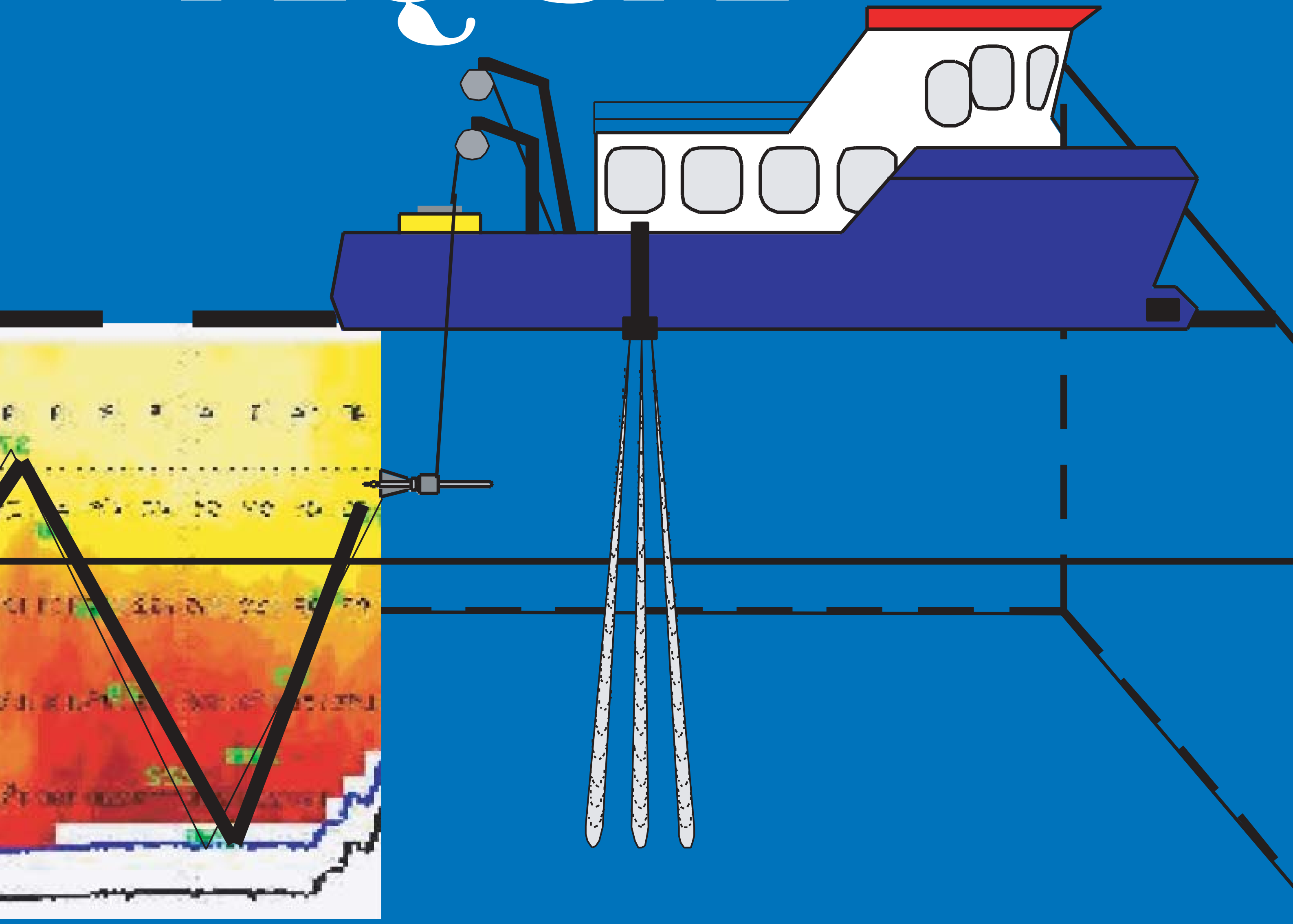
International Journal on
Public Works, Ports &
Waterways Developments
Number 84 • September 2001

TERRA ET AQUA

International Association
of Dredging Companies



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 the development of ports and waterways, and in particular, the associated dredging work.
The name *Terra et Aqua* is a registered trademark.

Please address inquiries to the editor.
Articles in *Terra et Aqua* do not necessarily reflect the opinion of the IADC Board or of individual members.

ISSN 0376-6411

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

Front cover:
Monitoring methods used in Zeebrugge, Belgium: Diagram of a vessel with a hull-mounted Acoustic Doppler Profiler and a towfish equipped with OBS sensors which measure the current speed and direction below the hull (see page 8).

IADC
P.J.A. Hamburger, *Secretary General*
Duinweg 21
2585 JV The Hague, The Netherlands
Tel. 31 (70) 352 3334, Fax 31 (70) 351 2654
E-mail: info@iadc-dredging.com
http://www.iadc-dredging.com

International Association of Dredging Companies

Contents

TERRA ET AQUA

Editorial

As the autumn approaches, conferences and seminars are gearing up again. Top of the list is the IADC International Seminar on Dredging and Reclamation Works (see page 32). This seminar has been successfully presented for many years in Delft in cooperation with the International Institute of Hydraulic Engineering (IHE), in Buenos Aires, and in Singapore in cooperation with the National University of Singapore (NUS). Attendance at the Singapore seminar is always excellent and this year is no exception. So if you are interested in participating send in your form as soon as possible as space is filling up rapidly.

Speaking of conferences, you can meet an IADC representative at both Singaport (5-7 September) in Singapore and Europort (13-17 November) in Amsterdam.

Another activity of the IADC in trying to attract young professionals to dredging is the IADC Annual Award to a person younger than 35 who has presented an excellent dredging-related paper at a designated conference. The technical paper of this year's winner, Jasmin Ambrose, describing a project in Lumut, Malaysia can be found on page 17.

As we mentioned last time, the *FIDIC Form of Contract for Dredging and Reclamation Works* is now available in a "test" version (see page 27) and can now be ordered from the IADC for a nominal fee. This is your chance to let your opinion be heard — order it and try it out. With adjustments based on feedback from users, the final version should be ready next year.

And lastly, thanks go to Mr Louis van Gasteren for his excellent presentation in Japan, of which a synopsis is published here. Most of us had little knowledge of the interaction between East and West during the later part of the 19th century, in which the mutual interest in marine infrastructure had such historical significance — a time of daring and farsightedness. But, of course, dredgers are accustomed to planning for the future, be it for deeper harbours for the next generation of cargo ships, or for offshore platforms for the oil and gas industries, or for more efficient means of land reclamation. This innovative spirit is clearly evident in the continuing investments in R&D made by today's dredging industry.

Robert van Gelder
President, IADC Board of Directors

Louis A. van Gasteren

East Meets West: Lake Biwa Canal, Kyoto, Japan

Abstract

In the late 19th century the Japanese Emperor Meiji led Japan into the modern age. Realising the importance of Japanese participation in world trade, he despatched diplomatic missions, as well as students, to Europe and the United States to discover new techniques in transport, infrastructure, agriculture, water management, and harbour building. In addition he invited Westerners with technological expertise to Japan. This article relates how Western engineering skills met Japanese intellectual curiosity, resulting in the development of important waterworks and infrastructure in Japan, including the Lake Biwa Canal in Kyoto.

The article has been adapted from a lecture that was presented at the Annual Meeting of the International Association Dredging Companies, on 16 May 2001 in Kyoto, Japan.

Robert van Gelder, President of the Board of the IADC (left) with Louis van Gasteren in Kyoto, Japan at the statue of Japanese Engineer Tanabe Sakuro. Mr van Gasteren is a film-maker and founder of the Artec Foundation, an organisation dedicated to bringing artists and scientists closer together. He is also one of the founders of the Foundation "Four Centuries Dutch-Japanese Relations", which through a film and a publication celebrates the role of Dutch engineers in Japan during the Meiji period.
He has recently been awarded the "Zilveren Anjer" (Silver Carnation), the highest award of honor from the Prince Bernhard Cultural Foundation.

Introduction

Surrounded by mountains, Kyoto was the Imperial residence and capital of Japan from 784 until 1868. The emperor, however, played a merely formal and ritual role. The power was really vested in the *shogun* in Yedo, today's Tokyo.

In 1868 all this changed. In that year the 16-year-old crown prince Mutsuhito was invested as Emperor Meiji and he understood that Japan was destined to play a much more international role. Meiji means "enlightenment and peace" and the Emperor Meiji was full of these ambitions. Together with some Western-oriented ministers, Meiji was about to transform Japan from a feudal, medieval society into a modern state, modelled on a Western blueprint.

Meiji's justifiable fear was that his country would otherwise become a colony in the hands of the Western powers. He knew that the guns of the US naval vessels in the harbour of Yokohama were loaded and had been

Figure 1. Men at one of the tunnels of the irrigation canal, leading from the lake of Inawashiro to the dry Asaka plain, near Koriyama. The successful digging of this canal with its many tunnels proved to be an example for the Lake Biwa Canal. Courtesy of the Municipality of Koryama.

ready for serious action ever since Commodore Perry had arrived in 1853. The Westerners wanted to have access to Japan for commercial reasons and so, willing or not, Japan had to participate in the world economy.

Ministers and civil servants were recruited from the former knightly classes. By government decree, the class of the *Samurai* was abolished in 1871. And an official edict issued in 1876 banned the wearing of swords. Japanese officials were forced to adopt Western dress — including the bowler hat. Missions were despatched abroad by the same government to discover the outside world, to learn and to adopt what was most suitable for Japanese needs. The most famous one was the *Iwakura Mission*, which, following a tour of the United States, visited almost every country in Europe. In addition, Japanese students were sent abroad, and Western experts were invited to teach in Japan. In retrospect, these trips — gathering information from 1860 until 1873 — can be considered as uniquely historical. The country had chosen between life and death.

The choice for life expressed itself in the official slogan: *National Prosperity, Military Strength*. The seat of government was transferred from Kyoto to Yedo, later to be called Tokyo, or eastern capital, home base of the *shogun* (who resigned shortly afterwards). The information obtained must have been overwhelming for Japan's new rulers, since it was an inventory of what the country needed to be able to play a role amongst the dominant Western powers.

A Wide Range of New Technologies

Western experts instructed the Japanese in new techniques in transport, infrastructure, agriculture, water management, harbour building and the development of the armed forces. They also introduced the steam engine, gas and electricity. New forms of energy replaced the traditional Japanese water and wood economy.

The Englishman Brunton installed lighthouses along the coast. Americans gave lessons on the exploitation of mines and started large-scale agricultural projects in Hokkaido. Railroads were constructed by the British, streetcars were presented by the Belgians, the French built shipyards, the Germans established a medical department at Tokyo university, and the Dutch started water management at a scientific level.

With 3000 rivers and rain 10 times heavier than in Holland, Belgium, France or the UK, with shallow harbours, unsuitable for the steamships, and with rivers, unfit for transport, it was a difficult assignment.

Data show that the number of foreign employees reached as many as 2300 by 1889. The breakdown of the professional disciplines shows that the number of civil engineering-related employees was 146. Amongst them the 108 British engineers were the largest group. Most of them were employed in the railway and surveying sections. For rivers, harbours and agricultural water management, the Dutch were most active, since they were specialists in this field.

In 1872 a nationwide system of elementary schools was established. In the same year, the first railway — between Tokyo and Yokohama — was opened by the Emperor. Ordinary people could witness modernisation happening before their own eyes. In February of that year, the Dutch engineer Van Doorn was invited to come to Japan, together with the engineer Lindo as his assistant.

The Japan Peil

Van Doorn as Chief Engineer received a salary of 500 yen, equivalent to that of a Japanese minister. He is best known for the design of the Nobiru Harbour near Sendai and the survey of the plans for an irrigation canal, leading from the lake of Inawashiro to the dry Asaka plain, near Koriyama. The successful digging of this canal with its many tunnels proved to be an example for that of the Lake Biwa Canal (Figure 1).

Second Engineer Lindo, with a salary of 400 yen, surveyed the three rivers in the Kanto plain near Tokyo — the Tone, Yedo and Ara. Since there were no standards for water level measurement, the engineers were faced with difficulties in regard to design and planning of their projects. It was Lindo who started surveying by setting up scales in the rivers and fixed points at the river mouths. In this way he was able to establish an *ordnance datum*, the first in Japan, in 1872, at Choshi, located at the mouth of the Tone River in the Pacific Ocean. He called it the *Japan Peil* or JP. The Dutch word *Peil* means water level.

In addition, he put a water level scale in Horie, located at the mouth of the Yedo River and established its height relationship with the Japan Peil. On June 10, 1873, he set up a water level scale at the mouth of the Ara River and this became the basis of the later established Tokyo Peil (TP), now the Japan Standard, 24.4140 metre above the zero level of Lindo. The Tokyo Peil was approved by the Emperor in 1891 and can still be found opposite the Imperial Palace in Tokyo.

The metric system

Lindo executed his measurements using the metric system. Over centuries, Japanese surveyors had modified the Chinese measuring system. However, it did not dispose of very large or very small units and these became important with the introduction of the new technologies. The decimal system provided the right answer and the metre and the cubic metre entered the scene.

The British and Americans, however, involved with commercial interests, had brought the Anglo-Saxon system to Japan. The government now had to make a choice and it decided to adopt the metric one. Debates in the Japanese senate took weeks, and were broadly reported in newspapers at the end of the 19th century.

Measuring depth correctly was important as the harbours opened up to Westerners and were modernised. For instance, Captain Kuhe of the hopper dredger *Ayame* was taking no risks and, as was reported in the English-language newspaper, *The Japan Weekly Mail* on October 25th 1890, “six runs being taken with and against tide” before he was willing to deliver his high-quality product.

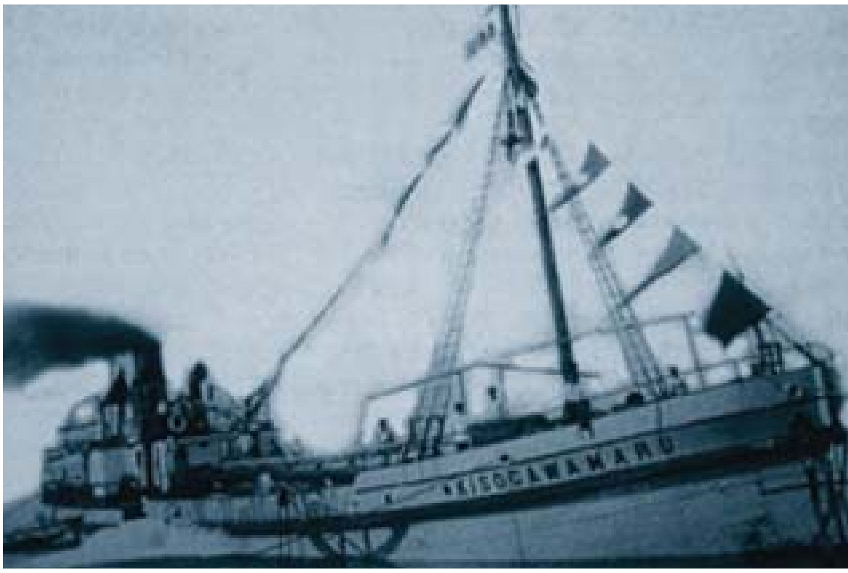
Earlier in 1887, the Dutch waterman Johannis de Rijke, who worked in Japan for 30 years, ordered the suction dredger *Kisogawa Maru* for his Kiso river works near Nagoya. The dredger was built in the Netherlands by Smit, Kinderdijk (Figure 2).

Japan's River Civilisation

All this leads to the paddy fields, food supply, and Japan's river civilisation. In addition to technical innovations, the Meiji Government had to insure a stable food supply. Whoever dominates food, dominates the population. Food, in fact is dependency and therefore power. So, in Japan, water supply determines the social and political balance. Cheap rice imports are still a political issue. The slogan at a recent symposium in Osaka was “Water management is the basic system that sustains civilisation”.

