International Association of Dredging Companies

Maritime Solutions for a Changing World

CONTRACTS FOR unforeseeable soil conditions

ENVIRONMENTAL IMPACTS mining seabeds versus quarries

SAFE DISPOSAL of dredged material using models
Guidelines for Authors

Terra et Aqua is a quarterly publication of the International Association of Dredging Companies, emphasising “maritime solutions for a changing world”. It covers the fields of civil, hydraulic and mechanical engineering including the technical, economic and environmental aspects of dredging. Developments in the state of the art of the industry and other topics from the industry with actual news value will be highlighted.

- As Terra et Aqua is an English language journal, articles must be submitted in English.
- Contributions will be considered primarily from authors who represent the various disciplines of the dredging industry or professions, which are associated with dredging.
- Students and young professionals are encouraged to submit articles based on their research.
- Articles should be approximately 10-12 A4. Photographs, graphics and illustrations are encouraged. Original photographs should be submitted, as these provide the best quality.
- Articles should be original and should not have appeared in other magazines or publications.

An exception is made for the proceedings of conferences which have a limited reading public.

- In the case of articles that have previously appeared in conference proceedings, permission to reprint in Terra et Aqua will be requested.
- Authors are requested to provide in the “Introduction” an insight into the drivers (the Why) behind the dredging project.

- By submitting an article, authors grant IADC permission to publish said article in both the printed and digital version of Terra et Aqua without limitations and remunerations.

- All articles will be reviewed by the Editorial Advisory Committee (EAC). Publication of an article is subject to approval by the EAC and no article will be published without approval of the EAC.

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COVER
Vulnerable creatures are often in need of beach nourishment. Shown here, a dredger diverts clean sand acquired at sea onto the beach by pumping through floating pipes, a method that is economically and environmentally advantageous compared to using quantified sand (see page 14).
EDITORIAL

ADVERSE PHYSICAL CONDITIONS AND THE EXPERIENCED CONTRACTOR
DAVID KINLAN AND DIRK ROUKEMA

Standard dredging contracts do not necessarily take into account “unforeseeable” soil conditions which can cause serious financial uncertainties. The time to consider these issues is before work commences.

ENVIRONMENTAL IMPACTS IN BEACH NOURISHMENT: A COMPARISON OF OPTIONS
ROBERTO VIDAL AND GOVERT VAN OORD

What is economically and environmentally better: obtaining sand for beach nourishment from an on-land quarry or from marine banks at sea?

SAFE DISPOSAL OF DREDGED MATERIAL IN A SENSITIVE ENVIRONMENT BASED ON INNOVATIVE PLUME PREDICTIONS
STEFAN AARNINKHOF AND ARJEN LUIJENDIJK

A state-of-the-art 3D plume model, used at the Ras Laffan Port Expansion project, simulates alternative disposal scenarios and helps develop Safe Disposal Maps.

BOOKS/PERIODICALS REVIEWED

Remote Sensing of Coastal Environments is part of a successful series published by Taylor and Francis and the newest publication in the IADC Facts About series is ready.

SEMINARS/CONFERENCES/EVENTS

WODCON XIX Conference and Exhibit in Beijing is only a few months away.
April was a remarkable month. On April 22nd 2010 more than 500 million people in 180 countries celebrated Earth Day, a project that was conceived forty years ago, when in 1970 a group of twenty-year-olds initiated an academic project to arouse awareness about the then-polluted rivers and air. Their efforts sparked a movement. Nowadays, not only environmentalists, but also political decision-makers and the business community in many countries have turned this day into a celebration of the Earth and a moment to remember the environmental challenges still before us.

In fact, also in April the environmental challenges and the vulnerability of our planet were acutely brought home when the Icelandic Eyjafjallajoekull volcano steadily spewed a cloud of ash into the atmosphere. According to European aviation officials, the April 15th eruption closed 80% of Europe’s airspace for as long as six days, disrupting travel within, and to and from, Europe, causing the cancellation of more than 100,000 flights, disturbing the travel plans for some 10 million passengers and costing the airline industry an estimated 2 billion euros. Other economic sectors felt the pinch as well. Vegetable and flower farmers in Zambia and Kenya, as well as US seafood exporters depend on the speed of air travel to get their goods to market whilst they are fresh. So at first glance, the steaming volcano looked as though it could cause disruption of the delivery of food and other perishables. What was under-reported is that, in fact, 40% of the EU’s internal trade and almost 90% of its external trade travels by sea, via inland waterways, rivers and/or ocean-going freighters. With some rerouting, food commodities and other perishables from Africa were transported to Spain by air and then overland and oversea to the UK and elsewhere. Why was this possible? Because the maritime infrastructure in Europe is well developed. Thanks in great part to the advancements of the international dredging industry, inland-water transport on European rivers and waterways are well utilised, and harbours such as Felixstowe, Rotterdam, Hamburg, Le Havre, Antwerp and others are state of the art.

Now in May air traffic in Europe is again threatened with disruptions as volcanic eruptions continue. Hopefully, with these experiences, more people may notice that waterborne transportation is the most environmentally friendly form of commercial transportation. When the talk turns to sustainability and low carbon emissions, the maritime industry is in the forefront. Perhaps this will give continuing impetus to improving and maintaining rivers for inland water transport as well as port and harbour development globally. Perhaps it will help re-establish ferry services between the European continent and the UK and elsewhere. Imagine if more cruise ship harbours were built to accommodate an increase in cruise ship vacations to replace the crush and rush of air travel.

For the dredging industry, Earth Day has a literal meaning, because literally that is what dredgers do – move earth from the seabed and place it onshore to extend land areas, build airports, extend ports and harbours, deepen shallow access channels and defend vulnerable coastlines and coastal communities threatened by rising ocean temperatures.

Environment and sustainability are always on the minds of the dredging community: Be it the efforts to reduce CO₂ emissions, as described in the Terra article on marine mining versus quarrying for sand or the article on the safe disposal of dredged materials in sensitive environments. In fact, as the first Terra article points out, the basis of all reasonable dredging endeavours and contracts is the careful analysis of the physical conditions through an accurate soil investigation report. Efficient, cost-effective and environmentally sound maritime construction and dredging are always the goals of the international dredging companies – on Earth Day and everyday.

Koos van Oord
President, IADC
ADVERSE PHYSICAL CONDITIONS AND THE EXPERIENCED CONTRACTOR TEST

ABSTRACT

The assessment of a Project’s soil conditions is the most important factor to determine dredgeability, the choice of suitable equipment, production rates and ultimately the associated costs for the dredging works. The basic principle of “adverse physical conditions” is whether or not they are foreseeable and whether or not there is a contract clause that will give the contractor the right to claim for additional time and money in case unforeseeable physical conditions occur, which were not reasonably foreseeable by “an experienced contractor,” the term commonly used by FIDIC.

A prudent tenderer when analysing the site data needs to be assured that the data has been collected and prepared by a competent soil investigation company in accordance with relevant international standards such as British Standards (BS) and American Society for Testing and Materials (ASTM) or others. Three examples are described to illustrate the direct relationship between dredging costs and actual soil or rock conditions encountered with examples of the relationship between soil and rock conditions on production and costs. Variations in soil or rock conditions contribute the greatest cost uncertainty involved in dredging projects.

Rather than rely on a standard adverse physical conditions clause in the case of significant capital works involving excavation of varying subsoil, weathered or solid rock, the suggestion is made that contracting parties should preferably establish limiting reference conditions in the Contract beyond which the Contractor is entitled to claim for additional compensation.

Of the contracts available for use on dredging contracts only the FIDIC 1999 Red Book and the United Kingdom’s NEC 3 Engineering and Construction Contract deal with the broad concept of reference conditions.

SOME SUGGESTIONS AND RECOMMENDATIONS

Some suggestions and recommendations are outlined therein for both Employers and Contractors. The authors wish to thank Jim Anderson and Bart Graswinckel for their peer review of the article.

INTRODUCTION

The concept of how adverse physical conditions are dealt with verges on the holy grail of marine infrastructure projects. On the one side they are part of a Marine Contractors “must have” clauses whilst Clients often view it as the equivalent of a “get out of jail free” card. The balance of risk has been hotly debated and fought over the years with the results little published or revealed due to disputes being resolved in arbitration or adjudication.

Added to this mix is the notion of “unforeseeability” and what “an experienced contractor,” the term used by FIDIC, can expect. It is no wonder that the vast majority of marine infrastructure claims revolve around the issue of sub-surface conditions.

The assessment of a Project’s soil conditions is the most important factor determining dredgeability, the choice of suitable equipment, production rates and ultimately the associated costs for the dredging works. Even a full-scale and technically perfect soil investigation will only test a fraction of the volume of material that is to be dredged by the Contractor. Combined with the fact that natural conditions like rock strength,
grain size, permeability, plasticity, presence of rock outcrops or boulders (to name a few) vary enormously, it is no surprise that disputes on dredging contracts often focus on conditions that are claimed to be different from what an experienced contractor could reasonably have foreseen.

This article examines the relationship between site inspection, unforeseeability and adverse physical conditions and their incorporation in contracts ranging from the UK’s ICE/ECC Contracts to their use in international construction contracts such as FIDIC, and their evolution over the years to the present day. Although the article focuses on sub-surface conditions, it should be realised that a broader spectrum of conditions such as wind, wave, current and human-made obstructions can also fall under the concept of “adverse physical conditions”. The article is dedicated to the memory of Frank Kinlan and the crews of the CSD Port Sunlight and TSHD Gouda who battled to dredge caprock in Manama Harbour, Bahrain in 1975 (Figure 1).

**BASIC PRINCIPLES**

The basic principle of foreseeability of adverse physical conditions is whether or not there is a contract clause that will give the Contractor the right to claim for additional time and money in case unforeseeable physical conditions – conditions not reasonably foreseeable by an experienced contractor – are encountered.

This simple principle is present in one way or the other in virtually every dredging contract. A dual purpose lies hidden behind this contract principle, namely to:

– *Compensate the Contractor* for encountering conditions more severe than could be derived from investigations available at the time of preparing the offer. Employers must not and should not expect the Contractor to gamble: Taking a risk provision to cover every imaginable situation would make an offer non-competitive, whereas the absence of a risk provision is a denial of the fact that dredging by its very nature has significant uncertainties. Employers tend to be overly

**CASE STUDY: REFERENCE CONDITIONS AT ØRESUND CONTRACT NO 2.**

At this project involving dredging of a trench in very weak to very strong rock, the soil investigation of the Employer was the basis of the BoQ (Bill of Quantities, with respect to quantities in the different rock qualities). Tenderer had to price these as part of his offer, resulting in a wide range of unit rates for the various grades of limestone as specified in the Contract.

