SEMINAR

Flanders, a maritime region of knowledge (MAREDFlow)

24 March 2006
Flanders Marine Institute
Oostende, Belgium

Yvo Peeters, Nancy Fockedey, Jan Seys and Jan Mees (Eds)

VLIZ SPECIAL PUBLICATION 29

Organised by:

Waterways and Marine Affairs Administration (AWZ), Ministry of Flanders

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VLAANDEREN MARITIEME KENNISREGIO

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MAREDFLOW A PROJECT UNDER THE REGIONS OF KNOWLEDGE PILOT ACTION

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Abstract

Launched by the Research Directorate-General of the European Commission in August 2003 at the request of the European Parliament, the Regions of Knowledge Pilot Action promotes the active involvement of local players in designing and shaping regional knowledge development models.

The Regions of Knowledge Pilot Action aims:

- to enhance regional research strategies, and promote clustering and public-private partnerships between regional authorities, universities and industry;
- to demonstrate the crucial role of knowledge in regional development;
- to support the goal of the European Research Area (ERA) to make Europe the most fertile ground for technology-based regional economic development in the world.

Fourteen pilot projects have been selected to take part in the Regions of Knowledge initiative. These projects help to build or sharpen regional research and innovation strategies; strengthen regional public-private partnerships; lay down links between researchers, companies and financial institutions; and promote networking between technological innovators in various European regions.

They fall into four specific areas:

- **Technology audits and regional foresight**: analyse the regional economy and its technology fabric, and identify future development scenarios
- **University-driven actions for regional development**: demonstrate how universities can act as important technology relay points by providing expertise to local companies and public institutions, by stimulating technology creation and uptake, and by creating spin-off companies
- **Mentoring initiatives**: help set up networks between technologically advanced and less favoured regions
- **Supporting activities**: promote the organisation of workshops or conferences to raise awareness on the importance of technology-based regional development

Under the first area falls the project MAREDFlow.

Background

The project partners cover diversified maritime regions (Flanders, Bremen, Mecklenbrug-Vorpommeren, Pori and Asturias) which will benefit from the development of transport logistics linked tot the maritime transport.

MAREDFlow wants to stimulate economic development in a number of maritime regions' transport logistics sectors, by developing the knowledge-based economies of these maritime regions. The gains obtained from the implementation of the technologies and techniques – in logistical supply chains and port and commercial clusters – will be used to improve the overall regional economic performance.

Implementation

Knowledge development maps are developed and used to identify relevant technologies that provide economic gains and the paths which may be used for the effective transfer of information, expertise and experience from those able to deliver to those requiring it. The maps are interactive and aim to determine the need for actions such as technology transfer, training, benchmarking, mentoring and consultancy. These actions will subsequently be executed. Indication is also provided on complementary requirements such as financial support. Private sector companies as well as more conventional academic and public sector organisations are targeted. The knowledge development maps link organisations involved in the logistical supply chain within maritime regions: companies, ports, research institutes, higher education establishments and public authorities. Further, the maps allow those knowledge flows that will stimulate economic and trade development. Linked financial flows will also be identified by the maps, such as when the flow of knowledge involves the transfer of intellectual property or requires capital investment.

Outcomes and benefits of the international co-operation

Once a sufficient number of transfers has been made, an assessment of their impact in terms of improved regional economic performance can be undertaken. The results of this investigation will consolidate the project and new, incrementally improved, cycles of the system will be launched – providing a continuous, adaptive process. Measurement of the regional economic impacts will be made and published. The knowledge development mapping technique will remain able for use by the participating regions, and other regions, once the MAREDFlow project has been completed.

The interconnection with IRC-network

In developing its participation in MAREDFlow the Flemish partners have decided, upon proposal of the Flemish Institute for Innovation by Science and Technology, which is the IRC-manager in Flanders, to graft the 'knowledge map'-principle of Maredflow upon the IRC-system.
In this way a genuine practical implementation of the project was assured.

The next speaker will dwell more extensively on this issue.

To assure a diversified input and perspective on the Maritime Knowledge sector a steering group was formed, composed of representatives of the Antwerp Maritime Academy, Port of Antwerp, Flanders Public Employment Service, Universities of Brussels, Gent and Antwerpen, Flanders Marine Institute, Flanders Hydraulics Research, Institute for the Promotion of

Innovation by Science and Technology Flanders, Waterways and Canal Agency and Flanders Institute for Logistics.

I want to thank the members of the SG for their valuable comments and contributions in these past two years. Finally I want to address the topic of today's seminar.

It is well known that Flanders is excelling in some maritime sectors such as dredging and maritime engineering, but in this seminar we also wanted to attract the attention to areas such as meteorology, digital mapping, safety devices, logistics, offshore wind energy, etc.

In general I hope that this project will have induced more interest for the maritime world in its multiple aspects, and through the label of Flanders, Maritime Region of Knowledge the topic will be perpetuated and accentuated.

IRC-FLANDERS AND MAREDFlow

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Introduction

The 'Regions of knowledge' pilot action, introduced in the 2003 Community budget as a 'pilot-project' by the European Parliament (http://www.europarl.eu.int/news/public/default_en.htm), aims at supporting experimental actions at regional level to develop 'regions of knowledge' in the area of technological development, co-operation between universities (http://www.cordis.lu/era/universities.htm) and research at a regional level and stimulate the integration of regions in Europe. Such actions should strengthen the regions' involvement and commitment towards the creation of the European Research Area (http://www.cordis.lu/era/home.html) as well as supporting the achievement of the Lisbon goals and the Barcelona (http://europa.eu.int/comm/research/era/3pct/index_en.html) objective (towards a higher investment in RTD with the target being 3% (http://www.cordis.lu/era/3percent.htm) of the Union's GDP by 2010, with 2/3 of the GERD coming from the private sector. The main aim of the action was to demonstrate the central role of knowledge in driving regional development and how regional actors can effectively participate in formulating their regions' future.

The European Commission has selected 14 pilot projects, to be allocated a total of EUR 2.5 million, to boost the regional dimension of the knowledge economy. One of these projects was MAREDFlow with as coordinator: The Alliance of Maritime Interests in Europe (BE). Other participants are Autoridad Portuaria de Gijon (E), City of Pori (FIN), Institute of Shipping Economics (DE), Administratie Waterwegen en Zeewezen (BE).

When IWT-Vlaanderen took notice of this project, it was investigated more closely and possible synergies were sought. Indeed, we saw that both tried to stimulate cross border-technology transfer. The MAREDFlow-project, however focussed on the maritime sector.

In this article, we describe the results of our combined efforts. Of course, these are put in a context. First of all there is a description of IWT in the Flemish Innovation Landscape. Secondly, a presentation is given about the IRC-Network. Of course, the IRC-Flanders services are put in this general perspective. Given all these information, the concrete combined efforts of both MAREDFlow and IRC-Vlaanderen are revealed.

IWT in the Flemish innovation landscape

The Flemish innovation landscape

Flanders is strategically located within the centre of Europe. Together with Wallonia and Brussels, it forms the Federal State of Belgium. The three regions have far-reaching autonomy on economic (territory-bound) matters, e.g. in the field of technology and innovation.

The Flemish region counts almost 6 million people (60% of the Belgian population). It covers 40% of the Belgian territory and is a very urbanised area. Flanders accounts for roughly 60% of Belgium's Gross Domestic Product (GDP). The economy has traditionally been based on international trade. Export accounts for 85% of the Gross Regional Product (GRP). Flanders has a highly educated work force with one of the highest productivities in the world. This attracts a large number of multinationals that choose Flanders as a base for their European operations. The backbone of Flanders' economic structure, however, is the SME. On a total of about 170.000 companies, over 99% have less than 250 employees, 89% count less than 10 employees. Large companies are often part of a multinational group.

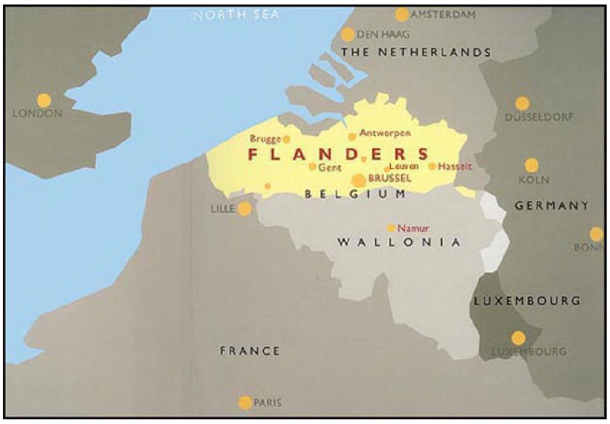

Fig. 1. Location of Flanders.

Industry in Flanders primarily involves processing, dominated by the chemical and metallurgic sectors. Car assembly comes in a strong third. High automation has reduced employment somewhat in recent years, but the service sector is providing new impulses.

Flanders' R&D efforts are well above the European average. The Flemish universities and research centres (VIB, IMEC, VITO, IBBT)[1] have a very good international reputation. On the industrial side, most of the research activity is still accounted for by large companies. However, the number of innovative SMEs is rising.

Both Belgium and Flanders have an average score on the European Innovation Scoreboard 2005[2]. In spite of high quality R&D and a high skilled work force, converting research efforts into commercially exploitable knowledge is a weak point.

Historically, the innovation landscape in Flanders is divided over a large number of local innovation actors: regional development agencies, chambers of commerce, sector organisations, cluster organisations, research centres, universities, etc. This historic scattering makes communication difficult.

Since 1999, the Flemish Government tries to rationalise these structures. In May 1999 the Innovation Decree put IWT[3] in a co-ordinating position over the intermediary organisations in the field. As a result, a Flemish innovation network has been established in 2002, in which organisations are to signpost to one another when applicable. The network is based on VIS[4]-projects, co-ordinated and (partly) funded by IWT. These projects cover collective research, technological services, sub-regional innovation encouragement and thematic innovation encouragement.

[1] VIB: Flemish Interuniversity Institute for Biotechnology; IMEC: Interuniversity Micro Electronics Centre; VITO: Flemish Institute for Technological Research; IBBT: Institute for Broadband Technology.
[2] www.trendchart.org/scoreboards/ scoreboard2005/pdf/EIS%202005.pdf or trendchart.cordis.lu/
[3] IWT, Institute for the Promotion of Innovation by Science and Technology in Flanders. Its main activities are funding of industrial research, co-ordination of Flemish innovation landscape, NCPs for 6FP, EUREKA contact point, IRC-host.
[4] VIS, 'Vlaamse Innovatie Samenwerkingsverbanden' = Flemish Innovation Co-operation Networks.

