OPENEARTH OPENS DOORS
sharing a knowledge databank

IMPROVING SAFETY
clients and contractors co-operate

CHALLENGES LEAD TO INNOVATION
lead to cost-efficient designs
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 A4s. Photographs, graphics and illustrations are encouraged. Original photographs should be submitted, as these provide the best quality. Digital photographs should be of the highest resolution.**
- **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.**

During construction of the Maasvlakte 2 block dam, laser scans and multibeam surveys were conducted to verify tolerance as the blocks were placed. As each 50-m section of the breakwater was ready, it was handed over to the client with a combined 3D model of the multibeam and laser scan data, such as the one pictured here (see page 18).
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Once every three years the worldwide dredging community gathers for a few days to exchange information and acknowledge the achievements of our colleagues. As we prepare to participate in and network at the WODCON XX (with the theme “the Art of Dredging”) in Brussels the first week of June, we have many reasons to be proud of the contributions that dredging has made to society: To the collective safety of our coastal regions. To the spread of prosperity as ports are expanded and seaborne trade grows, bringing more goods and services to more parts of the world than ever before. To the increased availability of offshore energy including wind power.

One of the drivers of this progress has been the commitment of the dredging industry to research and development, to environmental awareness and to scientific advancements that benefit all of us.

The Terra et Aqua line-up reports on a broad range of these advances. For instance, the OpenEarth (www.openearth.eu) system – or philosophy and user community as the authors call it – was developed as a free and open source of knowledge exchange. An alternative to the often ad-hoc, approaches to acquiring data, models and tools. OpenEarth was born from the frustration caused by project-to-project investments in data research which consume time and money. It is a remarkable, comprehensive system developed by Delft University of Technology and Deltares, and now implemented in a number of sizeable research programmes with multiple partners (such as the “Building with Nature” research programme with 19 partners from one country) and from multiple countries (such as the three-year European Union FP7 research programme MICORE with 15 partners from 9 countries).

Health, Safety and Environment is equally important to the successful execution of a dredging project. Consequently, dredging contractors continue to seek improvements in the “culture of safety” amongst all employees from top management to office personnel to crews onboard any number of vessels. And this concern extends to the co-operation of the client.

The pursuit of innovation in techniques, equipment and design remains a core value of the dredging industry. Faced with enormous challenges during the development of Maasvlakte 2, the industry rose to the fore. The discoveries and the test results from this project will have long-ranging impact on future projects – making them more cost efficient and more environmentally sound.

Why in these difficult economic times has the dredging industry held its head above water – even as it digs deeper and deeper underwater? Perhaps because scientific curiosity keeps the industry looking to the future. As Albert Einstein once wrote, “To raise new questions, new possibilities, to regard old problems from a new angle requires creative imagination and marks real advances in science”. And that is both the art and the science of dredging.
ABSTRACT

Research and consultancy as well as construction projects often spend a significant part of their budget to set up some basic infrastructure for data and knowledge management, most of which dissipates again once the project is finished. Standing initiatives so far have not been successful in providing a proper data and knowledge management system for data, models and tools. OpenEarth (www.openearth.eu) was developed as a free and open source alternative to the current often ad-hoc approaches to deal with data, models and tools.

OpenEarth as a whole (philosophy, user community, infrastructure and workflow) is the first comprehensive approach to handling data, models and tools that actually works in hydraulic engineering practice at a truly significant scale. It is implemented effectively not only at its original founding organisations, Delft University of Technology and Deltares, but also in a number of sizeable research programmes with multiple partners (such as research programme “Building with Nature” with 19 partners from one country) and from multiple countries (such as the 3-year European Union FP7 research programme MICORE with 15 partners from 9 countries). It has been adopted as the main data management workflow for all research programmes around the Sand Engine Delfland and was awarded the Dutch Data Prize 2012 for technical sciences by 3TU.datacentrum, the data archiving institute of the Dutch technical universities, and DANS, the data archiving institute of the Dutch National Science Foundation (NWO) and the Royal Dutch Academy of Sciences (KNAW).

For data, models and tools that are truly strategic and really cannot be shared, OpenEarth stimulates the set-up of internal OpenEarth clones. This way the OpenEarth workflow can still be adopted, promoting collaboration within an organisation, while taking care of security considerations at the same time.

This article is based on and updates the OpenEarth philosophy, infrastructure and main workflow protocols as presented at WODCON XIX in Beijing, China (Van Koningsveld et al., 2010). A number of practical example applications that have been realised to date are given to illustrate OpenEarth’s potential for the dredging industry.

INTRODUCTION

The sustainable interaction between humankind and planet Earth poses huge hydraulic and environmental engineering challenges. Confronting these challenges one-project-at-a-time, while seemingly attractive from a budget management perspective, results in grave inefficiencies in developing and archiving the basic elements that are invariably involved: data, models and tools. Hardly any project is by itself of sufficient scale to develop easily accessible and high-quality data archives, state-of-the-art modelling systems and well-tested analysis tools under version control. Research, consultancy as well as major construction projects commonly spend a significant part of their budgets to set up some basic data and knowledge management infrastructure, most of which dissipates again once the project is finished.

Internally institutions generally employ intranet services and internal networks to collaborate and exchange information. However, owing to increasing complexity, large projects nowadays are regularly executed by consortia.
The internal services of individual institutions do not allow for collaboration because of technical limitations or simply denial of permission for exchanges. As a result the way data, models and tools are currently managed, while presumably aimed at protecting the knowledge capital of organisations, in fact also inhibits (individual as well as collective) progress.

Over many years Delft University of Technology and Deltares, together with many partners from the hydraulic engineering industry, developed OpenEarth (www.openearth.eu) as a clonable, free and open source alternative to the project-by-project and institution-by-institution approaches to deal with data, models and tools (e.g., Van Koningsveld et al., 2004; Van Koningsveld et al., 2010; Baart et al., 2012; De Boer et al., 2012). OpenEarth transcends the scale of single projects facilitating that each project builds on the heritage of previous projects.

OpenEarth at its most abstract level represents the philosophy that data, models and tools should flow as freely and openly as possible across the artificial boundaries of projects and organisations (or at least departments). Put in practice OpenEarth exists only because of a robust user community that works according to this philosophy (a bottom-up approach). In its most concrete and operational form, OpenEarth facilitates collaboration within its user community by providing an open ICT infrastructure, built from the best available open source components, in combination with a well-defined workflow, described in open protocols based as much as possible on widely accepted international standards.

OpenEarth as a whole (philosophy, user community, infrastructure and workflow) is the first comprehensive approach to handling data, models and tools that actually works in hydraulic engineering practice at a truly significant scale. It is implemented effectively not only at its original founding organisations, Delft University of Technology and Deltares, but also in a number of sizeable research programmes with multiple partners (such as the €28 million 4-year research programme Building with Nature with 19 partners from one country) and from multiple countries (such as the €4.6 million 3-year European Union FP7 research programme MICORE with 15 partners from 9 countries).

It has been adopted as the main data management workflow for all research programmes around the Sand Engine Delfland and was awarded the Dutch Data Prize 2012 for technical sciences by 3TU.datacentrum, the data archiving institute of the Dutch technical universities, and DANS, the data archiving institute of the Dutch National Science Foundation (NOW) and the Royal Dutch Academy of Sciences (KNAW). As a result OpenEarth is now carried by a rapidly growing user community that as of April 2013 comprises some 1000 users, over 280 LinkedIn group members, more than 150 active developers, creating upwards of 6500 contributions, originating from a multitude of organisations and countries. Together they share and co-develop thousands of tools, tera-bytes of data and numerous models (source code, raw data and data products, model schematisations and pre- and post-processing tools).

**THE OPENEARTH PHILOSOPHY**

As outlined above, the availability and accessibility of high-quality data, models and tools is crucial in successfully handling hydraulic engineering problems. The three in some shape or form are involved in any project design, risk analysis, cost estimation, impact assessment, production optimisation and so on. Past experience from sizeable consultancy projects as well as numerous research programmes (e.g., Capobianco, 1999; Wilson, 2002; Stodden, 2010) have shown that while everybody acknowledges its importance, nobody as yet has been able to establish a sustainable, functioning knowledge management system for data, models and tools.

The widely used and extensively standardised project-based approach effectively handles document control at the start-up, execution and closure phases of projects. Numerous archive systems are available to safely store important project-related information such as tender documents, bids, method statements, reports, official correspondence, contracts, presentations, financial information and more. As a result the workflow in projects is now highly traceable and reproducible with the main aim to achieve the best possible hold on the project realisation process in order to avoid unnecessary errors and mistakes and associated financial penalties, losses and claims.

From this perspective the project approach is clearly effective, explaining its world-wide popularity and implementation. In 2010 the International Organization for Standardization (ISO) announced that ISO 9001 certifications, which are widely regarded as a global benchmark for quality management, topped the one million mark (see also: http://www.iso.org/iso/news.htm?refid=Ref1363, last checked 18-04-2013).

The main strength of the project-based approach, viz., effectively managing a project given its available means in terms of time, money, people and equipment, can become a weakness or even a threat if applied too rigidly. As is commonly acknowledged, certification to, for example, an ISO 9001 standard does not guarantee any quality of end products and services. It only certifies that formalised business processes are being applied. This potential weakness is most visible for those elements that transcend the scope of a single project, notably the quality, availability and accessibility of data, models and tools (in combination with knowledge and practical experience of course).

Project management systems deal with an estimated 20% management, overhead and reporting share of the project budget only. For the actual knowledge and information generated with the other 80% of the budget, no effective, integrated and widely applied quality management system exists to our knowledge (NB: percentages estimated by the authors). An effective approach would be particularly useful for the explicit knowledge as knowledge management founders like Polanyi (1966) and Nonaka and Takeuchi (1995) called it.

It is in fact this “knowledge capital” that can most easily be reused and further developed in subsequent projects, whereas project specific management documents are generally of no further practical use, except perhaps in legal cases.

Many attempts have been undertaken to deal with these issues. Numerous EU and Dutch national research programmes have promised...
to deliver and disseminate data gathered throughout the project. This has resulted in many databases, web-portals, CD Roms, DVDs and ftp-sites that have gradually gone rogue. As soon as a project has ended and the incentives to maintain the databases and web links are gone, slowly but surely they are forgotten. When a new project comes along, setting up a new database rather than reviving the old one seems more attractive.

A common reason that numerous existing data, models and tools management initiatives fail is that they are either imposed top-down or they emerge bottom-up without proper consideration for the bigger picture. Both methods are highly unlikely to be successful in the long run. Instead, OpenEarth emerged as a bottom-up approach with a long-term perspective on knowledge sharing and use, rather than focussing on just the technology (even though the use of proper technology is obviously important).

OpenEarth effectively provides and maintains all required technological infrastructure in-support-of, yet independent-from, any individual project. At the same time OpenEarth offers the essential training to allow project members themselves to make use of and contribute to the centralised repositories already available during the course of a project, rather than at its end. A small team invests some editorial and reviewing effort to prevent divergence of the proposed standards and ensure quality of the OpenEarth products.

