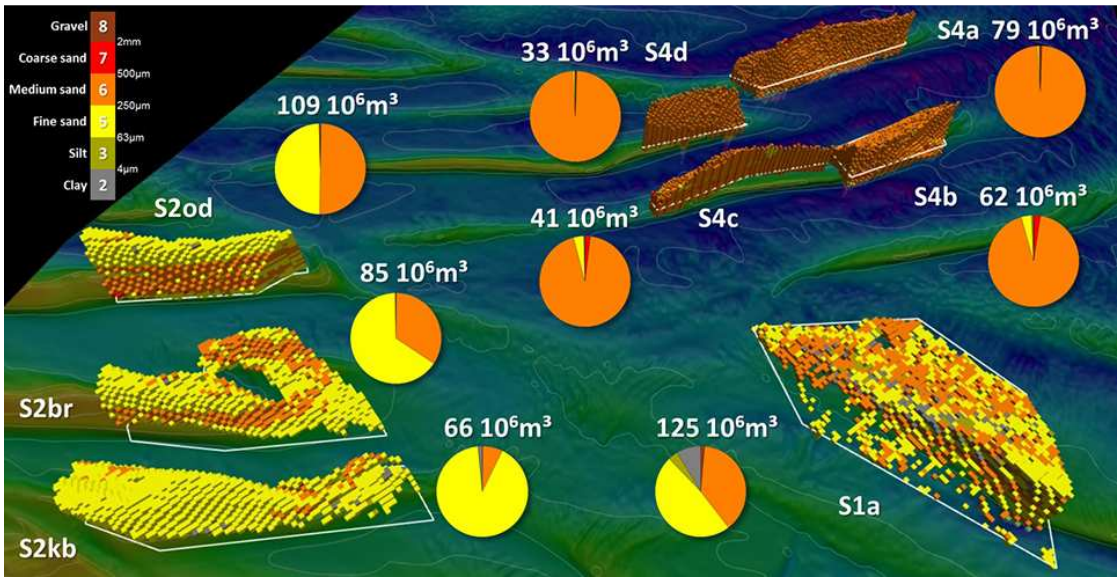

Figure13: Voxel-model for extraction zones 1, 2 and 4, based on the intermediate results of the Tiles project. Sediment types are distinguished. The quota for each sediment type is presented in polar-wedge diagram for each sector.

On the Hinderbanks (control zone 4, with sub-areas 4a, 4b, 4c and 4d) the concentration of medium coarse sand is highest (Figure 13). At the Kwintebank (zone 2kb) the available stock of the same type of sand is the lowest. The intermediate sectors (2br, 2od and 1a) present a mix of both fine and medium sand. The Voxel model shows where the most valuable sediments for mining are present and the available volumes, from an economic point of view, should be maximized.

In the next phase of the project the information from the Voxel model will be combined with maps of the seabed surface sediment type and information on the quality of sand made available by the extraction firms.This will allow a further evaluation of the economic sustainability of the different scenarios. One of the principles of this project is the transition from theoretically exploitable and undifferentiated sand stocks to

realistic and useful volumes per type of sediment. This must lead to a more future-oriented and thus more sustainable management of the sand extraction on the Belgian part of the North Sea.

Acknowledgements

Nathalie Debese and Jean-José Jacq from ENSTA Bretagne and IMT Atlantique Télécom Bretagne are acknowledged for their contribution to the development of the sandbanks basic forms – osculatory surfaces. The members of Zeegra are thanked for their input of valuable information, the excellent cooperation and feedback. The colleagues from ILVO and OD Nature are thanked for the collaboration in the testing and evaluation of the different scenarios and feedback. This is an ongoing project that greatly depends on the collaboration of all the involved institutes and the sand extraction industry.

References:

Debese, N., & Jacq J.J, (2016). Extraction of the intra-sediment osculatory surfaces of sandy bedforms with application to the nine sand extraction sectors of the Belgian part of the North Sea, Collaborative Research Report, ENSTA-Bretagne and IMT-Atlantique, 47p, 7 October 2016.

De Clercq M., Chademenos V., Van Lancker V. &Missiaen T. (2015). A high resolution DEM for the Top-Palaeogene surface of the Belgian Continental Shelf, Journal of Maps: http://dx.doi.org/10.1080/17445647.2015.1117992.

Degrendele, K., Roche, M. and Schotte, P. (2002). Synthèse des données acquises de novembre 1999 à avril 2001 quant à l'incidence des extractions sur le Kwintebank. Brussels: Fonds pour l'extraction de sable. Ministère des affaires économiques de Belgique, 23 pp.

Degrendele, K., Roche, M., Schotte, P., Van Lancker, V.R.M. &Bellec, V. (2010). Morphological evolution of the Kwinte Bank central depression before and after the cessation of aggregate extraction. Journal of Coastal Research, SI, 51, 77-86.

Degrendele, K., Roche, M., De Mol, L., Schotte, P. &Vandenreyken, H. (2014). Synthesis of the monitoring of the aggregate extraction on the Belgian Continental Shelf from 2011 till 2014 in "Which future for the sand extraction in the Belgian part of the North Sea?", Proceedings Study day 20/10/2014, FPS Economie, Brussels, 3-27.

Hademenos, V., Kint, L., Missiaen, T., Stafleu, J, Van Lancker, V. (2016). Quantifying the resource potential of Quaternary sands on the Belgian Continental Shelf: a 3D voxel modelling approach.ICES CM2016/K:431.

Roche, M., Degrendele, K., De Mol L., Schotte P., Vandenreyken, H., Van Den Branden R. and De Schepper G. (2011). Synthesis of the monitoring of the impact from the aggregate extraction on the Belgian Continental Shelf.Brussels: ProceedingsStudyday Marine AggregateExtraction 2011.

Van Lancker V, Baeye M, Evagelinos D, Francken F, Montereale-Gavazzi G, and Van den Eynde D (this volume).MSFD-compliant assessment of the physical effects of marine aggregate extraction in the Hinder Banks, synthesis of the first 5-yrs.

Van Lancker V, Francken F, Kapel M, Kint L, Terseleer N, Van den Eynde D, Degrendele K, Roche M, De Tré G, De Mol R, Missiaen T, Hademenos V, Stafleu J, van Heteren S, van Maanen PP, van Schendel J (this volume). Flexible querying of geological resource quantities and qualities, a sustainability perspective.

Verwaest, T., Verelst, K. (2006). Effect bodemverlaging Kwintebank op kustveiligheid. WL Rapporten, 765/20. Waterbouwkundig Laboratorium: Antwerpen. 11 + appendices pp.