Furthermore, a system of Reference Conditions was applied. The Contractor executed an additional soil investigation programme after award but before commencement of the works. The investigation was executed in accordance with an approved quality proposal with respect to geotechnical methodology, sampling and laboratory work. This investigation would reveal if rock indurations of the different rock grades were within their specific Reference Frames. This acknowledged the fact that during dredging different soil properties cannot be determined with accuracy nor reliability. The basic idea of the Reference Conditions system was that if the Contractor could prove (according to the results of his investigation) the quantities of the various bill items were no longer correct and that the quantities of the stronger rock grades were underestimated, the Contractor would be entitled to additional compensation. Following the preparations this compensation could simply be determined by renewed application of agreed unit rates.

This is a good example of a predefined system that can be used to make the uncertainty involved in “unforeseeable” physical conditions manageable for both the Employer and the Contractor embarking into a Contract.
biased towards achieving the lowest contract price for their work by passing all conceivable risk to the Contractor whether or not the Contractor is in a position to deal with such risk.

– **Protect the Employer** from Contractors who may try to claim additional compensation for interpretation or calculation errors made by the Contractor which result in a loss on the project. A loss in itself is no justification for additional compensation; furthermore an Employer has very limited possibilities to assess the factual cause of the loss.

In between the relative simplicity of these two extremes lies a gray area, and it is here that disputes are generally fought out. The authors support the view that a sufficiently high threshold for additional compensation should be present, balancing the interests of the Employers (by not having to battle over every minor issue) and of the Contractors (by having capped their risk and providing for additional compensation above a given threshold).

A further suggestion is that a risk matrix framework be established to assess the magnitude of the additional compensation before award of the contract.

**INSPECTION OF THE SITE**

Before tender submission, the Contractor is generally under an obligation to inspect the Site to evaluate the influence which the local conditions will have on the work to be carried out. But how is this inspection conducted when the Site consists of an expanse of water and a sub-surface many metres below it?

In general, the only chance tenderers have to do their own inspection will be on the site visit when they can do a visual inspection of the surrounding geology and geo-morphological aspects surrounding the Site (Figure 2). Land-based sources such as rock faces, road cuttings or nearby quarries can provide a useful guide, but nothing beats soil or rock samples taken from the Site itself and/or the location and immediate vicinity where the dredging is to be undertaken (Figures 3 and 4).
tenderers to weigh the information provided to them when making their own assessment. This principle was embraced and carried forward into the 3rd and 4th Editions of the FIDIC Red Books where Contractors were deemed to have based their Tenders on the data made available by the Employer, together with their own inspections and examinations. However what constituted the Contractor’s inspection and examination and whether this meant that the Contractor was obliged to source information about the Site and its environment remained unclear.

The IADC in its 1990 FIDIC User Guide publication attempted to remove any doubt as to inspection and examination with the suggestion to amend the standard FIDIC wording such that the tender was based solely on the Employer supplied data. This precept was largely resisted by Employers and Consultants tasked with drafting the terms and conditions of contract. As a balance and to avoid a Contractor “ambush” and claims of misrepresentation of information, Employers felt that Contractors should not entirely rely on the information provided by the Employer when there were circumstances when they had their own possibly conflicting information.

The more recent FIDIC Red Book 1999 includes in clause 4.10 [Site Data] that the Employer shall have made available all relevant data in the Employer’s possession both before and after the Base Date in the Contract. This is balanced by the provision in the same clause that the Contractor shall be deemed to have obtained all necessary information as to the risks, contingencies and other circumstances “to the extent which was not provided that the Contractor shall have “Inspected and examined the site, its surroundings and available information, and, shall have satisfied himself before submitting his tender as to the nature of the ground and subsoil”.

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The clause did not oblige the Employer to provide any information in its possession and in the past Employers were reluctant to provide such information to tenderers for fear of how this might negatively affect bid prices. Not surprisingly claims were the result. Fortunately this “no site information” loophole was closed with the publication of the FIDIC 2nd Edition 1969 which stated that the Tender shall be deemed to have been based on such data regarding physical conditions as shall have been supplied by the Employer in the documents furnished to the Contractor by the Employer for the purpose of tendering. It would then be up to the tenderers to weigh the information provided to them when making their own assessment.

Table I. Comparison of Site Investigation Techniques

<table>
<thead>
<tr>
<th>Technique</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seismic and geophysical methods: Sub-bottom profiler, parametric echosounder, chirp system, sparker, boomer.</td>
<td>Useful to establish the likely geology over a large area. Will assist to set-out a borehole grid and fill in detail between borings.</td>
<td>An expert is needed to choose best combination of available systems for the job at hand. Careful interpretation of data is needed. This can often lead to discussion. Especially vulnerable if only slight changes in strata occur (i.e. no distinct boundary between layers).</td>
</tr>
<tr>
<td>Side scan sonar</td>
<td>Detection of bottom surface and objects.</td>
<td>Not suitable for assessing soil properties.</td>
</tr>
<tr>
<td>Jet probes</td>
<td>Relatively easy and quick method to establish point readings for top of rock.</td>
<td>No other purpose. Accuracy doubtful: May identify boulders rather than top of rock.</td>
</tr>
<tr>
<td>Rotary drilling</td>
<td>Best method of obtaining core samples of intact rocks in-situ conditions.</td>
<td>Operated from platform. Weather delay while repositioning. Expense. Assessment of conglomerates or weathered rock is critical.</td>
</tr>
<tr>
<td>Shell and Auger boring</td>
<td>Method employed in order to obtain representative and undisturbed samples.</td>
<td>Usually operated from platform, otherwise prone to ship movements. Not applicable for rock or conglomerates.</td>
</tr>
<tr>
<td>Vibrocores</td>
<td>Frame lowered to seafloor. Relatively low costs.</td>
<td>Maximum penetration some 3 to 5 metres. Only suitable for sandy clayey soils. Slightly disturbed samples.</td>
</tr>
<tr>
<td>CPTs</td>
<td>Continuous reading of cone pressure and shear along penetration length. Indication of soil type in cohesive and sandy soils.</td>
<td>Not applicable for rock or conglomerates. No samples.</td>
</tr>
<tr>
<td>SPTs</td>
<td>Commonly used world-wide, yielding an indication of relative density. Combination with sampling.</td>
<td>Precise execution according to standard test often compromised. Large scatter in relation of relative density to SPT. Not to be used in cemented sands.</td>
</tr>
<tr>
<td>Van Veen sampling</td>
<td>Low cost.</td>
<td>Disturbed sample, from top of seabed.</td>
</tr>
<tr>
<td>Laboratory testing</td>
<td>Establish required engineering values (either classical soil mechanic parameters or special dredgeability indicators). A well-drafted laboratory programme greatly enhances the value of the in-situ investigations.</td>
<td>Often time-consuming. Selection of samples not to be underestimated. Same is true for proper reporting.</td>
</tr>
</tbody>
</table>
practicable (taking account of cost and time)”. The consensus is that in the limited time made available to tenderers, they cannot be expected to do the same degree of discovery of site investigation information as the Employer.

The onus is thus placed on the Contractors to review their own soil databases to confirm whether they may have any supplemental information on the site and its immediate environment on file. The large international dredging contractors have considerable geotechnical databases of information gleaned from past tenders going back many decades and may have information which the Employers and their consultants do not have. Whilst tenderers are under no obligation to mention this in their offers, if the information conflicts with that supplied by the Employer then it would be advisable to inform an Employer that they are relying on other information, especially as their data may have a significant negative price impact compared to other tenderers.

The ICE Conditions of Contract 7th Edition has a clear provision (Clause 11(3)) stipulating that Contractors have based their tenders on information, whether obtainable by them or made available by the Employer, with the proviso that information obtained by the Employer shall only be taken into account to the extent it was made available to the Contractor.

One of the most contentious aspects of site inspection is to what extent tenderers should be obliged to do their own investigations and research from archives, libraries and local sources when evaluating the site information made available by the Employer.

Clearly a tenderer’s time is limited and the tenderer does not have the time or resources to do detailed research in the same manner as the Employer and Engineer who have had many months, and in some cases years, to collate information. Often when disputes go to arbitration the Contractor and the Employer spend a great deal of time and sums of money employing geotechnical experts to support their cases. These experts may have a more academic approach to the evaluation of available data than the Contractor’s production estimator, who just focuses on the information at hand - which is primarily the site information supplied by the Employer with some supplementary information from past works and a site visit.

**DATA PROVIDED BY EMPLOYER**

In FIDIC Red Book 1999 maintains a continuing obligation for Employers to supply all data which comes into their possession both before and after the Base Date, a date 28 days prior to the Contractors submitting their tenders. Contractually the Employer is obliged to be transparent when gaining information which will adversely affect the Contractors’ operations and the basis of their pricing of the Works.

Not supplying such information if it comes available to the Employer could possibly lead to a Contractor claiming fraudulent misrepresentation by the Employer in that it knowingly withheld information from the Contractor in order to avoid the negative cost consequences. Certain case law in England, Australia and the USA address the duty of the Employer to supply full information. This case law is by no means conclusive about the duty of disclosure, however, in Brown & Hudson v York (1985) an Employer was held liable for the Engineer’s negligence in omitting water levels from the soils information given to tenderers.

Generally the sub-surface site information which is supplied to tenderers in the tender documents will consist of the following:

- a) geophysical data;
- b) borelogs or vibrocores; and
- c) laboratory test results

Readers will be familiar with the various forms of geotechnical and site information (e.g., M.J. Stone, *Terra et Aqua* No. 48, 1992 as well as *Site Investigation Requirements for Dredging Works*, PIANC, 2000). Being aware of various site investigation techniques (Figure 5) and their advantages and disadvantages and the influence that can bear on the interpretation of the data is important (see Table I).