In summary after several years of successful application, the OpenEarth philosophy consists of:
- A robust community of users …
- collaborating from the philosophy …
- that data, models, tools and information …
- should be exchanged as freely and openly as possible …
- across the artificial boundaries of projects and organisations …
- with an approach that fosters continuous and cumulative quality improvement.

The OpenEarth philosophy, while addressing a crucial gap in common quality management systems, also poses a challenging problem. The aim for maximum efficiency ideally means that all results should be shared – minimally, amongst the legal project contributors and, preferably, with the whole world. Co-operation results in greater overall progress aligning individual with total progress so that they reinforce rather than impede each other. At the same time, for any individual research project or organisation, full openness quite likely benefits competing consortia or organisations. This presents a typical problem known as the “Social trap” (Platt, 1973).

The term “Social trap” is used for situations where a group of people act to obtain short-term individual gains, which in the long run leads to a loss for the group as a whole (Rapoport, 1988). The “Prisoner’s dilemma” (proposed by Flood and Dresher working at RAND in 1950) and the “Tragedy of the commons” (Hardin, 1968) are some well-known examples.

A similar dilemma exists in the hydraulic engineering sector. Strategic data, models and tools are kept secret for competitive reasons. As a direct consequence, the sector as a whole advances less rapidly and is less advanced than it could be. Despite the downsides of knowledge protectionism, it is clearly an intrinsic characteristic of the dredging industry that cannot be ignored. To accommodate this, OpenEarth stimulates the set-up of internal OpenEarth clones, for data, models and tools that are truly strategic and really cannot be shared with other, outside organisations. In this way the OpenEarth workflow can still be adopted, promoting collaboration within an organisation, while meeting external security considerations at the same time.

**OPENEARTH INFRASTRUCTURE**

Improper management of data, models and tools can easily result in a wide range of very recognisable frustrations:
- Making the same mistake twice owing to the lack of version control
- Losing important datasets that are extremely hard to replace
- Being unable to reproduce what quantities have been measured and which units apply
- Missing information on measurement position and/or the geographical projection used
- Uncertainty as to the time and time zone the measurements were taken in
- Myriad formats of incoming (raw) data
- A multitude of (slightly different) tools for the same thing
- Difficulty combining numerous databases, each in its own language and style, and so on
- Finding out too late that a colleague has already solved a problem similar to yours
- Facing an impenetrable network of ad-hoc scripts and tools hindering QA/QC and reuse.

Although the above-described frustrations are very common throughout the hydraulic engineering industry, no practical and widely accepted remedy seems to be available.

Many initiatives have been developed though, usually targeting only data, models or tools rather than all three at once (although this certainly needs not be an issue). Some of such initiatives have been granted sizeable budgets to develop a state-of-the-art infrastructure, often outsourced to some ICT company. To promote potential partners to upload their information enormous effort is spent on system security, generally restricting access. As a result of lacking end-user involvement and a focus on access restriction, many systems have been developed at high cost but with low success in terms of active users.

Conversely, repelled by large ineffective yet expensive initiatives, many projects have gone for quick solutions such as simply sharing data on an ftp server or setting up a basic database using any available software. When all project members have write access to a shared project directory or ftp server, data archives can quickly become messy. Without such a shared directory or ftp server, people start to collect their own datasets for their dedicated purpose, resulting in greater claims on limited storage and backup resources, difficulties with data quality control and inefficiencies in terms of mutual learning.

What works better in practice is a Wikipedia-like approach: Set up and maintain an easy to use central system, give write access to anyone while employing a system that logs everything to enable quality control. All data, models and tools that are committed are free for use by anybody. Given a username and password developers can fix bugs, change, delete and add data, models and tools. The use of a version control system ensures that every change is logged.

In fact the version control system can identify for each bit of data and every single line of code who changed it and when. Since 2003 OpenEarth has experimented with numerous approaches available, in the end devising a most convenient infrastructure to support a bottom-up approach to long-term project-transcending collaboration.

The resulting best practice adheres to four basic criteria:

1. **Open standards and open source:** The infrastructure should be based on open standards, not require non-libre software and be transferable.
2. **Complete transparency:** The collected data should be reproducible, unambiguous and self-descriptive. Tools and models should be open source, well documented and tested.
3. **Centralised access:** The collection and dissemination procedure for data, models and tools should be web-based and centralised to promote collaboration and impede divergence.
4. **Clear ownership and responsibility:** Although data, models and tools are collected and disseminated via the OpenEarth infrastructure, the responsibility for the quality of each product remains at its original owner.

**Open standards and open source**
The first criterion, *open standards and open source*, is adopted to maximise the number of participants. Known bottlenecks for implementing a new data and knowledge management system are high set-up costs and a fear of changing standards. The first bottleneck is resolved by applying the best available free and open source system components only.

The second bottleneck is addressed by adopting a modular approach that allows for elements of the system to be replaced by other better ones at minimal effort and cost. Fortunately the web provides a large open source community. International groups such as the Open Geospatial Consortium (OGC) and numerous meteorological, oceanographic and remote-sensing collectives have created high-quality software suitable for the OpenEarth purposes. In addition, the requirement of the United States government that all data, models and tools funded by US taxpayers should be available openly has supplied a vast range of free software – an approach that clearly deserves a wider following.

**Complete transparency**
The second criterion, *complete transparency*, is achieved by demanding that collected data are reproducible, unambiguous and self-descriptive.

An important distinction made here is between the archival and the dissemination function of a database. To eliminate ambiguity and enhance self-descriptiveness, OpenEarth recommends storing the generally pluriform raw data files in a version-controlled repository with, alongside them, a routine to transform each data format into data products with one single commonly accepted data format.

The raw data and associated conversion scripts are stored to ensure reproducibility, whereas the common data format promotes unambiguity and self-descriptiveness (see Figure 1). For standardised gridded data, the netCDF format (NASA and OGC standard) in combination with the CF standard name vocabularies and EPSG codes for geospatial referencing are recommended. For ecological data, which commonly have a large amount of meta-data, the use of a Relational DataBase Management System (RDBMS) is recommended (the relational database approach is not discussed further in this article).

The distinction between raw data and data products has proven effective in other fields of application as well. In the remote-sensing community, for instance, NASA stores raw data from ocean colour sensing satellites (e.g., NASA’s satellites *Terra and Aqua* are equipped with the MODIS – Moderate Imaging Spectroradiometer – system) as so-called L0 files. These files generally are not available in an easy accessible format as they are optimised to maximise data transmission.
from the satellite to a ground station. The L0 files are stored as raw data files and archived permanently.

The raw data are subsequently enriched with meta-information, such as minimally the satellite locations, and stored as L1 data. NASA also adopts a standard exchange format (i.e., HDF). Further processing is carried out to translate sensor readings to geophysical quantities (L2), and generate data for climatologies and other applications on standard grids (L3 and L4). The levels L1 and higher are considered data products and are primarily meant for dissemination. Each level (except L0) can be recreated with different processing steps, using the same open source software (SeaDAS – tool: http://oceancolor.gsfc.nasa.gov/seadas; reprocessing: http://oceancolor.gsfc.nasa.gov/REPROCESSING/).

The data products are frequently deleted and replaced by improved versions (bug fixes, better calibration, incorporating deterioration of the equipment). All data products carry a version number, i.e., the version of the SeaDAS version that created it.

Unfortunately, outside the remote-sensing community, data products are often considered to be a permanent entity. As a result of human errors and progressing knowledge, in reality, data products are ephemeral entities and only the raw data should be considered permanent. OpenEarth adopts NASA’s philosophy that data products are ephemeral entities, the sole purpose of which is to facilitate dissemination. Data products should always carry a version number. In line with NASA, OpenEarth prescribes that all data processing scripts needed to transform and enrich the raw data should be stored alongside the raw data. This enables automated data processing.

To ensure reproducibility OpenEarth currently uses the open source version control system Apache Subversion (to be called here Subversion for short) for version control, backup, and access control. If the raw data are really raw, Subversion in practice does not have to do any versioning of these files and storage is mainly for backup purposes and to determine ownership. Although for version control ASCII formats are preferred, binary files can be added to the raw data repository also. The database behind Subversion scales well for large repositories. User friendliness considerations triggered the set-up of separate repositories for data, models and tools.

Centralised access
The third criterion, centralised access, is incorporated in the OpenEarth infrastructure through use of the state-of-the-art regarding management of data, models and tools: web-services. A myriad of functionalities is already available via web services, and for some, such as webmail, OpenEarth is fully dependent on “the cloud”. Computing and storage in general move towards common commodities that can best be provided on centralised large servers (Carr, 2008).

Strangely for data, models and tools old-fashioned approaches like storing data decentralised on local PCs are still widespread. Offering the OpenEarth infrastructure as web-services allows users to participate with “normal” laptops requiring some form of web access only. The bulk data is stored on the central database and users only extract what data they need. Though the OpenEarth data, models and tools are disseminated via web services the netCDF files can be used off-line too (albeit not updated). A user can for example choose to download a certain (part of a) data file once and store it on the local hard drive if for a certain type of use this is more convenient (e.g., use in a remote location where internet access is not available or slow).

A big advantage of employing web-services is that any dataset, any model and any tool will be accessible via the web, via a known URL; preferably even a permanent URL (PURL). The importance of web-services has been recognised by the open source GIS community that is developing various standards. Basically two kinds of web services are available:
- URLs for data numbers, and
- URLs for data graphics.

For both kinds the Open Geospatial Consortium (OGC) web-services are a promising solution: Web Map Service (WMS) for maps (images), Web Feature Service (WFS) for features and Web Coverage Service (WCS) for coverages (data). The actual implementation of the OGC spatial web services, however, is still in its early stages.

The definition stage of OGC temporal services is still on-going. OpenEarth proposes to adhere to W*S services (WMS, WFS and WCS) as soon as easy implementations become operational. Meanwhile, OpenEarth adopted two existing web services that are already fully operational and have a large community of users: OpenEarth proposes to use the OPeNDAP protocol for accessing data numbers, and the OGC approved the Google Earth KML standard for accessing data graphics.
Clear ownership and responsibility
The fourth criterion is clear ownership and responsibility. Each dataset, model and/or tool has a clear owner and licence for use. OpenEarth facilitates storage, quality control and dissemination as best as possible. At the same time OpenEarth cannot assume any responsibility for the data, models and tools that users put into the system. Each user is thus individually responsible for using each dataset, model and tool with the utmost caution.

Results should always be checked carefully and users are encouraged to feed any resolved data errors and software bugs back into the system. To make ownership transparent, all data are stored under a directory with the name of the copyright holder (see protocols below). In addition, each data product is supposed to have the name of the owner as a global attribute and each raw data file from a European institute is supposed to have an INSPIRE meta-data file stored with it.

OPENEARTH PROTOCOLS
The OpenEarth infrastructure outlined above already involves adhering to a number of open source software/standards: Subversion, OPeNDAP, netCDF, KML, for example. However, while using these standards, still a number of important choices remain: what data storage structure to use, how to deal with units, how to deal with variable names, how to deal with coordinate projection information and so on.