IWT: mission and activities (www.iwt.be)

IWT-Flanders, the Institute for the promotion of innovation by science and technology in Flanders, is a governmental agency established by the Flemish Government in 1991. Since innovation policy is a regional matter in Belgium, IWT-Flanders is the key organisation for support and promotion of R&D and innovation in Flanders. The total funding of IWT-Flanders amounts to EUR 218 million in 2004. IWT is both a programme owner (in close co-operation with the Flemish Minister of Innovation) and a programme manager (selection and follow-up of research and innovation projects).

The scope of existing funding is quite broad including industrial R&D projects, EUREKA-projects, feasibility studies and innovation projects for SMEs, support to industrial networks (sectoral research, technological advisory services, innovation stimulation), support to universities for strategic basic research, support to higher education engineering schools for technology diffusion actions, individual grants for PhD and post-doc research, support to universities for exploitation of their R&D-results and to larger 'ad hoc' initiatives as decided by the Flemish government. In 2004 about 486 R&D projects (incl. EUREKA) were funded for a total amount of EUR 78M. Different horizontal measures (VIS, TETRA) to support industrial networks and clusters active in generic sectoral research, technological advisory services, stimulation of technology transfer and innovation are focused on interaction with and transfer of knowledge to the local SMEs.

Companies can make use of services such as information dissemination about international actions and more especially about the Framework Programme and assistance in the preparation of FP6 project proposals, guidance in the innovation process, advice on IPR-issues, transnational technology transfer. IWT is in co-operation with the Science and Innovation Administration of the Flemish Community the unique NCP organisation (incl. SME NCP) for Flanders. IWT is also the IRC for Flanders.

Besides promotion of innovation through funding of R&D-projects and services, one of the main tasks of IWT-Flanders is the co-ordination of the regional innovation actors as regional development agencies, technological advisory services, sectoral research centres, industrial federations, etc.

IWT participates in six ERANET projects as a partner (CORNET, Era-SME, eTRANET, MATERA, MNT, SUSPRISE) and is coordinator of the COMPERA project.

The annual budget of IWT for support to RTDI actions is approx. EUR 218M, EUR 27M of this budget is dedicated to horizontal innovation measures to support industrial networks and clusters active in generic sectoral research, technological advisory services, stimulation of technology transfer and innovation are focused on interaction with and transfer of knowledge to the local SMEs.

Innovation programmes managed/owned

IWT is both programme manager and programme owner for all the funding programmes it implements. Most of the funding programmes that are managed/owned by IWT allow for direct or indirect foreign participation.

More information on the horizontal innovation measures aiming at technology transfer can be found on the innovation trend chart:

- Flemish Cooperative Innovation Networks (VIS): http://trendchart.cordis.lu/tc_datasheet.cfm?id=8206
- TETRA-Fund: technology transfers between technical high schools and SMEs: http://trendchart.cordis.lu/tc_datasheet.cfm?id=8739
- University Interfaces or Industry Liaison offices: http://trendchart.cordis.lu/tc_datasheet.cfm?id=7742

No specific programmes regarding technology transfer or co-development with partners from third countries are implemented at the moment. Activities regarding the international exploitation and distribution of research results and new technology are mainly focussed on Europe. The main instrument here is the IRC-Network. To maximise its radius of action, the Flemish IRC (http://www.iwt.be/irc) closely cooperates with the network of Flemish innovation actors (also coordinated by IWT: http://www.innovatienetwerk.be). On the long term a further internationalisation of these services (incorporating countries outside of Europe) is envisaged.

General presentation of the Innovation Relay Centres Network[5]

General approach

The mission of the IRCs is to support innovation and transnational technological co-operation in Europe with a range of specialised business support services. IRC-services are primarily targeted at technology-oriented small and medium-sized enterprises (SMEs), but are also available to large companies, research institutes, universities, technology centres and innovation agencies.
The first Innovation Relay Centres were established in 1995 with the support of the European Commission. The aim was to create a pan-European platform to stimulate transnational technology transfer and promote innovation services.

Over the past five years the IRCs – working together in close co-operation – have been of assistance in over 12,500 technology transfer negotiations, and have helped more than 55,000 client companies to meet their technology needs and to exploit their research results.

IRC-staff (a total of nearly 1,000) are experienced specialists with backgrounds in business, industry and research. To date, they have facilitated more than 1,000 transnational transfers of technology-signed agreements for the sale, licensing, distribution or joint development of new technologies.

Today, 71 regional IRCs span 33 countries: 25 EU-Member States and Bulgaria, Romania, Iceland, Israel, Norway, Switzerland, Turkey and Chile.

Most IRCs are operated by a consortia of qualified regional organisations such as Chambers of Commerce, Regional Development Agencies and university Technology Centres. Altogether, almost 220 partner organisations are involved, ensuring wide geographic coverage.

General service portfolio of the IRC-Network

Advice on innovation, technology transfer and exploitation

Innovation Relay Centres adopt a one-to-one approach with local companies. As part of the service IRC-experts will be pleased to visit your company to discuss whether you would like to

[5] For more information, cf. www.cordis.lu/irc

take advantage of the opportunities that the IRC-Network offers. IRC-staff can arrange for a technology assessment to be carried out for your organisation. On the basis of this, they can advise you on the opportunities for introduction of new technologies into your company, and to also help promote your own innovative technologies to the rest of Europe.

Identifying technology need and/or technology potential

Technology to offer: promoting your products in European markets
The Innovation Relay Centre Network is proactive in the promotion of new and innovative technologies throughout Europe. Each IRC-Network member has strong links with industry in its region and can help your company to:

- create a technology profile in English, choosing the right technology keywords, documenting the innovative aspects and main advantages, etc.;
- locate potential partners throughout Europe for licensing and/or manufacturing agreements;
- with the process of negotiating such agreements.

Technology needs: finding technology solutions for your business
If you would like to be more proactive in finding innovative technologies, your local IRC can send details of your technology need to the 71 Innovation Relay Centres across Europe. The IRC will help you to:

- create a technology profile in English, to choose the right technology keywords to describe your technology requirements;
- find businesses or R&D centres in Europe that can supply you with new technologies or ideas;
- identify new business opportunities.

Confidentiality
Your identity will remain confidential unless and until you are prepared for it to be revealed. Any responses will be passed on to you, and the IRC will help you receive further information if you wish.

Finding European partners

The technology profiles produced by the IRC can be used in a number of different ways in order to find business partners for your company.

Partner search via the IRC-Network
The 71 IRCs are connected by intranet which allows rapid diffusion of technology profiles across Europe. These profiles are also stored in a searchable database.

Partner search via trade missions
Your local IRC can use your technology profile to match your company to others in Europe. These companies might be interested in visiting you or vice versa. These visits are generally sectoral in nature and based upon a series of pre-arranged meetings. Social events, travel and accommodation can be provided as part of the package by the IRC.

Partner search via technology brokerage events
Your local IRC can use your technology profile to help organise meetings for you at European brokerage events. If you are unable to attend, the IRC can represent your company at these events. The Relay Centre can also promote your technologies at exhibitions, trade fairs, partnering events and through the day to day interaction it has with the rest of the IRC-Network.

Further support and advice

Advice and signposting on issues relating to innovation financing
Your local IRC can help with the selection and identification of projects, which are suitable for innovative financing, organise meetings with business angels and venture capital funds operators, organise transnational innovation financing brokerage events such as for investment and, if the expertise is available, assist your company with the preparation of the technical part of the business plan for investors.

Advice and signposting on issues relating to intellectual property rights
Your local IRC can provide advice on how best to protect your company's innovative technologies. Advice may also be provided by a third party, a patent lawyer, employed by the Relay Centre or this service may even be delivered by Relay Centre staff themselves.

Contract negotiation assistance
The Innovation Relay Centre not only helps you to identify partners but also gives you assistance during the negotiation phase of the contract. The Relay Centre may bring in third parties with relevant expertise (even if the service is delivered by Relay Centre staff). For more information on the exact terms and conditions please contact IRC-Flanders (http://irc.cordis.lu/whoswho/). This assistance may include:

- the drafting of a confidentiality agreement;
- the organisation of the first meeting with provision of a venue and if necessary a translator;
- the organisation of the visit to the partner;
- the provision of model technology transfer agreements;
- etc.

Some IRCs may be able to help you in the complex process of valuing never-before-seen technologies, in unfamiliar industries. They can direct you to specialists who can advise on the value of different types of agreement and so ensure that you pay or receive a fair price for a technology. This assistance can lead to greater efficiency in negotiating licensing agreements and it can help your organisation set financial targets for technology transfer.

IRC-Flanders

General background

IRC-Flanders has been hosted by IWT since the start of the IRC-project in 1995. At the start of the past contract period (2000-2004), the IRC-tasks were shifted entirely from upstream work (supporting participation to 6FP) to downstream work (technology transfer). During the first two years IRC-Flanders has invested in the development of a number of tools, facilitating the communication of transnational technology transfer (TTT) opportunities to clients and internal follow up of TTT projects. Quality and efficiency within the IRC have benefited from this effort.

The IRC disposes of three full-time equivalent in staff (+ assistant). To guarantee a full coverage of the region and work on in-depth relations with clients, a strong co-operation with the local innovation actors is needed. The large number of organisations involved in the VIS-projects offers IRC-Flanders the opportunity to increase its coverage. Their diversity allows IRC-Flanders to select the most appropriate partner for each specific IRC-activity.

Objectives and services

Objectives

The overall objective for IRC-Flanders is to provide cost-effective and high quality technology transfer services which answer to regional needs and which are provided in synergy with the regional support structures in Flanders.

The main goal is to increase the added value of the IRC in the process of TTT partner search in Flanders. Given the specific situation in Flanders the main operational objectives of IRC-Flanders are:

- objective 1: to improve communication towards (potential) IRC-clients;
- objective 2: to continue delivering high quality transnational technology transfer services to its clients, making optimal use of the contacts within the IRC-Network;
- objective 3: to optimise synergism with other services provided by IWT, local innovation actors and other networks.

To reach these objectives, IRC-Flanders is delivering services towards its clients using the typical IRC-awareness, contact and assistance type services.

These services are supported by intensive national and international networking and use of synergies, the IRC-Network and an efficient internal management.

Service portfolio of IRC-Flanders

<u>*Awareness*</u>
In terms of awareness activities, a substantial additional effort is put in communication towards our clients and to increase the IRC's reach.

The main activities are:

- co-operation with a selection of local innovation actors for IRC-awareness activities in their target group;
- selection of an additional target group for awareness activities by IRC-staff;
- improvement of existing communication tools towards our clients and the development of new tools.