This was equally true in the late 19th century when Western European hydraulic engineers came to Japan and deepened and constructed harbours. Though they worked in an unpretentious way on the riverbanks, they had an enormous impact. During the presence of the *oyatoi gaikokujin*, hired foreign employees, the Japanese government established the Imperial University in Tokyo, and the British set up an Engineering College in the same city. It was Brunton again who emphasised the importance of practical training for students. No theory, but direct action. It was he who championed the brick stone as an answer to the many fires by which the wooden houses and other construc-

Figure 2. The suction dredger Kisogawa Maru*, built in the Netherlands for Johannis de Rijke. Courtesy of J.D. Smit, Kinderdijk.*



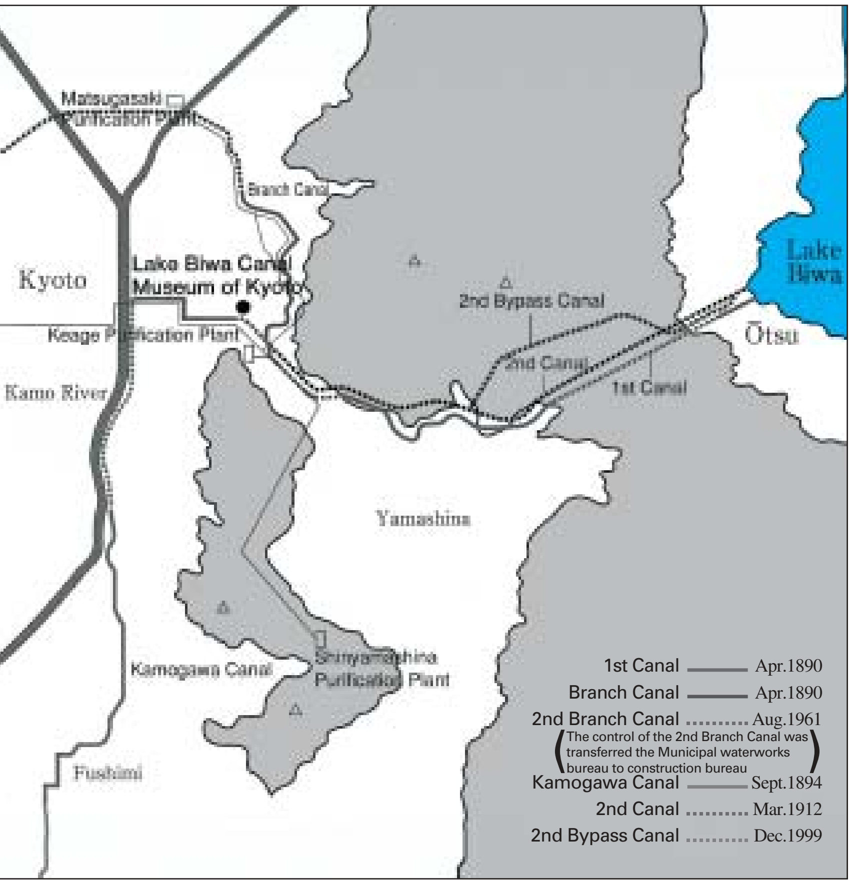


Figure 3. Map of the Lake Biwa Canal. Lake Biwa is situated 7 miles east of Kyoto and its water surface is 140 feet above Kyoto's ground level.

tions as well were so easily destroyed. Earthquakes also became a basic issue in the discussion of his preference.

Graduates of the Imperial College of Engineering and those who returned from Western institutes ousted the foreign employees and caused their dismissal from Japan. Amongst them was Okino Tadao, who on the basis of a design by Engineer De Rijke, finished the building of the harbour of Osaka. Another student, first levy of the Engineering College, was Tanabe Sakuro (1861-1944) who was responsible for the digging of the Biwa Canal.

The Biwa Canal had already been planned in the 12th century but the population had always been against it because they feared that Lake Biwa would run dry. They were anxious about modernisation, they feared the disappearance of their salmon and were scared to death when they learnt about accidents with steam-ships. But the time had come.

The Lake Biwa Canal

The Biwa Lake is situated 7 miles east of Kyoto and its water surface is 140 feet above Kyoto's ground level (Figure 3). After the Emperor's move from Kyoto to Tokyo, Kyoto fell into decline. The government decided to stop this process and became convinced that a canal between Biwa and Kyoto could provide transportation and waterpower to modernise the city's textile industry. The canal could also solve irrigation problems and supply drinking water.

An energetic person, Kitagaki Kunio, was appointed governor of Kyoto and he strongly promoted the construction of the canal. The Japanese chief engineer of Van Doorn, who had made the design for the Asaka Canal, was asked to make a study of the site. Johannis de Rijke also reviewed the site in February 1884 and they both declared the canal feasible, although the latter had his doubts regarding the financing and recouping of costs.

The Emperor agreed and not only verbally. The total estimates for the works amounted to a million and a quarter silver dollars. Of this about one third was a gift from the Emperor, and a quarter from the Central Government, whilst the remainder was to be raised by local taxation.

Tanabe Sakuro

At this point the young architect Tanabe Sakuro enters the picture. In 1883, years before these considerations, he had written his thesis at the Imperial Engineering College on the Biwa Canal. In 1889, Professor T. Alexander published in the journal *Engineering* a laudatio on this genius.

Tanabe was indeed a genius, a man of mathematical talent. He took his degree in 1883 after six years of study. The college had printed — in pamphlet form — an original work of Tanabe's *On shearing stress due to travelling load systems*. Whilst just about to complete the practical part of his study, he lost the use of his right hand. He soon learned to write both Japanese and English with his left hand, and actually drew his diploma designs with it. They comprised a scheme for improving the navigation of a Japanese river by a canal cut, for he had already turned his attention in particular to hydraulic engineering. These designs were exhibited at the world exhibition in America.

Tanabe gained the confidence of the governor of Kyoto (and even married the governor's daughter). In August 1885 he started building and digging. One of the problems in the design proved to be the sharp drop in the canal as it emerged 118 feet above the eastern part of Kyoto. The Dutch recommended that locks should not be used, but rather that an inclined plain with rails be installed to carry the canal boats up and down.
This suggestion and the existing textile mills in Holyoke and Lowell, Massachusetts, run by waterpower, brought Tanabe to the United States. Although he had not proposed generating electricity by waterpower to the

Kyoto government, the idea was already in his mind. During his U.S. trip he became convinced about the addition of that function.

Tanabe consulted two engineers in the US — Clemens Herschel and James Francis. Following their advice and after having visited the first hydroelectric plant in Aspen, Colorado, he ordered two turbines: 120 horse-power Pelton wheels from the manufacturer in Oakland.

Three tunnels

The canal itself is a mixture of traditional and modern architecture. There are three tunnels, one of them 2.4 kilometres, the largest ever built at the time. Tanabe wrote in articles in US and British engineering journals about "cheap labour" and how the stonemasons and miners had to be trained to accustom them to modern excavation techniques, for instance the Adachi brothers, who were foremen during the canalisation work of the Asaka canal from the Inawashiro Lake. Tanabe used a telephone line, dynamite, and imported steam pumps from England, and combined all of these together with ancient Japanese foot-tread-water-wheels when these could not keep up with flooding.

Frequent cave-ins added greatly to the difficulties in the work. At one point, near the Biwa entrance, 65 men were trapped by a cave-in for 48 hours. Women sorted and carried the bricks for the tunnels, as there were no mules and even no tow-path.

The canal was planned for small, wooden canal boats, polled from the back by a single man. Rice would be the cargo on the easy way downstream pull to Lake Biwa. As a boat emerged from the third and last tunnel, it was attached to a cradle with steel wheels, which carried it down the 576-metre incline at an angle of 1:15 in less than 15 minutes. Meanwhile, at the other track another boat was being carried up, since the process was operated by a continuous steel rope moving around drums, one at the top, the other in a pool at the bottom. The drums were turned by a 50-horsepower motor, which got its electric power by two generators belted to the Pelton wheels. These turbines, driven by the force of the canal water, were the first hydroelectric power utilised for a public purpose.

Right behind the last tunnel the canal splits into two canals. One goes via the incline to Kyoto, the Yodo river and Osaka, the other via a beautiful aqueduct, goes north and east for irrigation purposes. Its power brought streetlight and streetcars to Kyoto and electricity to the mills. It was so successful that a second hydroelectric power plant was built in 1912.

When after 5 years in April 1890 the canal was finished, the governor of Kyoto proclaimed three whole days of celebration. On 1st of April a religious ceremony took place, followed on April 8 by a feast for 1200 guests. On April 9 the Imperial family and the government attended the opening of the canal.

Conclusion

The three tunnels express the intermix of technology, art and politics in the Meiji era. They all bear an inscription on the entrances and exits, made by members of the Meiji Government.

Minister Ito Hirobumi wrote: *Ten thousands kinds of weather* — which probably means that the canal can withstand the onslaughts of nature.
Yamagata Aritomo left a poem: *This structure has its own integrity.*
Inoue quoted Confucius: *Pious men enjoy the mountains, scholars the waters.*
Saigo warns the people: *One reaches the fountainhead only after climbing the mountain.*
Minister Matskata is optimistic: *After the rain passes, see the colour of the pines.*
And Sanjo Sanetomi is exultant: *How beautiful are the mountains and rivers.*

Tanabe is said to have written, *An elegant sight, an extraordinary idea*. And it is certain that it was he who financed and made the stone monument at the top of the incline honouring the 17 workers who died building the canal: *For every victim that fell, a million benefitted.*

References

Finn, Dallas.
Meiji Revisited: the Sites of Victorian Japan, Weatherhill Inc., New York, 1995.

The Japan Weekly Mail, "Constructive Art in Japan", by R.H. Brunton, 23 January 1875.
The Japan Weekly Mail, "Public Works", 18 Sept. 1875.
The Japan Weekly Mail, "The Biwa Canal", 5 May, 1888.
The Japan Weekly Mail, "Notes", 13 April, 1889.
The Japan Weekly Mail, "Lake Biwa Canal", 10 May, 1890.
The Japan Weekly Mail, "Steam Hopper Dredger for the Harbour Works", 25 Oct. 1890.

The Japan Times, "Lake Biwa and Water Power", 20 May, 1899.

Supplement to the Japan Gazette, 7th October 1876.

Van Gasteren, L.A. et al. (editors).
In een Japanse Stroomversnelling (In Japanese Rapids), Walburg Pers, Zutphen, 2000.

Stijn Claeys, Guido Dumon, Jean Lanckneus and Koen Trouw

Mobile Turbidity Measurement as a Tool for Determining Future Volumes of Dredged Material in Access Channels to Estuarine Ports

Abstract

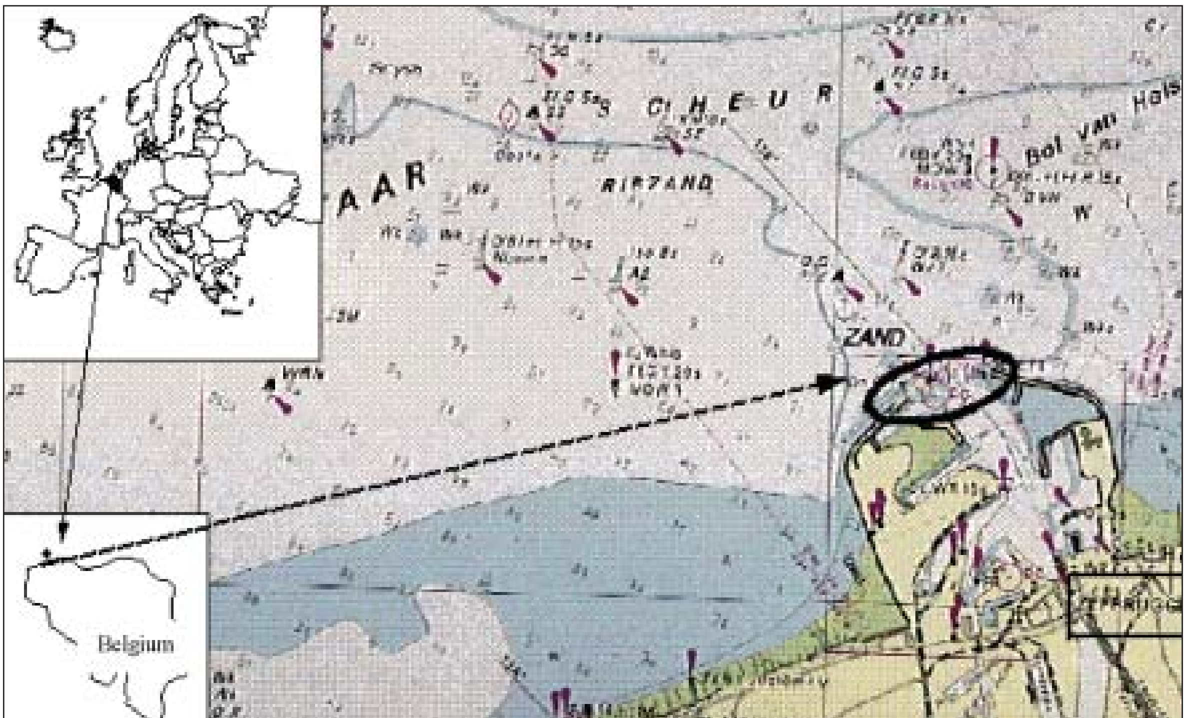
Monitoring the environmental impact of dredging and relocation operations and estimating the turbidity (sediment flux) is becoming increasingly more important. Predicting the natural relocation of dredged material can lead to a better planning of the dredging activities. Of equal importance is the monitoring of the background turbidity in order to assess the relative importance of the turbidity plume created by dredging activities.

Monitoring the sediment flux, caused by the action of tidal currents, waves and wind, with the help of mobile measurements at the entrance of the harbour of Zeebrugge is part of the research project "The ecological monitoring of dredging works in the Belgian coastal harbors", (MOBAG 2000) of the Ministry of the Flemish Community (Waterways and Maritime Affairs Administration, Environment and Infrastructure Department, Coastal Waterways, Oostende, Belgium).

On-line mobile monitoring was performed using an Acoustic Doppler Profiler (model NDP, mounted at the hull of the vessel). The NDP was calibrated with backscatter turbidity sensors (mounted on a computer-controlled towfish). Turbidity and current data were visualised and used to estimate the sediment flux.

During the project 13 hours of measurements took place during neap and spring tides. Data through the water column were collected along a track crossing the entrance of the Outer Harbour of Zeebrugge. The data were corrected off-line for errors. Finally, the sediment flux was calculated from the corrected current and turbidity profiles.

Figure 1. Location of the sediment flux monitoring at the Outer Harbour of Zeebrugge, Belgium.



The recorded profiles made it possible to visualise flow rate and sediment flux. The profiles showed a very complex pattern of in- and outflow of current and suspension material. The amount of sediment that remains in the harbour after completion of a tidal cycle is quite different for a neap and a spring tide. Measurements showed that after a tidal cycle during neap and spring tides, respectively 795 tonnes and 3200 tonnes of sediment remained in the harbour. The obtained results proved as well that the turbidity caused by dredging activities (in the harbour), is merely a short-time local phenomenon and for the most part does not exceed background turbidity.

Introduction

The sediment flux, entering the harbours, is subject to very complex tidal and meteorological influences. The sediment behaviour cannot be completely understood when sensors are used that only provide information from single points. On-line mobile monitoring of the turbidity, current speed and current direction over practically the entire water column makes it possible to visualise the complexity of the sediment flux.

A mobile survey campaign was successfully executed at the Outer Harbour of Zeebrugge during neap and spring tides.

This kind of monitoring campaign is very useful for predicting the amount of sediments coming into the harbours. Therefore dredging campaigns can be better planned.

Description of the Monitoring Campaign

Location and period
Two campaigns, one at spring tide and one at neap tide, were carried out during which measurements took place for an entire tidal cycle.

Profiles were measured along a track located across the axis of the access channel near the entrance of the harbour (Figures 1 and 2). The position of the vessel (determined by DGPS) in relation to the theoretical track was visualised on-line with the help of two navigation computers (location and period: Figures 1 and 2, Table I).

Because of the strong current coming into the harbour, all measurements were performed in the same direction (from southwest to northeast) to prevent the towfish from being dragged under the vessel by the current.

Monitoring method
After evaluation of available current information,

Stijn Claeys received his degree in Mining and Minerals from the University of Ghent, Belgium in 1995. During the last three years he has worked as project engineer at the environmental-technical DEC NV. For the last two years he was also project leader for the environmental survey projects in the hydrographic department of DEC where he developed an acoustic-optical (online) method for determining turbidity in the entire water column.

Stijn Claeys

Guido Dumon received a degree as a Civil Engineer in Chemistry and Engineer in the Environmental Sanitation from the University of Ghent, Belgium. He is presently Senior Engineer at the Coastal Waterways Division of the Ministry of the Flemish Community, Head of the Department of Hydrometeorology and the Environment.

Guido Dumon

Dr Jean Lanckneus received his Doctor of Sciences in Mining and Minerals from the University of Ghent, Belgium in 1987. For 13 years he worked for the Dept of Physical Geography. In 1996 he founded a consultancy company Magelas BVBA, which specialises in survey work and in the practical scientific analysis of sediment fluxes and morphological evolution patterns of the seabed.

Jean Lanckneus

Koen Trouw received his degree as a Civil Engineer at the KU Leuven, Belgium in 1994 and will defend his doctoral work on sand transport as a result of irregular waves at the end of 2001. In 1999 he became project engineer at International Marine and Dredging Consultants (IMDC), where he is involved in morphological modelling of estuaries and coastal seas and the preparation and interpretation of measuring campaigns.

Koen Trouw

Table I. Date of the monitoring campaign, amount of sailed profiles. Information concerning the time of the measurements.

	Date	Hour	1°Low tide	2°Low tide	# Profiles transverse	# Profiles lengthwise
Spring tide	19/04/'00	6u34-20u05	07u10	19u23	21	4
Neap tide	28/04/'00	1u15-16u45	01u40	15u30	36	2

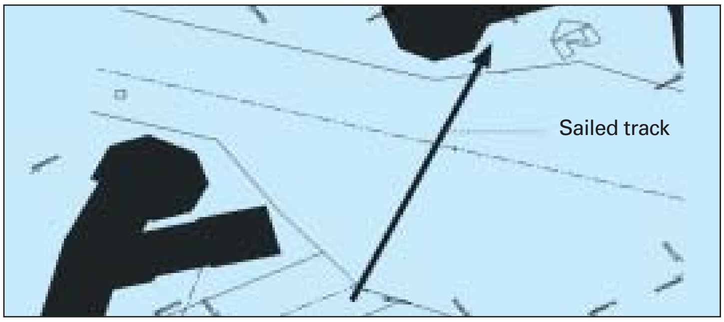


Figure 2. Theoretical track across the entrance of the harbour of Zeebrugge.