Based on experiences from numerous applications and lessons learned from other initiatives, OpenEarth suggests a workflow protocol for the most important choices that invariably come up.

The next subsections briefly outline the OpenEarth protocols for handling data, models and tools (more detailed information is available from www.openearth.eu).

Data protocol
A well-developed protocol for data collection is made available by OpenEarth. This protocol has been developed within numerous projects, notably the EU FP 7 project MICORE and the Building with Nature innovation programme.

The data collection protocol is kept up to date at www.openearth.eu. The OpenEarth data collection procedure is modelled after the Extract, Transform and Load (ETL) process that is commonly adhered to in the world of database developers and especially in data warehousing. It involves:
- Extracting data from outside sources;
- Transforming it to fit operational needs (which can include quality levels); and
- Loading it into a database or data warehouse.

Although the actual use of the data is implicitly included, presumably in the transformation process, OpenEarth decided to make this part of the process an explicit element of the data collection procedure by extending the ETL procedure to ETL+P: Providing the data back to the user.

In the end OpenEarth put data in a database primarily so that an end-user may easily get it out again. This may seem like a trivial extension – but practical experience shows that it is not! Regularly databases are optimised for only one of the ETL steps, and the focus lies usually on making the life of data managers easier. OpenEarth aims for a system that makes the life of the end-users easier as well.

OpenEarth thus adheres to the ETL+P approach, where data use and dissemination are an integral part of the definition. ETL+P as used by OpenEarth comprises the following steps (see Figure 2 above):

1. Extract. Take measurements/run models and store the measured raw data files/model input in the OpenEarth repository.
2. Transform. Enrich the gathered raw data/model results with metadata and transform it from its original arbitrary format to the agreed upon standard format for data products (e.g., netCDF).
3. Load. Load the data products into the OPeNDAP database.
4. Provide. Provide access to the OPeNDAP database and facilitate easy dissemination to all potential end-users allowing them to easily continue to use their own favourite software.

As still a number of important choices can be made following this approach, the protocols for each of the steps are elaborated slightly below.

Extract
- Collect your raw data.
- Commit your raw data to the open OpenEarth raw data repository (using the Subversion client TortoiseSVN available from: http://tortoisesvn.tigris.org/) under https://svn.oss.deltares.nl/repos/openearthrawdata or to an in-house clone.
- Store your raw data (and associated transformation scripts) in the following folder structure (as shown in blue below):

```
</institution/copyright holder>
\<project number if appropriate> \<descriptive name>
\<category> (e.g. bathymetry, grids, vessel logs)
\<data files> (e.g. bathy1.dat, bathy2.dat)
\<metadata>
\<documentation>
\<inspire description.xml>
\<internet link.url>
```
Transform

OpenEarth adopts the philosophy that raw data files can have any format, but all data products should have the same format. OpenEarth uses netCDF with the CF convention as its standard format for data products that are gridded (either in space or in time or both).

Note that the relational database approach that is recommended for ecological data with large amounts of metadata is not addressed here. Although the technical specifications for the netCDF storage format are set, still a wide range of choices is left to the user.

To enhance transferability of the OpenEarth data products a number of standards are promoted by OpenEarth transforming and enriching raw data:

- **Time**: Use the time convention suggested in the netCDF Climate and Forecast (CF) Metadata Convention (http://cf-pcmdi.llnl.gov/) (use the Gregorian calendar, express time as time in <time units> since <epoch>, e.g., “days since 1970-01-01 00:00:00 +1:00”, always include information on the time zone etc.)

- **Spatial reference**: Include for each coordinate system the parameters that should be used for conversion to lat/lon. A useful spatial reference is provided by EPSG (http://www.spatialreference.org) (include in any netCDF file conversion parameters for the regional coordinate projection the data was measured in, including its EPSG code, for easy use in the regional context (x and y), as well as longitude and latitude information with a WGS84 datum, to enable easy projection on Google Earth for example)

- **Units**: Use the standards defined by the SI (http://www.bipm.org/en/si/) using the controlled units vocabulary of the UDUNITS package (http://www.unidata.ucar.edu/software/udunits/).

- **Variable names**: For variable names use the standard naming convention as suggested in the netCDF Climate and Forecast (CF) Metadata Convention (http://cf-pcmdi.llnl.gov/) and the National Environmental Research Council (NERC) Data Grid Vocabularies (http://www.bodc.ac.uk/products/web_services/) as much as possible.

- **Custom standard names**: Where no ready to use standard names are available (as is the case for example for various signals in vessel log files) develop a custom standard name convention. If possible, share it via the OpenEarth website to propose the customised naming convention as a new standard.

- **Automatically added version information**: Use Subversion version keywords in the script that creates the netCDF file to enable reproducible and unambiguous data products. These keywords should be applied in a code line that writes global attributes of the netCDF file, so that each data file contains the full URL of the script that generated it, as well as its version.

Load

Load the newly generated netCDF data product to the OPeNDAP server for easy access. Unlike the raw data repository, the netCDF collection under an OPeNDAP server does not have automated version control.

Since all raw data have their processing scripts stored along with them, an automated procedure can easily be set up. To make ownership transparent, it is recommended to use as much as practicable the same directory structure for the OPeNDAP server as was applied in the raw data repository (see Extract).

Provide

The data can now easily be used by users, e.g., employing any web browser or using Matlab, Python, Fortran, R and so forth. The OpenEarth tools repository, hosted freely by Deltares, contains routines facilitating working with netCDF files and communicating with OPeNDAP servers.

The addresses of the OpenEarth community OPeNDAP servers can be found via OpenEarth.eu. Preferably each institution has its own OPeNDAP server, e.g., http://opendap.deltares.nl; and so on.

To further facilitate easy inspection of geographically (and temporally) specified data it is recommended to generate a KML file for each netCDF file to enable easy visualisation on Google Earth. The address of the OpenEarth community web server for KML files can be found via OpenEarth.eu. Preferably each institution has its own KML server, e.g., http://kml.deltares.nl.

Models protocol

Especially for locations where models are regularly used, model schematisations and especially the lessons learnt in developing them are not easily transferred beyond the boundaries of an individual project.

By scripting the model set-up process as much as possible and putting the model set-up scripts and the resulting model schematisations under version control the efficiency by profiting/learning from past experiences increases.

Note that OpenEarth considers only the model schematisations as MODELS (e.g., a mesh type grid with initial and boundary conditions). The model codes are considered as TOOLS (e.g., Fortran, Matlab), and the model output as DATA (e.g., netCDF files).

In fact, for MODELS the OpenEarth team proposes to include all components that are not strictly DATA and TOOLS, i.e., all components that are needed for complete mapping (in mathematical sense) of all input components to all output components.

- Prepare your model schematisation.
- Commit your models to the open OpenEarth model repository under https://svn.oss.deltares.nl/repos/openearthmodels or to an in-house clone.
- Store each model (and associated generation scripts) in the following structure (as shown in blue below):
Tools protocol
Core of the OpenEarth philosophy on tools is that by systematically storing, maintaining and disseminating data I/O routines, general engines and applications at a central location, slowly but surely a toolbox emerges that acts as a collective memory to which analysts and end-users naturally gravitate regarding their basic information needs. The long-term focus of the approach promotes collaboration and the exchange of ideas (across the artificial boundaries of projects, departments and organisations) which in the long run will be beneficial to any organisation that uses customised analysis tools on a regular basis.

OpenEarth suggests several ways to generate tools that are easily used and improved by others:
- Conform to the standards of the programming language of your choice (e.g., Matlab).
- Adhere to some basic conventions for well-documented tools.
  - Provide a proper help block and adequate comments to make the code understandable.
  - Include a copyright block indicating terms for use (LGPL recommended).
  - Add an example, either in the documentation or as a “_test” script (see below).
- Commit your tools to the open OpenEarth tools repository under https://svn.oss.deltares.nl/repos/openearthtools or to an in-house clone.
- Store your tools and scripts in the following structure (as shown in blue below):

```
programming language (specific folder per language)
  /to
    /general
      (contains general input/output routines)
    /applications
      (general routines for multiple applications)
      /application1
        ...
      /application2
```

In summary, the following community repositories and web links are available openly from OpenEarth: http://www.openearth.eu – OpenEarth homepage with information on standards, tutorials and so on, and up-to-date links to the following dedicated services:
- https://svn.oss.deltares.nl/repos/OpenEarthRawData – better not checkout entirely: large!!!
- https://svn.oss.deltares.nl/repos/OpenEarthModels
- https://svn.oss.deltares.nl/repos/OpenEarthTools – checkout and update regularly!
- http://opendap.deltares.nl – location of all netCDF data products

Companies that also host an internal clone of the OpenEarth infrastructure for information security reasons are recommended to follow a similar structure to facilitate exchange.

Test protocol
To ensure its quality all OpenEarth content should be rigorously tested. As all content in a specific OpenEarth instance can be freely exchanged between its users, it can be modified by all users that have access to that instance.

This urges adopting the Wikipedia-like approach to quality control: Immediate and continuous peer review rather than the one-time peer review commonly implemented at scientific journals. However, the increasingly complex computer tools that are used to analyse and convert data are a serious impediment to this process (Merali, 2010). Peers cannot be expected to go through lengthy tool codes and conversion scripts in detail to judge their quality.

To solve this issue the authors propose to adopt the scientific method in combination with component level unit tests as proposed by Kleb and Wood (2005). For each tool or data product the quintessential properties need to be tested independently using well-defined test cases. Reviewers can now simply assess the quality of a tool or data product by assessing the completeness of the set of test cases rather than having to examine the tool itself. Test cases may be added or modified if adapting the tool itself is too cumbersome.

OPENEARTH DREDGING EXAMPLES
The previous sections outlined the OpenEarth philosophy, its enabling ICT infrastructure and practice based workflow protocols. To demonstrate the potential of the OpenEarth approach for the dredging industry a number of applications as they have been implemented on dredging projects are discussed.

Facilitating eco-morphological research around dredging projects
An interesting dredging project where the use of OpenEarth as a standard for data sharing is applied is the Pilot Sand Engine Delfland project (www.dezandmotor.nl). The project itself, executed in 2010-2011 in a joint venture between Van Oord and Boskalis, is a large-scale experiment with an alternative method for coastal maintenance.

Rather than nourishing a given coastal stretch regularly with small amounts of sediment, the Sand Engine Delfland project experiments with applying the amount for 20 years’ worth of maintenance all at once: 21.5 million m$^3$ of sand in the form of a hook-shaped peninsula between Ter Heijde and Kijkduin, on the North Sea coast of the Netherlands (Figure 3). This innovative approach to coastal maintenance is hypothesised to be more efficient and environmentally friendly as the concentrated nourishment uses a relatively small footprint and makes use of natural processes to gradually redistribute the sediment over the coastal system.

Local flora and fauna is quite capable of dealing with this gradual redistribution of sediment. Furthermore, the hook-shaped peninsula stimulates other functions besides coastal safety such as recreation and nature development. This latter aspect is a clear added value compared with the traditional approach.