<u>*Contact and assistance*</u>
IRC-Flanders is offering the same basic contact and assistance services as in the previous contract. Quality of and communication about these services will be continuously improved. IRC-Flanders uses and improves the tools developed over the past contract to support these activities. The activities of IRC-Flanders within the IRC-Network, are supporting the services towards our clients.

Contact services:

- assisting Flemish companies and research organisations looking for an international partner for technological co-operation by generating Flemish TOs and TRs;
- distribution of European opportunities for technology transfer within Flanders;
- participation in partnering events, missions and other TT activities organised within the IRC-Network;

- organisation of own TT partnering activities, in co-operation with local innovation actors and with the IRC-Network.

Assistance services:
IRC-Flanders follows up on expressions of interest resulting from its contact activities and assists its companies or colleague IRCs when required.

Networking: signposting and optimal use of synergies, locally and internationally

To overcome the problem of IRC-Flanders' limited manpower, co-operation with external actors is required. This assistance is most important when it comes to awareness activities and signposting of TTT opportunities. More new potential clients need to be reached in order to increase results.

IRC-Flanders follows a multiple approach to tackle this issue:
- Within our host organisation IWT, the exploitation of possible synergies between the different departments in a structural way. The IRC-services will be included in the IWT product portfolio. IRC-Flanders will provide its IWT colleagues with the required communication tools to actively signpost potential clients to the IRC.
- Flanders counts a large number of innovation actors. The main players are now grouped in the VIS-project structure, coordinated by IWT. IRC-Flanders is setting up a structural co-operation with a number of these actors.
- If opportunities are presented to co-operate with other innovation services networks, European or other, the added value for the IRC-services and the time available will determine IRC-Flanders' involvement with these networks. The cooperation with the MAREDFlow initiative must be situated in this context.

MAREDFlow linked to the IRC-Network through IRC-Flanders

One of the goals of the MAREDFlow-project is to facilitate knowledge transfer in the field of marine technology. The European IRC-Network, co-funded by the European Commission celebrated its 10th anniversary last year and has built a wide expertise in the field of promoting technology transfer within Europe, Turkey, Israël and Chili.

IRC-Flanders, hosted by the IWT, saw an opportunity for the MAREDFlow-consortium to take benefit from the services delivered by the IRC-Network: the idea being that the knowledge transfer aimed for in MAREDFlow could make use of the services of the IRC-Network which has technology transfer as its main goal. This required a 'translation' of the 'knowledge'-related terms used in MAREDFlow towards the technology transfer formats used in the IRC-Network: knowledge creators could formulate 'technology offers' of interest to knowledge users and knowledge users could formulate 'technology requests' of interest to knowledge creators.

In order to set up the necessary communication channels between the MAREDFlow-partners and the IRC-Network, IRC-Flanders provided access to a webapplication that allows the MAREDFlow-partners to enter new 'technology offers' and 'technology requests' according to the guidelines and templates used in the IRC-Network. These entries will be processed further towards finalised and by the IRC-Network accepted technology profiles with the assistance of the IRC's that represent the regions involved in MAREDFlow. These accepted profiles will subsequently be disseminated in the entire IRC-Network and in addition be published on the web application provided by IRC-Flanders (together with other technology profiles coming from the IRC-Network and of relevance to MAREDFlow).

Once disseminated in the entire IRC-Network, each of the IRC's processes the profiles in its own region and tries to identify partners that are interested to co-operate with the 'owners' of the profile.

Further follow-up of these expressions of interest on the published profiles fits into the core-business of the involved IRCs and bilateral contacts with the MAREDFlow-partners ensures that everyone is being kept up-to-date on the results achieved.

IRC-Flanders has informed all the IRCs that represent the regions that are involved in the MAREDFlow-consortium and these are all interested in taking up the knowledge transfer opportunities of MAREDFlow and try to process them towards concrete agreements.

Fig. 2 shows the proposed communication routes. The different steps in promoting technology offers and requests would be as follows:

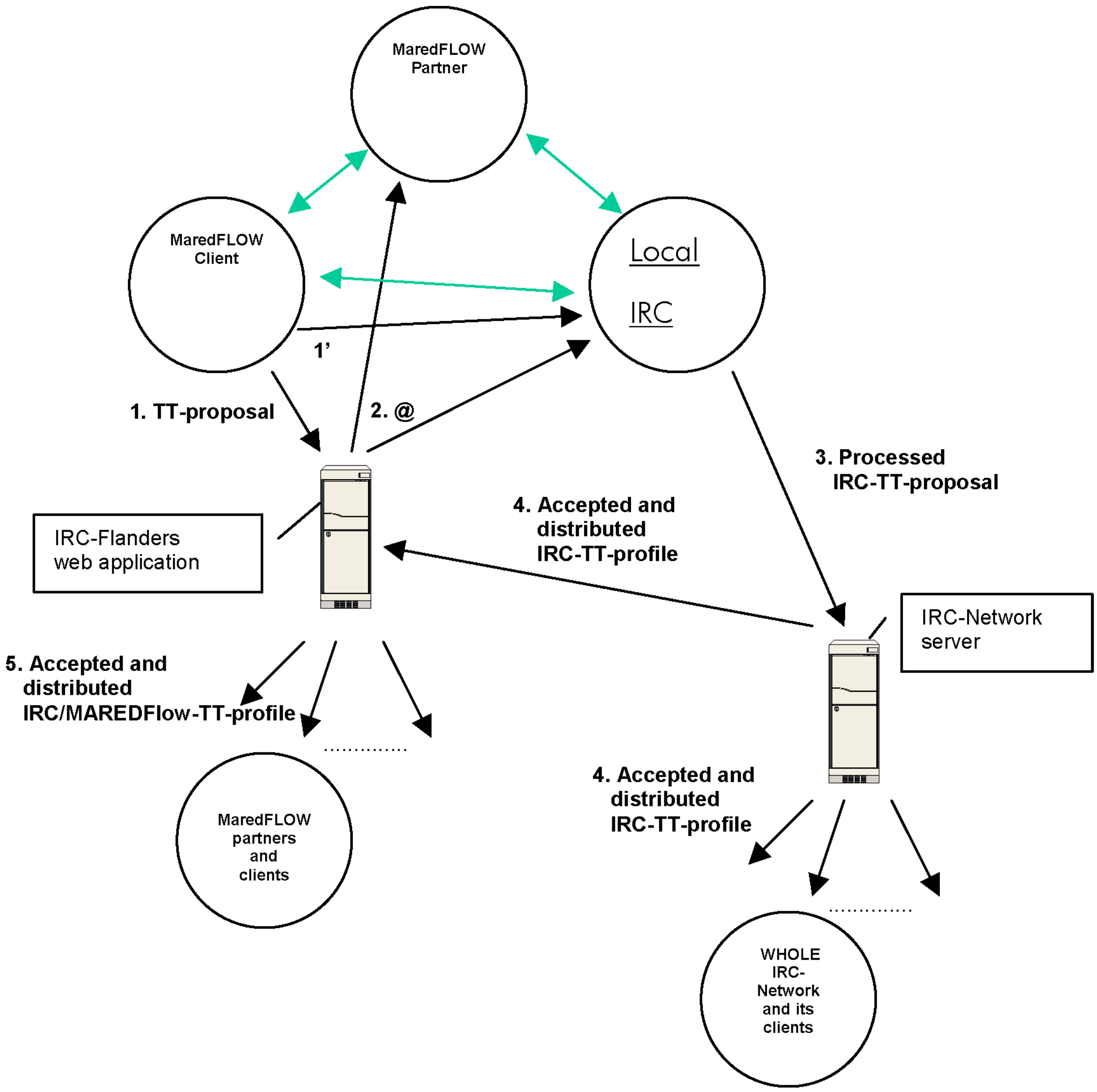

Fig. 2. Proposed communication routes.

- A client of MAREDFlow (project partner or company) enters a technology profile proposal on the webapplication provided by IRC-Flanders or ….1'. …contacts the IRC in his region (jump to step 3 in this latter case).
- Upon registering the proposal in the web application both the MAREDFlow partner and the IRC from the client's region would be informed by e-mail (@).
- The IRC from this region would process this entry further towards a IRC-TT-proposal and present it to the IRC-secretariat (using the IRC-Network server).
- If accepted, this profile will be distributed in the whole IRC-Network and …
- … is also published on the web application provided for MAREDFlow-partners and clients.

Once the technology/knowledge profile is disseminated in the IRC-Network, each IRC is disseminating it further into its own region and will receive expressions of interest on it from interested organisations willing to investigate the possibilities for co-operation.

The web application that is developed by IRC-Flanders for the MAREDFlow consortium can be found at http://www.iwt.be/irc_ttm/irc_partner.asp?id=7 and gives several possibilities (see Fig. 3):
- Upon registration, organisations can subscribe to an automated information tool: every three weeks the subscriber will receive an email with information on the latest technology profiles that have been published within technology sectors that are of interest to the subscriber.
- The visitor can browse through the IRC-database of all technology profiles within the sectors of interest to the MAREDFlow-consortium.
- The registered visitor can enter proposals for technology profiles, these will be processed further by IRC-Flanders and routed to the IRC that represents the region of the registered visitor.
- The registered visitor can enter expressions of interest on any of the profiles that can be browsed through the option described above in point 2. These expressions of interest are processed to the IRC representing the region of the registered visitor and this IRC will establish the contact between the registered visitor and the profile-owner.
- The visitor can browse information on brokerage events that are planned in the IRC-Network in technology fields that are of interest to the MAREDFlow consortium. The information on each event includes possibilities for subscribing at the event.

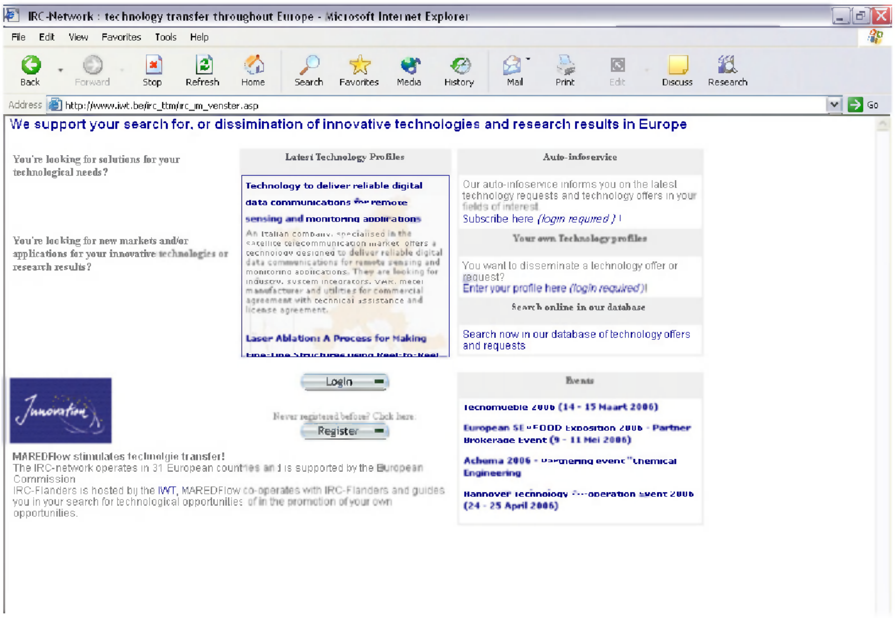

Fig. 3. Screenshot of IRC-Network – technology transfer throughout Europe.

