MARITIME SOLUTIONS FOR A CHANGING WORLD

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SAFETY ROUNDTABLE

SHARING STRATEGIES CAN LEAD TO SAFER CREW TRANSFERS

NUMERICAL SIMULATION
Analysing unsteady characteristics to improve dredge pump performance

MUD MOTOR
A pilot study naturally disperses dredged sediment to develop nearby mudflats and salt marshes

HIGHLIGHT

SAFETY ROUNDTABLE

SHARING STRATEGIES CAN LEAD TO SAFER CREW TRANSFERS

Routine crew transfers are an integral part of completing a dredging project, as crews are transferred from vessel to vessel, equipment to vessel or land to vessel during the course of a project. These crew transfers are a complex activity which demand heightened awareness by all involved to address unexpected situations.

Weather conditions at sea can change in a moment's notice, the quality of locally sourced crew boats can vary greatly across the globe and language barriers between crew and local skippers may complicate communication. How do marine contractors ensure safe crew transfers even if conditions are not optimal?

To address these challenges, IADC held a roundtable exclusively on the subject of safety in crew transfers. A panel of experts on the subject from IADC's member companies partook in a discussion moderated by Joep Athmer, who opened the session stating: 'Safety should not have boundaries. Each company should not keep safety to themselves. Share what you know. We want everyone to come home safely.'

Key risks in crew transfers were identified and the roundtable shared their thoughts on the selection criteria for crew boats such as ensuring clear, structured communications, establishing safe environmental criteria, certifying the competence of crew boat skippers and facilitating management's involvement. **Read more on page 23.**

CONTENTS

WHY IS INNOVATION A TOP PRIORITY FOR THE DREDGING INDUSTRY?

Frank Verhoeven
President, IADC

At IADC's latest networking event held on June 12 this year, innovation and its importance to the success of the dredging industry was a central theme. With some 56 participants in attendance, subjects such as 'the future and innovation' and 'drivers of dredging' were highlighted. The emphasis on a fossil-free, circular economy and climate change spoke directly to the concerns of a dredging industry involved with world trade, the production of oil and gas and wind energy, urban development, tourism and increased environmental awareness. During the workshop sessions these themes of 'drivers and innovation' were animatedly debated.

Innovation is one of the cornerstones of the dredging industry and the industry has always stood ready to tackle new challenges.

One part of innovation is encapsulated in the concepts of sustainability. And this is the focus of the IADC-CEDA book *Dredging for Sustainable Infrastructure*. The book's insights are garnered from the knowledge pooled by a team of scientists and practicing industry experts. It represents years of expertise and a deep concern for the impacts that dredging can have on the environment. The philosophy behind the book is not to merely focus on the compensation/ mitigation of negative results of dredging, but to create an optimal value based on the pillars of sustainability. The key elements for successful dredging projects are: Early contractor involvement, ecosystem services, adaptive management and planning for the beneficial use of dredged material.

IADC member companies have a broad understanding of the positive influences that dredging can have on the enviroment. They use this know-how to design ports and harbours, support the oil and gas and wind energy suppliers and mitigate affects of historical contamination. Sometimes it is frustrating to see that this knowledge is not coming to the attention of relevant parties, which could benefit from it, economically and socially.

Dredging for Sustainable Infrastructure (available through IADC) reaches out to these groups – project owners, regulators, consultants, designers and contractors looking for an up-to-date reference of solutions for designing, implementing and managing water infrastructure projects.

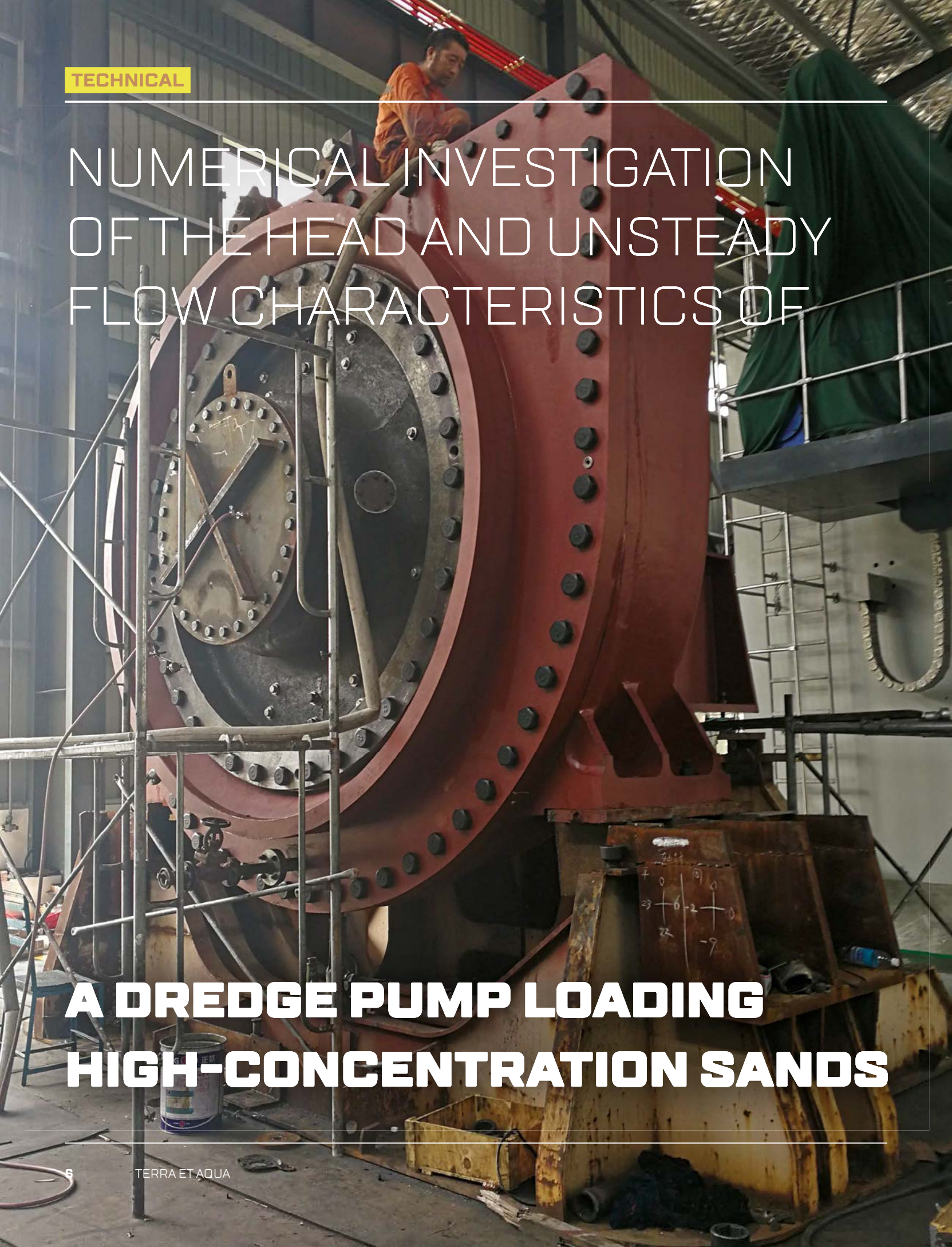
In this issue of Terra, some other areas of the industry's innovative spirit are on display: the Mud Motor, an innovative approach to beneficially re-use dredged sediment to enhance salt marshes; the ideas shared at the Safety Roundtable for crew transfers; and investigative research on dredge pumps, an article from IADC's Young Author winner.

In addition, the recently published book, *Breaking New Ground: Dutch Dredging Pioneers*, chronicles the many innovations of the past that led Dutch dredging contractors to become the world leaders they are today.

Bold thinking in the past gave birth to today's complex dredging industry and it remains crucial to a sustainable future.

TECHNICAL

NUMERICAL INVESTIGATION OF THE HEAD AND UNSTEADY FLOW CHARACTERISTICS OF A DREDGE PUMP LOADING HIGH-CONCENTRATION SANDS



The following research numerically simulates the unsteady water flow and silt-laden flow in a dredge pump and comparatively analyses the unsteady characteristics of the pump performance and the flow field in three typical conditions to expound the influence of sands and the relationship between head and flow field.

The research object is a three-blade dredge pump and the calculation domain includes a suction pipe, an impeller, a volute casing and two sidewall gaps beside the impeller shrouds.

Introduction

In the dredging industry, a dredge pump is a key equipment which is used for increasing the pressure energy of the pumped medium. Head is one of the most important performance parameters for a pump. However, even if the pump works in a stable operating condition, the head will periodically change, especially in off-design conditions. Strongly fluctuating head may affect the operating stability of the pump unit.

The essential reason accounting for the fluctuant head is the unsteady variation of the interior flow field. For common pumps that transport water, a lot of research has been conducted on the unsteady flow field, which has analysed the blade-tongue interaction effect, instable flow phenomena such as flow separation, backflows and secondary flows, and so on. While for dredge pumps which transport silt-laden flow, the detailed flow field depends on not only the pump structure and operating conditions, but also the interaction between solid phase and liquid phase. Hence, it is more difficult to understand the unsteady characteristics of the multiphase flow, and relevant research is not enough so far.

The existence of sands will increase the inertia and viscosity of mixture fluid. Meanwhile, the motion of sands may interact with the eddy flow in the flow passage, and the wake behind each sand particle may also influence the turbulence intensity of the water flow and furthermore affects the flow instability (Crowe C. T., 2000). However, it has not come to a consensus on how sands influence the flow instability. Through an experimental observation of the particle motion trails, Wu et al presented that the flow state was more stable as the particle diameter increased due to the increasing inertia. Mehta et al via PIV found that increasing the particle concentration could decrease the turbulence kinetic energy of the particles and shrink the backflow scale around the suction surface of blades. However, based on a numerical investment, Cheng put forward that the increase of particle diameter and concentrate both lead to an increase of average turbulence intensity in the pump.

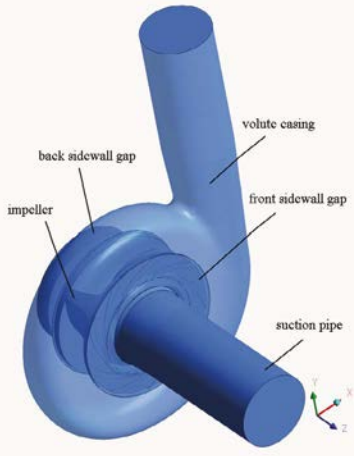
Recently, silt-laden flow in dredge pumps is usually investigated through steady simulation, and engineers usually focus on the value of the designed head but rarely on the fluctuation characteristics of the head. So far, only few works on unsteady multiphase flow in pumps have been published. Huang et al obtained a greater fluctuation in head when calculating with solid-liquid flow compared to with clean water. Zhang et al also found that it needed more time for the head to reach a stable state when simulating the start-up process of a pump with a solid-liquid mixture.

To sum up, research on the unsteady silt-laden flow in dredge pumps is still in an early stage. It remains to be further investigated that how the particle motions interact with water flow and influence the pump head, which is important to better control the dredge pump in engineering.

Research object

The research object is a three-blade dredge pump and the calculation domain includes a suction pipe, an impeller, a volute casing and two sidewall gaps beside the impeller shrouds. The suction pipe diameter is 160 millimetres

A



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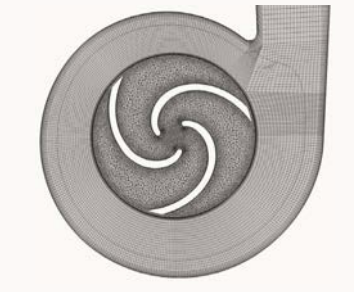

FIGURE 1

Flow passage of the dredge pump used for numerical simulation depicted as a 3D model (A) and mesh (B).

and the impeller outer diameter is 310 millimetres. The whole 3D passage of the pump is built, as shown in Figure 1A. The design flow rate is 0.08 m^3/s, recorded as Q_d and the design head is 11.5 metres, recorded as H_d.

Each domain is meshed via ANSYS ICEM CFD. The impeller is divided by unstructured elements and the grid density is increased around the blade surface. Other domains are divided by hexahedral structured elements. Mesh independence check is conducted among five sets of mesh which have similar topology but different element size. Finally the mesh with total 293 million elements is determined to be used in this research, as shown in Figure 1B.

Numerical model

Unsteady simulations are respectively performed for pumping water and silt-laden flow. For the latter, sands are assumed as balls with a uniform diameter d_p = 0.3 mm and a density of ρ = 2650 kg/m^3, and the volume concentration is c_v = 20%.

Since the concentration is relatively high, Euler–Euler two-fluid model is applied to model the silt-laden flow, in which water is regarded as continuous medium and sand is regarded as quasi continuous medium composed of dispersed particles. According to order analysis of the interphase forces acting on particles (Li Yi, 2014), for those with a diameter of 0.3 mm, drag force derived from interphase velocity slip should be taken into consideration and virtual mass force, Basset force, Magnus lift and Saffman lift can be ignored. The drag force on sands per unit volume of mixture is:

$$\boldsymbol{F}_{\mathrm{D,p}} = \frac{3}{4}\frac{C_D}{d_p}\alpha_p\rho_l\left|\boldsymbol{u}_l - \boldsymbol{u}_p\right|\left(\boldsymbol{u}_l - \boldsymbol{u}_p\right)$$

(1)

where α is volume fraction, ρ is density, d is particle diameter, u is velocity, C_D is drag coefficient, and the subscript l and p respectively represents liquid and particles. The Schiller-Naumann drag coefficient proposed by Schiller et al in 1933 is applied:

$$C_D = \left(1 + 0.15\mathrm{Re}_p^{0.687}\right)\frac{24}{\mathrm{Re}_p}$$

(2)

Furthermore, considering the high concentration, the authors add an additional drag force which forms when sands move from a high-concentration region to a low-concentration region and is modelled by the Favre Averaged Drag Model proposed by Burns et al:

$$\boldsymbol{F}_{\mathrm{TD,p}} = -\frac{3}{4}C_{\mathrm{TD}}C_{\mathrm{D,lp}}\frac{\alpha_p\rho_l}{d_p}\frac{\nu_{t,l}}{\sigma_{t,l}}\left|\boldsymbol{u}_l - \boldsymbol{u}_p\right|\left(\frac{\nabla\alpha_l}{\alpha_l} - \frac{\nabla\alpha_p}{\alpha_p}\right) = -C_{\mathrm{TD}}\frac{\nu_{t,l}}{\sigma_{t,l}}\left(\frac{\nabla\alpha_l}{\alpha_l} - \frac{\nabla\alpha_p}{\alpha_p}\right)\frac{\boldsymbol{F}_{\mathrm{D,p}}}{\boldsymbol{u}_l - \boldsymbol{u}_p}$$

(3)

Where $\sigma_{t,l}$ is the turbulent Schmidt number of the continuous phase and is take an experience value 0.9, C_{TD} is turbulence dispersion force coefficient and is also taken an experience value 1.0.

The governing equations of the silt-laden flow are as follows.

