

TERRA ET AQUA

WORKABILITY TOOL

**MODELLING
LOCATIONAL DATA
ENSURES DREDGING
DURING OPTIMAL
WAVE CONDITIONS**

**STATUS QUO
CHALLENGER**

Academia and practice team up to incite sustainable port development

MANOEUVRING IN MUD

Whether thick or thin, fluid mud layers impact a vessel's movements

WORKABILITY TOOL MODELLING LOCATIONAL DATA ENSURES DREDGING DURING OPTIMAL WAVE CONDITIONS

When dredging in exposed waters, wave conditions may seriously impact the workability of a dredging project. Especially stationary dredging equipment that makes use of spuds in order to remain in position and transfer the dredging forces to the seabed, like a backhoe dredger or a cutter suction dredger, is vulnerable for harsh wave conditions. The workability of such vessels is not only affected by the wave height, but also the wave period.

In addition to a considerable cost impact when specialised vessels are on stand-by, the safety of the crew working on board of a vessel in harsh conditions is also at stake. An environment engineer and coastal engineer from DEME group as well as a metocean consultant and modeller from BMT Argoss introduce an operational tool which aims to give crew necessary information to make decisions which eliminate the execution of dredging work during unsafe wave conditions. Read more on page 27.





TECHNICAL

How navigable are fluid mud layers?

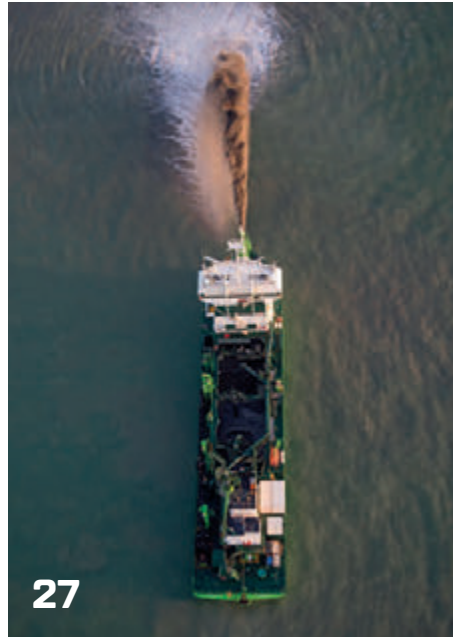
Safe navigation through ports and waterways is determined by the space available under a ship's keel, but a seabed of fluid mud can get in the way.



INTERVIEW

'There should be a shift in the way of thinking about designing infrastructure'

A newly appointed Professor Emeritus at TU Delft and former project manager at the Port of Rotterdam Authority, Tiedo Vellinga discusses his role as a bridge between academia and practice and its impact on the direction of port development.



TECHNICAL

Can Workability be Enhanced by Operational Wave Modelling?

IADC's Young Author Award winner François De Keuleneer and co-authors Joris de Vroom and Arjan Mol discuss the Workability Tool which ensures captains of specialised vessels can make informed decisions to dredge during favourable wave conditions.



EVENTS

CEDA and IADC's Dredging for Sustainable Infrastructure Conference prepares to sweep Amsterdam this fall and the global dredging industry gears up for WODCON XXI in Shanghai.



BOOK REVIEW

Patrick Verhoeven encapsulates the port city of Antwerp with *Harbour Life*, a guidebook which invites readers to intimately experience the port city's sights and history from the author's informed perspective.

CAN A TRADE ASSOCIATION SERVE TODAY'S DREDGING INDUSTRY?



Frank Verhoeven
President, IADC

In 1965, the main dredging contractors at that time established the International Association of Dredging Companies. Back then, the 'trade association' was considered a vital tool to help private dredging and maritime construction contractors navigate the highly competitive global dredging industry brewing in the '60s.

Over fifty years later, nothing has changed.

The dredging industry is as competitive today as ever. Working on projects worldwide, contractors still share the interests which led to IADC's founding mission:

- to inform the world about the fundamental need for dredging and the economic, social, technological and environmental benefits;
- to improve the international business climate for the private dredging industry;
- to promote fair contract conditions and fair competition within the dredging markets;
- to promote worldwide the Standards of Professional Conduct which form the basis for all members' operations;
- and to promote the industry as an innovative industry with attractive career opportunities.

To fulfil its long-standing mission, IADC simultaneously wears five hats: Advocate, Educator, Guardian, Information Provider and Facilitator.

Advocating on behalf of the industry

This past March, IADC attended International Association of Ports and Harbors's launch of the World Ports Sustainability Program and will bring the dredging industry's interests to the table during the formulation of the port sector's highly anticipated initiative.

Educating the masses

By organising dredging seminars, IADC assists in conveying dredging-related information. The five-day course prepares its international participants – comprised of consultants,

authorities, stakeholders and students – for the dynamic nature of maritime construction projects and informs them about the key steps in the process from a dredging contractor's perspective. Come see for yourself at our seminar in Panama this October.

Guarding the environment

IADC promotes sound environmental practices as well as prepares literature pertinent to dredging, especially on topics which are intended for a wide range of target groups. Case in point, the Central Dredging Association (CEDA) and IADC's publication *Dredging for Sustainable Infrastructure* informs all stakeholders how to achieve sustainability in maritime infrastructure projects and an upcoming conference will delve into the subjects presented by the book.

Providing knowledge and facilitating its spread

Through dynamic co-operations with parties involved in dredging, IADC organises international conferences and dredging-related events. IADC and CEDA are co-hosting an interdisciplinary conference to launch the publication *Dredging for Sustainable Infrastructure*. Taking place in Amsterdam's historic city centre, the two-day-long event will welcome all stakeholders involved in any and every facet of a maritime infrastructure project. Save the Date for 19-20 November 2018 and check out this issue's events section for more information.

Just like the dredging industry itself, IADC will continue to be proactive to benefit the dredging industry as a whole.

**IADC simultaneously
wears five hats.**

HOW NAVIGABLE ARE FLUID **MUD** **LAYERS?**



Navigation in ports and waterways with fluid mud seabed can be challenging due to several factors.

Safe navigation in ports and waterways should be insured by the port authorities and a good safety record is of utmost importance for the competitive position of the harbours. An important factor for safe navigation is the space that is available under a ship's keel, known as the under keel clearance (UKC).

Sufficient UKC can be achieved by either setting a restriction on the maximum draught of incoming vessels or by maintaining the desired navigable depth with intensive dredging operations in silted areas. The first option is usually undesirable from an economic point of view and would result in a severe restriction on future development of larger and thus more energy-efficient ocean traversing vessels. The second option is favourable in general, although the cost and environmental impact of the required dredging operations to dispose the fluid mud can become quite substantial.

Fluid mud is typically deposited on the bottom of the shipping route when the net sedimentation rate is larger than the consolidation rate (Winterwerp, J. C. & van Kesteren, W. G. M., 2004). Settling and consolidating in low-energy areas, fluid mud forms river and sea beds. Fluid mud consists of a highly concentrated suspension of sediment particles combined with microbial slimes. These slimes can be seen as a network of polyelectrolytes that keep the sediment particles in suspension, and fluid mud can be seen as a visco-elastic fluid.

Navigation in ports and waterways with fluid mud seabed can be challenging due to several factors. The fluid mud layer cannot be reliably detected by traditional acoustic methods. The interpretation of the measured acoustic data is ambiguous since the position of the seabed on the acoustic charts is not clear. Another challenge for navigation in muddy areas is the generation of internal waves (undulations). The controllability and manoeuvrability of a vessel can be hindered by such waves in case of a ship navigating in a close vicinity of a water-mud interface. In particular, the amplitude of the undulations affects the rudder and

Together with outcomes of towing tank studies, the results of the full-scale experiments led to a change of the nautical bottom density criterion from 1150 to 1200 kg/m³

propeller efficiency as was observed during the both in-situ and laboratory experiments.

In 1970, it was recognised that sonar measurements are not reliable in areas with substantial mud layers and, therefore, are no longer normative. On the basis of full-scale experiments in the Port of Rotterdam, in Bangkok and along the coast of Suriname, it was found that densities up to 1200 kg/m³ had a tolerable influence on manoeuvrability. The 'Nautical Depth' was defined accordingly. The illustration of this concept is shown in Figure 1.

In 1980, a series of full-scale experiments was conducted at the Port of Zeebrugge. The water-mud interface, that could be detected by the high-frequency (180-210 kHz) echo-sounder, was chosen as the reference for the UKC. The experiments were conducted with positive and negative UKC that correspond to the level above or below the depth that was detected by high-frequency echo-sounder. It was concluded that fluid mud with a low density may lead to a modified sailing behaviour, but does not give rise to dangerous situations. Together with outcomes

of towing tank studies, the results of the full-scale experiments led to a change of the nautical bottom density criterion from 1150 to 1200 kg/m³, see Table 1.

Currently, the following definition for nautical bottom is used for navigation in muddy areas: 'The nautical bottom is the level where physical characteristics of the bottom reach a critical limit beyond which contact with a ship's keel causes either damage or unacceptable effects on controllability and manoeuvrability' (PIANC, 2014). Unlike other ports, the Port of Emden uses the yield stress as the criteria for the nautical bottom since 2005 (Wurpts, R., 2005). In Emden, the adopted criteria above which fluid mud is navigable is a yield point of 100 Pa. It is thought that this parameter is related to the specific dredging method or the slime properties in this port. It remains to be investigated how the dredging properties affect the composition of the mud, and hence its rheological properties.

The overviews of full-scale and scaled experiments, and modelling of a ship's navigation in the channels with fluid mud

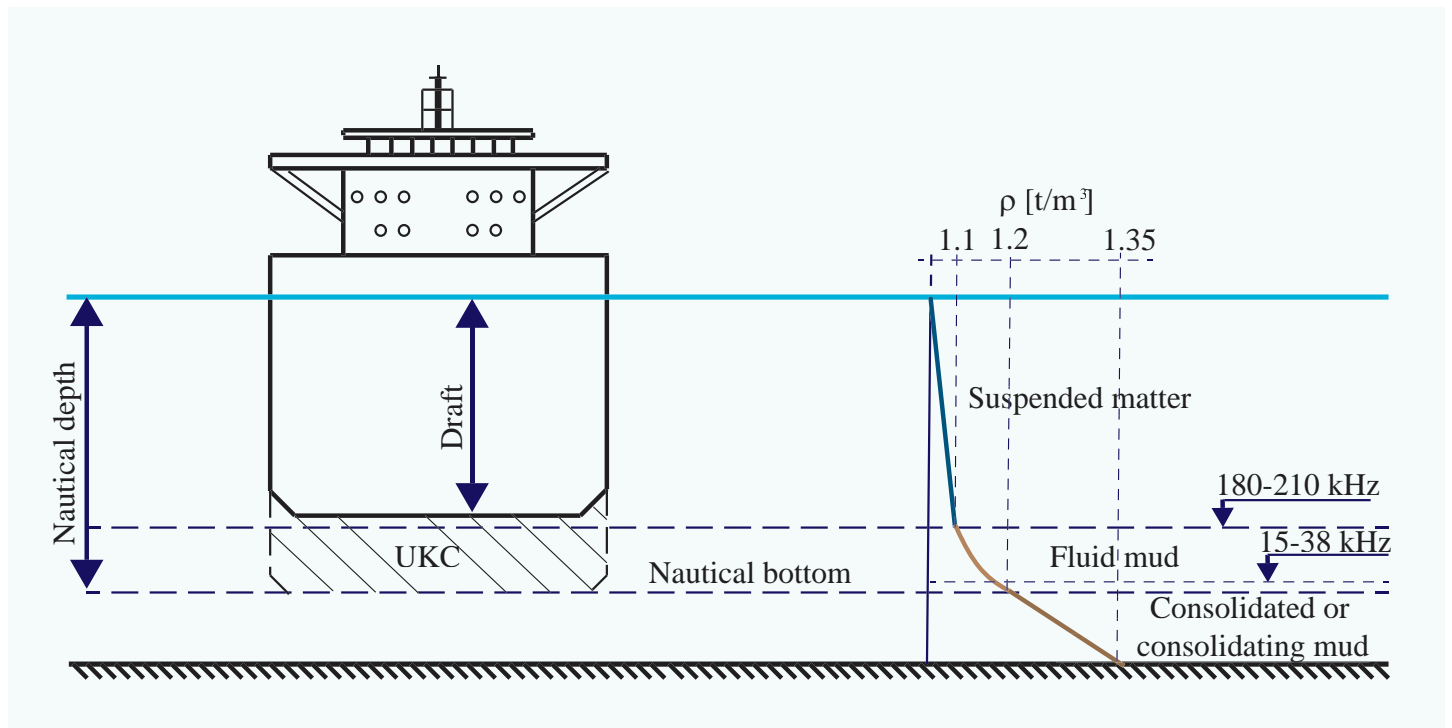


FIGURE 1 The nautical bottom concept, which was developed at the density limit of 1.2 t/m³. Diagram adapted from Nederlof, L. (1978).

TABLE 1

Criteria for nautical bottom from McAnally, W. H. et al. (2007).

Port	Country	Criterion	Value	Dimension
Rotterdam	The Netherlands	density	1200	kg/m ³
Zeebrugge	Belgium	density	1200	kg/m ³
Bordeaux	France	density	1200	kg/m ³
Nantes	France	density	1200	kg/m ³
Saint Nazaire	France	density	1200	kg/m ³
Dunkirk	France	density	1200	kg/m ³
Avonmouth	the UK	density	1200	kg/m ³
Yangtze	China	density	1250	kg/m ³
Liang Yungang	China	density	1250-1300	kg/m ³
Yianjing Xingang	China	density	1200-1300	kg/m ³
Bangkok	Thailand	density	1200	kg/m ³
Paramaribo	Suriname	density	1230	kg/m ³
Emden	Germany	yield stress	100	Pa

layers can be found in Vantorre, M. (1994), Delefortrie, G (2008) and Delefortrie, G. & Vantorre, M. (2015). The present article

provides an additional discussion on surveying methods that can be used for monitoring the fluid mud layers.

Full-scale experiments

The first reported full-scale experiments were conducted in the Port of Rotterdam in 1975

The nautical bottom is the level where physical characteristics of the bottom reach a critical limit beyond which contact with a ship's keel causes either damage or unacceptable effects on controllability and manoeuvrability.

It was concluded that during navigation with the UKC of +14%, less disturbance was caused with respect to the mud-water interface than to CSL Rhine at the same UKC.



