MEASURING EFFECTS OF DREDGING IN RELATION TO THE DYNAMICS OF NATURE

R.L. Koomans[1], J. Limburg[2]

Abstract: The discharge of fines during dredging and the impact of these fines on seafloor habitats is an important aspect in environmental impact assessments. Our vision is that the effects of dredging on the environment, should be related to the impact of the dynamics of nature itself.

The potential effects from sediment plumes on the seafloor sediments can only be understood when the total release of *fine* sediments from the overflow can be related to the natural variation in concentrations of fines in seafloor sediments. Today, the buffering capacity of the seafloor for fine sediments has been estimated, but has hardly been measured. The natural variation of fines and thereby the buffering capacity of the seafloor can be monitored and natural dynamics due to resuspension and large-scale sediment transport patterns can be quantified. The sediments released from the overflow of a hopper dredger are composed of sand and fine silts. Since the sands will behave completely different to the fines, information on the total volume of *fine* material from the overflow is an important parameter. The release of fine material from a hopper overflow during dredging can be measured . With this quantification of sediment release, and the information of the buffering capacity of the seafloor sediments, the net effect of the release of fines during dredging can be related to the dynamics of nature.

Keywords: Sediment composition, monitoring, sediment density, sediment plume

[1]Medusa Explorations BV, Verlengde Bremenweg 4, 9723 JV, Groningen, The Netherlands. tel: 0031(0)50 5770280, koomans@medusa-online.com, www.Medusa-online.com. [2]limburg@medusa-online.com

1 INTRODUCTION

The discharge of fines during dredging and the impact of these fines on seafloor habitats is an important aspect in environmental impact assessments. The scientific community lacks information on resuspension of fines (e.g. buffering of fine material in the upper sediment layer during summer), the release of fines from the overflow during dredging and the net effect of this release on the sediment bed. As a result, various projects have suffered from delay due to unanswered questions on the environmental effects of dredging.

Our vision is that the effects of dredging on the environment, should be related to the impact of the dynamics of nature itself. One can imagine how fine sediments are entrapped in the active layer of the seafloor sediments. During storms, these sediments are released from the bed are brought into suspension in the water column. However due to the small quantities involved, this release in the water column is difficult to measure. For example the complete resuspension of silt from a sediment layer with a silt content of 1% in the top 30 cm of the active bed, will result in a suspended silt concentration of about 300 ppm in a water column of 9m. This low concentration is about an order of magnitude lower than the lower limit of detection of commonly used concentration meters. Measuring variations of silt content in the concentrated form (which is in the seabed) gives higher accuracy, provided that the spatial resolution of the mapping is accurate enough. Detailed monitoring of sediment composition of the seafloor can help to determine the natural variability of silt content in seafloor sediments.

Understanding the effects of dredging on seafloor sediments not only requires understanding of the natural behavior of fine material, but requires detailed information on the losses of fines during dredging operations. One important loss of sediment during dredging is the release of material from the overflow of a hopper dredger. Projects investigating these effects (Aarninkhof, 2008) mainly focus on the total release of material from the overflow and do not distinguish between coarse and fine sediments. For a better understanding of the impact of fines on the seafloor sediments, not only the total release from the overflow should be monitored, also the composition of the released material should be measured. This paper focuses on two aspects:

1) We will show how natural variability of fine material in seafloor sediments can be monitored
2) We will show how the composition of sediments released from the overflow can be monitored during dredging

2 MAPPING SEDIMENT COMPOSITION

Traditionally, silt content in the sediment bed is determined by taking sediment samples by (box)coring or taking grab samples. These measurements give accurate information on one spot, but spatial variation in the silt content e.g. due to the presence of small-scale morphological features as ripple structures can result in data that is not representative for large areas. Spatial variation can be mapped by taking large amounts of sediment samples, which is often too expensive.

Different hydrographic methods exist to map the variation in the composition of the sediments on the seafloor. Analysis of the acoustic signals multi-beam and single-beam echosounders or side-scan sonar, gives high-resolution images of the composition sediments. This information helps to zone the seafloor in a classes with one type of acoustic reflection that can be related to a certain type of sediment. It is though not possible to determine absolute concentrations of silt and sand or absolute values of grain sizes of the sediment bed (du Four et al, 2005). We propose a method that directly measures some chemical constituents of the seafloor sediments, that can directly be related to sediment composition. This relation is established by a calibration in the laboratory.