Tenderers are regularly confronted with problems arising from the quality of the investigations performed or the reporting of the results which is sub-standard. This greatly undermines the proper intention of making available sound geotechnical information to tenderers. Using an independent geotechnical engineer experienced in dredging to supervise the work of the company running the site investigation is highly recommended as a way to check on the quality of work and the subsequent reporting of the in-situ conditions and laboratory results.
**Witnessing site investigations to ensure competency**

A prudent tenderer when analysing site data needs to be assured that the data has been collected and prepared by a competent soil investigation company in accordance with relevant international standards such as British Standards (BS), American Society for Testing and Materials (ASTM) or others. Employers should seriously consider inviting potential tenderers to witness the soil investigation campaign because it can provide them valuable insights into what information the tenderers will focus upon. All potential tenderers should accept this invitation to witness the site investigation to ensure an equal chance of evaluating the site investigation techniques and results.

Employers not used to offshore work can sometimes be taken aback by the high cost of offshore site investigation. They may try to limit their budget for this and then pass the risk of the soil conditions onto the Contractor. This risk receiving qualified offers from the potential tenderers. It may also mean that the short-listed Contractors require their own supplementary site investigation, or that the winning tenderer will need to do further investigation post-contract and prior to commencement of dredging to verify the Employer’s own site investigation results.

All of this brings extra costs.

Consequently, a client should not scrimp on the costs of the site investigation, otherwise the old adage “penny-wise, pound foolish” would be particularly apt. Any apparent savings at this stage increase the risk of significant delays and claims for differing conditions when the project is underway.

**Status of information vs. interpretation**

Modern Contract Conditions oblige Employers to provide all information that is known to them during the tender process. A distinct difference should be made between “factual information” and “interpretations”. The correctness of the former will remain the responsibility of the Employer, being part of the data supplied as a basis for the Contract. However, for the interpretations it is recommended that the Employer clearly state that “any interpretation is for information only and is no part of the data supplied nor a basis for the Contract”.

Whatever the value of geophysical surveys, their interpretative nature will always make it recommendable to label it as “for information only” as opposed to any result from geotechnical investigation or laboratory analysis. FIDIC enshrined

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**Table 6. Comparison of results of common head loss prediction formulas.**

<table>
<thead>
<tr>
<th>Mixture velocity [m/s]</th>
<th>Head Loss [KPa]</th>
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<tr>
<td>Water</td>
<td>Durand/Gibert</td>
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**Figure 6. Comparison of results of common head loss prediction formulas.**
the principle between factual information and interpretation in FIDIC 4th Edition by stating that “the Contractor shall be responsible for his own interpretation” of any such data made available to the Contractor by the Employer.

DEFINING DREDGEABILITY
Three examples are described below to illustrate the direct relationship between actual soil or rock conditions and production and dredging costs. In practice, when disputes arise the comparison can be significantly more complex and a number of significant other factors may have to be taken into account. In summary, variations in soil or rock conditions contribute the greatest cost uncertainty involved in dredging projects.

Example 1: Grain size defines pumping production
Pumping soil-water mixtures through (long) pipelines requires energy to prevent the settling of the particles in the pipeline (head loss). Installed pump power is a limiting factor for any given dredger, hence the maximum pumping productivity that can be achieved is determined to a large extent by the actual head loss of the mixture.

When calculating head losses a broad range of empirical formulas exist. Van der Schrieck (2009) describes a few commonly used one-dimensional calculation procedures for heterogeneous mixtures (e.g., Durand-Gibert, Jufin-Lopatin, and Führböter) and shows the wide scatter present in the original test results. These (and other) calculation procedures indicate a very significant effect of grain size (usually dmf) on head loss and ultimately on pumping production. However, the results are quite different regarding the relative importance of grain size and mixture density on the head loss (see Figure 6 for comparative results).

To name a few complications associated with calculations of head loss:
– The formula of Jufin-Lopatin shows a head loss equal to the square root of the transport concentration, contrary to Durand-Gibert and Führböter in which the transport concentration has a power of one.
– Kazansky (1978) indicates that low, medium or high concentration values in fact require different prediction formulas, which is not commonly applied.

– Very high pumping concentration, feasible while emptying large trailing suction hopper dredgers, result in head losses significantly lower than predicted by classic empirical formulas. This is caused by hindered settlement: Due to the very high concentration the particles are preventing each other from settling, thus reducing the additional energy needed to keep them in suspension.
– The effect of fines (particles smaller than 63 micron) on the head loss is relatively unknown. The fines cause a decrease of the fall velocity of grains, effectively reducing the overall head loss. Van der Schrieck (2009) describes the straightforward calculation procedure by Bruhl.

When evaluating a dispute involving pumping productions that have been influenced by soil characteristics differentiating what is reasonable from unreasonable is not an easy task. An added complication is that most Contractors will have developed their own head-loss calculation procedure, based on but distinctively different from the above-mentioned criteria.

Granted that it is impossible to cover every single adverse condition in a contract beforehand, the chances of a settlement would be greatly improved by adding an appendix to the contract either specifying the outline of the calculation procedure in case of varying conditions or agreeing on unit rates for specific varying conditions. At least the discussion would then be narrowed considerably to a few elements.

Example 2: Rock strength and structure define cutting production
The two main geotechnical parameters which define the energy to excavate rock material are strength and structure. When evaluating these parameters a variety of tests, which describe parameter values, are available. From these the often-used measure of “specific energy” can be derived.

Specific Energy is defined as the amount of energy needed to excavate a volume of rock (in formula: $E_{spec} [\text{MPa}] = \text{cutting power} \ [\text{kW}] / \text{cutting production} \ [\text{m}^3/\text{h}]$). The physics of the process is very complex and is still only partially understood and information is not widely published because of the desire to protect innovative knowledge.

All dredging contractors use their own production calculation models, based on a combination of theoretical basics and practical experience with their equipment in a variety of rock conditions. In this respect technological developments are a significant factor which should not to be underestimated (see Wijma 2009).
To illustrate the importance of properly establishing the geotechnical conditions on a project, results from a simplified and indicative model are shown here (Figure 7), with Specific Energy being based on Unconfined Compressive Strength and Rock Quality Designation.

Assume the actual UCS-value (case B) is 15% more than the estimated value based on rock data (case A), and RQD value is 80% instead of 60%. This model indicates a reduction of the production rate per operational hour of 50%(!). In addition to this, the wear rate of all dredge parts will increase significantly, adding to the weekly costs. The idle time for repair of worn parts like cutters and pickpoints will increase significantly as well, reducing efficiency hence weekly production even further (Figure 8). In this example, the actual total costs (case B) could well be twice the estimated value (case A). Project duration will also increase significantly.

Poorly carried out site investigation programmes, along with associated lab tests on the rock samples, can easily result in a failure to predict the conditions correctly. The choice of drill locations, sample selection, budget constraints on the number of test locations, compromising quality during execution of investigation, post-investigation layout shifts, are a few likely causes for test results not being representative for the actual situation encountered during execution of the dredging works. The example above gives an indication of the possible consequences from actual conditions being adverse from anticipated ones.

**Example 3: CSD dredging sandy material**

Dredging sandy material with a CSD (Figure 9) and depositing it at a relatively short distance is limited, mainly by the excavation production (until the suction limit of the first dredge pump is reached, indicated by the dashed line in Figure 10). Figure 10 indicates the importance of soil characteristics.

A soil investigation that is not executed properly, for instance, failing to report any slight cementation or small layers of cohesive material, will under-report the actual geotechnical parameters for Contractors to base their production assessment correctly.

**ADVERSE PHYSICAL CONDITIONS**

The FIDIC 1st Edition 1956 included “Clause 12” to deal with Adverse Physical Conditions and Artificial Obstructions. The clause stated that if during the execution of the Works unfavorable physical conditions (other than weather conditions) were encountered, which could not in the opinion of the Engineer have been reasonably foreseen by an experienced contractor, then the Engineer should certify and the Employer should pay the additional expense by reason of such conditions.

The basic principle contained in Clause 12 has remained in the ICE and FIDIC suite of contracts (other than the FIDIC Silver Book) for more than 40 years with only very minor modifications. The Australian Standard suite of contracts also has a Clause 12 dealing with “latent conditions” which, although worded differently, contains the core provisions of the ICE/FIDIC Clause 12.

The courts have only very rarely dealt with Clause 12 as written in Ceredigion CC v Thyseen Construction Ltd (1999): “Those who drafted clause 12 and those parties who chose to include it in their contracts conferred on an engineering arbitrator a very wide discretion with which the Court had in general no wish to interfere”.

A radical overhaul occurred with the issue of the Rainbow suite of FIDIC Contracts in 1999. The FIDIC Contracts Committee perhaps sensed the need to guide arbitrators as to some of the meanings in Clause 12 and sought to give definitions. New to the clause was the definition of “physical conditions”
and “unforeseeable”. The former had a wide definition to include natural physical conditions, physical obstructions, man-made obstructions as well as pollutants and hydrological conditions, whilst excluding climatic conditions. The definition of “unforeseeable” in the new FIDIC 1999 is “not reasonably foreseeable by an experienced contractor by the date for submission of the tender”.

In the UK the widely used NEC3 has as a Compensation Event in Clause 60.1 (12) which states that if the Contractor encounters physical conditions, which an experienced contractor would have judged at the Contract Date to have such a small chance of occurring, then it would be unreasonable to consider that the Contractor should have allowed for such in his pricing. It further states that only the difference between the physical conditions encountered and those which it would have been reasonable to have expected should be taken into account.

There is little published material to guide Employers and Contractors in the operation of physical conditions and unforeseeability and what constitutes an “experienced contractor,” and the relevant case law is sporadic.

**Case study UK**

The first significant case which dealt with what constitutes a physical condition was the *Humber Oil Trustees Ltd v. Harbour & General Works (Stevin) Ltd* (1991) which concerned the collapse of a jack-up barge resulting from encountering an unforeseeable condition in the soil under one of the legs. The soil had a liability to shear at a much lower loading than had been withstood up to the date of the accident. The Employer argued that physical condition referred to a material thing such as rock or running sand not intransient conditions such as applied stress. The arbitrator in his decision found that an experienced contractor could not have reasonably foreseen this condition. The judges in the Court of Appeal agreed with him stating that the soil behaved in an unforeseeable manner and that was a physical condition within Clause 12.

This decision offered some guidance to arbitrators when determining Clause 12 claims in not being too restrictive when assessing what constitutes a “physical condition”. The FIDIC 1999 Red Book has gone some ways to defining physical condition as meaning natural physical conditions and man-made and other physical obstructions and pollutants including sub-surface and hydrological conditions, but excluding climatic conditions.