Conclusion

In this project, there was the challenge of two European funded projects working together. On the one hand, there is the MAREDFlow project in the call 'Regions of Knowledge'. On the other hand, we have the IRC-Flanders as node in the European IRC-Network. Since both have the objective of stimulating technology transfer, it was in a sense logical to try to combine efforts. Between the idea and the concrete realisation, a lot of resources have been spent. Nevertheless, we think that the end result may be considered as a good practice. We hope that in the end these may lead to a cross-border intensive knowledge transfer in the maritime sector, with concrete spill-overs to the different regional economies involved.

A NOVEL METHODOLOGY FOR REVISION OF THE NAUTICAL BOTTOM

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Abstract

Since the 1980s, the nautical bottom in the outer harbour of Zeebrugge is determined by the 1150kg.m^{-3} density level, as due to siltation conventional bottom survey techniques are not adequate. As a consequence of modifications of the mud layer characteristics, a revision of this criterion was required. A research project, involving comprehensive captive model testing in a manoeuvring tank with a bottom covered with mud simulating materials, mathematical modelling and real-time full mission bridge simulator runs, resulted in new criteria, based on the ship behaviour and controllability in muddy navigation areas. The application of the results of this research project increases the efficiency of maintenance dredging works and contributes to the safety of shipping traffic, as the pilots involved in the manoeuvres obtain a more profound insight into specific aspects of ship behaviour.

Motivation

Introduction

Due to sedimentation, permanent maintenance dredging works are required to keep many ports accessible for deep-drafted sea-going vessels. In case of hard bottoms such as rock, clay or sand, the depth of the navigation areas can be determined unambiguously by means of echo sounding techniques; if the bottom is covered with soft mud layers, however, the boundary between water and bottom may be hard to define. In this case, the customary concepts 'bottom' and 'depth' are to be replaced with 'nautical bottom' and 'nautical depth'.

Navigation in muddy areas is not a new problem. The Flemish coastal harbour of Zeebrugge is subject to sedimentation since its major extension in the 1970s. Also in other harbours all over the world, the definition of the bottom and sounding techniques needs to be adapted to the presence of sedimentations: this is the case for the access channels to several harbours in the Netherlands (Rotterdam), France (Bordeaux, Nantes – Saint-Nazaire, Cayenne), Germany (Moderort, Emden, Weser, Brunsbüttel fairways) and the USA. In many harbours (e.g. Bangkok, Maracaibo), it is even common practice to navigate through the mud layer.

Neither is ship controllability in muddy navigation areas a new research topic. The first tests with a tanker model above and in contact with mud layers simulated by a mixture of chlorinated paraffin and kerosene were carried out in 1976 at MARIN (Wageningen, the Netherlands: Sellmeijer *et al.*, 1983). In 1986-89, a preliminary test facility for self-propelled ship models was constructed at Flanders Hydraulics Research (Antwerp, Belgium: Van Craenenbroeck *et al.*, 1991; Vantorre, 1991) in order to investigate some aspects of a ship's behaviour in muddy waterways; for this purpose, both natural, artificially composed and simulated mud layers were used. Also at SOGREAH (Grenoble, France: Brossard *et al.*, 1990) towing tests with a tanker model were carried out in 1989. More recently, model tests were conducted at the Bundesanstalt für Wasserbau in Hamburg (Uliczka, 2005). Not only model tests were conducted: reports of full scale experiences with ships navigating with reduced and even negative under keel clearance referred to the water-mud interface in Rotterdam, Nantes – Saint-Nazaire and Zeebrugge were published in the 1970s and 80s.

The present paper intends to give an overview of a comprehensive research project executed in 2001-2004 at Flanders Hydraulics Research (Antwerp) in close cooperation with the Maritime Technology Division of Ghent University, with the main purpose of redefining the boundaries of safe navigation in the harbour of Zeebrugge. This investigation, that was required due to considerable modifications of the local mud properties, followed an innovative approach as the definition of the nautical bottom is closely linked to the acceptable limits of ship behaviour and controllability.

Nautical bottom concept

Definition

The navigation of ships in channels and harbours subject to sedimentation is closely linked to the nautical bottom concept that is often introduced in these areas in case of difficulties with bottom survey techniques or with the interpretation of survey results. A typical example is the frequency dependence of the results of echo-sounding: while high-frequency echoes (e.g. 210kHz) reflect at the mud-water interface, lower frequency signals (e.g. 33kHz) penetrate much deeper into the mud and also give less clear results.

A joint PIANC-IAPH working group (PIANC, 1997) defined the nautical bottom as 'the level where physical characteristics of the bottom reach a critical limit beyond which contact with a ship's keel causes either damage or unacceptable effects on controllability and manoeuvrability'. In this way, the nautical bottom is identified as the level that should not be touched by the ship's keel. In case of a hard bottom, this is an obvious statement, but the definition is valid in other situations where the bottom can be defined in different ways, e.g. when the bottom is covered with boulders or sand dunes. In muddy areas, the nautical bottom can be interpreted as the level where the navigable fluid mud ends and the non-navigable seabed begins.

Implementation

The strength of this definition is, therefore, the very general application field. On the other hand, this definition rather suggests a general philosophy, without giving a practical solution. On the contrary, a number of questions are raised:

- Which physical characteristic should be selected?
- Which numerical value for this characteristic should be considered as a critical value?
- What is meant by 'unacceptable effects'?

With respect to the last question, it is clear that the degree of acceptance depends on a huge variety of – objective and subjective – parameters, including local environmental conditions, degree of training and expertise of the pilots, availability of tug assistance, quality of aids to navigation, economic considerations.

Considering the first two questions, it is most obvious that a physical characteristic should be selected that is directly linked with forces exerted by contact between a ship's hull and mud layers. In this respect, a rheological property – such as viscosity or yield stress (i.e. the shear stress to be overcome in order to initialise material flow) – could be used to determine a suitable criterion. A typical depth-rheology relation is shown in Fig. 1, left. Just below the water-mud interface, the rheological properties of the mud are hardly different from those of water. At a certain level, defined as the 'rheological transition', yield stress and viscosity increase very quickly with depth. Moreover, full scale tests with a suction hopper dredger in Zeebrugge have shown that a ship's behaviour becomes unacceptable if her keel touches this level: a ship becomes uncontrollable and follows the 'easiest' way in the mud. At the same time, it is practically impossible to decrease speed, even not at one or two knots. This rheological transition level could therefore be identified as the nautical bottom.

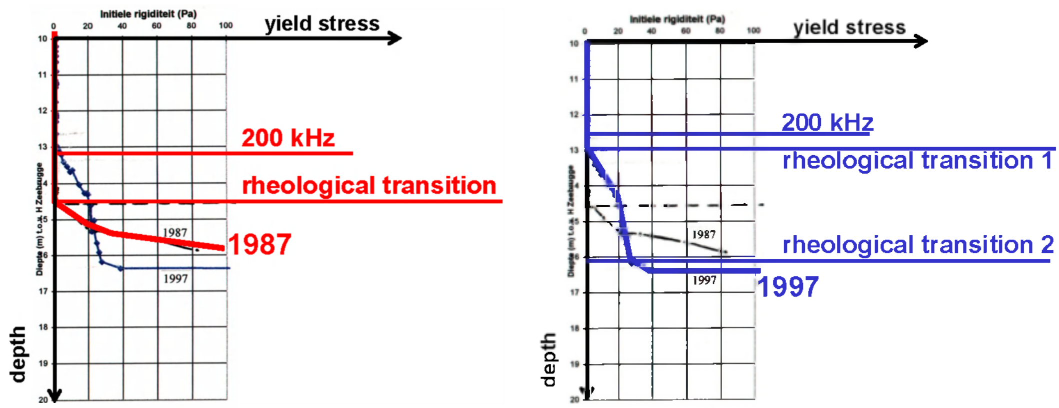

Fig. 1. Rheology as a function of depth in Zeebrugge harbour: measurements in 1987 (De Meyer and Malherbe, 1987) and 1997.

Nevertheless, most harbour and waterways authorities that have introduced the nautical bottom concept make use of a density criterion: in Rotterdam, Nantes – Saint-Nazaire and Bordeaux a density level of 1200kg.m^{-3} has been adapted; in Cayenne, the nautical bottom coincides with a density of 1270kg.m^{-3}. An exception should be made for the methodology applied in the access channels to German harbours, where a dynamic viscosity of 10Pa.s is used as a criterion; the corresponding density values vary from 1100 to 1250kg.m^{-3} (Uliczka and Liebetruth, 2005). The reason for this variation can be found in the fact that there is no fixed relationship between the mud density – a characteristic that is directly related to the concentration of solid material in the suspension – and the rheological properties of the mud. It is clear that the latter increase with increasing density, but also the dimensions of the solid particles matter: for an equal density, the viscosity increases if the fraction of small particles is larger. Therefore, the rheological properties also depend on the mud content, i.e. the fraction of particles smaller than 63μm. Therefore, it is impossible to define a universal value for the critical density.

The reason why the nautical bottom is usually expressed in function of a critical density, is related to the disadvantages of rheological *in-situ* measurements. A continuous rheological survey method, comparable to echo-sounding, is not available. Furthermore, mud rheology is influenced by the sampling method, which makes it difficult to compare data from different sources. This is a consequence of the thixotropy of the mud: the yield stress decreases if the material is disturbed, so that mud behaves more like a liquid after it has been stirred.

It can therefore be concluded that a rheology-based property such as the rheological transition level provides an excellent criterion, but can only be determined by time-consuming point measurements. In order to provide a practical criterion, a critical density is selected, based on considerations about the rheological properties of the local mud. In Zeebrugge, the density corresponding with the rheological transition was determined at a large number of locations;

eventually, the 1150kg.m^{-3} was selected as at all locations the rheological transition was located below that horizon (Kerckaert *et al.*, 1985, 1988).

