Dredging Rocks!

Number 110 | March 2008

TERRA ET AQUA

Maritime Solutions for a Changing World

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International Association of Dredging Companies

COVER

At the Bashayer II Oil Export Terminal at Port Sudan, extremely hard coral blocks were fragmented by a new generation of ripper draghead (see page 9) .

CONTENTS

EDITORIAL: DREDGING ROCKS! 2

IMMEDIATE DISPLACEMENT OF THE SEABED DURING SUBSEA ROCK INSTALLATION (SRI) 3
RENÉ VISSER AND JOOP VAN DER MEER
The installation of pre-lay rock supports and post-lay rock covers by Flexible Fall Pipe Vessels can safeguard the integrity of subsea pipelines endangered by large free-spans, upheaval buckling and physical impacts like fishing nets and anchors.

NEW POSSIBILITIES FOR RIPPER DREDGING OF ROCK 9
BERNARD MALHERBE AND PETER DE POOTER
When the trials at the Port of Sudan to open a trench with explosives were unsuccessful, trenching equipment – a backhoe dredger with a rock bucket and a TSHD with a new generation of ripper-draghead – was brought in to accomplish the task.

THE HANSJE BRINKER SAFETY AWARD 13
Acknowledging the maximum effort put into safety and security, while working in an extraordinarily challenging environment, Van Oord Nigeria Ltd was presented with a company award for overall achievement in QHSE (quality, health, safety and the environment).

THE DAY AFTER WE STOP DREDGING: A WORLD WITHOUT SEDIMENT PLUMES? 15
STEFAN G.J. AARNINKHOF
To assess the environmental benefits of an "idyllic" world without dredging, the impacts of dredging activities are compared to the impacts of other human and natural sources of sediment plumes.

POSSIBILITIES OF MINIMISING SEDIMENTATION IN HARBOURS IN A BRACKISH TIDAL ENVIRONMENT 26
OLIVER STOSCHEK
By studying the different mechanisms of sediment movement, solutions were developed to reduce sedimentation in harbours, and thus reduce the need for maintenance dredging.

BOOKS/PERIODICALS REVIEWED 33
The new edition of The Rock Manual: *The Use of Rock in Hydraulic Engineering* published by CIRIA is evaluated and a new "Facts About" has arrived.

SEMINARS/CONFERENCES/EVENTS 34
WEDA XXVIII in St. Louis, USA, CEDA Dredging Days in Belgium and a new IADC Seminar in Delft are planned for 2008.

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TERRA ET AQUA

EDITORIAL

As you have seen on the cover, we have described this first issue of Terra in 2008 with two words: "Dredging Rocks!" Now these words have a double meaning. To begin with, this issue focusses on various aspects of rock when dredging -- installing rock and removing rock. First of all, there is the precision installation of rock to safeguard the integrity of subsea pipelines; and secondly, the removal of extremely hard rock utilising a new, stronger generation ripper draghead. In both cases the articles describe the high-tech material in use in the dredging industry and the important investments which the industry makes in ongoing R&D. In addition, a review is included of a recent book, published by CIRIA, *The Rock Manual*. This 1260 page tome should be entitled, "Everything you ever wanted to know about rock and didn't dare to ask."

But "Dredging Rocks!" has another meaning: Taken in the vernacular it means dredging is rocking, it's vibrant, it's growing. It describes an industry that has retooled itself, not only with newer and better machinery, but also with a younger generation of employees. A dynamic industry where people are enthusiastic and excited. Dedicated and innovative. And where experienced staff members are anxious to welcome the next generation of staff onboard.

Two such young professionals are the researchers whose award winning papers are published in this issue of Terra. One author was presented with the IADC Best Paper Award for Young Authors at CEDA Dredging Days last November. The other received the CEDA Environmental Commission Award at the Black Sea Coastal Association Conference on Port Development and Coastal Environment, September 2007, in Varna, Bulgaria. Both of these engineers are examples of the kind of fresh talent working in the dredging and maritime construction industry. They are young professionals whose energy is keeping the industry looking forward. They are deeply involved in their research, and are taking the initiative to improve technologies and forge a way into the future. A spark of idealism ignites their work, because, while they build on the scientific information of the past, they clearly believe we can do things even better in the future. Their contributions to our knowledge about dredging, environment and cost-efficient solutions are invaluable to our industry.

As dredging and maritime construction has become increasingly complicated, these younger workers are symbolic of one very simple tradition that has remained intact. Many IADC companies began as family businesses in which mutual respect for each other created strong bonds. Nowadays, although the companies have merged and grown, these basic bonds of comradeship and support remain steadfast amongst our dredging colleagues, crewmembers and engineers.

Koos van Oord
President, IADC

RENÉ VISSER AND JOOP VAN DER MEER

IMMEDIATE DISPLACEMENT OF THE SEABED DURING SUBSEA ROCK INSTALLATION (SRI)

ABSTRACT

The integrity of subsea pipelines can be endangered by large free-spans, upheaval buckling and physical impacts like fishing nets and anchors. This can be avoided by installing pre-lay rock supports and post-lay rock covers. During rock installation a number of effects take place, such as surface erosion, rock penetration and immediate settlement of the subsoil. These processes are called “immediate displacement” and have a direct impact on the volumes of rock required to provide sufficient support to the pipeline.

The immediate displacement of the subsoil, and therefore the need for extra volumes of rock, can be accurately determined as long as sufficient geotechnical information on the seabed characteristics is available. Van Oord dredging and marine contractors has extensive experience in installing subsea rock by using flexible fallpipe techniques.

The Ormen Lange and Tyrihans Projects in Norway and Penguin Project in the UK are recent examples of projects where the flexible fallpipe (FFP) technique was used. On the Ormen Lange Project it was used to a depth of 870 m.

INTRODUCTION

As part of offshore oil & gas field developments pipelines and/or umbilicals are installed on the seabed. These lines may have to be protected against physical forces or upheaval buckling by the installation of post-lay rock covers or pre-lay rock supports in order to mitigate large free-spans. During rock installation a number of effects take place, such as surface erosion, rock penetration and immediate settlement. These processes are called “immediate displacements” and have a direct impact on the volumes of rock required to provide sufficient support and/or protection to the pipeline. The required volume of rock depends, amongst other factors, on the immediate displacements of the seabed during rock installation. Accurate knowledge of this is of importance to ensure proper project management. Van Oord as an experienced contractor in subsea rock installation (SRI) works, has extensively studied the effects of immediate displacements of the seabed and the impact on required rock volumes.

Above: FFPV Nordnes is a large (24,000 tonne) Flexible Fall Pipe Vessel used for securing subsea rock during the installation of pipeline (courtesy of VO/Truls J. Løtvedt).

This article describes the applications of subsea rock installation and gives a brief history of how this method has been developed and optimised. Possible alternatives to subsea rock installation are summarised. The immediate displacement of the seabed during rock installation is elaborated, focussing on the processes that occur when installing supports by a Flexible Fall Pipe Vessel, and taking into account the different soil conditions that may be encountered.

APPLICATIONS OF SUBSEA ROCK INSTALLATION

Subsea rock installation is applied to support and/or protect an offshore pipeline. More specifically subsea rock installation is applied to provide:

- physical protection from external objects like anchors and fishing nets (Figure 1);
- axial locking and upheaval buckling mitigation to prevent lateral movement of the pipeline e.g. owing to temperature changes of the pipe (Figure 1);
- free-span mitigation of pipelines in undulating terrain (Figure 2); and
- safe and stable crossings of previously laid pipelines (Figure 3).

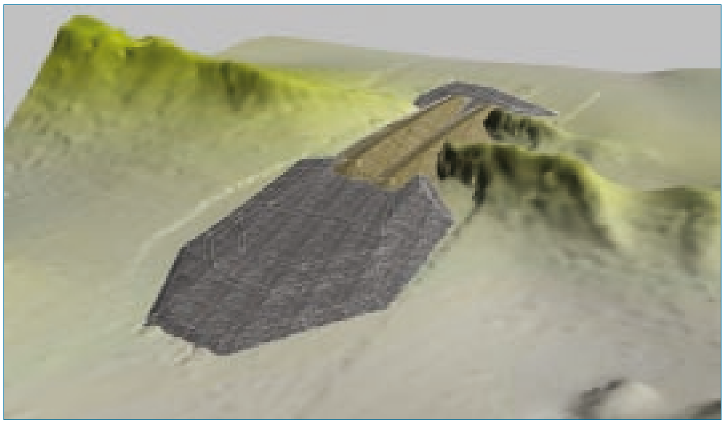

Figure 1. The basic design of supports (in brown) and counter fills (in green) for axial locking, preventing upheaval buckling and physical protection is basically identical (in green).

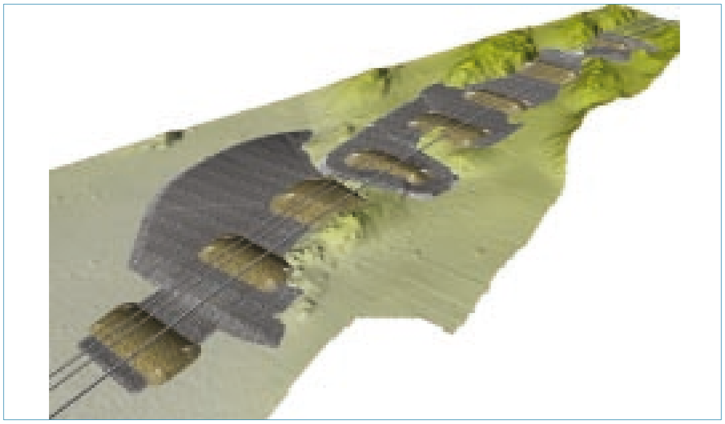

Figure 2. Free span mitigation supports (in green) including counterfills (in grey) for geotechnical stability.

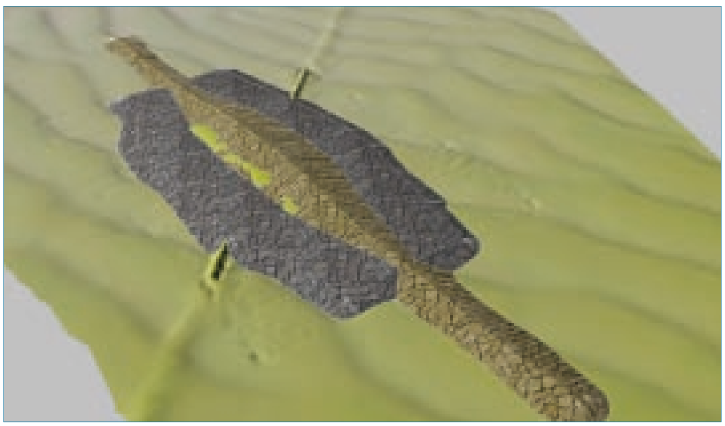

Figure 3. A support for a pipeline crossing (in green) and counter-fills (in grey).

A BRIEF HISTORY OF SUBSEA ROCK INSTALLATION

Rock has been used for protection purposes for hundreds of years, e.g. for dikes and breakwaters. At first the installation of rock was done from ashore and from a vessel by hand (Figure 4). About fifty years ago the first automated rock dumping vessels were designed, built, tested and used for the massive Delta Works in The Netherlands. The rock was placed on deck and shoved over the side and fell through the water column to the designated location on the seabed. Nowadays this technique is still used and is referred to as side-stone dumping (Figure 5). With the increase of projects at greater water depths, the accuracy of rock placement was decreasing because of currents and dispersing of the rock. At this stage a new solution was developed entailing the use of a fallpipe in order to guide the rocks over a greater water depth (Figure 5). At the end of the 1970s a telescopic fallpipe was developed for rock installation at even greater water depths inducing large (drag and gravity) forces on the fallpipe.

In 1985 the *MV Trollnes* was equipped with a flexible fallpipe consisting of a string of bottomless buckets along two chains.
At the lower end of the string a remotely operated, self-propelled vehicle (ROV) was attached. This ROV secured more accurate placement of the rock amongst others by correcting the off-setting by currents.
The success of this technique has been proven during the past decades and resulted in the commissioning of two more Flexible Fall Pipe Vessels (FFPVs), the *Tertnes* (9,500 tonnes) (Figure 6) and the *Nordnes* (24,000 tonnes) (Figure 7). A new FFPV is under construction and will be operational in the first half of 2009.

ALTERNATIVES TO SRI

There are different alternatives to SRI for the physical protection and upheaval buckling mitigation of offshore pipelines. The most commonly used method is to apply a thicker armour layer or shell around the pipe, to cover it with concrete mattresses or to install the pipeline in a trench.

Instead of SRI for free-span mitigation, the pipe can also be supported with concrete elements or steel frames. Another option is to dredge the higher spots (applying the so-called pre-sweeping technique) to create a more even seabed, thus reducing the length of the free-spans. For a crossing with an existing pipeline, concrete mattresses may be used between the two pipes to avoid damage to both pipelines.

In general environmental conditions, the technical feasibility and cost aspects are considered after which eventually the most efficient and economic solution is chosen. Subsea rock installation is considered to be a competitive and reliable method to ensure the pipeline’s integrity.

RENÉ VISSER
is an engineer at the Engineering Department of Van Oord DMC. After graduating in Physical Geography in Utrecht, he worked for a consulting company for high-end water-related instruments. In 2000 he joined the dredging industry, where his specialty is in quantitative risk analyses, project engineering, soil investigations and civil engineering.

JOOP VAN DER MEER
worked for many years in civil engineering with international consultants. In 2000 he joined Van Oord DMC as a senior engineer at the Engineering Department. He is primarily involved with projects which have a special emphasis on geotechnical aspects related to land reclamation, retaining- and offshore structures.

Figure 4. Installation of rock was done from ashore and from a vessel by hand.

ENGINEERING

General

If subsea rock installation is required, the consultant assisting the operator and/or pipelaying company designs rock supports focussing on pipeline integrity and geotechnical stability of the subsoil at the location where the pipeline will be installed. The subsea rock installation contractor is then requested to perform the following actions:

1. review the design in order to optimise the installation efficiency
2. calculate the theoretical volume and the necessary practical tonnage of rock
3. check the geotechnical stability analysis (which is mostly done by an independent third party)
4. make project procedures and construction drawings for the FFPVs.

Review of the design is necessary as the Client will only give a so-called minimal design that fulfils the basic requirements for the pipeline integrity and the geotechnical stability.

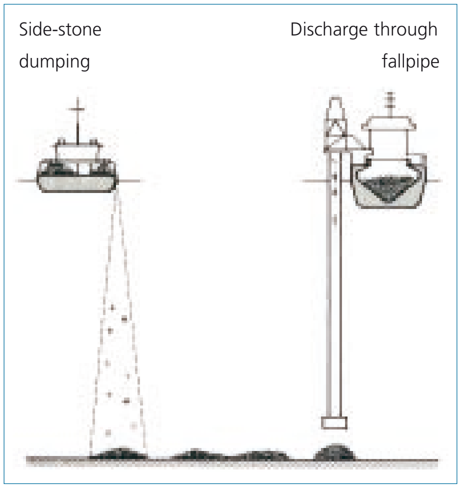

Figure 5. Schematic drawing of two methods of rock placement.

In some cases the installation efficiency can be improved by adaptations to the basic design, for instance, by installing counter fills with a sloping top surface instead of building up several terraces in a time-consuming operation.

Theoretical vs practical volume

The total required volume of rock for one support can be determined when the following items are taken into account:

- Theoretical rock volume required to install the support
- Installation losses during operations
- Immediate displacements of the seabed.

These items are graphically shown in Figure 8. The theoretical volume between the model and the original seabed can be calculated accurately using Digital Terrain Model (DTM) software. The installation losses depend on several aspects like sea state, currents, survey quality, water depth, support size, rock installation rate and experience of personnel onboard. Usually the losses can be determined based on expertise from previous projects. Immediate displacement will be described in detail below.

IMMEDIATE DISPLACEMENT

During rock installation a number of effects take place on the seabed. These processes are called immediate displacement.

The following phenomena have been recognised to contribute to immediate displacement:

- surface erosion;
- penetration of rock particles into the seabed and material flow into the rock skeleton;
- immediate deformations of the subsoil.

Each of the above-mentioned phenomena will be discussed below. The long-term settlements caused by drainage of subsoils under pressure and creep have not been considered in this article. A practical way of dealing with long-term settlements is to install the rock in two phases.

After installing approximately 80% of the final support height, the final 20% can be installed to the final design height when a period of 3 to 6 months for subsoil settlement has been allowed for.

Surface erosion

The seabed is generally covered by a thin weak top layer which can be detected by

Figure 6. The FFPV Tertnes worked on the recently completed Ormen Lange project.

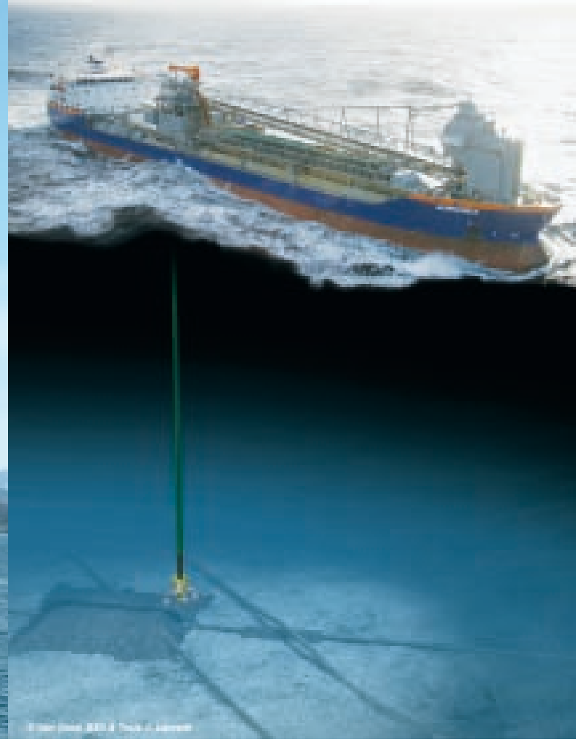

Figure 7. Artist's rendering of the FFPV Nordnes working on a pipeline crossing.

survey of the seabed with multi beam echo sounders. Cone Penetration Testing (CPT) is not sufficiently reliable to accurately assess the characteristics of this top layer. During subsea rock installation a mass flow is created within the fallpipe system. The velocity of this mass flow is in the order of 4 m/sec at the end of the fallpipe when it is located about 5 m above seabed. Owing to this mass flow a water overpressure occurs at the seabed, thus washing out the weak top layer and resulting in surface erosion. Depending on the available soil information an assessment of the surface erosion that may be expected can be made.

In general the erosion varies between 0 and 15 cm for hard clay or dense sand to soft clay with a water content equal to the liquid limit or very loose sand respectively.