Continuous equations:

$$\frac{\partial}{\partial t}\left(\alpha_l\rho_l\right) + \nabla\cdot\left(\alpha_l\rho_l\boldsymbol{u}_l\right) = 0$$

(4)

$$\frac{\partial}{\partial t}\left(\alpha_p\rho_p\right) + \nabla\cdot\left(\alpha_p\rho_p\boldsymbol{u}_p\right) = 0$$

(5)

$$\alpha_l + \alpha_p = 1$$

(6)

$$\frac{\partial}{\partial t}\left(\alpha_l\rho_l\boldsymbol{u}_l\right) + \nabla\cdot\left(\alpha_l\rho_l\boldsymbol{u}_l\boldsymbol{u}_l\right) = -\alpha_l\nabla p + \nabla\cdot\left(\alpha_l\mu_l\left(\nabla\boldsymbol{u}_l + \left(\nabla\boldsymbol{u}_l\right)^{\mathrm{T}}\right)\right) + \boldsymbol{F}_{\mathrm{D,l}} - \boldsymbol{F}_{\mathrm{TD,p}}$$

(7)

$$\frac{\partial}{\partial t}\left(\alpha_p\rho_p\boldsymbol{u}_p\right) + \nabla\cdot\left(\alpha_p\rho_p\boldsymbol{u}_p\boldsymbol{u}_p\right) = -\alpha_p\nabla p + \nabla\cdot\left(\alpha_p\mu_p\left(\nabla\boldsymbol{u}_p + \left(\nabla\boldsymbol{u}_p\right)^{\mathrm{T}}\right)\right) + \boldsymbol{F}_{\mathrm{D,p}} + \boldsymbol{F}_{\mathrm{TD,p}}$$

(8)

As the impeller blade has a large curvature, flow separation is easy to occur. Consequently, the SAS-SST turbulence

model is chosen to solve the governing equations and meanwhile a curvature correction is also applied. Additionally, the turbulent viscosity with a particle-induced eddy viscosity coefficient proposed by Sato et al is modified to reflect the turbulence enhancement by particles.

$$\mu_{t,m} = \mu_{t,s} + \mu_{t,p} =$$

$$\frac{a_1 \rho_m k}{\max\left(a_1\omega, SF_2\right)} + C_{\mu,p}\rho_c r_d d_p \left|\boldsymbol{u}_p - \boldsymbol{u}_l\right|$$

(9)

Where $C_{\mu,p}$ is an experience coefficient and is taken the recommended value 0.6.

The entrance of the suction pipe is set as a total pressure inlet and meanwhile a solid volume concentration is specified there. The exit of the volute casing is set as a mass flow rate outlet. A Transient Rotor Stator model is applied to deal with the data exchange between a rotational part and a stationary part.

For each condition, the single-phase flow is computed first, and then the stable pressure and velocity field is used as an initial condition for modelling silt-laden flow. Each unsteady computation lasts at least 15 revolutions.

Result and discussion

Unsteady characteristics of head

Water flow and silt-laden flow were respectively simulated in six conditions from part-load conditions to over-load conditions. Efficiency, head and axial power of each condition is averaged over nine revolutions and the performance curves are shown in Figure 2. Compared to the results with water, the efficiency and head with silt-laden flow is lower and the axial power is larger. For the two types of pumped medium, the shape of corresponding curves is mostly similar, except for an obvious drop in the head curve of silt-laden flow when the flow rate is below $0.5Q_d$ which means that the existence of sands greatly decreases the head in part-load conditions and result in a change in slope. The condition of $0.5Q_d$ is a critical point, below which unstable operation may be easier to occur.

Under the effect of impeller-tongue interaction, there are inevitable flow fluctuations inside a pump, which will cause a fluctuant head. The influence of the existing sands on head fluctuation characteristics for three conditions – $0.5Q_d$, $1.0Q_d$ and $1.3Q_d$ – is illustrated in Figures 3 and 4.

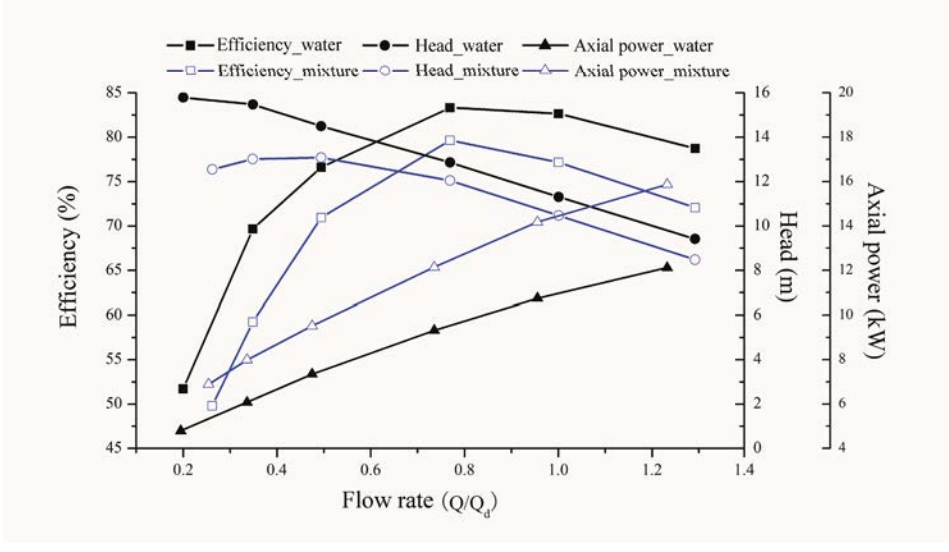

FIGURE 2

Performance curves of the dredge pump.

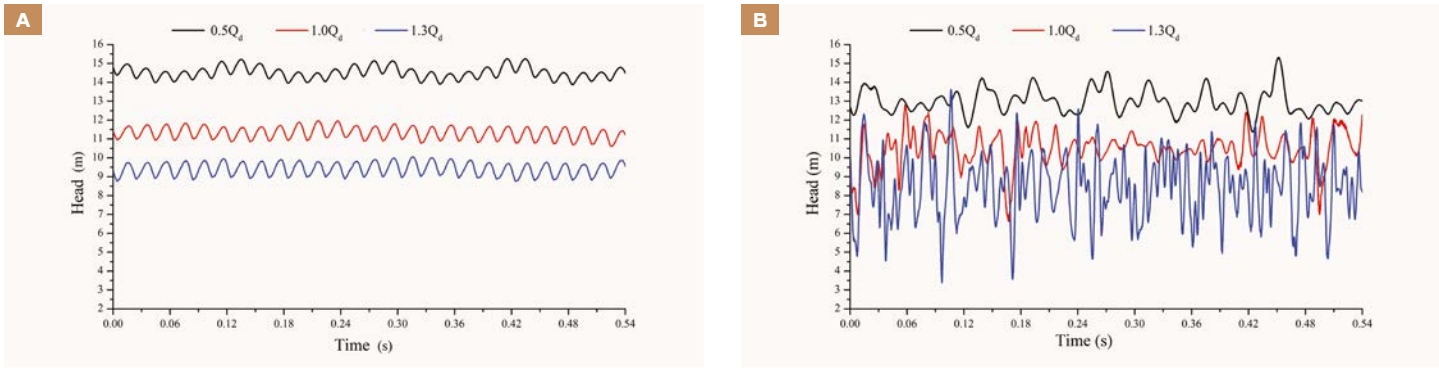

FIGURE 3

Head fluctuation over time shown for water flow (A) and silt-laden flow (B).

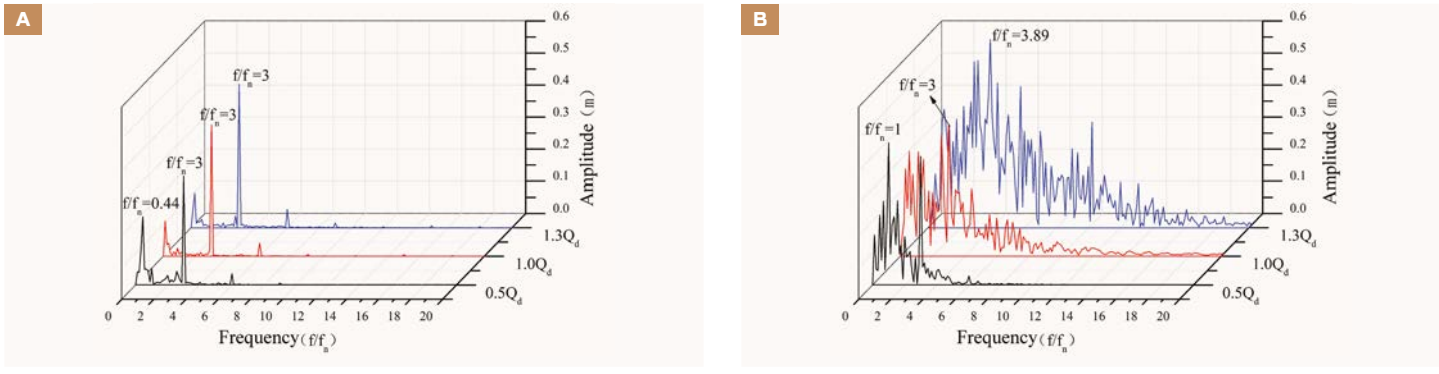

FIGURE 4

Spectrogram of head shown for water flow (A) and silt-laden flow (B).

As seen in Figure 3A, with water, head is periodically fluctuated over time and the pattern is similar for the three conditions. Meanwhile, there is also an evident low-frequency wave in the condition of $0.5Q_d$, which results in a higher peak-to-peak fluctuating amplitude in this condition than in the other two conditions. Further FFT analysis is displayed in Figure 4A. The dominant frequency is all the blade passing frequency, $3f_n$, where f_n is the axial rotational frequency. There is a low frequency, $0.44f_n$, with a relatively high amplitude in condition of $0.5Q_d$, consistent with the time-domain plot.

In contrast, it is more complicated that head varies over time for silt-laden flow and the amplitude increases by 3~10 times, as shown in Figure 3B. It is difficult to recognise the main frequencies with the naked eye. FFT analysis shown in Figure 4B demonstrated that the dominant frequency differs among the three conditions. In design condition, the dominant frequency is still the blade passing frequency $3f_n$, while in the condition of $0.5Q_d$, the dominant frequency drops to $1f_n$, and in the condition of $1.3Q_d$, the dominant frequency goes up to $3.89f_n$. In addition, compared with water flow, there are more frequency components in each condition and the amplitude of many subdominant frequencies is much higher, especially in overload conditions. This result may have to do with the complicated interactions between the two phases and the turbulent enhancement from sands.

Comparison of flow field

The root cause of the unsteady head is the variation of inner flow field of the pump. Instantaneous flow streamlines in the three conditions with water flow are displayed in Figure 5. In condition of $0.5Q_d$, there are three low-velocity separation vortexes respectively in each blade channel and the flow field is approximately symmetrical. The head fluctuation at $0.44f_n$ may be derived from the low-frequency variation of these separation vortexes. As the flow rate increases, the separation vortexes shrink. In the design condition one of these vortexes seems disappear, and the flow field in impeller becomes asymmetrical which enhances the impeller-tongue interaction. When the flow rate increases to $1.3Q_d$, the separation vortexes totally disappear and the unsteady characteristics of the flow field is not affected by the separation vortexes any more.

The instantaneous streamlines in the impeller with silt-laden flow are shown in the first line in Figure 6. The separation vortexes

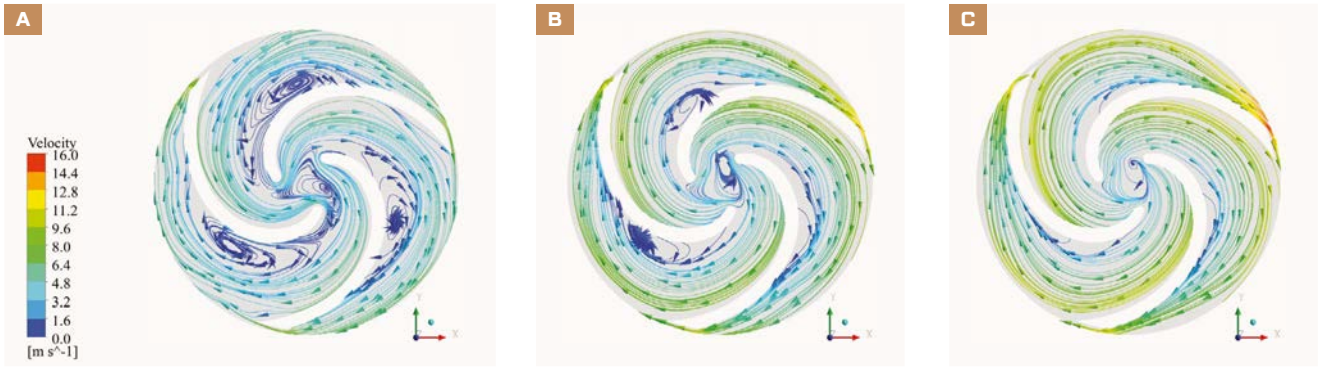

FIGURE 5

Instantaneous streamlines in the impeller with water flow shown for three conditions: $0.5Q_d$ (A), $1.0Q_d$ (B) and $1.3Q_d$ (C).

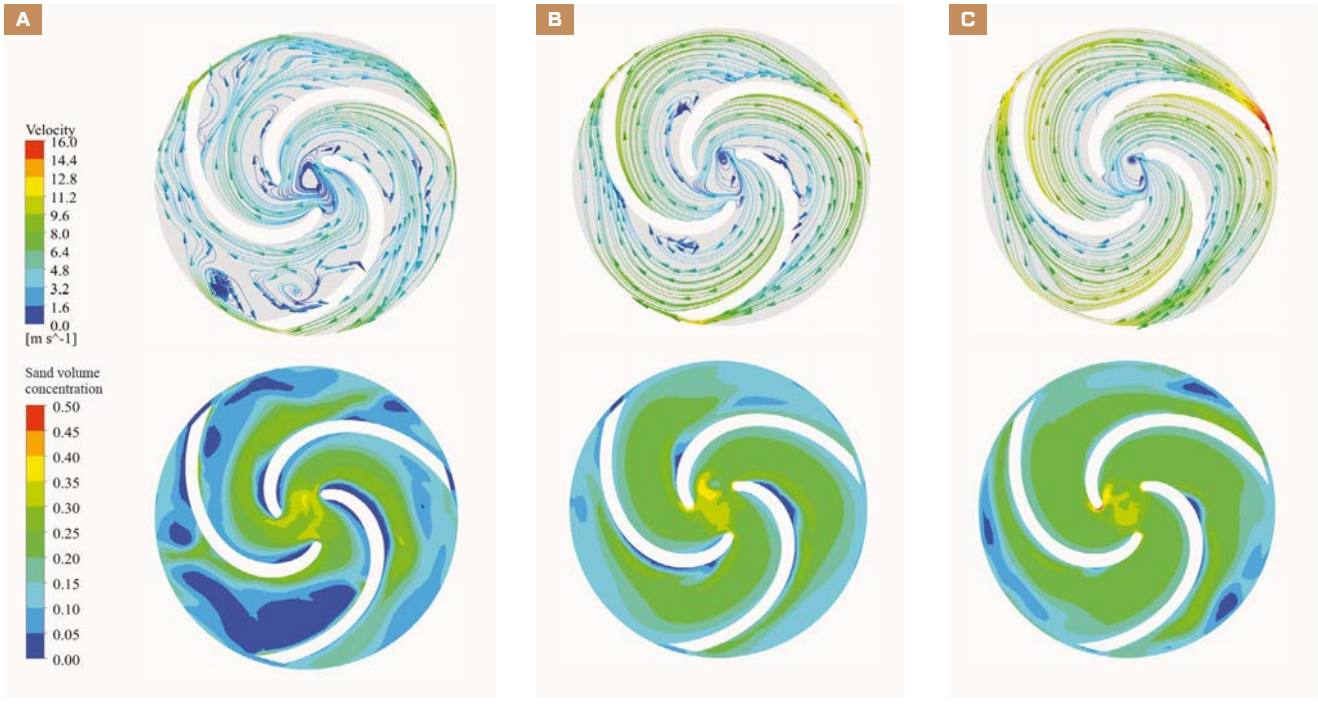

FIGURE 6

Instantaneous streamlines in the impeller with silt-laden flow shown for three conditions: 0.5Q_d (A), 1.0Q_d (B) and 1.3Q_d (C).

concentrate in one blade channel rather than symmetrically distribute in the impeller. In one channel, the vortex moves to the blade outlet at the suction surface, and in the other two channels there exists flow separation in some degree without forming vortexes. According to the sand distribution contours shown in the second line in Figure 6, the asymmetrical streamlines are directly related to the uneven distribution of sands. In part-load condition, the sand velocity is relatively low, sands cannot move evenly within the whole flow passage due to their own inertia and the asymmetric effect from the volute casing, and then they will pile up in some blade channels. In the channel with a small sand concentration, separation vortex forms, and in turn the expansion of vortex prevents other sands from entering this channel. The interaction between the vortex and the tongue may be the main source of the head fluctuation at 1f_n. The separation vortex rotates with the impeller and spreads among the three channels at a certain speed, which looks like the phenomenon of rotating stall and causes large hydraulic loss. This may be the reason why the slope of the head curve changes at this point.