FIGURE 2

The 318 tonne deadweight oil tanker SS Lepton was a subject of investigation for the full-scale experiment at the Port of Rotterdam in 1974. Here, the SS Lepton filled with water enters the Port of Rotterdam. Observers on board carefully follow the sailing behaviour of the ship. The Lepton was 350 metres long and 55 metres wide, the draught was 20.90 metres, the average throat clearance was 1.60 metres, and the average mud layer was about 1.15 metres (Nederlof, L., 1979).

(Nederlof, L., 1978 and Nederlof, L., 1979). The 318 tonne deadweight oil tanker SS Lepton (see Figure 2) was sailing within the Europort area at Hoek van Holland, in and out the port. During the tests, manoeuvrability data and the density depth profiles were recorded. The average mud layer thickness in the investigated area was about 1.15 metres. The manoeuvres were done at UKC of 6% of the draught with respect to the depth indicated by the 210 kHz echo-sounder. Although the pilots experienced the entry as 'difficult', a comparison of the manoeuvring behaviour of the Lepton with that of other incoming tankers shows that in fact it was not more difficult than other large ships and even easier than other vessels. This conclusion was also supported by the measurement of the speed of the tanker, maximal percentage of available rudder and propulsion which were analysed during the experiment.

Other well-reported full-scale experiments were conducted in Zeebrugge from 1986-1988. Seventeen full-scale tests of three types were carried out with the trailing suction hopper dredger Vlaanderen XVIII (van Craenenbroeck, K. & Vantorre, M., 1991). Short engine manoeuvres (acceleration/ deceleration tests), constant power manoeuvres, yawing tests at zero speed by means of bow thrusters were conducted in the outer harbour of Zeebrugge. The manoeuvres were performed with keel clearances from -0.35 to +3.0 metres with respect to the depth indicated by the 210 kHz echo-sounder. The rotation tests were conducted at a keel clearance from -0.3 to -0.4 metres. During the trials, the presence of internal waves on water-mud interface was confirmed. The solitary stern internal waves were detected by the 210 kHz echo-sounder. An internal wave of about 2 metres

height was detected by surveyor vessels during the passage of a deep-draughted OBO carrier.

Two full-scale trials were conducted in the Port of Delfzijl from 2013-2015. The first trial was conducted with the general cargo vessel CSL Rhine at positive UKC of 14% and larger with respect to mud-water interface that was detected by 210 kHz echo-sounder. The results showed that the manoeuvring and propulsion behaviour were influenced by the mud layer at UKC smaller than 18%. The second trial was carried out with the hopper dredger Geopotes 15. The tested UKC was between -5% and +17% draught to the depth detected by 210 kHz echo-sounder. During the test, it was concluded that during navigation with the UKC of +14%, less disturbance was caused with respect to the mud-water interface

than to CSL Rhine at the same UKC. It was concluded that the manoeuvrability was much more favourable with fluid mud layers of 2.5 to 3.5 metres thickness in combination with a negative UKC than with a positive UKC from +1% to +13%. At the UKC from +10% to 20%, the ship-induced internal waves hindered the propeller and the rudder of the vessel at low viscosity mud layers. It was reported that the vessel's manoeuvres were in line with simulation studies (Verwilligen, J. et al, 2014 and Barth, R. et al., 2015).

Scaled experiments

Scaled modelled tests were performed to get a better understanding of ship's manoeuvring in muddy environment. These tests were coupled to mathematical manoeuvring models to quantify the effect of the mud layers on the controllability of the ship. The scaled experiments with real mud can be problematic

because of the time effects (e.g. settling, consolidation) of mud. Therefore, a dense viscous fluid is typically used to mimic the fluid mud in a two layer system. The physical properties of an artificial mud (density, viscosity) are chosen to be close to the ones of the fluid mud.

One of the first scaled tests that were carried out to investigate the effect of fluid mud on manoeuvres were conducted with a 1:82.5 scale model of a tanker that was equipped with rudder and propeller, sailing above or in contact with a dense fluid layer (Sellmeijer, R. & van Dortmerssen, G., 1983). A mixture of chlorinated paraffin and kerosene was used to simulate the fluid mud layer. Two density values, 1140 kg/m³ and 1240 kg/m³, were chosen to mimic the real mud conditions at the Port of Rotterdam during the winter and summer periods, respectively. The tested

dense fluid layer thickness, from 1.35 to 3.85 metres, was varied. Both positive and negative UKC with respect to the water-dense fluid interface were tested by changing the water level in the basin. Two types of experiments were carried out: free running tests were conducted to evaluate the total effect of the mud on the manoeuvres of the vessel and the captive experiments were carried out to predict standard manoeuvres by means of mathematical models, which describe the ship motion in a horizontal plane. The effects of mud on squat and trim of the tanker were analysed. It was observed that the tanker becomes slower with the UKC of 3-5% of the draught above the dense fluid. However, further reduction to negative values of UKC makes the tanker less slow in its manoeuvres. Furthermore, the presence of dense fluid on the bottom tends to reduce the steady motion and to accelerate the dynamic motions.



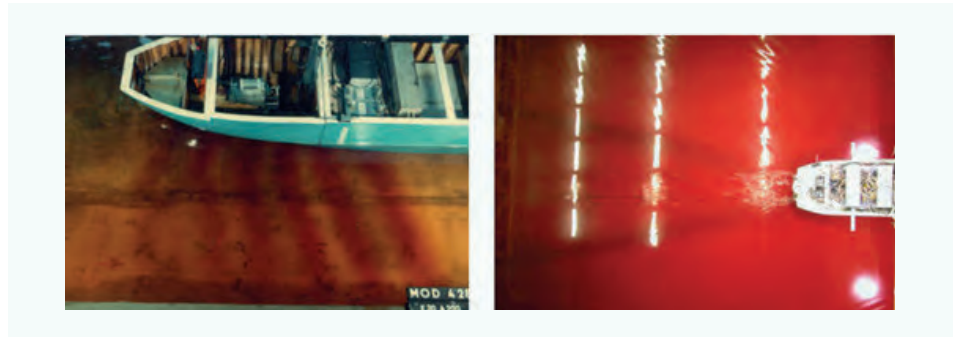


FIGURE 3

Propagation pattern of internal waves of the water-dense fluid interface for viscosity 0.002 Pa s (left) and 0.03 Pa s (right) (Delefortrie, G. & Vantorre, M., 2015).

Self-propelled tests were conducted with scale models of an LNG-tanker and a hopper dredger along a guiding rail above water-mud system with a dense fluid mud layer.

One important observation was the internal waves that occurred in the water-dense fluid interface when a ship is passing. The amplitude of these internal waves (see Figure 3) increases with the thickness of the dense fluid layer and with decreasing fluid density, and affect the propeller efficiency as was observed during the free running trials.

A series of model scale tests were carried out in a wave flume with a tanker model of scales 1:100, 1:70 and 1:55 (Brossard, C. et al., 1991). The model was equipped with sensors for measuring squat, trim and tractive force. The goal of the experiments was investigating the resistance and squat variations above an artificially composed mud layer. The tested mud layer had density gradients over the depth. Three types of mud were tested: with low, intermediate and high gradients. The layers with different yield stresses were used in the study. The undulations on the water-mud interface had been observed in this study.

The self-propelled tests were conducted with scale models of an LNG-tanker and a hopper dredger along a guiding rail above

water-mud system with a dense fluid mud layer. Unstable rudder behaviour and poor propulsive efficiency was observed if due to a combination of initial UKC, squat effects and internal waves, the ship's keel is in contact with both fluids (Vantorre, M. & Coen, I., 1988). A series of captive tests were conducted for different simulated manoeuvres (Delefortrie, G. et al., 2005). During the tests, longitudinal and lateral force components, vertical motion, rudder parameters and propeller parameters were measured. A mixture of chlorinated paraffin and petrol was used to mimic the mud. Mathematical manoeuvring models were developed for fluid type of densities 1100–1250 kg/m³ and of viscosities 0.03–0.46 Pa s, dense fluid layer thickness of 0.75, 1.5 and 3 metres, scaled models of 1:80 and 1:75 sailing with UKC of -12 to +21% relative to water-dense fluid interface, and with speeds between 2 knots astern and 10 knots ahead.

Monitoring methods

Traditionally, the reflections of acoustic signals are used to determine the positioning of water-bed interface. The emitted acoustic pulse propagates through the water column

and reflects back from the bottom of the waterways. The distance from the acoustic source to the reflecting surface is proportional to the travel time of acoustic waves in the water column. In muddy navigational areas, different frequencies of the emitted signal are employed. Standard low frequencies (15–38 kHz) and high frequencies (180–210 kHz) signals are used to provide information about water-fluid mud interface (lutocline) and bed-fluid mud interfaces, respectively. The former typically exhibits a strong contrast. The latter is often inconsistent due to a weak density gradient within a fluid mud layer that plays an important role in the reflection of emitted acoustic signals (Kirby, R. et al., 1980). Therefore, other measuring techniques have been proposed for the monitoring of the water-bed interface in muddy navigational areas. These techniques are typically based on the physics of the scattered and transmitted gamma-radiation, acoustic and optical backscatter, or through mechanical devices. One of the most accurate methods so far is based on scattered and transmitted gamma-radiation. This nuclear method is typically used to determine the density of the water column, including fluid mud layers. The instruments that are based on acoustic and optical backscatter typically measure the concentration of suspended particles in the water column. All the non-acoustical methods have several common drawbacks. Due to the nature of the profilers, the spatial resolution of these tools is limited to 1D vertical profiles (see Figure 4). Thus, the interpolation between the measurements to obtain a spatial map is generally done by combining these methods with acoustic sounding. Another important

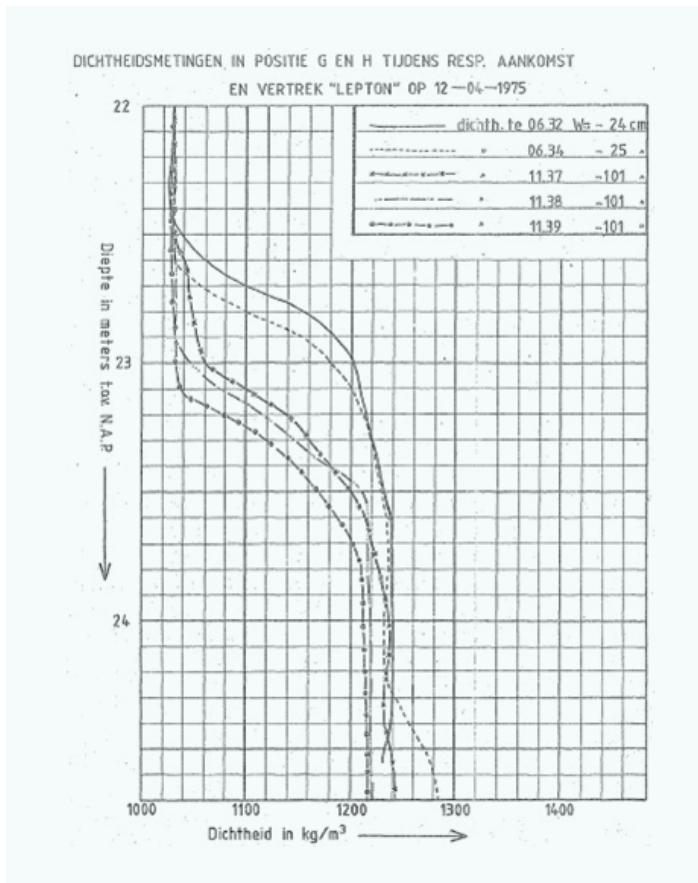


FIGURE 4
Diagram of the temporal changes in density profiles during the full-scale experiment of the SS Lepton in 1975 (Rijkswaterstaat, 1977).

disadvantage of these methods is their intrusive nature of surveying. The measuring tools have to be in a direct contact with fluid mud layers in order to provide quantitative characterisation.

Even though it has been recognised that the surveying methods that are based on rheological parameters are the most suited for nautical purposes, the in-situ measurement of these parameters is a challenging task. Two strategies can be found to determine these parameters. The first one is that samples are taken in-situ and analysed in the laboratory. The second one is to use in-situ

instrumentation. Both strategies are discussed in this article.

Laboratory

Rheological properties can be routinely determined in the laboratory, for instance by the vane-type tests or rotational rheometers. These laboratory methods measure the resistance of fluid mud samples to flow in response to applied shear forces. This can be done by controlling the shear rate, $\dot{\gamma}$, or shear stress, τ , that gives the flow curves (see Figure 5) for different mud samples. Two mechanical behaviours of mud can be deduced from a traditional flow curve: elastic and viscous. The

elastic behaviour is conventionally observed at very low shear strains rates. As soon as the strength of the soil matrix weakens, mud starts to flow exhibiting viscous behaviour. In this mechanical state, deformations correspond to the rate of deformation. The shear stress, at which this soil matrix starts to deform (or to flow) is conventionally called the yield stress. Typically, the yield stress, τ_y and dynamic viscosity, μ_∞ , can be obtained for different mud samples from measured flow curves. Two additional parameters are required for reconstructing the complete flow curve: the Bingham stress, τ_B , and the initial differential viscosity, μ_0 . As can be seen on

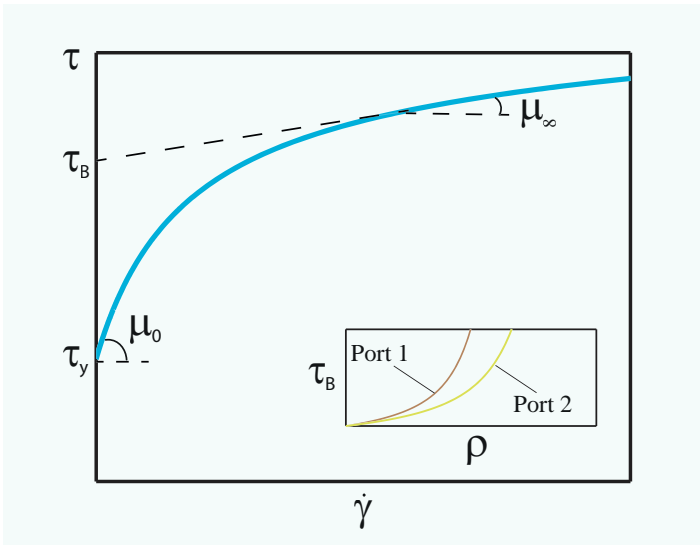


FIGURE 5
The sketch of the flow curve with rheological parameters.

Two mechanical behaviours of mud can be deduced from a traditional flow curve: elastic and viscous.