Initial rock penetration into seabed

During the rock installation the individual particles will penetrate into the seabed. The penetration depth depends amongst others on the diameter of the stone, its velocity at impact, and the strength as well as the consistency of the subsoil.
The penetration depth is calculated by using the impulse balance:

$$F_{net} \cdot \Delta t = m \cdot \Delta v \quad (F_{net} = m \cdot a = m \cdot \frac{\Delta v}{\Delta t}) \qquad (1)$$

where

F_{net} = net force acting on the stone [N]

m = mass of the stone = $\rho_r \cdot \frac{1}{6} \pi (D_s)^3$ [kg]

Δt = time step [s]

Δv = variation in the velocity of the stone in a time step [m/s]

a = acceleration of the stone [m/s²]

The reduction of the velocity of the stone during each time step can be calculated using:

$$\Delta v = \frac{F_{net}(t)}{m} \Delta t \qquad (2)$$

The penetration finally stops when $v_{stone} = 0$, so the duration of the impact, t_{impact}, and the initial penetration, S_{init}, (see Figure 9) are given by (3) and (4):

$$v_{bot} = \int_{t=0}^{t=t_{impact}} \Delta v(t)dt = 0 \qquad (3)$$

$$s_{init} = \int_{t=0}^{t=t_{impact}} v(t)dt \qquad (4)$$

where:

v_{bot} = stone velocity just above seabed

To solve equation (2), the resultant force acting on the stone, F_{net}, has to be determined for every t.

$$F_{net}(t) = F_{gravity}(t) - F_{archimedes}(t) - F_{drag}(t) - F_{bearing}(t) \qquad (5)$$

where:

$F_{gravity}(t)$ = gravity force on the stone

$F_{archimedes}(t)$ = buoyancy force (as defined by Archimedes)

F_{drag} = drag force by the water on the stone

$F_{bearing}$ = force by the soil acting on the stone as given by Brich-Hansen [1].

The main results of penetration depths calculated for a number of different clay strengths and loose sand when using rock with a diameter of 1 to 5 inch are summarised in Table I.

There is no proven formula available to calculate the penetration of a falling stone into the seabed. Due to the lack of such a formula, alternative calculation methods have been studied. Calculations based on the bearing capacity formula, which is originally meant to analyse an equilibrium condition only, appear to provide realistic results for the analysis of a failing mechanism as well.

Additional penetration by material flow into the rock skeleton

After the occurrence of the initial penetration, contact stresses at the rock-subsoil interface are increasing during further build-up of the structure. Initially and for small additional loads this interface is stable. When higher contact stresses

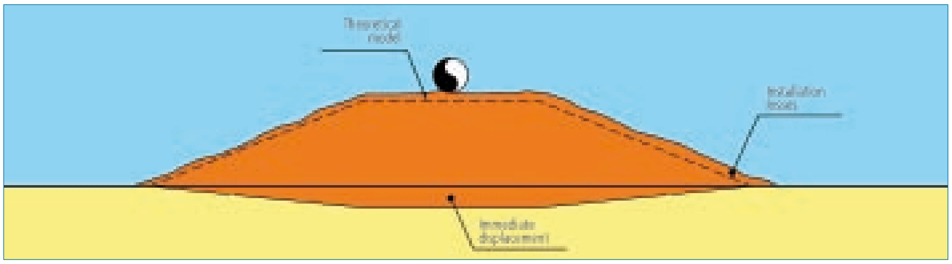

Figure 8. The total required volume of rock for one support can be determined when the theoretical rock volume required to install the support, the installation losses during operations and the immediate displacements of the seabed are considered.

between subsoil and rock fill occur, the rock will penetrate further into the subsoil until a new equilibrium is obtained.
This mechanism is graphically shown in Figure 9. The additional penetration D can be estimated by using a reological model. The pressure loss over zone D can be estimated by using the following formula:

$$p = S_u * \sqrt{(n / \kappa)} * \alpha * D$$

where:

p = pressure [Pa]
S_u = remoulded undrained shear strength [Pa]
n = porosity [-]
κ = intrinsic permeability [m^2] the best estimate for D_{15} = 0.04 m and n= 0.4 is $\kappa = 2*10^{-6}$ m^2
α = constant in the range 0.6 to 0.9 with a best estimate of 0.75 [-]
D = additional penetration [m]

Based on the above method a graphical representation of the results of the calculations for different undrained shear strengths and support heights is given in Figure 10. The results show that the material flow into the rock skeleton is rather limited. Only when installing higher supports on very soft clays can an effect caused by material flow into the rock skeleton be expected. Since the rock particles squeeze the clay during the installation process, it is realistic to consider the remoulded undrained shear strength.

Immediate deformations subsoil
Owing to the weight of the support structure immediate deformations can be expected in sand as well as in clay. The occurrence of immediate deformations depends on several aspects.

Compressibility subsoil
The compressibility of sand is normally small. The settlement is calculated considering drained characteristics of the material. Although only small displacements occur in sand, they still contribute to the immediate settlements to be accounted for.

The immediate deformations of clay can be calculated using the effective strength characteristics (φ', c') and deformation parameters (oedometer modulus M) while allowing for the development of excess pore pressures simulating undrained behaviour. In this way the immediate deformation for every support can be calculated.

Layer thickness
The thickness of especially clay layers governs the magnitude of the immediate deformation. The greater the thickness of the layer, the larger the settlement. Owing to the fact that clay layers intermediate with sand layers, some consolidation settlement during the rock installation should be taken into account.

Geometry support structure
The geometry of the support structure determines the loading on the seabed. A higher support results in a higher loading, thus causing larger deformations in the subsoil. An increase in length and/or a width of the structure will further result in an increase of the stress at deeper levels in the subsoil, thus resulting in a higher level of immediate deformations.

Calculation method
A 2-dimensional finite element analysis should be used since vertical displacements are introduced by horizontal deformations. This is caused by the fact that, in principle, no volumetric change occurs during undrained loading conditions in clay. This principle is graphically represented in Figure 11 which shows a deformation pattern obtained with the finite element software Plaxis. Immediate deformations as a function of the support height and clay layer thickness are presented in Figure 12. The immediate deformations in sand with a deformation modulus of 10 MPa are in the range of 0 to 2 cm for supports of maximum 5 m height on sand layers of 3 m thick.

CONCLUSIONS

Immediate displacements during subsea rock installation can be accurately assessed as long as sufficient and reliable soil information is available.
The immediate displacement can be divided into four phenomena:
1 surface erosion,
2 penetration of rock particles into the seabed,
3 material flow into the rock skeleton and
4 immediate deformation of the subsoil.

The surface erosion varies generally between 0 and 15 cm for hard clay or dense sand to very soft clay or loose sand, respectively. The initial penetration of rock particles into the seabed and the material flow into the rock skeleton mainly depends

Table I. Penetration S_{init} in seabed

	remoulded undrained shear strength S_u in kN/m^2.			sand
	S_u = 1	S_u = 5.0	S_u = 15	Loose
S_{init} in cm	21	6	3	9

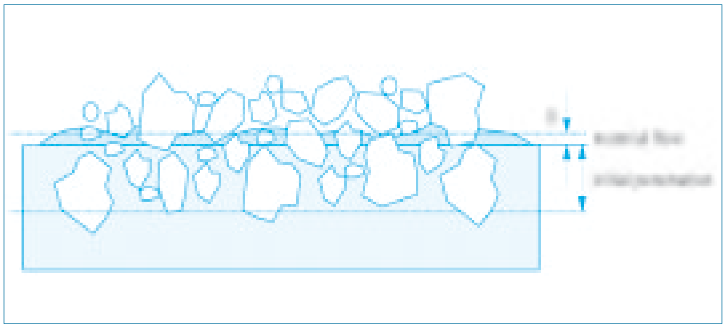

Figure 9.
Rock penetration.

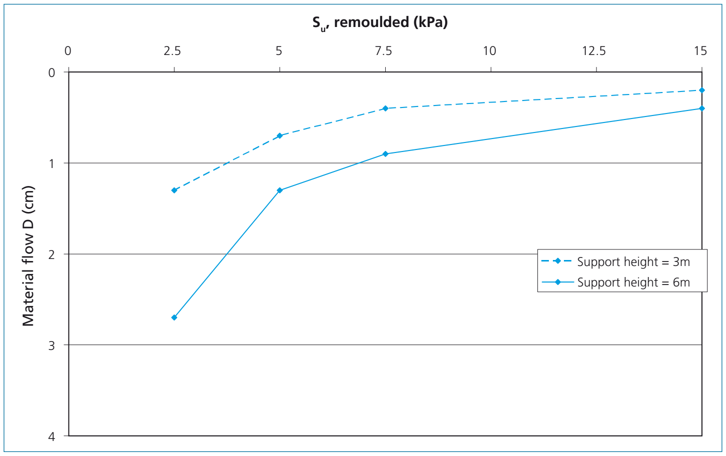

Figure 10.
Material flow D as a function of remoulded undrained shear strength S_u and support height.

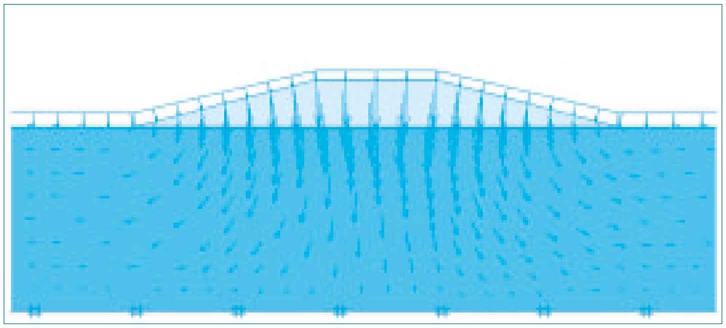

Figure 11.
Deformation pattern in finite element software.

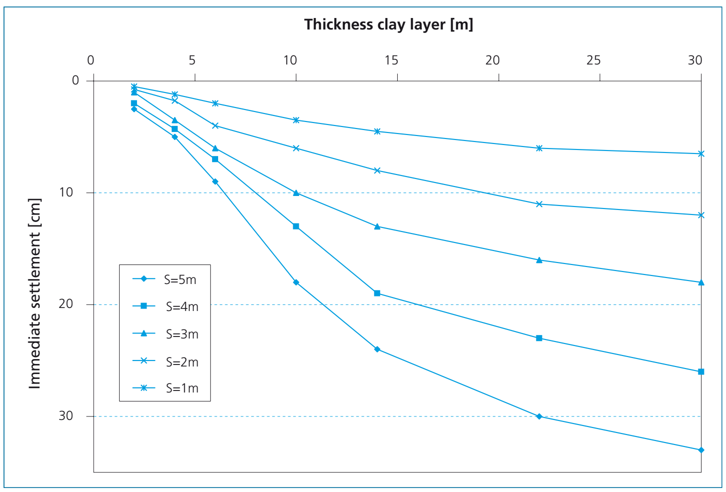

Figure 12. Immediate deformations in clay for deformation modulus M = 2MPa. Each line represents a different support height S.

on the support height and the remoulded undrained shear strength of clay or the internal friction angle of sand. This results in a penetration of 0 to 20 cm in practice.

The immediate deformation of the seabed owing to the static weight of the supports is calculated by means of a finite element programme. For sand the deformation modulus in combination with effective soil parameters is used. For clay the oedometer modulus M and effective strength parameters in combination with undrained behaviour (allowing for the development of excess pore pressures) is adopted. In practice the immediate deformation ranges from 0 to 25 cm depending on the support height and the consistency of the subsoil. The following recommendations should be considered when assessing the immediate displacements:

- The information on the strength and consistency of the first 0.5 m thick top layer is considered not to be reliable if only CPTs results are available.
- A remoulding effect of 50% is considered in the analysis regarding the penetration of the individual particles and the material flow into the rock skeleton. In sensitive clays a higher reduction in strength may be expected.

The effects caused by long-term settlement can be addressed by installing rock supports in two phases with a 3 to 6 months settlement period in between.

As a result of evaluating several projects the conclusion can be made that the difference between the estimated volume of rock, including immediate displacement, and the actual installed volume is only 2 to 3%. This shows that the effects of immediate displacements can be calculated accurately by using the methods described here, provided that the knowledge of the subsoil characteristics is sufficient.

REFERENCES

Brich-Hansen, "A revised and extended formula for bearing capacity". *Bulletin 28,* The Danish Geotechnical Institute, 1970.

BERNARD MALHERBE AND PETER DE POOTER

Above, In order to ascertain the vessel's nautical safety above the coral reef, the TSHD *Vasco da Gama's* draught was kept below 8.6 m by rainbowing the dredged materials sidewards from the bow instead of loading inside the hopper.

NEW POSSIBILITIES FOR RIPPER DREDGING OF ROCK

ABSTRACT

Part of the Melut Basin Development Project at the Bashayer II Oil Export Terminal at Port Sudan – one of Sudan's most important ongoing economic development projects – was the dredging of a shore-approach trench trough in the coral-rich seabed at the Red Sea coast, for twin 36" oil export pipelines and 14" effluent pipeline.
The project was undertaken for the Petrodar Operating Company (JV CNPC, PCOSB/ Petronas, SUDAPET, AL-THANI) and the general EPC contractor was Peremba, INTEC, Sudan Pile Consortium (PISP).
The total length of 36" pipeline was twice 2,850 m and the length of 14" effluent pipeline was 1200 m. The trenching was CD – 0.5 m (at shore) to CD -49 m (at KP 0.980 m) of soil consisting of coral rock and coral debris with UCS between 2 and 12 MPa.

After unsuccessful trials by the EPC Contractor to open the trench in the steep slope of the coral reef with explosives, the decision was made to use trenching equipment. To achieve this, the backhoe dredger *Jerommeke* with rock bucket and the trailing suction hopper dredger *Vasco da Gama* with a new generation of ripper-draghead were brought into service.

INTRODUCTION

The joint company PETRODAR (PDOC) – a Joint Venture between China National Petroleum Company (CNPC), PETRONAS, SUDAPET and Al-Thani Corp. – awarded a general EPC (Engineering-Procurement-Construction) contract to PISP – a J.V. of PEREMBA SDN BMD (My) INTEC (US) and Sudan Pile (SU) – for the construction of the Bashayer II Oil Export Terminal at Port Sudan on the Red Sea Coast in Sudan (Figure 1). The Bashayer II OET is located approximately 40 km south of Port Sudan and is the terminal for the oil pipelines coming from the onshore Melut Basin Oil Field in southern Sudan. Both offshore pipelines with a total length of 2,850 m are connected to an offshore PLEM and SPM buoy for tanker loading; PLEM and SPM are anchored in water depths in excess of CD –50 m.

Very little soil information was available about the shore-approach seabed, and what scarce information there was showed the existence of a double-bump profile (see Figure 3). The first bump nearshore was documented by 3 boreholes as consisting of silty sand and clays at the very end of a coral reef. The drilling/corings at second bump further offshore at KP 0.650 to 0.950 indicated clay, soft clay, sand and coral debris [Ref 2].

The overall environment of the Red Sea coastline indicates a general presence of fringe-coral reefs. Jan De Nul therefore mentioned the likelihood of hidden coral reefs on both bump areas and a dedicated soil investigation was found necessary. According to the Operator and EPC Contractor [Ref 1], the coral-reefs, if any, were supposedly highly weathered and mainly loose. The EPC Contractor had already attempted to open the trench using explosives or a small cutter suction dredgers; both attempts were unsuccessful.

Because the project already suffered significant delays for various reasons, the Operator and the EPC Contractor decided to charter heavy-duty dredgers to open the pipeline-trench and to execute additional soil investigations just before the start of the works. There was no time left for additional geotechnical engineering and therefore, the

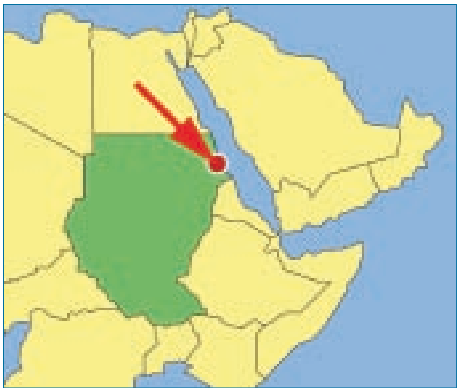

Figure 1. Location of Port Sudan situated on the Red Sea.

consortium PISP, represented by PEREMBA SDN BHD, decided to charter the 1.063 kW Backhoe Dredger (BHD) *Jerommeke* and the 37.060 kW Trailing Suction Hopper Dredger (TSHD) *Vasco da Gama* of Jan De Nul Dredging Ltd.

Because of the uncertainties about the exact soil conditions and characteristics before arrival of the vessel on site, Jan De Nul Dredging Ltd. strongly advised the EPC Contractor to adapt the design and dredge the deeper trench in the steep slope with a cut-&-fill profile instead with one of Jan De Nul Group's powerful seagoing rock cutter dredgers. However, the project team did not allow for any modifications in the design and the EPC Contractor, in the end, decided to attempt to dredge the trench with the *Vasco da Gama*.

Therefore Jan De Nul had to make a number of technical assumptions upon which the design of the rock-rippering draghead was to be based in order to maximise the chances of success. Assumptions were made about the strength of the coral, its homogeneity, the dynamic reaction forces, the wear and tear, the productivity, to

Figure 2. Coral blocks with size up to 2 m excavated by the backhoe dredger.

name a few. Furthermore the databases of previous works carried out in coral-dredging works were considered and several simulations were done.

Even with all the uncertainties mentioned above, the EPC Contractor declared that the execution of this work could not bear any further delays, that there was no time left to wait for results of the soil investigations (which were also delayed). The order was given to mobilise both dredgers and attempt to open the pipeline-trench by any and all means.

TRENCH DREDGING IN CORAL REEF 1 WITH A BACKHOE DREDGER

The BHD *Jerommeke* was transported from Dubai to Port Sudan on board the submersible barge DN 116, together with its assistance tug, a KRUPP 4000 hydraulic breakhammer, spare rock-buckets, and sufficient spare parts.

The trench bottom width was 12 m with side slope designed at 1 vertical and 3 horizontal. The average trench depth with respect to the adjacent seabed was 4 m. The natural seabed consisted of hard coral with an Unconfined Compressive Strength (UCS) between 2 and 4 MPa, coral debris and silty sand.

The trench-dredging of the Coral Reef 1, between KP 0.048 (at the shore) and KP 0.480 (water depth CD –18 m) was successfully executed with the 740 kW BHD *Jerommeke*. The dredged material was deposited to each side of the trench. The work was executed between August and October 2006.

During dredging, coral blocks of up to 2 m diameter were excavated (Figure 2). The trench was surveyed at regular intervals during execution in order to monitor the progress. These surveys indicated that the backhoe dredger achieved a constant and high productivity.

TRENCH DREDGING IN CORAL REEF 2 WITH A TRAILING SUCTION HOPPER DREDGER

The Coral Reef 2 was located between KP 0.610 (CD –19 m) and KP 0.980 (CD –49 m). The seabed consisted of a hard coral formation with coral blocks of more than 2 m in diameter and with UCS values between 8 and 12 MPa. The designed trench had a bottom width of 12 m, side slopes of 1 vertical and 3 horizontal and a trench depth (BOT) between 1 m and 17 m below original seabed as shown on the longitudinal profile in Figure 3. The target BOT depths of max CD –49 m excluded the use of a rock cutter suction dredger; the EPC Contractor therefore decided to have the trench dredged by a large trailing suction hopper dredger and, in that respect, selected the world's most powerful trailer.