A great quantity of survey data was already gathered during the execution of the project. Additionally a number of research and monitoring programmes, each with sizeable budgets and a variety of involved partners, have been initiated to study the behaviour of the innovative Sand Engine design:
- 3.5 M€ Building with Nature programme, Holland Coast Case
- 2.5 M€ EIA Measurements Rijkswaterstaat
- 3 M€ EU EFRO Grant for additional measurements Sand Engine
- 4 M€ STW Perspective Grant: NatureCoast
- 3 M€ EU ERC Grant: NEMO
An integral part of the monitoring plan was the establishment of the Sand Engine Data Lab: A central data management facility for all monitoring programmes for the benefit of current as well as future research.

The Sand Engine Data Lab is developed in close collaboration with Delft University Library and the 3TU.datacenter, and adopts the OpenEarth workflow and protocols to establish good quality data archives that can easily be shared amongst the researchers involved in the various programmes.

A data use and publication protocol has been developed to create a clear set of ‘house rules’ for the use of each other’s data within Data Lab. The involvement of Delft University Library and the 3TU.datacenter is crucial to guarantee durable data storage (also beyond the lifetime of the current research programmes) and professional data dissemination using digital object identifiers (DOI’s) per dataset.

Using system knowledge to enhance efficiency in long-term maintenance projects

The Sand Engine Data Lab is a nice example of dredging companies working together with a large number of research institutes and universities to develop new knowledge on the behaviour of an innovative design. In practice such collaborations are not abundant. A much more common setting, where system knowledge can make the difference, is for long-term maintenance contracts of navigation channels or ports.

When awarded a long-term maintenance contract it is worthwhile to develop a good understanding of how the navigation channel or harbour responds to natural variations and human-regulated events such as fluctuations in river discharge, storms, dredging and dredge material placement. Especially when a project runs for several years, storing and processing project information consistently for later analysis is extremely helpful.

Depending on the nature of the phenomena observed, models may be used to predict/understand some parts of the systems behaviour. Think of natural sedimentation rates and hotspots during normal conditions or the advent and decay of sand dunes during high water discharge events. Such knowledge may be used to optimise dredging and placement strategies. In any case, tools are needed to analyse, visualise and report the observed and predicted system behaviour.

Various sources of data need to be combined to develop an understanding of the system’s behaviour, viz., consecutive surveys to enable the analysis of volume changes, design levels to assess the need for dredging, production information to understand where volume changes may have been caused by natural processes or dredging or placement of material, hydrodynamic data to understand how volume changes in the project area correlate with discharge events, sediment samples to identify what kind of material is found where, and so on.

Figure 3. Left panel: Aerial photograph of Sand Engine Delfland. Right panel: Visualisation of measured bathymetry and topography for the same date.

Figure 4. Left panel: Measured bathymetries for the long-term maintenance of the Dortsche Kil, the Netherlands. Right panel: Visualisation of calculated volume changes (outside) and dredging and placement records (inside) for the same area. Notice that the both visualised datasets can be animated over time.
is highly dynamic. To promote economically viable dredging strategies the concept of the “nautical depth” was introduced. Nautical depth is defined as a calculated plane below which ships encounter so much resistance from the mud layer that it inhibits manoeuvrability.

Conveniently deriving this nautical depth from various sources of data requires the development and smooth applicability of tools and the availability of a large and consistent dataset. The OpenEarth workflow was used to store various available datasets in a consistent manner. As a result, five years of monthly surveys and dredging/placement info is made available for easy analysis.

![Figure 5](image_url)

Figure 5. Left panel: Measured “nautical depths” for the long-term maintenance of the entrance channel of IJmuiden Port, the Netherlands. Right panel: Visualisation of calculated “nautical depths” relative to design levels (green colours indicate ‘nautical depths’ deeper than the design level; red colours indicate high spots).

Figure 4 shows a long-term maintenance project of the Dordtsche Kil and Merwede. All available survey data has been stored and processed according to the OpenEarth workflow. Figure 4 (left panel) shows a visualisation of the measured bathymetries per dredge box. Also all available dredging and placement records, again specified per dredge box, were stored and processed.

Post-processing of the available data enabled engineers to produce the visualisation in the right panel of Figure 4, which shows calculated volume changes (outside) and dredging and placement records (inside) for each dredge box. Notice that the both visualised datasets can be animated over time. Combined with information on river discharge one can develop an understanding of the system behaviour.

With this understanding knowledge-based dredging strategies may be developed and put into practice.

Another example is the long-term maintenance contract for the entrance channel of IJmuiden port, the Netherlands, shown in Figure 5: Left panel, calculated ‘nautical depths’; right panel, visualisation of calculated “nautical depths” relative to design levels (green colours indicate “nautical depths” are deeper than the design level; red colours indicate high spots to be dredged). The entrance channel of IJmuiden port contains large quantities of fine sediment/mud in a layer that is highly dynamic.

![Figure 6](image_url)

Figure 6. Left panel: Control boxes on a reclamation and locations of cone penetration testing. Right panel: Easy visualisation of detailed project information.
The resulting data set can now easily be visualised (see Figure 5) as well as analysed (OpenDAP, netCDF, Matlab). Work is on-going to increase understanding of the available datasets. The use of models is considered to help better understanding of the systems behaviour.

Advanced project reporting and strategic knowledge development

A third example deals with the analysis, reporting and visualisation of deep compaction activities in the Middle East. Figure 6 shows a reclamation that has been divided into so-called control boxes. For each of these control boxes a complicated analysis must be performed to determine if bearing capacity and resistance against liquefaction are sufficient.

Initially the client requirements were implemented in an Excel sheet. Anywhere between three and eight cone penetration test (CPT) files were manually loaded in this sheet that took some 20 minutes to iterate to the final verdict: Compliant/non-compliant.

Though this approach had worked before on smaller-scale projects, the sheer number of tests and control boxes (thousands) required a more advanced approach. Not only to reduce the workload, but especially to be able to learn lessons from the work already done by, e.g., accessible visualisation of test results.

Following the OpenEarth philosophy, a data management and IT infrastructure was implemented. Key aspects were that:
- data would be checked, stored and structured by personnel on site;
- analysis tools would be developed by experts based in the Netherlands;
- data products (reports, visualisations) would be available on site as well as in the Netherlands; and
- the application of more efficient tools on-site would help site personnel to focus on soil mechanics rather than programming Excel sheets.

Above key aspects may only be achieved when a fixed protocol is available to assess the bearing capacity. First of all per box a fixed minimum number of CPTs has to be performed at predetermined locations.

Analysis of this data and a comparison to the bearing capacity requirements imposed by the client yields either success or failure of the control box. In case of insufficient bearing capacity additional measures have to be taken, e.g., in the form of a re-compaction method, rapid impact compaction or surface rolling. After the additional measures, new CPTs have to be performed to reassess the control box.

One can imagine that depending on the size of the reclamation the number of data files and analysis steps can quickly get out of hand. Next to the fact that soil improvement projects are already logistically challenging in themselves, it is important to realise that subsequently demonstrating the quality per control box is equally challenging.

To get a feeling for scale it is not uncommon to have projects with several thousand control boxes each requiring between the 40–80 vibro poker actions and 3–8 CPTs to demonstrate sufficient quality. Often payment of the project is coupled with the approval of the control boxes. One can imagine that in such projects careful data storage and easy access, combined with effective and efficient data processing, visualisation and reporting scripts is of crucial importance.

To limit the number of (highly trained) project engineers and data secretaries needed to collect, check, process, analyse and visualise the data, the whole process is automated as much as possible. After adopting the OpenEarth workflow for ground improvement works, this process is streamlined such that just one project engineer, supported by a small number of data secretaries, is now responsible for the whole project.

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Figure 7. Left panel: Visualisation of one hopper track from dredging area to disposal site. Right panel: Environmental measurements around a cutter.
CONCLUSIONS

OpenEarth as a whole (philosophy, user community, infrastructure and workflow) presents a comprehensive approach to handling data, models and tools that actually works in practice at a truly significant scale:

• The infrastructure is built from the best open source components available, and thus free to use and easy to implement, and the associated workflow is based on widely accepted and open international standards as much as possible.
• The workflow is implemented effectively not only at its originally founding organisations Delft University of Technology and Deltares in a research setting, but also at Van Oord in large commercial dredging projects where proper handling of (big) data, models and tools is of direct influence on the project success.

Practical applications in various research programmes and projects show that management of data, models, tools and knowledge can indeed be lifted to a higher level. Otherwise competing organisations now work together exchanging information via the OpenEarth repositories.

But also within companies collaboration between départments is improved:
• Sharing the most generic datasets, models and tools has clear positive spin-off in the sense that many basic analyses can be performed much more efficiently. This facilitates that more work can be done given the same amount of available resources.
• The practical examples illustrate the potential of OpenEarth for dredging projects. For data, models and tools that are truly strategic and really cannot be shared, OpenEarth stimulates the set-up of internal OpenEarth clones. This way the OpenEarth workflow can still be adopted, promoting collaboration within the organisation, while taking care of security considerations at the same time.

Just like other quality systems, OpenEarth cannot guarantee the quality of the analysis but it adds to the complete transparency and durable accessibility of the data products, models and tools used in the process. Various practical applications of the OpenEarth workflow have demonstrated the power of collaboration and the positive effects of the project transcending approach.

REFERENCES


ABSTRACT

Safety in dredging relates to safety and health of personnel, safety of the ships and quality of the environment. In the past, dredging contractors often had inadequate safety management systems, which led each client to insist that its own safety management systems be used by a contractor to ensure compliance. Nowadays, however, the leading dredging companies have mature safety management systems and they have earned the trust of their clients. The will to prescribe systems is no longer necessary and may prove to be counterproductive. When the contractors can implement their own systems, it enhances their strengths, values, knowledge and safety culture and leads to better results. Rather than switching temporarily from one client’s system to another, using a single reliable system within a dredging company helps the safety management to improve. This article aims to share views and ideas on how contractors and clients can jointly improve the safety performance on projects.

INTRODUCTION

The leading international dredging companies have come a long way regarding their safety performance. The number and seriousness of incidents have significantly been reduced over the last decade and contractors have shown adequate responses when an accident does happen to ensure prevention in the future. The will to learn from what has gone wrong in the past is strong. Still serious incidents do occur and keeping performance improvement growing requires constant vigilance.

In the past, contractors often had inadequate safety management systems, which consequently lead clients to prescribe their own safety management systems to contractors to ensure compliance. Nowadays, however, as the leading dredging companies have mature safety management systems, prescribing different systems is no longer necessary and may prove to be counterproductive. Given the present advanced state of contractor’s safety systems, clients would be advised to assess the safety management system of their contractor and, if at all possible, accept it and not advocate their own systems. In this way the client actively participates in the contractor’s safety culture, the contractor’s staff will be empowered to act and change.