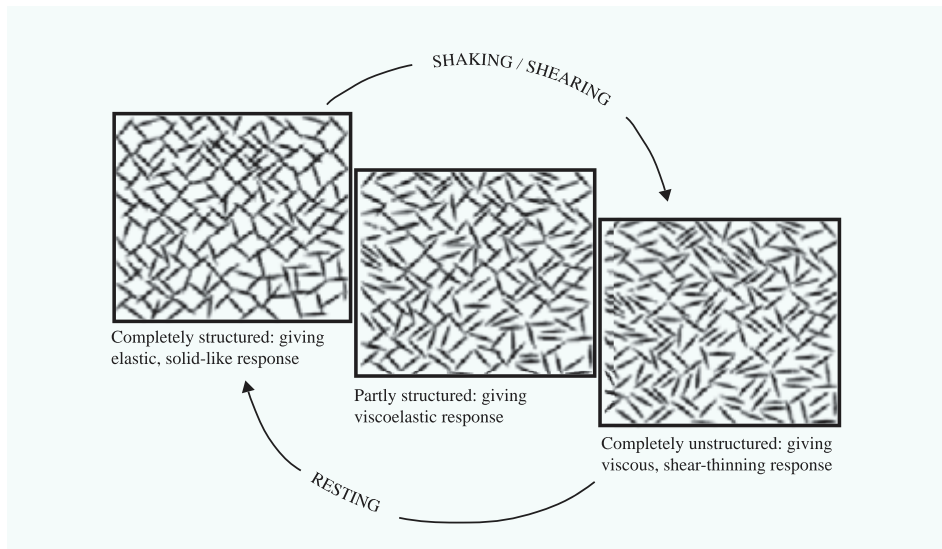


FIGURE 6
Breakdown of the thixotropic structure (Barnes, H. A., 1997).

Figure 5, a given density does not necessarily correspond to a unique yield stress. This implies that the relation between density and rheological parameters should be carefully studied in order to assess the best set of parameters required to characterise the nautical bottom.

Due to the complexity of fluid mud, the shear stresses exhibit a non-linear relationship with the density, ρ . This can be explained by the thixotropic behaviour (deformation, history and time dependence) that is illustrated in Figure 6. Therefore, sampling and measuring procedures, followed by data processing and

interpretation of the measurements, have to be standardised by means of recognised practical protocols (Claeys, S. et al., 2005).

In-situ instrumentation

Free-falling cone penetrometers

The physics of a free-falling cone penetrometer is based on recording the penetrometer's acceleration/deceleration for getting the information about the cone penetration resistance. Using a calibration procedure, the rheological properties of the site-specific mud can be related to this cone-end resistance. In this way, the

water-mud column profiles can be mapped by using this type of instrument.

One of the advantages of this type of equipment is that the vertical positioning of the penetrometer can be derived from the recordings of accelerometer. In general, an accelerometer is more accurate in indicating the depth than standard pressure sensors.

Tuning fork profilers

The tuning fork profilers are based on the recording of the amplitudes that are triggered by mechanical vibrations at different frequencies. These recordings can be used to get the information about the yield stress and viscosity of mud. For this purpose, an accurate calibration procedure that requires laboratory rheological measurements is necessary. The tuning fork profilers can provide sufficiently accurate rheological properties in the areas of low sediment concentrations.

Towing objects

The depth level of the towed object is defined by the viscosity discontinuity between consolidated and fluid mud. The high viscous forces in the consolidated mud and heavy cable weights attached to the towed object assure the cable to position itself on the interface between fluid and consolidated mud unless a critical towing velocity is exceeded and the towed object starts floating in the water above the fluid mud layer. In the case of the Rheocable, the continuous measurements of the electrical resistivity value is used to verify whether the cable is on the seabed or floating above it. The depth level of the towed object is defined by a pressure sensor on the

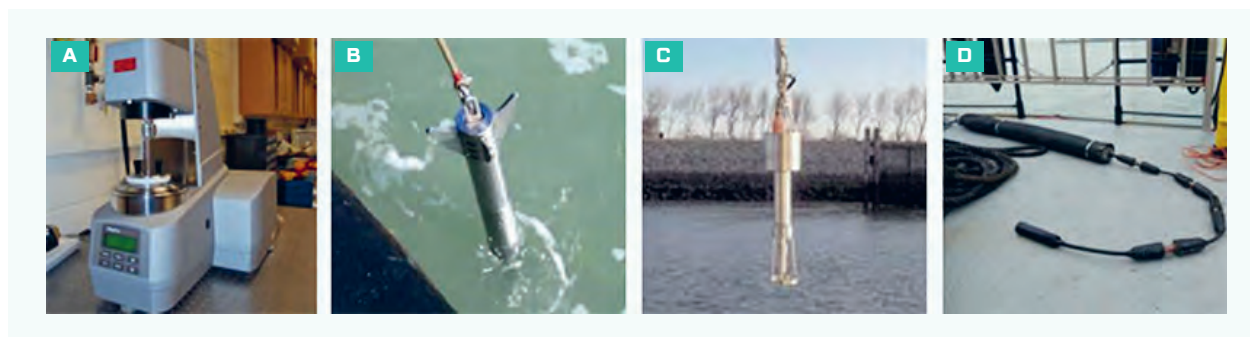


FIGURE 7
Photos show rheology-based methods including a lab rheometer (Anton Paar) [A], free-falling cone (Graviprobe) [B], tuning fork (Rheotune) [C] and towing object (Rheocable) [D].

seabed measuring the hydrostatic pressure (Druyts, M. & Brabers, P., 2012).

Comparison of density- and rheology-based monitoring

In order to compare the density- and rheology-based monitoring, the water injection dredging method was employed in the 8th Petroleumhaven at the Port of Rotterdam (see Figure 8). The water injection dredging (WID) was used for liquefying the top layers of the sediment around a man-made pit in the river bed so that the mud would flow into the pit (500 x 200 metres). The pit collected the fluid mud layer up to 1.5 metres thick from the surrounded area. The Graviprobe and DensX were used to capture the development of the fluid mud layer in the pit over a period of two months. The results of the monitoring are presented in Figure 9.

The recordings of the Graviprobe are shown as the cone resistance measurements as function of depth. The dark blue profile represents the measurements in the pit conducted before mobilising of fluid mud into the pit by water injection. The cyan, green, magenta and red profiles show the fluid mud strength development in the deepening after two weeks, three weeks, one month and two months after the water injection, respectively. The same colours are used to show the density profiles that were measured with DensX. From the measurements, it can be concluded that the density of fluid mud develops faster than its strength.

Figure 10 shows the comparison of the Rheocable and Graviprobe surveys which

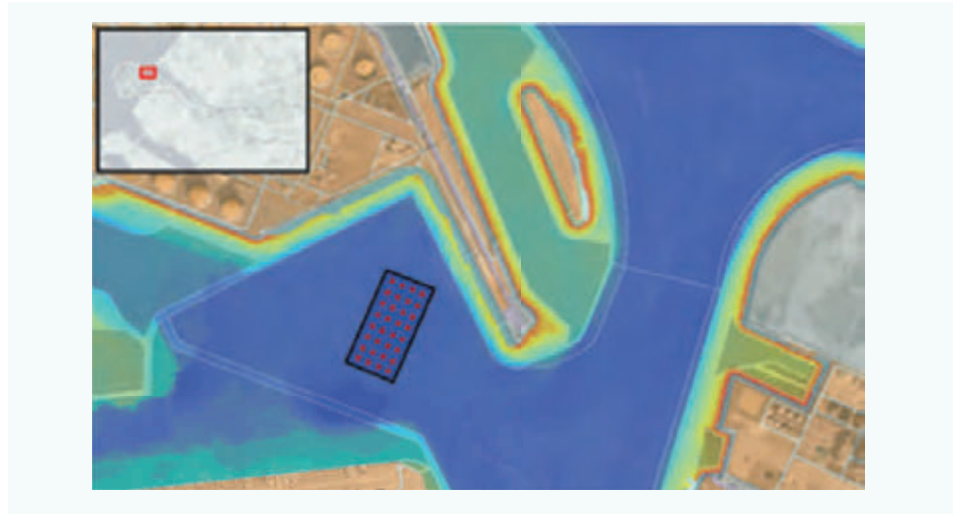


FIGURE 8

Location of the experiment in the 8th Petroleumhaven. The man-made pit has dimensions of 500 x 200 metres.

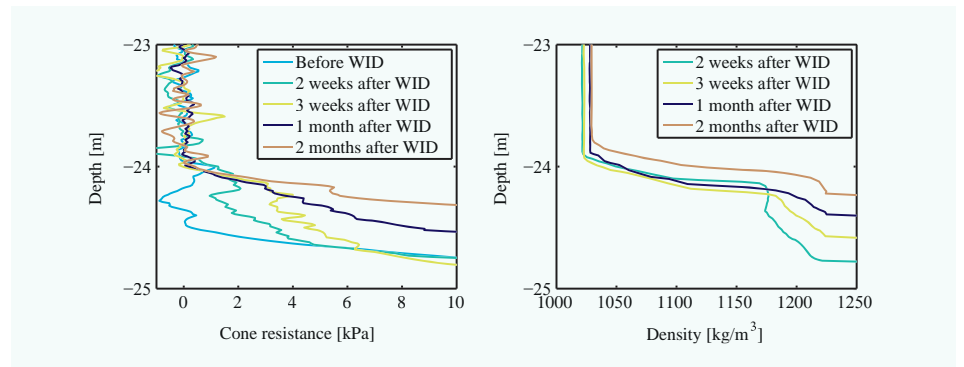


FIGURE 9

Fluid mud development in time, that is measured by Graviprobe (left) and DensX (right).

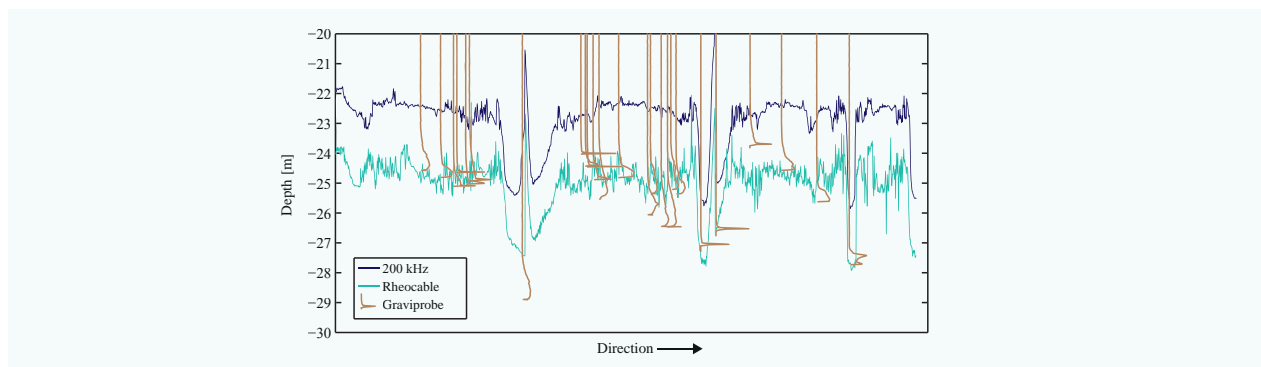


FIGURE 10

Correlation of the high frequency echo-sounding (200 kHz), Rheocable and Graviprobe measurements in the 8th Petroleumhaven.

were conducted after the WID in the 8th Petroleumhaven. The results provide a good agreement regarding navigable depth that is given by the methods. The high frequency echo-sounding measurements (200 kHz) are included for comparison.

The way forward

The safe navigation requires a new reliable and universally accepted criteria for the definition of the nautical bottom. Until now, this criteria was related to the density of fluid mud layers. Some steps have already been taken toward the new definition, for example in the Port of Emden that considers the yield stress as the parameter for the nautical bottom.

Already several decades ago, the importance of improving the parameters used in the definition of the nautical bottom was recognised. At that time, in-situ rheological experiments were practically impossible. This forced the community to adopt an alternative parametrisation, based on density. Over the years, there has been a whole new set of equipment put on the market meant to study the rheological properties of the fluid mud layer (e.g. Graviprobe, Rheotune, Rheocable). These instruments are currently tested in different ports, and it remains to be investigated if the parameters derived from the experimental results are compatible with one another. More advanced 3D acoustic methods are needed for mapping the fluid mud layers. Open questions are:

1. How to relate acoustic measurements to the rheological properties of fluid mud?
2. Can rheological point-measurements be used to calibrate acoustic mapping?

Measuring rheological parameters, and in particular yield stresses, require a well-thought and universally accepted protocol, as these parameters are strongly history-dependent and lead to thixotropic effects.

3. What would be an accepted protocol for measuring rheological parameters?

The measured in-situ rheological parameters have, for calibration purposes, to be compared to samples analysed in the laboratory. Care should be taken during the sampling, storage and analysis of these samples. The composition of the mud

samples (in terms of mineralogy, biological and organic matter content) should be related to the rheological properties and the thixotropic behaviour of mud.

4. How can mud composition be incorporated in the rheological parameters?

The mud properties (density, viscosity, yield stress, mud layer thickness) are time-dependent because of consolidation processes in the fluid mud layer. Moreover, mud layers can be mobile. More knowledge is needed to understand the time dependence of the fluid mud layers.

5. What is the development of the mud layers over time and what is the link between density and rheological parameters?

The rheological parameters are to be incorporated in computational fluid dynamics

(CFD) models to predict the forces acting on the ships, in accordance with the suggestions made by Delefortrie, G. & Vantorre, M. (2015).

6. How to successfully implement the complex rheological behaviour of fluid mud in CFD models?

After answering the questions given above, it is necessary to engage all the key stakeholders into the discussions on a global acceptance of new criteria for the nautical bottom.

7. How to obtain and promote an international implementation of the new criteria related to the nautical bottom definition?

All these points are currently under investigation in different research groups world-wide.

Summary

This article gives an overview of the research that has been conducted to get a better understanding of the navigation in ports and waterways with fluid mud layers. In particular, the up-to-date review of reported full scale experiments that involve real vessels is provided. To study physical processes, the full-scale experiments are accompanied by scaled experiments and numerical modelling. This combination provides valuable insight into ship behaviour with respect to different navigation conditions and physical properties of fluid mud. Another aspect of this article involves the surveying methods that can localise the fluid mud layers and potentially provide information about the strength of these layers. Some of these methods were tested on fluid mud produced by water injection dredging in the Port of Rotterdam. It was concluded that the new rheology-based method show a potential for understanding of strength development in fluid mud layers. Finally, some open research questions with respect to the applicability of the navigation through fluid mud are discussed.