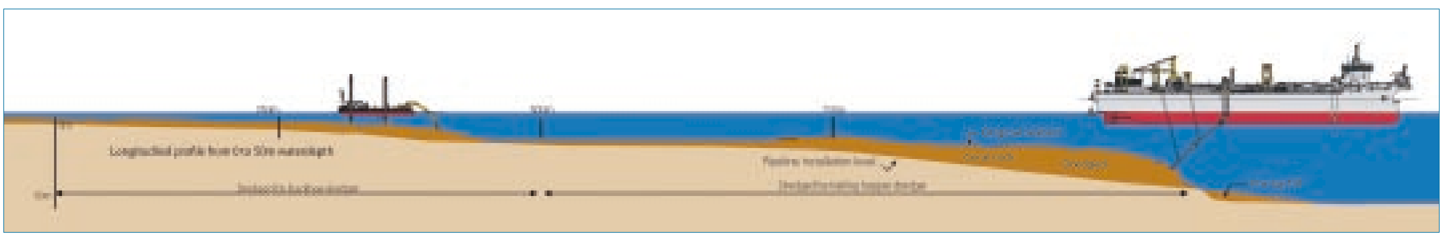

Figure 3. Longitudinal profile of the shore-approach trench (brown sections indicate the dredged section).

BERNARD MALHERBE
graduated in 1976 with a MSc in Geology at the University of Leuven (Belgium). In 1980 he completed his studies as a Master of Engineering Science in Geological Engineering at the École Nationale Supérieure de Géologie (France). He worked in the dredging industry for more than 20 years – for a contractor joint venture and as an engineering consultant – before joining the Jan De Nul Group in 2004. Since then he has been employed as Area Manager on many offshore projects. Presently he is Engineering Manager for project development.

PETER DE POOTER
graduated in 1990 with a MSc in Civil Engineering at the University of Ghent (Belgium). He worked in the engineering and construction industry for more than 10 years before joining the Jan De Nul Group in 2003. Since then he has been employed as Engineering Manager on the offshore project Sakhalin II in Sakhalin (Russia) and as Project Manager on several offshore projects. Presently he is working as Project Manager of the Manifa Field Causeway and Island Construction Project in Saudi Arabia.

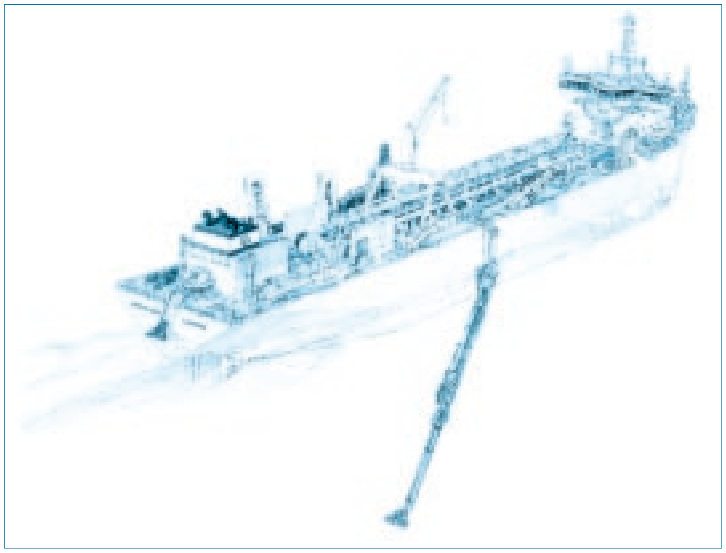

Figure 4. Artist's rendering of the *Vasco Da Gama* which has a maximum dredging depth of 135 m.

Consequently, the *Vasco da Gama* was selected and fitted with a specially modified draghead equipped with an adaptable number of ripper-teeth (Figure 4).
During this work, this heavy and solid rock-rippering draghead would prove its unique efficiency and flexibility. The extreme installed propulsion power of the *Vasco da Gama* (29,400 kW of a total installed 37,000 kW) ascertained a continuous and efficient operation and production, despite the fact that each dredging track commenced inshore with a ground-speed of 0 knots, because the ship is in fact going backwards. Moreover, the vessel was equipped with an onboard multibeam echo-sounder in its central moon-pool for continuous online monitoring the dredged profile by the client and project team on board without having to wait for survey results. The ultimate generation of rock-rippering dragheads, developed by Jan De Nul for the *Vasco da Gama* weighs 60 tonnes, is 8 m wide and is fitted with 7 ripping-teeth (1 metre long) on the draghead's heel and 20 pick points on the draghead's visor (Figures 5 and 6). For security reasons in case of excessive ripping forces, a security-flange system with breaking bolts was installed at the draghead/suction-tube flange.

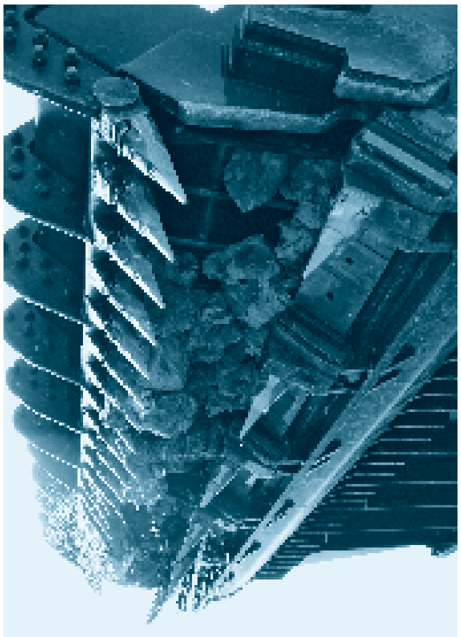

Figure 5. Ripper draghead with 1 m long ripper teeth.

By the time the ship arrived on site in September 2006, new geotechnical investigations had been done and the cores indicated heterogeneous coral reef rocks over the full thickness of the reef: Unconfined Compressive Strength (UCS) values of up to 12 MPa of the coral rock

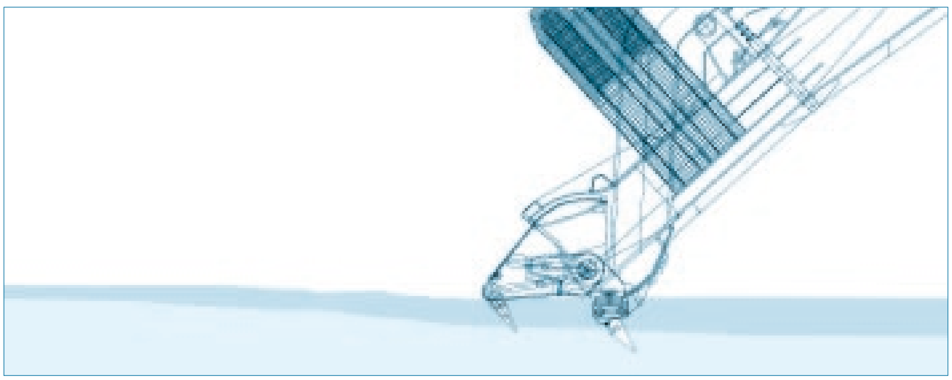

Figure 6. Drawing of draghead with ripper teeth on seabed.

were found. These values are extreme and never before in the history of trailing suction hopper dredging have such hard rocks been dredged; despite this, the EPC Contractor decided to proceed with the planned work-execution with the *Vasco da Gama*.

In order to ascertain the vessel's nautical safety above the coral reef, the dredger's draught was kept below 8.6 m by rainbowing the dredged materials sidewards from the bow instead of loading inside the hopper. Trenching started at the end of September 2006 and was completed by mid November 2006. The trenching operation was executed by having the vessel navigated with stern towards shore, lowering the suction tube and trailing to the offshore end whilst dredging and ripping. At the end of each dredging track, the suction tube was hoisted and a new dredging cycle was executed. Dredging/ripping productivities ranged from 2,000 to 4,000 m³/day and a total of 140,000 m³ of soil was excavated and moved to achieve a cut-&-fill profile as shown on the longitudinal profile; approximately 75% of the excavated soil was dredged and side-casted. The other 25% were bull-dozed downhill the slope of the Reef 2.

This material consisted of coral blocks fragmented by the ripper teeth (Figure 7) and trailed toward the end of the slope. It showed to be stable rockfill for the pipeline foundation. The bearing capacity was tested by load test with the draghead compensation system. Ultimately, the EPC Contractor accepted the cut-&-fill trench profile executed based on the bearing capacity assessment, the free-span analysis and the pipeline stress-strain analysis.

MONITORING OF TRENCH PROFILE AND FREE-SPAN ANALYSIS

During the whole trenching operation, the trench and stockpile areas were monitored daily with multibeam echo-sounding

Figure 7. Coral blocks removed from the ripper draghead.

surveys (Figure 8). This allowed both the dredging operators and the Client's representative to monitor the trenching operation.

CONCLUSIONS

Too often insufficient attention is paid to geotechnics in engineering dredging works. In the Melut Basin Bashayer II project this was clearly the case. Despite this, the controlled dredging of an acceptable seabed profile in water depths up to 50 m and in hard coral rock was successfully completed.

The *Vasco da Gama*, equipped with a special modified ripper-teeth draghead has proven to be able to meet this challenge and pushed the limits of trailing suction dredger ever further. Coral rock in massive reef and blockformations with UCS values between 8 and 12 MPa was excavated successfully, thanks to a combination of the vessel's extremely high-installed power and this new generation of ripping draghead. The work was executed in over less than half the time originally estimated for the Client.

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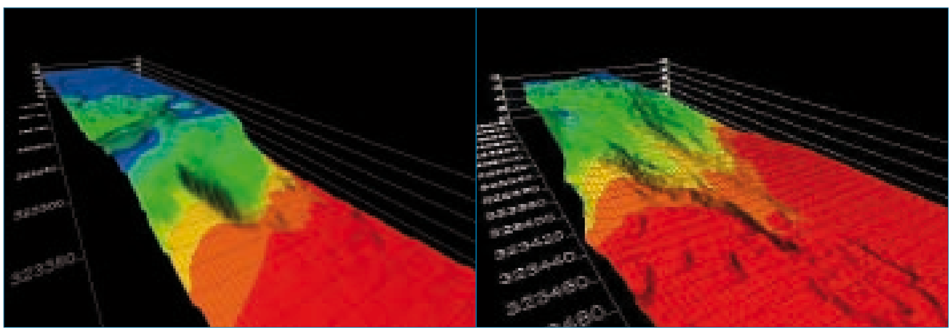


Figure 8. 3D view of the trench made through the coral reef survey result (Left: in-survey; Right: out-survey).

THE HANSJE BRINKER SAFETY AWARD

Each and every one of the International Association of Dredging Companies (IADC) member companies has made on-the-job safety a top priority. At Van Oord this attention to safety is recognised in the annual Hansje Brinker Safety Award, an in-house safety award for projects and yards of the worldwide-operating Van Oord group. Mythically renown as the young boy who put his finger in a hole in the dike and saved Holland from being flooded, Hans Brinker has become Van Oord's symbol for safety, health and the environment. Accordingly, each year the Hansje Brinker Award is presented to honour excellence in the implementation of the Van Oord Management System during the execution of the works on projects, vessels and yards with respect to safety (main criteria), health and environmental issues.

The QHSE (quality, health, safety and the environment) policy at Van Oord has been codified in very elaborate and detailed inspection lists to determine the award winner. For each category - vessels, projects and yards - a specific list has been collated that includes questions concerning the availability of the Management System and Safety Awareness as well specifics relating to the site office, workshop and crane, the yard office, the vessel's bridge and engine room, to name just a few categories.

These lists clearly define the spearheads and the safety levels to be achieved, and they are based on several national and international standards, such as:

- ISO-9001 - International Organisation for Standardisation: a quality standard regarding customer satisfaction, process management and experience.
- VCA - A Dutch safety system for contractors focused on safety aboard ships and on project sites, accident prevention and protection of the environment.
- ISM Code - International Safety Management Code: the international standard for ships' management aimed at safeguarding safety at sea and prevent damage to property or the environment.
- ISPS Code - International Ship & Port Facility Security Code: a code to identify and eliminate safety risks on board and in ports.
- ISO-14001 - Environmental Standard: a guideline applicable in certain countries that have prioritised environmental matters and encourage possibilities to improve the environment.
- OHSAS-18001 - Occupational Health and Safety Assessment Series guideline: a guideline that safeguards the safety of personnel and visitors on a project site and at the same time focuses on possible improvements.
- Van Oord is also certified for ISO-9001, VCA, ISM and ISPS, and several of local branch offices also hold ISO-14001 and OHSAS-18001 certificates.

Above: Cutter suction dredger *Calabar River* at work in Tinapa, Nigeria, where a world-class multipurpose resort is being developed.

THE AWARD WINNER

Work safety is thus completely integrated in the execution of all Van Oord projects and the safety policy is firmly embedded in the management system. Reducing the number of accidents and incidents as much as possible and reducing the risks for both people and the environment alike is the objective. Managers and crew have an important role to play in the field of safety, as it is their job to motivate their people to work safely and monitor the implementation of the company safety policies.

Progress in the execution of safety policies is monitored on a quarterly basis. Because of the large amount of work, a safety officer is appointed on every sizeable project. This inspector safeguards a high safety level. In the past few years, while turnover has been growing, the number of accidents has been declining.

All Van Oord ships over 500 GT are certified according to the ISM Code in compliance with international legislation. This means that these ships meet the international standards for ship management safeguarding safety at sea and preventing damage to property and the environment.

These vessels are frequently inspected by Van Oord auditors as well as auditors from an external agency. Given this close attention to safety standards, choosing one project over another for an award takes careful consideration.

In 2006, acknowledging the maximum effort put into safety and security measures while working in an extraordinarily challenging environment, Van Oord Nigeria Ltd was presented with the Hansje Brinker Award for its overall achievements (Figures 1 and 2).

The award recognised three Nigerian project sites, a well-equipped maintenance yard in Port Harcourt and the branch office in Lagos. One of the projects was the dredging for the creation of an artificial lake, "Lake Tinapa", which is part of a world-class integrated business resort complex being constructed on the banks of the Calabar River. Tinapa is located north of Calabar, eastern Nigeria's main port. Some 885,000 m^3 soil has been removed with a cutter suction dredger and the soil has been efficiently reused to create new land for future leisure development.

A second project is at Calabar, eastern Nigeria's main port, which is situated 83 km up the Calabar River in the Niger Delta. Nestled in the far southeast of Nigeria, Cross River State is Nigeria's frontier to Cameroon, Sao Tome, Equatorial Guinea and beyond. The seaport, named

Figure 1. At the awards presentation, Safety Officer J. Ogbo accepts the Hansje Brinker Award from Koos van der Geer on behalf of Van Oord Nigeria, Ltd.

Figure 2. A Toolbox meeting in progress: They are an essential aspect of the stringent safety measures and occur almost daily somewhere in Nigeria.

Calabar New Port, has an array of modern facilities for the export and import trade. Between 1976 and 1995 Van Oord carried out several projects in the vicinity, including recently the maintenance of the Calabar Channel for National Ports Authority.

The award-winning project involved the upstream dredging of the access channel to Calabar New Port being done by two trailing suction hopper dredgers, which are deepening the channel from -7 m to -10 m over a width of 150 m and a length of 46 km. This will allow vessels with a length of 170 m and a deadweight of between 10,000 and 15,000 tonnes to safely reach the port. The estimated volume of sediment to be dredged is 12,750,000 m^3. The dredged material is placed in allocated disposal areas.

All these projects have been supported by the yard at Port Harcourt. Generally speaking, Nigeria is not an easy country to work and so winning this award was a significant accomplishment.

The standards of health and safety management demanded in Nigeria were no different than those required by other Van Oord projects. In fact, the difficult circumstances created an optimum awareness by all employees both national and expatriate staff. Oil and gas standards also enhanced a high level of safety and security morale.

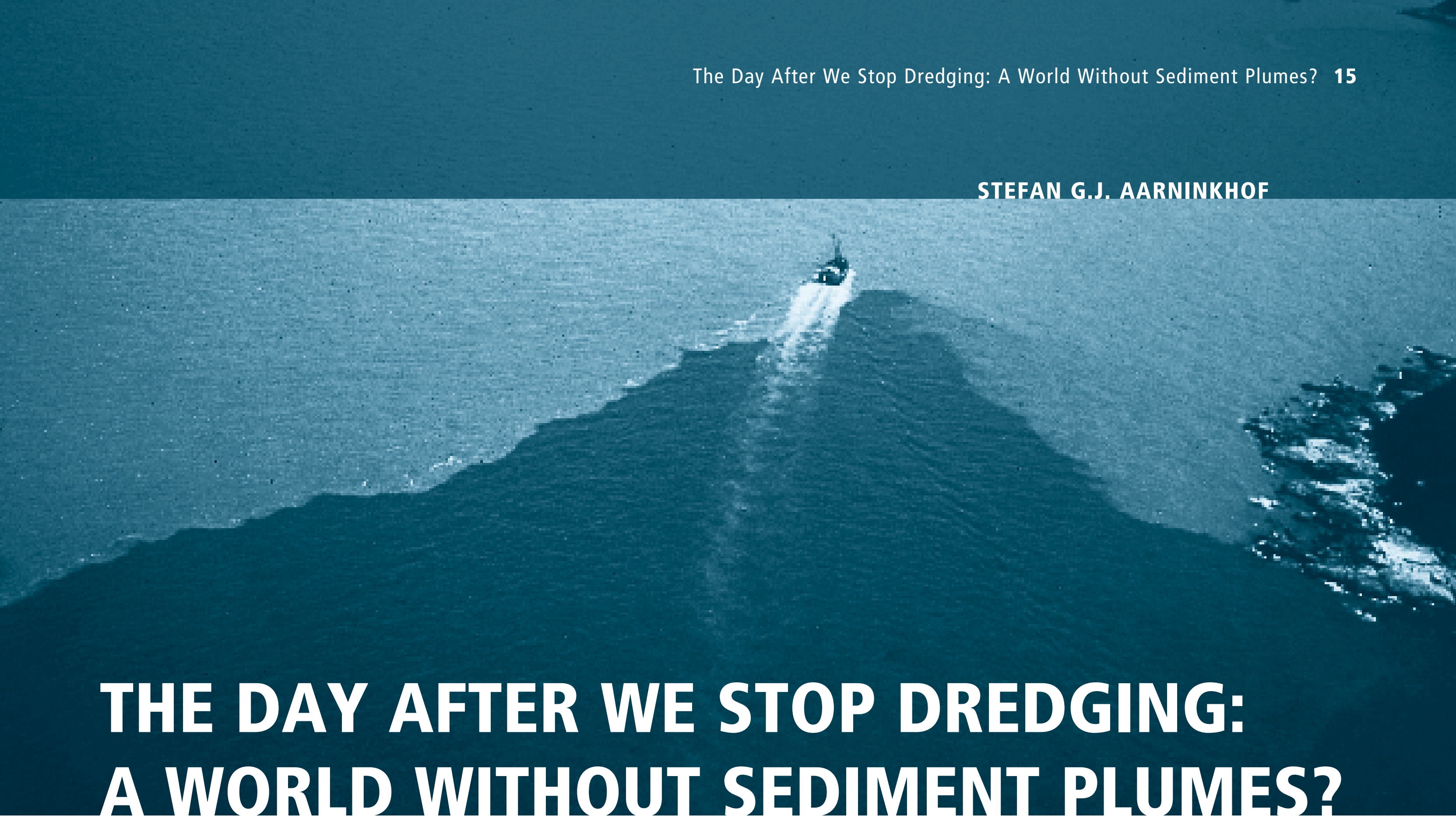
Amongst the safety measures considered were the Toolbox meetings which occur almost daily somewhere in Nigeria. Toolbox meetings are brief meetings at which (near-) accidents, HSE (health, safety, environment) news and special subjects, are discussed in relation to relevant activities (vessel-specific, project-specific or yard-specific). Safety walks, audits and implementation of consequential measures are a day-to-day activity. Van Oord Nigeria Ltd. also regularly undergoes external audits.