The use of classical echo-sounding techniques in a nautical bottom approach requires some attention (Fig. 2). If acoustic signals with different frequencies reflect at different levels, a useful qualitative indication is given about the presence of fluid mud layers. High frequency echoes (100-210KHz) indicate the interface water-mud, while low frequency signals (15-33KHz) penetrate deeper and are normally reflected somewhere in the consolidated mud layer or the hard bottom.

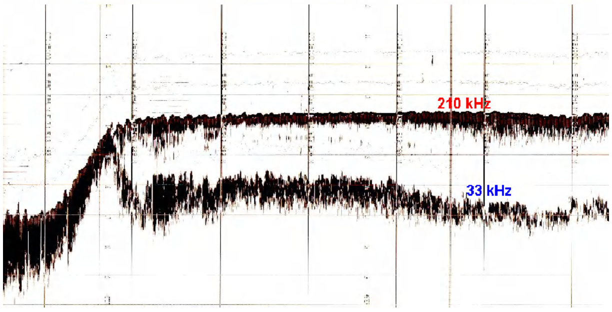

Fig. 2. Echo sounding in muddy areas: high and low frequency signal (De Brauwer, 2005).

At some locations, the low frequency echo is considered to coincide with the nautical bottom. This approach offers the advantage of simplicity: no additional instrumentation is required. On the other hand, the interpretation of low frequency echoes in mud layers is rather subjective, as several echoes may be registered. Moreover, several observations show that the reflection of a low frequency signal takes place at a level where the mud is characterised by a considerable yield stress and viscosity.

Additional requirements

In order to guarantee safe navigation in muddy areas, a clear definition and practical survey method for determining the nautical bottom is a first requirement. However, additional information is required to assess safety of navigation.

In the first place, a minimum value of the under keel clearance (UKC) needs to be determined; this value may depend on temporal and local conditions, as is also the case above a hard bottom.

The pilot and master should also have a clear insight into the ship behaviour in the given conditions. A ship may be controllable, but her reactions to actions of rudder, propeller, bow thruster or tugs may be completely different compared to solid bottom conditions. This behaviour may depend on a variety of parameters, such as vessel speed, the ship's (positive or negative) under keel clearance referred to the mud-water interface, the physical characteristics of the mud layers touching the ship's keel, etc.

Revision of the nautical bottom criterion for the harbour of Zeebrugge

The methodology described above to determine the nautical bottom by means of a critical density is a pragmatic one, but has several drawbacks. In the first place, it should be borne in mind that this density level has no absolute value, but is linked to the local mud characteristics.

Secondly, the validity of this critical density value should be checked on a regular base, as mud characteristics such as mud/sand content may vary over the years.

In the outer harbour of Zeebrugge, the determination of the nautical bottom based on a critical density value of 1150kg.m^{-3} worked well in practice for several years. In the mid 1990s, however, an increase of the mud layer thickness was observed; moreover, it appeared to be more difficult to control the 1150kg.m^{-3} level by maintenance dredging works. A measuring campaign in 1997 revealed that the rheology profile of the mud had significantly changed (Fig. 1, right). A first, small rheological jump occurred just below the water-mud interface while a second, more important one occurred at a depth of 3 to 4m under the interface, corresponding with a density that is significantly higher than the current critical value of 1150kg.m^{-3}. The interested parties consequently considered an increase of the critical density limit. For maintenance dredging the intrinsic dredge output could be significantly improved by dredging mud of a higher density.

From a nautical perspective, however, an increase of the critical density would have important consequences. With a critical density of 1150kg.m^{-3} and an under keel clearance of 10% of draft the ship's keel hardly ever touches the mud layer, but an increase of the critical limit would inevitably result in contact between the keel of deep-drafted container ships and the mud layer and possibly in unacceptable effects on ship handling. In order to investigate these effects, a research project was started at Flanders Hydraulics Research in Antwerp, with the scientific support of the Maritime Technology Division of Ghent University. Indeed, the information available appeared to be insufficient for a complete assessment of controllability of ships in contact with mud layers, so that more in depth research was required (PIANC, 1997; Vantorre, 1994).

Initial state of the art

As mentioned above, only a few research institutes have investigated ship behaviour in muddy areas. A summary of the results of these research projects will be given in order to define the initial state of the art.

Causes of deviating behaviour

At first, the causes of different behaviour due to the presence of mud layers compared to a solid bottom situation are considered. Two main causes can be identified:
- the rheological properties of the mud;
- the presence of a second fluid layer and, therefore, a second interface: above a solid bottom, only a water-air interface is present, while in muddy areas also a water-mud interface occurs.

Although interactions cannot be denied, in general it can be stated that the first cause is mainly of importance in case of contact between the ship's keel and the mud layer; the second, on the other hand, also affects the ship's behaviour in case no contact takes place, as a result of undulations – vertical interface motions – generated in the mud-water interface due to the pressure field around the moving hull.

Interface undulations

These vertical interface motions are influenced by the ship's forward speed (Fig. 3):

- At very low speed, the interface remains practically undisturbed (1st speed range).

▪ At intermediate speed, an interface sinkage is observed under the ship's entrance, which at a certain section changes into an elevation. This internal hydraulic jump is perpendicular to the ship's longitudinal axis and moves towards the stern with increasing speed (2nd speed range).
▪ At higher speeds, the interface jump occurs behind the stern (3rd speed range).

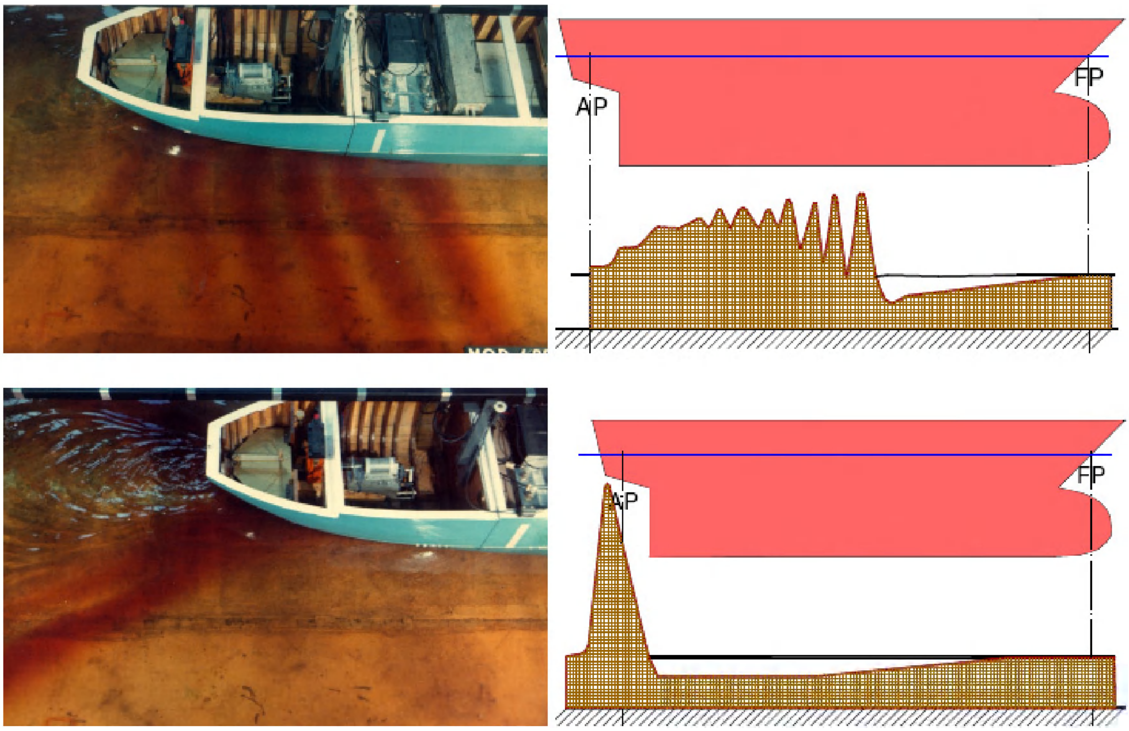

Fig. 3. Mud-water interface undulations: second speed range (above), third speed range (below) (Vantorre, 2001).

It can be shown by means of a simplified theory that the critical speed separating the second and third speed ranges can be calculated as a function of the mud to water density ratio and the water depth (Fig. 4). It is clear that this critical speed value is situated in the usual speed range at which harbour approach takes place.

Resistance and propulsion

The effect of interface deformation on the propulsive properties of a ship is clearly illustrated by the relation between forward speed and propeller rate. In the second speed range, a given propeller rpm results in a significantly lower speed compared to a solid bottom situation; it appears to be difficult to overcome the critical speed. In the third speed range, the effect of the muddy bottom is practically nil (Fig. 5). The transition between second and third speed range is very clear at under keel clearances of 10 to 20% of draft relative to the interface, but is smoothed with decreasing under keel clearance.

One would expect this effect to be caused by increased resistance in the second speed range. There are indications, however, that the speed reduction in the second speed range observed in the speed-rpm relationship is not caused by increased resistance, but by obstruction of the flow to the propeller due to contact between the ship's keel and the risen interface. An important increase of the thrust coefficient is observed in these conditions, which indicates an increase of the wake factor.

It can be concluded that poor propulsive efficiency can occur in the second speed range, if the risen interface touches the ship's keel, while the entrance is fully in contact with the water. In these conditions, controllability problems with a backing propeller are expected as well, which may affect the stopping distance.

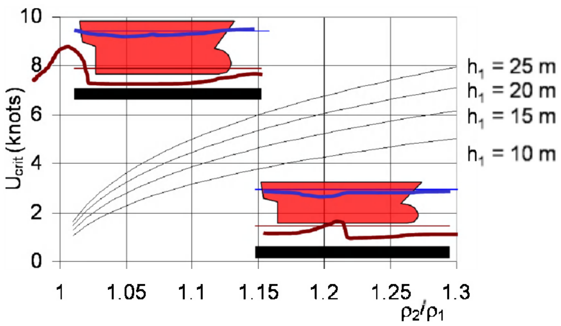

Fig. 4. Critical speed separating 2nd and 3rd speed ranges as a function of mud-water density ρ_2/ρ_1 ratio for different water depths h_1:

$$U_{crit} = [0.296\, g h_1 (1 - \rho_1/\rho_2)]^{0.5}$$

(Vantorre, 2001).