As the flow rate increases, the sand distribution turns to be more symmetrical and the distribution region expands, and compared with water flow, the degree of flow separation decreases. Although there is no evident vortexes in the impeller, the streamlines are not as smooth as those in the water flow. The bounce of sands and the instantaneous interaction between sands and water will also cause random fluctuations. The larger the flow rate is, the stronger the interaction effect is.

The instantaneous streamlines in the volute casing in the three conditions respectively with water and silt-laden flow are shown in Figure 7 and Figure 8. In part-load conditions, the flow field in the volute casing looks similar. The main difference between the two pumped medium is embodied at the flow field in the downstream region of the tongue and the diffused section in design condition and overload conditions. The existence of sands decrease the water flow velocity and flow symmetry in the volute. In the condition of 1.3Q_d, with water flow the flow velocity at the outlet section is uniform, about 5~7 m/s, while with silt-laden flow, there is a large velocity

Water flow and silt-laden flow were respectively simulated in six conditions from part-load conditions to over-load conditions.

FIGURE 7
Instantaneous streamlines in the volute casing with water flow shown for three conditions: 0.5Q_d (A), 1.0Q_d (B) and 1.3Q_d (C).

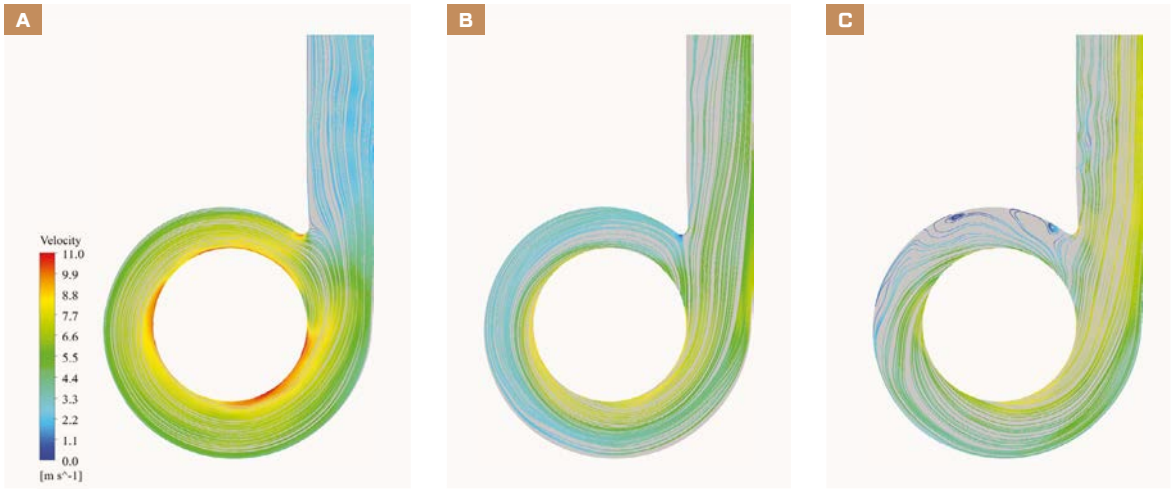

FIGURE 8
Instantaneous streamlines in the volute casing with silt-laden flow shown for three conditions: 0.5Q_d (A), 1.0Q_d (B) and 1.3Q_d (C).

difference, about 3~7 m/s and the waves of streamlines also reflect a turbulent status at the volute outlet. The shape of volute is always designed based on flow characteristics in the design condition, hence in the condition of 1.3*Q*d, there is a flow impact at the downstream of the tongue and the sands increase the impact region, which means it strengthens the mismatch of the volute casing in overload conditions and then increases the complexity of head fluctuation characteristics.

Conclusion

In this research, unsteady simulations of water flow and silt-laden flow are conducted in several conditions for a dredge pump to analyse the effect of sands on pump performance and unsteady flow characteristics. Results show that, the existence of sands will lead to a decrease in head and efficiency and a rise in axial power, and the head curve will turn from a negative slope to a positive slope when the flow rate is lower than 0.5Q_d. Sands also change the head fluctuation characteristics, increasing its amplitude and frequency components. In the condition of 0.5Q_d, sands make the separation vortexes asymmetrical distribute within the impeller and change the dominant frequency of head fluctuation from blade passing frequency to axial rotational frequency.

In design condition and the condition of 1.3Q_d, the flow field is more symmetrical, but under the influence of sands, the average flow velocity in the volute casing decreases, and the interaction between sands and water become more complicated and random. Especially in the condition of 1.3Q_d, the flow state degrades around the volute outlet, causing the dominant frequency of head fluctuation increasing to a higher region, and forming other more frequency components.

In conclusion, comprehensively considering the performance and unsteady flow characteristics of the dredge pump, when transporting high-concentration silt-laden flow, engineers should first apply a suitable numerical model to obtain the pump performance curves and the unsteady flow characteristics of some important conditions, and then seriously choose proper operation conditions in order to avoid flow instability problems in some part-load conditions and high-frequency vibration in some overload conditions. In the future, further study will keep on simulating conditions with different sand parameters so as to obtain operation characters throughout whole conditions and scientifically put forward a safe and highly efficient operation region.

Summary

The article presents research which numerically simulates the unsteady water flow and silt-laden flow in a dredge pump and comparatively analyses the unsteady characteristics of the pump performance and the flow field in three typical conditions to expound the influence of sands and the relationship between head and flow field. Results show that high-concentration sands enhance the flow fluctuation and change the head curve slope at part-load conditions which is adverse to operation stability of the pump-pipe combined system.

In the condition of 0.5 times of the design flow rate, the uneven distributed sands induce rotating stall in the impeller and makes the dominant frequency of head fluctuation decrease from three times of rotational frequency to the rotational frequency. In the design condition, the dominant frequency of head fluctuation maintains at three times of rotational frequency, but the turbulence enhancement of sands enrich the frequency components. In the condition of 1.3 times of the design flow rate, sands exacerbate the complexity and random of the flow state near the downstream of the tongue and the diffused section of the volute casing, causing the dominant frequency of head fluctuation increase to 3.89 times of rotational frequency and there are more frequency components and larger amplitude.

Therefore, in engineering, considering the safety and stability of the dredge pump system, an accurate performance curve should first be obtained and then the pump should be controlled to work in a reasonable range of flow rate.

First presented as a paper at the 22nd World Dredging Congress, this article has been published in a slightly adapted version with permission of the copyright holder, WODA. At the conclusion of the conference, the Young Author Award was given to Cao Lei to recognise her outstanding paper and presentation.

At the conclusion of the the 22nd World Dredging Congress, IADC's Secretary General René Kolman (right) bestowed the Young Author Award to Cao Lei (left) to recognise her outstanding paper and presentation.

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Results show that high-concentration sands enhance the flow fluctuation and change the head curve slope at part-load conditions which is adverse to operation stability of the pump-pipe combined system.

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Cao Lei received her PhD in Fluids Mechanics and Engineering from Tsinghua University in 2017. She jointed CCCC National Engineering Research Center of Dredging Technology and Equipment CO. LTD after graduation. As a R&D Engineer, she is involved in simulation study on dredging equipment, especially on the multiphase flow in dredge pumps. She is currently responsible for a project about reliability analysis of dredge pump shafting.

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Zheng Lin-zhu
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CEO OF DEME GROUP
LUC VANDENBULCKE

‘WE HAVE A GROUP THAT, BY ITS NATURE, **IS RECEPTIVE TO CHANGE.’**

At the start of 2019, Luc Vandenbulcke took the reins of DEME Group. A civil engineer employed for 21 years within the group, he has noteworthy qualifications: he cofounded and led DEME’s fastest growing subsidiary company which specialised in hydraulic engineering projects and offshore wind farms. His track record is directly applicable to his new role as he leads an organisation which wholly embraces constant change, welcoming innovation and navigating the evolving nature of sustainability.

How have you experienced the transition from your former roles within DEME Group to your new role as CEO?

I have already been quite closely involved with all of the activities – dredging, offshore, environmental and infrastructure activities – through my Deputy COO function so I would say that I know the group well.

GeoSea, now DEME Offshore [DEME's specialist in complex offshore marine engineering projects] – and the offshore business in general – has been responsible for a very significant chunk of the DEME Group's turnover for a couple of years. DEME Offshore is itself a big enterprise, but of course DEME Group is much bigger. In terms of the scope of responsibilities and so on, the transition is mostly the fact that as CEO of the group, you report to a Board of Directors.

What is your vision for DEME? Does your vision change or build upon your predecessor, Alain Bernard?

The vision is certainly building upon what Alain Bernard has done, and we have our management team and board. DEME has always been a company with many stakeholders and a team leading it, and that vision is not changing because one individual person has now changed.

You have to look at the total dredging industry. There are fewer contractors than fifteen or twenty years ago, and DEME has grown into a global maritime solutions provider. And that is certainly the vision that we will continue to build upon. We are developing a number of strong activity lines and through all of these activity lines, we are building upon our vision of 'offering solutions for global, worldwide challenges'. These challenges include a growing world population, rising sea levels, coastal protection, reducing the effects of greenhouse gases or the exhaust of gases through our wind farm construction and concessions, remediating pollution, the scarcity of mineral resources and cleaning up plastic soup and polluted environments. For us, maritime-related challenges are domains where we aim for sustainable solutions.

Our activity lines include: dredging – which continues to grow with innovation at the core, offshore with a sharp focus on sustainability and renewables but also in oil and gas, environmental remediation works, and infrastructure works.

How will you approach change at DEME?

Change is constant at DEME. The grouping of the offshore activities is one change. Where we used to have a lot of companies operating in the group, more or less doing dredging or dredging plus activities, we are now emphasising four activity lines and have grouped the companies along those lines: Dredging, offshore, environmental infrastructure and on top of that we have our concession activities.

We own and operate a number of wind farms which is something we have being doing for many years. That is one of the domains that Alain Bernard and I together will continue to focus on. Another domain where we certainly see growth is deep-sea mining and harvesting activities, where we will collect nodules. And that is because another challenge we see is a shortage of minerals going towards a more electrical/ sustainable energy mix. The world will also see a need for a number of materials which are going to be in short supply. Be it cobalt, manganese, nickel, or copper. All of these are available on the sea bed in some of the areas of the Pacific where we have gained concessions. These concessions and the deep-sea mining and harvesting are new activities that we are exploring, in addition to our four key activity lines. This represent how we are in a constant movement and change.

These materials seem quite important. What would happen if we run out of them?

First of all, we think that they are very abundant on the ocean floor. Although there is some terrestrial mining, the question really is the upsides and downsides of both mining locations. In the deep sea, these materials are really lying on the sea bed, not buried, so it's really a matter of picking them up. While there are political and geographical issues, with land mining there is a lot of deforestation going on. Which convinces us that maritime harvesting is a viable alternative and a place where the minerals are still abundantly available.

Are there short term goals you hope to accomplish?

Within the next year we will achieve the changes which we announced in October 2018. At the forefront are supporting the concessions and a number of growth domains like deep sea harvesting. I don't foresee too many problems. We have a group that is by its nature – by setting up new projects every day – receptive to change.

Innovation is really at the core of the DEME Group. We have a number of people that "manage" the innovation or nurture it but not as in some companies where you have a separate R&D department where a couple of people are inventing stuff. No, we have a department that is encouraging the whole group to invent things and to innovate and improve things and then we bring the people together in innovation. We have innovation contests but we also bring in what we call DEMEx, the young innovators, we bring them together for a couple of days, two or three

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Meet Luc Vandenbulcke

A civil engineer, Luc Vandenbulcke received a Master of Engineering from Katholieke Universiteit Leuven (Catholic University in Leuven, Belgium). His professional career began with maritime research and two years of work experience at a Belgian maritime contractor until 1998 when he joined DEME Group. There he started out in Hydro Soil Services as a project manager of offshore projects. Then in 2004, he and two colleagues co-founded GeoSea, a subsidiary of DEME, and in 2006 he became General Manager.

Outside of his work role, he makes time for personal interests which include nature, biking, small dinghy sailing and spending time with family. Luc Vandenbulcke concedes: 'That's more than 100% of my time so it's a constant occupation. These are my hobbies outside of work but I would say my work is part of my hobby as well.'

days, together and try to bring up new ideas. We have them in task forces and working groups. Amongst other things, we've had coming out of these gatherings, the principle of the Living Stone cable installation vessel, the plastic soup collector, and a number of other initiatives that we are nurturing at the moment. For me, all the 5,200 people in the group are the innovation department.

What for you is the most critical initiative of all the things you have mentioned?

The most critical initiative for me is the people. Let's say the critical point – whether it is an initiative or not -- is an improvement action to get the right number of people on board with the right skill sets and to get them acquainted with the group. We have seen a massive growth in annual turnover. But not only that, the complexity of projects that we are dealing with has grown massively. To deal with this, you need more people, but you also need more and more different skill sets. We used to primarily recruit people who are civil engineers in construction or civil works. Now we need electrical engineers in our environmental business and we need people dealing with chemistry. As you know the world is increasingly turning to IT systems, anything which is artificial intelligence. So that is certainly something that I would not say is difficult but it's a challenge. That is one of our focus points – to get the right people on board and get them up to speed on what we do. That I think is most critical for me: The specialisations and the global footprint as we move our activities to Taiwan, for instance, or in renewable energy, to China.

Combining the technical complexity with the geographical spread means you need to find the right people with the right skill set, the right attitude to be able to travel and be flexible – all of that is a challenge.

How do you yourself drive the innovation, beyond the Innovation Department?

We will continue to have DEMEx, who are the younger innovators that we bring together for a few days. And we'll have the 'innovation diver' that is the permanent-semi permanent contest where we try to gather the innovation ideas and innovation events for the group. We will continue to do that at the pace we did before. Sometimes these initiatives are seen as coming fast one after the other, but the world is changing at an extremely fast pace so you have to keep up.

To give you an example, remotely-operated vessels – ROVs – that could be something which may be operational faster than self-driving cars. There's a little more space on the sea than on the road. Another thing is drones. A lot of the land-survey works has been taken over by flying drones. And floating drones are doing the seaside of it.

Our employees who have worked here in the office for a long time, when they are looking for somebody's phone number, they have a phone book and look it up. The younger generation doesn't do that anymore. So we developed an app where you can find everybody within the company with a profile. But it's those things that we will continue to do and even accelerate. We have to.

What happens to the people who were operating the survey vessels? Are they now operating the drones?

Yes, they are. For instance, on a reclamation site. Surveying the levels used to be a job of a surveyor with a total station and another with a stick and they went to do this job. It was a pretty dangerous job working in between the machines and sometimes in swamps. Those people have turned into drone operators and survey much faster. They are still doing those jobs but are happy to gradually convert into the more modern version of their jobs. It's the same for all of us.

The new coastal road being built at Reunion Island. Read more about this project in *Terra et Aqua* #151, page 27.

The company's culture seems to emphasise innovation. How do you ensure this culture is maintained? Do you have a personal role in enforcing or strengthening this?

We emphasise innovation but we also emphasise sustainability. People talk a lot about sustainability. But when you think a bit deeper it's a very obvious word. Something sustainable means it will still be there in 20 years. If you have a company that makes typewriters today, you are probably having a hard time against computers. If you have a company making CDs or video recorders, that is not sustainable. And the same applies to our business. Being sustainable as a company means taking the initiative to reduce your carbon footprint on your own, reducing your environmental impact, striving for ethical business, gender equality and sustainable development. What will be for me a constant challenge is to see what the sustainable direction for our business and business portfolio will be. The world is rapidly changing and we must find solutions.

What about the image of dredging in the eyes of the public?

Not only do we have to work on the dredging industry's image – because that's the traditional green washing – we also have to do something substantive about it. When we are questioned about sand, we have to make sure that the projects that we do are done in a sustainable way and have a sustainable goal. I think you will hear me more often on that subject because I simply think it is obvious and only companies that think in a sustainable way will be here in the long-term.

There is constant innovation and implementation in your business model. How can we make the industry as a whole improve when only some companies are making changes?