This system (called Medusa) is towed over the seafloor behind a vessel. Each second, the system measures concentrations of the natural occurring radionuclides of the seafloor. These radionuclides (^{40}K, ^{232}Th and ^{238}U) are present in rocks and sediments since the origin of the earth and can be measured with a gamma spectrometer. The system is completely passive and measures the background radiation that is emitted by soil and sediments. Various research projects have shown how silt, sand and heavy minerals contain different concentrations and ratios of radionuclides (de Meijer, 1998). This method is also commonly used to measure median grain size in the field (Nederbracht and Koomans, 2005). The specific concentrations of these radionuclides for each sediment fraction (also called fingerprint) allows the measurements of the radionuclides in the sediment to be translated into maps of sediment composition.

The advantage of the proposed system over traditional sediment sampling, is that the detailed maps of sediment composition determine the spatial variation at a small scale. Moreover, it is a cost effective method for monitoring purposes.

In a project for Rotterdam harbor, the transport of fine material, relocated to in several gravel pits, was monitored with the medusa system and with a multibeam. Therefore, two surveys have been conducted: one survey prior to disposal and one survey after two years of disposal. An area of 10x9 km^2 was monitored. The entire survey was carried out in four days and comprises about 120 .000 datapoints.

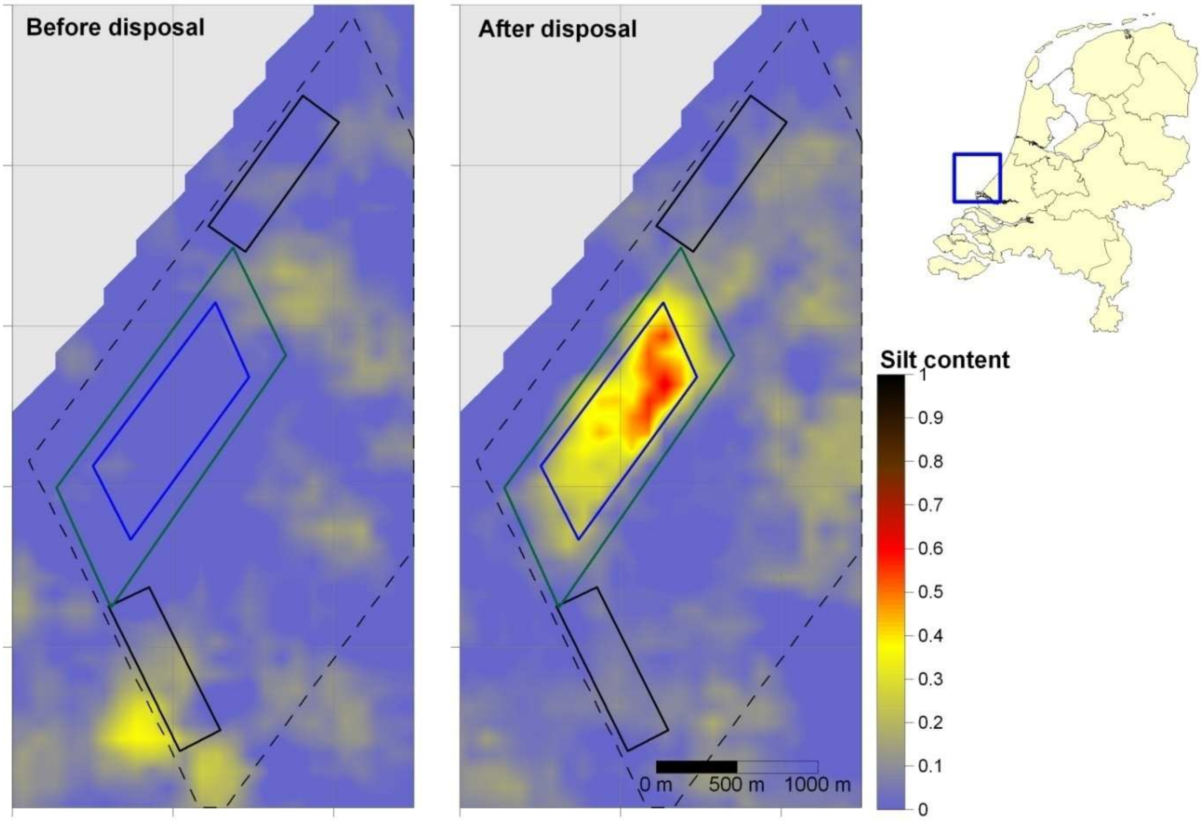

Figure 1: Comparison of silt fraction (ranging from 0 to 1) of totale sediment of the seafloor, before and after disposal.