First presented as a paper at the 34th PIANC World Congress 2018, this article has been published in a slightly adapted version with permission of the copyright holder, PIANC.

This research was financially supported by the Port of Rotterdam and Rijkswaterstaat. The first author thanks Arie Noordijk, Ronald Rutgers, Chris Schot and Karoune Nipius for their help with the experiments.



Dr Alex Kirichek

Alex developed a strong background in soil mechanics and rheology during his MSc study in Civil Engineering (Cum Laude). Later on, he obtained his PhD degree in Applied Geophysics at Delft University of Technology, where he developed a novel geophysical monitoring method for quantitative characterisation of undrained porous rocks and granular soils. Currently, Alex works as a postdoctoral researcher at the Department of Hydraulic Engineering, Faculty of Civil Engineering and Geosciences, Delft University of Technology. His postdoctoral project is supported by the Port of Rotterdam and Rijkswaterstaat, who are aiming to develop an innovative cost-effective maintenance concept for ports and waterways with substantial fluid mud layers. This goal can be achieved by revising current criteria for the nautical bottom concept and applying new dredging and surveying methods.



Dr Claire Chassagne

With a background in physics and mathematics, Claire specialised in colloid science. Her work focuses in particular on the use of electrokinetic techniques (electrophoresis, impedance spectroscopy, electroacoustics) to characterise colloidal suspensions and sand/mud layers. In her current position as assistant professor at the Delft University of Technology, she specialised in the physico-chemistry of clays. Over the years, she has demonstrated that colloid science and electrokinetics can provide useful information about the behaviour of clays and in particular explain their cohesive properties in given environmental conditions. At present this knowledge is parametrised in view of being integrated in large-scale sediment transport, deposition, consolidation and erosion models.



Han Winterwerp

Han is Professor Emeritus at Delft University of Technology, as the chair of Sediment Dynamics. He is an expert on morphodynamics and sediment transport, and Senior Specialist on cohesive sediment transport at Deltares. He is participating in and responsible for basic research and consultancy on sediment transport and morphological development in estuarine and coastal environments. He has executed many hydrodynamic, hydro-thermal and hydro-morphological studies all over the world as project leader and as expert in multi-disciplinary project teams, using the various mathematical models developed by Deltares. For many years, a major part of his work is dedicated to basic research into the behaviour and properties of cohesive sediments and the application of the results to estuarine studies. A part of this research is carried out during his part-time affiliation as associate professor with Delft University of Technology.



Tiedo Vellinga

Tiedo obtained his degree in Civil Engineering (coastal engineering) at the Delft University of Technology in 1979. For 38 years until 2017, he worked for the Port of Rotterdam Authority in the field of infrastructure- and water management. He was in the management team for the realisation of the port expansion Maasvlakte 2 as As Strategic Advisor Environmental Management. Since being appointed in 2010, he was Professor Ports and Waterways, Hydraulic Engineering Section, Civil Engineering and Geo-Sciences at Delft University of Technology, and continues as Professor Emeritus mainly doing research projects. He was a project manager for the development and the implementation of the Environmental Ship Index (ESI), an IAPH World Ports Climate Initiative. For PIANC's Environmental Commission, he has served as chairman of the PIANC/IAPH joint WG 150 on Sustainable Ports and is now co-chairman of WG 174 on Sustainability Reporting for Ports.

Safe navigation requires a new reliable and universally accepted criteria for the definition of the nautical bottom.

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**PROFESSOR
EMERITUS OF
PORTS AND
WATERWAYS
AT TU DELFT
TIEDO VELLINGA**

‘THE CHARM OF BEING IN THE PRIVATE SECTOR ON ONE END AND UNIVERSITY ON THE OTHER, IS TRYING TO CONNECT THOSE WORLDS.’

After seven years serving as a professor at Delft University of Technology, Tiedo Vellinga recently assumed the new title of Professor Emeritus of Ports and Waterways. During his concurrent career at the Port of Rotterdam Authority, he practiced what he preached, constantly challenging the status quo in port development. The result was an innovative and sustainable approach which expanded the port as well as delivered clear-cut benefits to People, Planet, and Profit.

Photos Mees van den Ekart

What was your role in the Maasvlakte 2 project?

My role in the project was in the management team. I was responsible for all the conditions – as they call it in the Netherlands – which meant the stakeholders, permits and all the environmental studies related to the permits. I was mainly responsible for all the environmental procedures.

What was a factor in the Maasvlakte 2 project's success?

We got a lot of support from the stakeholders and that was a key issue for such a project. In the end it went very well just because we had a good strategy looking back – and not knowing it – which was to include the stakeholders *and* try to be as sustainable as we could. Also by having a very transparent approach, *wanting* to know it *all*, and most importantly, by sharing, which took some time to develop within the project

Normally, projects are rather isolated. People don't like to share information because they are afraid of interference from the outside world. But we changed that all the way around. I think that was the great asset of the project and factor of its success as well.

Why were stakeholders a key to the Maasvlakte 2 project's success?

There are port stakeholders which is the port industry and service providers such as shipping lines, and your own clients and users of the ports. Then you have the local communities and the urban surroundings as well as NGOs that have concerns with all kinds of environmental issues related to nature, air quality, fishing, and agriculture. We also had to realise natural and recreation areas. Farming and fishing had to be bought out so it was a huge project with *many* stakeholders and *many* issues going on.

The legal situation was quite complex. In fact, building into a Nature 2000 site and air quality which presented puzzling legislation. A lot of projects failed before the high court so we did not want to run any risk in the project. That meant we needed to know *everything* that could *obstruct* the project. Every stakeholder that could have a levee or a possibility of power to block something in the project. We wanted to know all of the pitfalls and needed to be very well-informed about all air quality issues, like what would be the emissions over the lifetime of the project? And not just guesses.

With a Nature 2000 project, gaps in knowledge are not accepted because of the precautionary principle. If there was a gap in knowledge, we had to go for the worst case. So we went one step deeper in our initial research to find out what the effects would be on turbidity and turbidity on algae, shellfish and birds. We spent a lot of time talking with experts in seals and birds to try to know it *all*, and then to share the uncertainties and vulnerabilities with stakeholders to make them a partner so you could have a negotiated agreement on the state of the art of the knowledge.

In the past, many projects had failed with the high court because people do not understand each other or agree on certain issues. So we usually had three steps. First, you need to talk about what you and stakeholders want to know, and define your programme of requirements for your research. Then half way, discuss your first results. And in the end, try to agree on results and facts. I especially say *facts* because you should not try to agree on *values*. You may *never* be able to agree on values.

I remember once doing an assessment for the effects in the Wadden Sea which is in the north of the Netherlands and a UNESCO nature conservation site. We made detailed studies with stakeholders and the individuals responsible for the area. In the end, we agreed on the fact that the effects to the environment were minimal and negligible. At the end of the process, the chairlady of the Wadden Sea said to me: 'But still, I don't like your project. For me, every bird counts.' And *that* is a value. We learned a lot and experienced what it is like to work with the People, Planet and Profit concept in practice.

In Maasvlakte 2's Profit situation, there was a clear business case, but in the People situation, a lot of resistance against the project was encountered, and it becomes clear that people have very different needs than the port. If those needs and values are attached to the project and the people's needs are satisfied, the project does much better. In the Planet situation, a lot was learned about the biodiversity and the ecosystem, and that was very important because the effects on the ecosystems were



Meet Tiedo Vellinga

With a background rooted in Civil Engineering, his prolific 38-year career at the Port of Rotterdam Authority culminated with his role as Director Environmental Management for the port's expansion, Maasvlakte 2. As part of the project's management team, his position involved proliferating stakeholder relations and spearheading the environmental studies and permits. While employed by the port, he shared his professional time with the role of professor of Ports and Waterways at Delft University of Technology. Since the end of 2017, after seven years of merging the worlds of academia and practice, he is now fulfilling academic duties in the department as Professor Emeritus.

relatively small and we compensated for all the effects.

Do you believe mitigation and compensation is an ideal route for port planning or should a preventative approach be employed to guarantee the most added value for all stakeholders?

As a result of this project, I agree that to *think* in terms of mitigation and compensation is not the right way, it is only half way. You should be one step ahead and incorporate it in your earlier designs.

I teach students that stakeholder agreement is extremely important but never replaces compliance with legislation. The compliance with legislation must be leading even if you don't like the legislation. The habitat and birds directive from Nature 2000 is complicated but it's there for a reason. The legislation is extremely strict and rigid because 80% of the wetlands has been lost. We need to help governments make this legislation more *fit for purpose*. Don't expect when stakeholders agree that it is also legally compliant. If you

go one step too quick, then it may not be accepted because the legislation stops it. Bring lawyers on board in the mission.

Of course within nature, there is conservatism and fundamentalists which is very complicated. We have internally fundamental discussions about nature-based solutions and where you should plan ports. There are people within my team that say a port could never be planned in a nature conservation site because it will always bring damage. In my opinion, you can do so if you co-create, you lose some *and* you gain some. But if you are a fundamentalist, nothing can be lost no matter how much is gained.

This fundamental discussion is linked to this European legislation in which acceptance but be achieved first, and then you can lose and gain at the same time. That can happen if you address the issues very much upfront in your project and not after the project is made and in the assessment of the mitigation and the compensation. Once you compensate, you are already in the discussion that you have done something very wrong. Bring in a solution

from the beginning that's already accepted by everybody but is also viable within the legislation.

Would it be an option to educate or inform stakeholders to help promote shared values?

Yes, but you have to be serious about it and understand what you are doing. Connect to other disciplines as well as NGOs and bring them onto your team.

We also welcomed co-decision making. We had stakeholder agreements which in my opinion is a co-decision. The stakeholder also decides on the decisions you make. Transparency and openness is extremely important as well as sharing data. The other one is bringing people in your project.

What did you learn from the completion of Maasvlakte 2?

What I learned from the Maasvlakte 2 project is that there should be a shift in the way of thinking about designing infrastructure. In the past we designed infrastructure for a function, for example for the port to make a basin a channel and a quay wall. In Maasvlakte 2, we started out this way as well and then had obstructions. In the end, however we solved those potential problems and created a lot of value for stakeholders. And then I realised when you design it's better to start with the needs and values, and try to create value for stakeholders from the beginning. People always say that is more expensive but I don't believe so. Over the longer term, it's certainly not more expensive and you create more value and also more acceptance. In fact that's also what we now try to pick up as lessons learned for other projects: to start with an inventory of needs and values. The Maasvlakte 2 had many values. Of course there is nature – the biodiversity which has not been affected due to compensation – but it's also creating natural values. There is a lot of landscape, recreation and also clean air. There is less congestion on the roads which is a value for society. There is archaeological value – and lots of it. This is also public value and you can see it at FutureLand in the exposition.

In fact, FutureLand wasn't there in the beginning. It was part of change in thinking during the project that the public should be informed to make people feel part of the project. We had to do dredging and then we

**Through young people,
the world is changing,
and really changing
for the better.**

ran into paleontological artefacts – fossils – offshore. We realised people were extremely interested because the project would be on the evening news because you found fossils, not because you are making a new port. So we invested to do it better and made a programme for the archaeological and paleontological findings. An expert suggested giving some background on the geological context. And we said alright, we have a budget for that research. We did borings and tried to link the findings from the sand mining area to its geological context.

Then we even went one step further. Where we dredged, we could link every cubic metre of dredged material to where we disposed it on the beach. A lot of artefacts, fossils and archaeological objects were found on the beach. So we developed an archaeological app that people can use on the beach and if they find something, they can log in to the app and the app will tell them about the geological context. If it is something they want to know more about, they can immediately send a picture to amateur archaeologists and palaeontologists.

The app is still working today. That's a very good example of something simple: the data you have creates value for society.

Is the research consortium 'Port of the Future' documenting the successes experienced in Maasvlakte 2 ongoing? What so far can be deduced from collected results/data?

We received a research grant to make a framework for integrated and sustainable port design in Africa. One of the linked projects is an eco-based port design. The project works bottom up from an existing pilot on the Port in Tema in Ghana where €1.5 billion is being invested in a new port. That is a good time to connect with a project because once people are investing in the port, it's a reason to look at the scope again and can more easily make some add-ons to improve the project itself. You may spend a little bit more money, but you are already dredging and then it may be relatively easy to link the dredging works to the lagoon and to include the revitalisation of the lagoon.

Research projects are a reason for change. Changes happen because knowledge is gained and awareness is created. We are creating awareness with students from the University of Ghana, and we could connect the research project to a real project. Through young people, the world is changing, and really changing for the better.

The project is very interdisciplinary. There are five universities on the team as well as post-docs from four universities. Its connected to the University of Ghana and TU Delft's faculties of civil engineering – which is myself – and policy and planning which looks at governance and design with structuring methods. The University of Amsterdam is involved in relation to the economics of Ecosystems Services, predominantly in terrestrial ecosystems but they also developed marine ecosystems. Ecologists from the Wageningen Marine University as well as IHE Delft are also connected.

The project is very much into the management of the integration. My role is dominated by process management, to integrate the different disciplines. We have research integration meetings with an engineer, ecologist, economist and governance expert. For them, it is new and not that easy.

For example, the engineer is not so satisfied because he wants to think and develop new engineering concepts and he feels it's difficult to develop something new, and now he has to negotiate primarily with the ecologist about the engineering. I need to tell him that's really the value of the project, to do things together.





Port of the Future

Alongside his active presence in academia, Tiedo is leading the 'Port of the Future', an ongoing research consortium which spawned from successful completion of Maasvlakte 2. One development which resulted from the consortium is the Port of the Future Serious Game. The board game and accompanying virtual environment is an exercise in *polderen*, a dialogue-driven model which involves all stakeholders of a project and was founded in the Netherlands.

Each player – or if played on a larger scale, each group – assumes the role of a different stakeholder such as the port owner, members of the nearby community, unions, NGOs or bankers. When the port wants to expand, players – or groups – choose from cards which describe diverse options for how the port's expansion can take shape. Members of the group must negotiate and agree on which cards will be chosen, and the group either gains or loses credits in the categories of People, Planet and Profit. If only Planet and Profit credits are gained, then in the end, there will be a lot of opposition against the project.