The Van Oord Community Relations Plan safeguards a good relationship with the indigenous host communities at worksites and offices throughout the country.
In addition, a major focus is on medical care. The high safety standard within Van Oord Nigeria features the presence of an ambulance, a doctor and clinic from SOS International at all project offices.

The healthcare standards and Medivac arrangements are optimised through an SOS International contract whereby helicopter service can be rendered on demand and present at site within a minimum time frame. The SOS clinic in Port Harcourt renders service for the expatriate staff, while two audited retainer hospitals provide care for the Nigerian staff.

In a brief overview: Van Oord Nigeria had 459,000 work-hours, with 310 toolbox meetings, 23 safety inspections and/or audits, 5 safety checks by independent organisations and only 1 accident that resulted in absence. The LIFR, number of Lost Time Injuries per 1,000,000 work hours, was a minimal 2.18. All in all these numbers testify to the heightened safety awareness at Van Oord Nigeria.

STEFAN G.J. AARNINKHOF



Above: Dredging operations often generate no more increased suspended sediments than are naturally present. Above a clear boundary forms where a river with high-levels of suspended sediments meets an ocean environment with low-level suspended sediments.

THE DAY AFTER WE STOP DREDGING: A WORLD WITHOUT SEDIMENT PLUMES?

ABSTRACT

Dredging activities are a pre-requisite for the development of human welfare, coastal safety and economic profit, yet the dredging industry is often criticised for having an adverse environmental impact, particularly through generation of sediment plumes during project implementation. Would the day after we stop dredging mark the onset of a world without sediment plumes? To answer this question a wider range of natural and human-induced drivers of sediment plumes in delta areas should be considered. Would shipping activities cease the day after we stop dredging? Would natural rivers stop discharging large quantities of fine sediment during periods of high water run-off? To assess the environmental benefits of an "idyllic" world without dredging, the impact of maintenance dredging activities as compared to the impact of other, ongoing drivers of sediment plumes must be evaluated.

The research presented here reflects recent progress in the framework of the TASS (Turbidity Assessment Software) programme, which involves a series of large-scale field trials to collect high-quality data that can be used for model validation purposes. Recent field trials in Bremerhaven (2006) and Rotterdam (2007) resulted in valuable insight in optimal means to collect overflow samples for the quantification of overflow losses over a range of soil types, overflow configurations and environmental conditions.

Moreover, the Rotterdam (2007) field trial is expected to help to assess the relevance of draghead plumes and propeller wash in view of dredging-induced turbidity, as well as the benefits of using a green valve. Both data sets will be used for TASS model validation and the identification of future model developments and research needs. Although the TASS programme focusses on dredging-induced turbidity increases, it should be noted that dredging is just one out of a series of processes that drive sediment plumes. These processes include natural events, shipping operations and fishing activities. An inventory of these processes suggests, at least qualitatively, that the annual impact of these processes is of the same order of magnitude as dredging. The author wishes to acknowledge the important contributions to this research by W.F. Rosenbrand of Royal Boskalis Westminster nv, Dredging Development Department, C. van Rhee of Van Oord Dredging and Marine Contractors BV and T.N. Burt, recently retired from HR Wallingford Ltd., UK as well as the funding by Stichting Speurwerk Baggertechniek (SSB) and Fonds Collectief Onderzoek as part of CROW. The paper was originally presented at the CEDA Dredging Days in November 2007 and was published in the conference proceedings. It is reprinted with permission in a slightly revised and updated version.

INTRODUCTION

Dredging activities are a pre-requisite for the development of human welfare, coastal safety and economic profit. Nevertheless, the dredging industry is often criticised – and not seldom without any scientific justification – for having an adverse environmental impact, particularly through generation of sediment plumes during project implementation. Would the day

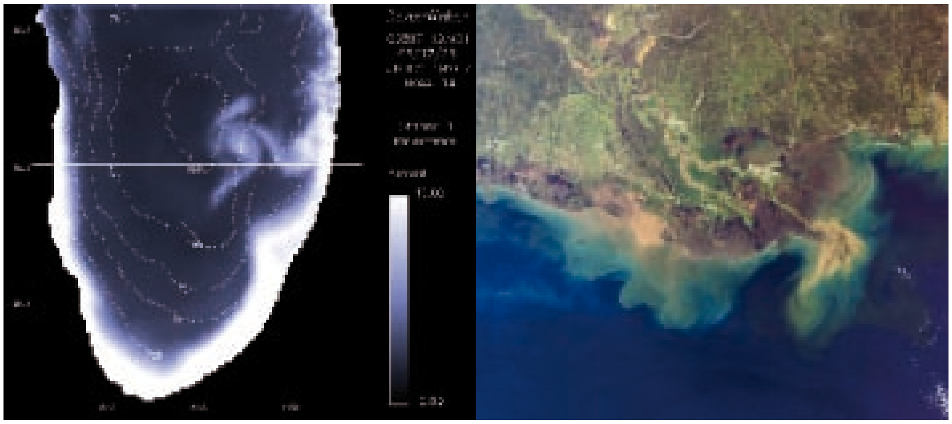


Figure 1. Examples of natural sediment plumes: An annually recurring sediment plume in Lake Michigan (left) and the Mississippi River sediment plume (right). The first is driven by sediment resuspension off the bottom during storm events; seasonal and inter-annual fluctuations of the second correspond closely with large fluctuations in river discharge.

after we stop dredging mark the onset of a world without sediment plumes?
To answer this question a wider range of natural and human-induced drivers of sediment plumes in delta areas must be considered. Would shipping activities cease the day after we stop dredging? Certainly not. In fact, propeller wash impacts during ship-manoeuvring operations are likely to increase since vessels will face channels and basins of decreased water depth.
Also, would natural rivers stop discharging large quantities of fine sediment during periods of high water run-off? Again the answer is no. To assess the environmental benefits of an 'idyllic' world without dredging, evaluation of the impact of maintenance dredging activities as compared to the impact of other, ongoing drivers of sediment plumes is necessary.
The research here addresses the impact of dredging-induced sediment plumes in a broader context of natural and human-induced turbidity variations, which govern suspended sediment background levels.

For the time being, this assessment is done mostly qualitatitvely, on the basis of a series of key examples of natural and human-induced sediment plumes. However, in search of further quantification of these impact assessments, the dredging industry is funding and promoting a research programme called TASS (Turbidity Assessment Software). This programme aims at the development and validation of a model to predict suspended sediment concentration as a result of dredging operations (overflow, LMOB – "light mixture overboard") as well as other dredger-related sources (such as propeller wash). A key component of the programme is a series of large-scale field experiments to obtain quantitative insight in these processes and collect high-quality ground-truth data.

This research presented here represents recent work performed in the framework of the TASS programme, involving, amongst other things, two large-scale field trials in Bremerhaven (2006) and Rotterdam (2007). Prior to that, an overview is given of high-turbidity events not related to dredging.
In the summary section, the question of whether the day after we stop dredging will mark the onset of a world without sediment plumes is addressed qualitatively.

NATURAL AND HUMAN-INDUCED DRIVERS OF SEDIMENT PLUMES

Sediment plumes are often perceived as a phenomenon with adverse environmental impact. Water quality can be affected, for instance, through an increase of the biological oxygen demand of the water column or the release of previously bound-up contaminants. Shading and smothering may affect marine ecology, both in the water column and on the sea bed. Moreover, shell-fisheries can be impacted by sediment plumes as a result of effects on their filter-feeding efficiency. Thorough insight in the generation and evolution of sediment plumes is a prerequisite for longer-term, sustainable development of aquatic environments.

Although sediment plumes do certainly occur in the direct neighbourhood of dredging operations, it is important to realise that dredging activities are not the only driver of sediment plumes in delta areas. Natural processes (such as river peak discharges and resuspension of fine sediments during storms) as well as other human-induced activities (such as fishing and ship-manoeuvring operations) are associated with sediment plumes as well.
In fact, because of the worldwide scale and intensity of the latter processes and activities, their combined impact may be an order of magnitude larger than turbidity rates induced by dredging.

Natural processes

Natural sediment plumes are a commonly observed feature along many shorelines

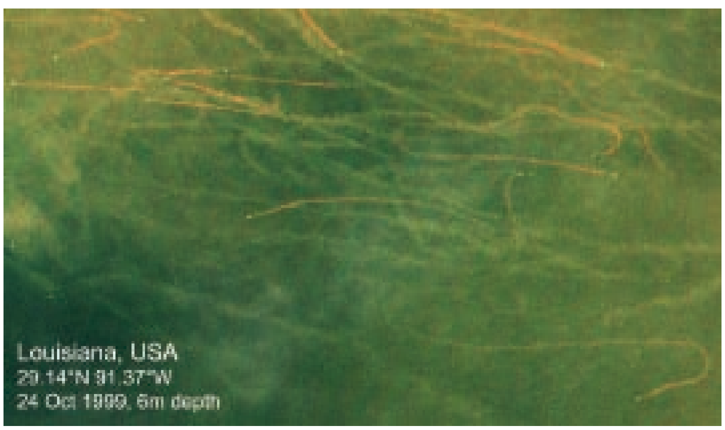


Figure 2. Landsat 7 image of shrimp trawler fleet in the northern Gulf of Mexico, USA. The entire scene here is tinted a brown hue from mud resuspended by trawlers. Scale bar is 1 kilometre. Courtesy of the Global Land Cover Facility (2007).

IADC Secretary General Constantijn Dolmans congratulates Stefan Aarninkhof (right) on winning the IADC Award for younger authors.

IADC AWARD 2007
PRESENT AT CEDA DREDGING DAYS,
NOVEMBER 7-9, 2007

An IADC Best Paper Award was presented to Stefan Aarninkhof, who is a senior project engineer at Hydronamic, the engineering group of Royal Boskalis Westminster. In 2003 he received a PhD from Delft University of Technology, the Netherlands, for a thesis on the quantification of coastal bathymetry from video imagery. Prior to joining Boskalis in 2006, he spent 10 years at Delft Hydraulics. He currently fulfills a specialist role in the field of morphology and marine environment, with a focus on the environmental aspects of dredging.

Each year at selected conferences, the International Association of Dredging Companies grants awards for the best papers written by younger authors. In each case the Conference Paper Committee is asked to recommend a prizewinner whose paper makes a significant contribution to the literature on dredging and related fields. The purpose of the IADC Award is "to stimulate the promotion of new ideas and encourage younger men and women in the dredging industry". The winner of an IADC Award receives €1000 and a certificate of recognition and the paper may then be published in *Terra et Aqua*.

worldwide. Figure 1 shows examples of these, involving a massive recurring plume along the south shores of Lake Michigan and the Mississippi River sediment plume on the US south coast, in the northern Gulf of Mexico. The Lake Michigan plume was extensively studied as part of the "EEGLE", the Episodic Events Great Lakes Experiment, funded by the US National Oceanic and Atmospheric Administration NOAA in conjunction with the National Science Foundation (NSF). The great plume of silt appears each year after winter and was first captured from satellite imagery in 1996, extending approximately 10 miles offshore and 200 miles along the southern coastline of Lake Michigan, from Wisconsin, past Chicago, and back into Michigan. It typically lasts less than a month. Investigations of multiple plumes by Vanderploeg *et al.* (2007) reveal total suspended matter concentrations in the core of plumes in the order of 15-30 mg/l. The plume is driven by storm events and most sediment in the plume is re-suspended off the bottom. The latter is associated with a redistribution of contaminants such as PCBs. Moreover, the sediment resuspension events were found to alter the short-term nutrient and light climate of the nearshore waters (photic depths reduced to 1-2 m, Vanderploeg *et al*., 2007), temporarily reducing phyto-plankton reproduction and photosynthesis inside the plume.

Variability of the Mississippi river plume was studied by the Louisiana Universities Marine Consortium (LUMCON) and reported in Walker (1996). Investigation of five years of satellite imagery (112 images) showed that the sediment plume ranged in size from 450 km^2 under low discharge conditions to 7699 km^2 under high discharge conditions. Suspended sediment concentrations of 10-30 mg/l were used to define the plume extent. On seasonal and inter-annual time scales, variations in plume area were mainly driven by fluctuations in river discharge; however, day-to-day variability in plume size was more closely associated with changes in the wind field.

Fishing

Marine fisheries catch more than 120 million cubic metric tonnes of sea life each year (Pauly *et al*., 2002). Among the various methods to catch fish, trawling and dredging are considered particularly unsustainable (Van Houtan and Pauly, 2007b). These fishing gears adversely affect

Figure 3. Aerial photograph of Port Elizabeth, New Jersey. The picture reveals prominent sediment plumes behind a container ship entering the Elizabeth channel (upper right) and the container ship approaching along the eastern berthing area (right). Hardly any sediment plume is visible near the dredger also operating in the channel. Image courtesy of the Port Authority of New York and New Jersey, taken from Clarke *et al.* (2007a).

non-targeted benthic animals and the structures they build (such as reefs), thus creating flat, muddy areas with little biodiversity. In addition to the direct impact, fisheries also re-suspend mud into the water column which yields sediment plumes in the wake of fishing vessels.
Van Houtan and Pauly (2007b) assess the occurrence and dimensions of mudtrails left in the wake of fishing vessels from high resolution satellite images sampled across the planet. Images were taken from Google Earth (2007).

Sites investigated include Louisiana (USA) in the Northern Gulf of Mexico, Perhak (Malaysia) in the East Indian Ocean, Sonora (Mexico) in the Gulf of California, Luzon (Phillippines) in Manila Bay and Jiangsu (China) near the mouth of the Yangtse River. Trailer mudtrails are frequently found in shallow waters, typically appearing several hundreds of metres wide and several kilometres in length. Figure 2 is taken from their work, showing the impact of fishing activities on the marine eco-system along the Gulf of Mexico coastline of Louisiana (USA). The discovery of these images has revealed new insights the scale of sediment plumes induced by fisheries.

Shipping operations

Shipping operations are often associated with the generation of sediment plumes, particularly with decreasing water depths in harbour areas. Measurements by Pennekamp *et al*. (1991) in the Port of Rotterdam revealed a strong turbidity increase caused by the sailing and mooring of vessels (propeller impact of tugboats and return flows between bottom of vessel and sea bed in shallow water). Turbidity increases up to 500 mg/l (background concentration 20 mg/l) were measured at distances of about 50 to 200 m from a large bulk carrier during mooring at a quay with assistance of four tugs. An order of magnitude analysis by Pennekamp *et al*. (1991) indicated that the annual dredging-induced turbidity is of the same order as the total turbidity generated by all shipping and mooring operations in the same basin. Very recently, Clarke *et al*. (2007a) reported the outcome of a measurement campaign to assess sediment resuspension by ship traffic in Newark Bay, New Jersey (USA). Sediment plumes were found to vary substantially among type (e.g. deep draft container ship versus shallow draft barge/tug) and movement pattern (e.g. container ship under power or manoeuvring with assistance of tug tenders, passage in open water versus docking at berths).
Total suspended sediment concentrations often exceeded 90 mg/l over broad areas following vessel manoeuvres, and remained detectable against background conditions in open waters for at least 50 minutes after departure of the vessel. Residual plumes in the lower 2 m of the water column with concentrations of 40 mg/l or less were measured at the point of deep draft vessel passage for at least 65 minutes.
Clarke *et al*. (2007a) conclude that the assessment of dredging impacts without reference to these processes can result in misleading conclusions.

Intriguingly, resuspension caused by too deep draft vessel traffic has seldom been measured simultaneously with concurrent turbidity induced by dredging activities. Clarke *et al*. (2007b) report results from a turbidity monitoring campaign near a grab dredger working on navigation dredging in the Arthur Kill Waterway (New Jersey).

The dredger was equipped with an environmental bucket and worked with relatively small hoist speed, at relatively low production rates. Rather than the absolute values of the measured turbidity levels – which are relatively small owing to the particular environmental conditions and dredging characteristics met on site – the main interest for this study is in the simultaneous measurement of dredging- and shipping-induced sediment plumes (Clarke *et al.* 2007b). For the situation considered here, dredging activities and shipping operations do indeed generate sediment plumes with concentrations of comparable magnitude, whereas the spatial extent of the shipping induced plume may be somewhat larger. Notice that this observation particularly applies to the deeper part of the water column, where shipping-induced impacts are relatively large. In the upper part of water column, grab dredging does have a discernable impact (albeit small) whereas hardly any effect of the shipping operations is observed.

Dredging in perspective

The case examples of sediment plumes induced by fishery gear, natural processes and shipping operations readily reveal that "the day after we stop dredging" is by no means synonymous with "a world without sediment plumes". Dredging is just one process out of a series of processes driving sediment plumes. The environmental impact of dredging works may be considerable in the direct vicinity of the dredger, however the impact usually acts on relatively small spatial and temporal scales (Erftemeijer and Robin Lewin III, 2006) and dredging operations often generate no more increased suspended sediments than commercial shipping operations, bottom fishing or severe storms (Pennekamp *et al*., 1996).
These observations find support in recently published data on dredging-induced turbidity (Clarke *et al*. 2007b; Burt *et al*. 2007; Land *et al*. 2007), sampled with the help of state-of-the-art ADCP-based techniques to measure suspended sediment concentrations.

An effective assessment of the environmental impact of dredging operations therefore demands thorough insight in dredging-induced turbidity levels for various environments and types of equipment, as well as fluctuations in the background turbidity level as driven by other processes such as storms, river peak discharges, fishing and shipping. Unfortunately, a straightforward, quantitative comparison of turbidity levels associated with the various driving processes is not entirely trivial, since sediment plumes are site-specific by nature owing to variations in sediment composition, environmental conditions, characteristics of dredging respectively, fishing operations, and other site-specific elements. Moreover, the establishment of threshold levels for the allowable dredging-induced increase of turbidity levels should ideally be based on sound knowledge on recovery capabilities of ecological habitats at various time scales (Van Raalte *et al*., 2007). The latter

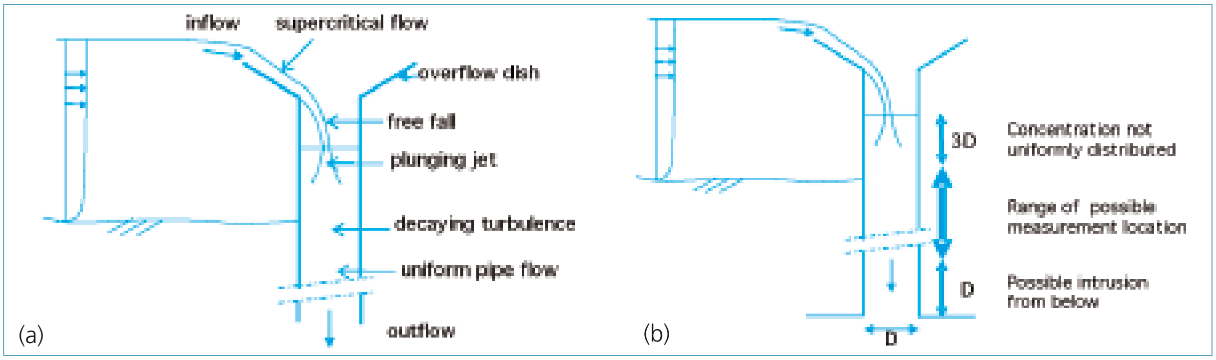


Figure 4. Theoretical analysis of overflow mixing processes (Svasek, 2006). Identification of relevant processes (a) and feasible vertical range for collecting well-mixed samples from single-point sampling device (b).

demands further research on natural ecosystem dynamics.