Figure 3. Picture of towfish (Navitracker equipped with OBS sensors).

Figure 4. The Acoustic Doppler Profiler, mounted on the hull of the vessel.

two theoretical tracks were defined and visualised on the navigation computer. All instruments were time-stamped with the KART DGPS-time.

Measurements were carried out with the help of a towfish (Figure 3) and a hull-mounted Acoustic Doppler Profiler (type NDP) (Figure 4). The following parameters were recorded:
- by the NDP: intensity, current speed, current direction over practically the entire water column;
- by the towfish equipped with OBS-3 and OBS-5-sensors: turbidity, pressure, position.

To provide on-line data during the survey, the optical backscatter sensors were calibrated with sludge taken from the survey area (harbour). Because the optical backscatter sensors are sensitive to the colour of the sediments the sensors (OBS) were calibrated using oxidised (lighter coloured) sludge. The registered data gave us an idea about the order of magnitude of the turbidity. The "fine-tuning" of the data was done by using the analysed suspended solids-concentration of the water samples. This combination provides an accurate calibration of the optical backscatter sensor.

The vessel mounted Acoustic Doppler Current Profiler measures the current speed and direction below the hull (Figure 5). This is performed by measuring the scattered acoustic signal reflected by particulate matter in the water column together with the Doppler effect. The system determines the vessel's velocity with the ship's navigation system, removes this velocity from the measurements and obtains the current velocity relative to the earth. By combining acoustic and optical information, this instrument can also provide information about the quantity of the particulate matter. This information is obtained from the intensity of the received reflection, also referred to as the backscattering strength or signal amplitude.

Different instruments from different manufacturers are available on the market. The equipment used during the survey was the "VM-NDP" (1.5 MHz) produced by Nortek AS. The NDP was interfaced with a high resolution kinematic DGPS. A vertical resolution of 0.5 m bin (maximum vertical resolution) and a horizontal resolution of 1 profile/ 2 sec were chosen. This configuration can be adapted according to the situation and the

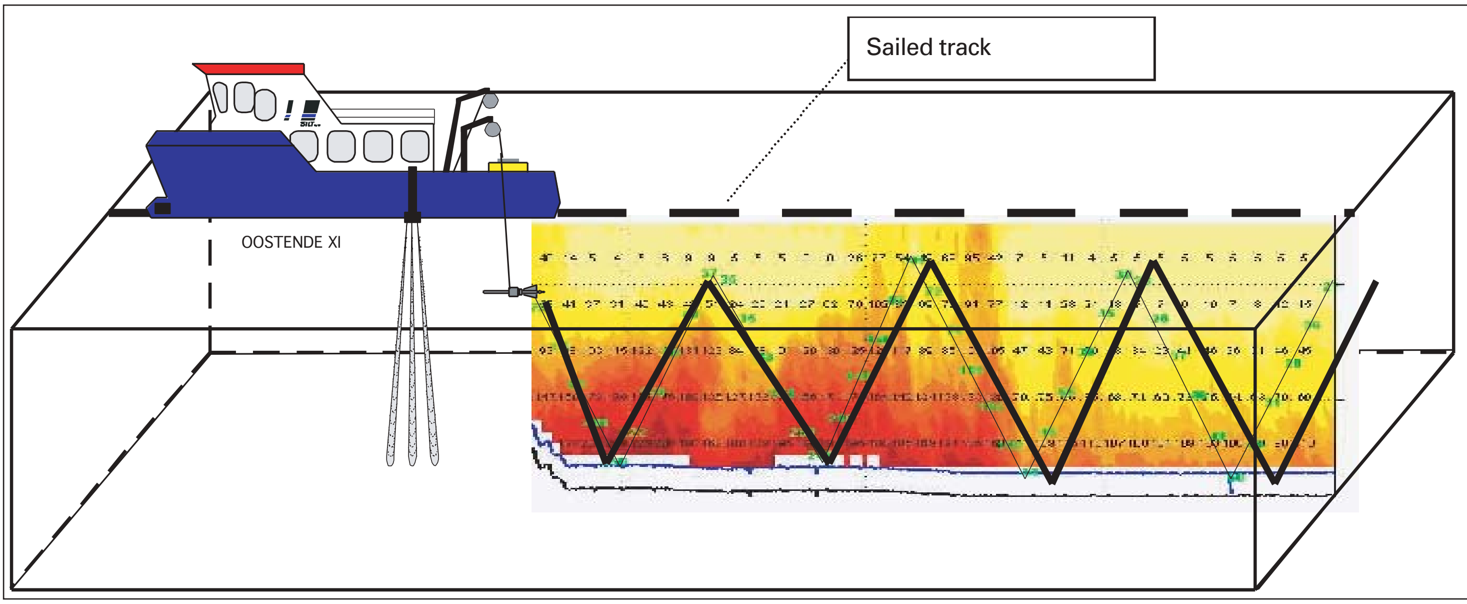


Figure 5. Monitoring method using a hull-mounted Acoustic Doppler Profiler and a towfish equipped with OBS sensors.

desires of the client. The speed of the vessel varied between 1 and 2 knots.

The towfish with OBS sensors, driven by a computer operated winch, automatically undulates in the water column between 2.4 m under the water surface and 1.5 m above the bed.

During the conversion of the acoustical backscatter signal into turbidity, a large number of parameters have to be taken into account. Most of these parameters are known:
- frequency of the acoustical waves;
- angle of the acoustical waves;
- speed of sound: salinity (conductivity, pressure, temperature);
- distance to the bin; and
- concentration (OBS), grain-size.

Collecting and visualising turbidity information, using the in-house developed software package "Sedidec", provides a turbidity profile. This visualisation can be done on-line and semi- on-line (after each sealed track). Also different tracks can be visualised on the same 3D figure. However it is still necessary to control the data for errors (spikes).

Using a hull-mounted NDP has following limitations:
- no information (caused by reflection from the bottom) for the last 3 bins starting from the bottom (= 3 x 0.5= 1.5 m);
- no information for the first cell from the sensor (NDP) = blanking distance;
- acoustical waves are sensitive for air-bubbles (caused by the propeller of passing vessels).

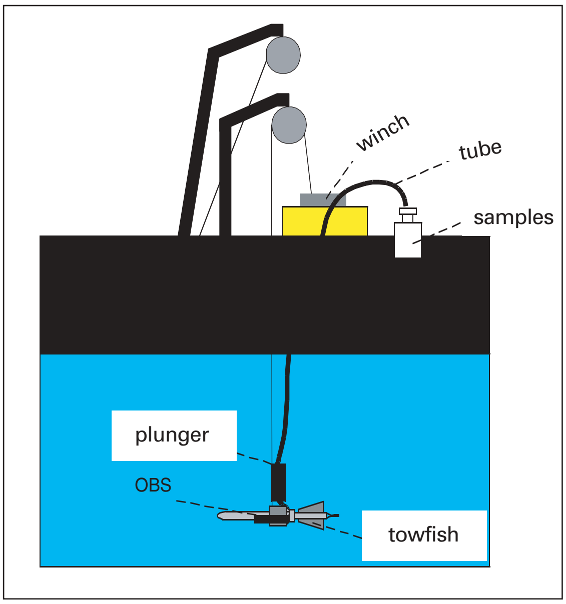


Figure 6. Taking water samples with a plunger.

Data Processing

Correction of the calculated turbidities by in situ sampling

The calculated turbidities were re-calculated using suspended solid data from the samples taken on board. A plunger, mounted on the towfish nearby the OBS-sensor, took these samples (Figure 6). A very good relation between the measured turbidity (OBS) and the analysed samples was found.

Using NDP data for calculating turbidity values is a relatively new technique in which careful calibration of the system is of great importance. DEC believes that

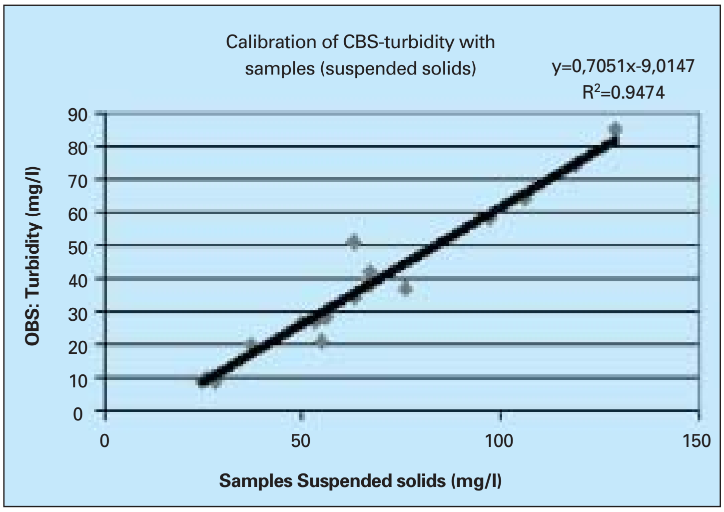


Figure 7. Calibration of OBS turbidity with samples (suspended solids), $y = 0.7.51x — 9.0147$, $r^2 = 0.9474$.

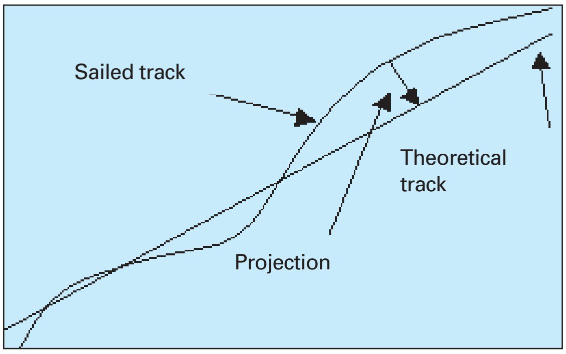


Figure 8. Projection of the sailed track on a theoretical track.

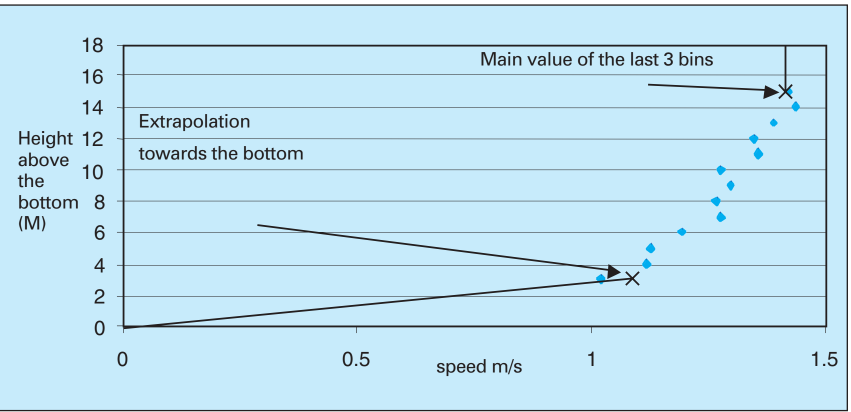


Figure 9. Extrapolation of the speed towards the bottom and the water surface.

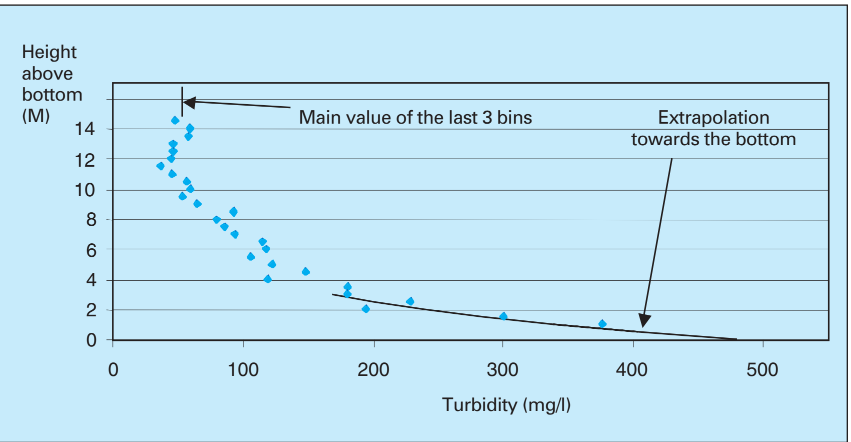


Figure 10. Extrapolation of the turbidity towards the bottom and the water surface.

this technique has a great potential and has put a lot of effort in the assessment of its reliability. The equation, provided by the manufacturer of NDP, was used as a starting point. Its effectiveness was confirmed by DEC after performing a large number of tests. DEC found however that the reliability could greatly be improved by a continuous calibration with an OBS. This additional and continuous calibration could furthermore lead to a simplification of the equation.

DEC performed a large number of measurements in which the value of turbidity deduced from the NDP was compared with the turbidity value measured by OBS. A correlation (r^2) between the turbidity values obtained with the two methods gave in all cases high values varying between 0.60 and 0.93.

At the same time the turbidity measured by the OBS was controlled by measuring the suspended solids in water samples. Correlation coefficients for these turbidity values were also very high and varied typically between 0.90 and 0.95. The correlation coefficients calculated for the measuring campaign described in the paper were 0.75 for the correlation between NDP and OBS and 0.95 for the correlation between OBS and samples (Figure 7).

Current speed and direction deduced from NDP are in agreement with the data obtained from previous measuring campaigns.

Sediment flux

General

A theoretical track was determined by averaging the sailed tracks. This track has the following coordinates: 513270 E and 5689800 N (UTM) and a direction of 54.7 ° N.

The sailed tracks differ very little from this theoretical track. Each bin of the current-profile (also recorded with the NDP) is characterised by a current (speed and direction) vector. To measure the incoming and outgoing sediment flux each current vector had to be projected perpendicularly on the theoretical track (Figure 8). This allows the transformation of the current vector to a vector that is going in or out of the profile.

Currents
As mentioned above, the reflection from the seabed and the blanking distance near the water surface lead to a hiatus in the profile.

The hiatus nearby the seabed was filled by extrapolation assuming that the current speed on the bottom (210 KC) had a value of zero. The hiatus nearby the surface was filled with the mean value of the last three vertical cells (Figure 9).

Turbidity
The turbidity hiatus nearby the seabed was filled up by extrapolation of the turbidity values (of the lowest measured bin) towards the seabed. This extrapolation does not take the sediment-transport over (density flow) the seabed into consideration. This transport can be very important concerning the total sediment flux of the harbour.

The hiatus nearby the surface was filled with the mean value of the last three vertical cells (Figure 10).

The errors caused by air bubbles (propellers of passing vessels) were replaced by a mean value of the surrounding cells. The errors were detected by taking into account the difference between the calculated turbidity and the turbidity measured by the OBS.
The measured turbidity was considered as correct.

Flow and sediment flux
Multiplying the area of a bin (= 12.5 m^2) with its current speed value provides us with the flow rate. Multiplying the flow rate of a bin with its turbidity value gives the sediment flux.

The sediment transport of each profile was multiplied with a time period corresponding to half the period between the preceding and following profile. The total net transport is the sum of all these products during one tidal cycle. The variation in time of the sediment flux and flow rate is visualised in a graph in which every point represents the total sediment or flow passing trough the entrance of the harbour over a period corre-sponding to half the period between the preceding and following profile.

Discussion

Turbidity profiles
The maximum turbidity measured during spring tide is 2.200 mg/l and during neap tide is 900 mg/l. The mean lowest turbidity measured varied between 30 and 50 mg/l. As it is not possible to understand the sediment

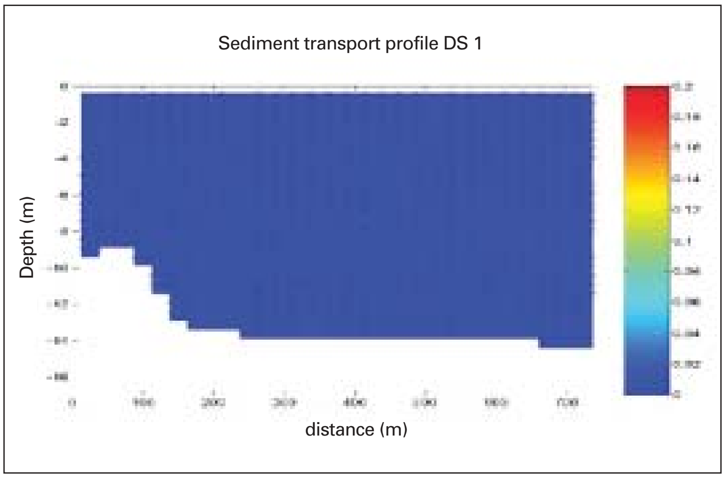


Figure 11. Sediment transport (kg/m^3/s); neap tide cycle; low tide; profile DS 1.