With respect to what is unforeseeable with the definition as given, the Contractor in his notice must merely establish that based on the information available at time of tender, a reasonable thorough investigation would not have brought to light the particular adverse physical condition which is causing the delay. This is based on the principle that the Contractor has a limited ability to inspect and examine all possible data. The FIDIC Contracts in both the 4th Edition and 1st Edition 1999 maintained the principle that the Contractor was limited “to the extent which was practicable taking account of cost and time”, it being important that both Employers and arbitrators are aware of the extent of a Contractor’s own investigation.

**Case study Australia**

A more recent case in Australia sheds some interesting light on the aspect of disclaimers, notices and the examination of information supplied by the Employer. The case is *BMD Major Projects Pty Ltd v Victorian Urban Development Authority* [2007] VSC 409.

It was a latent (physical) condition claim under the Australian Standard AS 2124 contract. So-called “disclaimers” were stated to be for the benefit of the Contractor and not for the Employer to avoid liability for the information given. Concerning the requirement to examine all data made available by the Employer, the Judge found that this was an objective test (i.e. related to facts and not subjective, that is based on opinion or interpretation) and that it was unreasonable to expect the Contractor to undertake or seek expert advice or analysis to look for inaccuracies in the information supplied. It was found that a reasonably competent contractor could not have been expected to investigate the information to the extent claimed by the Employer.

**ESTABLISHING ADDITIONAL COSTS FOR UNFORESEEN PHYSICAL CONDITIONS**

The dredging process itself remains a mystery for a large number of Employers, and the mystery is even more profound as to how costs for dredging projects are comprised. In a dispute situation, with a level of mutual trust being generally low, the situation gets worse and the Employer does not believe any of the figures of the Contractor are true (irrespective of the factual truth). It is then left to the dispute resolution process to determine compensation based on expert opinion and the balance of probabilities with the adjudicator or
arbitrator believing one party or the other (Figure 11).

Contractors often have to put in considerable effort to back up a claim, not just with site records but also with reference to theoretical publications in order to prove their point. This is not an easy task, since often knowledge of the dredging process is not openly published. No solution for this inherent inequality of knowledge is in sight.

For the contracting parties two options remain:
– Accept the unpleasant consequences of disputes and deal with them if and when they occur, or
– Deal with the possibility of unforeseen conditions, and their consequences in terms of additional compensation before award of the Contract.

The second option has its limitations, but often in the pre-award stage an agreement describing the consequences of an unfavorable variation of a number of key characteristic engineering parameters of the soils or rocks to be dredged can be reached. Combined with a threshold value that effectively acts as an upper value for the Contractor (capping the Contactor’s risk) and a lower value for the Employer (budget consequences only above this value), both Parties agree on the basics for solving a dispute of unforeseen physical conditions. This conceivably will greatly improve the chances of a smooth settlement.

General recommendations on the threshold value to be chosen are not appropriate: During every contract that is drafted one should carefully evaluate the options and the preferences of the Employer. Generally, the range between the upper limit of the conditions encountered during the geotechnical investigations and the chosen threshold value determines the level of risk the Contractor has to absorb.

This is to be reflected in the base rate (being valid for all conditions below the threshold value). In case the threshold value is close to the technical limitations of the dredging equipment planned for the project, the Contractor’s risk increases even further.

Of the contracts available for use on dredging projects only the FIDIC 1999 Red Book and the UK’s NEC 3 Engineering and Construction Contract deal with the broad concept of reference conditions.

In the FIDIC 1st Edition 1999 in both the “Red” and “Yellow” Books, when evaluating a claim the Engineer may also review whether other physical conditions in similar parts of the Works were more favourable than reasonably could have been foreseen to counterbalance the Contractor’s claim, providing any adjustment is not lower than the original Contract Price.

The NEC 3 EEC Contract takes this a stage further. In the Guidance Notes it states that all that is necessary to substantiate a claim is a clear definition of the reference conditions, with conditions outside the reference condition boundaries constituting a compensation event. It is thus sensible to define criteria recognising that conditions in the new investigation are outside the reference boundary conditions. This can be detailed by using Option Z in the contract to describe the boundary conditions in the form of soil characteristics, level of rock, and so on.

It should be noted that the FIDIC “Blue Book” Form of Contract for Dredging and Reclamation Works just relies on site data the Employer has made available at time of tendering, together with the basic principle of what is reasonably foreseeable by an experienced Contractor.

Users should not rely on the statement in the Notes for Guidance that the contract is intended to be suitable for all types of dredging and reclamation work as there is no allowance for the application of reference conditions.
CONCLUSIONS

Employers should ensure that an extensive and sound geotechnical investigation is executed before or during the tender process for a dredging project. An independent geotechnical engineer experienced in dredging should supervise the work of the company running the investigation, to check on the quality of work and the subsequent reporting of the in-situ conditions and laboratory results. Employers should seriously evaluate the option of inviting all Tenderers to witness the investigations in cases where varying subsoil conditions are expected.

Professional Employers and Contractors should be transparent concerning their assessment of the available site investigation data whilst negotiating and entering into a contract. Potential geotechnical related risks should be openly discussed before the award of the contract. This may increase the possibility that additional payments have to be made upfront; however, these payments will be significantly less and the effort involved can be considerably reduced by avoiding the need to resort to dispute resolution to resolve any disagreements.

Rather than rely on the basic adverse physical conditions clause in the case of significant capital works involving excavation of varying subsoil, weathered or solid rock, it is suggested to apply reference conditions in the Contract based on the actual information which can easily be measured and reviewed from the soil survey, outside of which the Contractor is entitled to claim additional compensation.

Employers should not rely on blanket disclaimer provisions in respect of the accuracy of all data supplied to tenderers as they are proven to be ineffective. In case it is not reasonably possible for Employers to eliminate specific issues on accuracy, completeness or ambiguity of the information before asking for tenders, a qualification can be added that the data are “for guidance only”, alerting tenderers to take particular care if they intend to use this information.

Where tenderers are concerned as to the accuracy, completeness or ambiguity of information supplied by the Employer they should not remain silent and should raise their concerns prior to tender submission.

If the Contractor has concerns as to the information given and considers that supplementary site investigation should be undertaken prior to commencing with the Works, then both parties should consider the option to agree on unit rate variations relative to characteristic soil parameters beforehand.

Each dredging project is unique in its scope, conditions and the potential for adverse conditions. Although much can and should be learned from former experiences, preparing a Contract should involve more than briefly re-visiting and revising a previously used contract. Careful analysis of the project characteristics and choosing the required contractual balance will eventually save time and money, and probably lengthy disputes as well.

REFERENCES


de Kok, Maurice, Dirks, Wouter and Hessels, Rienk (March 1997). “The Øresund Fixed Link: Dredging Reclamation”. Terra et Aqua Nr. 66.


Wijma, K. (2009). Wear resistant dredge cutter teeth - a look at the development of the tooth and its impact on the economical and environmental aspects of dredger logistics and foundry. CEDA Dredging Days Proceedings, Rotterdam, the Netherlands.

ABSTRACT

It is estimated that by 2100 the average temperature increase on our planet will fluctuate between 1.8 and 4°C. This will lead to coastal retreat, brought about by a rise in sea level of between 20 and 60 m. Data from the *Eurosion Report* presented in 2004 shows that 20,000 km of coastline in European Union countries had serious sustainability problems. The need for corrective measures on the coast is undeniable.

Corrective measures generally fall into two categories – hard and soft solutions. “Hard solutions” such as breakwaters, stone filling, walls, free dykes, and so on, have only proved to be effective in the short term and at a local level. In fact these solutions have sometimes shown negative results such as the unsightly structures and the building up of sand on beaches. On the other hand, the negative effects of “soft” techniques of artificial sand replenishments are only temporary. “Soft solutions”, however, depend on extraction of sand and so a lack of sources for extraction (either quarries or marine banks) and/or the biotic effects of extraction must be analysed.

That said, “soft solutions”, where replenishment sand is taken to a beach, has generally been proven to be effective and economically feasible. This article focuses on the comparison of the most common two origins of sand: quarries and marine banks. Quarry sand comes from open-air operations and the sequence of operations for obtaining sand (blasting, crushing, sorting, sieving, land transport to the beach and the spreading of it) has notable environmental impacts. Quarries are eyesores that spoil the surrounding landscape and lead to the desolation of the countryside. Quarrying also has an effect on surface and underground waters in the area and causes substantial emissions of CO₂ throughout the process.

The process of beach nourishment through dredging – extraction from marine banks, sea transport and final spreading on the beach – will have an effect on nature by changing water levels and currents, turbidity and by causing the disturbance of sediments and the destruction of natural habitats. In each specific case, a rigorous study must be undertaken to evaluate the environmental impact of each of these factors on the chosen process and thus determine the viability of the proposed form of replenishment.

All things considered, in comparison to obtaining sand from a quarry, beach nourishment with sand from marine banks, in many cases and countries, has become a normal practice that has very satisfactory results. The research concludes that the execution period by dredging is of the order of ten times shorter, the price is between two and three times lower, and it emits seven or eight times less CO₂.

INTRODUCTION

In 1995 the IPCC (United Nations Intergovernmental Panel on Climate Change) stated: “Evidence suggests a certain amount of human influence on global climate. The differences in mean temperatures on earth between the glacier age and the present are about 5 or 6°C. Modifications of 2 or 3°C could rapidly change the climate”.

By the end of this century, the overall temperature of the Earth may rise by between 1.8 and 4°C and may lead to an increase in the sea level of between 18 and 60 cm,
Environmental Impacts in Beach Nourishment: A Comparison of Options

causing a retreat of the coastline of 20 to 60 m, depending on the location an earth.

Following the global average, it has been shown that between 1993 and 2005, the sea level in Spain rose by 3.3 mm per year (Figure 1). The coastline is an extremely fragile area. Today, as it is structured, it cannot defend itself against climate change.

Data supplied by the European Union are relevant. The Eurosion Report (2004) stated that 20,000 km of European coast (20% of the total) are affected by serious impacts, estimating that public expenditure on coastal protection were 3,200 million euros. In the EU in 2001, protection projects were under way along 7,600 km.