The range of knowledge gaps identified above can only be filled through dedicated collaboration between universities, research institutes, public authorities and the dredging industry, involving both engineers as well as environmental specialists.
The dredging industry actively adds to this by running research programmes aimed at the quantitative assessment of dredging-induced sediment plumes. Recent work carried out in the framework of the TASS programme is presented here.

ASSESSMENT OF DREDGING-INDUCED TURBIDITY (TASS PROGRAMME)

With increasing appreciation of the importance of environmental issues amongst public, government agencies and other stakeholders, the dredging industry and associated parties have carried out significant research efforts in the quantitative assessment of sediment plumes (e.g. Pennekamp *et al.* 1996; John *et al.* 2000) and will continue to do so in the nearby future (Van Raalte *et al.*, 2007). One of the major programmes currently running is the TASS programme (Land *et al.*, 2004). The TASS progamme aims at the development of Turbidity Assessment Software (TASS) for the prediction of the sediment release in the water column amongst different type of dredging equipment. The initial stages of the project were funded by VBKO (*'Vereniging van Waterbouwers in de Bagger-, Kust- en Oeverwerken'*) and the Dutch Ministry of Public Works Rijkswaterstaat, resulting in a preliminary model developed by HR Wallingford (1998-1999). This model includes formulations to predict the rate of release of sediment from the following dredging plant:

- grab (clamshell) dredgers;
- backhoes;
- bucket (ladder) dredgers;
- cutter suction (cuterhead) dredgers;
- trailing suction hopper dredgers.

Later stages of the project were funded by the SSB (*Stichting Speurwerk Baggertechniek*), a strategic research cooperation of Royal Boskalis Westminster and Van Oord. During these later stages, TASS research efforts – at least those funded by the Dutch dredging industry – focussed entirely on the trailing suction hopper dredgers.

Further model extensions during this period involved, amongst others, the inclusion of a dynamic plume model to describe the descent of the sediment plume under the dredger, directly after release from the overflow. Shortly after release of the models, it was recognised that high-quality data sets (i.e. suitable for validation of overall model behaviour as well as model sub-components) were not available in the public domain. Field measurement methods were inconsistent and often failed to obtain (and/or report) all the data required to assess releases from different types of plant working in different soil conditions. Consequently, a set of standard field measurement protocols was developed for each of the five dredgers covered by the project (Land *et al.*, 2004). The protocols are freely available for anyone interested and are still in use for the design of TASS field experiments.The applicability of the protocols was tested on the basis of two large-scale field trials, both described by Land *et al.* (2004). The first took place on the River Tees (UK) in May 2000 around a grab dredger undertaking maintenance work (Burt *et al.*, 2007). The second was organised in June 2002 and measured sediment release from a trailing suction hopper dredger working on sand mining and maintenance dredging in the Port of Rotterdam (the Netherlands).

Given the present focus on trailing suction hopper dredgers, the Rotterdam (2002) trial was particularly relevant in view ongoing TASS research presently undertaken.
The outcome of the two trials can be summarised as:

- Overall the two trials were considered as successful in terms of providing useful data for model validation and testing the measurement techniques;
- Nevertheless, it must be recognised that some of the measurement were and will be complex to undertake, thus yielding data of little practical value.
  This particularly holds for the sonar measurements of the dynamic plume (success rate 15%) and the ADCP measurements of draghead plumes (success rate 50%).
- The Rotterdam (2002) TSHD experiment was less successful in that it revealed discrepancies, when dredging sand, between two different techniques deployed for overflow sampling. It was found that the flow-through samplers (mounted on the rim of the overflow) yielded much higher concentrations than the bottle sampler. Despite several efforts, no clear explanation was found for these discrepancies.

These findings were adopted as the starting point for two successive TASS field trials carried out in Bremerhaven (June 2006) and Rotterdam (May 2007). Both are described below.

TASS FIELD TRIAL BREMERHAVEN (2006)

Design of field trial

As a continuation of the Rotterdam (2002) field trial, experiments were carried out in Bremerhaven with the specific objective to arrive at a robust technique to collect representative overflow samples during dredging. As the use of sampling devices on the rim of the overflow had proven to be non-successful, it was recognized samples should be taken from within the overflow with the help of a suction-type device. This involved two challenges.
The technical challenge was to design a sampling system which is robust enough to withstand the hostile hydrodynamic environment in the overflow and flexible enough to take samples at various locations and elevations within the overflow. This system is described below. The theoretical challenge was to make sure that overflow samples taken from a single point were representative for sediment concentrations across the entire overflow cross-section. In other words, the samples should be taken from an area where the sediment concentration is uniformly distributed over the overflow cross-section.

The latter question was addressed by means of a theoretical analysis of mixing processes in the overflow (Svasek, 2006). The stages considered include the inflow, supercritical flow over the rim, a free fall phase followed by a plunging jet, decaying turbulence in the pipe, uniform pipe flow and the outflow (Figure 4a). Based on simple hydronamic rules and a few conservative assumptions, it was found that for an open (i.e. non-drowned) overflow, samples could reliably be taken from an area between 3 times the pipe diameter below the water surface and 1 pipe diameter above the bottom end of the overflow (Figure 4b). Moreover, since the presence of air bubbles adversely affects the performance of the sampling pumps, it was recommended to locate the pumps as deep as possible. The theoretical analysis did not reveal a preferred horizontal position within the overflow cross-section.

During the field trial, dedicated experiments were carried out to verify the feasibility of the submerged pump sampling system and the representativeness of the samples taken. The latter involved high-frequency sampling (typically twice per minute) in a single point, repetitive sampling at two to three different locations across the overflow cross-section (fixed elevation) and repetitive sampling at different elevations over a 2.5 m range.

Field measurements

The Bremerhaven field trial was carried out between June 8 to 13 around the trailing suction hopper dredger *Cornelia*, which was built in 1981, has two suction pipes and a hopper capacity of 6360 m^3.

During the measurement period she was dredging sand in the harbour entrance channel for the construction of a new container terminal CT4. The site (Figure 5) is characterised by a tidal range of 3-4 m, significant tidal flow velocities (up to about 2 m/s) and fine sand. Being located within the Weser estuary, the entrance channel is somewhat sheltered from direct wave action.

For the purpose of this field trial, an overflow sampling system was developed and mounted in the overflow of the *Cornelia* (Figure 6). The system consisted of a suction tube (Figure 6a) which was connected to two sub-merged pumps (Ircem DA 12M), mounted in series, with a maximum head of 10.4 m each.
The suction device could be rotated around a vertical axis to enable sampling from different locations over the cross-section. The whole system was mounted on a vertical plate (Figure 6b) which could be moved up and down the overflow, so that samples could be taken at different elevations. Samples were collected by filling bottles (Figure 6c) of known weight and volume, which were weighted onboard to determine sediment concentrations.
To obtain in-situ flow velocities, a Marsh McBirney single axis current sensor was mounted near the suction mouth (Figure 6a). Finally, a CTD diver of Van Essen was used to measure salinity, temperature and conductivity throughout the experiments.

The Bremerhaven field trial yielded a total number of eight successful experiments, two of which were carried out during maintenance dredging of muddy material in front of the existing container terminal and the other six during offshore sand mining for the construction of the new terminal.

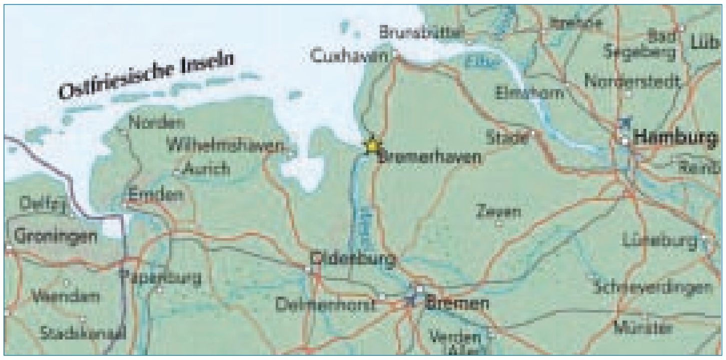


Figure 5. Location of the Bremerhaven test site.

Results

Figure 7 shows example time series of sediment concentrations (a, b) and flow velocities (c, d) measured in the overflow, representing a fine sand run (Trip 158, panel a, c) in the offshore borrow area and a maintenance run with muddy sediment (Trip 157, panel b, d) in front of the existing terminal. The upper panels also show time series of the hopper volume for both trips, to indicate when the overflow was being operated.

Figure 6. Overflow sampling during the Bremerhaven (2006) field trial. Sampling device in lifted position (a), deployment of total sampling system on movable plate in overflow (b) and filling 1 liter bottles (c).

Trip 158 was meant to investigate the temporal variability of overflow samples taken from a single point at a fixed elevation. The results show that the pump sampling system is capable of measuring a consistent time series, particularly if the overflow is at a constant level (i.e. prior to 21:00 hr). While lowering the overflow (21:00-21:20 hr) the flow pattern is more irregular and air entrainment becomes more of an issue, and consequently variations in sampled discharges occur. This may explain the somewhat larger variability in measured concentrations as observed from Figure 7a. Nevertheless, also during the latter phase, variability is small as compared to the overall signal. It is concluded that a sampling frequency of once per minute is sufficient to resolve the evolution of overflow concentrations over time. The measured concentration profile of Trip 157 illustrates the effect of sampling at different locations within the overflow cross-section (while dredging mud). Samples were taken at 30 (blue dots), 60 (red dots) and 90 (green dots) cm from the wall. The concentrations measured in the three locations are entirely consistent with each other, thus demonstrating spatial uniformity of the concentration distribution. Similar results were obtained while dredging sandy material, albeit that sampling system often failed to collect material at the near-wall sampling location. This was attributed to the presence of air bubbles; a sound explanation for this observation has however not been found yet. The two lower panels (c, d) show large fluctuations in the flow velocity in the overflow, suggesting a highly turbulent flow with major eddies. To ground-truth these data, the total discharge through the overflow was computed from integration of the measured velocities over time, multiplied with overflow area.

For all experiments, the overflow discharge was rougly similar to the combined discharge in the two suction pipes as determined from the on-board instruments. To minimise sampling logistics and complexity, it was concluded that for future experiments the average velocity in the overflow could safely be estimated from the velocity meters in the suction pipes. Overall, the following conclusions are drawn from the Bremerhaven (2006) field trial:

1. the use of a submerged pumping system to collect in-situ samples from a single point near the bottom end of the overflow is a reliable method to quantify sediment losses in a free-flow overflow (i.e. without the use of an environmental valve);
2. the presence of air bubbles in the mixture causes occasional failure of the sampling system;
3. a sampling frequency of once per minute is sufficient to resolve the evolution of sediment concentrations over time;
4. for the purpose of this work, measurement of in-situ flow velocities is of little added value as compared to the use of velocity estimates determined from the on-board sensors in the suction pipes.

The Bremerhaven (2006) data are presently being exploited for the validation of the overflow model in the trailer module of the TASS model.

TASS FIELD TRIAL ROTTERDAM (2007)

Design of field trial

The Rotterdam (2007) field trial was set-up with a four-fold objective (Figure 8):

1. measurement of overflow losses, to enable validation of the TASS trailer module;
2. measurement of concentrations in the sediment plume behind the dredger, to enable validation of passive plume models (which are feeded by the TASS dynamic plume model) and to assess the benefit of the use of a green valve in the overflow;
3. measurement of draghead-induced turbidity, to address the importance of bulldozing effects and jets for environmental assessments;

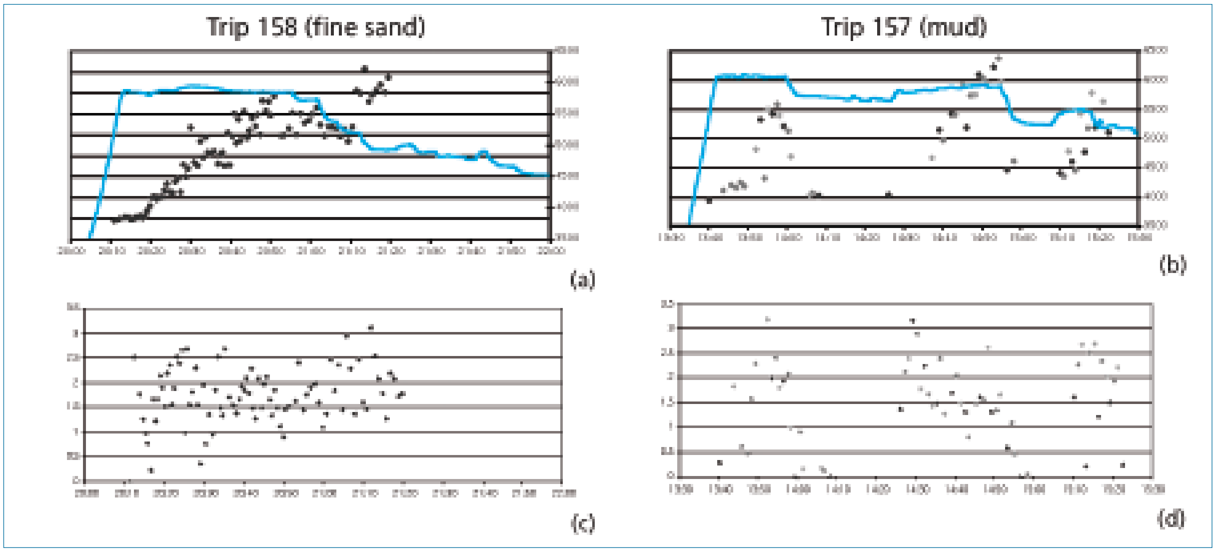


Figure 7. Example time series of sediment concentration (a, b) and flow velocity (c, d) for a mining run (Trip 158, fine sand) and a maintenance run (Trip 157, mud) during the Bremerhaven (2006) field trial. The upper panels also show time series of hopper volume (blue line) to indicate when the overflow was being operated.

4. measurement of propeller wash behind the dredger as well as other vessels, to facilitate evaluation of dredging-induced turbidity increase against other, "natural" sources affecting the background level.

The "Protocol for the Field Measurement of Sediment Release from Dredgers" (HR Wallingford, 2003) was adopted as a starting point for the design of the Rotterdam (2007) trial. As an extension of this, it was decided to follow a top-down approach as regard to the balance between overall impact measurements and detailed process measurements. For instance, the assessment of the benefits of the green valve will be based on measured passive plume concentrations rather than detailed process measurements of active plume – propeller interaction and bubble dynamics under, besides and direct behind the trailer. The latter (complex) process measurements are only relevant for TASS development if the application of a green valve does indeed result in substantially smaller plumes and lower sediment concentrations.

A similar rationale applies to the measurement of propeller wash. An SSB-funded review of the effect of propeller wash near dredging equipment (HR Wallingford, 2006) indicated that for fairly regular conditions, the vertical erosion rate at the point of greatest erosion could be in the order of 10-15 cm/s. On the basis of this study, it was decided to attempt to quantify propeller wash from simple depth sounding behind the moving vessel, in combination with simultaneous ADCP concentration measurements over the water column, rather than putting frames on the seabed equipped with very advanced sensors that measure propeller wash during passage of the vessel over the frame.

The harbour entrance of the Port of Rotterdam (Figure 9a) was selected as the field site for this trial for several reasons. Since most parties involved are based in Rotterdam or its direct neighbourhood, logistics are relatively easy. Moreover, the site offered the opportunity to monitor a combined nourishment / maintenance dredging project, which was carried out by the trailing suction hopper dredger *Oranje*.

This dredger, operated by Boskalis, is equiped with a green valve and was scheduled for a docking period just prior to the field trial. The latter offered the

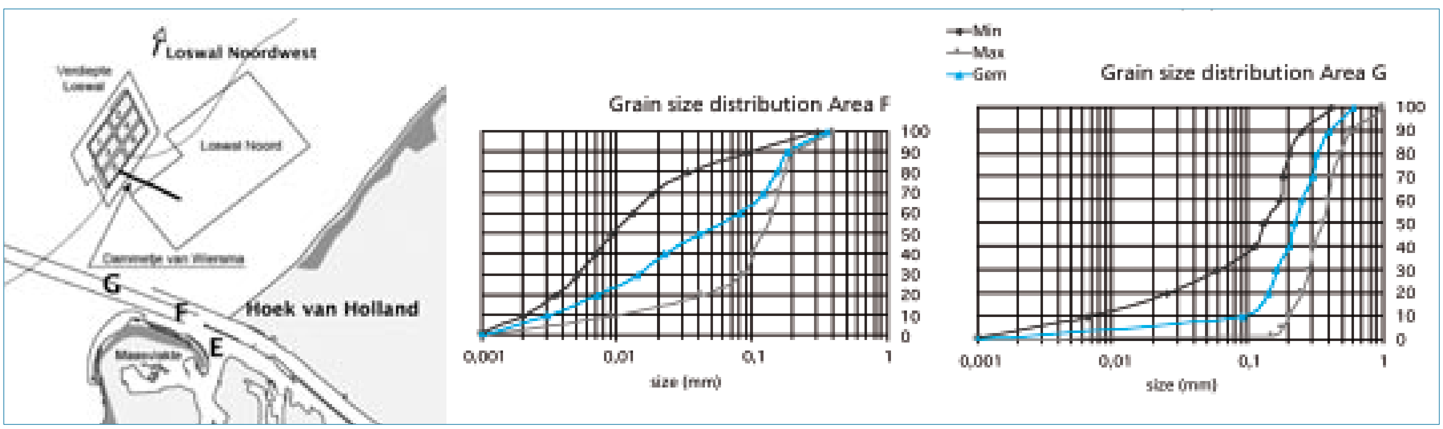


Figure 8. Site layout left, of the Rotterdam (2007) field trial and of grain size distributions of areas F and G.

Figure 9. Overflow measurements were carried out onboard *TSHD Oranje* involved with the Rotterdam (2007) field trial.

opportunity to mount specific overflow sampling equipment safely and accurately under controlled, dry conditions.

Field measurements

The Rotterdam (2007) field trial was carried out between May 1 and May 12, covering a total of 7 measurement days. Overflow measurements were carried out onboard of the *Oranje* (Figure 9); all other measurements were taken from with the help of the survey boat *Corvus* (Figure 10), which is operated by The Dutch Ministry of Public Works Rijkswaterstaat.

During the first two measurement days, the *Oranje* was dredging sand for beach nourishment in front of Hook of Holland; the other five measurement days were spent on maintenance dredging in the Maasgeul (areas E, F and G, cf. Figure 8). Most good-quality measurements were collected during maintenance dredging. The site is characterised by a 1-2 m tidal range, fairly strong currents (up to 1.5 m/s) and, being fully exposed to North Sea waves and swell, possibly big waves.
A variety of sediment grain sizes is found, ranging from sand in the offshore borrow areas, via fine sand, Area G and fine sand with silt, Area F to mud, Area E (Figure 8). The measurements onboard of the *Oranje* focussed on the quantification of overflow losses. To that end, an airlift was being designed and built to lift mixture samples from the lower end of the overflow to deck level. An airlift type construction was chosen to enable in-situ sampling in the overflow, while avoiding the need to mount vulnerable, submerged pumps in the overflow and minimizing possible failures due the presence of air bubbles. The airlift (Figure 11a) consisted of a 2.5 cm wide, approx. 18 m long suction tube mounted within a strong, steel pipe to create sufficient stability. Near the lower end, a vertical suction mouth was placed, which was continously flushed while not in use to avoid siltation. A third, 1 cm tube was mounted within the overflow to inject air in the suction tube at approximately 1 m above the lower end. After being collected, the mixture is run through a combined mixing / sampling device (Figure 11b/c).