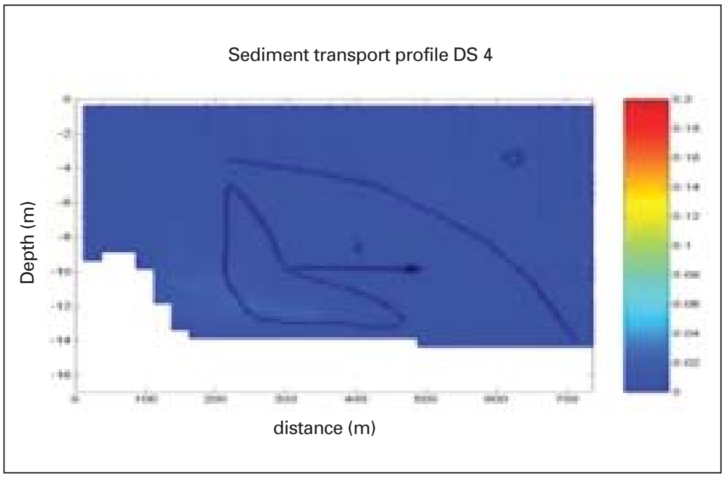


Figure 12. Sediment transport (kg/m^3/s); neap tide cycle; two hours after low tide; profile DS 4.

behavior from only the turbidity profiles, it is necessary to take into account as well the prevailing current direction and speed.

Sediment flux
The pattern of the sediment flux during spring tide differs little from the one during neap tide, but large differences in magnitude are however found. During low tide a homogeneous sediment flux output takes place as it is visualised in the profile of Figure 11.

One to two hours later, a sediment flux input consisting of a core appears in the western part of the profile (Figure 12) after which it is shifts from west to east over the bottom.
One hour before high tide, the sediment flux profile is divided into an input (east) and an output (west) part; at this time the flux core is expanding itself vertically in the eastern part (Figure 13).

The core of this sediment flux input moves from the eastern part to the western part. On high tide, a core of sediment input is surrounded by sediment output

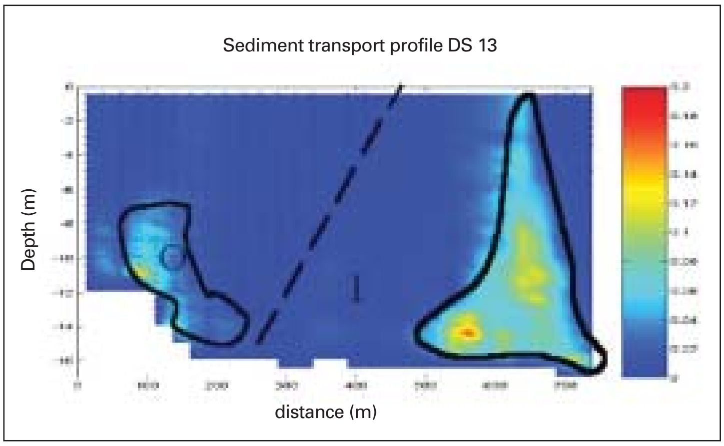


Figure 13. Sediment transport (kg/m^3/s); neap tide cycle; one hour before high tide; profile DS 13.

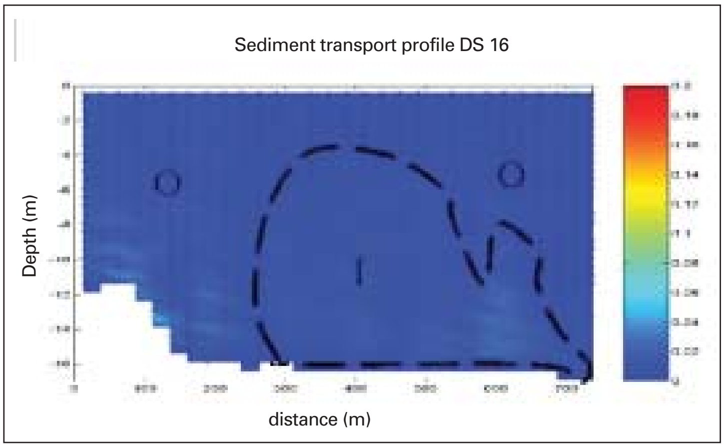


Figure 14. Sediment transport (kg/m^3/s); neap tide cycle; high tide; profile DS 16.

(Figure 14). The input still moves from east to west where it disappears. At low tide the pattern repeats itself.

Quantification of the profiles during a spring tide

The monitoring campaign of a tidal cycle during spring tide started at 9h10 (6 hours before high tide) and ended at 21h23 (6 h25 after high tide). Interpolation between the flow profiles gives us the following results: 46 10^6 m^3 water flowed into the harbour and 44 10^6 m^3 flowed out of the harbour.

The current pattern is very complex during this period. An evaluation of the total sediment flux (not taking the bottom transport into consideration) during one tide cycle gives us an estimation of the amount of incoming and outgoing sediment: Sediment input, about 9200 tonne and sediment output, about 6000 tonne.

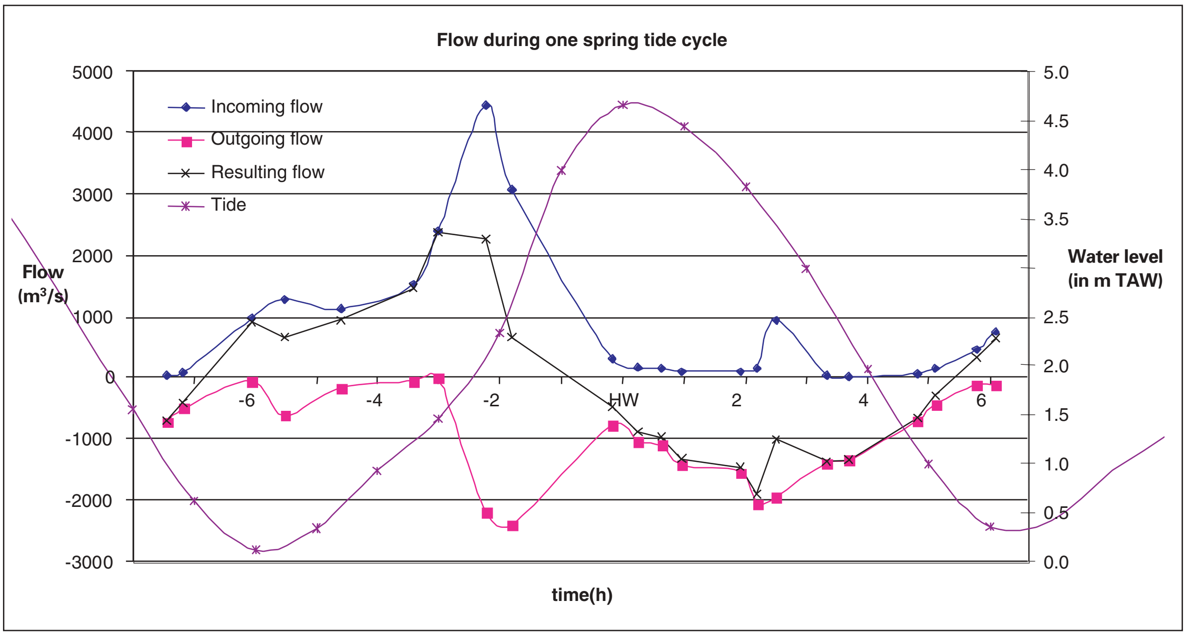
Using these data, it was assumed that a total of 3200 tonne of sediment remained in the harbour. The highest sediment input and the highest flow rate took both place 2 hours before high tide (Figures 15 and 16).

Quantification of the profiles during a neap tide

The monitoring campaign of a tidal cycle during neap tide started at 2h38 (5h30 hours before high tide) and ended at 15h15 (7 h00 after high tide). Interpolation between the flow profiles gives the following results: during these period 33.3 10^6 m^3 water flowed into the harbour and 32.8 10^6 m^3 flowed out. The current pattern is as well very complex during this period.

An evaluation of the total sediment flux (not taking the bottom transport into consideration) during one tide cycle gives us an estimation of the amount of incoming and outgoing sediment: A total sediment input of about

Figure 15. Incoming, outgoing and resulting sediment flux during one spring tide cycle.



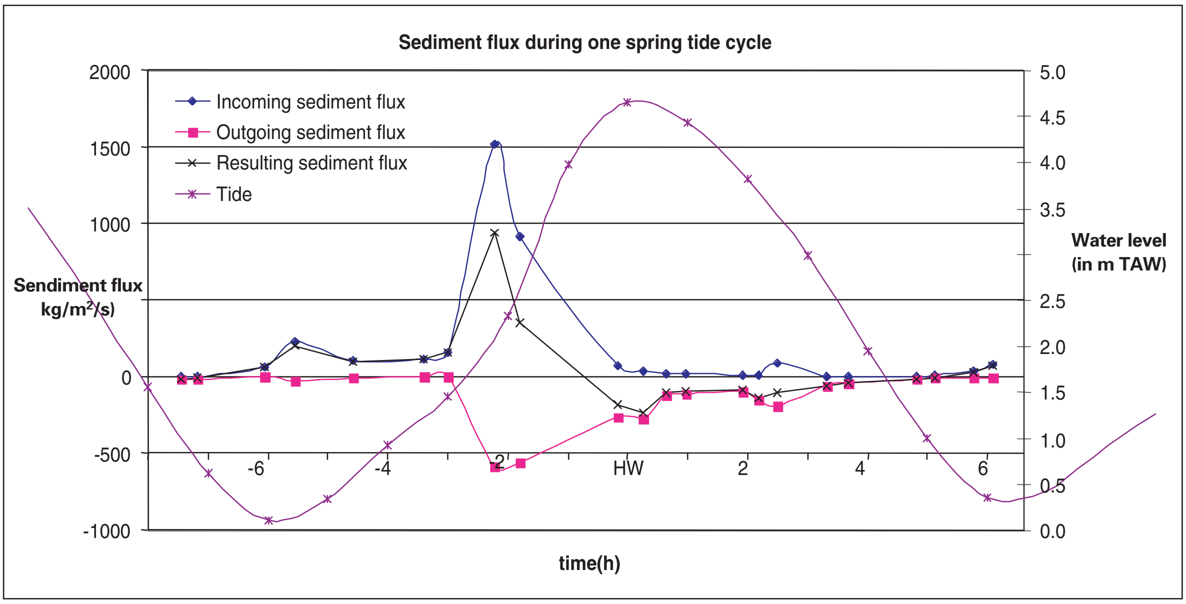


Figure 16. Incoming, outgoing and resulting flow during one spring tide cycle.

2050 tonne and a sediment output of about 1260 tonne took place in one neap tide cycle.

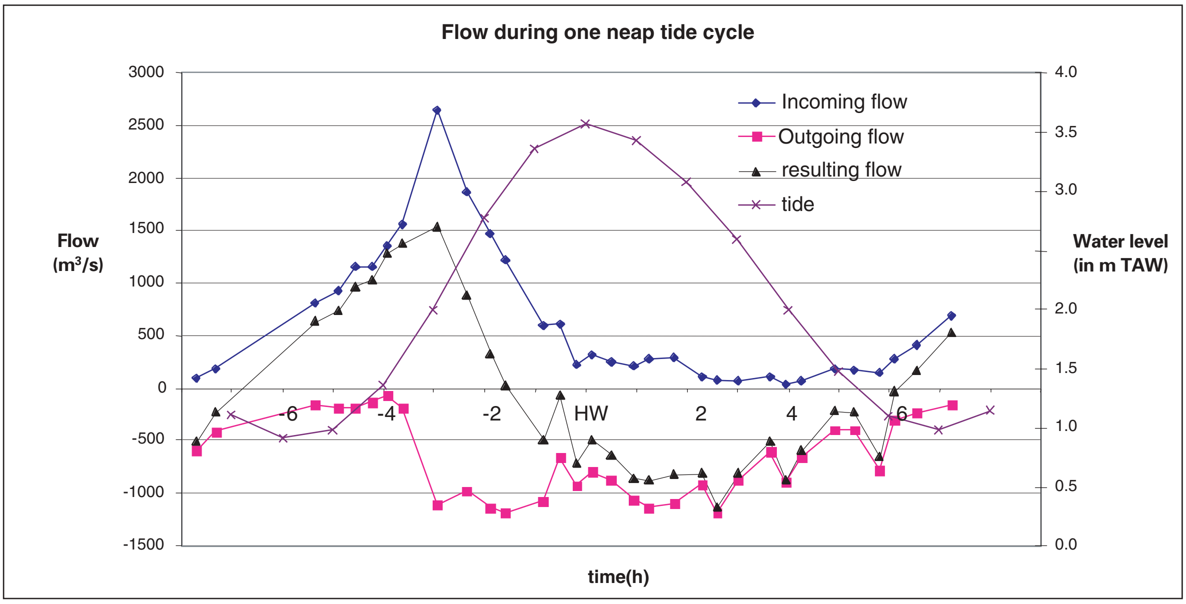
Using these data, it was assumed that a total of 795 tonne of sediment remained in the harbour. The highest sediment input took place 3 hours before high tide (Figures 17 and 18).

Discussion

The 13 hours measurements across the harbour entrance were performed once during a neap tide period and once during a spring tide period. Although the exercise was not repeated, which undoubtedly would have increased the reliability of the results, the authors are confident in the correctness of the produced results. Bonds of reliability were not added to the results, as it is extremely difficult to assess the degree of correctness of, for example, the necessary extrapolations (Figures 9 and 10) applied to the calculations.

However the results of the calculations of the resulting sediment flux coincide well with results of completely different methods. The sedimentation rate in the Central Part of the Outer Harbour was as well assessed by using a gamma-ray backscatter probe. Sedimentation rates were calculated based on measurements carried out nearly every month and this from 1996.

Figure 17. Incoming, outgoing and resulting flow during one neap tide cycle.



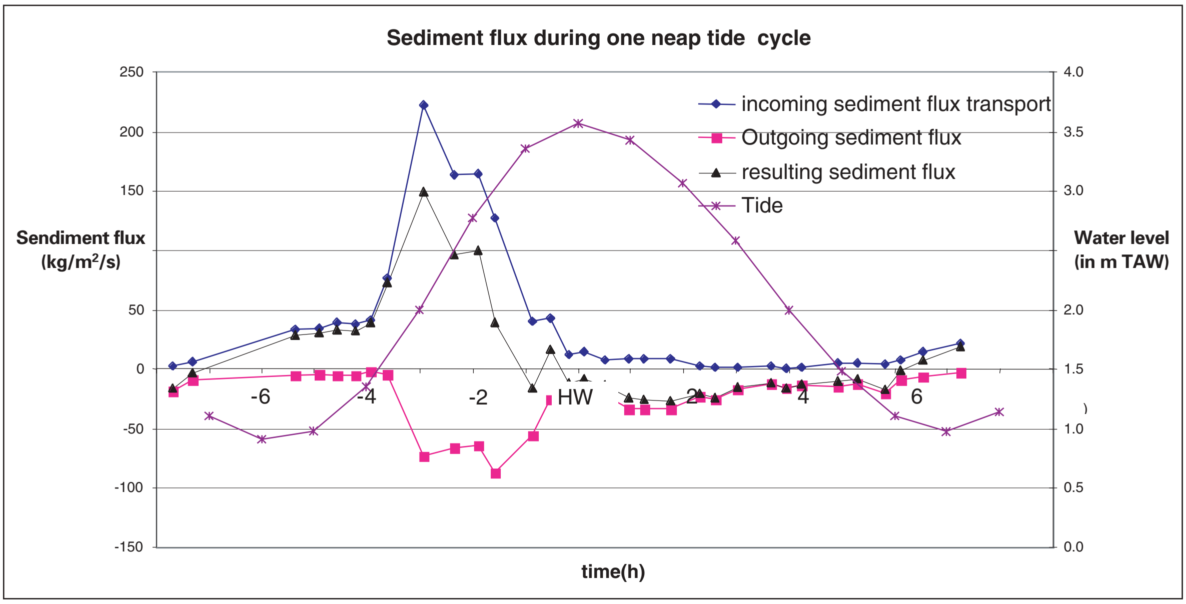


Figure 18. Incoming, outgoing and resulting sediment flux during one neap tide cycle.

The rates give an indication of the net inflow of suspended sediment over a period of ± 30 days. From these calculations it can be derived that during a mean tidal cycle a net sediment inflow of 3500 to 8000 Tonnes Dry Material takes place. These quantities are of the same magnitude as the 3500 tonnes calculated with the NDP for a tidal cycle during spring.

Conclusions

The entrance of the harbour of Zeebrugge is subject to strong variations in current speed and direction caused by the tidal action. During neap and spring tide a similar current pattern occurs, but large differences in the incoming and outgoing flow exist. Incoming and outgoing flows could be measured for one tidal cycle in spring and in neap tide.

A difference of 25% between the (average of the incoming and outgoing flow) flow between neap (33.0 10^6 m^3) and spring tide (45.0 10^6 m^3) is responsible for a large difference in sediment input. Using the data of this survey, calculation gives an evaluation of the net sediment input of 3200 tonne during a tidal cycle at spring tide and a net input of 795 tonne during a tidal cycle at neap tide (four times as much).

This monitoring campaign made it possible to calculate the sediment input during one tide cycle. Important is to know that the monitoring campaigns were performed in good weather conditions. Stationary monitoring, using similar equipment, demonstrated that wind speed and direction have a very big influence on the sediment behaviour. Therefore a monitoring campaign during stormy weather conditions would certainly provide interesting results.