THE CONTRACTOR’S SAFETY CULTURE

As an example of the advances the dredging community has made in safety compliance, Van Oord’s safety management system includes (but is not limited to) specific policies on several subjects: An overall integrated management system, tools such as a Safety Observation Cards and Work Safe Rules – which define the basic principles regarding activities that historically result in the most incidents, and Use of Safety Performance indicators. Policies have been developed in line with the company’s vision and mission on Safety, on Environment and CO₂ emissions, and goals have been set to improve results within a given timeframe.

VOMS

Van Oord has a very comprehensive management system (VOMS) which describes its business processes. It has integrated Quality Assurance, Health & Safety as well as Environmental Management. The company aims to ensure compliance with numerous norms and standards, such as ISO 9001, ISO 14001, OSHAS 18001, ISM, ISPS and MLC, for which the company has been certified by the
recognised certifying authority. Amongst the positive reinforcement tools developed is a Safety Observation Card. This card invites personnel to be proactive in addressing safety issues. It is a simple tool which is easily used, and supervisors are mandated to address each card individually and ensure that feedback about any necessary actions is given within a reasonable amount of time. The card stresses the positive aspects of safety by empowering all personnel to act before a situation escalates or an incident occurs (Figure 1).

WORK SAFE RULES
The incidents from the company’s recent history have been thoroughly assessed and staff have identified several activities where incidents occur more often than in other activities, the so-called “higher risk” activities. Focussing especially on those areas resulted in the development of Work Safe Rules, which specify the most important “do’s and don’ts” for those activities. A poster campaign as well as a DVD with specific short movies per Work Safe Rule emphasises each of these rules and the safety department stresses the importance of addressing those within Toolbox talks and prestart meetings and such (Figure 2).

In total the company has developed more than 50 Safe Work Practices (SWPs), which are more detailed instructions on numerous subjects, varying from UXO (Unexploded Ordnance) to Food Safety in catering. These SWPs were recognised by the IADC Safety Award in 2011. They continue to be expanded on a number of subjects which are covered by comprehensive, detailed, clear and unambiguous instructions for all to follow.

SAFETY PERFORMANCE INDICATORS
Safety appears to be one of the few activities which are quantitatively measured via actual unsafe parameters – which means “unsafety” is actually being measured. This is because traditionally safety is measured with Lagging Indicators, incident frequency and other accident statistics.

Van Oord is moving towards a more positive and predictable way to measure safety, by Leading Indicators – such as the number of safety observations and the time span within which actions are taken to address an incident. Such Leading Indicators allow management to act and change things proactively rather than reactively (Figure 3).

SAFETY IS A CULTURE
When talking about safety, issues such as trust and blame, care and commitment are raised. These are subjects in addition to the statistics, the procedures and the checklists that are necessary to adequately address safety performance and attitudes within an organisation. Focussing solely on standards, safety equipment and management systems does not provide the whole picture (Figure 4). Safety must be part of a company’s culture.

What one observes historically within the company with respect to incident frequency conforms with what science has reported. Originally as technology improves, the frequency of incidents is greatly reduced. Initially contractors start to actively implement safety management systems. But gradually after a while the rapid improvement flat-lines somewhat. To continue to see improvement in safety performance demands developing “a safety culture”.

CLIENT PARTICIPATION
The client’s participation in the contractor’s efforts is very much welcomed. As a team, contractor and client can address issues, including cultural issues, which can lead to very valuable improvements. Outsider’s eyes can see blind spots, and often contractors are so much part of their own safety culture that they may overlook opportunities for improvement. If a client is actively engaged in safety and addresses safety attitudes, this will empower the contractor’s personnel to speak up, be proactive and raise issues. So, within Van Oord a client’s active participation is certainly welcome. However, clients should also assess against their own requirements, with the focus on what they aim to achieve – rather than which means or methods they are going to use. In this way they can make a contribution and yet accept the contractor’s safety management systems, without prescribing their own (new) rules and procedures.

This will have several positive effects:
- It will avoid “changing the rules” all the time,
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Figure 3. Leading Performance Indicators are a more positive and predictable way of measuring safety.

A client’s involvement in addressing the contractor’s safety culture is appreciated. Clients can contribute by adopting a behavioural-based safety approach, leading by example. They will be able to empower the contractor’s personnel by giving priority to safety issues and as a more objective observer they will see things which the contractor may miss. In this way, the best of both worlds can be used.

SAFETY INCENTIVES – ADVANCED PAYMENTS, NOT BONUSES

This approach, allowing the contractor to use its own safety management systems, has led to some very positive experiences with clients. Additionally, a specific experience with a client has taken this idea a bit further. It led Van Oord to suggest a new approach to safety performance in contract administration and management. At the start of the contract the contractor should look at what the client wants to achieve in safety performance and then identify the specific tools and systems, initiatives, trainings and programmes to reach this goal. Together, client and contractor can define (positive) leading Key Performance Indicators (KPIs) and agree on a programme/“milestone schedule”—Leading Indicators to ensure a positive and predictive approach and to avoid any reluctance to pursue full transparency on incident reporting.

The client can then commit specific parts of the lump-sum of the entire contract towards these milestones. This is NOT an additional amount, but a part which was already agreed to be payable under the contract for executing the entirety of the scope of work. The safety performance would dictate WHEN this part would be paid, not IF it would be paid. Upon achieving a milestone, a part of the overall lump-sum would be payable. If a milestone were not met, the payment of that portion would move back to the end of the contract. In this way a cash-flow benefit is attached to the “milestones” and the contractor will be incentivised to achieve them.

What might possibly be even more effective is to make a project’s progress quantitatively visible. As most dredging company employees are generally quite competitive, they will be driven to achieve these milestones in a timely manner. When confronted with clearly defined quantitative goals and milestones, they would certainly do their utmost to accomplish the tasks.

CONCLUSIONS

Safety awareness amongst the leading international dredging contractors has grown and improved over time. At present, these contractors have mature, sophisticated systems in place. By implementing their own systems, rather than that of various clients, the safety systems gain acceptance and improve the dredging contractor’s commitment to a safety culture.

In addition, by working with Financial HSE KPIs and financially rewarding the achievements of the contractor through advanced or early payments (not bonuses) better work procedures are encouraged. This keeps the costs the same for the client, but acts as an incentive to the contractor by improving the cash flow.
ABSTRACT

The Port of Rotterdam is currently undergoing a massive extension called Maasvlakte 2. During the first phase 700 hectares of new port area will be created. A combination of hard and soft sea defences in the North Sea will protect the new port from the elements.

To realise this massive project, innovative design, techniques and equipment were necessary. A design was developed to ensure that wherever possible the sea defence would be soft, since a hard seawall is more expensive. One of the innovative design features of the soft sea defence is the use of Pleistocene sand. In other areas a hard seawall was needed and large quantities of rock fill were necessary. This demanded other innovations and the development of specialised equipment. For instance, although the multi-beam system has been an accepted method of surveying rock layers for quite some years now, Project Organisatie Uitbreiding Maasvlakte (PUMA) and Port of Rotterdam agreed that new research was necessary to quantify the differences between conventional survey techniques and the multibeam. This article describes some innovative survey techniques and equipment used at the Maasvlakte 2.

INTRODUCTION

The Port of Rotterdam is currently undergoing a massive extension called Maasvlakte 2. Between 2008 and 2013, 240 million cubic metres of sand have been deposited from which 210 million m³ is dredged from a sand extraction area in the North Sea and around 30 million m³ comes from dredging the port basins and the Yangtzehaven. During the first phase 700 hectares of new port area will be created (Figure 1). A combination of hard and soft sea defences in the North Sea will protect the new port from the elements.

Beach and dunes with a length of 7.3 km form the soft part of the sea defence. The 3.5-km-long hard sea defence comprises 7 million tonnes of rock and around 20,000 concrete blocks weighing 40 tonnes a piece. PUMA (Project Organisatie Uitbreiding Maasvlakte) formed by Netherlands-based dredging companies Van Oord and Boskalis are responsible for the design, construction and maintenance of this immense project.

The economic importance of the port extension is significant. The area added to the port in the 1970s, Maasvlakte 1, has virtually no room left for new companies and existing clients that wish to expand. The Maasvlakte 2 project will contribute to keeping the Port of Rotterdam in its current position as Europe’s most important port. With the construction of the 20-m-deep harbour basins and access channel it will be ready for the container ships of the future.

DESIGN

The design for the soft and hard sea defences was calculated to withstand a once-in-10,000-year storm with a wave height of 9 m coming from the north to north-west (348º) and duration of 12 hours (Figure 2). Wherever possible the sea defence would be soft, as the cost of a hard seawall is considerably higher. Still, during the execution of the project the design of the hard sea defence was further optimised, which resulted in lower construction costs. Model tests were carried out to verify the stability under various circumstances.

To prevent unsafe situations for shipping in the port entrance, criteria were set to the flow conditions for both the construction phase and the final layout. To analyse and quantify the effects, a current model was developed.
that can simulate the current in existing and future situations.

**Soft sea defence**

One of the innovative design features of the soft sea defence is the use of Pleistocene sand. By using this coarser grain of sand a steeper foreshore can be constructed, which requires less sand. The sand will be extracted till approximately –40 m NAP which is around 20 m below the current seabed level. This deep extraction method will limit the area affected by the construction activities.

The row of dunes adjacent to the wide beach varies in height +10 to +13 m NAP. The new beach will provide room for recreation while the dunes will offer a lively habitat for nature.

**Hard sea defence**

The hard sea defence on the north side of Maasvlakte 2 was selected from a number of alternatives and comprises a so-called “stony dune with a reef of blocks” (block dam). The core consists of sand which is divided in two types. Finer sand (approximately 150 μm) located in the deeper part is covered by coarse sand (> 370 μm) in the upper part. Under the reef the sand is covered with filter material (0.3-35 mm). Next a layer of cobbles (20-135 mm) is placed.

In the stony dune area the cobbles are placed directly on the sand creating a cobble beach with a 1:7 slope approximately 4 m thick. Under the concrete blocks two more quarry stone layers can be found: First 5-70 kg rock, secondly a top layer consisting of 150-800 kg armour rock.

A total of 7 million tonnes of quarry stone are required. Some 2 million tonnes of this rock are recycled from the existing block dam of Maasvlakte 1. In the surf zone 40-tonne concrete blocks are placed that measure 2.5 by 2.5 by 2.5 metres. In order to accurately place these blocks the development of a unique crane called the Blockbuster was required. To prevent the blocks from shifting, a toe construction of 1-10 tonne rock has been placed on both sides of the concrete block formation.

The large scale of rock and concrete blocks that have been reused from the Maasvlakte 1 block dam contributed to a cost reduction and made the design also sustainable.

**DETERMINING ROCK QUANTITIES**

For the Maasvlakte 2 project a large amount of rock fill is needed to be placed above and underwater within relatively thin layers and small tolerances. The standard method for surveying rock levels is described in the manual on the use of rock in coastal and shoreline engineering (CUR 154) and requires the use of a semi-spherical foot as a reference.

The greater part of the quality assurance on the sea defence works will be based on data acquired with a multibeam echosounder. The multi-beam system has been an accepted...
method of surveying rock layers for quite some years now. Research in the past pointed towards lower volumes being detected using multibeam surveys as opposed to the semi-spherical foot.