Human presence is intensive along the coast. In Spain, one out of every three inhabitants lives in a 5 km band along the coastline. That is, 35% of the population lives in 7% of the territory. This is an area that generates 14% of the GDP. In the last 50 years, the population of coastal municipalities has more than doubled.

The consequences of coastal flooding would have significant impact in many regions around the globe:

– Damage and economic risk for coastal cities and basic infrastructure. Eight out of ten largest cities on Earth are located near the sea. In the EU alone, more than 70 million persons live on the coast.

– Losses of territory and frontier disputes, including the disappearance of entire countries located on small island states.

– Massive migrations. In Asia alone, 40% of the population (almost 2,000 million persons) live within 60 km of the coast.

– Generalised conflicts over the possession of resources, because of the reduction of cultivatable land, the lack of drinking water, increased flooding, and so on. In the Nile Delta, for example, the rising sea level will cause the salt pollution of wide agricultural areas; it is estimated that between 12% and 15% of the cultivated land will be lost by 2050, affecting more than 5 million persons.

The increase of temperature globally has come an increased risk of flooding along the Spanish coast.

Figure 1. With the increase of temperature globally has come an increased risk of flooding along the Spanish coast.

Figure 2. Stone jetties are one of the hard solutions to coastal flooding.
One must also think of oil reserves, a large part of which are in Saudi Arabia and the Arab Emirates, at a very low level above the sea and, therefore, very vulnerable. All of this could lead to instability in many nation states, situations of radicalisation between them and a dangerous pressure on international governability. Corrective measures are absolutely necessary to minimise the probability and effect of coastal flooding as a result of climate change.

CORRECTIVE MEASURES FOR COASTAL EROSION BY SUPPLYING SAND TO BEACHES: HARD AND SOFT SOLUTIONS

As is well known, corrective measures are often defined as either “hard” or “soft” solutions. “Hard solutions” are based on the installation of breakwaters, blocks, rock fills, sea walls, free dykes, defences and such solutions with the following properties (Figure 2):
- Effective over the short term.
- Effective in limited sections.
- They may have a visual impact.
- Building up of the beach (domino effect).

The “soft solutions” are based on artificial nourishment with sand (Figure 3), the main properties of which are:
- Effects are temporary.
- Resources for extraction whether on land (quarries) or marine banks are scarce.
- Biotic impacts must be evaluated.

Although a hard solution may be acceptable in many cases, a soft solution is preferable where it is possible.

ENVIRONMENTAL ASPECTS OF BEACH NOURISHMENT

Although not always, generally speaking sand for replenishment comes from two sources: land, i.e., quarries, and the sea, from marine banks on the seabed. The construction processes and the issues of regenerating beaches are different, depending on the origin of the sand. In each specific case, a rigorous study must be undertaken to evaluate the environmental impact of each of the factors of the chosen process in order to determine the viability of the proposed form of replenishment.
Sand from quarries
If the sand comes from a quarry, the operation will take place in the open air (Figure 4). The sequence of nourishing the beach is:
– Quarrying the rocky material by blasting.
– Loading and transporting the material from the quarry to the crushing plant.
– Crushing the rock in the crushing plant which, for sand, involves four stages of crushing, each with the relevant feeders, sieves, conveyor belts, intermediate stockpiles, sand washers, and such.
– Loading and transporting the sand from the quarry to the beach.
– Spreading the sand on the beach.

What are the most important ecological effects in the process of sand-winning from a quarry?
– Disturbing the natural terrain and animal life as a result of the process of cleaning the area prior to blasting.
– Visual impact: After the stone is extracted and the plant coverage removed, a desolate landscape is left, bare and without live resource (Figure 5).
– Effects on aquifers, canals and surface and underground water courses in the area which could have environmental consequences such as rainwater retention, interruption of underground irrigation to specific ecosystems, dust invasion forming mud, and so on.
– Important emissions of CO₂, as will be seen below.

Sand from marine banks
Sand can also be obtained from marine banks with the following construction process:
– Extraction of the sand from the seabed by dredging.
– Sea transport from the marine bank to the beach.
– Pumping of the sand by pipes from the dredger to the beach.
– Spreading the sand on the beach.

What environmental impacts are involved in winning sand from marine banks?
– Disturbing and burying of habitats and the stirring up the seabed (Figure 6).
– Changes in the flow of water, currents and waves in the area of extraction as a result of creating deeper bottoms.

– Putting contaminated products in suspension, if they exist.
– Turbidity that reduces the supply of light to the system with the consequent damage to the photosynthesis process and the incorporation of oxygen in the water. Coral beds, the breeding grounds for fish and molluscs, for example, are especially sensitive to this phenomenon. The impact could be damaging if it is maintained over the long term.

Turbidity
It is necessary to open a parenthesis here to mention some questions regarding turbidity in dredging because sedimentation is seen as a highly adverse factor from the environmental point of view. For greater redundancy, sediment plumes are always associated with dredging. There are proofs of this in European Union directives. Dredging is anathematised for this reason. But turbidity is not a phenomenon created exclusively by dredging.

There is natural turbidity (Figure 7) in the estuaries of deltas, flooding of rivers, on beaches after a storm. According to a 1996 study of the Mississippi River, sedimentation extends over 450 km² when the discharge is low and 7,700 km² in times of flooding, with concentrations of between 10 and 30 mg/l. The sediments discharged by the River Guadalquivir in Spain are estimated at 20,000,000 m³ per year.
Turbidity caused by other human actions such as fishing, for example, must also be mentioned. The area of seabed affected by trawling in United Kingdom in 2001 totalled some 1.23 million km².

Some areas were fished four times per year. Nevertheless, the area of seabed affected by maintenance dredging in the United Kingdom in the same year totalled 35 km², representing 0.003% of the area altered by fishing. Another example is in navigation, caused by the effects of the propellers of ships manoeuvring in shallow water. Data taken in 2007 show that sometimes these actions create sediment concentrations of 90 mg/l at 2 m from the surface after 50 minutes of occurring and 40 mg/l after 65 minutes.

Studies carried out in 1993 on a suction dredging process provided average turbidity data. At 100 m from the dredging on the surface, levels of 20-30 mg/l were measured 30 minutes after occurring and 40 mg/l around the same dredging after 15-20 minutes.

To summarise, it must be said that turbidity plumes generated by natural processes, trawling and ships are comparable to those produced by dredging, with this last case being shorter over time and of lesser extent (Figure 8).
“Soft” solutions by nourishing beaches with sand have been shown to be effective and economically feasible. Most European beaches are permanently being artificially regenerated by supplying them with sand.

The Tables I, II and III shown here analyze a beach regeneration project in two cases:
a. when sand is obtained from a quarry and 
b. when sand comes from a marine bank.

In both cases a detailed calculation of the CO₂ emissions produced is presented.

Table I shows the most important properties of the example, a regeneration with 500,000 m³ of sand, a size of D₅₀ = 0.5 mm.

The origin of the sand is:

**Case a:**
- a quarry 30 km (= 18 miles) from the beach.

**Case b:**
- a marine bank at 30 km from the beach and at a depth of 50 m.

The equipment required is:

**Case a:**
- Extraction phase: drilling and blasting equipment.
- Crushing: plant of 200 tonnes/hour and a total installed power of 1,800 kW (Figure 9).
- Transport and unloading phase:
  - The sand is transported from the quarry to the beach by a fleet of 20 trucks each with a capacity of 20 m³.
  - Phase of spreading the sand on the beach, using a wheel loader.

**Case b:**
- Extraction phase: by trailer suction dredger with a hopper of 10,000 m³ and a total installed power of 12,000 kW in order to dredge the sand from 50 m deep (Figure 10).
- Transport and unloading phase:
  - in the dredger’s hopper with final discharge of the sand on the beach by pumping through pipes.
  - Phase of spreading the sand on the beach, using a wheel loader.
COMPARISON OF THE MOST IMPORTANT RESULTS

The production and execution period:

Case a:
- 12,800 m³/week.
  (13 hours - day; 5.5 days - week).
- Execution period: 40 weeks (9 months)

Case b:
- 175,000 m³/week.
  (24 hours - day; 7 days - week).
- Execution period: 3 weeks (0.7 months)

Guideline prices (referring to the Spanish market prices) are given in Table II.

Case a:
- Estimated direct execution cost: € 12.25/m³
- For 500,000 m³, total material undertaking: € 6.125 million

Case b:
- Estimated direct execution cost: € 4.85/m³
- For 500,000 m³, total material undertaking: € 2.425 million

For CO₂ emissions see Table III.

Case a:
- 22.005 kg CO₂/m³
- For 500,000 m³: 1,445 tonnes

Case b:
- 2.89 kg CO₂/m³
- For 500,000 m³: 11,000 tonnes
- 175,000 m³/week.
  (13 hours - day; 5.5 days - week).
- Execution period: 40 weeks (9 months)

Case b:
- Estimated direct execution cost: € 6.125 million
- For 500,000 m³, total material undertaking: € 2.425 million

Based on these measurements, regarding length of time, direct execution costs and CO₂ emissions, the dredging option from marine banks rather than quarrying yields better economic and environmental results.

REFERENCES


European Commission (2005). Resultados del estudio EUROVISIÓN.


CONCLUSIONS

Climate change studies like the United Nations IPCC demonstrate that the present recession of the coastline, and the continuing threat of recession, is a proven reality in many areas of our planet. The solutions to defending the coastline against recession include both hard and soft techniques. In both cases, it is necessary to carry out an eco-balance for each specific project (economic/ecological, case by case) based on scientific and technical knowledge. Recent research has shown that soft solutions provide more long-term, sustainable protection against receding coastlines.

Of the soft solutions for beach replenishment – winning sand from quarries or from marine banks – beach regeneration using sand from the sea, i.e., marine banks, has unquestionable advantages over those that use sand from a quarry:
- The execution period is of the order of ten times shorter.
- The price is between two and three times lower.
- And this method emits seven or eight times less CO₂.
Above: Qatar’s large reserves of natural gas prompted the decision to implement a land reclamation project, known as the Ras Laffan Port Expansion programme, which will provide a major extension of Ras Laffan Port to accommodate the continued growth of the country’s LNG production.

INTRODUCTION

Qatar’s North Field is the focus of attention of some of the world’s largest oil conglomerates. Studies have shown that the certified reserves currently stand at more than 25 trillion cubic metres of natural gas.