Important to know is that the above-mentioned quantities are the results of a calculation of the measured data for the *suspended solids only*. The extrapolation towards the bottom has not been tested for reality. Combining detailed measurement (with a bottom mounted device) in the 2 m from the bottom will give a better idea of the bottom transport. The “density-flow” over the bottom can be of great important to the total estimation of sediment input in the harbour. Also the calculated data cannot be generalised for each tide cycle, therefore a repetition of this survey is needed.

This survey gives a more detailed image of the complex structure of the sediment flux in the water profile at the entrance of the harbour of Zeebrugge. Knowledge on the sediment fluxes will, together with sounding data of the harbour, allow a better understanding of the sediment behaviour which will result in a better planning of the dredging activities.

Jasmin Ambrose

Displacement Filling at Lumut, Sg. Dinding, Malaysia

Abstract

This case study is on a design and build turnkey project using a displacement filling method whereby the design methodology and construction technique of displacement filling in Lumut will be discussed to highlight the steps undertaken to ensure the effectiveness of this method and its overall economic advantages.
A new method of extracting geotechnical parameters called Iternative Technique (IT) used to obtain critical parameters for slope stability analysis will be introduced. Some aspects and observations of rock bund construction on soft soil will also be explained. Apart from that, measures taken as part of the environmental management plan due to the usage of the displacement filling method will also be elaborated.

The author wishes to acknowledge the support of M.N. Rajah, Managing Director of Asbil Engineering & Construction, with this study. This paper first appeared in the WODCON XVI Proceedings and is reprinted with permission.

Introduction

This paper overviews a case study on the reclamation in Sg. Dinging Lumut, Malaysia. The reclaimed land will be developed for shipbuilding operations and the general location of the project site is as shown in Figure 1.
The reclamation area that is located at the river mouth of Sg. Dinding is protected by Pangkor Island and located 170 km Northwest of Port Klang and 125 km Southeast of Penang Island. The approximate coordinate of Lumut, based on State Cassini Coordinate is W 23700, N 65100.

A reclamation technique that has long been used as the basis for reclamation on soft soil called the displacement filling as described by Terzaghi *et al.* (1995) and the mechanism involved in relation to reclamation using a Trailing Hopper Suction Dredger will be elaborated. Design techniques in terms of displacement filling considering possible heaved soft soil will also be highlighted.

Jasmin Ambrose (right) receiving the 2001 IADC Award from Mr Peter Hamburger, IADC Secretary General.

IADC Award 2001

Presented during the 16th World Dredging Congress,
Kuala Lumpur, Malaysia
April 2-5 2001

At the Sixteenth World Dredging Congress entitled “Dredging for Prosperity; Achieving Social and Economic Benefits”, Jasmin Ambrose was presented with the annual IADC Award for young authors. Mr Ambrose is presently a Senior Design Engineer at Asbil Engineering & Construction in Klang Selangor, West Malaysia.
Each year at a selected conference, the International Association of Dredging Companies grants an award to a paper written by an author younger than 35 years of age. The Paper Committee of the conference is asked to recommend a prize-winner whose paper makes a significant contribution to the literature on dredging and related fields. The purpose of the award is “to stimulate the promotion of new ideas and encourage younger men and women in the dredging industry”. The IADC Award consists of US$ 1000, a certificate of recognition and publication in *Terra et Aqua.*

Figure 1. General location of reclamation area in Sg. Dinding in Malaysia.

The general plan called for dredging of the softest of the clay, and dumping sand to build up the embankment. It was also necessary that side slopes be trimmed to optimise the overall fill volume. Using this method it would be difficult to predict the stability of the embankment owing to the endless uncertainties involved with the initial method of reclamation. Overall the decision to design the embankment for the construction stage using displacement filling and a safety factor (SF) near one was made based on economic considerations. Calculated risk taken by the engineers weighed costs of failure repairs against the cost of conservative design. This decision made in the early planning stage, contributed more than any other to the economic completion of the job.

Basic Concept of Displacement Filling

Displacement filling has always been understood in simple terms as removal of soft bearing material owing to heavier fill material. To elaborate further on this observable fact, the heavier fill material causes high stresses on the soft soil, therefore a general shear bearing capacity failure occurs in the soft soil and this causes displacement of the soft soil and penetration of the fill material into the soft soil. As shown in Figure 2, the active earth pressure of the fill material which is $K_a*\gamma*H$ (K_a + active earth pressure coefficient, γ = Bulk unit weight of fill material and H is the height of fill). The passive lateral resistance pressure of the soft soil that is fluid in behaviour will be $\gamma*H$.

Therefore the soft soil will be displaced laterally as long as the active pressure of the fill is larger than the soft soils passive pressure.

Both bearing capacity failure of soft soil and larger lateral pressure of fill should be satisfied to have an effective displacement of soft soil. Apart from this simplified description to determine lateral pressure of soil, there are various other computational methods that can yield better results using standard empirical formulae. However, detailed analyses are difficult as the properties of the soft soil changes throughout the process of reclamation (displacement filling).

Preliminary consideration for selection of displacement filling

Reclamation on soft soil may be unable to sustain the weight of a fill more that a metre or so in height. Basic bearing capacity formula such as $5.14*c_u$ may be used to determine the quality of fill material required for displacement. However owing to non-homogenous characteristics of soft soil beneath (increase in soil strength with depth), it was assumed that only the top most layer that is very soft (slime) will be effectively displaced. This assumption was adopted because there is no previously documented experiment on displacement filling that can be used to confirm the effectiveness of this method.

Considering the above circumstances the engineer may choose between two alternatives which is to either displace the soft soil or to apply the fill at a certain rate that the soft soil does not fail but gains sufficient strength by consolidation to support the fill at its final height with acceptable settlement. Weighing the soil conditions, soft soil thickness, availability of fill material, construction period and feasibility, it was decided that the displacement method is the most suitable method for this project. Some advantages and disadvantages of displacement filling are shown in Table I.

In Lumut, usage of geotextile reinforcement was initially suggested. However stability analysis conducted showed that its application was not effective to stabilise the embankment and the construction period would be longer. It is also normal practice that reinforcing geotextile (woven geotextile) are used with a factor of safety as high as 3. This would cause the overall construction cost to increase tremendously. Apart from that settlement of soft soil beneath fill will cause unaccounted strain on reinforcing geotextile that causes rapid loss in strength of geotextile reinforcement which defeats the whole purpose of installing a geotextile reinforcement. Soil improvement using vertical drains which was planned for installation once fill is above high water level will cause propagating tensile failure on the reinforcing geotextile and a similar problem was addressed by Koerner (1995) whereby an increase in SF was recommended owing to the reduction in geotextile's strength.

Table I. Advantages and disadvantages of displacement filling.

Advantages	Disadvantages
a) Overall cost effective.	a) Larger fill volume due to direct discharge technique adopted.
b) Reduced settlement at location of displaced soft soil.	b) Removal of heaved slime causes cost and possible to slide if removed.
c) Shorter construction period since there is no need for controlled filling.	c) Possibility of excessive sliding due to reduction of soft soils shear strength to residual shear strength.
d) Does not need geotextile reinforcement during embankment construction.	d) Entrapment of clay layer that leads to invalid assumption of the final embankment gometry causing inaccuracies in stability analysis.
e) Cost saving on soil improvement since soft soil thickness is reduced.	e) Increased settlement at locations where soft soils are trapped.

Soil Parameters for Embankment Stability Analysis

To perform embankment stability analyses it is crucial that sufficient soil data are available. A method developed using IT will be utilised to obtain all parameters required to perform stability analysis. Using this unique IT, soil parameters such as γ and ϕ can be rationally determined for stability analyses.

The (IT) is a theoretical approach to utilise N-values and its correlation to derive soil parameters (Ab. Malik and Ambrose, 1999). Although the standard penetration test is an inexact method, it can be used advantageously for the study of soil properties and in most instances (depending on the scale of the project) N-values may even be sufficient for final design (Bazaraa, 1982).
The IT using N-values allows the engineer who conducts the analyses to control the input and output information of the analyses in a systematic and organised fashion. IT is useful especially for soil properties prediction using N-values whereby important soil parameters have not been obtained in the soil investigation due to some unknown reason.

N-values and IT

The Standard Penetration Test (SPT), developed around 1927 (Bowles, 1988), is currently still one of the most popular and economical means to obtain subsurface information of soil (Moh, 1985). It has been used in correlation to determine unit weight, γ, relative density, D_r, angle of internal friction, ϕ', and the undrained compressive strength, q_u (Carter, 1983). It has also been used for estimating the stress strain modulus of soil, E, and the bearing capacity of foundations.

Iterations known previously in geotechnical engineering application for approximate determination of total stress values (Yu and Houlsby, 1991), while Christuolas (1985) have suggested N–ϕ, D_r–ϕ and N–D_r correlations for the determination of pile capacity in sand.

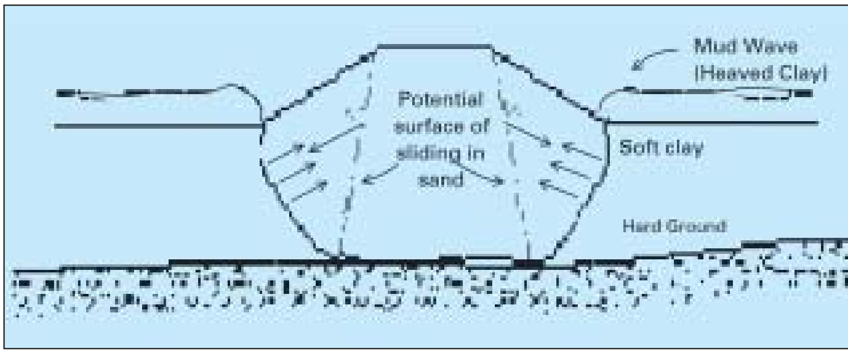


Figure 2. Forces that act on soil adjacent to buried part of a fill constructed by the displacement method (after Terzaghi et al. 1995).

However, this correlation does not relate N with overburden stress and unit weight of soil.

Iterative Technique is an approach that is used based on the assumption that the correlation used to relate N-values and the soil properties (ϕ', c_u, D_r, γ) are valid. A description of this technique will be presented here, covering the iteration process, and the suggested correlations. The IT process is presented in a stepwise manner to achieve better understanding of this method. For embankment stability ealuation N-values are used to derive ϕ', c_u and γ in soft soil and these parameters are the basic soil properties required for embankment stability analysis.

Stepwise procedures for IT

STAGE 1. N-Value is firstly corrected for the water table and to account for fine or silty sand below water (Coyle & Costello, 1981; Heydinger, 1984), as given in Eqn. 1. This correction factor is for the common form of error in performing the standard penetration test in sand or silt below ground water table (Bazaraa, 1982).
Water table correction on N-Values is just an example of one correction factor that can be applied on N-Values

for discrepancies occurring due to, e.g., differences in equipments' manufacturers, uncertainties in geotechnical parameters and drive hammer configuration. However corrections for all these parameters are site specific and differ from one manufacturer to another.

$$N' = {}^{1}/_{2}(N–15)+15 \qquad \text{Eqn. 1}$$

STAGE 2. The effective friction angle of sand, ϕ', can be correlated with the N'-values corrected for overburden-stress, N" (Norlund, 1963), using the relationship as presented by Peck et al., in 1974 (Wolff and Conroy, 1991; Ab. Malik, 1992), which can be approximated as:

$$\phi' = 26.7 + 0.36N'' – 0.0014(N'')^2 \qquad \text{Eqn. 2}$$

However, because N" is not available due to unavailable overburden stress data, σ_V, where N" is N-value corrected for overburden stress. In other words the unit weight, γ, is not available, therefore a preliminary assumption of N' = N" is presumed in Eqn. 2.
After the 1st iteration of the IT LOOP (1st IT LOOP), when N" is available, ϕ' can be calculated using N".
This step requires at least two complete iterations, i.e. 2nd iteration of IT LOOP (2nd IT LOOP).
This process is shown in Figure 3.

STAGE 3. The effective angle of shearing resistance ϕ' and the relative density, D_r, als in Eqn. 3 can be correlated as presented by Meyerhof in 1959 (Bowles, 1988). Equation 3 is rearranged to obtain D_r as a function ϕ' in Eqn. 4 whereby:

$$\phi' = 28 + 0.15 * D_r \qquad \text{Eqn. 3}$$

$$D_r = \frac{\phi' – 28}{0.15} \qquad \text{Eqn. 4}$$

Even though Eqn. 4, can give a rough approximation of D_r, the expression in Eqn. 3 was not derived for the purpose of evaluation relative density from effective angle of internal friction, ϕ'. However, preliminary stability analysis utilising these data has provided satisfactory results.

STAGE 4. Now the relative density from Eqn. 4 can be applied into Eqn. 5 to find the unit weight, γ, of sand.

$$D_r = \frac{(\gamma' - \gamma'_{min})\gamma'_{max}}{(\gamma'_{max} - \gamma'_{min}) \text{ x } (\gamma\gamma)} \qquad \text{Eqn. 5}$$

Whereby γ_{max} and γ_{min} are arbitrarily chosen values considering medium and dense sand as a preset limit for normal sand conditions. Preset values chosen are γ_{max} = 20 kN/m^3 (D_r = 0.65) for dense sand and γ_{min} = 17 kN/m^3 (D_r = 0.35) for medium dense sand

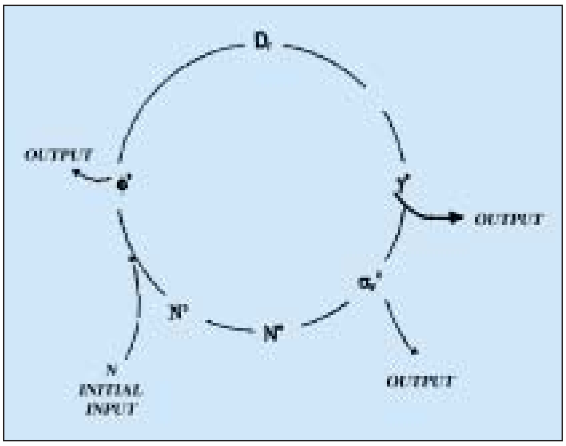


Figure 3. The IT loop for prediction of design parameters.

(relative density for most soil is in between 0.35 – 0.65). The simplification of this formula is as shown in Eqn. 6.

$$\gamma' = \frac{340}{20 – 3D_r} \qquad \text{Eqn. 6}$$

Equations 4, 5 and 6 are applied to find D_r and γ'.
To obtain effective unit weight, γ', γ_W is subtracted from the bulk unit weight as in Eqn. 7 (for submerged cases).

$$\gamma' = \gamma – \gamma_w \qquad \text{Eqn. 7}$$

STAGE 5. It is known from soil mechanics theory that the effective overburden stress, σ_V', can be determined as long as the unit weight and the depth of the soil element can be determined accurately. Therefore overburden stress, σ_V', dan be represented as:

$$Q_v' = \sum_{i=0}^{n} \left[\gamma_n' z\right]_i \qquad \text{Eqn. 8}$$

STAGE 6. The final link for this procedure is completed using a correction factor for overburden stress similarly used by Coyle and Costello (1981) (Heydinger, 1984) will be used in this study. This correlation is as presented in Eqn. 9, and this will be used in all the analyses using IT.

$$N'' = N' * 0.77 * \log\left(\frac{1915.2}{Q_v'}\right); (Q_v' \text{ is in kPa}) \qquad \text{Eqn. 9}$$

STAGE 7. Now a loop has been created where the corrected SPT-N value, N", can be used to obtain ϕ', D_r, γ' and c_u (N–c_u correlation) by continuous iteration. This loop as shown in Figure 3 need only a single input, N-value, however input and output can be at any level of iteration in the loop.

Abbreviations

ϕ'	– Drained angle of friction
γ	– Bulk unit weight of soil
D_r	– Relative density of soil
K_a	– Active earth pressure coefficient
H	– Thickness of soil
SF	– Safety factor
P_a	– Active earth pressure
IT	– Iterative technique
q_u	– Unconfirmed compressive strength of soft soil
N-values	– SPT-N values derived from standard penetration test
SPT	– Standard penetration test
E	– Stress strain modulus of soil
σ'_v	– Effective overburden stress
z	– Depth in soil from ground level
c_u	– Undrained shear strength of soft soil
c'	– Drained shear strength of soft soil
MLWS	– Mean low water spring level
MHWS	– Mean high water spring level
σ_{cu}	– Standard deviation of undrained shear strength values around mean strength value

The method described in Stages 1 to 7 can now be used to determine γ, ϕ' and c_u to conduct embankment stability analyses.

Method of Embankment Stability Analysis

This paper was not intended to elaborate on detailed numerical stability analysis because of space limitations and there are many other references and publications with detailed explanations on slope stability analysis (e.g. Nash {1987}, Fredlund and Krahn {1977}, Lafleur and Lefebvre {1980}, Charles and Soares {1984} and many others). However the different stages of analysis considering displacement filling as the adopted methodology are highlighted to elaborate on the various possibilities considered before arriving at the intended solution. Soil data extrapolated using IT was used for the stability analysis.

