

# Investigation of natural sand transport on the Belgian continental shelf (BUDGET)



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## Introduction

On the Belgian continental shelf (BCS), a variety of sediment dynamical studies have been performed both by governmental organisations and research institutions. Each study proposed to achieve a better insight in the sediment dynamical processes taking place on a specific spatial scale and during a particular time period. However, all these studies contain a piece of information, which contribute to the knowledge on the sediment dynamical behaviour of the sediments of the BCS.

In the course of the BUDGET project, an overview has been produced of all these studies in order to assess and understand the residual sediment transport on the Belgian Continental Shelf (BCS) and this on different time and spatial scales. The assessment was based on a compilation of available information followed by a critical analysis of the data in which results from different methods such as modelling and a large number of sediment dynamic techniques based on field work were compared.

Answers were sought for a number of basic questions such as:

- Which paths does the bed-load sediment follow on the BCS?
- Which processes cause the sediment transport and what is the influence of external factors such as storms and wind on the tide-induced transport?
- Can a realistic sediment budget be calculated for the BCS?

Answers to all these questions have not only a scientific interest but they are as well indispensable for drawing up environmental policy plans. These answers are relevant to a number of activities such as aggregate extraction and relocation operations of dredged material.

The compiled information concerned the sedimentology, the geology, the morphology, the sediment dynamics and the hydrography of the BCS. In many cases the original data (digital or analogue) of the different research and government institutions could be used what allowed a more dynamic and flexible processing and comparison of the data. Although no field work was included in the original proposal, the results of a number of field activities could be integrated in the final project results.

## Results

The results of the BUDGET project were presented in three different ways. First an inventory was made of the principal sediment transport studies which results were presented in a separate easy-reference handbook. Secondly all results were critically analysed and compared and the time and spatial scales of the validity of the results were assessed. The conclusions of the compilation work and of the critical analysis together with recommendations for future research were presented in a report. Finally the main information on the characteristics of the BCS, the directions of the residual sediment transport and quantities on sediment transport were presented on a map.

### *Overview of sediment transport studies related to the BCS*

An inventory was made of all sediment transport studies related to the BCS. This inventory contains the results of all major studies on bed-load and suspension load transport. For each study a summary is presented which includes information on (i) the method used to derive the sediment transport information, (ii) the principal results and (iii) the directions and quantities of the sediment transport that were deduced. The studies were classified according to the principal technique that was applied.

### *Critical analysis*

The study comprised a critical analysis of the data and methods used. The deduction of residual transport directions was evaluated on the basis of the asymmetry of bedforms, tracer experiments, sediment differentiation, current and suspended sediment concentration measurements and based on numerical sediment transport modelling. Evaluation criteria were set-up regarding the different space and time scales involved. The influence of hydro-meteorological conditions on the sediment dynamics was discussed.

### *Overview map*

Most of the data has been re-evaluated and the results were compiled in a overview map to characterise the natural sand transport on the Belgian continental shelf.

The map indicates the general nature of the surficial sediments of the BCS grouped into the occurrence of very fine, fine and medium sand based on the median grain-size of the sand fraction.

Geologically, areas are indicated where the thickness of the quaternary deposits is less than 2.5 m as these sediments might take part in the sediment transport process.

This information is superimposed by the most recent bathymetrical data provided by the Waterways Coast division of the Ministry of the Flemish Community.

Subsequently, all available information on the occurrence of large dunes was added. The crest lines of the large dunes, deduced from side-scan sonar or multibeam recordings, were digitised or imported if digital information was available and were used to deduce residual sediment transport directions.

To illustrate the hydrodynamics of the BCS, current ellipses have been selected based on modelling results on a 750 m grid resolution. Additionally, locations are indicated where current meter or other hydrodynamic data has been collected.

Finally, a variety of arrows are drawn indicative of sediment transport directions. A distinction is made between transport vectors based on geo-environmental methods and those based on in-situ sediment transport measurements and on modelling results. The geo-environmentally based residual sediment transport vectors are drawn on the basis of the direction of the steep slope of the large dunes, albeit generalised. In the near coastal area comprising the Nieuwpoort Bank and Stroombank residual sediment transport vectors have also been drawn on the basis of generally valid grain-size trends. This was done, as bedforms are scarce. Slightly veering transport vectors relative to the global NE directed sediment transport represent local transport related to the dynamics of the sandbanks; NE directed vectors merely indicate the regional transport trend.

It was preferred to have vectors with a uniform length for the results from the in-situ sediment transport measurements and from the modelling. If budgets were available, they were recalculated in tonnes/m/day with an annotation within the arrows. The model results represent the total load transport of sand (Mu-SEDIM model) for the year 1999 under the influence of currents alone.

## Conclusions

The compilation map of the BUDGET project reveals the large amount of sedimentological, morphological, geological and sediment dynamic data available on the BCS. Due to its small size, the overall BCS has been generally well studied.