While doing so, the material passes a perspex cylinder with a so-called Medusa sensor mounted on it, which measures mixture density in real time from the radiance decrease across the cylinder.

In addition, simultaneous bottle samples were collected during a few runs, in support of further ground-truthing (in retro-respect) of overflow samples taken during the Rotterdam (2002) field trial.

The survey boat *Corvus* was responsible for all measurements around the trailer, including collection of bed and water samples for calibration purposes. The *Corvus* was equipped with two ADCPs, one mounted on a stabilised towfish (Figure 12a) for the monitoring of draghead plumes and a second mounted on a frame aside the *Corvus* (Figure 12c) for the monitoring of passive plumes behind the trailer. The data on draghead resuspension were obtained by sailing the *Corvus* extremely close astern the *Oranje* (Figure 12b) with the ADCP towfish floating at a depth of about 10 m to avoid any interference with propeller impacts.

Besides the frame-mounted ADCP data, concentration measurements were also collected with the help of a string equipped with three OBS sensors. During sailing these sensors migrate up and down the water column to arrive at a good spatial coverage of the plume. The two duplicate measurements were carried out to obtain good understanding of the accuracy of both methods, as a function of the distance to the dredger (hence air bubble effects).

Figure 10. The survey boat *Corvus* which was provided by The Dutch Ministry of Public Works Rijkswaterstaat.

Figure 11. Measurement of overflow losses on-board of the Oranje: (a) Airlift, (b) overview of measurement area including Medusa sensor and (c) mixture sampling in 0.5 liter bottles from mixing device.

Finally, regular survey equipment was deployed for the measurement of propeller wash from bathymetric changes and water quality parameters such as salinity and temperature.

Results

During the Rotterdam (2007) field trial, overflow losses were measured during 14 different trips. Besides, a total number of 6 passive plumes, 11 draghead plumes and 8 propeller wash events were measured. When compared to numbers aimed for prior to the trial, this corresponds to data return rates of about 90% (overflow losses), 30% (passive plume), 70% (draghead plumes) and 80% (propeller wash). The large percentage for the overflow losses is attributed to good performance of the airlift, in combination with the added value of the bottle samples and Medusa concentration measurements.

The somewhat disappointing percentage of data return for the passive plumes is due to the large wave height offshore, which exceeded 1.5 m during most of the experiment. Fairly good percentages of data return were obtained for the draghead and propeller wash measurements. The data sampled during the Rotterdam (2007) field trial are presently being analysed. Preliminary results reveal robust performance of the airlift system to collect sediment samples from the overflow.

Moreover, mixture densities thus measured are consistent with the data retrieved from the Medusa sensor. The data will be used for the validation of specific components of the TASS model as well as the identification of future model developments.

CONCLUSIONS

The work presented here shows the recent progress in the framework of the TASS ("Turbidity Assessment Software") programme, which aims at the development of a validated model to predict dredging-induced turbidity levels. A key component of this program is the execution of a series of large-scale field trials to collect high-quality data that can be used for model validation purposes. Recent field trials carried out in Bremerhaven (2006) and Rotterdam (2007) resulted in valuable insight in optimal means to collect overflow samples for the quantification of overflow losses over a range of soil types, overflow configurations and environmental conditions.

Moreover, it is expected that the Rotterdam (2007) field trial will help to assess the relevance of draghead plumes and propeller wash in view of dredging-induced turbidity, as well as the benefits of using a green valve. Both data sets will be used for TASS model validation and the idenfication of future model developments and research needs.Although the TASS programme focusses on dredging-induced turbidity increases, it should be noted that dredging is just one of a series of processes that drive sediment plumes.

These processes include natural events, shipping operations and fishing activities. An inventory of these processes suggests, at least qualitatively, that the annual impact of these processes is of the same order of magnitude as dredging. Consequently, the conclusion must be that "The day after we stop dredging" will by no means mark the onset of a world without sediment plumes.

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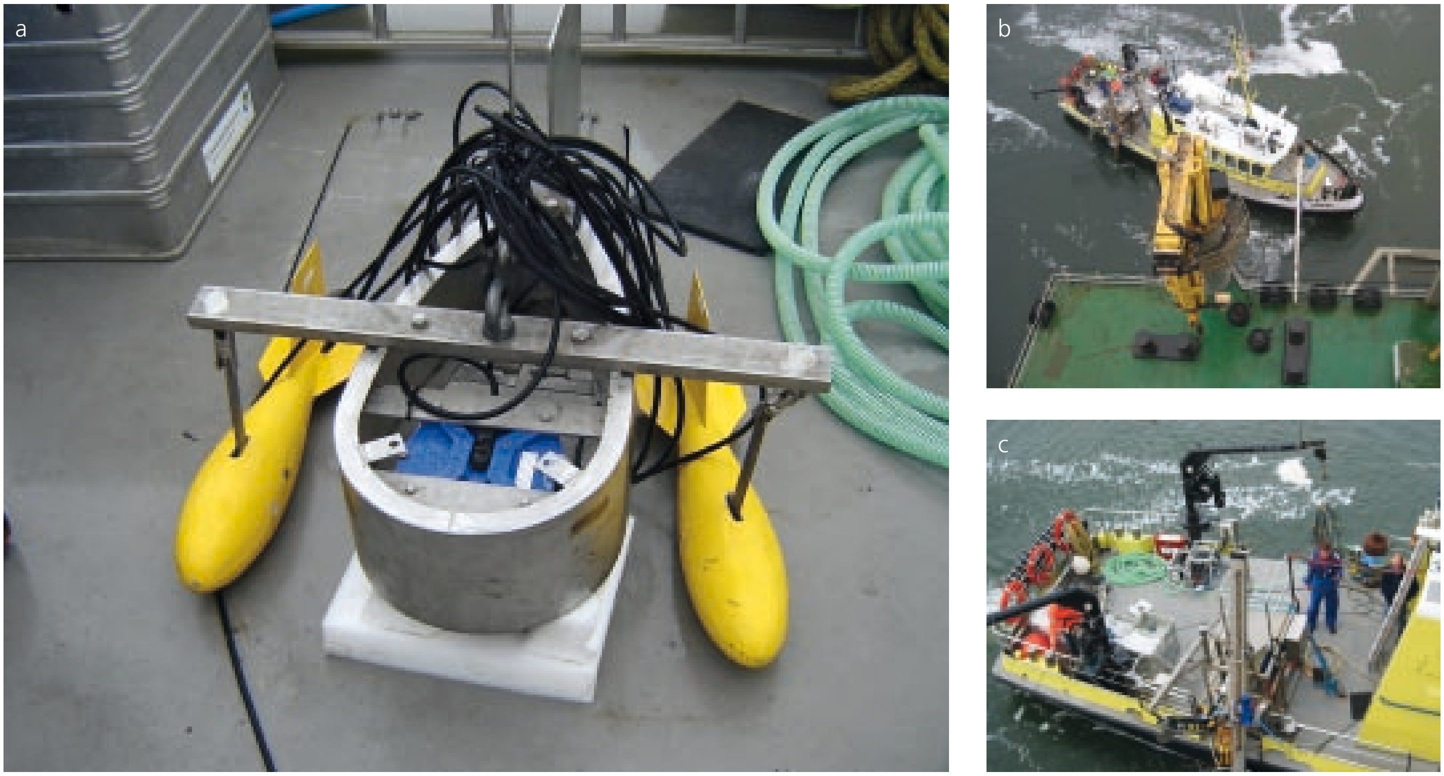

Figure 12. Deployment of survey boat Corvus during Rotterdam (2007) field trial: (a) Stabilised ADCP, (b) Corvus passing astern of the Oranje while monitoring draghead plumes, and (c) overview of measurement equipment onboard of Corvus including. frame for ADCP- as well as OBS-based passive plume monitoring.

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OLIVER STOSCHEK

POSSIBILITIES OF MINIMISING SEDIMENTATION IN HARBOURS IN A BRACKISH TIDAL ENVIRONMENT

ABSTRACT

Sedimentation in harbour entrances at tidal and brackish rivers owing to tidal currents and turbulent mixing processes cannot be avoided. Reducing sedimentation in harbours can significantly decrease maintenance dredging costs. Different mechanisms of sediment movement into a harbour in a tidal and brackish environment are evaluated in a regional numerical 3-dimensional-model of the Weser Estuary. In a parametric study, complex multi-dimensional boundary conditions were extracted from this regional model to run several detailed numerical 3-dimensional-models with different geometries, tidal conditions and salinity.

The influence of these parameters on sedimentation in harbours was determined. The results of this parametric study were used to develop solutions to reduce sedimentation in harbours in a brackish tidal environment.

The study was part of a joint research project financed by the German Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung, BMBF) and carried out at the Franzius Institut, University of Hannover. The author gratefully acknowledges the cooperation and provision of field data from Prof. H. Nasner, University of Applied Sciences, Bremen and the Federal Waterway Authority (WSA Bremerhaven). This article was presented at the Black Sea Coastal Association Conference (BSCA) on Port Development and Coastal Environment, September 2007, held in Varna, Bulgaria and is reprinted here with permission in a slightly adapted version.

INTRODUCTION

Harbours in sediment-laden rivers and estuaries with their changing flow velocities and directions and water levels owing to daily tides often show heavy sedimentation. To keep such vital facilities operational, costly removal of sediments is necessary either permanently or periodically. Sediment loads originate from bed and bank erosions or influx from the catchment areas upstream. Variation in sediment qualities and in quantities is considerable with the discharge varying over the year.

Above: Tugboats lined up at the entrance to the Kaiser-Lock, at the port of Bremenhaven.

In the downstream part of an estuary mixing of salt water from the sea with fresh river water results in density variation causing density currents near river beds and additional sediment transport caused by brackish water effects.

The large quantities of often contaminated sediments to be removed from a harbour basin and the cost associated with such maintenance dredging and disposal create a strong stimulus and interest to understand the exchange processes between rivers and harbours and, upon such understanding, find solutions for reduction or even prevention of sediment intrusion and deposition.

OBJECTIVES

The objectives of this study are to analyse the complex coherencies in a brackish tidal zone. For this reason the complex 3-dimensional currents were split into the different components to gain new knowledge on sedimentation in harbours. The complex situation in the brackish tidal zone of the River Weser was used to set up a conceptual model to investigate the effects of tidal and density induced currents on

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received the CEDA Environmental Commission prize for the best paper from Neville Burt (left), Chairman of the Central Dredging Association Environment Commission at the Black Sea Coastal Association Conference on Port Development and Coastal Environment, September 2007, in Varna, Bulgaria.

Dr. Stoschek graduated in 1997 as a civil engineer with a speciality in hydraulic engineering (Dipl.-Ing.) from the University of Hannover, Germany and in 2003 received a Ph.D. in coastal engineering from the Franzius-Institut, University of Hannover. He is presently Head of the Hydraulic Department at DHI Wasser & Umwelt GmbH, Syke, Germany.

sedimentation in harbours. The results were used for investigations to reduce the sedimentation inside a harbour in the brackish tidal zone in Bremerhaven.

WATER AND SEDIMENT EXCHANGE

Numerous experimental investigations have been carried out on the exchange of waters between a river and a harbour basin for more than six decades to understand the basic processes. A first systematic approach by Rohr (1933) was limited to 2-dimensional horizontal flow fields, neglecting vertical velocity profiles.

It could be shown that the so-called flow effect initiates one or more vertical large scale vortices in the harbour, depending upon the entrance width and harbour geometry as well as river flow velocities (Figure 1). Experiments and site observations confirmed that sedimentation is concentrated in the centres of such vortices with the gradation of sediment to the outside from fine to coarse.

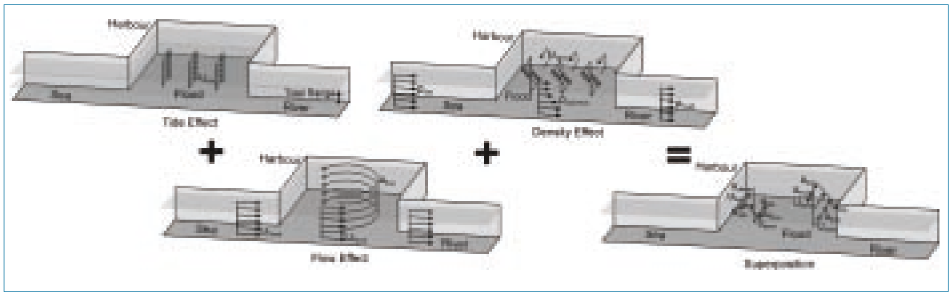

Figure 1. Density differences, flows, sediment and water exchange in a tidal harbour.

Reversing and unsteady river flows in an estuary during a tidal cycle change the directions of vortices while sediment influx from the river continues, depending upon sediment loads and variation of the river flow velocities (Langendoen, 1992). Additional water exchange during a tidal cycle from the so-called tide effect, which depends on the tidal range, increases sediment influx into the harbour.

In lower parts of an estuary inflow of salt water from the sea, stratification caused by density differences and the resulting initiation of density currents may occur, adding considerable complexity to the sedimentation problem (Figure 1).
In addition, specific biogenic and cohesive flocs and their time dependent behaviour increase the complexities. In this study a 3-dimensional approach as applied by different researchers, e.g. Mehta (1986) and Langendoen (1992) gave better insights into the problem and some technical proposals for reduction of sediment influx and deposition.

Only recently, detailed measurements with advanced instrumentation gave a basis for a detailed calibration of 3-dimensional simulations. With observations and data from the lower part of the Jade-Weser Estuary discharging into the southern North

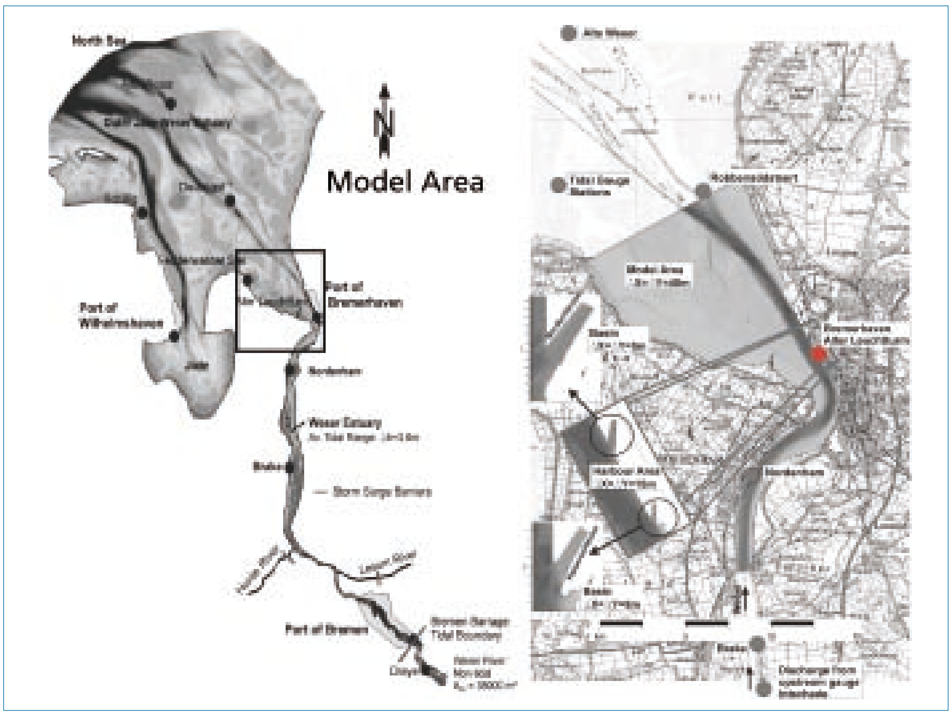

Figure 2. Weser Estuary around the port of Bremerhaven and model boundaries.

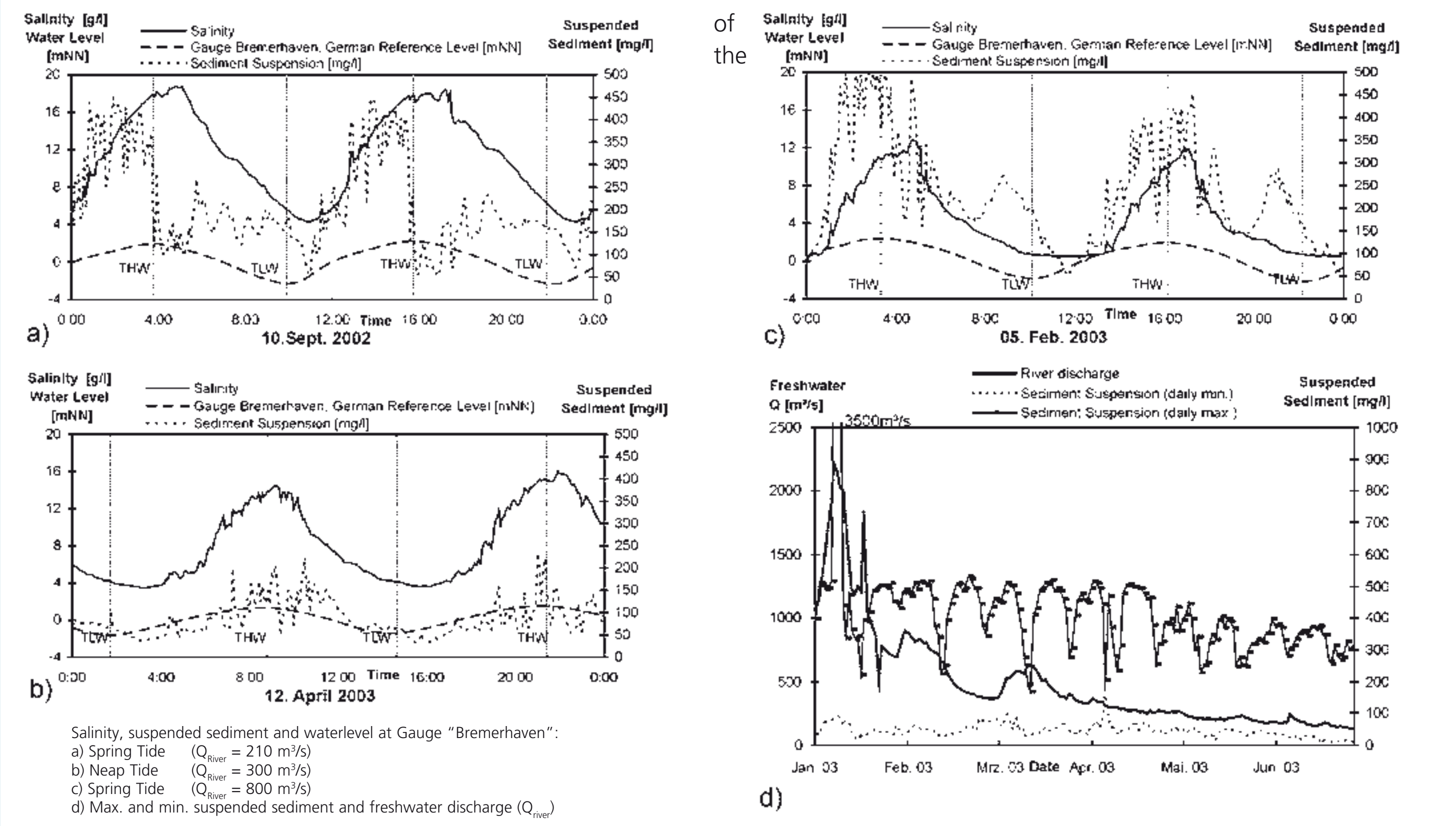

Figure 3. Suspended sediment and salinity varying with tide and river discharge at Bremerhaven.