Analysis was carefully separated into Pre-Construction, During Construction and Post-Construction conditions. This is important because the geometry and soil property of the embankment change during the different construction stages described. In terms of slope stability it is usually related to the changes in sub soil strength, which in this case is the controlling factor (for deep seated failure check). Relating to the different construction stages, the slope stability analysis on soft soil will be for the different construction stages, the slope stability on soft soil will be for undrained shear strength, c_u (During construction) and drained shear strength c' (Post-construction).

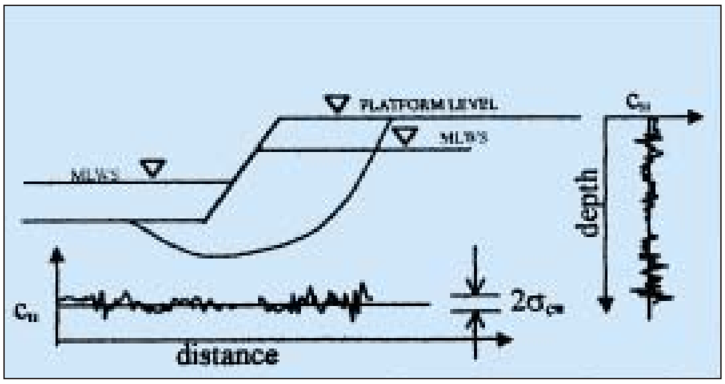


Figure 4. Variation of soil properties with varying depth and distance to embankment profile.

Delineation of the soil profile (soil properties) as shown in Figure 4 and different methods for computation of SF have to be considered. Any method of analysis may be adopted and all are generally accepted and in this case the critical condition that needs to be checked would be for a deep-seated failure. One logical approach for taking a systematic conservative shear strength value would be $c_u - \sigma_{cu}$, whereby c_u is the average shear strength of soft soil in a particular layer while σ_{cu} is the standard deviation of the soft soil's shear strength value in a particular soft soil layer.

This is as shown in the c_u *vs* distance graph in Figure 4. The c_u *vs* depth graph is only used for cases of homogeneous soil condition which almost never exist. This is consistent with the input data that are usually required by most slope stability analysis software.

Some considerations during analyses

Some factors to be considered in the design of reclaimed embankment on soft soil (approximately 10 m thick) with embankment fill height of approximately 13 m high (from toe to crest) include:

a) Embankment construction is in water (reclamation), therefore increased stability due to water frontage whereby sea water level taken as MLWS and water level in soil as MHWS to consider water logged condition which would be the most critical condition.
b) The angle of the slope is directly related to the stability of the slope, but there is limitation due to the allowable boundary of reclamation and gentler slope means higher sand volume and increased cost of reclamation.
c) Changed soft soil geometry due to displacement filling (original soft soil strength approximately

10 Kpa) whereby geometry of slope is crucial in any stability analysis.

d) Properties of soft soil at the seabed changes throughout the process of reclamation.
e) Embankment failure need not be defined as slight movement of embankment, but as large slips which can be identified by very low SF, whereby SF is the ratio of resisting moment over acting moment of the embankment mass.
f) Varying slope geometry involving different soils underneath causes a certain level of uncertainty in the analysis conducted.

Pre-construction analysis

At this stage the analysis includes extraction of parameters obtained from the soil investigation. The soil investigation should be conducted in an alignment perpendicular to the direction of the embankment to ease modelling of embankment geometry and its respective soil properties. The engineer may conduct simple statistical data treatment at this stage whereby the average shear strength values c_u minus σ_{cu} will give conservative shear strength values. A more rigorous method of analysis includes using Reliability theory to determine cost of variation, Mean Factor of Safety, Reliability index, Safety Measure and probability of failure.

Well known techniques include Monte Carlo technique and Bayesian theorem whereby the latter is more widely accepted. The simpler statistical method using c_u minus σ_{cu} described earlier, was the method adopted for the final design while the more vigorous analysis may be used in the final analysis of Intermediate and Post-Construction stages but will not be elaborated in this paper.

Intermediate construction analysis

This stage of analysis is important to check the stability of the embankment during construction and would determine the method of construction to be adopted. To further elaborate, it was understood that a construction period of three months was allocated for construction of the embankment and another three months for installation of shore protection works. The three months allocated for the construction stage was chosen because this would give time for increase in soil strength and the duration must be compatible with the dredger's capacity chosen for reclamation.

Based on the construction schedule, a trailing hopper suction dredger was chosen. As a design and build turnkey contractor, the analysis was to include the effect of the dredger chosen for the embankment construction. The main concern was the high rate of filling that could cause embankment failure. Here the definition "failure" should be related to the extent of failure or better described as to what extent it would affect the overall project. Different embankment geometry throughout reclamation area was analysed using undrained soil strength values (short term stability) using a simple assumption that there is no increase in soil strength values owing to increase in overburden stress (filling).

This assumption was necessary as release in excess pore water pressure in soft soil resulting in gain in shear strength will require longer time and this assumption obviously will give conservative results to the overall design. Adopting displacement filling for embankment construction with SF less than unity shows that there will be some movement of the embankment, and this should not be understood as a failure whereby filled slope construction (reclamation) in water using displacement filling will definitely have high localised movement. After construction, the embankment movement must be minimal to ensure that the superstructure and infrastructure constructed on this reclaimed land will be stable and safe. This will be checked in the long term stability analysis.

The movement of the embankment's mass will gradually stop once the acting moment (acting slope mass) equals the resisting moment (resistance from shear strength of soil), but this movement will also reduce the undrained shear strength of the soft soil (along with the slip circle) to residual shear strength values. Another fact also considered is that slips that occur will cause displacement of the subsoil and heaving at toe stabilizes the embankment.

The embankment construction using reclamation technique was analysed and it was decided that for all cases the embankment shall be overfilled by 10 m beyond the limit of reclamation. This is important to ensure the heaved soft soil at the toe of the slope is separated from the main embankment toe and allowing for further extent of prefabricated vertical drain (PVD) installation. This is also important to ensure that any future dredging around this area that can cause movement of the soft soil at the toe does not affect the main embankment. From the slope stability analysis is was determined that the short term stability (Undrained analysis) without any soft soil heaved at the toe is with a SF = 1.067 – 1.4. The lower range of these values is slightly below the adopted value of SF = 1.2 for short term stability, showing that some slips are bound to occur at some of these locations.

Post-construction analysis

Post-construction analysis refers to long term stability of the embankment taking into account creep, chemical weathering, or removal of soluble binder from soil mass. Other factors not related to the geotechnical properties of the embankment but affecting the selection of SF includes the possibility of a slide that might endanger life or property. Long term stability analysis (drained analysis using ϕ' values extracted from plasticity index (PI) *vs* sin ϕ'correlation) without any clay formation at the slope toe was carried out and a SF = 1.54 was obtained. However, the critical slip circle obtained showed that these failures are owing to surface slips in the fill material which are not critical.

This analysis is not usually preferred because ideally drained shear strength values should be obtained from laboratory tests (which models actual behaviour of the soft soil under controlled load due to its site specific behaviour) instead of standard correlations.

However, in the absence of sufficient test data these standard correlations may be applied. A deep seated failure analysis which is the most important aspect of slope stability in relation to reclamation on soft soil was carried out and the drained ϕ' values were obtained using the above chart for long term stability analysis and the lowest SF of 1,85 was obtained. This value is larger than the usual long term SF of 1.5 indicating long term stability of embankment is satisfied.

Adopted Design

During reclamation activity, two methods of filling were adopted in stages. In the initial stage (1st stage) of reclamation the dredger's central discharge system was used whereby this technique will displace very soft material (slime) on the surface layer of the seabed. An illustration of the explained concept is as shown in Figure 5. As for the second stage of filling (2nd stage), land based equipments were used to complete the displacement filling exercise and these are detailed in the section below.

Referring to the concept highlighted in Figure 5, there are limitations to this method and one of this limitation includes the minimum factor of slope stability, as explained by Eqn. 10. Safety factor with respect to sliding of fill material may be expressed as follows:

$$SF = \frac{tan\phi'}{tanß} \qquad \text{Eqn. 10}$$

Therefore clean dry sand, with internal angle of friction of ϕ', can be heaped with a slope angle lesser than ß, irrespective of its height and keeping in mind that free falling sand (heaped sand in Quarry as an analogy) will be stable with a slope angle lesser than its own angle of internal friction. However this is not possible during pumping of sand (during reclamation using direct discharge) because of the high water to sand ratio pumped and therefore water pressure from the high mix ratio that is required to assist in sand particle transportation causes a temporary reduction in the effective angle of friction of sand and resulting in a gentler slope (1:6 to 1:8). This discourages displacement filling and

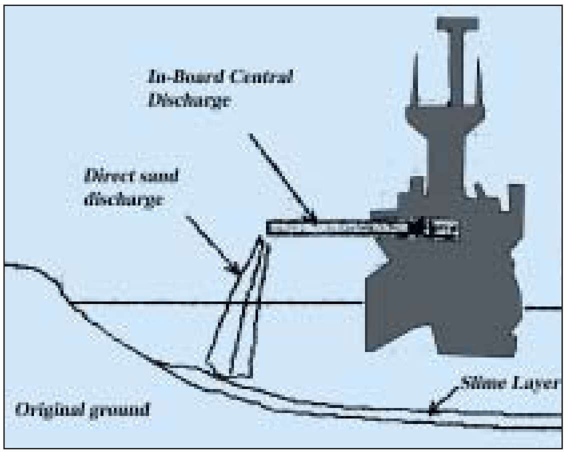


Figure 5. Direct discharge from in board central discharge system.

causes an increase in sand volume required to form the final embankment. The gentle slope causes another problem, that is, the dredger has lesser draft thus reducing its reach to discharge directly to the dry embankment to reduce sand loss.

In relation to reclamation in Lumut, the trailing hopper suction dredger was initially used as a direct discharge method (without using pipeline to displace soft soil) as shown in Figure 5. The reclaimed embankment not only resulted in higher sand volume, it also increased the cost of slope protection because the slope face (distance between crest and toe) length increased.

Definitely one way adopted to reduce this problem was by using a pipeline after displacement of the soft soil, and this was the second stage of embankment construction. This proved that sand pumped on permeable ground (sand) allows the fill material to gain strength once the water is drained out from the fill material. This drained sand was used to construct the embankment and it is important to provide slope protection as soon as possible to reduce sand loss.

Another approach used to recollect the excessive sand on the slope was by using small size pontoons with lesser draft requirement to pump the excessiv material at the slope face onto the dry embankment resulting in a steeper slope angle. Other options explored include using Clamshell and Long Arm Excavators.
However both of these equipments have insufficient reach on the long slope face that needs to be trimmed to its final profile.

Control of fill drection to assist displacement
Controlled filling of sand transported onto embankment using pipelines was carried out using land based equipment and this is identified as the 2nd stage of reclamation. This technique is somewhat new as it is undocumented in terms of its effectiveness. The usual problem faced in displacement filling is the entrapment

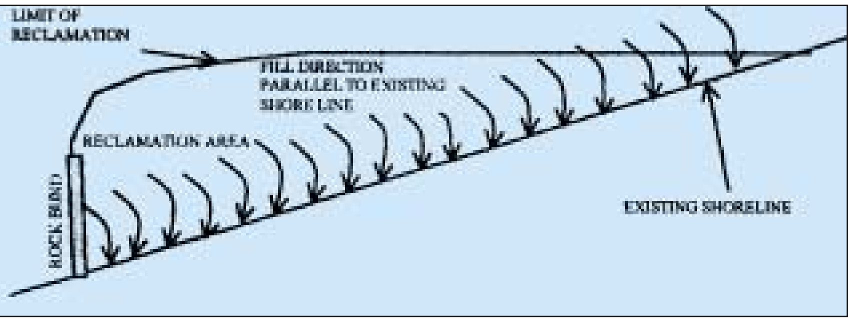


Figure 6. Controlled fill direction to reduce entrapment of soft soil as practiced in Lumut, Malaysia.

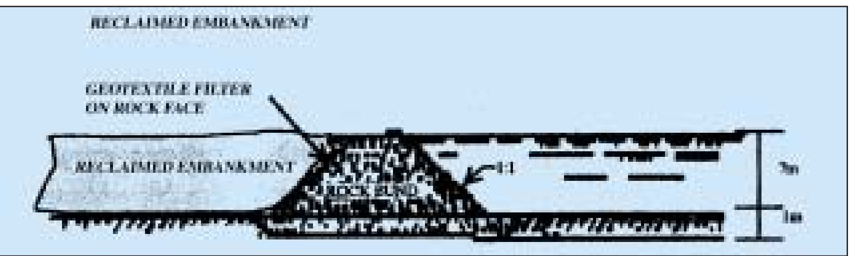
of the soft heaved slime causing reduced stability of the embankment and excessive settlement after construction. To assume that these pockets of heaved slime layer entrapped are to be taken as the controlling factor for soil improvement, will cause a significant increase in soil improvement cost. Therefore controlled direction of discharge parallel to the slope as shown in Figure 5 was adopted to continuously push the heaved soft soil away from the embankment.

Using displacement filling technique, it was also important to ensure that the direction of filling is in a manner that there are no horizontal entrapments (parallel to existing and new shoreline) occurring. The method adopted is as shown in Figure 6, whereby the fill direction was always maintained parallel to the existing shoreline and as the embankment construction progresses away from the existing shoreline, fill direction was maintained parallel to the final embankment shoreline.

Rock Fill on Soft Soil

A rock bund was constructed at a location as shown on Figure 7 to increase the stability of the steep slope. This rock filled embankment was constructed to protect the main discharge drains from being clogged. As anticipated the rock filled embankment settled 1.2 m immediately after its construction. This however cannot be defined as settlement due to consolidation of soft soil underneath, but as a localised bearing capacity failure. A total embankment failure causing excessive settlement was avoided using a sand layer beneath the rock bund. This method was used to avoid direct contact between the rock face and soft soil that will cause high concentration of local stresses that causes punching failure in soft soil. Total settlement after construction is approximately 1.6 m.

Figure 7. Rock Bund constructed on soft soil to create a steep slope face in Lumut, Malaysia.



Instead of placing a sand layer on the rock placement area, direct discharge technique using displacement filling was used as described earlier. Settlement curves of the rock bund shown in Figure 8 indicated that the local bearing failure of the rock bund occurred within days while the local bearing failure of the sand filled embankment (collapsed to displace the bearing soft soil) occurred 1 to 2 weeks after construction. This is due to the higher density of the rock fill compared to sand filled embankment.

No excessively heaved clay was recorded at site during construction or 6 months after construction. However continuous observation is necessary to determine the final results. Barbesis 1935 explains that similar techniques have been successfully used in construction of breakwater in the harbours of Valparaiso, Chile and Kobe, Japan (Terzaghi *et al*. 1995).

Silt Screen as a Control for Displacement Filling

The environmental aspects of dredging and reclamation cycle can be described by the different processes involved in a dredging operation. In Lumut, the process involved dislodging of the in-situ material during reclamation, raising of the dredged material, horizontal transport of dredged material and placement of dredged material. Of the four phases described, only placement of material (reclamation) is of relevance to this project.

During construction of the embankment using central discharge system to accommodate displacement filling, fine sediments were dispersed causing heavy pollution to the surrounding waters. The water quality in this area had to be controlled to avoid adverse impacts on marine life, especially in Lumut as this area is known for its fishery and tourism activities. As part of the environmental management plan, a silt screen and water quality monitoring programme were introduced to reduce the adverse affect owing to displacement of soft seabed sediments. To maintain water quality of the reclaimed area, a silt screen was designed and constructed at site.

In the design stage of the silt screen some of the factors considered were wave action, wire rope strength, type of connections, distance between floaters, materials to be used for sediment screening, counter weights, tide fluctuations and anchors. Initially a 70 m test silt screen was constructed to verify

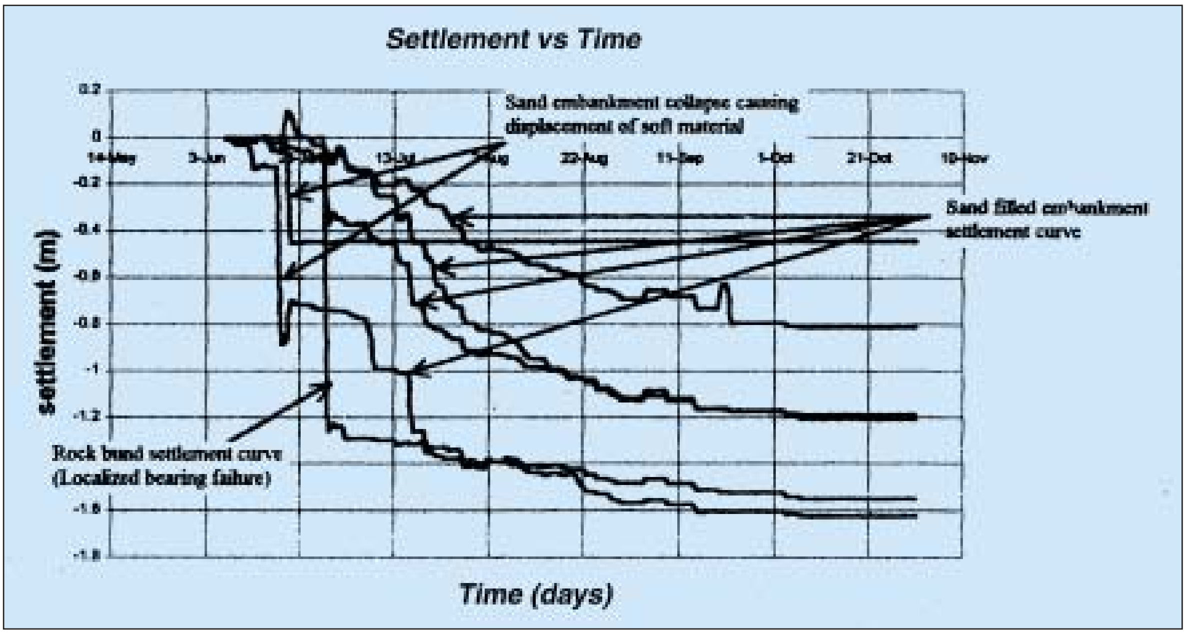


Figure 8. Settlement curves for rock bund and sand embankment showing immediate collapse as proof of displacement filling.

its performance especially against the wave action and strong current in Sg. Dinding, and it was concluded that the designed counterweights were inadequate to maintain the silt screen in its location. Therefore additional anchorage to seabed was provided using anchors fabricated from high tensile steel bars.