However, a closer look at the distribution of data points shows that most of the research has been carried out in a narrow coastal section over a width of  $\pm 8$  km. It can be stated that the amount of research on a particular site offshore is inversely proportional to the distance from the coast. This means that few studies concentrated on far offshore locations such as the Hinder Banks. Future research will have to focus in some particular locations and fields of interest in order to find satisfactory answers to some of the questions that remain unsolved.

From the data available and its critical analysis, some conclusions can be drawn regarding the main bed-load transport pathways on the BCS. Regarding bed-load, bedforms remain the most important indicators. It has been shown that a distinction should be made between local and regional transport pathways. On a sandbank level, both bank flanks are subdued to opposite sand streams with a convergence to their crest line and even a circulation of sand has been postulated which was confirmed both by tracers as modelling studies. On a regional scale, and from offshore to onshore, it has been outlined that bedload transport is mainly to the SW in the Hinder Banks region, in the swales of the Flemish Banks and near the Goote Bank. Closer to the coast, the situation becomes somewhat ambiguous. From current modelling, the coastal zone is clearly flood dominated though the shape of the bedforms tends to reflect a dominant influence of the ebb tidal current and their asymmetry is often nearly symmetrical. This is especially clear near the French – Belgian border where complex bedload pathways are found even in the swales that strongly funnel the flood current. Also east of Zeebrugge bedforms reflect an alternance of flood and ebb dominant episodes, likely related to the ruling hydro-meteorological conditions. Although based on total load transport formulae, the model mu-SEDIM developed in the framework of this project, gives a first good indication of the likely pathways on the scale of the BCS.

A challenge remains the set-up of a realistic sediment budget for the entire BCS. Theoretical estimates of the residual sediment fluxes have been presented, but they are all based on substantial simplified models. Input parameters are averaged values of water flux, residual current, depth section and surface sediment concentrations and the origin of some starting assumptions, put forward by some authors, is sometimes hard to find out and leads often to conflicting results.

On the compilation map, different values for residual suspension transport are given, mostly restricted to the near coastal zone. These values, obtained with different techniques, are in the same order of magnitude. However, realistic quantification of the residual transport, based on extensive field measurements, is only available east of Zeebrugge, over a width of  $\pm 5$  km. The existing figures such as the ones offshore Knokke cannot be extrapolated as the suspension values near the coast are all extremely high and the values decrease substantially in an offshore direction. This is an important gap in the knowledge on the sediment fluxes across the BCS and a meaningful estimation can only be obtained if extra measurements are carried out along the borders.

## Recommendations

Emphasis is put on an efficient mapping of the seabed as such data is highly relevant for as well the research community as end-users and this as well for small- as large-scale applications. Two mapping techniques are recommended: multibeam and side-scan sonar. Both techniques are complementary and in combination they allow a very-high resolution quantitative mapping of the seafloor including information on its intrinsic nature.

Groundtruthing remains a necessity especially since more research is needed regarding the true correlation of acoustic means and sediment characteristics. Stratified sampling based on the different acoustic facies could allow to set-up groundtruthed seabed classes that ideally comprise the variety of aggregates found on the BCS. However, according to the sediments involved, appropriate sampling tools should be chosen, preferentially integrated with video imagery.

Hydrodynamical and sediment transport measurements remain of vital importance for any sediment transport study. Although, a mathematical model may be the most suitable technique for calculating the effect of long-term and large-scale sediment transport processes, it is a necessity to feed the models with realistic data on current speed and sediment concentration data.

Especially, towards sand transport studies, multi-sensor bottom-mounted frames should be used that are deployed over at least a spring-neap tidal cycle. The frames should be equipped with an acoustic doppler current profiler in combination with optical backscatter sensors (to calculate sediment fluxes over the vertical water column) and with laser in-situ scattering and transmissometer (LISST) to study the particle size of the suspended matter.

The sediment dynamic related field measurements can be used as input, calibration and validation of numerical modelling. Nowadays software allows 2D depth-average or fine-grid 3D hydrodynamical modelling of the current and water transport as well due to tidal as to different hydro-meteo conditions. In combination with sediment transport modelling (bedload, suspended and total load transport) the morphological evolution of the seafloor can be simulated over time-scales of days to years.

To enhance the efficiency and practical use of seabed data, the set-up of an overall *Geographical Information System* (GIS) on the available marine aggregates becomes timely and would enable to select data according to end-users' needs.

Moreover, it is recommended to set-up guidelines and protocols on the prerequisites of mapping and sampling projects since this would largely facilitate the set-up and evaluation of environmental impact assessments (EIA). If indeed a GIS on the BCS seabed would exist, it could provide standardised background information. It could also include numerical reference material to guide sediment budgeting studies. In any case, an overall data management seems inherent to efficiently anticipate on future needs and to facilitate the decision-making.