Figure 1 shows the distribution of fine sediments in the area around the former gravel pits (blue rectangle). At t_0 the disposal site does not contain any sludge. The concentrates of sludge in the other parts of the area originate from a former disposal site (Venema and de Meijer, 2001). At t_1 the disposal of the harbour silts can clearly be noticed by the increased silt concentration in the former gravel pit. The dispersal from the gravel pit is small; the sludge extends only 250 m around the sides of the pit.

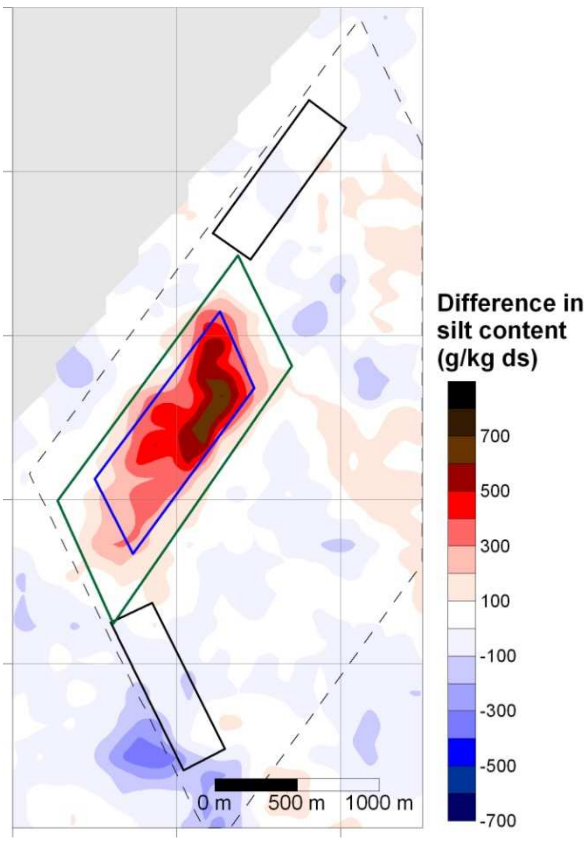

Figure 2: Map of the difference in silt content of the sediment before and after disposal.

The transport of the sludge from the dumping site is quantified with a map showing the difference between the two measurements (figure 2). With this information, a mass balance is constructed that has been used to validate the results of model calculations. The quantitative information on the transport of sediment can help to refine models for an improved assessment of the effectiveness of a spoil depot.

3 MEASURING THE COMPOSITION OF SEDIMENTS RELEASED FROM THE OVERFLOW

The dredging industry is often criticized for having an adverse environmental impact, particularly through generation of sediment plumes during project implementation. Various studies are started to estimate plume generation during dredging (see e.g. Aarninkhof, 2008) with particular emphasis on the sediments released from the overflow during dredging. One of the major difficulties in these studies is the measurement of the total volume of sediment released from the overflow and in particular to differentiate between the loss of fines and the loss of coarse sands during dredging. In these studies, information on the composition of the material released is determined by a number of sediment samples. Apart from the fact that this is a very elaborate procedure, the measurements give only point information from one part of the overflow system.

We have developed a metering system for real-time measurements of the sediment concentration and sediment composition (sand/clay ratio) in the overflow of a hopper dredger. This system has been demonstrated in pilot experiments during dredging operations. The system is based on identical principles as described above (the Medusa system) and uses the fact that the absolute concentration of fine sediments within the overflow system depends on the total concentration of sediments in the water passing the overflow (the sediment/water ratio) and the concentration of fines within the sediment mixture (the clay/sand ratio).