Large-scale investments in LNG infrastructure enable ongoing growth of the country’s annual LNG production, which is expected to reach 77 million tonnes per annum by 2010. Ras Laffan is expected to become the major GTL terminal, the single largest complex and most comprehensive gas processing city in the world and one of the biggest producers of ethylene and derivatives (Figure 1). In this context, QP has decided to extensively expand Ras Laffan Port and Ras Laffan Industrial City. The new port will accommodate around 225 million tonnes of products per year, more than double its present capacity.

The first stage of the works commenced in 2005 and covered the large civil marine work related to the engineering, procurement, installation and construction for dredging, reclamation and breakwaters. The approximate quantities involved were:

- 20 million m³ of hard rock dredging with cutter suction dredgers.

ABSTRACT

Ras Laffan Port Expansion Programme foresees in a major extension of Ras Laffan Port (Qatar) to accommodate ongoing growth of the country’s LNG production. Marine works related to dredging, reclamation and construction of breakwaters were inherently associated with the release and accumulation of fine material within the new port area. This fine material had to be removed. As it was not suitable for filling purposes, it had to be disposed in an offshore disposal area.

To demonstrate that such disposal operations could be carried out without violating strict environmental criteria around the disposal areas, a state-of-the-art 3D plume model was used to simulate a variety of disposal scenarios. The results provided valuable insight in the dynamics of sediment plumes over a spring-neap cycle. To enable operational use on-board, a novel interpretation method was developed to transform the model predictions into so-called “Safe Disposal Maps”. These maps showed green areas where disposal operations could safely be carried out as a function of the tide conditions at hand.

This article adopts the Ras Laffan case to demonstrate the capability of presentday numerical models to provide realistic simulations of sediment plumes and – equally important – the applicability of such complex techniques in dredging practice through innovative interpretation of model results. In the context of increasing environmental awareness on dredging projects worldwide, the availability of such tools is of crucial importance to enable reliable impact assessments and environmentally safe planning of dredging operations.

The work presented here was carried out as part of Ras Laffan Port Expansion project and funded by the Ras Laffan Joint Venture consisting of Jan de Nul Dredging Ltd. and Boskalis Westminster Middle East Ltd. The collaboration with Mr. Tom de Wachter, environmental manager on the project, is gratefully acknowledged. The paper was originally published in the Proceedings of CEDA Dredging Days in November 2009 and is reprinted here in a slightly adapted form with permission.
– 27 million m³ of sand reclamation from offshore borrow areas.
– 16 million tonnes of rock from Qatar for breakwater construction.
– 7 million tonnes of rock from overseas for breakwater construction.

These large-scale dredging and reclamation activities were inherently associated with the release of fine excess material (because of cutter spill and overflow losses during barge loading), resulting in the accumulation of fine material in the new port area. This material had to be removed. As it was not suitable for filling purposes, it had to be disposed in an offshore disposal area. Numerical models were used to demonstrate that dredging and disposal operations could safely be carried out without violating environmental requirements. This article adopts the Ras Laffan case to demonstrate the capability of present-day numerical models to provide realistic simulations of sediment plumes and – equally important – the applicability of such complex techniques in dredging practice through innovative interpretation of model results.

SAFE DISPOSAL OF DREDGED MATERIAL IN A SENSITIVE ENVIRONMENT
To guarantee safe disposal of excess material at sea, careful selection of a disposal site is of paramount importance. The Environmental Impact Assessment for the Ras Laffan Port Expansion project had demonstrated that the nearshore coastal zone (with water depths less than 20 m) and the waters to the southeast of Ras Laffan are the most sensitive locations from the perspective of biological productivity, fisheries and ecological habitats. Offshore disposal at water depths above 20 m is thus preferred.

The sand mining area JV4 is located at 19 km northwest of Ras Laffan Port, at water depths of 19 to 25 m (Figure 2a). As a result of the extraction of approximately 6 million m³ of material for the present port expansion, it offers sufficient space to accommodate the anticipated 3 million m³ of excess material from Ras Laffan Port. Hence no reduction of water depth would occur. An extended environmental study, carried out prior to the start of the sand mining operations, revealed that the seabed in the JV4 area was mostly covered with soft material and that benthic communities were not particularly rich. This observation applied to the full sand mining area. The authors are not aware of previous use of JV4 for earlier sand mining operations, however, if so, it is very unlikely that these earlier operations covered the full area of JV4. Consequently, it could be concluded that local ecological sensitivity for the JV4 area was low by nature. To avoid further disturbance in other, pristine areas, it was decided to select JV4 as the primary disposal location. The sand mining activities in JV4 were subject to environmental requirements to minimise possible environmental impacts to surrounding waters. These requirements stated that during dredging, the concentration of suspended solids was not allowed to exceed a depth-averaged limit level of 30 mg/l on an environmental boundary surrounding JV4 (Figure 2b).

To verify whether these requirements were met, the suspended solids concentration (SSC) was measured on a daily basis, at 21 locations along the environmental boundary. SSC measurements were carried out by lowering and subsequently raising a calibrated YSI turbidity sensor through the water column. This yields a vertical concentration profile, which was averaged over depth. Owing to the relatively large distance to the dredging operations, vertical concentration profiles were found to be virtually depth-uniform. A proposal was offered to apply the same environmental requirements to the execution of the disposal activities as were used earlier during the sand mining operations.

To obtain permission for the start of the disposal works, authorities demanded a demonstration that the disposal operations could be carried out without exceeding SSC limit levels at the environmental boundary under all possible current and weather conditions. A state-of-the-art numerical model was used to do so.

MODEL PREDICTION OF PLUME DISPERSION
In order to evaluate the dynamic plume created by the process of jet release by trailing suction hopper dredgers, and the subsequent descent and collapse, a computational grid of
Approach

The work method for the removal of unsuitable fine material from Ras Laffan Port foresees the use of trailing suction hopper dredgers (TSHD) (Figure 3). After sailing to JV4, this fine material is disposed by opening the bottom doors of the TSHD. This yields a fluid-like jet of fine material that rapidly descends to the seabed (e.g. Van Rijn, 2005). The bulk behaviour of this water-sediment mixture is important, rather than the settling velocity of the individual particles (Winterwerp, 2002). After impact upon the bed, the sediment load will radially flow away from the point of impact over the bed as a density current in the lower 15 to 20% of the water column. This phase is characterised by rapid dissipation of energy and settlement of material. The process of jet release, descent and collapse is generally referred to as the dynamic plume (e.g. Spearman et al., 2007).

While the fine material jet descends through the water column, part of the material gets eroded from the outside of the bulk load (slurry jet) and suspended in the surrounding water (entrainment). After impact on the seabed, resuspension of fine material occurs from the near-bed density current, caused by turbulence-induced upward mixing at the upper surface of the mud layer.

Both mechanisms yield entrained sediments that act as the source term for the so-called passive plume. The passive plume is capable of transporting low-density material away from the direct disposal site owing to advection with tidal currents and diffusion processes.

The near-bed density current propagates, depending on initial density and momentum of the sediment-water mixture, over a distance of typically 100 to 500 m. Given the size (several kilometres) and bed slope (typically 1:1000) of JV4, no sediment will be lost from the disposal area owing to migration of the near-bed density current. As a result, the model study focused on the assessment of suspended sediment losses.

Appropriate representation of these processes asked for the use of two coupled models. The first, Jet3D (Koster, 1988; Morelissen, 2007) determined near-field entrainment rates over the vertical during descent of the dynamic plume from the TSHD. Jet3D is a semi-empirical model which calculates the dispersion and entrainment effects of jets based on an experimental database. The second model, Delft3D (e.g. Lesser et al., 2004), assessed the resuspension from the density current and far-field dispersion of disposed sediments. The coupling of the two models is shown in Figure 4. The calculated entrainment rates from Jet3D together with the durations of disposals served as input for a three-dimensional flow and sediment dispersion model.

Model schematisation

For the purpose of this study, the computational grid of an existing hydrodynamic model for the Ras Laffan region was refined in and around the JV4 area. The resolution of the new JV4 model varied from 375 x 155 m offshore to 35 x 35 m inside the JV4 area. The hydrodynamic model simulates tide-driven flows only; no wind or wave effects are taken into account.

The model is set up in three-dimensional mode with 10 vertical layers with increasing resolution towards the bed. This allows for appropriate representation of the near-bed...
density currents. Model validation against current magnitude and direction data sampled near Ras Laffan Port revealed good performance of the tidal model, with differences in measured and computed current magnitude typically well below 10%.

During storm conditions, differences tend to increase, as a result of differences in wind set-up on both sides of Ras Laffan Port. However, as this phenomenon does not play a role at deeper water where JV4 is located, the conclusion was that the tidal model is suitable for providing the flow conditions to assess plume dispersion during disposal activities at JV4.

Each disposal event was characterised by a means of a fines release of 8400 kg/s during 300 seconds. Jet3D simulations revealed that approximately 10% of this was entrained during vertical descend through the water column. The remaining 90% of the material forms a density current (after impact on the seabed and a hydraulic jump at some distance from the disposal, cf. Figure 4).

Both source terms serve as input for the Delft3D plume dispersion model. The sediment involved is schematised by means of three fractions with a $D_{50}$ of 5, 18 and 43 μm, respectively. The model accounts for the effect of hindered settling, while a minimum settlement velocity of 0.10 mm/s is adopted to account for the process of flocculation. The model also computes the settling of the sediments at the bed when the bed shear stresses become small.

The disposals have been applied at two different locations in the JV4 area in order to take into account the variation of the bed slope, water depth and tidal currents. The disposal locations have remained the same throughout the simulations. As a result of the frequent disposals, a dredging-induced sediment plume will be produced around these disposal locations. This plume is able to enlarge during some tidal phases and in some cases because of the cumulative build-up of sediment concentrations in time. SSC maps are regularly mapped as output during the simulation.

**Model results: SSC maps**

The results shown here represent a scenario with two dredgers, each with a cycle time of 6 hours. Each cycle starts with a disposal event (5 minutes), followed by sailing to the mining location within JV4 (20 minutes), dredging (95 minutes – 20 of which with no overflow) and activities outside JV4 (sailing to port, pumping ashore, clean-up dredging and sailing back to JV4, total 240 minutes). The scenario thus combines the disposal of fine sediments in the SE part of JV4 with subsequent sand mining in the NW part of JV4. This allows for a realistic representation of dredging processes in the area as well as to examine possible accumulation of suspended sediment concentrations originating from multiple dredging activities at the same time.