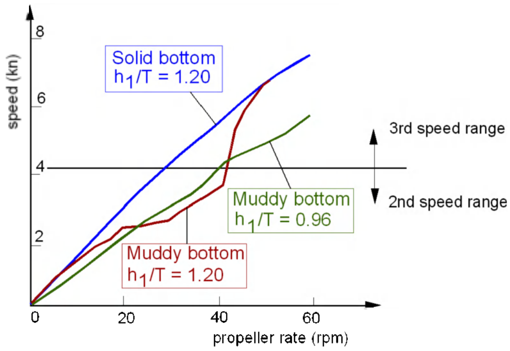

Fig. 5. Relationship speed – propeller rate: influence of bottom characteristics and under keel clearance (Vantorre, 2001).

Manoeuvrability

Simulations based on the captive model tests carried out at MARIN resulted into following conclusions concerning the effect of mud on ship manoeuvrability:

- The effect of mud is larger at low speed (3 knots) than at higher speed (7 knots).
- Manoeuvres are slower with mud, especially at low positive UKC relative to interface.
- Mud slackens steady motions (speed, drift, rate of turn during turning circle tests), but accelerates dynamic motions (overshoot and swept path during zigzag tests).
- A correlation between manoeuvrability and internal waves is observed.

Rudder action is affected due to the presence of a fluid mud layer in several ways. The most striking effect is so-called instability of rudder action which was observed during self-propelled model tests at Flanders Hydraulics Research if the ship's keel touches both water and mud: in these conditions, a rudder deviation may lead to reversed effects at small rudder angles.

Summarised, manoeuvrability and controllability are mainly affected at low speed and small positive under keel clearance referred to the mud-water interface.

Discussion

The conclusions of former research programs are certainly useful for a better understanding of the physical mechanisms that cause the modified ship behaviour in muddy navigation areas.

However, the available information was certainly not sufficient for redefining the nautical bottom in the harbour of Zeebrugge. As a matter of fact, several questions remained unanswered:

- According to the information summarised above, ship behaviour is mostly affected at small positive under keel clearance with respect to the mud-water interface; further penetration into the mud would lead to an improvement of the controllability of the ship. On the other hand, common practice indicates that there must be a maximum acceptable penetration into the mud.
- Previous work mainly considered low viscosity mud layers, so that the present range of rheological characteristics of the Zeebrugge mud was not covered (Fig. 6).
- Only full form ships, mainly tankers, were investigated in the past, while presently container traffic has the highest priority for most harbours, including Zeebrugge.
- A complete mathematical model allowing simulation of harbour manoeuvres, including backing and berthing, has to be available to assess the full range of manoeuvres that a ship arriving at or departing from the harbour has to carry out by means of real-time simulation runs.

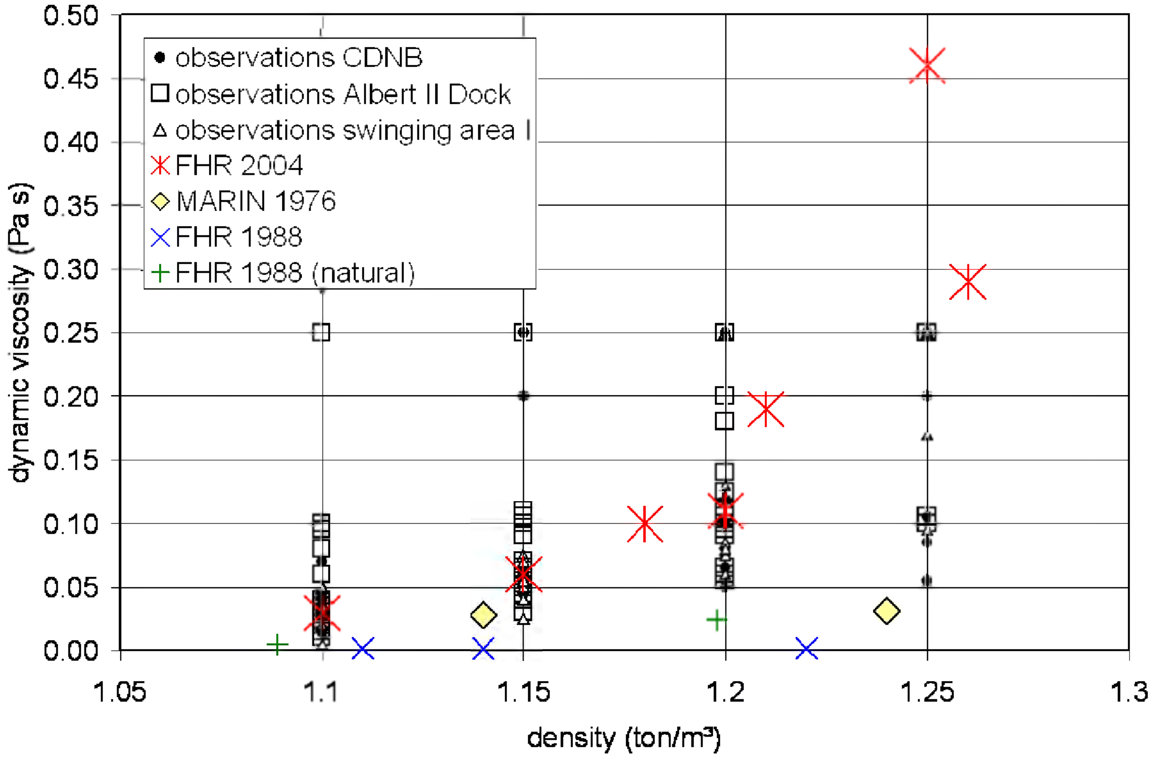

Fig. 6. Density-viscosity combinations: observations in Zeebrugge (1998) and model tests.

An extensive research program has therefore been carried out at Flanders Hydraulics Research, Antwerp, with the scientific support of the Maritime Technology division of Ghent University. The project consisted of three phases:

- captive model tests in the towing tank for manoeuvres in shallow water with ship models navigating above and through simulated mud layers;
- development of mathematical models suited for manoeuvring simulation based on the model test results;
- execution of fast-time and real-time simulation runs in realistic situations.

Experimental program

Test facilities

Flanders Hydraulics Research, the hydraulic research station of the Waterways and Maritime Affairs Administration of the Ministry of Flanders, is particularly concerned with the investigation of ship hydrodynamics for problems in relation with the concept, adaptation and operation of navigation areas. Therefore, the (very) shallow water range – occurring in access channels, canals, harbours – is a main research domain.

Nautical aspects of these problems can be investigated by means of two full mission ship manoeuvring simulators. In order to provide the mathematical model of these simulators with reliable and realistic data, experimental facilities for ship model testing have been developed. At present the latter consist of a shallow water towing tank (88m*7.0m*0.6m), equipped with a planar motion carriage, a wave generator and an auxiliary carriage for ship-ship interaction. The computerised control and data-acquisition allows fully automatic operation of the facilities, so that tests can be performed twenty-four hours a day, seven days a week.

Ship models

For the investigation of navigation in muddy areas, two 1/75-scale models were selected: a 6000 TEU container carrier (model D: L_{pp}= 289.8m; B= 40.25m; T= 13.50m; C_B= 0.59) and a full form (type tanker / bulk carrier, model E: L_{pp}= 286.8m; B= 46.77m; T= 15.50m; C_B=0.82). A limited number of model tests was also conducted with an 8000 TEU container carrier (model U: L_{pp}=331.8m; B=42.8m; T=14.5m; C_B=0.65; scale 1/80). Most experiments have been carried out with model D, taking account of the importance of container traffic for the harbour of Zeebrugge. All ship models were equipped with a propeller and a rudder.

Bottom conditions

The mud was simulated by a mixture of two types of chlorinated paraffin and petrol, so that both density and viscosity could, within certain ranges, be controlled. For environmental reasons, the tank was divided into three compartments: a test section, a 'mud' reservoir and a water reservoir. Bottom and walls were covered with a polyethylene coating (Fig. 7).

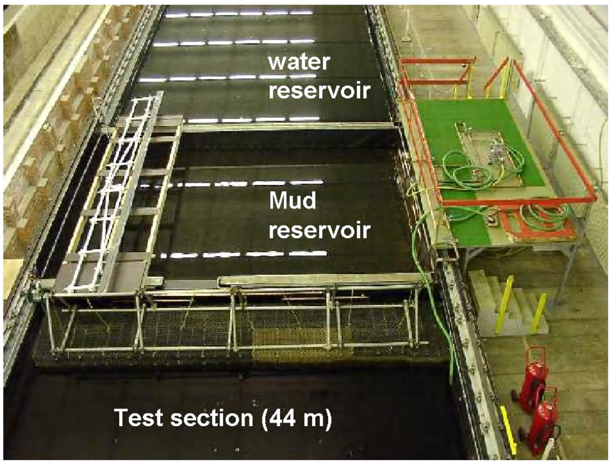

Fig. 7. Towing tank lay-out (photograph Flanders Hydraulics Research).

The selected density-viscosity combinations and the tested bottom conditions are represented in Fig. 6. This selection was based on measurements of density and rheology profiles *in situ* carried out in the outer harbour of Zeebrugge in 1997-98. A mud layer configuration is defined by two characters: a letter (b, ..., h), denoting the material characteristics and a figure (1, 2, 3), representing the layer thickness (0.75m, 1.50m and 3.00m, respectively). Tests carried out above a solid bottom are referred to as 'S'. The bottom conditions applied to ship model D are listed in Table I.

Table I. Tested bottom conditions for model 'D' (6000 TEU container carrier)

Mud type	'd'	'c'	'b'	'f'	'h'	'e'	'g'	'S'
Density (kg.m^{-3})	1100	1150	1180	1200	1210	1260	1250	–
Dynamic viscosity (Pa.s)	0.03	0.06	0.10	0.11	0.19	0.29	0.46	–
Layer thickness no.	1/2/3	1/2/3	1/2/3	2	1/2/3	2	1/2/3	–

For model D the under keel clearance relative to the tank bottom was varied between 7 and 32% of draft, yielding an under keel clearance relative to the mud-water interface varying between –12 and +21% (see Fig. 8). For model 'E' the values for the under keel clearance were extended between 10 and 15% of draft referred to the tank bottom, and from –10% to +10% relative to the mud-water interface.