The Medusa system passively measures concentrations of natural occurring radionuclides. When the system is placed in a clay/sand/water mixture, the concentrations of the radionuclides will depend on the amount of water in the medium measured (the signal will be diluted, de Groot et al, 2009) and the signal will depend on the silt/sand ratio in the medium (van Wijngaarden et al, 2002). After a proper calibration of the 'fingerprint' of the sediments dredged, the measured signal can be translated in a silt/sand ratio and in a sediment/water ratio. The system can be operated continuously and can be used to make a mass balance of the total amount of fine sediments, and coarse sediments released from the overflow. Measurements in an overflow (figure 3) show the variation in total density during a dredging cycle and show the contribution of mud (silt) to the released material.

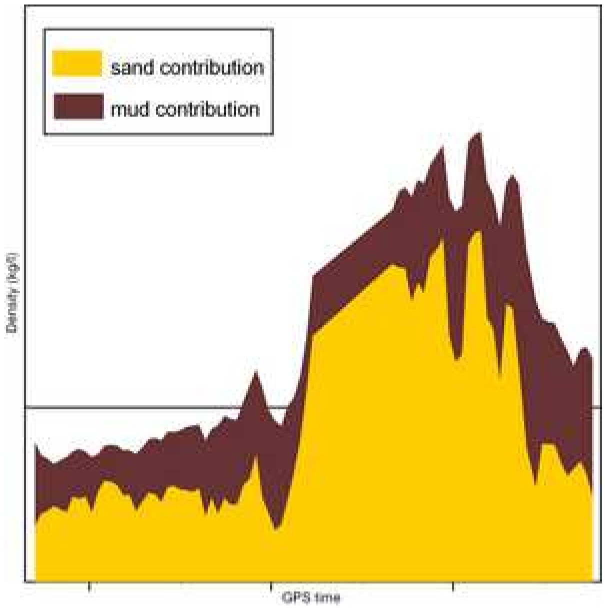

Figure 3: example of density measurements and concentrations of mud and sand from an overflow release.

4 EFFECTS OF DREDGING IN RELATION TO THE DYNAMICS OF NATURE

The potential effects from sediment plumes on the seafloor sediments can only be understood when the total release of *fine* sediments from the overflow can be related to the natural variation in concentrations of fines in seafloor sediments. Today, the buffering capacity of the seafloor for fine sediments has been estimated, but has hardly been measured.

We have shown that successive mappings of seafloor sediment composition can be used to monitor the transport of fines from a disposal site. The natural variation of fines and thereby the buffering capacity of the seafloor can be monitored in a similar way: long term monitoring of the silt content of the seafloor can help to quantify natural dynamics due to resuspension and large-scale sediment transport patterns.

The sediments released from the overflow of a hopper dredger are composed of sand and fine silts. Since the sands will behave completely different to the fines, information on the total volume of *fine* material from the overflow is an important parameter. We have shown that the release of fine material from a hopper overflow during dredging can be measured . With this quantification of sediment release, and the information of the buffering capacity of the seafloor sediments, the net effect of the release of fines during dredging can be related to the dynamics of nature.

5 REFERENCES

Aarninkhof, S. (2008). "The Day After We Stop Dredging: A World Without Sediment Plumes?" Terra et Aqua(110): 15-25

Du Four, I., Deleu, S., Darras, I., Roche, M., Koomans, R., & Van Lancker, V. (2005). Comparison between different seabed classification techniques and validation with sediment samples on two shallow-water dumping sites (Belgian continental shelf). Shallow Survey 2005 4th International conference on high resolution surveys in shallow water, Plymouth, Devon, UK.

de Groot, A.V., E.R. van der Graaf, R.J. de Meijer and M. Maucec (2009). "Sensitivity of in-situ [gamma]-ray spectra to soil density and water content." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 600(2): 519-523.

de Meijer, R. J. (1998). "Heavy minerals: from 'Edelstein' to Einstein." Journal of Geochemical Exploration 62(1-3): 81-103

Nederbracht, G. and R. L. Koomans (2005). Nourishment of the slope of a tidal channel: from experiment to practice. Coastal Dynamics, Barcelona, Spain, ASCE.

van Wijngaarden, M., L. B. Venema, R. J. de Meijer, J. J. G. Zwolsman, B. van Os and J. M. J. Gieske (2002). "Radiometric sand-mud characterisation in the Rhine-Meuse estuary Part A. Fingerprinting." Geomorphology 43: 87-101

Venema, L. B. and R. J. de Meijer (2001). "Natural radionuclides as tracers of the dispersal of dredge spoil dumped at sea." Journal of Environmental Radioactivity 55(3): 221-239.