Sea extensive simulations for the Port of Bremerhaven and for similar harbours were made to extract the different effects. Based on these model results technical options for reduction of sedimentation in a tidal harbour were evaluated (Stoschek, 2004; Stoschek *et al.*, 2003).

MODEL AREA AND BOUNDARY CONDITIONS

The Port of Bremerhaven, located at the lower end of the Weser Estuary (Figure 2) at the southern North Sea coast is one of the major ports of Germany with a throughput of 14 Mio tonnes annually. Navigation on the 60 km long lower River Weser, which has been continuously deepened and widened within the fairway for more than 110 years, allows ships to approach with a draft of up to 14.5 m at tidal low waters. Sediment intrusions into the various harbour basins require annual dredging of sediment, to be disposed on land after separation and specific treatment various contents and fractions. The model area is shown in Figure 2. The model resolution rages from 45 m in the outer regions to 5 m in the harbour area. In these detailed areas the numerical results will be compared with measurements.

Tides are semidiurnal and asymmetric. The mean tidal range is about 3.8 m at Bremerhaven. The long-term mean river discharge recorded about 30 km upstream from the tidal barrage at gauge "Intschede" is about 320 m³/s. Sediment discharges

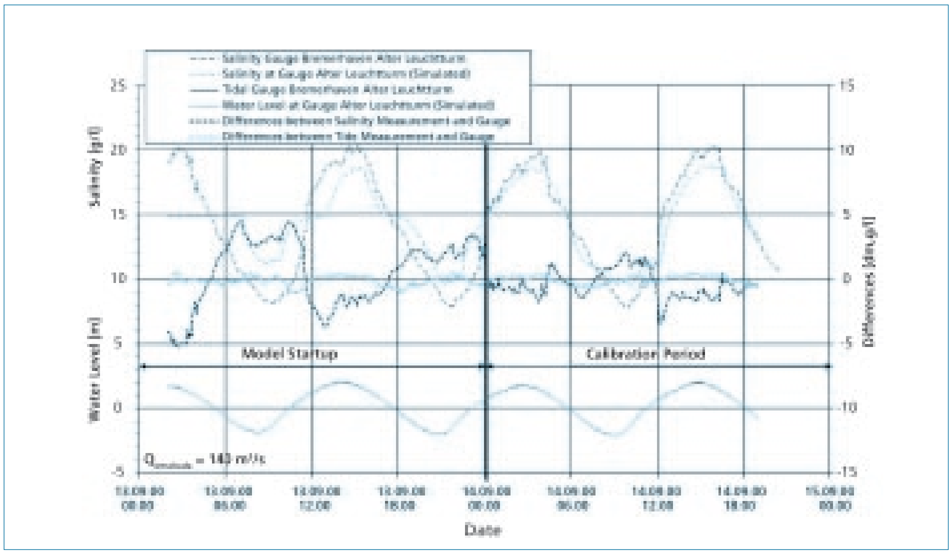

Figure 4. Water level differences and salinity variations at gauge station Bremerhaven for period A.

from upstream vary from 10 kg/m³ to more than 500 kg/m³ and salt water concentrations vary from 0 to above 32 g/l (Figure 3).

MODELLING TECHNOLOGY

To set up this study a numerical finite differences model of DHI was used (MIKE 3): The programme was selected after comparison and tests of various 3-dimensional programmes, considering the adequate modelling of turbulence, shear stress, mass exchange between bed layers of varying consolidation, settling of particles and flocs in cohesive sediments, sedimentation and erosion processes at and within the layer and density effects from varying salinity intrusions. It uses Finite Difference (FD) algorithms, solving the 3-dimensional non-hydrostatic Navier-Stokes Equations. Small-scale structures could be modelled with horizontally compacted grids (nesting). Vertical resolution was with equidistant layers, except for the bottom and top layer, to allow bottom and tidal variations (DHI 2003 a, b). The theoretical background of MIKE 3 HD can be found in Vested *et al.* (1992) and Ekebjaerg and Justensen (1991).

MODEL AND MODEL CALIBRATION

Calibration of the hydrodynamics and densities/salinities for Gauge "Bremerhaven - Alter Leuchtturm" were made for two periods (Period A - spring tide: 13.09.2000 02:00 to 14.09.2000 22:00 and Period B - neap tide: 14.05.2001 06:00 to 16.05.2001 01:00). The calculated tidal water level showed maximum deviations of 0.08 m from the recorded tidal range of > 3.4 m (Figure 4).

For additional calibration and verification of flow velocities, ADCP measurements from a harbour basin and some river profiles in front of the harbour of Bremerhaven North Lock (IWA-Bremen, 2003) were used. Comparison has to be done extremely careful, due to the necessary time to produce an area map of flow velocities from ADCP profiles. Thus, flow velocities were selected on a point-to-point basis and compared with model results at precise

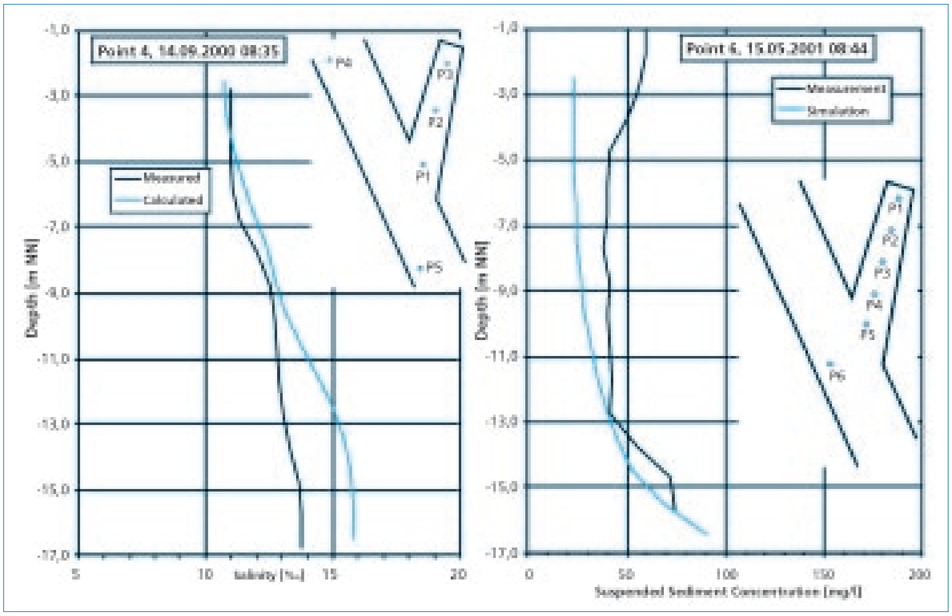

Figure 5. Measured and calculated salinity (left, point 4: 14.09.2000 8:35, around TLW) and suspended sediment concentration (right, point 6: 15.05.2001 08:44, 2.2h after THW).

time and location of the measurement (Franzius-Institut, 2003). Flow velocities were averaged over MIKE 3 cells and transferred to calculation nodes for each vertical ADCP measurement (spot).

Flow velocities in the harbour entrance and in the River Weser differ with a maximum of 10 cm/s. Comparisons show that major eddy structures are reproduced (dimension, time of development, rotation, shape and movement through the harbour during tidal cycle). The resulting parameter set after the hydrodynamic calibration is shown in Table I. The comparison of the measured and computed salinity show differences of less than 3 g/l from a maximum of 21 g/l in salinity (Figure 4). Good agreements could also be observed for the vertical salinity profile (Figure 5). Larger deviation between measurements and simulations are owing to the single location measurements in the River Weser, and mixing zones of sea and river water vary with tides and river discharges.

Suspended sediment intrusion and sedimentation inside the harbour showed

Table I. Parameter set after hydrodynamic model calibration.

Bottom roughness for the whole model area: k=0.05 m Turbulence Model: $c_{sm}=0.5$, $c_{\mu}=0.09$, $c_1=1.44$, $c_2=1.92$, $c_3=0$, $\sigma_k=1$, $\sigma_\varepsilon=1.3$, $k=1e^{-7}$, $\varepsilon=5e^{-10}$

Table II. Calibration parameter for sediment transport model.

Model Parameter	Value
Dispersion Factor [-]	0.01
Settling Velocity [mm/s]	0.2
Maximum Concentration for Deposition [kg/m³]	3.0
Partial Shear Stress for Deposition [N/m³]	1.5
Critical Shear Stress for Deposition [N/m³]	0.06
Erosion Constant [-]	1.00E-05
Critical Shear Stress for Erosion (upper Layer) [N/m²]	0.3 (Harbour) / 2.0 (River)
Density of Bed Layer (upper Layer) [kg/m³]	1000 (Harbour) / 2000 (River)

good agreement between measurement and simulation (Figure 5). Transport of suspended materials along the River Weser and, during certain tidal phases, the large tidal mud flats, its motion and fluctuation of concentration over the tidal cycles could be visualized (Stoschek, 2004). In Figure 5 the calculated and the measured vertical distribution of the suspended sediment concentration 2.25 h after THW is shown. The calculated SSC underestimates the measurements. The calibration parameter are given in Table II.

Model results show that sedimentation occurs mainly at the end of the flood period (last 30%). The maximum suspended sediment concen tration can be found at the end of the flood period and at the end of the ebb period of spring tide. Consequently, the period of main sediment transport into the attached harbours of Bremerhaven is identified.

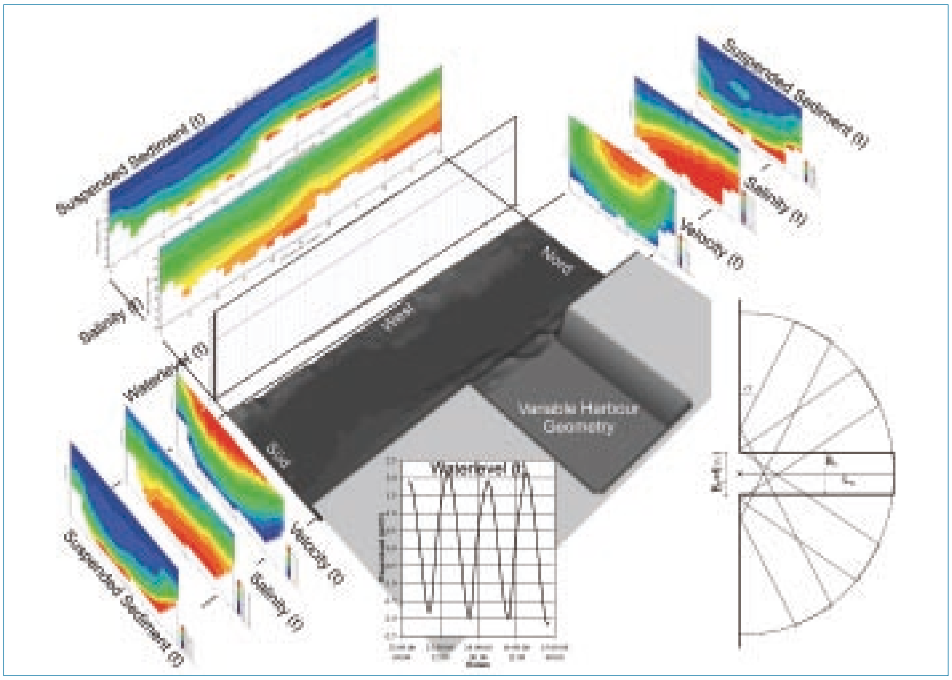

Figure 6. Detailed model area and boundary conditions of a parametric study.

EFFECT OF HARBOUR GEOMETRY ON SEDIMENTATION

This model from a real estuary was taken to analyse the relation between flow effect, tide effect and density effects with systematic simulations of various harbour geometries, i.e. varying basin lengths, widths, entrance openings and diversion angles (Stoschek, 2004). For this reason the depth- and time-varying boundary conditions for a detailed harbour model with varying harbour geometries were extracted from this calibrated Weser model (Figure 6).

A significant result is the importance of density currents on sediment intrusions, driven by varying salinities over the tide, initiating a two-layer counteracting vortex system in the harbour basin (Figure 7) over certain periods of a tidal cycle. During flood tide in the upper parts of the harbour with less salinity and sediment in suspension, flows are directed seawards.

Near the bottom, velocities are directed into the harbour. These velocities are below critical bed shear stress that major parts of the suspended sediments can settle down.

Sand sediments will settle near the harbour entrance while fine sediments will be transported inside the harbour. Two different typical types of harbour were used for the systematic study. The first one (A) is a nearly quadratic type of harbour (width B_H: 450 m; length L_H: 550 m). This harbour has a larger surface and, in general, a reduced entrance width. In this case the entrance width B_E was altered from 450 m to 50 m

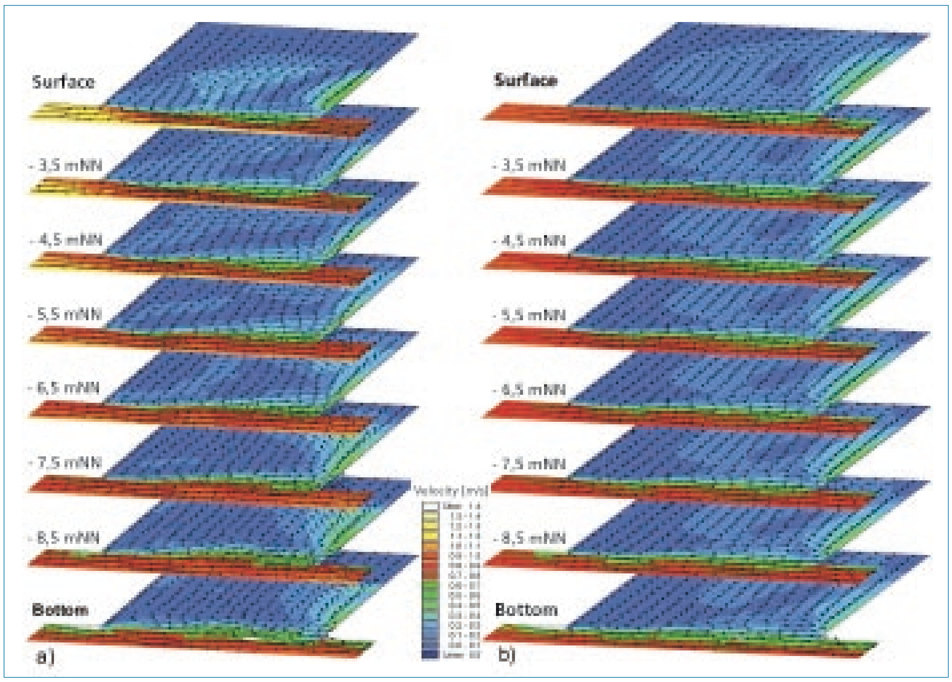

Figure 7. 3-dimensional exchange flows between a nearly rectangular harbour and a river showing differing vectors and directions from surface to bottom due to flood currents a) with density effects and b) without density effects (B_E=B_H; spring tide, mNN= German Reference Level).

(Table III). The second investigated harbour type (B) is a rectangular harbour basin. This basin has a significantly reduced width B_H as well as a significantly reduced harbour surface.In general the angle α of the harbour axis to the river axis differs from 90° due to nautical reasons. In this case the harbour length is L_H=500 m. The harbour width is B_H=120 m. The angle from the basin axis to the river axis α differs from 30° to 150°.

The entrance width is a function of the harbour width and the angle α (Table III). The systematic study shows that, together with the increased suspended sediment concentration in the lower part of the water body, the harbour basin fills with additional water by a factor up to 3.3 for the harbour A and up to 4.6 for the harbour B, compared to the situation without density gradients (Table III). The density effect is getting more important (proportional) due to smaller harbour entrances. The overall amount of exchanged water in a brackish tidal environment will be reduced nearly linearly to the width of the harbour entrance (Table III). The amount of sediment will be reduced significantly (Figure 8).

The effect of the angle between basin and river axis, which for nautical reasons often deviate from 90°, results in increased inflows and intrusions of sediment loaded waters from the river (Table III). Here it has to be noted that in order to keep a constant basin area the entrance width becomes larger for geometrical reasons resulting in higher sedimentation.

A summary of results in basin sedimentation is given in Table III. It shows that salinity driven currents clearly increase sedimentation. Without salinity gradient the inflowing sediment would be driven out of

Table III. Water Exchange and Sedimentation due to systematic simulations of various harbour geometries.

				Water Exchange [m³/Tide]			Sedimentation [m³/Tide]		
Harbour Type	Entrance width [m]	Diversion Angle with River [°]	Harbour Area [m²]	Spring Tide, ΔH=3.94m, with Flow + Tide Effects	Spring Tide, ΔH=3.94 m, with Density Effects	Neap Tide, ΔH=3.55 m, with Density Effects	Spring Tide, ΔH=3.94 m, with Flow + Tide Effects	Spring Tide, ΔH=3.94 m, with Density Effects	Neap Tide, ΔH=3.55 m, with Density Effects
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1	450	90	247.500	4.917.391	10.513.386	8.338.120	-6,74	374,87	46,37
2	350	90	247.500	3.322.590	8.698.277	6.915.276	-7,41	368,13	44,46
A 3	250	90	247.500	2.178.146	6.651.345	5.262.207	-5,00	355,73	43,37
4	150	90	247.500	1.260.375	4.157.517	3.092.442	-2,58	276,22	35,46
5	50	90	247.500	1.060.565	1.679.478	1.339.391	1,42	134,87	12,65
1	240	30	60.000	2.457.937	4.352.531	3.659.360	-6,95	99,71	6,50
2	165	45	60.000	1.390.596	3.263.988	2.540.703	-3,72	100,38	10,67
3	135	60	60.000	1.057.531	2.787.299	2.204.052	-2,38	99,10	11,99
4	120	75	60.000	770.196	2.658.203	2.017.014	-1,89	107,09	12,13
B 5	120	90	60.000	666.495	2.633.147	1.920.268	0,30	123,97	12,23
6	120	105	60.000	581.919	2.700.524	1.927.273	-1,40	131,65	13,53
7	135	120	60.000	852.847	2.825.066	2.031.677	-1,16	134,94	14,00
8	165	135	60.000	1.144.178	3.262.983	2.345.280	-1,65	156,09	14,57
9	240	150	60.000	1.909.930	4.211.583	2.855.396	-4,88	166,15	12,39

Table IV. Mean water exchange and sedimentation between harbour and Weser during 1 Tide for different harbour entrances.