The game was played at PIANC's 34th World Congress in Panama with young engineers from around the world to expose this way of collaborating, and it has also been played with real world stakeholders. Tiedo explains: 'We've played with real port developers, NGOs and government, and those people said to us 'we never talk to each other about port development'. And they were very glad that now, with this game, they had a reason to talk to each other.' The activity helps individuals realise and understand there are other interests to consider and they should be aware of and negotiate these interests. According to Tiedo, 'the game works quite well in the sense of creating awareness. I think it's a good investment to try to interest people in a different way of thinking'.

Parties – most of them involved in Maasvlakte 2 – helped develop the game including Deltares, Wageningen Marine University, Port of Rotterdam, Boskalis, Royal HaskoningDHV and the World Wide Fund for Nature, and support has been given from organisations including the Netherlands Embassy in Panama and PIANC.

It's also a good learning experience but I see it's by far the best way to move forward, to try to do this interdisciplinary research, but really

interdisciplinary. Not everyone is doing their own research and scoring by themselves. That you try to score as a team and so far things are

It's not all about one animal. It's not all about one species. It's about the integrity of your natural system.

going well. In September we have our midterm assessment with the NWO (Netherlands Organisation for Scientific Research) to report and evaluate our scientific research findings. I think that's a good example of bringing scientific knowledge further.

If you do cross-disciplinary research – not disciplinary – that's where you can get your gains. You *have* to expand your horizon. That's the beauty of working for TU Delft and in the scientific arena: you can easily expand your horizon. In Delft, this can be done by connecting to 3mE (Mechanical, Maritime and Materials Engineering Department), transport and planning, both airport and port design, as well as departments in other universities. The charm of being in the private sector on one end and university on the other is trying to connect those worlds.

Are you continuing with other research initiatives bridges the worlds of academia and practice?

We have SmartPort Rotterdam which is focusing on scientific research between the users. It's very much demand-driven so it includes the port users, the port authority and the city of Rotterdam, and on the other side, universities, dominated by Erasmus University and TU Delft. They support writing scientific project proposals and also I have a few lines of research even after my retirement.

How do you manage the different interests of the private and academic arenas?

The culture is of course completely different but in the end you try to match those agendas

as well as you can. It's on one hand very inspiring to be in the commercial sector which is very active and needs to produce. It's the one world where there is no time to think and reflect. In the other world, there is abundant time to think and reflect, and that's almost contradictory. How can you balance those two things? I think it's really great because the one can inspire the other. I've always experienced it as very rewarding to be able to work in both worlds. The important thing is that you connect those worlds. I think that's the most important task of my successor, Mark van Koningsveld.

It seems you've gone to great lengths to bridge these two worlds in your work. Is that a choice you've made because of your own interests or has it come more naturally?

For me, it came more natural but I have had many discussions with people that are almost in the same situation and they experience it to be difficult. They feel like they don't have enough time to live in both worlds and that they should make choices. I believe I was a pioneer in trying to link those two worlds.

How has your simultaneous work in academia or practice benefit the other?

I've made pleas to people within the port to recruit young people that can have a dual objective. Let them make a career either in university or in the ports.

Give them one day a week in university and also make them fit for eventually a tenure track, that they can do a PhD or become a university associate professor or professor if that better matches their talents and ambitions. There are a few people that understand it and can cope with those two worlds which seem to be completely different but I think it should be advocated more.

After I worked at the port, the Port of Rotterdam is changing its attitude. They say 'knowledge is more important than it was before and we need to be able connect to your PhDs. We need to hire people that can understand and talk to your PhDs'. In the past, these worlds were still too far apart. If the port wants to improve, it must make this shift towards being a smart port and make progress in regards to knowledge which is extremely important. It's too complicated

today to do it the 'old way', you need people that are able to communicate with researchers. The world is improving. It's changing and I like that.

Will inherent differences between your background and your successor's background lead to any adjustments to the Ports and Waterways curriculum?

Since I'm retired, the Port of Rotterdam picked up my way of linking academia and practice. With TU Delft, the Port of Rotterdam made a contract for five years with my successor, Mark van Koningsveld, to create the 'Second Tiedo'. So that's very nice to be honoured in that way, that they want somebody like you again.

It's a little bit charming when he comes to a meeting with the port and then introduces himself 'I'm the new Tiedo'. I think Mark is extremely knowledgeable and very smart, and he may certainly do things differently but that is also a good thing.

Do you have any advice for your successor in your role at TU Delft?

I've had nice discussions with him about his legacy and also about how his role can be within university and how to link to other bright professors. And that you should try to cooperate and not compete. That's still a real struggle within universities because there is so much pressure on competition because they want individuals to score. Individuals must have high scholar indexes and that does not really invite directly for cooperation between scientific groups.

I've never had much interest in scholar indexes. I became a professor too late to become a big star with a high scholar index, and for me that was not the most important part of the work. But today's young professors at university are very much pushed to excel in terms of their academic scores.

There is an inherently conflicting interest of cooperating and maybe giving some credit to other people or simply scoring with the scientific results by yourself. Hopefully that approach will change when people are pushed more to cooperate. Usually in funded projects – in the European Union and also the NWO (Netherlands Organisation for Scientific Research) – you are forced to cooperate with other universities and other experts. If you



Would you say there has been improvement within the sector?

There is a long way to go. Some of the sector is doing extremely well and others are still far behind. I think this will still be the case for the next decade. It will be possible to recognise the traditional approach to port development but also the new approach. Of course the new approach will be winning in the end by far, but it takes time and you can change the world quicker by creating more awareness by showing examples and pilot projects. That's what's so beautiful about university, students and young people get to try it out.

Do you have students exploring this new approach to port development?

I have a new student doing site selection for new port development in Myanmar. He is aiming to select locations from the ecosystems services (ES) perspective. First he is making an inventory of all the ES of locations and then tries to score in those services against all the ecosystem effects of port development. I think that's a new way of designing. It's only a matter of time before this will be easier with tools. Tools must still be developed to have assessment procedures, but these tools are well on their way.

How do you think the Ports and Waterways sector, and dredging industry as a whole, is stacking up to the task of sustainability?

We still need to create a lot of awareness. For example, I had a student doing his Master's thesis on the design of a marina in Mauritius. Mauritius is a beautiful island with coral reefs but they don't have many marinas because there was no acceptance for marinas due to environmental deterioration. So I gave him my message: 'design a marina with coral reefs and mangroves'. Then he was puzzled and asked 'how can I design a marina with coral reefs and mangroves?', but this set him into thinking. He then came onto the path of ES and he made an inventory of the different locations dominated by coral reefs, mangroves or river inlets in Mauritius, and he valued those different habitat types. He looked at all the elements of a marina – like a jetty – and what it would need. He scored the requirements for the infrastructure against the opportunities for ES of coral reefs and mangroves. I think that was a very good exercise. He received a high grade and now he's working for Royal HaskoningDHV and is part of the PIANC international

don't, then you won't get the funding easily. So there is a mechanism already in place to force them to cooperate but that's still a struggle for those in university. They want to score in their own fields while I think we should score by *connecting* different fields. Then the value of your own project is that you make something interdisciplinary which means you must change your way of designing.

I tell ecologists that their role is completely changing. In the past, the ecologists

were usually attracted to the project in the end when the ideas were already there. But now, the ecologist needs to be involved upfront. You can design *after* there is an *understanding* the system. You have to *start* with people that *understand* the system, so it's the ecologist is the one that starts the process. The ecologist also has to shift towards holistic thinking. It's not all about one animal. It's not all about one species. It's about the integrity of your natural system.

It's changing and I like that.

working group on Ecosystem Services. He is expanding the thinking of alternative concepts to people in the real world. You need patience but if you do the right thing, then in the end it will come.

One may think they are doing something well for nature but knowledge can be lacking. Much more knowledge is needed to do it well, so to make a point, we may need to become a little bit more *extreme*. Another example I'm working on now is Navigation with Nature. In this new navigational concept, the students – which are engineers – have to adapt the ship to the river and not the river to the ship. It's a completely new way of thinking from traditional engineering. You have to understand the river, the meandering and natural character of the river. When there is more water, more cargo can be carried, and when there is less water, different kinds of ships are used. Ships which are very flexible and made of polyesters, and can consist of modules that are deeper for use when there is more water and less deep for when there is less water. The other aspect is to integrate technology and users, and use big data in the concept. The boats on the river have smart phones so they can measure and share data.

These boats are on rivers which are not in Europe because European rivers are man-made and are more or less ruined nature-wise. This is a concept for rivers in South America and Myanmar which is also where we are trying to prove this concept through exchanging and gathering knowledge about currents, water depth and user experiences.

Modern technology can support the shippers by using models – like SOBEM from Deltares – that learn from the day-to-day data and generate prediction models for the next days. The shipper can download the data and knows where the river is going to be navigable. That means things can be changed and the ship can be adapted to the river.

Traditional aides of navigation are not needed nor the channels that are dredged to keep them in place. The system itself knows where the gullies are, how deep the ship can go and how deep it will be the day after tomorrow. Of course this may be a little bit disappointing for dredgers because they want to dredge and make infrastructure but I think they have to get past that way of thinking. If you think along these new concepts, there would still be lots of work for dredgers and contractors, but it will be different.

How then might the role of dredgers evolve with an approach like this?

Don't worry about it, there will be a lot of dredging! Sea level rise and climate change will make extreme efforts necessary. We need a lot of engineers and a lot of dredgers in the future but it will be different. Even in the Netherlands, if we see a sea level rise of two metres...we will not give up and will still protect ourselves. Dredgers will need to think differently. They need to follow nature instead of trying to shape nature. Working with Nature – and Building with Nature – is an extremely complicated concept. Not everyone understands it well enough. There are still too

many people that think Working with Nature is using soft solutions and building with clay and sand. But it's much more than that. It's just a completely different approach where nature is really leading in the design. But we are on our way. And you cannot blame engineers or companies that they are only thinking half way in their philosophies. It just means we need to create more awareness and bring more examples.

Does the education of the Ports and Waterways sector need to shift to remain competitive in the future? Is the Building with Nature concept seeping into education?

The education is extremely good. We have the course in civil engineering but I still run into people that don't really grasp the philosophy that you really have to make nature leading in the design. If the answer is 'it's not possible', then that's not a good answer.

Of course it's very difficult to do so and you have to make it a little more extreme, such as designing with coral reefs and mangroves. You have to make a design that the ship is adapted to the river and you don't jump into river training methods. You don't jump into dredging and making groynes to try to force nature. No... you should be more creative. You should use underwater robotics *and* big data *and* all your users *and* new technology *and* autonomous ships which can be completely different. Why do autonomous ships need to be so *big* that they can only sail in *deeper* water? So be *smarter!*

Resumé

2018-Present

Professor Emeritus of Ports and Waterways at Delft University of Technology

2010-2017

Professor of Ports and Waterways at Delft University of Technology

www.tudelft.nl

1979-2017

Manager and Strategic Adviser at Port of Rotterdam Authority

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CAN WORKABILITY BE
ENHANCED BY OPERATIONAL

WAVE MODELLING?

Various regions all over the world are known for their problematic wave climate; the African west coast, the French and Spanish Atlantic coast, the Indian coastal waters, and so on are known for their long swell coming with long wave periods. But also less swell-dominated seas such as the North Sea may have severe wind sea systems with typical wave peak periods around 6 to 7 seconds. In extreme cases, even for large cutters, workabilities of less than 50% are not exceptional. Given the large stand-by costs of such specialised vessels, this can have a huge impact on the cost of a dredging project.



There is not only a considerable cost impact. The safety of the crew working on board of a vessel in harsh conditions is also at stake. Usually it is the responsibility of the captain to decide when the works need to be ceased in case of upcoming bad weather conditions. Therefore, the captain needs to have a thorough knowledge of the limits of the vessel in terms of metocean conditions, and he/she should also have good insight in the current and upcoming weather conditions. When there is uncertainty in one of those elements, the captain's decision might be subjective and lead to unsafe situations or inefficiency:

- Unsafe working conditions follow from the fact that the equipment is being exposed to conditions beyond its workable limits. This could lead to damage to the equipment, for example damage to the spud, and uncontrollable motions of the vessel. In

such case there is a risk for unsafe situations for the crew.

- Loss of efficiency is caused by a captain's decision not to work, while in reality the weather conditions are below the critical limits. This often happens after a period of bad weather, and conditions start to improve again, but the decision to resume the works is dominated by over-conservatism. The quality of the consulted weather forecasts also plays an important role in this process.

In order to improve this situation, DEME has developed an operational tool in cooperation with BMT Argoss which aims to provide the on-board crew and site staff with information on the present and near-future sea states and whether operational thresholds are expected to be exceeded. The sea state is broken down in systems of common meteorological genesis which are considered

to be statistically uncorrelated. With the use of response amplitude operators, key operators are determined and presented via a web application. Whenever the actual wave conditions are getting too rough the system will indicate that the workability limits are being reached and work should be ceased. Real time sea state data can be acquired from buoys that are deployed near the works. Future sea states are provided by a combination of operational atmospheric and wave models that typically deliver a forecast window of five to eight days. To be able to further increase the accuracy and skill of these forecasts, the models are calibrated on the measured waves. The wave forecasts make it possible to plan the works more efficiently and to optimally use available workable windows. It generally results in less downtime, less damage and a safer working environment.



The tool has initially been applied for the Wheatstone downstream project, Australia, where a large access channel for a new port had to be dredged. This article discusses a project case where the tool has been applied in the dredging works for a new highway at La Réunion island (Indian Ocean). The focus will be on the quality of the wave forecasts by operational wave models and the continuous calibration efforts which are increasing their reliability during the project.

Introduction

The Workability Tool (WoTo) has been developed to objectify the decision-making process regarding the weather conditions when active in harsh weather conditions. Combining measured and forecasted metocean parameters with the workable limits of vessels, the crew is able to evaluate the workability at any time. The comparison

between the measured and forecasted wave parameters gives an appreciation of the confidence one can have in the forecasts.

The deployment of this tool has significantly increased the safety, the awareness, the efficiency and the planning on the different projects where it has been deployed. The reliability of the tool is highly dependent on the quality of the weather forecasts and, depending on the location of a project, the wave modelling can be more or less accurate. The development and improvement of wave models are therefore generally necessary to increase the reliability in the forecasts. These step by step improvements are then validated and/or calibrated using measured metocean data.

After a short introduction of the different hardware and software components, a case study will be presented and discussed.

Description of the WoTo

The workability tool needs different entries to compute different outputs. Some inputs and outputs of the tool will be briefly explained below.

Measured wave parameters

To evaluate the current wave conditions, statistical parameters have to be derived from wave energy spectra. These can be obtained from different instruments (radar, buoy, ADCP, etc.). The focus here will be on directional wave rider buoys.