The model simulations for this scenario result in the prediction of SSC maps throughout a 14-day spring-neap cycle. Results are presented by means of depth-averaged suspended sediment concentrations above natural background level.

An example SSC map is shown in Figure 5. Suspended sediment concentrations in the plume typically range between 0 and 50 mg/l, with higher values above 50 mg/l only found in the direct neighborhood of the dredging equipment. The black line denotes the instantaneous location of the (depth-averaged) 30 mg/l concentration contour, while the red line marks the location of the cumulative 30 mg/l exceedence contour. The exceedence contour marks the outer limit of the area where computed suspended sediment concentrations have (at least once) exceeded the 30 mg/l environmental limit level – for the fixed disposal location considered in the simulations. In addition, the SSC maps provide background information on the current tide conditions (water level, flow magnitude & direction) as well as the status of the dredging works (disposal, sailing or dredging).
Animations of such SSC maps over time clearly show the dynamics of Ras Laffan sediment plumes, characterised by large variations in plume direction and extent. In addition, they show the accumulation of suspended sediments in the water column resulting from cumulative dredging and disposal events. Plume excursion typically increases during spring tide.

Perhaps somewhat surprisingly, maximum plume excursions are not found for disposals during periods of maximum tidal velocities, but for disposals carried out 1 to 3 hours before reaching peak flow velocity. Subsequent flow acceleration causes a maximum excursion of the sediment plume, whereas for disposal at peak velocity, subsequent flow deceleration reduces plume excursion, hence mitigates dredging impacts. This observation reveals the added value of using a non steady-state hydrodynamic model that accurately resolves the dynamics of the tidal motion.

The results presented in Figure 5 can be considered as conservative, particularly because of the chosen schematisation of fines (smallest fraction 5 μm with settlement velocity 0.10 mm/s) and the way Jet3D results for a single jet have been interpreted for use with a TSHD with 44 bottom doors, hence 44 different jets. Theoretically Jet3D describes the dynamics of an individual jet fully enclosed by fresh water; however, in reality, each of the 44 jets underneath the TSHD will interact with neighboring plumes during descent under the vessel. Consequently, real-world sediment entrainment rates to the surrounding water are likely to be smaller than predicted by the models, hence calculated suspended sediment concentrations in the plume can be considered as conservative.

OPERATIONAL PLANNING OF DREDGING ACTIVITIES AT RAS LAFFAN

The operational planning of these disposal activities included the development of Safe Disposal Maps based on the SSC maps and the use of the Safe Disposal Maps on a trip-by-trip basis.

Safe Disposal Maps

The time series of SSC maps throughout a spring-neap cycle provides the starting point for the generation of so-called Safe Disposal Maps. These maps mark the area where sediment can safely be disposed (i.e. without violating the environmental requirements), as a function of the tidal conditions at the time of disposal. Safe Disposal Maps are generated for 10 different tidal stages, each characterised by the flow velocity and direction at the time of disposal. The selected tidal stages are summarised in Figure 6.
Figure 7a. Safe Disposal Maps Ras Laffan JV4 for five tidal stages during flood.

Figure 7b. Safe Disposal Maps Ras Laffan JV4 for five tidal stages during ebb.
To generate the Safe Disposal Maps, all disposal events throughout a 14-day spring-neap cycle plus their associated sediment plumes were categorised according to the tidal classes specified in Figure 6. For each class, the location of the 30 mg/l exceedence contour was determined based on the evolution of the set of sediments plumes in that class. By moving the exceedence contour within the JV4 area along the environmental boundary, areas of unsafe disposal are being blanked. Consequently, the remaining area can be marked safe disposal zone, or suitable area. In this way, Safe Disposal Maps were generated for all 10 tidal classes specified in Figure 5.

The outcome of this novel post-processing on model results is presented in Figure 7 (a and b) for the situation of combined dredging/disposal with two TSHDs. The figures show the 30 mg/l exceedence contour (red line) for each of the 10 tidal classes at hand. The results confirm that maximum plume excursions are found for disposals during flow acceleration and, to a lesser extent, during peak tidal velocities.

For disposal during flow deceleration, plume excursions are minimal and SSC typically drop well below 30 mg/l within 1 km from the disposal location. These observations apply to both ebb and flood tides, though absolute plume excursions are larger during flood. As the ebb tidal velocities (towards NW) are only slightly dominant compared to the occurring flood velocities (towards SE), the latter observation indicates that cumulative effects of ongoing dredging and disposal operations plays an important role here.

The green-shaded areas in Figure 7a and 7b denote the regions where disposal operations can safely be carried out for that particular tidal class. A minimal area of the safe disposal zone is found for situations of flow acceleration, although the available safe area for those...
conditions (increasing flow velocities between 0.2–0.4 m/s towards NW) still measures about 5 km². As expected, safe disposal areas tend to increase with decreasing excursion of the 30 mg/l exceedence line. Ultimately, for situations of flow deceleration, virtually the entire JV4 region can be used for disposal activities without violating the environmental limits.

From the Safe Disposal Maps the conclusion can be drawn that disposal operations can safely be carried out during each phase in the tidal cycle. However, depending on the tidal phase at the time of disposal, restrictions may exist in the chosen disposal location within JV4. The latter particularly applies to periods of tidal flow acceleration which are associated with maximum dispersion of the dredging-induced sediment plumes.

Operational use of Safe Disposal Maps

The Safe Disposal Maps can be used in practice for the determination of suitable disposal locations on a trip-by-trip basis. Steering parameters are the expected tidal conditions (flow magnitude, acceleration or deceleration and direction) at the time of disposal. These parameters can reliably be predicted with the help of a validated numerical model.

For the Ras Laffan Port Expansion project, time series of tidal flows at JV4 were predicted at 20-minute intervals, for the entire period that dredging and disposal operations were carried out. The predicted tidal conditions allow for the identification of the appropriate tidal class and associated Safe Disposal Map for each time step. Results are summarised by means of planning tables for safe disposal operations (Figure 8), which were provided to site.

The planning tables and underlying Safe Disposal Maps were successfully used while carrying out dredging and disposal activities for the Ras Laffan Port Expansion project. During execution of the works, turbidity levels along the environmental boundary surrounding JV4 were measured on a daily basis. No environmental limit exceedence was measured throughout the period of dredging and disposal operations, thus confirming good performance of the disposal strategy based on Safe Disposal Maps.

CONCLUSIONS

Application of two coupled models to simulate dynamic plume behaviour and subsequent passive plume dispersion during dredging and disposal operations at Ras Laffan (Qatar) has demonstrated the capability of present-day numerical models to provide realistic simulations of dredging-induced sediment plumes over a spring-neap cycle.

Perhaps somewhat surprisingly, maximum plume excursions are not found for disposals during periods of maximum tidal velocities, but for disposals carried out 1 to 3 hours before reaching peak flow velocity, during flow acceleration. In addition, cumulative effects caused by ongoing dredging and disposal operations in the area were found to be important.

Novel interpretation of model-predicted patterns of suspended sediment concentration over a spring-neap cycle has resulted in so-called Safe Disposal Maps. These maps were generated for 10 different phases of the tidal cycle and mark the area where disposal operations can safely be carried out. The maps revealed that disposal operations can safely be carried out during each phase of the tidal cycle, although restrictions may apply to the choice of the disposal location depending on the tidal conditions at the time of disposal.

This is particularly the case during periods of tidal flow acceleration, which are associated with maximum dispersion of the dredging-induced sediment plumes.

To facilitate operational use of the Safe Disposal Maps, planning tables were generated based on calculations with a validated hydrodynamic model. The planning tables and underlying Safe Disposal Maps were successfully used while carrying out dredging and disposal activities for the Ras Laffan Port Expansion project.

No environmental limit exceedence was measured throughout the period of dredging and disposal operations, thus confirming good performance of the disposal strategy based on Safe Disposal Maps.

REFERENCES


REMOTE SENSING OF COASTAL ENVIRONMENTS
YEQIAO WANG (EDITOR)

This publication is one of a series published by Taylor and Francis on Remote Sensing Applications. The others cover remote sensing of global croplands, global mapping of human settlement, hyperspectral remote sensing, remote sensing of impervious surfaces and multispectral image analysis.

As the editor points out, over 38% of the world’s population live in the coastal zone, and this zone possesses one of the most dynamic interfaces between human civilization and environmental conservation. Climate change has made the coastal zone the most challenging frontier in environmental planning and management, because many of the coastal zones face the danger of being submerged. Remote sensing is one of the most effective technologies for monitoring and assessing the condition of coastal environments.

The editor for this book, the much-lauded Dr Yeqiao Wang, has brought together the efforts of 46 contributors to produce this state-of-the-art book on coastal remote sensing. With a few exceptions the authors are predominantly from the USA and the subject matter likewise. It would have been interesting to have compared their thoughts with those from other regions, such as Europe or Australasia, but no doubt there are good reasons for this omission, not the least in the size and cost of the publication.

The book commences with an overview of the subject by the editor. This in itself is almost a mini “state of the art” of the subject matter, particularly of the various remote sensing techniques, and it gives a synthesis of each of the papers to follow. With its seven pages of references, abundance of acronyms and subject-specific language it is a challenging read, but well worth the perseverance, particularly if one returns to it having reviewed the papers that follow. These are split into five categories:

- Active remote sensing (LiDAR/Radar)
- Hyperspectral remote sensing
- High spatial resolution remote sensing
- Integration of remote sensing and in situ data
- Effects of land-use/land-cover change (LULCC)

Active remote sensors are radio or light detecting and ranging systems. The radar systems are well suited to obtaining data in all weathers and day-and-night conditions, and the intensity of the backscattered signal is sensitive to terrain slope, roughness and dielectric constant. LiDAR systems, the laser version of radar, can penetrate vegetation cover and give topographical information, as well as providing data on tree and vegetation height. Papers in this section give examples of mapping of wetlands, detection of mangrove canopy 3D structure and ecosystem productivity, and measurement of 3D coastal change. Paper titles are: Interferometric Synthetic Aperture Radar (InSAR) Study of Coastal Wetlands Over Southeastern Louisiana by Zhong Lu and Oh-Ig Kwoun; Mangrove Canopy 3D Structure and Ecosystem Productivity Using Active Remote Sensing by Marc Simard, Lola E. Fatoyinbo, and Naia Pinto; Integration of LiDAR and Historical Maps to Measure Coastal Change on a Variety of Time and Spatial Scales by Cheryl J. Hapke; Coastal 3D Change Pattern Analysis Using LiDAR Series Data by Guoqing Zhou.