3.0 m				1.5 m				0.75 m	
+10%	+15%	+26%	+32%	+10%	+15%	+26%	+32%	+10%	+15%
–12%	–7%	+4%	+10%	–1%	+4%	+15%	+21%	+4%	+9%

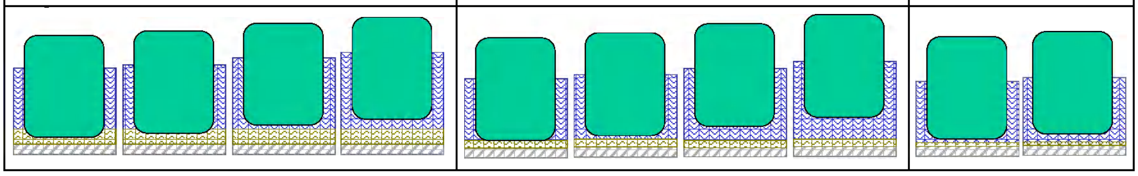

Fig. 8. Tested combinations of mud layer thickness (1st row), under keel clearance to solid bottom (2nd row) and to mud-water interface (3rd row).

Test types

For each combination of mud type, layer thickness and under keel clearance, a captive test program was carried out for determining mathematical manoeuvring models covering a range of forward speeds between 2 knots astern and 10 knots ahead. During captive model tests, a trajectory in the horizontal plane – involving combined longitudinal (surge) and lateral (sway) translations and rotation about the vertical axis (yaw) – is imposed to the ship model by means of the planar motion carriage; however, the ship model is free to move in the vertical plane (heave, pitch). The roll motion was fixed during the test program. These motions can be combined with rudder and propeller actions, which do not influence the ship's trajectory, but make it possible to investigate the effect of control parameters on the hydrodynamic forces and moment acting on the ship. Indeed, during captive tests, lateral and longitudinal force components are measured at two measuring posts, fore and aft, so that the horizontal force components and yaw moment due to a combination of kinematic (velocities, accelerations) and control (rudder angle, propeller rate) on the ship. Forces acting on the rudder (normal and tangential components, torque) and the propeller shaft (thrust, torque) are measured too, as well as the vertical ship motion (sinkage, trim). In particular cases, the vertical motion of the mud-water and water-air interfaces were registered as well.

The experimental program consisted of:

- Bollard pull tests: tests at zero speed with varying rudder angle and propeller rate;
- Stationary straight-line tests ('oblique towing'): combination of ship speed, propeller rate, rudder angle and drift angle;
- Harmonic yaw and sway tests: combinations of speed, rpm, amplitude and period;
- Multimodal tests: harmonic variation of propeller rpm, rudder angle or ship speed;
- Combined multimodal tests for validation.

For each combination of ship model, bottom condition and under keel clearance, a standard test program of 224 runs was carried out.

Mathematical manoeuvring model

General concept

Based on the results of the captive model tests, a mathematical manoeuvring model for simulation purposes has been developed for each combination of ship model, bottom condition and under keel clearance. A mathematical manoeuvring model consists of a set of equations expressing the longitudinal (X) and lateral (Y) force components and the yawing moment (N) as a function of the ship's horizontal motion (velocities, accelerations) and control parameters (rudder and propeller actions). The mathematical models are of the modular type, so that the force and moment components are expressed as a sum of hydrodynamic reactions on the hull, and terms induced by the propeller and rudder action: $F = F_H + F_P + F_R$.

The mathematical models have to be valid in a broad range of conditions; during the access to a harbour, all combinations of speeds (ahead and astern) and propeller rates (forward and reversed) occur, so that the model should be able to simulate four-quadrant propeller action, together with drift and yaw angles from 0 to 360deg. It was decided to formulate force components by determining functions of non-dimensional parameters in a tabular form, rather than attempting to define analytical expressions.

For more details about and a complete formulation of the mathematical model, reference is made to Delefortrie *et al.* (2005). Only some typical aspects regarding the influence of the bottom properties on ship manoeuvrability will be mentioned in this chapter.

Hull forces

Following results are of interest for a better insight into the physical mechanisms determining a ship's behaviour in muddy navigation areas:

- The effect of the under keel clearance on the ship's resistance is shown in Fig. 9 for several bottom conditions. A very sharp increase of resistance is observed in case of contact with high density mud layers; in case of lower density mud, on the other hand, the interface does not appear to be a strict boundary.
- Hydrodynamic inertia ('added mass') terms for sway and yaw increase significantly with decreasing water depth and increasing density and viscosity of the mud layer, as is illustrated in Fig. 10. In case the ship's keel penetrates deep into the mud, very large values are observed, up till seven times the ship's mass – which implies that for inducing a lateral

motion, an equivalent mass equal to eight times the ship's own mass needs to be accelerated. The layer characteristics appear to be important parameters, even if no contact occurs with the mud layer: the shallow water effect is smoothened with increasing layer thickness and decreasing mud density and viscosity. Indeed, an abrupt transition cannot be observed at $h_1/T = 1$.

- The magnitude of lateral force and yawing moment due to drift increases significantly with decreasing water depth, as is illustrated in Fig. 11 (left). However, this increase appears to stagnate when the keel touches the interface; penetration into the mud layer does not result into a further increase. For a given positive under keel clearance relative to the interface, the presence of a mud layer appears to smooth the shallow water effects, especially in case of layers with low density and viscosity (Fig. 11, right).

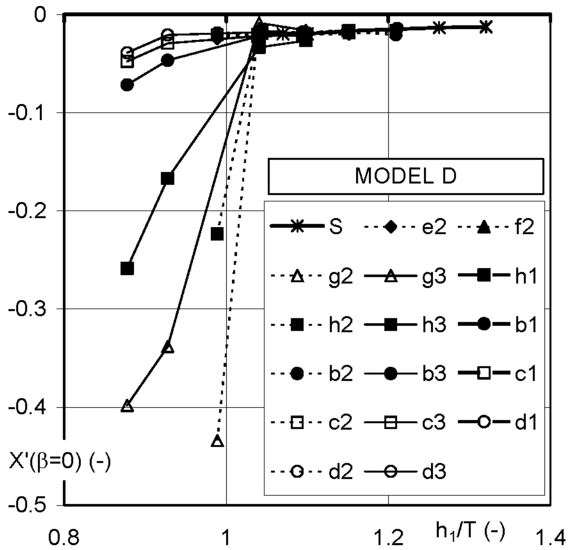

Fig. 9. Non-dimensional ship resistance: influence of bottom characteristics and under keel clearance.

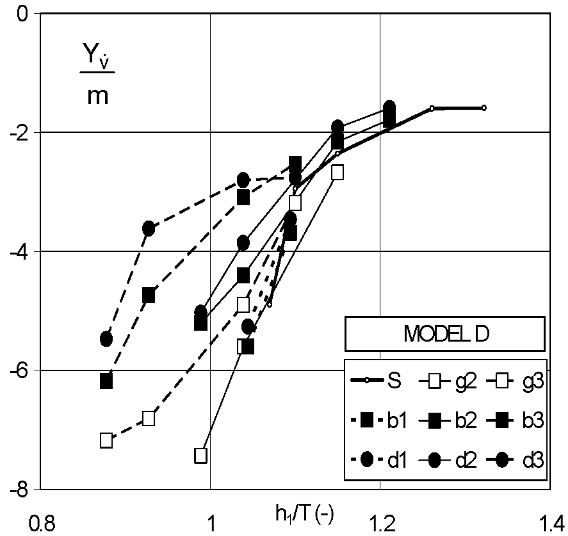

Fig. 10. Sway added mass: influence of bottom characteristics and under keel clearance.

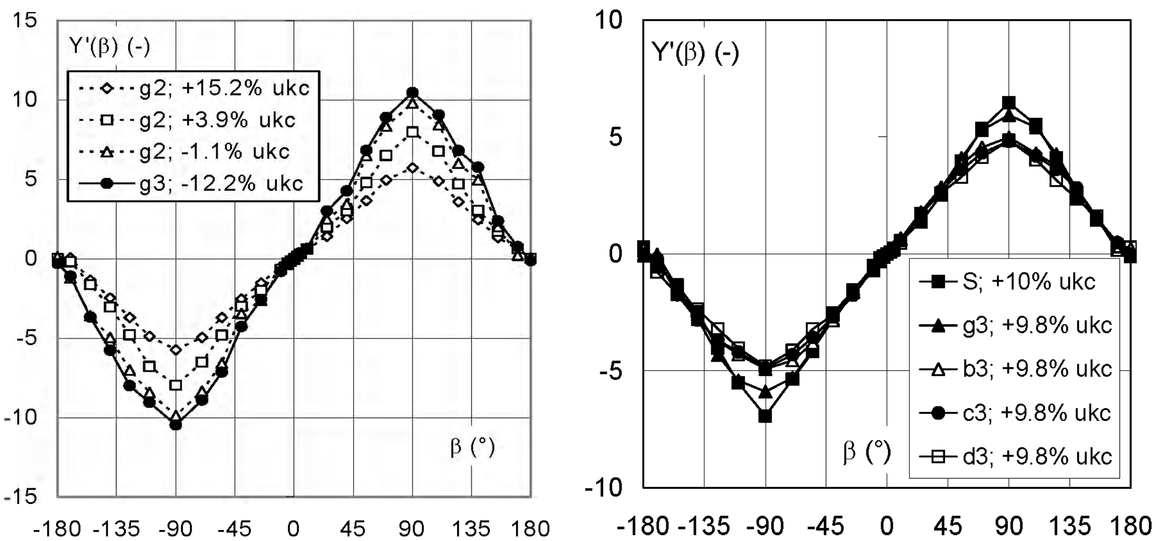

Fig. 11. Ship model D. Non-dimensional drift induced lateral force as a function of drift angle: influence of under keel clearance (left) and bottom characteristics (right).

Propeller induced forces

The longitudinal force acting on the ship due to propeller action depends on the propeller thrust, but also on the thrust deduction factor; the larger the thrust deduction factor, the smaller the fraction of the thrust that is useful for the ship’s propulsion. A larger value for this factor – which implies a smaller longitudinal force for a given thrust – is obtained at positive under keel clearances relative to the interface with high density mud layers; if the ship's keel touches the mud, on the other hand, the thrust deduction factor is larger for the lightest mud layers.

The propeller thrust is determined by the propeller rate and the axial inflow velocity. The latter depends on the ship’s forward speed, but also on the wake factor: a larger value for this factor implies a smaller inflow velocity and, therefore, a larger propeller loading. The wake factor is clearly affected by the bottom conditions:

- the wake factor increases with decreasing mud density, which implies an obstruction of the flow to the propeller; this phenomenon can be ascribed to the vertical interface motions;
- contact between the ship' s keel and higher density mud layers causes an inflow of two fluids into the propeller, resulting into higher thrust and torque and, therefore, small wake factor values.

Fig. 12 shows that the effect of the presence of mud on the overall efficiency of the propeller: compared to a solid bottom, a significant loss of efficiency is stated, especially for negative under keel clearances.