Most wave rider buoys are generally delivering a wave spectrum every 30 minutes. To get closer to a real-time monitoring of the waves, specific software has been developed to reprocess the buoy raw displacements data and obtain new wave spectra containing the buoy displacements of the past 30

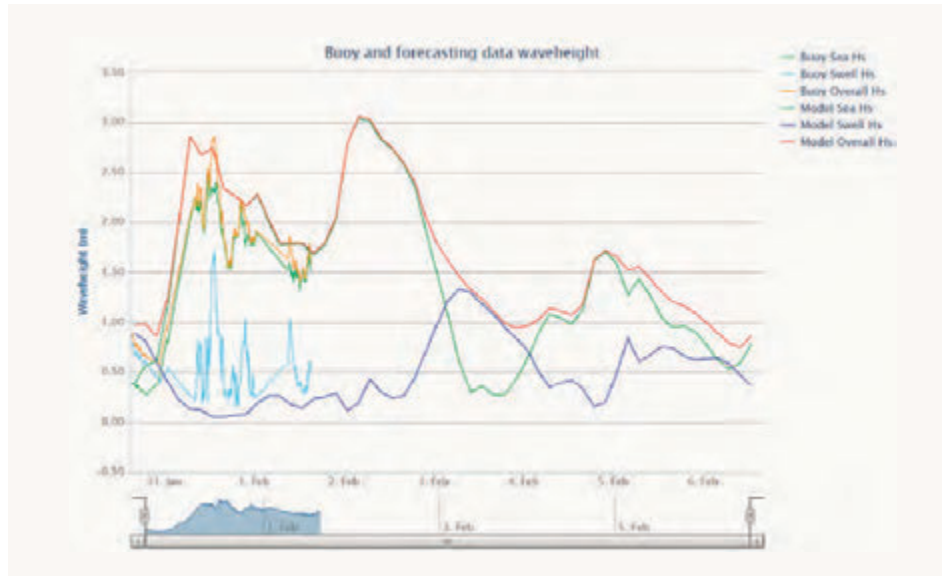


FIGURE 1

Visualisation of the measured and forecasted statistical wave parameters.

minutes every 3.75 minutes using a rolling buffer.

To obtain the wave statistical parameters from the spectra, a splitter has been developed by BMT Argoss and integrated in the WoTo. The splitter uses a wind component (from the forecast or measured) to allocate the spectral energy to a swell or a wind system.

A significant wave height (Hs), a mean period (Tm) and a direction (Dm) will thus be obtained for both the sea/wind and swell components. The system will then look at which system is the most impacting the workability of the vessel.

Forecasted wave parameters

The forecasting models are run several times a day by BMT Argoss and the output (Hs, Tm and Dm for both sea/wind and swell components) is imported in the WoTo. Depending on the operations, the frequency of the forecasts is adapted. In the WoTo, the forecast is shown next to the measured data (see Figure 1) in order to get a feeling on the quality of the forecast.

The model setup will be discussed in more detail in the case of La Reunion.

Workable limits of the operation

Depending on the operation of interest, different workable limits are considered.

Stationary vessels will generally be modelled in a diffraction model to determine the forces/movements generated under specific wave conditions. Each vessel and activity has its limits and on their basis, workability tables are generated. The WoTo shows the actual wave conditions in a workability plot from which it becomes clear if the conditions are workable or not (see Figure 2).

Project case

La Réunion

Project description

La Réunion is a French island and department in the Indian Ocean situated 700 kilometres east of Madagascar. On this island, a new highway is planned from the capital Saint Denis to La Possession. This nine-kilometre-long highway will replace the existing cliff road. This road, constructed in 1976, has two lanes in both directions and was designed for 10,000 vehicles per day. Nowadays, about 60,000 vehicles make use of the road every day. Further, the existing road is subject to rock-falls from the steep cliffs adjacent to it and flooding during tropical storms resulting in unacceptable traffic jams. During heavy rain storms, the road is closed for any traffic. The road is the only link between the port area and the capital city.

The new highway is being constructed partly as a viaduct and partly as a causeway (see Figure 3) and it is designed to be operational during wind speeds up to 150 km/h and waves up to significant heights of 10 meters. The project is financed partly with European funds. The main contractor for this project is a joint venture between French companies. SDI (DEME group) is working on both parts of this project (viaduct and causeway) as a subcontractor.

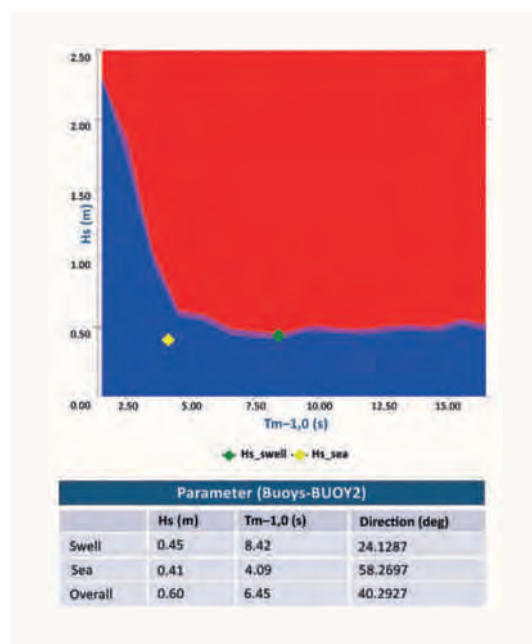


FIGURE 2

Visualisation of the comparison between the measured waves and the workable limits of an activity.



FIGURE 3

The new highway is being constructed partly as a viaduct and partly as a causeway.

For the causeway, the work consists of dredging a trench and making the foundation of the revetment of the highway.

For the causeway, the work consists of dredging a trench and making the foundation of the revetment of the highway. Three sections of the highway are being constructed as a causeway. The total length of the first dredged trench is about 3,070 meters. The trench has a width of 25 meters at the base and a depth of about five meters below existing seabed. The total dredging volume amounts about 250,000 m³. The dredger material is partly reused in the body of the revetment.

Apart from the dredging works, the work consisted of the placing of two layers of rock. The first layer is a 2-150 millimetres rock filter of which a total of 170,000 tonnes must be placed. The second rock layer consists of 0.2-1 tonne rock with a total weight of 340,000 tonnes.

For the viaduct, the work consists of dredging 48 pits and laying filter material (by dumping with barges and levelling with a backhoe) as support for the 48 GBF (Gravity based foundations). The backfilling of the pits is also part of SDI's scope. The total dredging volume amounts about 650,000 m³. The dredged material is partly reused to backfill the pits. Filter material dumped as bed layers under the pits is totalling 50,000 m³ of 2/30 mm and 40/80 mm.

The dredging works are carried out by the backhoe dredger Pinocchio. The dimensions of this dredger are 60 x 19 m². It has three spuds with a length of 40 meters and the total installed power is 2,416 kW.

Two methods of disposal of the dredged material are used. The first method is to sidecast the material using a pontoon which is moored alongside of the Pinocchio (causeway). A second method (viaduct) is used with two split hopper barges (1,000 m³ of capacity each) to dispose the material.

Climate

The volcanic island of La Réunion is characterised by a complex orography. High peaks and deep valleys have a strong effect on the atmosphere over and around the island. In winter and spring, the trade winds blow over the region. Strong lee effects can be observed on the west side of the island which are highly correlated to the background wind conditions over the region; small differences in the background wind direction cause significant changes in wind conditions at La Possession. For example: with winds blowing from the E or ENE, the north-easterly wind velocity is higher, up to 20-25 knots, and blows throughout most of the day. Under conditions with a slightly veered background wind (ESE) the enhanced north-easterlies are sparser and weaker. They are then alternated by weak sea breezes. Sea breezes play a very important role

in the wind climate on and around La Réunion. A background sea breeze is caused by the difference of surface temperature between land and sea.

Diurnal heating of the island surface by the sun causes, in combination with the high mountains on the island, a strong convection over the island in general and particularly over the mountain tops. This phenomenon occurs virtually every afternoon, especially in summer. The opposite takes place in the evening and early nights. As the convection, triggered by the heating of the sun, stops at the end of the day, the air in the mountains starts to cool. The colder air flows downhill and reaches the coastal areas as a weak to moderate land breeze. When the temperature drop in the mountains is relatively strong in comparison to the one over the coastal areas, the air in the mountains will start to descend rapidly. Like any fluid it will follow the easiest path which is through valleys towards the coast. These so called katabatic winds can reach high speeds and occur very locally. Occasionally, these gusty winds can last for approximately (half) an hour.

Waves do not grow significantly due to the diurnal wind effects at the site of interest as the forcing surface winds are so short lived. During the stronger trade winds in winter waves from the ENE can refract around

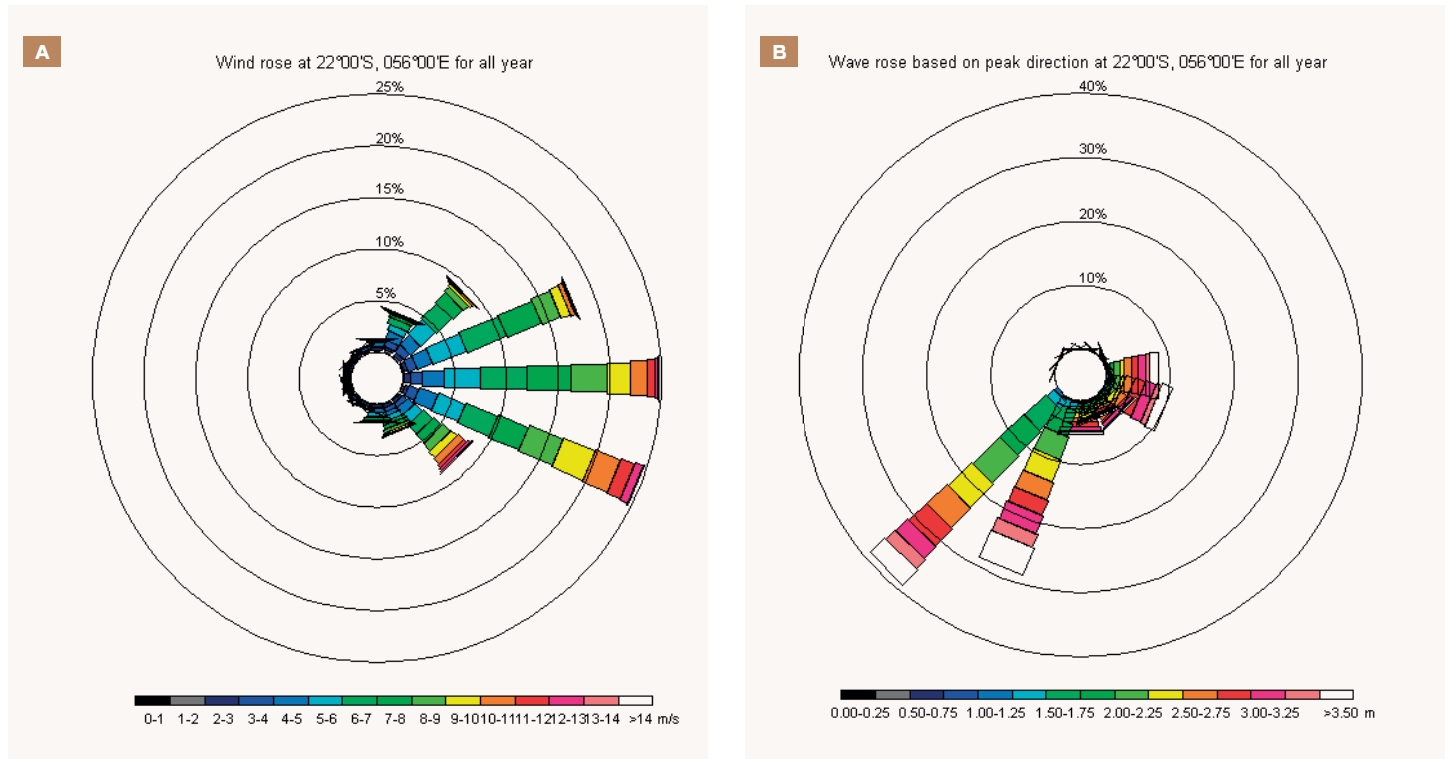
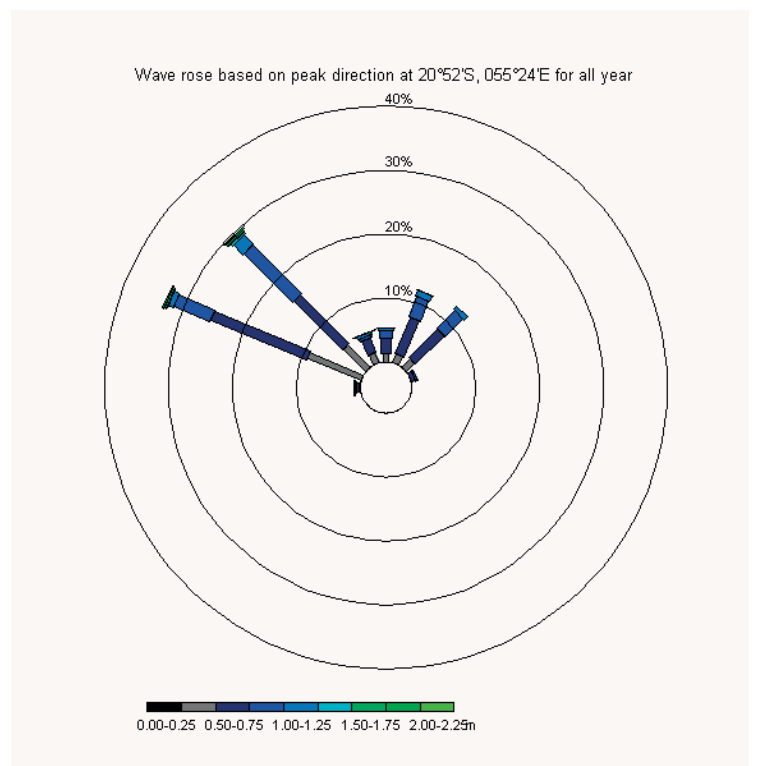


FIGURE 4 Directional roses of u_{10} (A) and H_s (B). Data was taken from grid point 22°00'S, 56°00'E from WW3-global model. Years used: 2016-2017.

Saint Denis which results in waves travelling along the shore and reach La Possession. Cross seas can be found with an additional wave system, generated by southern ocean depressions, which refracts around La Reunion and approaches La Possession from the northwest. During summer low, variable winds are, as an exception, alternated with severe storms (Ceulemans & Hulst, 2016).