PUMA and Port of Rotterdam agreed that new research was necessary to quantify these differences—in particular for the rock grades that will be used for the Maasvlakte 2 project.

Test pit
For this purpose a test pit was dug out on a construction site near the Yangtzehaven. Layers of 20-135 mm, 5-70 kg, 150-800 kg and 1-10 t were placed in the test pit with a minimum thickness of 2 times the nominal stone diameter. A natural roughness of the bed was simulated.

The bottom of the pit consisted of a flat area and a 1:7 slope. Slopes on the side were respectively 1:2 and 1:1.5 (Figures 3 and 4).

First measurements were performed in a 1x1 m grid with a semi-spherical foot having a diameter of half the nominal average stone diameter ($D_{50}$). This measurement gives a reference level of about 10-15% below the top of the rocks. With an ingenious design the point measurements were simultaneously carried out using the same rod with the semi-sphere on exactly the same geographical location (Figure 5).

In addition, measurements were performed using a square plate of 1 m$^2$ ($\pm 4xD_{50}^2$). For the 1-10 tonne a 4 m$^2$ plate was used. During construction of the stony dune with block dam it was the intention to also use measurements carried out by cranes using their bucket or grab. The position is calculated within the Crane Monitoring System (CMS) and thus can be used to log the level of the rock surface. This method was also tested in the pit (Figure 6).

Static and mobile laser measurements, including a helicopter using the FLI-MAP (airborne laser scanning system of Fugro) system, concluded the test.

After the dry measurements, the test pit was flooded and a small survey vessel (Figure 7) was used to perform test with 6 different types of multibeam systems, a single-beam system with a standard and narrow beam transducer and an Echoscope (Figure 8). Lines were sailed...
with 100% overlap and the transducers mounted at a height of approximately 4 and 6 metres above the test bed. Swath width was reduced to 90°.

A 1x1 m grid was filled with multibeam data which had the same orientation and origin as the land survey data. The centre of the grid cells are corresponding to the topographical survey grid. A resulting correction table was established for each rock gradation with corrections for the various types of survey such as multibeam, single-beam, laser systems and CMS measurements. All correction values refer to the semi-sphere as a reference. When discussing results, it is important to define a reference level to which the results obtained can be compared.

CHALLENGES
The construction of the hard seawall presented quite a few challenges for the PUMA team. One of PUMA’s goals was to carry out as much work as possible with land-based machinery. This would have the advantages of working more accurately and almost continuously, whereas floating equipment is much more dependent on weather conditions (Figure 9).

Blockbuster
The Blockbuster (Equilibrium Crane) has been custom built to meet the project requirements. One of the main design criteria for the Blockbuster was the necessity to place 40-tonne concrete blocks at a distance of approximately 50 m within 0.15 m accuracy (Figure 10). Already at an early stage a team was formed to develop a unique Crane Monitoring System (CMS) that would provide the operator with all the information and tools needed to comply with the design criteria during construction. Because of the dimensions of the crane and the conditions in which it would work special care was taken in choosing reliable sensors that would feed the CMS system with all the information needed (Figure 11).

Above the king pin of the crane a survey mast was placed with a GNSS antenna exactly in the center. A second GNSS antenna was placed near the end of the boom. The second antenna was thought to provide a more accurate starting point of the bucket or block clamp position calculation.

Further on, the baseline between the two antennas supplies a heading which can be

Figure 7. Survey vessel Seapilot in the background carrying out a survey in the test pit. The Trimble SPS 930 Robotic total station was used to monitor possible variances in RTK height onboard the survey vessel.

Figure 8. Results obtained from the CodaOctopus Echoscope 3D sonar.

Figure 9. Three specialised land-based machines used at Maasvlakte 2: Blockbuster, Hitachi 1200 and Condor.
used as a backup system. The main device that provides the heading, pitch and roll information is an Octans IV. The boom and stick angles are measured with rotation sensors. When the crane was assembled, a thorough survey was carried out to determine the geometry of the crane. After the first checks it appeared that the end of the stick could be positioned well within 0.10 m by using the main GNSS antenna in the center of the crane.

The next step was to accurately calculate and present the position of the block which is positioned in the clamp below the end of the stick. The additional computations needed were divided into the computation of the tilt angle of the clamp suspension, the attitude and position of the clamp, the translation offset for the position of the clamp from the taut wire system and the position of the block in the clamp. With these additional calculations it was proved to position a block meticulously within the design criteria of 0.15 m (Figure 12).

Presentation of the blocks is done through the CMS system in a 2D and 3D environment. A target control system assists the operator during placement of the blocks.

To monitor any movement of the undercarriage while the crane is not driving, an MRU was fitted. During the construction process both pitch and roll were constantly measured. Any sudden changes, or slow movement in a fixed direction over a longer period of time, trigger an alarm. The alarm may indicate the undercarriage is sliding away which can lead to an unsafe situation.

Although the as-placed position of a block is logged three dimensionally in the CMS system it was deemed necessary to register the as-built situation with a conventional survey method. In addition, the 150-800 kg armour layer which is partly placed by the Blockbuster needs to be surveyed before the blocks are positioned.

**Condor**

Again the goal was to carry out these surveys from land which provided a new challenge for the PUMA team. As the production process was on a critical time path it was decided not to mount any survey equipment on the Blockbuster itself. Various options were considered taking into account that surveys partially had to be carried out in extreme shallow water with less than 2-m water depth. In addition surveys should possibly be carried out with current speeds up to 5 m/s and a significant wave height up to 2 m.
Tower cranes and crawler cranes were first considered. Hydraulic excavators were ruled out at first because they would be more expensive and could not have the reach that was necessary. On the other hand, a hydraulic excavator would provide a sturdy platform which could withstand the hostile environment of the North Sea.

Engineering was pushed to the limits which led to the construction of a specialised survey crane called Condor with a massive 46.5-m reach. The basis is a Cat 385C with a widened undercarriage. A double cabin was fitted to provide ample workspace for the surveyor (Figure 13).

One of the limitations of the Condor is its reduced lifting power of only 750 kg. Hence a 7-m-long lightweight frame was designed which consists out of a 5.5-m-long lightweight aluminum middle section, a stainless steel cage at the bottom to fit the survey equipment and a coupling piece at the top of the frame (Figure 14).

Accurate positioning proved to be the next challenge. To rule out any loss in accuracy caused by angle sensors on the boom and stick the antenna was placed on top of the survey frame. This way all sensors would be fitted on one frame, with relatively small lever arms, which would be beneficial for the overall accuracy of the system (Figure 15).

After having studied the behaviour of various kinds of multibeam systems on rubble mound structures in a purpose-built test facility, the choice was made for an R2Sonic 2022 multibeam (Figure 16). Alternatively, a CodaOctopus Echoscope system for underwater inspection purposes can be installed in the protective cage.

The compact multibeam has “on the fly” selectable swath coverage from 10° to 160° and focuses 1° x 1° beam widths. A mini sound velocity probe is mounted next to the transducer to do the receive beam steering, which is required for all flat array sonars. Near the end of the stick a small winch is mounted to lower a sound velocity profiler. The profile is used to compensate for any ray-bending effects through the water column.

As the Maasvlakte 2 construction site is located next to the shipping channel Nieuwe Waterweg, the artificial mouth of the river Rhine, changes can be expected in the sound velocity profile caused by temperature variations in the water column or a mixture between fresh and salt water. Heading and motion data are provided by an Octans 3000 which is mounted directly above the R2Sonic.
Next to underwater bathymetric measurements, surveying the part of the block dam that is lying above water was also required. For this purpose a SICK LMS151 laser scanner was mounted directly below the GNSS antenna pointing vertically downwards. The scanner works with a class I infrared laser (905 nm) and has an opening angle of 270º and 0.25º beams.

In some situations the crane operator could not see the location of the protective cage with reference to the underlying area. A camera was placed to provide the operator with visual information so any contact between the frame and the blocks could be avoided (Figure 17).

During the execution phase of the project the design of the survey frame was optimised by adding a rotator between the stick pin and the upper part of the survey frame. This makes it possible to survey not only perpendicular lines to the coast, by moving the boom and stick, but also parallel lines can be surveyed by swinging the crane from left to right.

The survey crane proved to be a valuable tool during the construction of the stony dune with block dam. By providing almost instant survey results to the operators and engineers the efficiency of the Blockbuster was improved. From August 2010 through January 2012 the Condor worked almost continuously, 24 hours a day, 7 days a week.

The SICK LMS 151 laser scanner turned out to be a helpful survey tool. Besides surveying the crest of the block dam it was also used to measure stockpile quantities. Owing to the size of some rock gradations measuring these piles on foot is unsafe. With the Condor survey crane these surveys could be carried out accurately and within a relative short time.

Because the Condor could only move at a pace of approximately 2.5 km/h, travel time to the stockpile area became an issue and an

Significant wave heights encountered during operational hours:
- $H_s < 0.5 \text{m}$: 40%
- $0.5 \text{m} < H_s < 1.0 \text{m}$: 27%
- $1.0 \text{m} < H_s < 1.5 \text{m}$: 15%
- $1.5 \text{m} < H_s < 2.0 \text{m}$: 11%
- $H_s > 2.0 \text{m}$: 7%

The SICK LMS 151 laser scanner turned out to be a helpful survey tool. Besides surveying the crest of the block dam it was also used to measure stockpile quantities. Owing to the size of some rock gradations measuring these piles on foot is unsafe. With the Condor survey crane these surveys could be carried out accurately and within a relative short time.
alternative was sought. All the components needed for a laser scan survey were built into a small aluminum box that was mounted on various equipment, such as the CAT980 Wheel loader and Manitou MT1440 telescopic forklift (Figure 22). Via a WiFi connection the computer in the box was controlled by a surveyor.

After gaining experience with this method, the project bought a John Deere 6200 tractor that was only used for survey purposes (Figure 23). Nowadays the tractor is still used on a daily basis to cover large terrains in a short time and with full coverage. To indicate, an area of 20 hectares can be measured within 30 to 60 minutes.

Recycling of the block dam
Some 20,000 blocks are reused from the existing Maasvlakte 1 block dam. The backhoes Nordic Giant and Wodan were mobilised to the Maasvlakte 2 project to remove the 40-tonne blocks and 2 million tonnes of rock fill. A special ripper tool was developed by PUMA so each block could be carefully extracted (Figure 24). Above water this was already quite some challenge. If the correct pressure was not applied at the correct place the possibility that the block would fall during the extraction process, causing damage to the backhoe or transport barge, was significant. Along the way modifications were performed to optimise grip on the blocks.