Some people know dredging from the pure dredging and dumping, but that's only one part of the activity as a maritime group like we are, certainly in the Low Countries. We have coastal defence, the construction of dykes, creating sand reclamations. Other countries have similar issues. The United States is not an accessible market but a lot of areas in the states do have issues with flooding and hurricanes and need similar techniques. Coastal protection is also dredging. Cleaning polluted soils is also dredging. Picking up plastic soup is also a kind of dredging. And making infrastructure, like new harbours and so on is dredging. I often say we have a harbour every 20 kilometres here in Europe. And that has brought us wealth. With a growing population worldwide, we have to make sure everyone has access to that type of infrastructure and we will have to make sure we construct that within our environmental programmes, in the most sustainable way we can.

What do you perceive to be the big issues facing the dredging industry and DEME? For instance, is increased flooding because of climate change an issue?

Flooding is not an issue for the dredging industry. It's an opportunity. The dredging industry is there to find a variety of coastal defence solutions which are not always building high dykes. There are soft protections with underwater berms and so on and we will certainly have solutions for it.

Generally the big issues for the dredging industry are things like geopolitical issues. There are a number of countries which have quite some restrictions on foreign dredging companies. In the United States we are faced with the Jones Act – more specifically the Foreign Dredging Act. That is obviously an issue but the same applies in other ways in other countries like China, to name one. And then you have a lot of countries like Venezuela where there is no political stability. If you take away all those countries, the dredging industry, which has been limited to a number of players coming from only a few nationalities, has to make sure that the market is not shrinking too much. These are the issues and challenges every industry is facing today. We will see what the outcome will be. I think as always it's probably not black and white and there will probably be a number of different types of grey. But certainly you can see that such measures go against globalisation and are a challenge for the dredging industry, which by nature is global. So the more free trade there is the more harbours will have to be built, more countries are accessible for us as dredgers. That is a big issue, and we have to be wary of that.

Would you say renewable energy is the top development that has most of your attention at the moment?

I would say that's one issue, but on the other hand we cannot deny that for DEME in the first place and our colleagues as well, we have all jumped on the train of offshore renewable energy which is a global growth market. So there are opportunities coming up and also a lot of change coming up. In the energy area, you see quite a lot of controversy. Oil

In the four months since I became CEO, we've already implemented a consensual strategy, put together all of the offshore companies. Where we used to have Tideway, GeoSea, A2Sea, GeoSea Maintenance, they now have been brought together under the umbrella of DEME Offshore.

is diminishing and I think it will continue to diminish in the global energy cocktail. That means we will go to electricity, so there will be a lot of cabling to be done, a lot of turbines to be built and energy storage to be constructed. LNG will take away from oil and certainly LNG and gas in general is a transition fuel for the next decade. There will be a lot of installations to be built and pipelines to be laid.

Of course, there are really many issues. We are not losing sight at all of obvious sea level rise and coastal defence issues going with that. We will see more flooding, we will see more requirements and we will see more harbours being built because of growing population. But going back to the energy sector – this is a personal conviction but I'm quite sure and the figures are proving that – that renewable energy will be *the* big growth market. You see that in the added capacity of energy today, renewables are growing at a much faster pace than other energy sources. I always say renewables are the last local market. They are produced and consumed locally.

For instance, you have a solar panel and you put it in your car or you heat something with it or plug in your computer on it, it's the same with wind. Wind-generated energy is transported 100 to 200 kilometers maximum. But some day, as soon as we can transport it long distances by converting it to gas or to something like that, you will see the global renewables market grow.

What is your view of IADC's role within the industry and what value does an association provide in today's market and society?

I think the dredgers are lone wolves, with the accent on both words. The companies are developing their own views on sustainability, on how to approach the dredging world, on how to deal with the more closed markets, on what sustainable fuels are and so on. So I think IADC has a very important role to be the centerpiece of where the dredging industry comes together with one voice and one view of itself.

If everybody has a different view of what sustainable dredging is, then the public will simply not believe us. We can only have *one* focused view on those subjects. And IADC has a difficult role to consolidate those views and to bring them to the outer world. But they are doing a great job. For instance, the new book, *Dredging for Sustainable Infrastructure*. That I fully support.

If you see that today investment in the Norwegian Sovereign Investment Fund. They are not investing in oil-related businesses

Meet DEME Offshore

One of the first tasks Luc Vandenbulcke oversaw in his new role as CEO was the debut of DEME Offshore. This is the official name for former subsidiaries of DEME Group which were involved in various offshore activities: GeoSea, Tideway, A2Sea and EverSea. The name of the now-united organisation is also a reflection of DEME Offshore's wider goal: to integrate the collective's expertise and capabilities to provide superior solutions for the evolving requirements and challenges of future projects.

DEME Offshore's activities include foundation and turbine installations such as at the world's largest offshore wind farm, Hornsea, shown on page 20.

which was unimaginable ten years ago. Where will we be in the next ten years? If in ten years we as an industry cannot prove we are now a sustainable business, then we may be very heavily disrupted because that will go very fast and very far. You will see that people – and you can see it today – are asking, 'what are you doing with your carbon footprint?'. If you go for financing the banks already have questions. Of course if you have export credit you have questions about ethical business and the questions about sustainability, you have the questions about carbon footprint. Again look back ten years ago everyone fueled their cars without any second thoughts, everybody was travelling as much as we could, saying we are sustainable, we are going to walk in nature or in the Himalayas and today you are a bit ashamed. And you see in how short a time that has popped up and then think about what will 'sustainability' be in the next ten years?

Our industry needs to be prepared for that and be sure that we have self-imposed rules and that we have progressed on the scale of sustainability – whatever that scale is – and we *prove* that we have progressed in a meaningful way to the industry.

The publication goes a long way in responding to the market of what that means.

And I can see the way IADC is followed on social media that they are doing a great job in bringing and creating the image of dredging as an innovative business, as an international business and sustainable business which is very important to have that voice for all of our stakeholders, stakeholders being NGOs, politicians and journalists. It's very important because we all have the same aim, all the dredging companies: bringing good people on board and that requires a group and a voice representing us. So I think that the role of IADC is important and cannot be underestimated.

What would you advise or say to young people considering dredging as careers?

Well of course I go to recruitment events and see a lot of young people and I can only say what's probably applicable for DEME but to many of the other dredging contractors, we have become maritime engineering groups with the diversity of maritime engineering projects going on the ones that we mentioned before – land reclamation tunnel construction coastal defence, offshore energy. It is important that when you recruit young people, you make that clear. Our companies are very diverse and offer many, many opportunities.

What is your greatest career achievement?

GeoSea which we started with two or three people in 2004 and then it grew. I have been lucky to have led GeoSea from its start until the 1st of January 2019. From the first day of GeoSea I have been either the General Manager or Managing Director and I have fulfilled that role for the last 14 years. I have always been in the same role. But before that I used to be a project engineer, tender engineer, project manager within the DEME Group, already doing offshore wind but also jetties and small dredging works. So I was doing a lot of things in the group. But these last 14 years in the group have been dedicated to renewable energy projects and then the last five years of that I was Deputy Operations Officer so focusing on mostly the master desk and risk management.

What is your greatest career disappointment?

That's a difficult question. I haven't been very disappointed. There have been years in which

The dredgers Reynaert and Amazone performing deepening works on the River Seine.

we had a number of target projects in which we said 'these are projects we need to score' and then it didn't happen, but they were then replaced with opportunities. So I think you have disappointments in your career as a contractor, but usually other opportunities appear and that leads you to the fact that you have to be optimistic in our business. It's an optimistic business that's always looking ahead.

In the four months since I became CEO, we've already implemented a consensual strategy, put together all of the offshore companies. Where we used to have Tideway, GeoSea, A2Sea, GeoSea Maintenance, they now have been brought together under the umbrella of DEME Offshore.

Branding them like this together brings the DEME Group more in the spotlight as one brand. We already had that as a vision and we've accelerated the process in the last four months. We still say 'that's a guy from GeoSea, oh no no I mean DEME Offshore', and that will continue for a little bit, but it will certainly phase out and the offshore people are now already operating under one umbrella on a number of projects. We have done that at a really fast pace and it's working out well and, honestly, I think it's well received by the market.

Resumé

2099–Present
CEO of DEME Group

2013–2018
Deputy Operations Officer of DEME Group, Managing Director of GeoSea

2005–2013
General Manager of GeoSea

2005
Co-founded GeoSea

1998–2005
Project Manager at DEME Group

www.deme-group.com

1996–1997
Project Manager at Herbosch Kiere

1994–1995
Postgraduate in Maritime Engineering UPC Barcelona and maritime researcher

1989–1994
MSc in Civil Engineering at KU (Catholic University) Leuven

www.kuleuven.be

CAN SHARING STRATEGIES LEAD TO SAFER CREW TRANSFERS?

As an integral part of completing a dredging project, crews perform routine crew transfers. But are these transfers so routine? Whether from vessel to vessel, equipment to vessel or land to vessel, crew transfers are a complex activity which take place multiple times during each and every project. Weather conditions at sea can change at a moment's notice, the quality of locally sourced crew boats can vary greatly across the globe, and language barriers between crew and local skippers may complicate communication. How do marine contractors ensure safe crew transfers if the presented conditions are not optimal?

Dredging companies are committed to safety. This was the motivation for IADC to hold a roundtable exclusively on the subject of safety in crew transfers. A panel of experts on the subject from IADC's member companies partook in a discussion moderated by Joep Athmer, who began the session by stating: 'Safety should not have boundaries. Each company should not keep safety to themselves. Share what you know. We want everyone to come home safely.'

Participants of the roundtable discussion were Peter Dotselaere from Jan De Nul Group, Harry Hesseling from Boskalis, Ruben Hulstaert from DEME Group, Arjan Jager from Van Oord (see Figure 1).

Goals for the discussion

The collective goal was to achieve a safer environment for all crews. The session presented the opportunity for participants to connect with other dredging companies and share in-house information and expertise.

The bottom line of holding such a discussion is to learn from each other. Each company strives to be better and has made great strides individually, but if companies can come together on the subject, then a standard can emerge which can serve as an industry-wide example. Integrating safety more routinely in daily crew transfers requires a change in behaviour of all people involved. This can only be achieved by constant coaching and managing.

Participants also concurred that having a common standard which can be shared with suppliers would be beneficial. If contractors set out common goals or standards and communicate them, then a lot can be gained from suppliers of equipment.

Identifying risks

There are specific aspects of the crew transfer process which can be addressed to increase safety. In particular, participants noted that safety of crew transfers can be enhanced by looking at various topics:

- Establishing selection criteria for crew boats
- Clear structured communications during the transfer process
- Establishing safe environmental criteria
- Ensuring competence of crew boat skippers
- Management involvement

In addition to these topics, the procedure itself must be written down clearly so as to eliminate concerns, which can result from overwhelming the crew with too many steps or details or using confusing terms.

Selecting a crew boat

A weatherproof and season-neutral decision regarding the crew boat should be taken upfront to ensure a suitable vessel has been selected for use in all seasons and possible weather conditions present at a specific project site.

The season or time of year when a boat is hired should be considered while selecting a crew boat for use in year-round projects. If a boat is selected during a calm season, crew may be able to easily step up and off, but six months later, when the monsoon begins, there may be waves of three, four or five metres.

Sometimes projects may be executed in areas where suitable equipment is not readily available. However, with some out-of-the-box thinking creative alternative solutions can be devised. These solutions may involve a higher cost but that should not be a reason to select or use equipment which is unsuitable or unsafe.

A project team's decisions, which are delineated at the start of the project, should not be infringed upon for operational reasons. If crew changes are planned to be done in the

This session is interesting because we are connecting with other dredging companies which is important if we can share some of our information and expertise.

FIGURE 1

The roundtable in action at Tideway in Breda, The Netherlands.

port and an inland boat is selected to support this decision, then this project-specific decision should be planned into the project's timeline. Likewise, if a project team decided that a vessel can only be boarded when the hopper is loaded, then the time frames where boarding the vessel are allowed should be allotted for within the project's schedule.

Crew boats should also meet minimum outfitting requirements. Harry Hesseling of Boskalis expects the crew boat 'to comply with a safety plan, first aid kit, fire extinguishers, emergency closing valve in the fuel system, navigation chart, GPS (global positioning system), VHF (very high frequency) radio, radar, reflector, navigational light, a designated transfer area – because it's not only the crew boat but it's also the stepping up and off the boat – and fenders'.

Communicating clearly

The authority of the captain of the main vessel is very important. Therefore if a captain needs to make a decision and say 'crew transfers in these conditions are not safe anymore', then without question, another solution must be found. If this means sailing to a sheltered port for a safe transfer, even if it would take more time, then this decision – apart from postponing the transfer – is the only correct one.

There must be clear communication between the hopper and crew boat, with the captain indicating when the crew boat is permitted to come alongside the hopper. Sometimes the hopper is overflowing and creating a wake on the side of the vessel. In this situation having a crew boat alongside the hopper should be avoided. In a designated area, it is common practice to give lee to the crew boat and the captain signals the correct moment, saying to the crew boat: 'Okay, you can come alongside, I will slow down.'

Captains must be given the confidence to make these kinds of decisions. Ruben Hulstaert of DEME states: 'The captain decides if the vessel is on stand-by. If the captain says "we cannot do the crew transfer yet" for some unknown reason, then you may have to wait an hour. There is no other solution, the captain is responsible'. Cultural behaviour takes time to grow, therefore the company culture must support decisions which ensure safe transfers are performed

The individual also has a vital role in ensuring safety. Individuals must be empowered to speak up if they feel unsafe in any way while performing a crew transfer. As well they must speak up *before* a situation becomes unsafe. It's an individual's responsibility to look out for themselves and also for others. Harry Hesseling of Boskalis explains: 'If you step into an unsafe situation, then you could put other people in that unsafe situation as well. If you are not confident in doing the transfer, then don't do it.'

Not everybody's mindset is on the same level when it comes to safety. Therefore, a way to push everyone to a higher level is through a shared way of thinking. A crew member, who is a newcomer, has a different way of thinking about safety than someone who has been working for 20 years. The experienced crew should help new crew and train them. While new crew may be eager and want to help, they should learn and use approved safety practices.

On the other hand, those who have been working in the industry for a longer period should update to current safety practices. This may require additional time to get workers up to speed and allow them to internalise new safety awareness within projects.

Peter Dotselaere explains how these issues are addressed at Jan De Nul Group: 'When the project gets presented, at the kick-off meeting, there is always a presentation about crew transfer in the template. All staff partakes in the safety management course with all procedures, one of which is the topic of crew transfer. There are always some people that have followed the course already. Many projects also have local QHSE advisers that are briefed in the office and know exactly what is required. In the beginning, it was difficult to get the information spread and know the standards, but now this is not much of an issue'.

Management's role

Management must safeguard the project, especially when it comes to the rules to support safe crew transfers.

Oftentimes, a company has fixed suppliers but in certain regions where pre-qualified or regular suppliers are not available, the local market must be explored. In this case, 'Do you have a special crew boat or a survey crew boat?' is the first question management should ask. For a project manager and line management, there is an obligation to be prepared to say 'No, we don't want that crew boat'. This clear decision-making sends a strong cultural message which is positive with regard to safety awareness and culture. It takes time for a cultural message to trickle down to all levels of crew therefore management has to establish its commitment from the start.

For the times when management needs to make tough decisions, Peter Dotselaere of Jan De Nul Group explains: 'When I review these crew boats, I do this with the backing

of International Operations. If there were an occasion where I was not able to come to an agreement with local management, I do have the possibility to get that extra bit of weight added to the scale'.

Testing skipper knowledge

Another risk involves the ability to assess the competence of the skipper operating the transfer boat. This can be complicated by language barriers and further amplified in locations with limited training availability or suppliers.

If there is a situation where a skipper of the crew boat has difficulty maneuvering alongside a vessel, miscommunicates or lacks experience, it can lead to a dangerous situation when crew wants to climb the ladder to make the transfer. This risk is amplified by the relative motion between the two vessels as well as during adverse weather conditions. Therefore, skilful manoeuvring by the skipper is important. The skipper must have sufficient experience, the right certifications and comply with STCW (Standards of Training Certification and Watchkeeping).