Figure 4 shows directional roses of 10 metre wind speed (one-hour sustained) and significant wave height from WaveWatch III Global offshore grid point 22°00'S, 56°00'E. The wave rose (Figure 4) shows the two majors wave systems from the east and from the southwest. Both wave systems curve around the Island of La Réunion and merge on the northern side of the island. This results in a sea state in which dominant peak switches between both wave systems. This is illustrated by a directional rose of significant wave height and peak direction in Figure 5. The data was taken from the swan reunionD grid using model grid point at the project site 20°52'21.1S, 55°24'31.0E. A spatial impression of this process is shown in Figure 6. This shows

FIGURE 5 Directional rose H_s . Data was taken from grid point 20°52'21.1S, 55°24'31.0E from swan reunion model. Years used: 2015.



significant wave height and direction from the reunionC grid. The project site (20°52'21.1S, 55°24'31.0E) is shown by the pink square.

Model description

The SWAN model is a third generation spectral model developed at Delft University of Technology that computes random, short-crested wind-generated waves in coastal regions and inland waters. The model is based on the wave action balance equation with sources and sinks. SWAN accounts for the following processes:

- Wave propagation in time and space, shoaling, refraction due to current and depth,
- Frequency shifting due to currents and non-stationary depth.
- Wave generation by wind.
- Three- and four-wave interactions.
- White-capping, bottom friction and depth-induced breaking.
- Dissipation due to aquatic vegetation, turbulent flow and viscous fluid mud.
- Wave-induced set-up (not applied in this project).
- Transmission through and reflection (specular and diffuse) against obstacles

The BMT Argoss model suite for La Réunion comprises of four nested SWAN grids. Specifications of these grids are shown in Table 1 and outline is shown in Figure 7. The large SWAN domain (reunionA) receives its boundary conditions from the WaveWatchIII Global wave model.

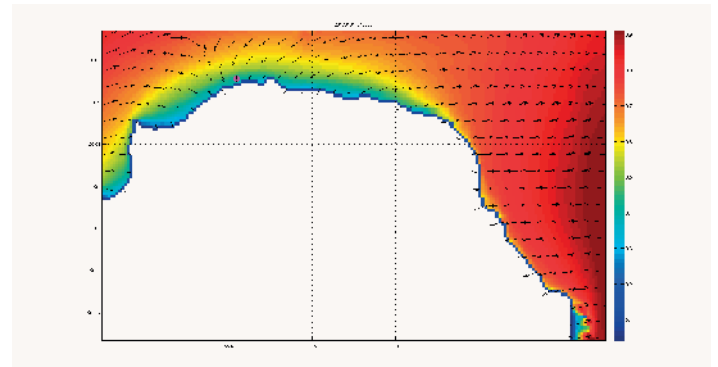


FIGURE 6

Significant wave height and direction from wave grid reunionC on 01-jan-2017 at 04:00 UTC. The project site is shown by the pink square.

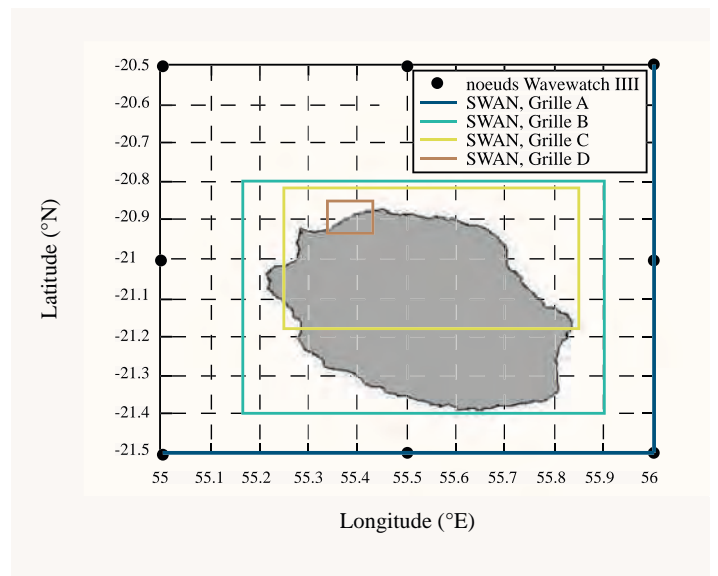


FIGURE 7

Extents of the swan grids for La Réunion.

TABLE 1

Model specifications for La Réunion model suite.

Grid	Engine	Forcing (resolution)	Boundary	Outline ([lon],[lat])	Resolution
reunionA	SWAN	WRF-DO1 (27 km)	WW3-Global	[55,56],[-21.5,-20.5]	10 km
reunionB	SWAN	WRF-DO1 (27 km)	reunionA	[55.17,55.9],[-21.18,-20.8]	2 km
reunionC	SWAN	WRF-DO2 (9 km)	reunionB	[55.25,55.85],[-21.18,-20.82]	300 m
reunionD	SWAN	WRF-DO2 (9 km)	reunionC	[55.34,55.43],[-20.93,-20.85]	90 m

TECHNICAL

During the project, several model developments were tested. The developments that lead to improvement of model results are shown in Table 2.

In August 2017, we switched nesting the outer grid (reunionA) from 1D spectra (spectral wave information per frequency) to 2D spectra (spectral information per frequency and per direction). The assumption was that this would improve the wave direction since directional information is better represented in 2D spectra as compared to 1D spectra.

In October 2017, the wave growth due to local wind was switched off. The local wind growth over grids reunionC and reunionD is assumed to be marginal, and it showed to affect the wave direction in a negative way.

Continuous monitoring of the waves combined with the know-how of BMT Argoss has led to a significant improvement in the accuracy of the forecasting.

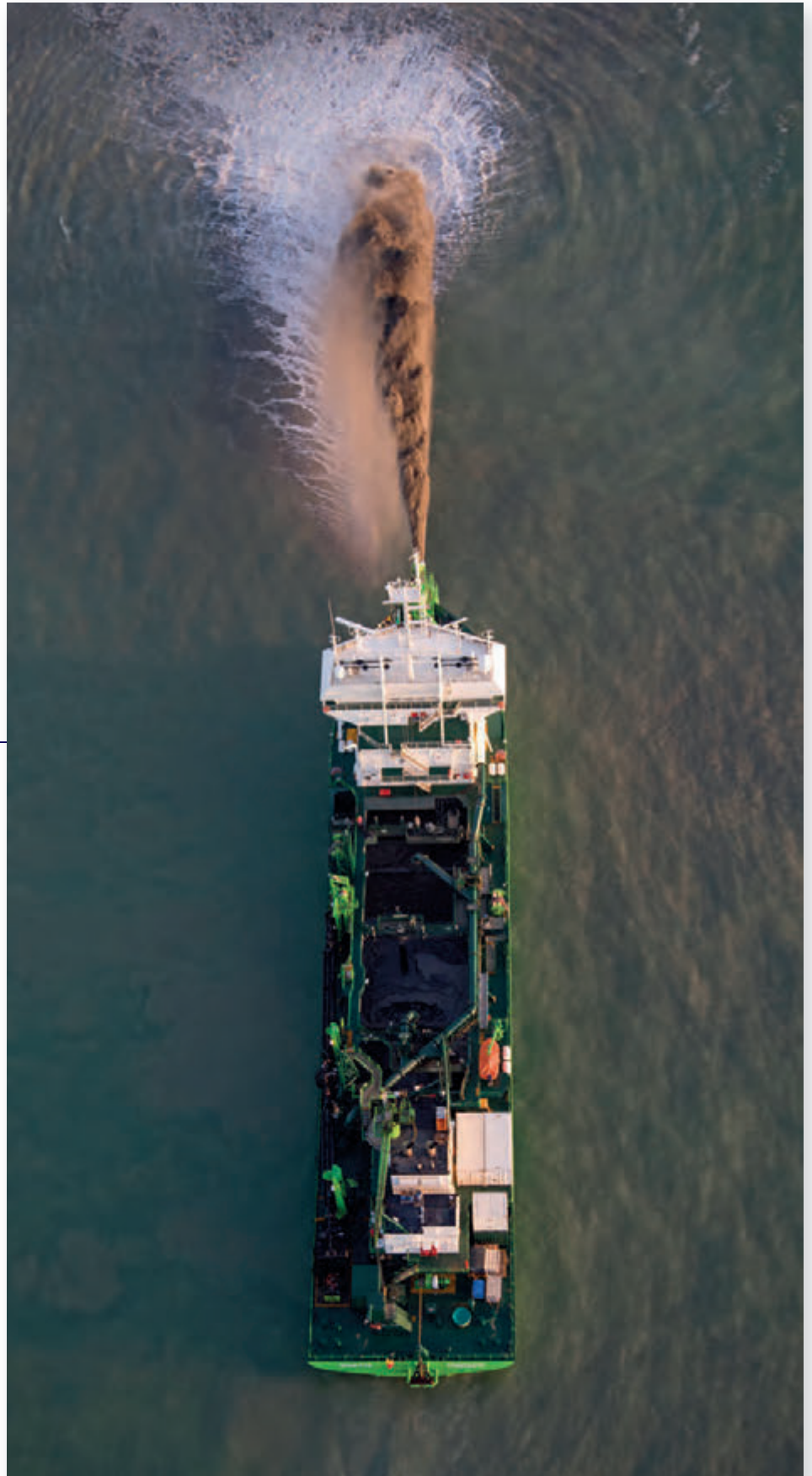


TABLE 2

Main model developments.

Development	Description	Used in grid	Date in effect	Effects
Nest in 2D spectra	Nesting of reunionA grid in WW3-Global 2D spectra instead of 1D spectra to allow for better representation of directional information.	A	August 2017	Wave direction
Switch off windgrowth	Local windgrowth results in unrealistic mean wave directions from the north. Windgrowth switched off for grids C and D.	C and D	October 2017	Wave direction, wave height

Results

The region of La Réunion is a very particular environment where a lot of local phenomena influence the wave climate. The continuous monitoring of the waves combined with the know-how of BMT Argoss has led to a significant improvement in the accuracy of the forecasting. Being in the middle of the Indian Ocean, the project is greatly benefiting from this increased reliability.

Therefore, the same type of figure is repeatedly used to indicate the performance of the model against the observations. These figures consist of an upper plot showing both the 0 to 24 hours, 24 to 48 hours and 48 to 72 hours forecasted (blue) and observed parameters (orange). The lower plot shows the bias where pink indicates forecasts higher

than the observed data and blue indicates forecasts lower than observed.

La Réunion

As explained in the section on the climate of La Réunion, the island is prone to very complex refraction as well as local phenomena. The model has thus needed some fine-tuning to accurately predict the wave height and direction.

Due to these refraction and local effects, the forecast and measurement locations are of crucial importance. The results presented here will focus on one location to keep it short and clear for the reader. To follow the evolution of the works, the wave rider buoy and forecast locations are modified on a regular basis.

In order to demonstrate the impact of the model performances that have been implemented in August-October 2017 (see Table 2), results from a period before the improvements (June 2017) have been compared to a period after the improvements (February 2018).

Note that the mean wave period is not further discussed here to keep it clear and concise for the reader. The significant height parameter is generally more relevant as limit for marine equipment.

Below, Figures 8 and 9 show comparisons of predicted and observed significant wave height and wave direction for the period of June 2017 (before model improvements).

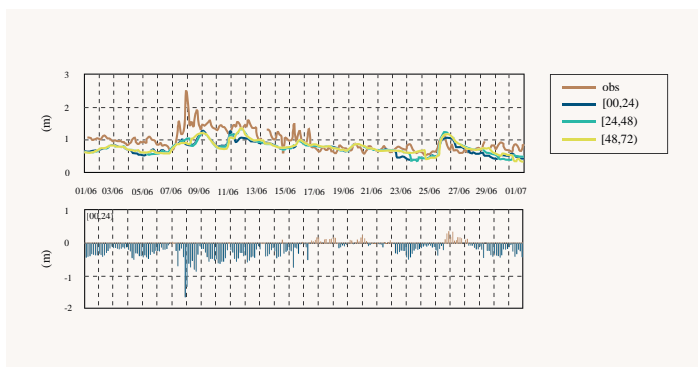


FIGURE 8

Wave height forecast for June 2017 (upper plot) and the bias (lower plot).



FIGURE 9

Wave direction forecast for June 2017 (upper plot) and the bias (lower plot).

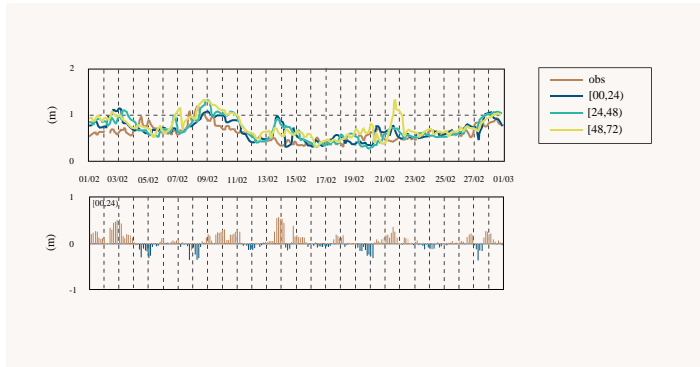


FIGURE 10

Wave height forecast for February 2018 (upper plot) and the bias (lower plot).

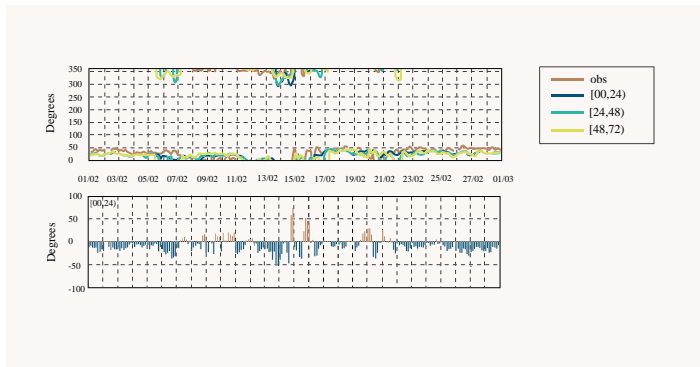


FIGURE 11

Wave direction forecast for February 2018 (upper plot) and the bias (lower plot).

Figures 10 and 11 show the same figures for February 2018 (improved model).

TABLE 3

Main model developments.