Below the water surface, where the majority of the blocks are located, the operators had no visual information which made it extremely difficult to position the ripper tool correctly around the block. In particular the danger was that the ripper tool would be damaged by moving blocks. From the start it was clear that a normal underwater camera system would not be a solution in the murky waters that surround the breakwater and that an acoustic viewing system would be necessary. At the Ras Laffan Northern Breakwater project both Boskalis and Van Oord had gained experience in safely and accurately placing 37,000 single layer armour protection units, called Accropodes™, with help of a Coda Octopus 3D Echoscope system. This innovative solution
quality and safety are some of the parameters that play an important role in this matter. Updates of the reclamation areas, stockpile quantities, location on objects such as roads and pipelines should preferably be carried out on a daily basis but given the enormous size of the project this is not always possible. The pre-survey covering the beach and dunes of Maasvlakte 1 and the old block dam was carried out with Fugro’s airborne laser scanning system (FLI-MAP). Point density at an average flight speed of 35 knots and 100 m above ground level will be 74 points per square metre with an absolute accuracy of around 2.5 cm. During the course of the project several other FLI-MAP surveys have been carried out to monitor the behaviour of the block dam and stony dune.

Airborne systems
Because of the vast area covered by the project PUMA has always looked at new survey techniques that could improve the way the daily surveys are conducted. Quantity, quality and safety are some of the parameters that play an important role in this matter. Updates of the reclamation areas, stockpile quantities, location on objects such as roads and pipelines should preferably be carried out on a daily basis but given the enormous size of the project this is not always possible.

The same technique was adopted on the Maasvlakte 2 project.

The Echoscope generates over 16,000 beams and has an opening angle of 50º (375 kHz) in both horizontal and vertical directions producing instantaneous three-dimensional sonar images of both moving and stationary objects. The Echoscope is mounted in a frame that is attached to the front of the pontoon of the backhoe. The frame is equipped with two electrical servo motors which can follow the position of the ripper tool in the horizontal plane (yaw) and vertical plane (pitch). The automated tracking of the ripper tool is controlled from the Crane Monitoring System (CMS).

Within the system certain parameters can be set to prevent the frame tracking the ripper tool when it only moves a few degrees or is lifted out of the water. For this specific job a new feature was added – the Echoscope-UIS™ software – to present the stick and ripper tool as 3D models with information from the CMS. This additional information was especially useful to the operators of the backhoe as it gives a clear picture of the position of the ripper tool with reference to the acoustic presentation of underwater objects (Figure 25).

Figure 24. Left: Backhoe Wodan extracting a block from the Maasvlakte 1 block dam. Middle: Close up of the Wodan’s ripper tool holding firmly to a 40-tonne concrete block. Right: A 40-tonne block is safely released on to the transport barge.

Figure 25. Left: 3D model presentation of the stick and bucket while removing riprap. Right: 3D model presentation of the ripper tool while removing a 40-tonne block.
For the day-to-day surveys this method is relatively expensive and results are not available instantaneously as the technique relies on GPS post-processing techniques.

Early in 2010 a test was performed with a Gatewing unmanned aircraft. Unfortunately the prototype crashed near the Maasvlakte 1 block dam. Two years later a new test was performed by Geo Infra with a production model called X100 (Figure 26). The 2-kg system with a shock-absorbing structure is powered by electric propulsion and carries a calibrated camera. Flights and landings are conducted in a fully automated manner and according to a pre-programmed flight plan.

No piloting skills are required to fly the Gatewing X100. The obtained accuracy with this system is within 5 cm (x,y) and 10 cm (z). For the PUMA project this new technology came too late but it would certainly be an alternative to carry out daily surveys over the immense area of Maasvlakte 2 (Figure 27).

**MILESTONES**

**Closure soft sea defence**
On July 11, 2012 a major accomplishment occurred when the last gap in the soft sea defence was closed in the presence of Her Majesty Queen Beatrix of The Netherlands. Since the construction of the Philipsdam 25 years ago this was the first large sand closure and unique in its kind.

A thorough study preceded the closure in which all aspects were analysed. During the course of June 2012 a “spoiler” was constructed on the north side of the closure area to divert the current and provide the lee side for the trailing suction hopper dredgers while discharging. Throughout the week before the closure an underwater bund was constructed by placing sand to about –8 m NAP. Next the bund was made higher till a level of approximately –1.5 m NAP.

This was done with a process in which the sand mixture is discharged as close as possible over the bow coupling (as opposed for instance to rainbowing in which sand is spouted in an arc as far as possible). The TSHD discharges and spreads the sand mixture as slowly as possible at a low speed and the material is thus deposited right in front of the bow. In this way the material can be accurately spread within the design tolerances.

Next the bund was widened to 300 m. On the day of the closure the seaside part of the underwater bund was raised to +2.0 m NAP with a combination of cutter suction dredger Edax discharging by landline from the north side and TSHD *Vox Maxima* and *Prins der Nederlanden* discharging by landline from the south side (Figure 28).

Despite the difficult circumstances the survey department managed to provide the operation and engineering department with vital information on seabed changes and current profiles on a day-to-day basis.

**Opening passage to Maasvlakte 2 from Yangtzehaven**
On November 25, 2012 another milestone was achieved when access to the Maasvlakte 2 was created from the Yangtzehaven. After closing the sea defence on July 11, a lake was
The Maasvlakte 2 expansion project is extensive and presented a number of challenges which were met by innovative design, survey techniques and equipment. These included:

- The use of Pleistocene sand which is a coarser grain of sand and allowed a steeper foreshore to be constructed which therefore needed less sand.
- A large scale of rock and concrete blocks were reused from the Maasvlakte 1 block dam which contributed to a cost reduction and made the design sustainable.
- One of PUMA’s goals was to carry out as much work as possible with land-based machinery, which has the advantage of working more accurately and almost continuously, as compared to floating equipment which is much more dependant on weather conditions: the results was the Blockbuster able to lift 40-tonne concrete blocks.
- The development of a unique Crane Monitoring System (CMS) that provides the operator with all the information and tools needed to comply with the design criteria during construction.
- A new feature was added to the Echoscope – the Echoscope-UIS™ software – to present the stick and ripper tool as 3D models with information from the CMS.
- Engineering was pushed to the limits when a specialised survey crane called Condor with a massive 46.5 m reach was constructed.
- Recycling the block dam from Maasvlakte 1 required improving the grip of the backhoes and special acoustic viewing systems as underwater cameras were not useful in the murky waters.
- An airborne system called the Gatewing was tested during the start of the project, but was not ready for use until the last construction phase of Maasvlakte 2. The later model Gatewing X100 does however represent a breakthrough which can clearly be applied to future projects.

On July 11, 2012 the soft sea defence was closed and on November 25 access to Maasvlakte 2 through the Yangtzehaven was achieved.
In recent times, the role of maritime transport in the globalisation of the world’s economy has grown significantly. At present more than 80 percent of world trade by volume is transported over water. With the deepening of the Panama Canal and the current expansion of ports, as well as the mega size of the newest freight, cruise and dredging vessels, the value of – and concerns about – maritime transport are also destined to increase.

This makes the interaction of waterborne transport (be it of cargo or people) with climate change and the impact of climate change on all aspects of maritime transport and trade worthy of examination and discussion. In fact, this is a double-edged sword: On the one hand, vessels are confronted with a need to reduce their carbon footprint; on the other, they and ports and harbours are subject to rising sea levels and other climate change consequences.

In this new book, in-depth papers are presented from 25 experts from the International Maritime Organization (IMO), the United Nations Framework Convention on Climate Change (UNFCCC), the OECD, the International Energy Agency (IEA), the World Bank as well as from the shipping and port industries. The book is edited by Regina Asariotis, a Senior Legal Affairs Officer and Chief of the Policy and Legislation Sections at the United Nations Conference on Trade and Development (UNCTAD) and Hassiba Benamara, an Economic Affairs Officer in the Policy and Legislation Section of UNCTAD.

The papers are selected from a three-day expert meeting of the same name as the book that was organised by UNCTAD. Some 180 delegates from 60 countries and 20 inter-governmental organisations and NGOs took part. The book is divided into four parts: First the groundwork is laid for understanding the effects of climate change in general and then specifically as regards maritime transport. The costs of adaptation to climate change versus the costs of the disruption of waterborne trade are weighed. Part II devotes several chapters to the international efforts to regulate carbon emissions including the UNFCCC and the Kyoto Protocol as well as recent work of the IMO.

Efforts to reduce gas emissions by innovations in vessel design and other technological improvements are also described. The chapters in Part III present the views of the International Chamber of Shipping as well as the “World Ports Climate Initiative” of the International Association of Ports and Harbors. And lastly Part IV evaluates the impact of extreme flood events on port cities including the Gulf Coast of the US, the southern African coast and adaptations at the Port of Rotterdam in the Netherlands.

The book and conference were motivated by a need to address the complexity of climate change. Especially the potential threat to global prosperity caused by uncertainties as regards all aspects of trade – food, energy, goods – as well as infrastructure, environmental impacts and biodiversity. Whilst it does not answer all our questions, it provides a basis for raising awareness and continuing the discussion.

**Maritime Transport and the Climate Change Challenge**

**EDITED BY REGINA ASARIOTIS AND HASSIBA BENAMARA**


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**FACTS ABOUT WATER INJECTION DREDGING**

An Information Update from the IADC

*Number 1. March 2013. 4 pp. Available free of charge online and in print.*

In this first *FACTS About* of 2013, a lesser known, but extremely interesting, dredging technique is described. Water injection dredging, a form of hydrodynamic dredging, is cost efficient and environmentally friendly for certain types of dredging operations. Invented some 25 years ago, water injection dredging has gradually come into favour for relatively shallow water depths from 0 to 26 metres and soil conditions where the undrained shear strength of the in-situ material is not too high. Specifically, water injection dredging is suited to maintenance dredging in harbours and access channels, dynamic waterways, where sedimentation and erosion are going on at the same time as dredging. In the last decades the fleet of purpose-built Water Injection Dredgers (WIDs) has grown and more than 20 WIDs are now active globally. *FACTS About Water Injection Dredging* gives an overview of the many benefits of this unique dredging process.

The *FACTS About* series is an initiative of the International Association of Dredging Companies (IADC) to distribute up-to-date information on various maritime construction and dredging subjects. This newest *FACTS About* (and all other in the series) is downloadable as a PDFs at www.iadc-dredging.com. Print copies are available by emailing the IADC Secretariat at info@iadc-dredging.com.

SEMINARS / CONFERENCES / EVENTS

IADC SEMINAR ON DREDGING & RECLAMATION
JUNE 24-28, 2013
IHE-UNESCO, DELFT, THE NETHERLANDS

For (future) decision makers and their advisors in governments, port and harbour authorities, off-shore companies and other organisations who have to execute dredging projects, the International Association of Dredging Companies has organised the International Seminar on Dredging and Reclamation at numerous venues often in co-operation with local technical universities. Since 1993 this week-long Seminar has been successfully presented in Delft, Singapore, Dubai, Buenos Aires, Abu Dhabi, Bahrain and Brazil. As is appropriate to a dynamic industry, the Seminar programme is continually updated. In addition to basic dredging methods, new equipment and state-of-the-art techniques are explained.