In Ruben Hulstaert's experience at DEME, 'The vessel's captain frequently asks skippers to come on board, has a chat with them and shows them what the vessel does and how big it is. At a shift change, the captain sends the first mate down to talk with the skipper to learn if there is a language barrier and how they can deal with that. If there is doubt, then a dummy run may be requested'.

In the situation where skippers who meet the safety standards are not found, then trainers should be deployed to project sites to train local crew. Trainers can then inform local skippers about the crew transfer procedure as well as specific skills such as safely going alongside a vessel or embarkation.

More procedures are less effective

At a certain point, the industry's approach to increasing safety involved writing *more* procedures. But contrary to expectations, instead of being safer, too much paperwork leads to less reading of the procedures and, in many cases, it then sits on a shelf. Crews complain about paper procedures when there is not enough time to tick all the boxes and perform required inspections ultimately preventing the goal of safety from being achieved.

In addition, by writing procedures in too much detail, authority and responsibility appear to be taken away from those involved with crew transfer and a false sense of security can be created. Joep Athmer states 'Write enough down so people say "this is an important issue" but leave it up to the people to think about it. Otherwise they will think "as long as I tick the boxes I'm safe". This is even worse for the awareness of safety and completely misses our goal.' Paperwork is only guidance. If people aren't competent and trained, then it becomes a dangerous exercise.

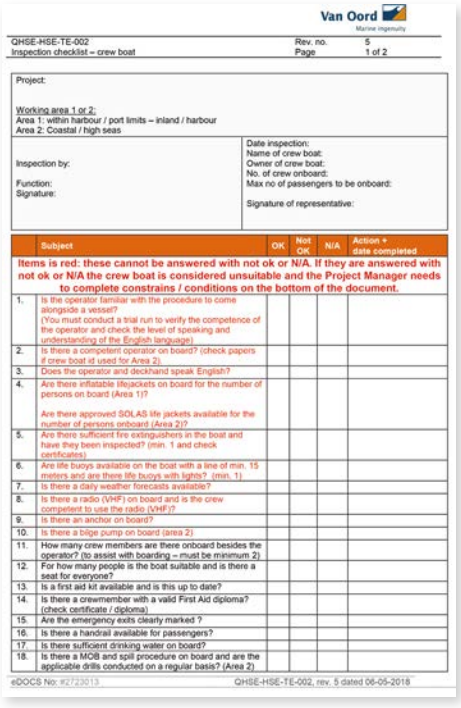
In the end, the procedure has to remain practical. Peter Dotselaere invites captains in the field to give him feedback on the procedures he has written. 'I will send the procedure over to them and say please have a look and give me your ideas. They want to give input and I want their input.'

A successful crew transfer procedure concisely addresses the diverse aspects of transferring with a combination of adequate text explanation and visual aids. If the corporate procedure includes all the steps ranging from ship-to-ship transfers and transfers to fixed installations, to helicopter transfers, then the project team can lift out what applies to their specific project and local arrangements. Whether inland, coastal or offshore checklists are needed, they can go into one document and become part of the project induction.

In addition, checklists for the boat with pictures and drawings can help in aiding all passengers – from crews to clients – to know what is expected in regards to safety. Likewise such checklists can inform non-marine passengers of unfamiliar terms such as a 'freeboard'. Similar procedural checklists for the gangway and pilot and embarkation ladders are also applicable.

Enforcing the procedures

Standards can be put on paper, but who ensures the standards are applied? Ensuring a transfer's details are known to people on the project is in the induction of the project and promotes compliance. It is also the role of the entire staff. Staff are to be competent and transfers are part of their competencies. Every individual on board the crew boat and sailing to the vessel should be aware of the safety procedure to ensure that everything goes safe.



Van Oord

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Inspection checklist – crew boat Page 1 of 2

Project:

Working area 1 or 2:
Area 1: within harbour / port limits – inland / harbour
Area 2: Coastal / high seas

Inspection by:
Function:
Signature:

Date inspection:
Name of crew boat:
Owner of crew boat:
No. of crew onboard:
Max no of passengers to be onboard:
Signature of representative:

	Subject	OK	Not OK	N/A	Action + date completed
	Items is red: these cannot be answered with not ok or N/A. If they are answered with not ok or N/A the crew boat is considered unsuitable and the Project Manager needs to complete constrains / conditions on the bottom of the document.				
1.	Is the operator familiar with the procedure to come alongside a vessel? (You must conduct a trial run to verify the competence of the operator and check the level of speaking and understanding of the English language)				
2.	Is there a competent operator on board? (check papers if crew boat id used for Area 2)				
3.	Does the operator and deckhand speak English?				
4.	Are there inflatable lifejackets on board for the number of persons on board (Area 1)? Are there approved SOLAS life jackets available for the number of persons onboard (Area 2)?				
5.	Are there sufficient fire extinguishers in the boat and have they been inspected? (min. 1 and check certificates)				
6.	Are life buoys available on the boat with a line of min. 15 meters and are there life buoys with lights? (min. 1)				
7.	Is there a daily weather forecasts available?				
8.	Is there a radio (VHF) on board and is the crew competent to use the radio (VHF)?				
9	Is there an anchor on board?				
10.	Is there a bilge pump on board (area 2)				
11.	How many crew members are there onboard besides the operator? (to assist with boarding – must be minimum 2)				
12.	For how many people is the boat suitable and is there a seat for everyone?				
13.	Is a first aid kit available and is this up to date?				
14.	Is there a crewmember with a valid First Aid diploma? (check certificate / diploma)				
15.	Are the emergency exits clearly marked ?				
16.	Is there a handrail available for passengers?				
17.	Is there sufficient drinking water on board?				
18.	Is there a MOB and spill procedure on board and are the applicable drills conducted on a regular basis? (Area 2)				

eDOCS No: #2723013 QHSE-HSE-TE-002, rev. 5 dated 06-05-2018

FIGURE 2

An example of a QHSE-HSE-TE inspection checklist for crew boats.

Utilising checklists (Figure 2) which can be performed by non-marine individuals also allows these individuals to answer their questions related to all safety aspects. Keep the checklist in plastic and next to the pilot ladder station.

Ensuring safe environmental conditions

At sea, weather conditions can deteriorate and become dangerous in a short amount of time. Amongst the most dangerous of situations is transferring onto stationary equipment when there is swell. With a hopper, a captain can provide lee to a crew boat but stationary equipment tends to be rigid.

If environmental conditions on a jetty or quay wall are not safe, then they must be made safe. Small pontoons can be shipped out with the equipment. This can be planned on a project level. Crew changes during the day are preferable, but if crew changes at night cannot be avoided, then lighting at the crew transfer location should be arranged. Every project needs a proper landing area and it is a mandatory part of the budget.

‘We can learn from each other. I think it’s to the benefit of us all. Are we perfect? No not yet. But we can learn from each other. If we pull together, then we can come up with something that can serve as an example to others.’

Summary

A roundtable on safe crew transfers was hosted by IADC to share the safety procedures utilised by dredging companies. Participants from different companies welcomed a discussion which shared safety practices employed by others in the hopes of formulating an industry-wide safety standard for crew transfer strategy.
An agreed-upon safety standard will enable clarity during joint ventures.

Peter Dotselaere
‘My background lies in the offshore drilling industry, where I worked for 25 years, ten of which as a Master. I started working for Jan De Nul in 2015 as QHSE Marine Adviser focused on offshore projects, but in the meantime that has grown to be quite a bit more than just offshore projects. One of the first tasks I did at Jan De Nul was to rewrite the personnel marine transfer procedure’.

Harry Hesseling
‘I have been working for a very long time – 38 years – at Boskalis. I started in project management as a superintendent and later became a project director within Boskalis. I was working in a commercial role for the continent of Africa. When I came back, I became an operational manager on several projects for dredging as well as offshore activities. For the last three years, I have been operations manager HR, so I’m staffing our projects and preparing our teams for departing to our projects.’

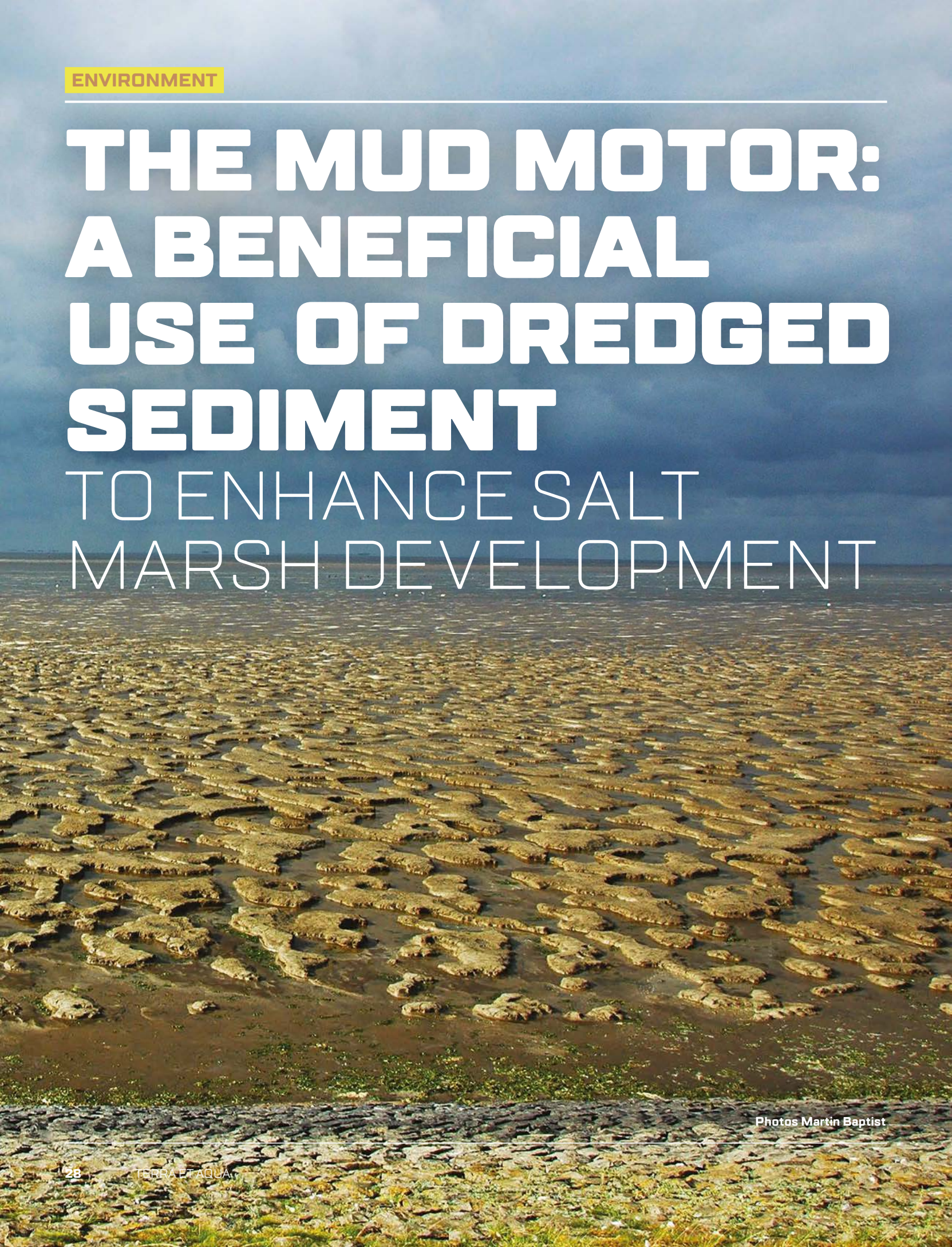
Ruben Hulstaert
‘I graduated in 2011 with a Master’s degree in nautical sciences from the Antwerp Maritime Academy. Thereafter I started sailing with DEME on trailing suction hopper dredgers (TSHD) and I worked my way up to Chief mate. For now, I’ve said goodbye to the sea and have started a shore employment as a Marine Coordinator’.

Arjan Jager
‘My background is a Bachelor’s degree in dredging engineering. I work at the QHSE support desk at Van Oord, mainly supporting dredging projects. I started off in operational parts as project engineer and superintendent, worked my way up to works manager, and decided to go into the safety department a few years go. I got additional training to be qualified as a safety practitioner.’

Joep Athmer
‘I spent 41 years in the industry and became the president of Van Oord Offshore. From project engineer to executive board, I held many roles within the company. I was very active in safety, not only in my role as director and board director. Safety has always been my passion.’

THE MUD MOTOR: A BENEFICIAL USE OF DREDGED SEDIMENT

TO ENHANCE SALT MARSH DEVELOPMENT



Photos Martin Baptist

An innovative approach to beneficially re-use dredged sediment to enhance salt marsh development has been tested. A Mud Motor entails the strategic disposal of dredged sediment to create a semi-continuous source of mud that allows natural processes to disperse the sediment to nearby mudflats and salt marshes. The concept has been piloted in the Kimstergat tidal channel near the Port of Harlingen in The Netherlands.

By applying the Building with Nature principles, an innovative method for the disposal of dredged sediment was considered and eventually piloted: the Mud Motor.

The Port of Harlingen is located in a sediment-rich estuary, which means significant maintenance dredging is necessary to keep it navigable. The dredged material, which is not contaminated, is disposed at two designated locations in the Wadden Sea, a UNESCO World Heritage site. Furthermore, the layout of the port (locally deepened and with fresh water releases in the basin) stimulates siltation and re-circulation. Part of the disposed sediment will sooner or later flow back into the port. By applying the Building with Nature (BwN) principles, an innovative method for the disposal of dredged sediment was considered and eventually piloted: the Mud Motor.

The Mud Motor entails the strategic disposal of dredged sediment in shallow water to create a semi-continuous source of mud that allows natural processes to disperse the sediment to nearby mudflats and salt marshes.Targeted at enhancing salt marsh development and thus fixating the sediment, both the local port authorities and local NGO's embraced the approach and a regional development fund, the Waddenfonds, supported the execution of the pilot . Within this article the pilot execution and accompanying research is described and the general application of Mud Motor concepts is discussed. The information in this paper is adapted from the Open Access scientific publication Baptist et al. "Beneficial use of dredged sediment to enhance salt marsh development by applying a 'Mud Motor'." *Ecological engineering* 127 (2019): 312-323.

Global background

The Port of Harlingen is not unique: Many ports are situated in deltas or regions with large loads of fine sediments. Consequently, many ports worldwide suffer from substantial volumes of maintenance dredging (IADC, 2015). Ports sometimes unintentionally stimulate the import of marine sediment, e.g., by channel deepening, thereby worsening the siltation problems. Dredged fine sediments are often considered unsuitable for re-use, despite an ever-increasing amount of attention raised to regard dredged sediment as a resource rather than a waste (National Research Council, 1985; Meade and Moody, 2010). Beneficial use of dredged materials therefore is an important topic on the agenda of many authorities and organisations worldwide, often categorising into engineered uses, agricultural and product uses and environmental enhancements (Brandon and Price, 2007).

Coastal habitats such as tidal areas and salt marshes are ranked among the most important habitats regarding ecosystem services (Temmerman et al., 2013). Tidal flats and salt marshes even form a vital part of coastal safety worldwide (Kirwan and Megonigal, 2013, Spalding et al., 2014). Moreover, these coastal habitats are invaluable for conserving biodiversity (Dijkema et al., 1984). Logically, the creation of (freshwater and saltwater) marshes has been well-developed already in the 1970s and 1980s both in Europe and the US (for example USACE, 1987). Creation either involves the direct placement of sediment directly onto the desired location with correct elevation, orientation, shape and size or the creation of structures to enforce local hydrodynamic conditions favorable to settlement of fine particles and associated land creation. Sometimes the active introduction of plants is also applied.

Data suggests that these created marshes do not have the same quality as natural marshes in that some functions are not developed (Streever, 2000). Also salt marshes created by managed realignments lack the diversity found in natural habitats (Lawrence et al., 2018). Added value can thus be created by finding work methods to use dredge material for marsh development, while mimicking, using or stimulating natural marsh geomorphology (Shafer and Streever, 2000).

Also more generally, the inclusion of nature-based solutions (NBS) has drawn the attention in hydraulic engineering. Since 2007, the Dutch consortium EcoShape has been developing knowledge on the Building with Nature (BwN) philosophy

Who's Involved in the Harlingen Mud Motor Pilot?