These anchors were installed after the silt screen was suitably placed without causing any distraction to the dredger's path, notably because the silt screen with anchors is not easily relocated as may be required from time to time. The silt screen functions mainly to diffuse fine particles movement safely using the physical method. Another advantage of this method is that it does not chemically pollute the environment. The biggest advantage would be that the silt screen can be fabricated at site and launched using minimum labour.

Conclusion

At the moment very little is understood about the behaviour of soft soil in relation to displacement filling. There is a need to model the interaction between soft soil material filled with denser fill material. This modelling will help to predict the extent or effectiveness of displacement filling. With better predictions derived from laboratory and site observations. it is also easier to justify the cost and explain the economic advantages of displacement filling in comparison to other methods of reclamation.

Despite the fact that the described methodology is widely used (even though not widely discussed), this case study serves as an outstanding model for future large scale reclamation on soft soil. This case study also serves as an excellent example on the factors to be considered when choosing a design SF with an eye towards the costs and risks associated with a project.

"Risks are inherent in any project that the existence of such risks should be recognized, and steps representing a balance between economy and safety should be systematically taken to deal with these risks. Two ways of defining calculated risk are:

a) The use of imperfect knowledge, guided by judgement and experience, to estimate the probable ranges for all pertinent quantities that enter into the solution of the problem.

b) The decision on an appropriate margin of safety, or degree of risk, taking in to consideration economic factors and the magnitude of losses that would result from failure."

From Arthur Cassagrande's Terzaghi Lecture of 1964 (Whitman 1984)

References

Ab. Malik, Rosely B., (1992).
Pile Foundation Design: Interrelation of Safety Measures from Deterministic and Reliability-Based Methods, Ph.d. Thesis, Department of Civil and Environmental Engineering, Michigan State University, East Lansing, Michigan 48823, USA.

Ab. Malik, Rosely B., and Ambrose, J. (1999).
Application of Iterative Technique for the Determination of Pile Capacity in Sand and Clay, Proc of the 1st World Engineering Congress (WEC). Kuala Lumpur.

Bazaraa, A.R. (1982).
"Standard Penetration Test", in *Foundation Engineering*, Ed.: Georges Pilot, Presses Ponts et Chausees, 28 Rue Des Saints-Peres 75007 Paris, pp. 65-72.

Bowles, J.E. (1988).
Foundation Analysis and Design, 4th Edition, McGraw Hill, N.Y.

Bruun, P.
Port Engineering (3rd edition) Gulf Publishing Company, Book Division, Houstan, London, Paris, Tokyo.

BS 6349: Part 5: 1991.
Code of Practice for Dredging and Land Reclamation.

Carter, M. (1983).
Geotechnical Engineering Handbook, Pentech Press Limited.

Charles, J.A. and M.M. Soares (1984).
"The stability of slopes in soils with non-linear envelopes". *Can. Geotech. J.*, 21, No. 3, pp. 397-406.

Christoulas, S.G. (1985).
"Uncertanties in the Design of Driven Piles in Sand:, *Proc. of the 11th ICSMFE*, San Francisco, 12-26 Aug., pp. 1365-1368.

Coyle, H.M., and Costello, R.R. (1981).
"New Design Correlations for Piles in Sand", *Journal of Geotechnical Engineering Div.*, Proc. of ASCE, Vol. 107, No. GT7, July, pp. 965-986.

De Mello, V.F.B. (1984).
"Design Decision, Design Calculations, and Behaviour Prediction Computations: Referred to Statistics and Probabilities", *Proc. 6th Conference on Soil Mech. And Found. Engl.*, Budapest, pp. 37-44.

Fredlund, D.G. and Krahn J. (1977).
"Comparison of slope stability methods of analysis", *Can. Geotech. J.*, 14, No. 3, pp. 429-439.

Heydinger, A.G. (1989).
"Predictions of Driven Pile Behaviour Using Load Transfer Functions", in Predicted and Observed Axial behaviour of Piles, Ed.: Richard J. Finno, Proceeding ASCE Symposium, Northwestern University, Evanston, Illinois, June 25, pp. 117-128.

Kamenov, B., Kysela, Z. (1984).
"Risk and Effectively of Design of Building, Foundation and Stability of Slopes", Proc. 6th Conference on Soil Mech. And Found. Eng., Budapest, pp. 123-129.

Koerner, R.M. (1995).
Designing with Geosynthetics, 4th ed., Prentice-Hall, Inc., pp. 213-248.

Lafleur, J. and G. Lefebvre (1980).
"Groundwater regime associated with slope stability in Champlain clay deposit". *Can. Geotech. J.*, 17, No. 1, pp. 44-53.

Lumb, P. (1970).
Safety Factors and Probabilistic Distribution of Soil Strength, *Canadian Geotechnical Journal*, 7, 225 pp. 224-241.

McConnell, K. (1998).
Revetment Systems Against Wave Attack, Thomas Telford Publishing.

Meyerhof, G.G. (1970).
"Safety Factors in Soil Mechanics", *Canadian Geotechnical Journal*, 7, 349, pp. 349-355.

Moh, Z.C. (1985).
"Site Investigation and In-Situ Testing", *Geotechnical Eng. In Southeast Asia*, A commemorative volume of the SEAGS, Ed: Balasubramaniam A.S., Bergado, D.T., Chandra, S., Balkema, pp. 9-25.

Nash, D. (1987).
"A comparative review of limit equilibrium methods of stability analysis", Chap. 2 in *Slope Stability*, Anderson and Richards (eds.) New York, John Wiley and Sons, pp. 11-75.

Norlund, R.L. (1963).
"Bearing Capacity of Piles in Cohesionless Soils", Journal of Soil Mechanics and Foundation Design, ACSE, Vol. 89, No. SM3, May, pp. 1-35.

Terzaghi, K. Peck, R.B. and Mesri (1995).
Soil Mechanics in Engineering Practice (3rd edition), John Wiley and Sons, pp. 151-152, 377-385.

Whitman, R.V. (1984).
"Evaluating Calculated Risk in Geotechnical Engineering", *ASCE Journal of Geotechnical Engineering,* Vol. 110, No. 2, Feb., pp. 145-189.

Wolff, T.F. and Conroy, P.J. (1991).
Discussion on "Improved Design Procedures for Vertically Loaded H-Piles in Sand", *ASCE Journal of Geotechnical Engineering,* Vol. 117, No. 3, Mar., pp. 213-231.

Wu, T.H. (1974).
Uncertainty, Safety, and Decision in Soil Engineering, Journal of Geotechnical Engineering Division, Proc. ASCE, Vol. 100, No. GT3, March, pp. 329-348.

Yu, H.S. and Houlsby, G.T. (1991).
"Finite Cavity Expansion in Dilatant Soils: Loading Analysis", Geotechnique, 41, No. 2, pp. 173-183.

Charles W. Hummer, Jr.

Books/ Periodicals Reviewed

FIDIC Form of Contract for Dredging and Reclamation Works.
Published by FIDIC. Switzerland. 2001.

P Jenkinson, T Sanders, E Corbett, P Boer, and C Dolmans (Task Group)

FIDIC, Fédération Internationale des Ingénieurs-Conseils (International Federation of Consulting Engineers), has a long history in publishing standard forms of contract for engineering construction. Their first standard forms were published in 1957, with new editions (the so-called "Red Book") in 1969 and 1979, which included explicit provisions for dredging and reclamation works. The Fourth Edition of the Red Book in 1987 did not, however, include these dredging provisions and so to meet the specific requirements of dredging projects, in 1990 in cooperation with FIDIC, the International Association of Dredging Companies (IADC) published a "Users' Guide to the Fourth Edition".

In 1999 FIDIC published four new standard forms of contract: the Conditions of Contract for EPC Turnkey Projects, for Plant and Design-Build designed by the Contractor, for Construction designed by the Employer and the Short Form of Contract. When no special attention was given to the different circumstances in dredging and reclamation works, the IADC contacted FIDIC about the possibility of a separate FIDIC dredging contract and a Task Group was formed. On the strong basis of FIDIC's Short Form of Contract, this Task Group produced the "FIDIC Form of Contract for Dredging and Reclamation Works".

The test edition of this "dredging contract" was published in June 2001. The formal first edition is to be published next year, taking into consideration the comments that may arise from the test edition.

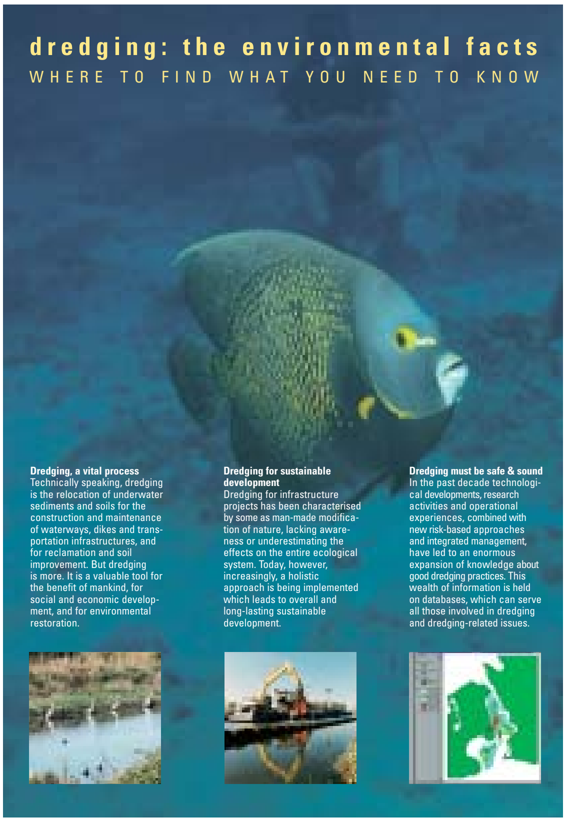
The contract is published under the auspices of FIDIC and the aim has been to produce a fair, balanced and straightforward document, which includes all essential commercial provisions. It may be used for all types of dredging and reclamation work and ancillary construction with a variety of administrative arrangements. Under the usual arrangements for this type of contract, the Contractor constructs the Works in accordance with design provided by the Employer or by his Engineer. As in the construction industry in general, more and more works are contractor-designed. The form, therefore, may easily be altered into a contract that includes, or wholly comprises, contractor-designed works.

The most essential part of a dredging contract is formed by the description of the activity itself, the specifications, drawings and design of the work. The "FIDIC Form of Contract for Dredging and Reclamation Works" provides only a legal framework to this. It governs the general obligations and responsibilities of the contracting parties. The document starts with an Agreement; a simple document that incorporates the tenderer's offer and its acceptance. All necessary information is to be included in the Appendix to the Agreement. References to documents forming part of the contract such as the specification and the drawings are also made in the Appendix. The General Conditions are expected to cover all essential elements of the legal framework. Nevertheless, every situation is unique. Modifications may be required in some jurisdictions or may be necessary as a result of special circumstances. Users are able to introduce Particular Conditions, if they wish, to handle such special cases or circumstances.

The FIDIC Form of Contract for Dredging and Reclamation Works is a two-party contract between the Employer and the Contractor. Contrary to FIDIC's Short Form, provision is made for an Engineer as usual for dredging and reclamation works. Although the Engineer is not a party to the contract, the Engineer may have an important role in the execution of the work. The FIDIC Dredging Form gives the Engineer several duties and authorities such as approval of contractors design, the authority to instruct variations to the Contractor, the issuing of Taking Over Certificates and the certification of payments. This important role – especially when executed by an experienced engineer – is for the benefit of both Employer and Contractor. The Employer is ensured of expert advice whereas the Contractor has an experienced partner to work with. The issuing of Taking Over Certificates and certification of payments by the Engineer may often be needed by projects that are externally financed by government bodies or international organisations like the World Bank.

In short, there is now once again a standard construction contract that fits the special requirements of dredging and reclamation projects. In large projects where dredging and reclamation are just a part of the work, one of the other FIDIC contracts may be appropriate. However, the straightforward provisions and clear conditions of the "FIDIC Dredging Form" may help to design particular conditions for these standard contracts to meet specific dredging needs. When needed due to specific circumstances the FIDIC Dredging Form can easily be adjusted and particular conditions can be added.

For further information contact the FIDIC, P.O.Box 86 (Chailly), CH-1000 Lausanne 12, Switzerland, e-mail: fidic@pobox.com or the IADC Secretariat in The Netherlands.



Dredging: The Environmental Facts
Published jointly by the International Association of Dredging Companies, Central Dredging Association and members of the PIANC-ENVICOM. The Hague, The Netherlands, 2001. Pamphlet, 4 pp. A4, illustrated, colour.

N. Bray, A. Csiti, P. Hamburger, T. Vellinga

Written by experts in the field, this pamphlet presents the basic fact: Dredging is a vital process for sustainable social and economic development. As such, it must be environmentally safe and sound — and generally speaking it is.

Rather than viewing dredging as a disturbance to the environment, the point of departure here is to demonstrate that dredging can be valuable to improving the environment. The pamphlet offers guidelines to consider when approaching any dredging project. Dredged materials are most often clean and can be used as a resource. Those dredged materials that are not clean must be characterised in order to determine the best methods of disposal or treatment. Assessment and mitigation of disposal and impacts on nature and man should be considered, as well as when to — and when not to — relocate dredged materials. Control at source should be a priority and an overall balance between economy and ecology must be sought. The principle of partnering is presented, as is a "dredging regulatory framework", with a chart that explains the jurisdictional boundary of the London Convention.

The uniqueness of each dredging project is clearly emphasised. Copying solutions can be inappropriate and have misleading effects. The importance of knowing where to find proper information is essential and constitutes the final part of the pamphlet.
For those considering a dredging project, this part of the pamphlet provides a most useful introduction to good sources of information.

This publication is a follow-up to *Dredging: The Facts*, published in 1999. Both are available from the IADC Secretariat in The Hague (info@iadc-dredging.com, the CEDA Secretariat (ceda@dredging.org) or PIANC (info@pianc-aipcn.org).

Seminars/ Conferences/ Events

NEVA

St. Petersburg, Russia
September 24-28 2001

This sixth NEVA Exhibition celebrates the revival of Russia's shipping, shipbuilding, offshore energy, port development, fisheries, and oceanography and ocean exploration sectors. The current modernisation of the commercial environment with the introduction of clearer operating regulations, laws and tax codes will increase investment and business. Two new major initiatives will be:

- the NEVA Capital Cruise Shipping in the Baltic, Black Sea, Arctic and Pacific Regions and for inland Waterways; and
- NEVA Capital Ports, a programme to increase the velocity and volumes of passenger and cargo traffic.

For further information please contact:
Dolphin Exhibitions
112 High Street, Bildeston,
Suffolk IP7 7EB, UK
tel. +44 1449 741801, fax: +44 1449 741628
email: info@dolphin-exhibitions.co.uk
Web: www.setcorp.ru/neva

International Conference on Remediation of Contaminated Sediments

Scuola Grande di San Giovanni Evangelista,
Venice, Italy
October 10-12 2001

To aid in the exchange of information on the remediation of contaminated sediments, Battelle-Geneva Research Centre and Azienda Multiservizi Ambientali Venezian (AMAV) are organising this conference in Venice. Given the extensive problems in the Lagoon of Venice and the recent research activities there, Venice is a uniquely appropriate setting. The session chairs will be drawn from academia, government and the private sector.

Battelle is a not-for-profit research organisation with operations in Europe and North America. AMAV is a company providing integrated management of a full range of environmental services in the area of Venice. Containment or impoundment or other means of treatment will be discussed as well as emerging technologies for reclamation and reuse.

For further information please contact:
Marco Pellei
Battelle Geneva Research Centre
27, Route de Drize
CH-1227 Carouge/Geneve, Switzerland
fax +41 22 827 2094
email: sedimentscon@batelle.org

India International Maritime Expo (INMEX) 2001

Mumbai (Bombay), India
October 10-13 2001

The second India International Maritime Expo (INMEX) will provide an opportunity for overseas companies to enter the maritime market in India and to meet with representatives from government such as the Ministries of Surface Transport (MoST) and Defence, and the Coast Guard.The MoST is responsible for policies for the development of modes of transport including the maritime sector.