Bremerhaven	Mean water exchange [m³/Tide]	Change [%]	Mean edimentation height [mm/Tide]	Change [%]
Actual	3.751.676		3.04	
40% reduced entrance width	2.860.040	-23.8%	2.91	-4.5%
CDW	3.382.488	-9.8%	2.90	-4.8%
Break line / level difference	3.613.193	-3.7%	2.81	-7.6%
CDW + break line	3.116.604	-16.9%	2.76	-9.1%

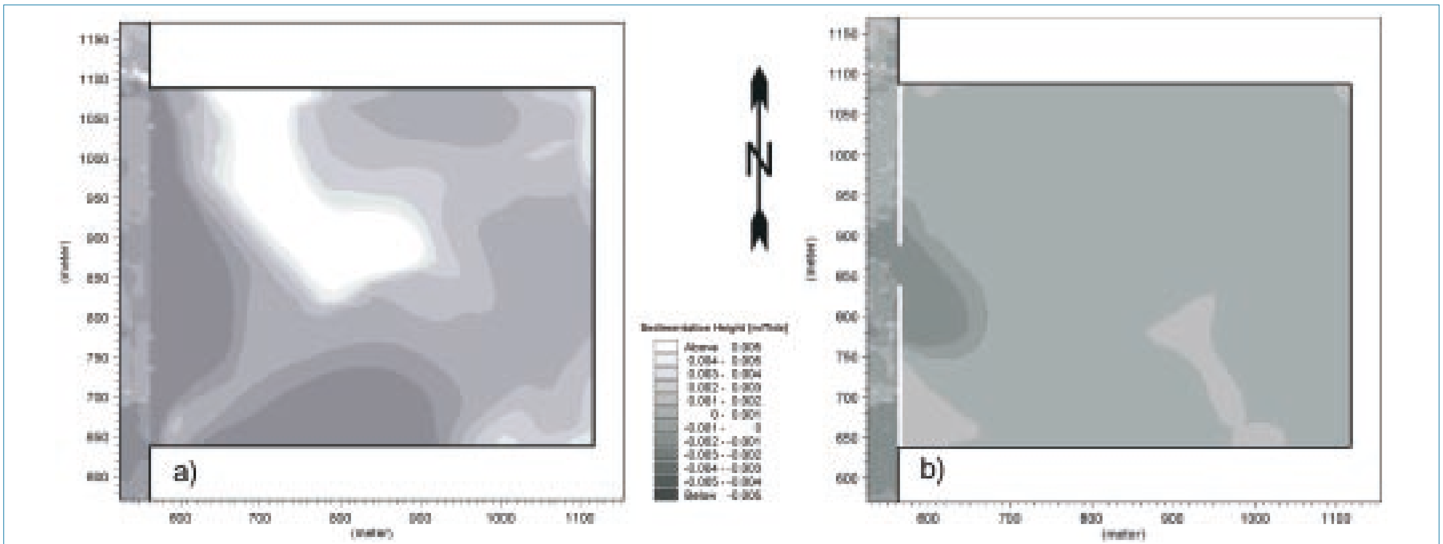

Figure 8. Mean sedimentation height per tide in a nearly rectangular harbour with a) full entrance width (B_E=1,0B_H) and b) reduced entrance width (B_E=0,11B_H)

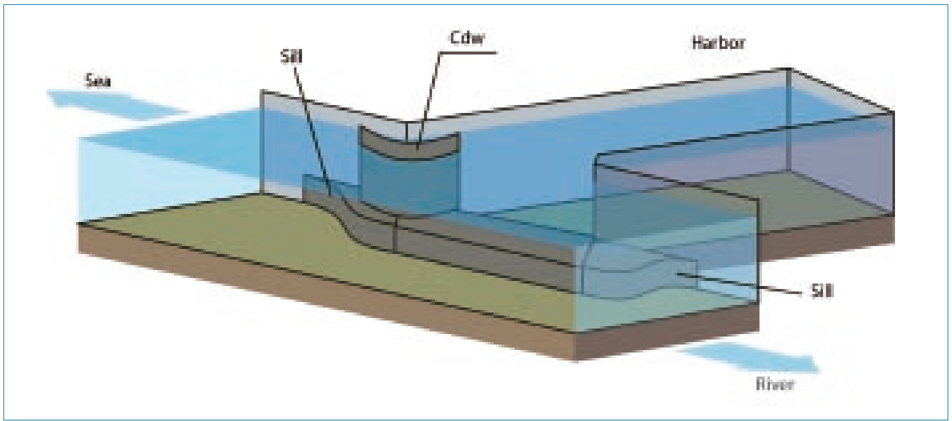

Figure 9. Current Deflecting Wall downstream a tidal harbour entrance combined with a sill.

the basin as indicated by the negative sedimentation in Table III.

CASE STUDY "BREMERHAVEN NORDSCHLEUSE"

For harbour type A from 50% (small entrance) to 90% ($B_E=B_H$) of the water exchange result from density and flow effect. Water exchange in harbour type B is permanently larger than 90% with small variations owing to the angle α. Limitation on the reduction of one of both main effects will not result in optimised harbour geometry.

For the Test Case "Bremerhaven Nordschleuse" the calibrated model will be used to redesign the entrance of the harbour in front of the North Lock (Figure 2). Four different entrance variations were tested:

1 The entrance width was reduces by 40%.
2 A Current Deflection Wall (CDW) was tested to reduce the flow effect (Leeuwen, Hofland, 1999; Figure 9).
3 Density currents were influenced by using a sill / bottom level difference in front of the complete entrance width.
4 The combination of the level difference and a CDW was tested.

The results are shown in Table IV. The water exchange between river and harbour was reduced significantly by reducing the entrance width. The sedimentation height was only notably reduced by a combination of two measures. A relation between water exchange and the mean sedimentation height could not be found.

CONCLUSIONS

Sediment intrusion from tide- and density-driven estuaries into a diverting harbour basin will remain a major factor in operation and maintenance of harbours. For optimisation of orientation of the harbour axis and entrance width an effective method of significantly decreasing harbour sedimentation 3-dimensional simulations have reached a reliable standard for identification of the governing local processes, from flow, tide, density effects on sediment intrusion and deposition. Maintenance dredging, fluidisation measures or structures against sedimentation can be rationally supported.

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BOOKS/PERIODICALS REVIEW

The Rock Manual: The Use of Rock in Hydraulic Engineering
BY CIRIA, CUR, CETMEF

Published by CIRIA. 2007.
ISBN: 0-86017-683-5. 1267 pp. + CD.

When you think of rock, you think of hard rock or solid rock, but in this case also of heavy rock. This manual, counting 1267 pages, feels like a rock and must weigh a few kilos. So if you are travelling you may not want to carry it in your luggage. Luckily, in the front of the hard copy of the book is also a CD with the whole manual in PDF format. However, since the resolution of the pictures in the PDF files is not very high, the CD is suitable as a search tool, but not as a replacement of the book. The electronic version can also be found on the websites of CIRIA (www.ciria.org, click on Bookshop, or www.ciriabook.com) and CETMEF (www.cetmef.equipement.gouv.fr).

Rock is a commonly used construction material in the hydraulic environment. It is used in the marine and fluvial environments to provide protection against scour and erosion and to limit wave overtopping and flooding. Estimates suggest that at least 10 million tonnes of armourstone per year are used in construction across Europe.

In 1991 CIRIA/CUR published the original *Manual on the Use of Rock in Coastal and Shoreline Engineering,* commonly referred to as "The Rock Manual". This was followed in 1995 by the *Manual on the Use of Rock in Hydraulic Engineering* by CUR. This new edition of "The Rock Manual" has been completely revised and updated by a joint UK, French and Dutch team represented by CIRIA, CETMEF and CUR, respectively, and presents current good practice for the design and construction of rock structures for erosion and flood control at coasts and rivers. Where appropriate it presents new or emerging technologies that have not, at the time of the writing, become standard practice, to allow the reader to be fully aware of, and make the best use of, the latest research findings.

The target audience for the manual is wide and includes planners, developers, engineering consultants and designers, architects, building managers, facility managers, contractors, producers and suppliers, owners, staff from regulators, funders and educational institutions. The guidance is suitable for worldwide applications with the stated aim of achieving a long-term improvement in the use of rock and will promote conservation of natural systems in balance with the proper protection of human life and property. Although the editors suggest that the reader should have a degree in Civil Engineering and at least two years of experience, Mechanical Engineers with an affinity to Civil Engineering should be able to understand the manual as well.

The manual is a very good enchiridion and is recommended to all who are involved in the use of rock in hydraulic engineering.
This book is available from www.ciriabooks.com.

S.A. MIEDEMA

FACTS ABOUT
Environmental Impact Assessments
INTERNATIONAL ASSOCIATION OF DREDGING COMPANIES
January 2008. 4 pp. Available free of charge.

Dredging is a complicated matter and nowadays trying to be an expert in everything is impossible. Yet all kinds of stakeholders come into contact with some of the technical aspects of dredging and are confronted with terminology that is not obviously comprehensible. *FACTS ABOUT Environmental Impact Assessments* is the third in an ongoing series of leaflets published by the International Association of Dredging Companies (IADC). The aim of this new series of concise, easy-to-read leaflets is to give an effective overview of essential facts about specific and important dredging and maritime construction subjects. Questions such as "What is the difference between an EIA, an EIS, an EES and an ES?" and "What is the World Bank definition of an EIA?" are answered in a succinct and clear manner. For those needing more in-depth or detailed information, a reference list of other literature is provided.
These publications are part of IADC's on-going effort to support clients and others in understanding the fundamental principles of dredging and maritime construction – because providing effective information to all involved parties is an essential element in achieving a successful dredging project.
All "FACTS ABOUT…" are available in PDF form on the IADC website: www.iadc-dredging.com. Printed copies can be ordered by contacting the IADC Secretariat: info@iadc-dredging.com.

MC

SEMINARS/ CONFERENCES/ EVENTS

CEDA Conference on Dredging and Reclamation
DOHA, QATAR
MAY 5-7 2008

For the first time, CEDA is organizing an international conference in the Middle East. Entitled "Dredging and Sustainability: How Wide is the Gulf", the conference will give a comprehensive overview of the latest developments and innovations of the various technical issues relevant to dredging and land reclamation works. It will run parallel to Ship & Port + Europort Maritime exhibition organised by Ahoy Rotterdam and Al Fajer Dubai, which are taking place in the brand new Qatar International Exhibition Centre. The Ritz-Carlton Hotel has been appointed as the conference hotel.

The conference programme is: May 5, Arrival, opportunity to visit Ship & Port + Europort Maritime and Icebreaker in the evening. May 6, Conference Day 1: all day technical sessions; May 7, Conference Day 2: morning, technical sessions, afternoon, a Site Visit and in the evening a farewell dinner. On May 8 a post-conference desert safari will be organised.

For further information contact:
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Web: www.dredging.org

5th International SedNet Conference
NORWEGIAN GEOTECHNICAL INSTITUTE
OSLO, NORWAY
MAY 27-29, 2008

Two themes will be dealt with in this conference. On days 1 and 2, Urban Sediment Management and Port Redevelopment will focus on areas often historically contaminated as as result of industrial activities, dockyard and harbour operations as well as discharges of municipal wastewater and urban surface water run-off.

On day 3, Sediment in River Basin Management Plans will be dedicated to state-of-the-art sediment management including major EC projects such as AquaTerra, Modelkey, and RISKBASE. Poster sessions will be held during all days. The conference programme will be available in December 2007.

For further information contact:
SedNet Secretariat: www.sednet.org
Email: marjan.euser@tno.nl

ConSoil 2008
STELLA POLARE CONGRESS CENTRE –
FIERA MILANO, MILANO, ITALY
JUNE 3-6, 2008

The 10th ConSoil Conference will continue the programmes of the previous ConSoil series. Besides the traditional focus on contamination of soil and groundwater, will again deal with the functioning of the soil-water systems. With this multi-focus, ConSoil 2008 will follow the EU policy that aims at the sound and integrated management of the soil-water systems in Europe and will thus stay the platform to exchange news and knowledge between scientists, policy makers, consultants/service providers, administrators, site owners/river basin managers, remediation companies/contractors, and banking and insurance companies.

ConSoil 2008 is supported by the Provincia di Milano (IT), German Ministry of Education and Research (BMBF/DE) and the Netherlands Ministry of Housing, Spatial Planning and Environment (VROM/NL).

For further information visit the website:
http://www.consoil.de/

WEDA XXVIII & 39th TAMU Seminar
ST. LOUIS AIRPORT MARRIOTT HOTEL
ST. LOUIS, MISSOURI, USA
JUNE 8-11, 2008

WEDA XVIII & Texas A & M's 39th Annual Dredging Seminar with the theme "WHY WE DREDGE" will focus on dredging throughout the Western Hemisphere, its impact on the ever-expanding global economy and areas of the marine environment. The theme selected will provide a unique forum for all throughout the Western Hemisphere: Dredging contractors, port & harbor authorities, government agencies, environmentalists, consultants, civil & marine engineers, surveyors, ship yards, vendors, and academicians to exchange information and knowledge with their professional counterparts who work in the exciting and challenging fields related to dredging. Discussions on "Why we dredge" and the importance of dredging will be asked and answered.

Also asked and answered will be the effect the inability to dredge would have on the world economy and its environment.

For further information please contact:
Larry Patella, Executive Director
Western Dredging Association
PO Box 5795, Vancouver, WA 98668 USA
Tel: +1 360 750 0209
Email: WEDA @comcast.net

30th International Seminar on Dredging and Reclamation

DELFT, THE NETHERLANDS
JUNE 16-20, 2008

Aimed at (future) decision makers and their advisors in governments, port and harbour authorities, offshore companies and other organisations which are involved with the execution of dredging projects, the International Association of Dredging Companies, in co-operation with UNESCO – IHE, organises the International Seminar on Dredging and Reclamation each year in Delft.

Since 1993 IADC has provided a week-long seminar especially developed for professionals in dredging-related industries. These intensive courses are often organised in co-operation with local technical universities and have been successfully presented in Delft, Singapore, Dubai, Buenos Aires, Bahrain and Mexico. The Seminars reflect IADC's commitment to education, to encouraging young people to enter the field of dredging, and to improving knowledge about dredging throughout the world.

This five-day course strives to provide an understanding through lectures by experts in the field and workshops. Some of the subjects covered are:
- the development of new ports and maintenance of existing ports;
- project phasing (identification, investigation, feasibility studies, design, construction, and maintenance);
- descriptions of types of dredging equipment and boundary conditions for their use;
- state-of-the-art dredging techniques as well as environmentally sound techniques;
- pre-dredging and soil investigations, designing and estimating from the contractor's view;
- costing of projects and types of contracts such as charter, unit rates, lump sum and risk-sharing agreements.

An important feature of the seminars is a trip on a trailing suction hopper or a cutter suction dredger to a nearby dredging project. A visit to a dredging yard is also included.

The cost of the seminar will be € 1,350. This fee includes all tuition, seminar proceedings and workshops and a special participants dinner during the week, but is exclusive of travel costs and accommodation. If needed, IADC can assist with finding accommodation.

For further information please contact:
Mr. Frans-Herman Cammel,
cammel@iadc-dredging.com or
The IADC Secretariat:
Tel: + 31 70 352 3334

International Symposium on Sediment Management

LILLE, FRANCE
JULY 10-12, 2008

Over the ages, river estuaries have given economic prosperity to those who live on their embankments. Much of this prosperity is based on the sediments brought by the rivers, which carry with them contaminants. Even if regulations and a better control of contaminants have been established to reduce their emission, many contaminants are still present in bottom sediments. In fact, some of them are persistent and continue to pose a risk to the environment. Since the contaminated sediment problem is extended throughout the world, this symposium will be international event, reviewing recent advances on sediments management related research and focus on engineering aspects including:
- Management of dredging operation and storage of sediments.
- Treatments and transport of contaminated sediments.
- Ecotoxicological approaches and developments of biotests.
- Analyses and water treatments.
- Beneficial uses of dredged marine and river sediments in civil engineering and in other fields.

CALL FOR PAPERS

All papers and presentations will be in English. Official languages of the symposium are English and French, with simultaneous translations provided during plenary sessions.

For further information contact:
Karine Kominiarz, Ecole des Mines de Douai
International Symposium on Sediment Management
941, rue Charles Bourseul, BP 10 838
F59508 Douai cedex, France
Tel: +33 3 27 71 30 05, Fax: +33 3 2771 29 16
Email: abriak@ensm-douai.fr

CEDA Dredging Days 2008
CONFERENCE CENTRE 'T ELZENVELD
ANTWERP, BELGIUM
OCTOBER 1-3, 2008

With the title "Dredging Facing Sustainability" CEDA Belgium intends to raise a wider awareness of the stakeholders to the efforts of the dredging world – contractors, shipyards and consultants – to sustainable development. Topics include: How to tackle sea level rise – dredging for coastal flood protection; Dredging as a key player in the energy discussion; Creating estuarine wetlands – vital ecosystems for sustainable development; Dredging in sensitive areas – balancing between socio-economic development and nature conservation – improving technology to achieve "no impact"; Efforts to reduce emissions in the dredging industry; sustainability concerning decision process.

For further information contact:
Technologisch Instituut, Att: Rita Peys
Desguinlei 214
BE 2018 Antwerpen, Belgium
Tel: +32 3 260 0861, Fax: +32 3 216 0689
Email: rita.peys@ti.kviv.be
www.dredgingdays.org/2008

Hydro8 Symposium
BRITANNIA ADELPHI HOTEL
LIVERPOOL, UK
NOVEMBER 4-6, 2008

The Hydrographic Society UK, on behalf of the International Federation of Hydrographic Societies, is to stage the 16th International Hydrographic Symposium, Hydro8, in Europe's 2008 Capital of Culture, Liverpool. To be held at the City's historic Britannia Adelphi Hotel, the three-day event will feature a main conference and an exhibition of equipment and services in addition to a series of workshops, equipment demonstrations, mid-afternoon technical visits and a social programme highlighted by a special Symposium Dinner in Liverpool's celebrated Georgian Town Hall.

Conference proceedings will cover a wide range of contemporary survey and environmental-related issues under the theme, New Opportunities. Scheduled topics include Deep Water Terminal Challenges, Sediment Hydraulics/Dynamics for Dredging, ENCs, Tidal Predictions, the EU Water Framework Directive & Its Hydrographic Implications, Wind Farm Development, and Latest Acoustic & Multibeam System Developments and Applications.

Abstracts of not more than 300 words on any of these topics and related technical issues are required by no later than 31 March.

Hydro8, which is expected to attract a worldwide delegate audience and over 50 major exhibitor companies and organisations,

For further information about abstract submission and further general details contact:
www.hydro8.org.uk

MEMBERSHIP LIST IADC 2008

Through their regional branches or through representatives, members of IADC operate directly at all locations worldwide

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Dredging and Reclamation Jan De Nul Ltd., Lagos, Nigeria
Dredging International Services Nigeria Ltd., Ikoyi Lagos, Nigeria
Nigerian Westminster Dredging and Marine Ltd., Lagos, Nigeria
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Terra et Aqua is published quarterly by the IADC, The International Association of Dredging Companies. The journal is available on request to individuals or organisations with a professional interest in dredging and maritime infrastructure projects including the development of ports and waterways, coastal protection, land reclamation, offshore works, environmental remediation and habitat restoration. The name *Terra et Aqua* is a registered trademark.

ISSN 0376-6411

Typesetting and printing by Opmeer Drukkerij bv, The Hague, The Netherlands.

International Association of Dredging Companies