The Mud Motor Pilot near Harlingen is one of the pilots of the BwN Wadden Sea Ports programme executed by EcoShape. Wageningen Marine Research, Arcadis, Royal Haskoning DHV, Deltares and Van Oord have teamed up to execute the pilot on behalf of EcoShape. The local port authority, the municipality of Harlingen and a ocal NGO 'It Fryske Gea' (a society for the protection of nature in the Dutch province of Friesland) joined EcoShape in its proposal to execute the pilot to enhance the salt marshes at Koehool. This proposal received funding from the regional development fund Waddenfonds.

In addition to the pilot execution, fundamental research took place. Researchers from the Royal Netherlands Institute for Sea Research (NIOZ), Wageningen University and Delft University of Technology, supported with practitioners from the EcoShape project partners, have executed fundamental research on the sediment transport and sediment dynamics around the Mud Motor and the targeted salt marsh as well as investigated ecological factors of importance to the salt marsh expansion.

The authors would like to specifically mention the following contributors: T. Gerkema, K. Schulz (NIOZ), M. van Regteren, K. Elschot, A.V. de Groot, M.E.B. van Puijenbroek (Wageningen Marine Research), B.C. van Prooijen, I. Colosimo (Delft Technical University), D.S. van Maren, J. Vroom, T. van Kessel, B. Grasmeijer, P. Willemsen (Deltares), J. Cleveringa (Arcadis), F. Schuurman, P.J.T. Dankers (Royal Haskoning DHV), H.J. de Lange (Wageningen Environmental Research), R.J. de Vries, J. Walta (Municipality of Harlingen), C. Bakker (It Fryske Gea), A. Bosch (De Laar).

by precompetitive collaboration between dredgers, consultants, knowledge institutes, governmental organisations and NGOs. As a part of their second BwN programme, the development issues of the ports of the Wadden Sea are studied, focussed at innovative approaches to sediment management in the Wadden Sea (Baptist et al., 2017; Van Eekelen et al., 2016).

The Harlingen Mud Motor Pilot setup

Setting

About 1.3 million m^3 of mainly fine sediments are dredged annually in the basins of the Port of Harlingen to safeguard navigation. The dredged sediment is disposed in the Wadden Sea, at locations with large water depth in the vicinity of the port at locations K1 and K2 (see Figures 1 and 2). It is expected that an unknown, but potentially considerable, amount of sediment shows a return flow towards the port, leading to a cyclic series of dredging and disposal.

During the Harlingen Mud Motor Pilot, the regular maintenance dredging operations with a small 600 m^3 trailing suction hopper dredger (TSHD) continued. For the duration of this experiment part of the dredged volume was disposed (not deposited at one single spot) further away from the port at a Mud Motor (MM) location (see Figures 1 and 2). The Mud Motor disposal location is chosen based on its water depth at low water (LW), mid water (MW) and high water (HW), to guarantee accessibility by the dredger, and on its effectiveness in transporting the sediment towards the upper zone of the mudflat and salt marsh as predicted by numerical simulations (see next sections).

Disposal of dredged sediment from the hopper took place through bottom doors. The targeted salt marsh is located to the northeast of Harlingen in a local indentation of the coastline between Koehool and Westhoek. This salt marsh area has developed from 1996 and has shown some periods of growth and others of stabilisation, indicating that conditions for salt marsh growth are not met every year.

Design and set-up

Numerical simulations

The first step in the design of the Mud Motor pilot was the exploration of a suitable disposal location. The most suitable location has sufficient depth for (bottom door) release of the material, in this case a minimum water depth of 3 m, while being as close (both cross-shore and long-shore) to the targeted salt marsh as possible. Due to channel characteristics of the Kimstergat (moving away from the coastline closer to the target area), the cross-shore and long-

Dredged fine sediments are often considered unsuitable for re-use, despite an ever-increasing amount of attention raised to regard dredged sediment as a resource rather than a waste.

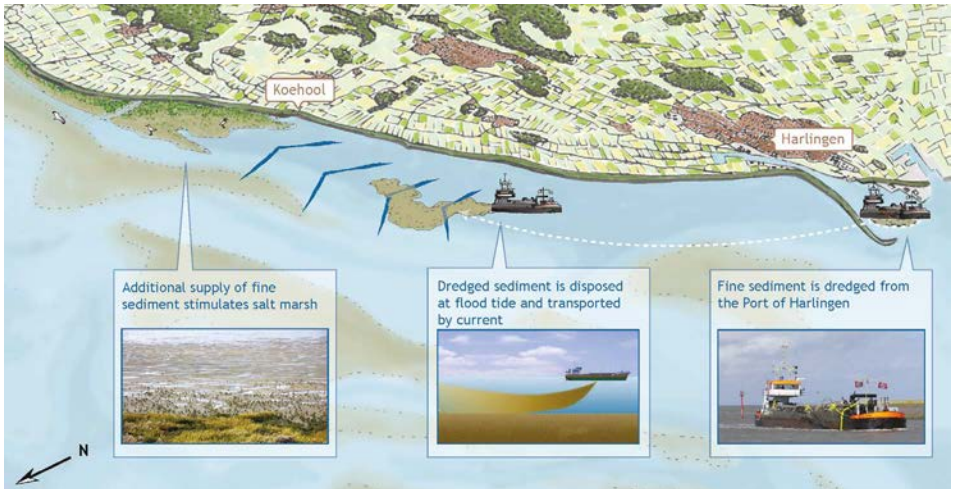


FIGURE 1

Illustration of the sediment transport route of the Mud Motor Pilot including dredging, disposal and flow.

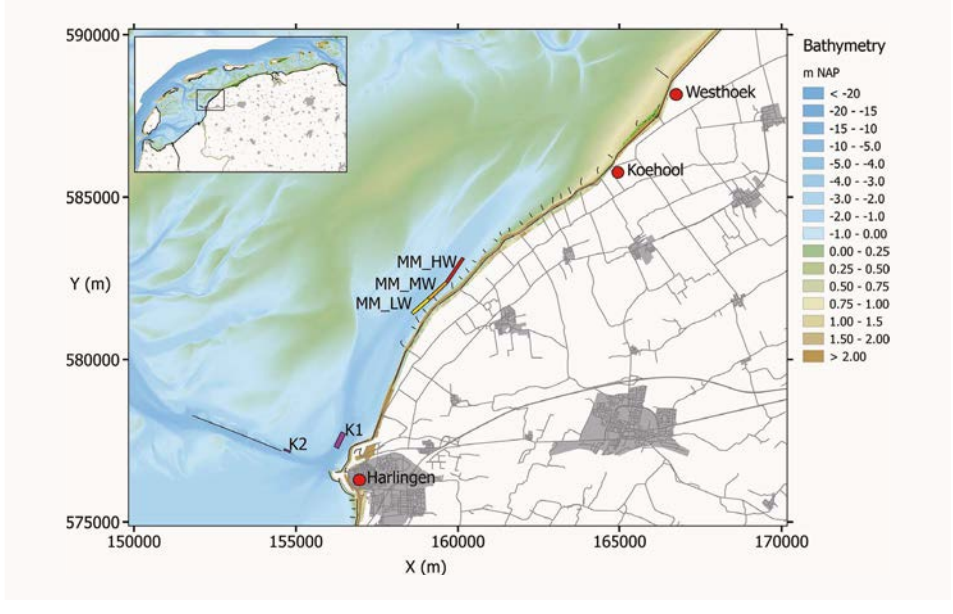


FIGURE 2

Location chart of the Harlingen Mud Motor Pilot.

shore distance became a trade-off, which was evaluated with a numerical sediment transport model. The numerical model (see Vroom, 2015) for details) revealed that sediment released close to the shore is more effective in nourishing the Koehool mudflat than sediment released at the landward limit of the channel. In Figure 1, showing the final disposal locations, this is translated in an MM_HW high water disposal site, an MM_LW low water disposal site and an MM_MW for the disposal with intermediate water levels, in order to guarantee the minimum navigation depth.

Tracer study

Based on the numerical simulations, a preliminary disposal location was chosen in shallow water on the south-eastern bank of the tidal channel. Prior to the Mud Motor experiment, a tracer experiment was carried out to determine how much of the sediment would be transported from the new disposal location towards the target area, in comparison with one of the original disposal locations. For each of the two locations, a different coloured fluorescent tracer with a particle size distribution and behaviour similar to sediment dredged from the port of Harlingen was applied. Tracer particles were released completely mixed with dredged sediment.The (relative) recovery of the tracer particles is then an indicator for the transport of sediment towards the desired salt marsh coast. Multiple sampling campaigns were conducted using a large number of sampling locations. The total amount of tracer in the area of interest could be compared to the total amount of tracer particles released as a measure of the effectiveness of the disposal location. The results showed that after one month 80% of the mud disposed at the new disposal location reached the targeted intertidal area where salt marsh enhancement is desired, compared to only 20% from the existing disposal location (see Table 1).

Legal requirements

Dredging projects are regulated by national and European legislation (Sheehan and Harrington, 2012). Because the Wadden Sea is protected by the

By careful and strategic sediment management – disposal of dredged material in conditions and locations favourable to salt marsh growth – the pilot reveals that the Mud Motor concept can be viable.

nature conservation laws of the EU Habitats and Birds Directives, a permit to work within the protected Natura2000-nature area was required. According to European law, an Appropriate Assessment had to be written, giving a detailed account of the natural values that potentially were at stake and describing possible options for mitigation (Baptist, 2015). The activities that needed to be assessed included the disposal of the mud as well as the research activities that were planned in the study area.To minimise potential effects on the ecosystem and the salt marsh system, disposal at the new location was only allowed in autumn and winter, i.e., between September 1st and April 1st, and initially only during daylight hours to minimise disturbance.

One of the objectives of the Mud Motor is to expand the salt marsh area. This objective is in itself in conflict with the nature conservation law. The law aims at conserving the surface area of EU habitat types and any activity that leads to a significant decrease in habitat area cannot be allowed. An increase in salt marsh area (EU Habitat 1310) will lead to a decrease in mudflat area (EU Habitat 1140A), with potential knock-on effects on subtidal area (EU Habitat 1110A), because the salt marsh expansion can only go forward due to coastal squeeze (Doody, 2013; Doody, 2004), and hence will be covering other existing and protected habitat. Similar issues of habitat trade-offs that were conflicting with large-scale tidal marsh development projects were apparent in the New York-New Jersey Harbor (Yozzo et al., 2004). Obviously the nature conservation law is primarily meant to stop activities that remove natural habitat, and although in this case there is only a shift in habitat type, strictly following the law, the significance of habitat loss should be assessed. A maximum salt marsh extension of 16 ha was expected prior to the Mud Motor pilot, potentially leading to habitat loss of 0.0012% of the total intertidal area in the Dutch Wadden Sea and this was considered insignificant.

Planning and technical feasibility

After determining a suitable new disposal location for the Mud Motor pilot, and having obtained the necessary licences, the planning of the dredging operations needed to be detailed. Based on the sailing distance, dredge cycle times, tidal water level predictions and daylight windows an assessment of the disposal options was made. Disposal was planned only during flood tides, i.e., when flow is directed towards the salt marsh target area. An analysis of the co-occurrence of flood flows and daylight hours revealed that in December and January there was not enough time for mud disposal of the required volumes. A change request for the permit was granted to extend the working hours to between the hours of 07:00 and 19:00, with sunrise and sunset within this interval. Taking all boundary conditions into account, a maximum dredge volume of 300,000 m^3 could be disposed over one autumn and winter season (Grasmeijer, 2016)

Monitoring and research programme

An extensive monitoring and research programme was designed to measure sediment transport rates and the response of intertidal flats and salt marshes to an increased sediment load. This includes detailed measurements of suspended sediment transport processes, and numerical modelling of the mud transport from the subtidal zone, through the intertidal area and towards the salt marshes. Furthermore, studies on the influence of biota, particularly oligochaeta, on salt marsh expansion were carried out.

Sediment transport rates

The disposal of the dredged sediment in the tidal channel leads to increased concentrations of suspended fine sediment in the water column. Field observations and ship-based measurements quantified the cross-shore and long-shore dispersal of large-scale frequent mud disposal in response

TABLE 1

Percent recovery in the area of interest of the blue tracer (released at existing disposal location K2) and the green tracer (released at the new location) after 5 days, 2 weeks, and one month. See Vroom et al. (2016) for details.

Time after release	Blue	Green
5 days	1%	13%
2 weeks	5%	12%
1 month	20%	80%

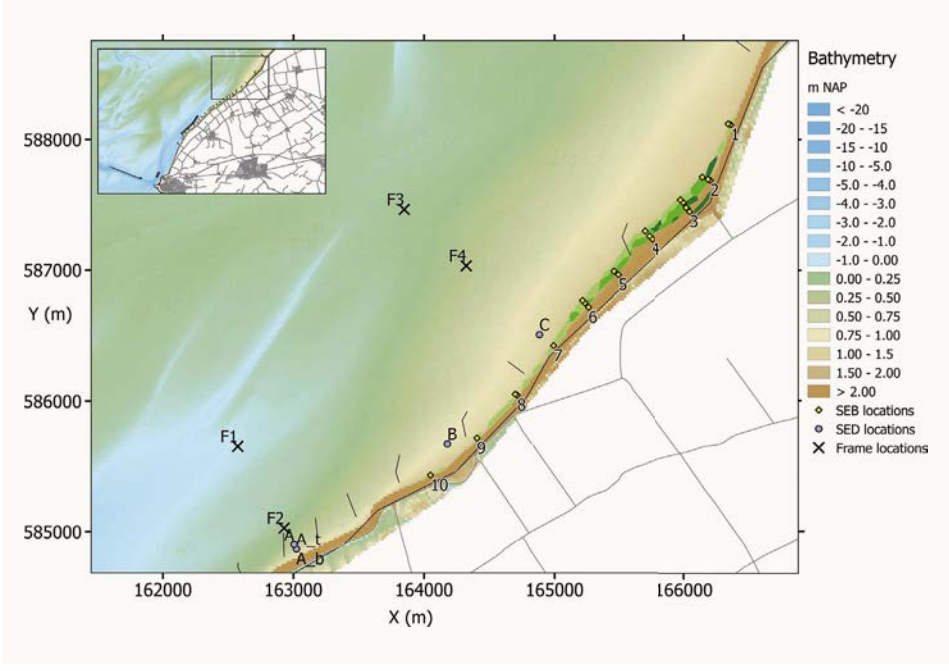


FIGURE 3

Measurement locations. F1, F2, F3 and F4 are hydrodynamic and suspended sediment frame locations. A, A_t, A_b, B and C are Surface Elevation Dynamics (SED) sensor locations. Transects 1–10 show 22 Sedimentation-Erosion Bar (SEB) locations in the salt marsh, with adjacent permanent quadrats (PQ). Coordinates shown in Dutch grid EPSG:28992.

to tides, waves, storms and nearby freshwater discharge events. Ship-based measurements were carried out in June 2015, April 2016, October 2016 and October 2017. The first two cruises were sailed before the start of the Mud Motor pilot, and the latter two during the pilot. On each cruise, suspended particulate matter (SPM) concentrations and current velocities were measured for 13 hours to calculate the residual SPM transport at two locations: close to the Port of Harlingen and near the new disposal location. Details on the ship-based campaigns and an analysis of the data from the first three cruises can be found in Schulz and Gerkema (2018).

Living Lab for Mud

In the Living Lab for Mud, EcoShape is working with our partners on five pilot projects to develop knowledge about the sustainable use of fine sediment. Fine sediment is an essential material for global sustainable development. Excess sediment dredged from lakes, coasts and rivers can be used to strengthen dikes, reclaim land or create natural islands. That generates social benefits in terms of flood risk management, navigability, nature development, water quality and the local economy, and in the form of building material for land reclamation and dike construction. Combining the use of sediment with natural processes like currents and vegetation is a perfect example of applying Building with Nature. The Harlingen Mud Motor Pilot is one of the five EcoShape projects in this programme.

The mudflats were investigated from December 2017 to February 2018 in severe weather.