In order to decongest the present major port facilities the MoST has launched an ambitious plans for infrastructure development in the port sector, the shipbuilding industry and inland water transport. Private investments are being encouraged for port development as well as ship building and repair.

For further information contact:
INMEX Secretariat
Pradeep Deviah & Associates
Nor. 35, Gover Road, Cox Town,
Bangalore 560 005, India
tel. +91 80 54 84 155/ 54 84 389
fax +91 80 54 85 214
email: pda@blr.vsnl.net.in
Web: www.inmexindia.com

Ghent Environmental Geotechnics

University of Ghent, Belgium
October 29-31 2001

In cooperation with ISSMGE Technical Committee 5, Laboratory of Soil Mechanics, this specialty conference GEG 2001 will focus on underwater geoenvironmental issues. It aims to bridge the gap between current technological and engineering skills in underwater geoenvironmental issues and their corresponding academic and research state of knowledge.

The conference topics include: environmental dredging and related technologies, underwater ground improvements; in situ and off situ remediation of dredged material; (bio)chemical phenomena rrelated tosoft soil mechanics; land reclamation problems, waste ponds/ tailings dams designs and case histories.

There will be a technical visit to observe the most advanced underwater geoenvironmental technologies used in the Antwerp area as well as some soil remediation facilities.

For further information please contact:
The Organising Committee of GEG 2001
Laboratory of Soil Mechanics,
Prof. W.F. Van Impe
Technologiepark 9, 9052 Zwijnaarde, Belgium
tel. +32 9 264 5717 (23), fax +32 9 264 5849
email: geg2001@pi.be
Web: allserv.rug.ac.be/~wvanimpe

International Conference on Port and Maritime R&D and Technology

Singapore
October 29-31 2001

The Maritime and Port Authority of Singapore (MPA), the National University of Singapore (NUS), Nanyang Technological University (NTU) and Singapore Maritime Academy (SMA) have organised a conference to bring togther researchers in the academic and research institutes, consultants and practitioners in the port and maritime industries.

The conference will cover port development, management and operations; coastal engineering; marine environment; innovative ship designs; and navigation and maritime training in the digital era. The six invited keynote speakers are: Mr Pieter Struijs of IAPH, Prof Kees d'Angremond of Technical University Delft, Prof Chou Loke Mingof the NUS, Dr Hans G. Payer, CEO of Germanischer Lloyd, Hamburg, and Mr EE Mitropoulos, Assistant Secretary General of the IMO.
An exhibition featuring the latest R&D and technological products, systems and services will be held concurrently.

For further information please contact:
Ms Hui-Sian Jong, Conference Secretariat
c/o Professional Activities Centre,
Faculty of Engineering,
National University of Singapore,
9 Engineering Drive 1
Blk EA#04-10, Singapore 117576
tel. +65 874 5113, fax +65 874 5113
email: icpmrdt@nus.edu.sg
Web: www.mpa.gov.sg/homepage/conference/RDT/main/html

Sea-Port 2001

BUEXCO, Busan, Korea
October 30-November 3 2001

This is Korea's primary exhibition of international port, logistics and environmental technology, simultaneously held with KOMARINE and Naval & Defence under the umbrella of Marine Week 2001. The show is authorised by the Ministry of Commerce, Industry and Energy and the Ministry of Maritime Affairs and Fisheries.
Top quality port-related industry products, logistics technology and environmental protection systems will be exhibited.

For further information please contact:
Sea-Port 2001 Show Management OfficeRm. 501,
Kumsan Bld., 17-1 Yoido-dong
Yongdeungpo-ku, Seoul 150-010, Korea
tel. +82 2 785 4771, fax +82 2 785 6117/8
email: kyungyon@netsgo.com

Europort 2001

RAI International Exhibition Centre,
Amsterdam, The Netherlands
November 13-17 2001

The Europort Exhibition is one of the largest trade shows for the international marine industry and is held every two years in Amsterdam. Exhibitors include all branches of the maritime industry from shipbuilding, to suppliers of technical and safety equipment, port authorities, port management and development, offshore and dredging industries. Visitors come from all over the world and represent a broad range of people in related industries, science, research, government and academia.

For further information please contact:
Mr Farouk Nefzi, Project Manager, Europort 200
Amsterdam RAI, PO Box 77777
Amsterdam, The Netherlands
tel. +31 20 549 1212, fax +331 20 546 44 69
email: europort@rai.nl
Web: www.europort.nl

CEDA Dredging Day 2001

RAI International Exhibition Centre,
Amsterdam, The Netherlands
November 15 2001

”Dredging Seen; Perspectives, from the Outside Looking In” is the theme of this years’s Dredging Day which will be held during the Europort Exhibition. How do people and organisations from outside the dredging world look at dredging? Do they know what dredging is? And if they are aware, does it provide the services required? To explore these questions CEDA has invited notable speakers from outside the world of dredging to offer their perspectives.

CEDA is also holding a substantive programme, “The Academic Hour”, in which university and college students and young faculty are asked to present their research on any matter related to dredging. In addition, CEDA has issued a “Call for a Dredging Song”.
It is meant to be informative, evocative, humourous or emotional, all in the spirit of good fun.

For further information please contact:
CEDA Secretariat, Anna Csiti
PO Box 488, 2600 AL Delft, The Netherlands
tel. +31 15 278 3145, fax +31 15 278 7104
email: ceda@dredging.org

Oceanology International 2001

Singapore Expo,
December 4-6 2001

OI Pacific Rim 2001 provides a unique place to network with industry, academia, the R&D community and governments in Southeast Asia. Disciplines such as marine environmental sciences, survey and engineering, navigation and remote sensing, marine pollution monitoring and control, hydrography, dredging and coastal engineering, renewable energy and more are represented at the exhibition.
The exhibition is supported by an important conference with the theme “Science and Technology for Surveying, Evaluating and Protecting Marine Resources and the Environment”. The National University of Singapore’s Tropical Marine Science Institute will help coordinate the conference and keynote speakers.
Topics include: coastal oceanography, marine information systems, ballast water management and coastal marine resource management.

For further information about the conference contact:
Angela Pederzolli
tel. +44 20 8949 98339
fax +44 20 8949 8186
email: angela.pederzolli@spearhead.co.uk
www.oceanologyinternational.com

Port China & Marintec China

Intex Shanghai, China
December 4-7 2001

China’s premier maritime conference and exhibition, Marintec China, will now include Port China. Currently China has over 2000 ports and 128 ports which are open to foreign vessels. Many ports are already being upgraded and increased trade is expected to come from China’s entry into the WTO. The port authorities of Shanghai and Rotterdam have signed a letter of intent to cooperate on technology interchange. Port China will address the demand for better port facilities and services and will benefit from running concurrently with Marintec China. High level seminars and the Senior Maritime Forum will allow policy makers and industry leaders a chance to exchange views.

For further information please contact:
Ms Ginnie Koay in Hong Kong,
email: ginniekoay@mfasia.com.hk

Madam Wang Lingzhi in Shanghai,
email: ssname@uninet.com.cn

Mr Richard Johnson,
email: rjohnson@seatrade-global.com

Mr Michael Kazakoff, Miller Freeman
email: mkazakoff@compuserve.com

Bahrain Naval & Maritime 2002

Bahrain International Exhibition Centre
January 14-17 2002

Bahrain International Naval & Maritime Exhibition and Conference is the Middle East’s first dedicated naval and maritime event featuring naval and merchant shipping and equipment; maritime engineering; environmental protection and control technology.
The conference running parallel with the exhibition will concentrate on issues related to coastal zone management with particular reference to the Arab world.
The venue will be spread between the International Exhibition Centre and the Port of Mina Sulman, offering a combination of covered and outdoor exhibit space, deep-water dockside moorings and conference facilities.

For further information please contact:
DW Associates
19 Bulstrode Street, London W1U 2JN, UK
tel. +44 20 7487 2551, fax +44 20 7487 5195
email: exhibitions@dial.pipex.com, or

Arabian Exhibition Management
PO Box 2020011, Manama, Bahrain
tel. +973 55 0033, fax +973 55 32 88
email: naval@aeminfo.com.bh

International Seminar on Dredging and Reclamation

Place: Hotel Grand Plaza Parkroyal, Singapore
Date: October 22-26, 2001

In cooperation with the National University of Singapore (NUS) and the Applied Research Corporation (ARC), International Association of Dredging Companies is pleased to organise, an intensive, one-week seminar on dredging and reclamation.

The course has been held for several years and has been met with such enthusiastic response, that IADC, building on this success, has decided to present this seminar again in 2001. The costs are US$ 2975, which include six nights accommodation at the conference hotel, breakfast and lunch daily, one special participants dinner, and a general insurance for the week.

The seminar includes workshops and a site visit to a dredging project. Highlights of the programme are:

Day 1: Why Dredging?
The Need for Dredging/Project Phasing
Day 2: What is Dredging?
Dredging Equipment/Survey Systems (includes a Site Visit)
Day 3: How Dredging?
Dredging Projects
Day 4: Preparation of Dredging Contract
Day 5: Cost/Pricing and Contracts

Representatives of port authorities, companies, and individuals interested in attending are requested to complete the preliminary registration form below as soon as possible and prior to September 31, 2001, and return to:
IADC Secretariat, Duinweg 21,
2585 JV The Hague, The Netherlands
tel. +31 70 352 3334, fax +31 70 351 2654
e-mail: info@iadc-dredging.com

(please print)

Name ....

Title ....

Company ....

Address ....

....

Tel. .... Fax ....

E-mail ....

Please send this form and your deposit by cheque or credit card for US$ 500 in order to guarantee your place at the seminar. Upon receipt of this form and your deposit your place in the seminar is confirmed. We will then send you further detailed information, final registration forms, and an invoice for the correct amount.

Without your deposit we cannot guarantee your place and accommodations at the seminar.

- ☐ A Cheque is enclosed.
- ☐ Please charge my credit card:
- ☐ American Express ☐ Eurocard/Master Card ☐ VISA ☐ Diners Club

Account no.: | | | | | | | | | | | | | | | | | | |

Expiry date: | | | | | | | Card validation code: | | | |

Signature .... Date ....

Membership List IADC 2001

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

Africa
Boskalis South Africa (Pty.) Ltd., Capetown, South Africa
Boskalis Togo Sarl., Lomé, Togo
Boskalis Westminster Cameroun Sarl., Douala, Cameroun
Dredging International Services Nigeria Ltd., Lagos, Nigeria
HAM Dredging (Nigeria) Ltd., Lagos, Nigeria
Nigerian Westminster Dredging and Marine Ltd., Lagos, Nigeria

The Americas
ACZ Marine Contractors Ltd., Brampton, Ont., Canada
Beaver Dredging Company Ltd., Calgary, Alta., Canada
Dragamex SA de CV, Coatzacoalcos, Mexico
Gulf Coast Trailing Company, New Orleans, LA, USA
HAM Canada Office, Calgary, Canada
HAM Dredging Curaçao, Curaçao, NA
HAM Sucursal Argentinia, Buenos Aires, Argentina
Norham Dragagens Ltda, Rio de Janeiro, Brazil
Stuyvesant Dredging Company, Metairie, LA, USA
Uscodi, Wilmington, DE, USA

Asia
Ballast Nedam Malaysia Ltd., Kuala Lumpur, Malaysia
Ballast Nedam Dredging, Hong Kong Branch, Hong Kong
Boskalis International BV., Hong Kong
Boskalis International Far East, Singapore
Boskalis Taiwan Ltd., Hualien, Taiwan
Dredging International Asia Pacific (Pte) Ltd., Singapore
Dredging International N.V., Hong Kong
Dredging International N.V., Singapore
Far East Dredging Ltd., Hong Kong
HAM Dredging (India) Private Ltd., Mumbai, India
HAM Dredging (M) Sdn Bhd, Kuala Lumpur, Malaysia
HAM East Asia Pacific Branch, Taipei, Taiwan
HAM Hong Kong Office, Wanchai, Hong Kong
HAM Philippines, Metro Manila, Philippines
HAM Singapore Branch, Singapore
HAM Thai Ltd., Bangkok, Thailand
Jan De Nul Singapore Pte. Ltd., Singapore
PT Penkonindo, Jakarta, Indonesia
Tideway DI Sdn. Bhd., Selangor, Malaysia
Van Oord ACZ B.V., Dhaka, Bangladesh
Van Oord ACZ B.V., Hong Kong
Van Oord ACZ B.V., Singapore
Van Oord ACZ Overseas B.V., Karachi, Pakistan
Zinkcon Marine Malaysia Sdn. Bhd., Kuala Lumpur, Malaysia
Zinkcon Marine Singapore Pte. Ltd., Singapore

Middle East
Boskalis Westminster Al Rushaid Ltd., Dhahran, Saudi Arabia
Boskalis Westminster M.E. Ltd., Abu Dhabi, UAE
Dredging International N.V., Middle East, Dubai
Dredging International N.V., Tehran Branch, Tehran, Iran
Gulf Cobla (Limited Liability Company), Dubai, UAE
HAM Dredging Company, Abu Dhabi, UAE
HAM Saudi Arabia Ltd., Damman, Saudi Arabia
Jan De Nul Dredging, Abu Dhabi, UAE
Van Oord ACZ Overseas BV., Abu Dhabi, UAE

Australia
Condreco Pty. Ltd., Milton, QLD., Australia
Dredeco Pty. Ltd., Brisbane, QLD., Australia
New Zealand Dredging & General Works Ltd., Wellington
Van Oord ACZ B.V., Victoria, Australia
WestHam Dredging Co. Pty. Ltd., Sydney, NSW, Australia

Europe
ACZ Ingeniører & Entreprenører A/S, Copenhagen, Denmark
Anglo-Dutch Dredging Company Ltd., Beaconsfield, United Kingdom
A/S Jebsens ACZ, Bergen, Norway
Atlantique Dragage S.A., Nanterre, France
Baggermaatschappij Boskalis B.V., Papendrecht, Netherlands
Baggermaatschappij Breejenbout B.V., Rotterdam, Netherlands
Ballast Nedam Bau- und Bagger GmbH, Hamburg, Germany
Ballast Nedam Dredging, Zeist, Netherlands
Ballast Nedam Dragage, Paris, France
Boskalis Dolman B.V., Dordrecht, Netherlands
Boskalis International B.V., Papendrecht, Netherlands
Boskalis B.V., Rotterdam, Netherlands
Boskalis Westminster Aannemers N.V., Antwerp, Belgium
Boskalis Westminster Dredging B.V., Papendrecht, Netherlands
Boskalis Westminster Dredging & Contracting Ltd., Cyprus
Boskalis Zinkcon B.V., Papendrecht, Netherlands
Brewaba Wasserbaugesellschaft Bremen mbH, Bremen, Germany
CEI Construct NV, Afdeling Bagger- en Grondwerken, Zele, Belgium
Delta G.m.b.H., Bremen, Germany
Draflumar SA., Neuville Les Dieppe, France
Dragados y Construcciones S.A., Madrid, Spain
Dravo S.A., Madrid, Spain
Dredging International N.V., Madrid, Spain
Dredging International N.V., Zwijndrecht, Belgium
Dredging International Scandinavia NS, Copenhagen, Denmark
Dredging International (UK), Ltd., Weybridge, United Kingdom
Enka-Boskalis, Istanbul, Turkey
Espadraga, Los Alcázares (Murcia), Spain
HAM Dredging Ltd., Camberley, United Kingdom
HAM, dredging and marine contractors, Rotterdam, Netherlands
HAM-Van Oord Werkendam B.V., Werkendam, Netherlands
Heinrich Hirdes G.m.b.H., Hamburg, Germany
Holland Dredging Company, Papendrecht, Netherlands
Jan De Nul N.V., Aalst, Belgium
Jan De Nul Dredging N.V., Aalst, Belgium
Jan De Nul (U.K.) Ltd., Ascot, United Kingdom
Nordsee Nassbagger- und Tiefbau GmbH, Wilhelmshaven,Germany
N.V. Baggerwerken Decloedt & Zoon, Brussels, Belgium
S.A. Overseas Decloedt & Fils, Brussels, Belgium
Sider-Almagià S.p.A., Rome, Italy
Skanska Dredging AB, Gothenborg, Sweden
Sociedade Portuguesa de Dragagens Lda., Lisbon, Portugal
Sociedad Española de Dragados SA., Madrid, Spain
Società Italiana Dragaggi SpA. "SIDRA", Rome, Italy
Société de Dragage International "S.D.I." S.A., Marly le Roi, France
Sodranord SARL, Paris, France
Terramare Oy, Helsinki, Finland
Tideway B.V., Breda, Netherlands
Van Oord ACZ B.V., Gorinchem, Netherlands
Van Oord ACZ Ltd., Newbury, United Kingdom
Wasserbau ACZ GmbH, Bremen, Germany
Westminster Dredging Co. Ltd., Fareham, United Kingdom
Zanen Verstoep B.V., Papendrecht, Netherlands
Zinkcon Contractors Ltd., Fareham, United Kingdom
Zinkcon Dekker B.V., Rotterdam, Netherlands
Zinkcon Dekker Wasserbau GmbH, Bremen, Germany

International Association
of Dredging Companies