Hyperspectral remote sensing methods are particularly well suited to detecting small changes in colouration, as well as giving information on habitat heterogeneity, plant cover distribution and mapping of the spread of invasive species. Examples in the papers in this section cover mapping of marsh dieback, estimating the amount of chlorophyll in coastal waters and mapping salt marsh vegetation. Paper titles are: Mapping the Onset and Progression of Marsh Dieback by Elijah Ramsey III and Amina Rangoonwala; Estimating Chlorophyll Condition in Southern New England Coastal Waters from Hyperspectral Aircraft Remote Sensing by Darryl J. Keith; Mapping Salt Marsh Vegetation by Integrating Hyperspectral and LiDAR Remote Sensing by Jiansheng Yang and Francisco Artigas.

The third section covers the use of high spatial resolution remote sensing. This type of sensing give accurate areal distributions of specific species, such as mangrove forests, and both terrestrial and benthic habitats. The papers in the book cover mapping salt marshes and terrestrial vegetation, high resolution coastal mapping, mapping of impervious surfaces and mapping of the South Asia tsunami disaster. Papers include: Mapping Salt Marsh in Jamaica Bay and Terrestrial Vegetation in Fire Island National Seashore Using QuickBird Satellite Data by Yeqiao Wang, Mark Christiano, and Michael Traber; Object-Based Data Integration and Classification for High-Resolution Coastal Mapping by Jie Shan and Ejaz Hussain; True-Color Digital Orthophotography Data for Mapping Coastal Impervious Surface Areas by Yuyu Zhou and Yeqiao Wang; FORMOSAT-2 Images in Mapping of South Asia Tsunami Disaster by Ming-Der Yang, Tung-Ching Su, and An-Ming Wu.
The following section brings together remote sensing and the ground truthing that is essential for its use. Papers in this section cover coastal marshes and their constituent species, biophysical conditions of herbaceous wetland vegetation, submerged aquatic vegetation mapping and applications used to inventory and monitor natural resources. Paper titles are: Remote Sensing and In Situ Measurements for Delineation and Assessment of Coastal Marshes and their Constituent Species by Martha S. Gilmore, Daniel L. Civco, Emily H. Wilson, Nels Barrett, Sandy Prisloe, James D. Hurd, and Cary Chadwick; Quantifying Biophysical Conditions of Herbaceous Wetland Vegetation in Poyang Lake of Coastal China via Multitemporal SAR Imagery and In Situ Measurements by Limin Yang, Huiyong Sang, Hui Lin, and Jinsong Chen; EO-1 Advanced Land Imager Data in Submerged Aquatic Vegetation Mapping by Eric Akins, Yeqiao Wang, and Yuyu Zhou; Remote Sensing Applications Used to Inventory and Monitor Natural Resources in North Atlantic Coastal National Parks by Sara Stevens and Courtney Schupp.

Finally, there is a section relating to land-use/land-cover changes. The acronym for this varies in the book between LULCC (in the index) and LCLUC (in the text). Possibly they are both used. This important theme is demonstrated by papers covering coastal land-cover changes in Connecticut, increasing urban impervious surface hydrology in Rhode Island, LULCC in the Pearl River Delta, China and geospatial information for sustainable development in coastal East Africa. Papers are entitled: Coastal Area Land-Cover Change Analysis for Connecticut by James D. Hurd, Daniel L. Civco, Emily H. Wilson, and Chester L. Arnold; Effects of Increasing Urban Impervious Surface on Hydrology of Coastal Rhode Island Watersheds by Yuyu Zhou, Yeqiao Wang, Arthur J. Gold, and Peter V. August; Contemporary Land-Use/ Land-Cover Change in Coastal Pearl River Delta and its Impact on Regional Climate by Limin Yang, Wenshi Lin, Lu Zhang, Hui Lin, and Dongsheng Du; Geospatial Information for Sustainable Development: A Case Study in Coastal East Africa by Yeqiao Wang, James Tobey, Amani Ngusaru, Vedast Makota, Gregory Bonynge, and Jarunee Nugranad.

All in all, this publication covers many remote sensing techniques and their various current applications. Whilst not being an easy treatise to absorb for those approaching the subject for the first time, it is no doubt an extremely useful and informative body of work for those already familiar with the subject matter covered. One suspects that the evolution of remote sensing techniques will be more rapid than the coastal changes that they are now being used to detect and monitor. For this reason, it is highly probable that we shall see more on this theme in the future. In the meantime, this publication represents an excellent snapshot of the current situation.

This book can be order from: http://www.taylorandfrancis.com/books/details/9781420094411/

NICK BRAY
Since 1993 the International Association of Dredging Companies (IADC) has regularly run week-long seminars especially developed for professionals in dredging-related industries to familiarise them better with the many aspects and challenges of dredging. Dredging experts from IADC member companies present the lectures and complement theory with their practical knowledge and experience. Amongst the subjects covered are the development of new ports and maintenance of existing ports; project phasing; descriptions of types of dredging equipment; costing of projects and types of dredging projects.

Events outside of the classroom are equally important and stimulating. A site visit to a local dredging project is conducted, where enthusiastic employees of an IADC company show participants dredging equipment in action and provide them with a deeper insight into the intricacies of the dredging operation.

For more information, please contact the IADC Secretariat:
Mr. Frans-Herman Cammel
• Email: camel@iadc-dredging.com

The Manta Port Authority (MPA) and the American Association of Ports Authorities (AAPA) are organising a congress with the main topic, “The Model of Relationship of the American Ports with Europe and Asia, in view of the new Development Opportunities”. Manta is the closest point to Asia, 56 miles from the equator, a crossroads for South American trade with the world and the competitive advantage of being located 25 miles from the international traffic route.

The academic agenda includes “heavyweights” of the port scene of all the Americas including keynoters such as Walter H. Kemmsies, Ph.D., Senior Economist, Moffatt & Nichol (USA); Armando Duarte Pelaez, Director, Sociedad Portuaria de Santa Marta SA (Colombia); Agustín Díaz, Managing Director, Curaçao Ports Authority (Netherlands Antilles); Rodolfo Sabonge, Market Research and Analysis VP, Panama Canal Authority (Panama); Larry Lam Choon Seng, Chairman, Portek International Ltd (Singapore); Fernando González Laxe, President, State Ports (Spain); many more distinguished port leaders from Costa Rica, Chile, Mexico and Peru.

For registrations please contact:
www.congresomanta2010.com (in Spanish and English)
• Email: inscripciones@congresomanta2010.com

IQPC is pleased to present Dredging 2010, the only event dedicated to dredging in Australia and New Zealand and aims to share knowledge with all stakeholders involved in any type of dredging project from approval through to delivery. The conference is organised in response to the large investments on capital and maintenance dredging projects now going on in these countries and will show how to effectively manage a project through these areas:
- How to collaborate effectively with state and federal government to ensure the entire approvals process goes smoothly.
- The best evaluation methods of your own environment to identify the right equipment for your project.
- Ensuring there are strong lines of communication between all stakeholders involved in the entire process.
- Minimising the negative impacts on the environment

Speakers include: Susan Fryda Blackwell, Chief Executive Officer, Ports Australia; Simona Duke, Manager Environment, North Queensland Bulk Ports Corporation; Peter Nella, Dredging Manager, Port of Brisbane; Adam Fletcher, Environmental Manager, Cairns Port.

For further information contact:
www.portsdredging.com.au

WODCON XIX Congress and Exhibition, with the theme, “Dredging makes the world a better place”, will be organised by EADA in association with CHIDA. Papers will cover the following topics: Relationship between dredging and sustainable development; Dredging technology and research; Beneficial uses of dredged material; Environmental aspects of dredging; Survey and positioning technology and equipment; Physical and numerical modeling; Sediment dewatering, treatment and disposal; Dredging equipment; Dredging project case studies. Technical visits and tours will take place on September 13-14.

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Coast Expo
SEPTEMBER 21-23, 2010
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This First Exhibition on the Protection of the Coast and Sea will be held within the 4th Remtech Expo 2010 - RemediationTechnologies and Requalification of the Territory Exhibition. Coastal areas represent a unique asset in terms of environment, economics and socially. Coast Expo 2010 will provide a focus on the areas of management, dredging, nourishment and remediation of port areas and the coasts and a total use of resources towards the possibility of bilateral meetings between stakeholders (operators, industry, public authorities, port authorities). The initiative will be a time for debate, discussion and debate among Ministries and public institutions, universities and research centers, companies and private companies, the state of the art and the developments and criticism of the integrated management of coasts. The Scientific Committee with national delegates (and representatives of the Ministries) and international delegates (including representatives of the European Commission) are supporting the exhibition as well as the following Congresses: a conference on dredging, a symposium on monitoring and risks and a symposium on applications of speech cases, studying or monitoring. Parallel projects at the REMTECH EXPO 2010 are currently being finalised.

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Port & Terminal Technology 2010
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7th International SedNet Event
APRIL 6-9, 2011
VENICE, ITALY

This is the first Call for Abstracts for the SedNet conference entitled “Sediments and Biodiversity: Bridging the Gap between Science and Policy. SedNet is the European network which aims to incorporate sediment issues and knowledge into European strategies to support the achievement of good environmental status and to develop new tools for sediment management. Its focus is on all sediment quality and quantity issues at the river basin scale, ranging from freshwater to estuarine and marine sediments. SedNet brings together experts from science, administration, industry and consultants. It interacts with the various networks in Europe that operate at national or international level or that focus on specific fields (such as science, policy making, sediment management, industry, education). In recent years, special attention has been devoted to the integration of sediment management in the EU Water Framework Directive implementation process.

Deadline for abstract submission: September 1 2010
Decisions to abstract authors: October 15 2010
Final Conference Programme: March 2011

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Vulnerable coastlines are often in need of beach nourishment. Shown here, floating pipelines, a method that is economically and environmentally advantageous compared to using quarried sand (see page 14).
CONTRACTS FOR unforeseeable soil conditions

ENVIRONMENTAL IMPACTS mining seabeds versus quarries

SAFE DISPOSAL of dredged material using models