Additional to measurements in the tidal channel, hydrodynamic and suspended sediment measurements on the intertidal mudflats have been carried out. Instrument frames have been placed at two different transects: The Koehool transect, where the upper flat is bare; and the Westhoek transect, where the upper flat is vegetated (see Figure 3). In spring 2016 (i.e. before the Mud Motor pilot started), a one-month monitoring campaign has been conducted at locations F1 and F2. From mid-April to mid-May 2017 (i.e. after the pilot started), a similar campaign has been carried out at locations F3 and F4. From December 2017 to February 2018 the mudflats were investigated simultaneously during winter, severe, weather conditions.

Mudflat and salt marsh accretion

The mudflat and salt marsh bed level changes were measured with two types of in-situ instruments. The multi-annual surface-elevation change was determined with Sedimentation-Erosion Bars (SEBs). The surface elevation is determined four to five times per year. Short-time surface elevation changes were determined with Surface Elevation Dynamics (SED) sensors (see Figure 3). The SEDs were checked

TABLE 2

Mud Motor disposed volumes per week. N is number of disposals per week, Volume is disposed volume per week (m^3) and Cumulative is cumulative volume (m^3) for Mud Motor Season 1 and Mud Motor Season 2.

Season 1	N	Volume	Cumulative	Season 2	N	Volume	Cumulative
week 2016–36	28	16,912	16,912	week 2017–36	23	13,892	13,892
week 2016–37	34	20,536	37,448	week 2017–37	24	14,496	28,388
week 2016–38	29	17,516	54,964	week 2017–38	22	13,288	41,676
week 2016–39	29	17,516	72,480	week 2017–39	16	9664	51,340
week 2016–40	16	9664	82,144	week 2017–40	22	13,288	64,628
week 2016–41	14	8456	90,600	week 2017–41	16	9664	74,292
week 2016–42	14	8456	99,056	week 2017–42	21	12,684	86,976
week 2016–48	30	18,120	117,176	week 2017–43	27	16,308	103,284
week 2016–49	25	15,100	132,276	week 2017–44	16	9664	112,948
week 2016–50	31	18,724	151,000	week 2017–45	28	16,912	129,860
week 2016–51	22	13,288	164,288	week 2017–46	30	18,120	147,980
week 2017–01	27	16,308	180,596	week 2017–47	29	17,516	165,496
week 2017–02	19	11,476	192,072	week 2017–48	8	4832	170,328
week 2017–03	28	16,912	208,984				
week 2017–04	31	18,724	227,708				
week 2017–05	29	17,516	245,224				
week 2017–06	27	16,308	261,532				
week 2017–07	3	1812	263,344				
week 2017–11	16	9664	273,008				
week 2017–12	30	18,120	291,128				
week 2017–13	15	9060	300,188				

approximately every eight weeks to ensure data collection, to clean the sensors and to retrieve the data.

For a synoptic view of the surface level of the mudflats and salt marsh, LiDAR was flown annually over the study area using an Unmanned Aerial Vehicle (UAV). Although the vertical accuracy of the scans is in the same order of the average expected increase in bed level by the Mud Motor, the scans can be used to assess changes in the small-scale morphology.

Salt marsh vegetation cover and composition

The development and cover of salt marsh vegetation was studied with historical aerial and recent UAV orthophotos. Yearly, in-situ measurements of vegetation diversity and density were performed at permanent quadrats (PQ) located adjacent to the salt marsh SEB-stations (see Figure 3).

An additional study aims to clarify the biogeomorphic role of oligochaete bioturbation in facilitating or hindering vegetation establishment in the salt marsh transition zone. Oligochaetes (Annelida) are minuscule worms that can be present in high densities in the transition zone between intertidal flats and salt marshes, especially in fine grained sediments. Experiments were performed to assess the effect of the disturbing activities of these worms, referred to as bioturbation on sediment properties, oxidation depth, algal biomass, seed distribution, and germination success of the so-called 'pioneer species', the first plants to grow on bare mud flats, see Van Regteren et al. (2017).

Results

Execution of the pilot

The mud was dredged from the basins of the Port of Harlingen using the 604 m³ TSHD 'Adelaar' of the company De Boer Dredging. Dredging operations were carried out daily. The average cycle time for the Mud Motor disposals was around 1:45 hours. The realised number of mud disposals was dependent on appropriate high tides inside the available time window, and on other factors such as weather conditions and technical issues. An average number of approximately 22 mud disposals per operating week, with a weekly volume of 13,288 m³ was achieved (see Table 2). In the first Mud Motor Season from 1 September 2016 to 31 March 2017 in total 300,188 m³ of dredged sediment was disposed at the Mud Motor disposal sites. In the same period another 433,672 m³ was disposed at the K1 and K2 sites (see Figure 1). In the second Mud Motor season, from 1 September 2017 to 1 December 2017 a total of 170,328 m³ was disposed at the Mud Motor disposal site and another 201,780 m³ at the K1 and K2 disposal sites.

The dredged volume needed to maintain navigable depth in the Port of Harlingen has decreased with both in 2017 and 2018to 1.0 million m³ compared with the long-term average of 1.3 million m³ (see Table 3). A reduction of the return transport may have resulted from the disposal at the Mud Motor site. However, it may also be that the both years has fallen within the variability found in the annual dredged volumes, similar to year 2012.

TABLE 3

Annual dredged volumes in the Port of Harlingen.

Year	Volume (m³)
2007	1,250,004
2008	1,448,480
2009	1,156,056
2010	1,357,188
2011	1,287,412
2012	1,036,555
2013	1,264,469
2014	1,412,866
2015	1,367,457
2016	1,441,748
2017	1,018,000
2018	1,032,270

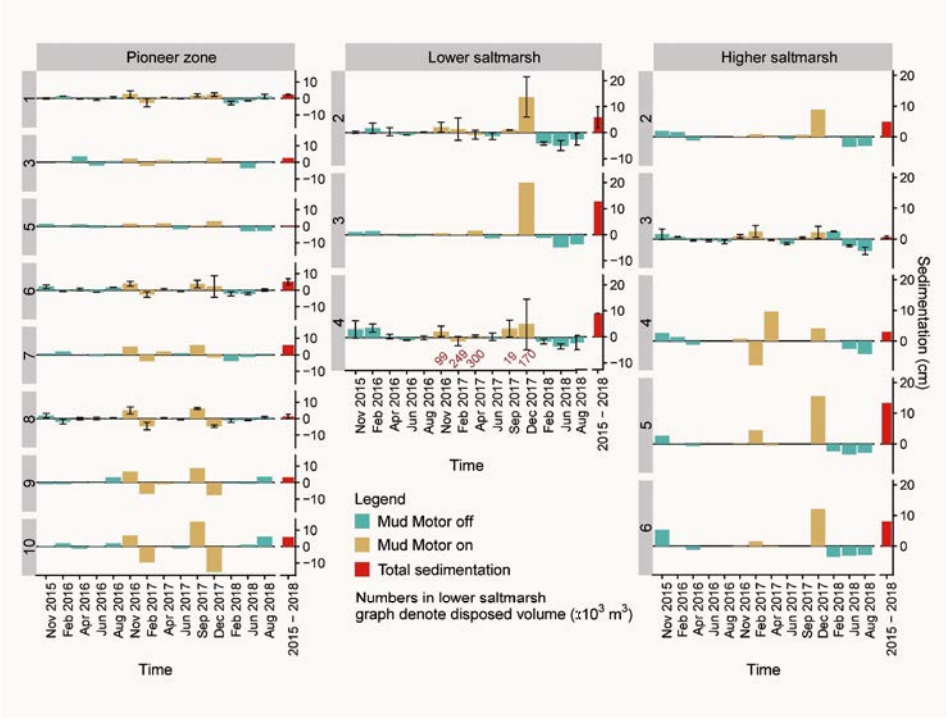


FIGURE 4

Results of the Sedimentation Erosion Bar measurements of salt marsh stations.

Sediment transport rates

Channel

The ship-based measurements in the Kimstergat channel revealed two main factors that influence the suspended sediment transport under calm wind conditions:

1. differences (asymmetry) between ebb and flood currents, and
2. a periodic vertical salinity stratification (fresh water from releases elsewhere are flowing on top of salt water).

Unlike the normal case in a classical estuary, the salinity stratification is built up during flood, and destroyed again with the onset of the ebb current. In short, the stronger flood currents have positive effects on sediment transport towards the target salt marshes. Likewise, the salinity stratification is attracting sediment toward the fresh water source, which is located at the mouth of the tidal channel. These two processes are thus counteracting one another.

Mudflat

The field measurements using instrument frames on the intertidal mudflat show that the tidal flow is also flood dominant on the flat, implying higher flood velocities than ebb flow velocities. This favours flood dominated sediment transport towards the upper flat. However, the shallow conditions make the flow very sensitive to wind. It was observed that the tidal flood flow direction (and thus the sediment fluxes toward the study area) can be reversed by a wind with opposite direction when the wind speed is about 10–12 m/s. As wind conditions of over 10 m/s are common and as wind speed and direction can vary in a few hours, the tide-only conditions cannot be considered representative. This implies a large temporal variability on daily time scale, but also seasonal and annual timescale.

Mudflat and salt marsh accretion

Results of the measurements with Sedimentation Erosion Bars (SEB) show relatively large changes in surface elevation. Layers of watery mud with a thickness of up to 20 cm were deposited in some locations in the salt marsh over a two or three-month period, though disappeared just as fast. The two- or three-monthly measurements could not differentiate between the processes causing this disappearance (erosion or compaction), but did show large fluctuations in bed height. The salt marsh SEB stations showed a net accretion with an average of 4.9 ± 0.9 cm (mean ± standard error) in the three year period from September 2015 to August 2018. Spatial variability in sedimentation was substantial with larger sediment dynamics (erosion as well as accretion) in the southern transects compared to the northern transects (see Figure 4). Highest sedimentation and erosion values occurred in winter and generally consisted of a layer of fluid mud that was deposited, or eroded again, in a single storm or a few high tides. The measurements did show notably higher sedimentation and erosion dynamics with the Mud Motor in use compared to the Mud Motor not in use.

Results from the Surface Elevation Dynamics (SED) sensors are in agreement with the SEB measurements and also show rather large and fast bed level variations with accretion/erosion events of up to 10 cm on a time scale of days (see Figure 5). Such events were not observed in other tidal flats at a similar distance from the salt marsh edge or dyke toe using similar instruments (Hu et al., 2017; Willemsen et al., 2018). These large bed level fluctuations are indicating the highly dynamic character of the study site, which is also reflected in the morphological pattern of hollows and hummocks, with a horizontal width of several meters and a height of several decimetres. An increase in sedimentation rates in relation with disposed Mud Motor volumes could not be established.

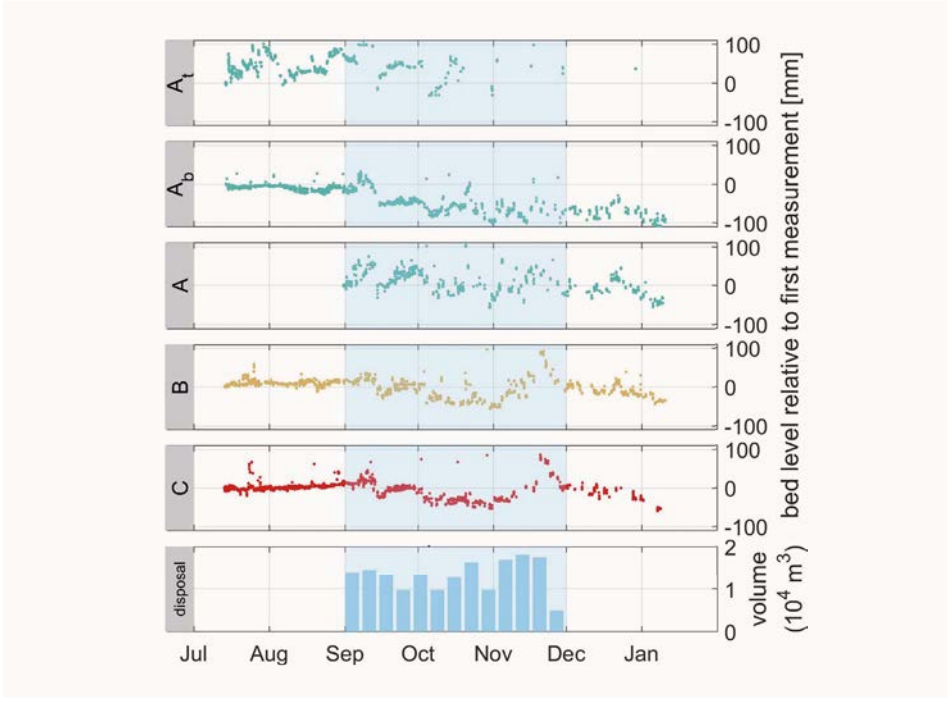


FIGURE 5

Results in bed level variation as measured by SED-sensors. Bottom plot shows disposed Mud Motor volumes per week.

Salt marsh vegetation cover and composition

The permanent quadrats for vegetation composition did not show an increase in pioneer vegetation cover on the edges of the marsh. Neither was there accelerated succession in the vegetated plots within the short time period of the first two years. Aerial photos taken at the end of summer/beginning of autumn each year showed that the salt marsh vegetation cover grew from 28.2 ha to 29.9 ha prior to the Mud Motor pilot between 2015 and 2016. The salt marsh cover lost 3.5 ha between 2016 and 2017, in which season 1 of the Mud Motor pilot was executed. It then increased to 27.9 ha with 1.5 ha between 2017 and 2018, during season 2 of the Mud Motor pilot.

Conceptual Framework for BwN Guiding Principles for Salt Marsh Development

Based on a literature survey, a selection was made of the most relevant parameters for salt marsh habitat requirements in relation to our Mud Motor pilot. These parameters are essential for the pioneer formation of salt marshes, i.e., inundation frequency, hydrodynamic energy, slope, suspended sediment supply and local seed source. A conceptual framework for BwN guiding principles for future applications of sediment management aiming at salt marsh development is presented (see Figure 6).

First and foremost the bed elevation needs to be high enough (near MHW) to have low inundation frequency and allow pioneer vegetation to establish. Secondly, the hydrodynamic energy needs to be low enough for a long-term accumulation of fine sediments. Thirdly, the mudflat in front of the marsh needs to have a gentle slope in order to reduce hydrodynamic stress. Fourthly, a sufficient supply of suspended sediment is needed to increase marsh elevation.

Finally, a local seed source needs to be present so pioneer vegetation can germinate and establish. When these criteria are fulfilled, and taking multi-annual Windows of Opportunity into account, a marsh may develop a robust morphology and may grow into a robust and sustainable salt marsh.

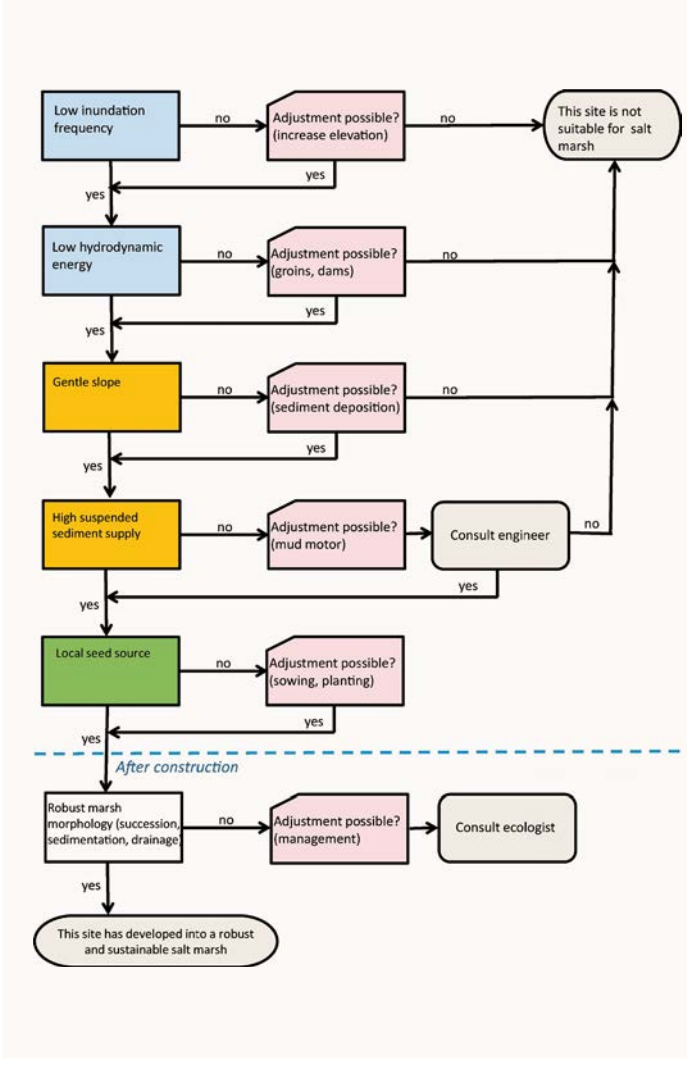


FIGURE 6

Conceptual framework for Building with Nature guiding principles for salt marsh development with sediment management.