To optimise the chances of the successful completion of a project, contracting parties should, from the start, fully understand the requirements of a dredging project. This five-day course strives to provide an understanding through lectures by experts in the field and workshops, partly conducted on-site in order to give the “students” hands-on experience. Highlights of the programme are:

Day 1: Why Dredging? The Need for Dredging/Project Phasing
Day 2: What is Dredging? Dredging Equipment/Survey Systems (includes a site visit)
Day 3: Production of various types of dredgers (includes a visit to a dredging yard)
Day 4: Preparation of a Dredging Contract, Reclamation, Tender, Cost Pricing
Day 5: Contracts

Subjects covered include:
- overview of the dredging market and the development of new ports and maintenance of existing ports;
- project phasing (identification, investigation, feasibility studies, design, construction, and maintenance);
- descriptions of types of dredging equipment and boundary conditions for their use;
- state-of-the-art dredging and reclamation techniques including environmental measures;
- site and soil investigations, designing and estimating from the contractor’s view;
- costing of projects and types of contracts such as charter, unit rates, lump sum and risk-sharing agreements;
- design and measurement of dredging and reclamation works;
- early contractor involvement.

An important feature of the Seminars is a site visit to a dredging project being executed in the given geographical area. This gives the participants the opportunity to see dredging equipment in action and to gain a better feeling of the extent of a dredging activity.

Each participant receives a set of comprehensive proceedings with an extensive reference list of relevant literature and, at the end of the week, a Certificate of Achievement in recognition of the completion of the coursework. Please note that full attendance is required for obtaining the Certificate of Achievement. The Seminar starts Monday 24 June at 8:45 hrs and ends Friday 28 June at 17:30 hrs. The fee for the week-long seminar is € 2,250.- (VAT inclusive). This includes all tuition, seminar proceedings, workshops and a special participants dinner, but excludes travel costs and accommodations. Assistance with finding hotel accommodation can be given.

For further information contact:
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WEDA 33 / TAMU 44
AUGUST 25-28, 2013
HILTON HAWAIIAN VILLAGE, HONOLULU, HAWAII

The theme of the Western Dredging Association’s 33rd Annual Western Hemisphere Dredging Conference and Texas A&M’s 44th Annual Dredging Seminar (WEDA 33/TAMU 44) is “So That Ships May Pass”. It will focus on the Historical, Structural and Operational Development of Navigation throughout the Western Hemisphere. Topics of interest include, but are not limited to:
- History of Dredging Milestone Projects (Last Millennium)
- Dredging Research
- Budgeting & Cost Estimating
- Development of Cargo Carrying Ships
- Dredging for Flood Control
- Geotechnical Aspects
- What Drives the Industry?
- Market Trends
- Navigation Channel Depths
- Surveying & Mapping
- Dredging for Beach Nourishment
- New dredging Equipment
- Dredge Safety Issues
- Environmental Clean-up Sites

Included in the dredging conversations will be the critical global economic need for dredging, the importance of enhancing the marine environment as well as historical dredging developments, trends and the dredging progress that has created today’s market trends and also emerging environmental issues. The conference will provide a forum for discussions between North, Central, South American and Pacific regions.

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www.westerndredging.org
FORUM ON EARLY CONTRACTOR INVOLVEMENT
NOVEMBER 14-15, 2013,
HOTEL ISTANA, KUALA LUMPUR, MALAYSIA

If you are a project owner, financier, insurer, contractor, construction lawyer, regulator, government agency or NGO working in the maritime infrastructure construction industry, you cannot afford to miss this interactive forum and networking event. This two-day forum with the theme Partnering Creates Possibilities will bring together top-level experts and advisors for an in-depth exchange of knowledge. The Forum is organised by the International Association of Dredging Companies (IADC) with the co-operation of the Eastern Dredging Association (EADA). EADA is part of the World Dredging Association, which serves the Asian and Pacific region.

With well-known keynote speakers setting the tone, the participants will explore the benefits of “contractual partnering” – that is, co-operation amongst all the contractual players from the very earliest stages of project development.

WHY DOES EARLY CONTRACTOR INVOLVEMENT MATTER?
Anyone involved in large infrastructure projects has come up against delays, postponements and risks. And the first question that arises is: How could this have been done differently? Why didn’t anyone see these problems coming?

Early Contractor Involvement (ECI) can help:
• identify risks and responsibilities,
• pinpoint obstacles to co-operation,
• suggest possible methods to eliminate or minimise differences.

The aim of the Forum is to explore the practical and legal possibilities of smarter and better use of the resources associated with “the early involvement of contractors”. The results of ECI can bring benefits to society in the form of faster and more cost-effective solutions. By examining recent successful projects from different parts of the world, this dynamic event aims to distribute existing knowledge and to stimulate new, creative ideas for achieving solutions for Best for the Project (win-win). This Forum on Early Contractor Involvement in Kuala Lumpur is a follow-up to the outstanding meeting on the subject organised in London 2 years ago. Dr. Dean Kashiwagi has agreed once again to participate along with other world-class speakers.

Keynoter Dean T. Kashiwagi, PhD, PE, is a Professor at Arizona State University’s School of Sustainable Engineering and the Built Environment (SSEBE), Director of Performance Based Studies Research Group (PBSRG) at the Del E. Webb School of Construction (DEWSC). Dr Kashiwagi is a worldwide expert in optimising the delivery of construction and other services using performance information. His structures/processes simultaneously minimise project/risk management functions up to 90%, increased vendor profit as much as 100%, increased performance to 98%, and decrease costs. He is the creator of the best value Performance Information Procurement System (PIPS) and Performance Information Risk Management System (PIRMS). His research has expanded to Finland, the Netherlands, Africa and Malaysia.

Prof Kashiwagi will be joined by Mr Gerlando Butera, an international construction law specialist with more than 25 years’ experience with marine engineering and dredging and reclamation projects around the world. Gerlando Butera’s experience encompasses both front-end advisory work involving project delivery structuring, contracting arrangements, security controls and project risk management; as well as acting in back-end claims and all forms of dispute resolution (including litigation, arbitration, expert determination, early neutral evaluation, dispute boards, adjudication and mediation).

His project experience includes dredging and reclamation works for the construction of new port and dock facilities; deepening and widening of approach channels to ports; dredging and backfilling for offshore pipelines and for the construction of an immersed tube tunnel; beach replenishment; and the placing of rock for the construction of offshore islands for coastal defences. Qualified to practice in Hong Kong and England, he relocated to Singapore with his law firm Nabarro LLP in the autumn of 2012.

LISTEN AND LEARN, DISCUSS AND DEBATE
The forum will provide a unique opportunity for participants to learn how several projects have already successfully applied ECI methods. These presentations will be followed by a vigorous discussion led by Marc Gramberger, managing director of Prospex, a consultancy group based in Brussels, specialised in co-operation for excellence. He is author of the official OECD handbook “Citizens As Partners”. Marc Gramberger and his team will introduce participants to the set of attitudes, skills and basic knowledge for making co-operation a success – beyond the “mediocracy” of a mere compromise.

Registration fee is € 995.- per person (this includes all tuition, proceedings and workshops but excludes travel costs and accommodation). Accommodation at the Hotel Istana can be arranged. Win-Win: Receive an Early Bird discount of € 100.- if you register before August 1, 2013.

For further information about the Forum please contact:
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PORTS 2013
AUGUST 25-29, 2013
SEATTLE, WASHINGTON, USA

PORTS ’13 is the thirteenth in a series of international port and harbour specialty conferences held on a tri-annual basis since 1977. With the theme, “Ports: Success through Diversification”, the conference is organised by PIANC USA; the Coasts, Oceans, Ports and Rivers Institute (COPRI); and the Inter-American Committee on Ports- Organization (CIP) of the Organization of American States (OAS) as cooperating organisation, This year’s conference theme recognises the broad spectrum of factors that make ports so important to their local, regional and national communities, including the broad missions they support, such as moving cargo, providing recreational opportunities, serving as engines of economic development, and providing for stewardship of environmental resources.

The PORTS Conference series is internationally recognised as an outstanding opportunity to network with hundreds of leading practitioners, researchers and specialists in the port engineering profession. This year PORTS ‘13 has expanded to 3 full days, resulting in a 50 percent increase in opportunities to present ideas and experiences.

For further information visit:
http://content.asce.org/conferences/ports2013/index.html

COASTS, MARINE STRUCTURES AND BREAKWATERS
SEPTEMBER 17-20, 2013
EICC EDINBURGH, SCOTLAND, UK

The Institution of Civil Engineers is pleased to announce the tenth in this highly-regarded series of specialist conferences. This is an international forum addressing the developments in offshore and nearshore energy production, procurement, issues with coastal defence, and the construction, management and refurbishment of all coastal assets.

Whilst retaining the historical coverage on shoreline structures, coastal processes, and design and construction of breakwaters and related structures, the conference will also emphasise aspects at the civil and coastal engineering interface, such as fluid loadings, resource modelling, interactions with the environment, construction, installation, cabling, servicing and maintenance. The conference will showcase some 150 technical papers, all of which are rigorously peer reviewed to ensure that they will have an in-depth technical aspect giving all attendees access to the highest quality information. Papers are available to delegates in advance of the event to stimulate discussion, and papers are discussed in formal proceedings following the event. In addition to the main session presentations, the ‘Fringe’ will give opportunities for presentations of recent news, continuing research, and developments in progress. Workshops, short courses and technical visits will also be offered as part of the event.

For further information contact:
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• Email: events@ice.org.uk
www.ice-conferences.com/Upcoming-events/ICE-Breakwaters

8TH INTERNATIONAL SEDNET CONFERENCE
NOVEMBER 6-9, 2013
LISBON, PORTUGAL

Sediment management has proven to be a significant issue in European rivers, estuaries and coastal areas. This has both a quantity and a quality aspect, as prior SedNet activities have clearly shown. Human interventions, such as river regulation, dredging, coastal and port construction and soil degradation often have large impacts on sediment supply, sediment transport and river and coastal morphology. Sediment-starved systems, particularly in coastal, lowland areas, are more vulnerable to extreme events, putting people, infrastructure and natural capital at risk. Mitigation measures may be technically feasible, but are quickly becoming too costly.

Sediment and biota in river systems have been exposed to multiple and interacting stressors for decades or even centuries. Europe has responded to the most apparent contaminants and pressures with a range of policies and measures since the 1970s. Clear improvements in water quality can be attributed to integrated river basin action plans and to the Programmes of Measures that resulted from the major and coordinated effort of the Water Framework Directive. However, improvements in sediment and longer-lived or bottom feeding biota lag behind due to storage and accumulation of contaminants, costly and laborious monitoring techniques, and sometimes lack of sufficient legal integration of sediment management into legislation.

To sustainably manage sediments, innovative and cost-efficient approaches and solutions are needed. Sediment management, which tends to be focused only on the apparent areas of concern, comes with the challenge of avoiding measures which have only short-term and locally positive effects, whilst having unforeseen negative consequences elsewhere.

Against this background SedNet is organising its 8th international conference in Lisbon with the theme “Innovative Sediment Management: How to do more with less”. The event is hosted and co-organised by LNEC. Given the tremendous diversity of Europe’s southwest coast, Lisbon is a highly appropriate venue for a conference that will pay special attention to estuarine and coastal sediment management.

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