ME [00.24]	Before model improvements April-June 2017	With improved model January-February 2018
Sig. wave height [m]	-0.24	0.08
Wave direction [deg]	37	-5

Table 3 presents the bias of the model performance for a period before model improvements (based on April to June 2017) and after the model improvements (January-February 2018). These numbers and Figures 8 through 11 show that in the old situation, the forecast on average significantly underestimated the wave height at the project location and that the wave direction



was systematically off by about 40 degrees (observations: northeast, model: north), while after improvements the wave height on average was only slightly overestimated while the wave direction is pretty much spot on.

Discussion

The case study shows the efforts being done to improve the predicted metocean conditions

on site by using feedback (observations) from the site. There are some restrictions however that have demonstrated it is impossible to let the forecasts exactly match the observations:

- It is hard to find a consistent data set from buoy measurements on a project due to the fact that sometimes the buoy is displaced by the project crew, the buoys

are taken out of the water (protection during storms), gaps in the data due to bad signal (remote sites), problems with acquisition software etc.

- It is not always straightforward to compare mean wave periods from models to mean wave periods from buoys. This is caused by the fact that the wave model and buoy may use



different techniques to compute the mean wave period.

- Comparing wave model output to buoy data can result in significant improvement of model results. However, there are a few limitations to this. These limitations include
 - Representability of model results for the buoy location
 - Wave model resolution
 - Differences in computation method of integrated parameters (wave height, wave period) between buoy and model
 - The wind data source driving the wave model. Poor quality wind data will in general result in poor quality wave data.
 - Quality of bathymetric data (for nearshore location)

Conclusions

Working in exposed marine environments may seriously affect the workability of the equipment being used in a project. Given the

large stand-by costs of specialised offshore equipment, this can have a huge impact on the cost of those projects. There is not only a considerable cost impact. Also the safety of the crew working on board of vessels in harsh conditions is at stake.

The Workability Tool has been deployed to inform the crew and site staff with information on actual and upcoming wave conditions linked to the working limits of the equipment. In numerous situations, the tool has proven itself by limiting downtime and letting crew work more safely and better plan the works. Besides, the tool makes the bridge personnel aware of the metocean conditions. With increased confidence upon having comparison between wave forecast and real-time measured waves, the crew can now easily make an objective decision to stop, start or relocate the works.

Input to the WoTo are forecasts coming from models. Wave models are developed to represent sea states on a global, regional and

local scale. Many processes are included in the wave model, which are used all over the globe. Specific locations require specific tuning of the wave model parameters, such as wind drag, coefficients influencing refraction and others, and for this it is vital to have reliable buoy information. This paper has shown that the quality of the weather forecast can significantly improve during the project by making use of the field observations. The expert meteorologists are able to use the observations in the interpretation of the model forecasts to deliver an improved manual forecast. Besides, at set times they will use the observations to adjust and tune the wave models to better represent the observed conditions. When the quality of the forecast is increasing, the crew will also gain more confidence in the forecast which will help them to better plan the works and take objective decisions.



François De Keuleneer

Following graduation from the University of Neuchâtel (Switzerland) with an MSc in Hydrogeology and Geothermics, François joined DEME group in 2014. After a year as an on-site project engineer, he joined the Research & Development department in DEME's head office. Currently an environment engineer, he is also involved in wave data acquisition systems and operational workability assessments for different projects. With his team and BMT Argoss, François is developing tools to assist the crew and project teams when working in exposed conditions. He is a member of the Ecosystem Restoration Camps Foundation's supervisory board, an organisation applying cooperative efforts for the ecological restoration of degraded lands.



Joris de Vroom

After graduating with an MSc in Physics from the Vrije Universiteit Amsterdam, Joris joined the Royal Dutch Meteorological Institute and worked in the field of climate and weather research. He joined BMT Argoss in 2010 and worked as an operational forecaster at the BMTA's weather desk. In 2015, he switched to his current role as metocean consultant and modeller at BMTA. He designs wave model grids for projects and operational use, and carries out consultancy projects for customers in the offshore industry.



Arjan Mol

Upon completion of his Civil Engineering study at the University of Twente (The Netherlands), Arjan began working at WL | Delft Hydraulics (currently Deltares) as an advisor/researcher in the hydraulic engineering department. He gained experience in the field of hydrodynamic and morphological modelling, metocean studies and hydraulic structure design. In 2011, he started working at DEME group in Belgium as a senior coastal engineer. He focuses on the hydraulic design of large projects, is involved in workability studies and has a special interest in the development of operational systems.

Summary

When dredging in exposed waters, wave conditions may seriously impact the workability of a dredging project. Especially stationary dredging equipment that makes use of spuds in order to remain in position and transfer the dredging forces to the seabed, like a backhoe dredger or a cutter suction dredger, is vulnerable for harsh wave conditions. The workability of such vessels is not only affected by the wave height, but also the wave period. Other types of marine operations, such as the construction of jetties, installation of wind turbines or the placement of scour protections are affected as well in their workability by the ambient conditions at sea.

Various regions all over the world are known for their problematic wave climate. In extreme cases, even for large cutters, workabilities of less than 50% are not exceptional. Given the large stand-by costs of such specialised vessels, this can have a huge impact on the cost of a dredging project.

There is not only a considerable cost impact, but also the safety of the crew working on board of vessels in harsh conditions is at stake. Usually it is the responsibility of the captain to decide when the works need to be ceased in case of upcoming bad weather conditions. Therefore the captain needs to have a thorough knowledge of the limits of the vessel in terms of metocean conditions, and he/she should also have good insight in the current and upcoming weather conditions. When there is uncertainty in one of those elements, the captain's decision might be subjective and lead to unsafe situations or inefficiency.

In order to improve this situation, DEME group has developed an operational tool in cooperation with BMT Argoss which aims to provide the on-board crew and site staff with information on the present and near-future sea states and whether operational thresholds are expected to be exceeded.

First presented as a paper at the 34th PIANC World Congress 2018, this article has been published in a slightly adapted version with permission of the copyright holder, PIANC. At the conclusion of the congress, the Young Author Award was given to François De Keuleneer to recognise his outstanding paper and presentation.

With increased confidence upon having comparison between wave forecast and real-time measured waves, the crew can now easily make an objective decision to stop, start or relocate the works.

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Boost your knowledge to enhance the quality of water infrastructure projects.

Dredging for Sustainable Infrastructure Conference

19-20 November 2018
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There is an increasing expectation that infrastructure projects should add value – beyond the economic aspect – to the natural environment and society in which they will serve. Therefore, those responsible for the planning, delivering or operating of water infrastructure with a dredging component must be up-to-date on the current thinking regarding sustainable dredging.

If your role is to deliver dredging projects with longevity which also maximise the benefits to society, nature and economy, then the Dredging for Sustainable Infrastructure Conference hosted by the Central Dredging Association (CEDA), International Association of Dredging Companies (IADC) and Dredging Today will be of particular relevance to you and your company.

The conference will feature speakers with decades of experience as scientists, practitioners and project owners with multidisciplinary backgrounds including engineering and environmental sciences. This must-attend event is an opportunity for planners, designers, decision makers, regulators, contractors, project owners and environmental advocates to learn the latest information directly from international experts.

The conference and networking area coincides with the official launch of the CEDA-IADC



guidebook *Dredging for Sustainable Infrastructure*. The sustainable benefits which are being delivered as part of waterborne infrastructure projects will be in focus during the two-day-long conference.

The Dredging for Sustainable Infrastructure Conference will cover key topics including:

- Integrating dredging into sustainable development
- Applying the concept of sustainability to water infrastructure development
- Identifying key enablers for successful sustainable infrastructure development
- Executing creative solutions through multi-disciplinary collaboration
- Assessing and managing sustainability in relation to dredging
- Reviewing dredging and construction operations
- Managing dredged sediments for win-win solutions
- Modelling for project initiation, planning and design
- Monitoring: collecting field data that is fit for the purpose, proportional and relevant

Technical presentations of the highest quality can be expected. The programme is being finalised by the technical committee and full details will be available on the event's website. With a dedicated networking area, there will be many opportunities for participants to engage with each other during the programme.



22nd World Dredging Congress & Exposition (WODCON XXII)

25-29 April 2019

Shanghai, China

<http://woda.org/wodcon-xxii>

To promote the technical innovation and sustainable development of the dredging industry, as well as enhance the communication and cooperation among the world dredging families, the China Dredging Association (CHIDA) and Eastern Dredging Association (EADA) host the 22nd World Dredging Congress (WODCON XXII) in Shanghai, China. Held once every three years, WODCON is the world's top summit on dredging.

The world's industry experts will discuss the harmonious developments between dredging and ecology, the continuous innovation of the dredging industry's image over time and contributions. Expert, scholars and engineer representatives of public authorities, related institutes, manufacturers, consultants and contractors are invited to participate as well as present advanced products, technologies and services for the dredging and marine engineering industry.

The congress's theme is 'Enhance the Harmony between Dredging and Ecology', and three main forums will be organised:

- Ecological dredging makes the world a better place
- Towards the new era of intelligent dredging
- Sustainable dredging and marine economic development

Additional topics to be covered at the congress include:

- Prediction of sustainable dredging strategy
- Environment and ecology assessments of dredging project, risk control and process dynamic management
- More environmental and efficient dredging and reclamation technology
- Construction technology, process and method of dredging projects
- Water environment and ecological management and restoration, and dredged material usage
- Design and manufacture of green and efficient dredging and ocean engineering equipment
- Intelligent Dredging and Information Technology
- Experiences or cases of construction, technology innovation and management of major projects
- International Engineering Guidelines, Legislations, Standards and Contract Management

FIRST CALL FOR PAPERS

Deadline 31 August 2018

Authors of selected abstracts may submit draft manuscripts of 3000-5000 words – maximum 20 pages including figures, pictures, and the copyright transfer form – addressing the theme and topics covered by the conference to the author's regional contact before 31 August 2018.

The official language for paper submissions and presentations is English. Papers must be original and should not have been published or offered for publication elsewhere. The Technical Papers Committee reserves the rights to accept, retain and publish the submitted papers. Authors must assign all copyrights of the submitted papers to WODA.

Papers must be sent to the contact of the submitting author's region:

Authors in China send papers to Guo Enze (CHIDA) at chida2018@163.com

Authors in Asia and Australasia – excluding China – send papers to John Dobson (EADA) at dobsoncj@hotmail.com.

Authors in Europe, Africa and Middle East send papers to Sylvia Minten (Central Dredging Association) at sylvia@mintenprojectmanagement.nl.

Authors in North, Central and South America send papers to Robert C. Ramsdell (Western Dredging Association) at info@WesternDredging.org.



HARBOUR LIFE

ANTWERP

Immersed in harbour activities since he was teen, author Patrick Verhoeven has bundled his in-depth knowledge and personal connection with Antwerp's port into a shareable experience. A new guidebook for dwellers, visitors and enthusiasts, *Harbour Life* identifies port-related sites in the Belgian city and explains their historic and cultural background.



Author: Patrick Verhoeven
Publisher: Pandora Publishers
Published: March 2018
Language: English and Dutch
Price: € 22.50
ISBN: 97890-5325-4356

Available from
<http://harbour-life.com>

Long-time urban residents and short-term tourists alike may often find themselves in a city shaped by port activities and be unaware of the impact a port has on the built and natural environment. To accommodate its frequent ship visitors, a port city and its inhabitants may trade entire towns – in Antwerp's case, four during the 1950s and 60s alone – in exchange for development and expansion projects.

After having spent 24 years in total in the role of Secretary General for diverse European port and shipping associations, Patrick Verhoeven is undeniably well-informed regarding the influence a port can have on its city. He has distilled his all-encompassing background into a relatable and portable book to acquaint readers with the city on the Scheldt river through his eyes.

Patrick Verhoeven

As the first to helm the role of Managing Director of Policy and Strategy for the International Association of Ports and Harbors (IAPH), Dr Patrick Verhoeven navigates his 24 years of academic roles and professional involvement in associations supporting Europe's stevedore, shipping, and port sectors to address the complex and manifold challenges facing these entities at the global level. Through initiatives generated by IAPH's recently launched World Ports Sustainability Program, he intends to assist international ports to develop strategically by improving interconnectivity and regional networks rather than simply scaling up every port to welcome the next mega-ship.

After a brief reminder to be safe when cycling in the port area, the book begins by setting the stage with a timeline starting in the eighth century of the changes to the port as well as the notable people, companies and wars that played a key role in shaping the port as it is today. Each chapter begins with a map highlighting the port's points of interest including nature reserves, museums and forts as well as infographics depicting the facts, figures and statistics regarding port trends over the decades

Insider tips about port-related destinations in harbour town, harbour island, and the right and left banks are bundled into two sets of carefully considered bicycling and walking tours, letting readers know exactly where to savour the city's oldest beer – which dates back to 1677 – or witness the grandeur of the Antwerp Port Authority's new home – designed by the late architect Zaha Hadid. Cultural and historical tidbits are complemented by 28 portraits of individuals with a diverse connection to the port

in careers such as traffic controllers and lawyers as well as a curator, customs officer or priest. First-hand accounts range from the president of the Antwerp Port Authority – who is keen on closing the gap between the city and the port with lively activity – to a nature conservationist – who disapproves of the court decision by the Council of State to block a proactive plan to expand the port – to a self-taught organ player from a church in the riverside city of Doel – a 700-year-old town demarcated to be wiped off the map to make way for the port's future expansion but is currently sitting vacant and graffitied.

Readers of this book – inhabitants, curiosity seekers and port enthusiasts alike – will be in the know about Antwerp's port gems and experience the city from a one-of-a-kind perspective. Just be kindly warned, the Lillo Bridge prioritises sailing ships, not cyclists.

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Photo © Ulrich Wirrwa, courtesy of DEME group

Back Cover

Photo © Gulf Cobla

Design

Smidswater, The Netherlands

Typesetting

ECC B.V., Hardinxveld-Giessendam,
The Netherlands

Printing

Tuijtel B.V., Hardinxveld-Giessendam,
The Netherlands

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Companies and individual contributors
ISSN 0376-6411

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Terra et Aqua is published four times a year by

International Association of Dredging Companies

Stationsplein 4
2275 AZ Voorburg
The Netherlands
www.iadc-dredging.com



ALWAYS READY

TO MEET NEW
CHALLENGES

IADC stands for 'International Association of Dredging Companies' and is the global umbrella organisation for contractors in the private dredging industry. IADC is dedicated to promoting the skills, integrity and reliability of its members as well as the dredging industry in general. IADC has over one hundred main and associated members. Together they represent the forefront of the dredging industry.

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