Our experimental study indicated that small, though numerous, oligochaetes may reduce the lateral expansion potential of the salt marsh by hindering the establishment of pioneer vegetation in the transition zone between salt marsh and mudflat. The way that these miniscule worms feed from the sediment buries *Salicornia* spp. seeds until below the critical germination depth, thus negatively effecting *Salicornia* spp. germination and seedling esablishment. The density of worms used in our experiments corresponded to 131,493 individuals/m^2. Because observed field densities of oligochaetes in our study site ranged up to 318,290 individuals/m^2, it seems likely that they can influence *Salicornia* establishment in the field (Van Regteren et al., 2017).

Discussion

Lessons learned from the Mud Motor pilot

From the results of the various monitoring, it is clear that the system in which the Mud Motor pilot was executed had various influencing factors which were (and are) not fully understood. The numerical model and tracer study indicated that significant amounts of sediment disposed at the Mud Motor location was likely to move to the salt marsh and would cause the marsh to grow. However, the field measurements of suspended sediment transport rates in the tidal channel could not confirm an increased flux of mud as a result of Mud Motor disposals. On the other hand the SEB measurements indicate extra sedimentation on the salt marsh in line with the anticipated extra sediment released and transported according to the tracer study result (i.e., 3 cm natural salt marsh growth +2 cm level increase due to the Mud Motor). However, the winds were found to dominate the distribution of sediment transport, with an ability to transport significantly larger mud layers. In other words the gross fluxes of mud were therefore much higher than the net accumulation. Still, these fluxes seemed to be higher in periods with a functioning Mud Motor.

Although the Mud Motor was applied in a study area suitable for salt marsh vegetation expansion (ample sedimentation, sufficient vegetation present and gently sloping mudflats in front of the marsh), horizontal expansion was not observed. It seems that the hydraulic stress is higher than foreseen. A possible explanation is that the growth of the salt marsh is not determined by short-term sediment supply from the tidal channel, but by a long-term sediment supply from the tidal divide further to the east, governed by waves and wind-induced transport. The development of the mudflats and salt marsh in this area does not seem to be restricted by the supply of suspended sediment but by the morphological evolution of the bed level in combination with other meteorological and ecological factors. Marsh growth seemed to be dependent on a so-called Window of Opportunity (Hu et al., 2015b), which also can explain for the alternating growth-stabilisation periods of this marsh in the past.

Applying the Mud Motor concept at locations with different physical settings can be more successful in promoting natural mudflats and salt marsh development, specifically in cases where a freshwater source is less disturbing (or even enhancing) the estuarine flow patterns. It is suspected that salt marshes located at the landward limit of tidal systems, for instance at the landside of a bay, may benefit from a Mud Motor because the trapping efficiency is expected to be larger.

General application potential for a Mud Motor

In general terms, the pilot reveals that the Mud Motor concept can be viable by careful and strategic sediment management (disposal of dredged material in conditions and locations favourable to salt marsh growth). Whether a particular salt marsh can be expanded via this method is very much dependent on the functioning and interactions with the hydrodynamic and ecological system:

FIGURE 7

Researchers at Koehool doing height measurements (A) and other studies on the mudflats (B).

- The limiting factors for salt marsh growth need to be determined first, in order to indicate whether further supply of sediment will create/enhance opportunities for salt marsh growth, or whether other measures would (also) be necessary (see Figure 6).
- The abundance and variability in transport rates need to be determined, to determine whether a Mud Motor may be sufficiently effective and at what minimum scale.
- The limiting factors for disposal of the material, both technically (in terms of clearance for the dredging vessel and cycle times) and regulatory (in terms of permit limitations) must be assessed and optimised to meet the derived minimum scale (see Figures 7 and 8).

Following the above steps, the technical feasibility for a Mud Motor can be assessed. The next step will be the economic feasibility. The necessity to dispose a certain amount of sediment at a specific location might increase the execution costs for the dredging works; the cycle time can increase both due to extra sailing (such as in the Harlingen Pilot) or by the extra need for manoeuvring and other limitations. In order to assess whether such investment is worth, the full cost-benefit analysis must be taken into account. This means that direct effects should be accounted for, such as the decrease in circulation of dredged material after release, but also indirect effects must be assessed like for instance the values created by salt marsh growth, such as CO2 fixation, nature values, recreational opportunities and flood safety benefits. It is important to not only try to account the magnitude and (un)certainty of these values, but also to determine who will benefit from these values as to determine how that stakeholder could contribute to the project cost.

CO2 Footprint of the Harlingen Mud Motor Pilot

For the Harlingen Mud Motor Pilot the disposal of sediment at the Mud Motor location meant that the sailing distance increased, leading to an extra release of CO2. On the other hand, the fixation of sediment in the salt marsh and mud flat, and the additional salt marsh habitat will store CO2 and give rise for additional sequestration. Whether the CO2 footprint of the Mud Motor is positive would be dependent on the amount of additional sequestration compared to the additional release.

However, especially in quantifying the additional sequestration, the analysis is dependent on the boundary conditions and limitations of the analysis, especially on substitution effects. As sediment disposal at the traditional location leads to higher sediment availability in the whole of the Wadden Sea, part of this sediment will contribute to salt marsh developments, either at the target site or elsewhere in the system.

With respect to temporal developments, similar discussions can be raised: from the historical analysis it was observed that the Koehool salt marsh was developing. It can be argued that in the long term (>100 years) the Mud Motor efforts could best be observed as a measure to speed up development and not as a creation of new marshes. This means that the CO2 benefits of the pilot are limited to the fact that the salt marsh (and its associated sequestration) is realised at an earlier time. For that reason the pilot outcome on CO2 footprint could be either positive or negative. Also in broader application of the Mud Motor, the substitution effects should be considered as part of the CO2 footprint analysis.

FIGURE 8

Plant growth at the Koehool mudflats.

Summary

An innovative approach to beneficially re-use dredged sediment to enhance salt marsh development was tested by a 'Mud Motor', i.e., a dredged sediment disposal method in which a semi-continuous source of mud in a shallow tidal channel allows natural processes to disperse sediment to nearby mudflats and salt marshes. The pilot occurred over two winter seasons with both ship-based and field measurements on the intertidal mudflat. The pilot showed that the feasibility of a Mud Motor depends on an assessment of additional travel time for the dredger, the effectiveness on salt marsh growth, reduced dredging volumes in a port, and other practical issues. It improved understanding of the transport processes in the channel and on the mudflats and salt marsh and provided guiding principles for future applications of sediment management that include a Mud Motor approach.

This article is based on the paper "Beneficial use of dredged sediment to enhance salt marsh development by applying a 'Mud Motor'" which debuted in *Ecological Engineering*, Volume 127, February 2019, pages 312–323, a publication of Elsevier. The original paper is available through Open Access.

The pilot reveals that the Mud Motor concept can be viable: By careful and strategic sediment management (disposal of dredged material in conditions and locations favourable to salt marsh growth).

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Erik studied at Delft University of Technology, the Netherlands, where he graduated as MSc (2007) on the subject of dynamic behaviour of dredging plumes of TSHDs. He then joined the environmental engineering department of Van Oord, working worldwide on the full range of environmental aspects of their projects, such as Eco-Design/BwN, stakeholder engagement, protection of marine fauna and turbidity monitoring and management. Currently he is Lead Engineer of that department. For Van Oord he is part of the Management Team of the EcoShape consortium that develops knowledge via pilots and research on the topic of Building with Nature.

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MEET THE PROFESSIONALS WHO BUILD MARITIME INFRASTRUCTURE

Conferences and seminars intended for all stakeholders in the field of dredging: government officials, port authorities, offshore companies, researchers, scientists and dredging contractors.

IADC Conference 'Dredging for Sustainable Infrastructure'

17-18 October 2019
Leela Palace Hotel
New Delhi, India
www.iadc-dredging.com

How can dredging be sustainable? This is the overarching question which will be explored at the IADC 'Dredging for Sustainable Infrastructur' Conference on Friday 18 October 2019 at the Leela Palace Hotel in New Delhi, India. It will feature speakers who are industry experts, scientists, practitioners and project owners with backgrounds in engineering and environmental sciences, such as Dr. K. Murali. Professor of Ocean Engineering and Engineering Unit Chairman at IIT Madras and Director of National Technology Centre for Ports, Waterways and Coasts, IIT Madras, Chenai, India.

About the conference

With growing environmental awareness and increasing climate pressures on low-lying deltas, modern-day society puts incredibly strong demands on the sustainability of water infrastructure projects. Classic approaches towards the design and implementation of such projects are no longer sufficient. Instead, radically different methods are needed. They demand multidisciplinary project teams to adopt entirely new ways of thinking, acting and interacting. At this conference, people will experience what it means to apply this new approach in practice. New avenues towards the development of sustainable water infrastructure will be explored.

Key enablers to make this happen will be discussed, including the issues of:
- stakeholder engagement;
- valuation of ecosystem benefits;
- adaptive management of dredging projects;
- beneficial use of dredged materials.

Who should attend

The conference will be of particular relevance for people involved in delivering dredging projects with longevity which also maximise the benefits to society, nature and economy. This will be an event for planners, designers, decision makers, regulators, contractors, project owners and environmental advocates who need to keep up-to-date. There will also be many opportunities for participants to engage with each other and the speakers during the programme, enhancing knowledge exchange and transfer.

Costs

For people with an Open Registration Ticket, the special registration fee is 125 EUR. This includes attendance to the conference programme, access to the networking area and all coffee breaks, lunch and closing drinks.

For registration:

http://bit.ly/DfSIDelhi

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CEDA Dredging Days 2019

7-8 November 2019
Ahoy Conference Centre
Rotterdam, The Netherlands
www.cedaconferences.org/dredgingdays2019

CEDA Dredging Days is the flagship conference of the Central Dredging Association (CEDA) and a major event on the dredging professionals' calendar in the European, Middle East and Africa (EMEA) region, a primary forum for leading researchers, and industry experts to share ideas, discuss challenges and consider potential solutions. With representatives attending from a cross-section of the dredging field, and hailing from the CEDA region and beyond, the conference is highly appreciated for offering exceptional networking opportunities.

This year CEDA Dredging Days will be held from 7-8 November in Ahoy Rotterdam, The Netherlands and will be the closing event of CEDA's 40th anniversary year. It will again take place alongside the Europort Maritime Trade Show. The two events – held in one venue -– provide a great opportunity for delegates to acquaint themselves with the latest maritime thinking and technological advances as well as network with their peer in the dredging community including experts from port authorities, knowledge institutes, universities, engineering consultants, government agencies, dredging contractors and manufacturers.

Papers addressing both practical applications, as well as applied and academic research, will be presented on advancements in equipment, processes, tools, methodology and contracting. Sample topics include:

- Reduced effects on the environment
- Use of nature-based solutions
- Capabilities of dredging deeper in harder soils, harsher conditions, or restricted spaces
- Improvements in dredged material management
- Use of dredging know-how in new industries (e.g. deep-sea mining)
- Improved contractual arrangements to benefit all parties
- Cost-efficiency

This list is taken from the ongoing work of CEDA's Dredging Management Commission on the advances in dredging technology, which measure existing technological developments against the needs of clients and project owners.

BOOK REVIEW

BREAKING NEW GROUND: DUTCH DREDGING PIONEERS

Published in November 2018, to coincide with the 150th anniversary of the founding of Van Oord marine contractors, this compelling and beautifully illustrated book is the result of exhaustive study of the dredging industry by Joke Korteweg. It relates the history of this quintessentially Dutch industry and the many Dutch dredging companies that have always played a prominent role in the life of the Netherlands and now play a prominent role in marine construction worldwide.

Be it the new Afsluitdijk, the Zuiderzee Works, the Delta Works in the Netherlands or the Palm Islands in Dubai or offshore wind parks: Dutch dredging and offshore companies like Van Oord are key players in marine mega-projects worldwide. *Breaking New Ground: Dutch Dredging Pioneers* chronicles the Dutch contractors which in an earlier period constructed the Nieuwe Waterweg and the North Sea Canal, deepened rivers and straightened unnavigable bends. The founding one hundred and fifty years ago of Van Oord by Govert van Oord, an independent trader in osier – a Eurasian willow for basket weaving – and other wood products from the Biesbosch region of the Netherlands, inspired the author to research the history of the industry.

Nowadays, Van Oord and other major dredging companies specialise in the construction and maintenance of ports and waterways around the world as well as coastal protection and construction at sea, such as the installation of pipelines and wind parks.

The story of how dredging grew from the laying of fascine mattresses to a major industry emerges through words and historical photographs, tracing the activities of the multiple companies which, through takeovers and mergers, have become world leaders in the industry. In the span of 150 years, marine contracting has developed from a traditional craft whose tools were wheelbarrows and spades into an international knowledge-intensive sector using state-of-the-art, advanced ships.

As Korteweg writes, '...as early as the middle of the nineteenth century the contractors from the Sliedrecht [the Netherlands] area enjoyed an international reputation. This was not based on their dredging abilities...but rather because of the quality of their willow products and fascine mattresses. Willow grove labourers from Sliedrecht and surroundings would weave withies into large mats known as "fascine matresses" that were used as protection of riverbeds and embankments'. It was this expertise, 'the ability of the labourers to place

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www.uitgeverijbalans.nl

Joke Korteweg

Dr Joke Korteweg is an accomplished maritime historian. Originally published in Dutch as *Grondleggers: Het Verhaal Van De Nederlandse Baggeraars.*

More than just the story of family-owned marine contractor Van Oord, the book is about Adriaan Volker, HAM, Amsterdamse Ballast Maatschappij and Broekhoven. Together they represent the rich history of the Dutch dredging industry.

the brushwood, which was weighed down with stones, at the desired place at just the right time' that brought them to the attention of engineers beyond the Dutch borders. It required a deep understanding of the water and the tides.

This understanding translated into ever larger projects such as the construction of the Noordzeekanaal and the Nieuwe Waterweg and resulted in a shift in the position of dredging contractors -- dredging changed from a labour-intensive sideline into its own separate industry with sophisticated equipment. According to Korteweg:

'This shift became clearly visible from the second half of the 1870s onwards. The Nieuwe Waterweg was officially opened in 1872 and the Noordzeekanaal in 1876. Within a short period of time both waterways no longer met requirements. The mouths of the waterways were blocked by silt, while newer ships had a deeper draught. As a result, a period of widening and deepening of both waterways started in 1896. Mechanical dredgers proved indispensable'.

From this beginning to the present-day, the dredging industry has been characterised by its ingenuity and foresight. Today the issues of climate change and rising sea levels, the need for ever-larger ports and the increasing demands for sustainable marine construction are the drivers of an incredibly interesting industry. Joke Korteweg has delivered this message in an effective book, researched in archives and oral sources, and complete with bibliography and index.

A

B

C

(A) The bucket dredger Arnhem from the Adrian Volker company. Bucket dredgers were introduced in the 1860s. Photo courtesy of the National Dredging Museum, Sliedrecht. (B) The development of the Port of Surabaya, Indonesia (then the Dutch Indies) in the 1920s. Photo courtesy Van Oord. (C) 27 May 1932, a day before the closure of the Afsluitdijk dam that closed off the Zuiderzee, creating the IJsselmeer.

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COLOPHON

Editorial
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