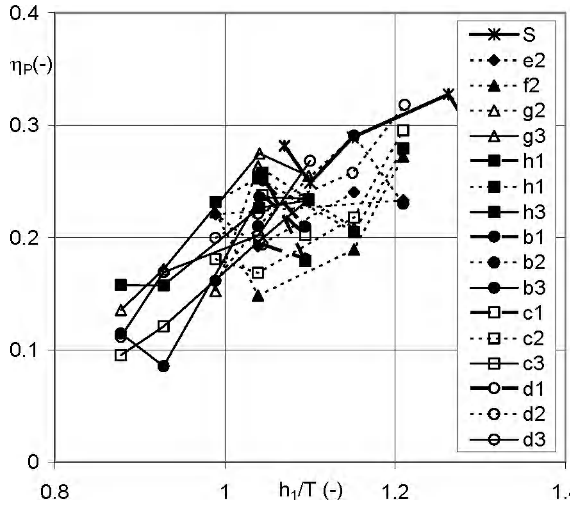

Fig. 12. Ship model D. Overall propeller efficiency: effect of bottom characteristics and under keel clearance.

Besides a longitudinal force, propeller action also causes a lateral force and a yawing moment, due to asymmetry of the flow. This phenomenon is especially important in the 2nd and 4th quadrant (combination of forward speed and backing propeller, or motion astern and propeller ahead). In shallow water, it is observed that these actions are not constant in time, but contain an important slowly oscillating component, the amplitude of which is in the order of magnitude of the propeller thrust. This effect was also included in the mathematical model.

Rudder induced forces

The forces and yawing moment caused by rudder action depend on the axial flow into the rudder. The latter is a function of the forward speed and the propeller rate, but also of the (longitudinal and lateral) rudder wake factors. The latter are significantly affected by the bottom condition and the under keel clearance: the wake factors decrease – and, consequently, the flow to the rudder improves – with increasing mud density and with increasing under keel clearance. As a result, the inflow to the rudder is very unfavourable when the ship penetrates deep into soft, low density mud layers.

Interface undulations

Several phenomena described above are at least partially linked to the deformation of the mud-water interface. Some examples of measured interface motions are shown in Fig. 13. The amplitude of the rising increases and its position moves more aft with increasing ship velocity and decreasing mud density. However, there is a limit to this increase. Once the maximum occurs at a certain distance after the ship, the rising will even diminish. When the ship's keel penetrates the mud layer, two maxima are observed, one amidships and a second one aft. The second maximum will increase, while the first maximum will decrease, with increasing speed and decreasing mud density.

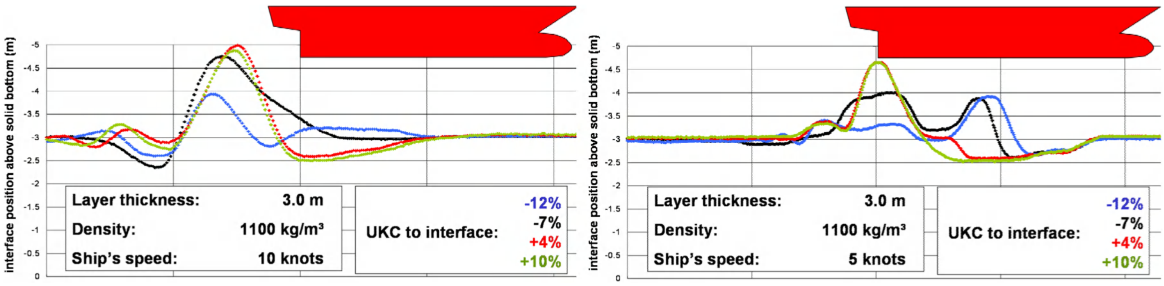

Fig. 13. Undulations of the interface: influence of speed and under keel clearance.

With the present measurements the transition from the second to the third speed range takes place at a higher speed than calculated with the formula mentioned in Fig. 4, probably due to viscosity effects.

Real-time simulation runs

Purpose

The final purpose of the research program consisted in determining revised operational limits for the navigation in the muddy areas of the harbour of Zeebrugge. As the pilots play a central role in the shipping traffic to and from Zeebrugge, the input of their experience and assessment in this project was required and highly appreciated. For a selection of bottom conditions, a real-time simulation programme was organised with Zeebrugge pilots at the full mission bridge simulator of Flanders Hydraulics Research, Antwerp. All runs were carried out with a container carrier (length over all: 300.0m; beam: 40.25m; draft: 13.5m) calling at and departing from the harbour of Zeebrugge.

Two full bridge ship-manoeuvring simulators have been installed at Flanders Hydraulics Research for research and training: SIM225 with a visual system of 225° view and SIM360+ with 360° view and lateral view of the ship's hull. Simulation runs in muddy navigation areas were carried out with SIM225 (Fig. 14). Both simulators consist of a mock-up of a ship's navigation bridge with telegraph, rudder, radar, etc. Communication equipment is available and manoeuvres can be assisted by up to four tugs.

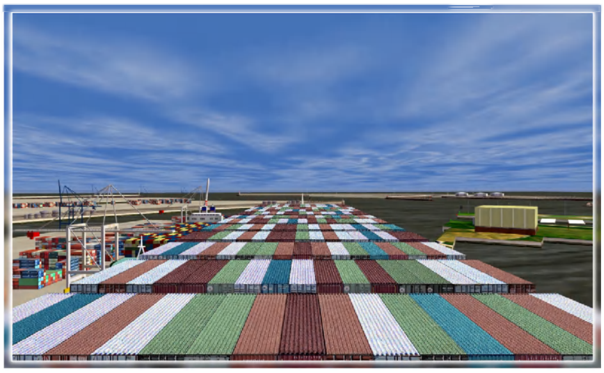

Fig. 14. Flanders Hydraulics Research, outside view of full mission bridge simulator SIM225.

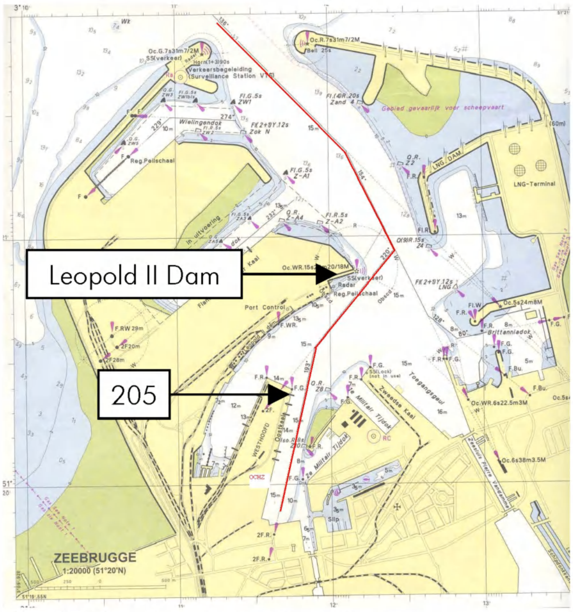

Fig. 15. Simulation runs: trajectory.

The simulation programme was composed paying attention to several aspects:

- Qualitative validation of the mathematical models. In order to evaluate the realism of the simulated ship's behaviour, simulations were carried out in situations that may be comparable with existing or realistic situations. For this purpose, a number of conditions above a solid bottom and above muddy bottoms with reduced under keel clearance was selected.
- Determination of the limits of the controllability. According to the PIANC definition, contact between the nautical bottom and the ship's keel causes unacceptable effects on controllability and manoeuvrability. In order to make an assessment in these matters, a series of simulation runs was carried out during which contact occurred between the ship's keel and mud layers with higher density and viscosity.
- Evaluation of the navigability of mud layers. An increase of the critical density level will possibly imply a penetration of the ship's keel into mud layers with low density and viscosity. A number of these conditions was selected for simulation runs.

Simulation programme

In total, 63 runs were carried out by 15 pilots during 8 days. The selected scenarios had to fulfil the following conditions:

- The manoeuvres should be typical for large container carriers calling at Zeebrugge, so that a feedback to the pilots' experience was guaranteed;
- The simulation runs should cover a broad range of hydrodynamic conditions (speeds ahead/astern, propeller rpm ahead/astern, drift angles, yaw rates, …).

A selection of four manoeuvres was considered; most of them concerned arrival at or departure from quay 205 (Fig. 15). The arrival scenario implies a deceleration phase, tugs making fast, turning the old harbour mole (Leopold II Dam) and berthing on either starboard or port side, the latter implying an additional swinging manoeuvre. Departure manoeuvres did not include swinging manoeuvres.

During each single run, the bottom characteristics were assumed to be constant over the entire harbour area. If such a situation appeared not to be realistic in the access channel 'Pas van het Zand', the manoeuvre was started at lower speed in the outer harbour. The selected bottom conditions are displayed in Fig. 16.

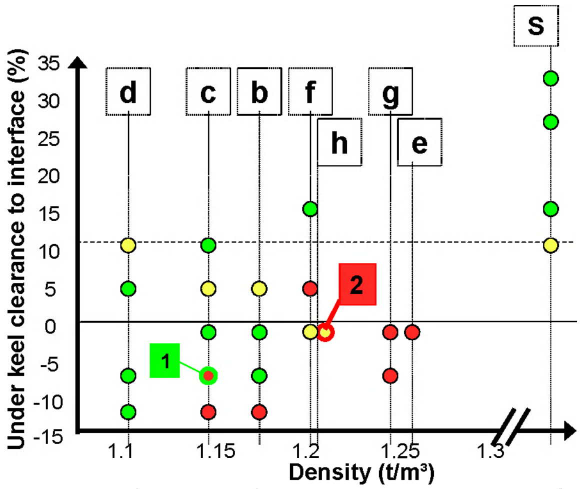

Fig. 16. Real time simulation program: overview of simulated conditions, with overall pilots' assessment (1: with extra tug assistance; 2: wind E, 6Bf).

The access channel to the harbour is characterised by important tidal currents in the zone beyond the breakwaters; at low tide, the magnitude of cross currents takes values of 2 to 2.5 knots. As these currents greatly affect the shipping traffic arriving and departing from Zeebrugge, realistic current patterns were introduced into the simulation environment.

All manoeuvres were carried out in frequently occurring, moderate wind conditions (SW, 4Bf); during some runs, more severe winds (up to 7Bf) were applied.

Tug assistance was guaranteed by two tugs of 45 ton bollard pull each; during some runs the available tug power was increased to 2 x 60 ton.

Qualitative evaluation of the simulation runs

All pilots were requested to complete a questionnaire just after the simulation run; this resulted into a first, very important assessment of the manoeuvres. According to the opinion of a large majority of the pilots, the simulation of the outside view, the ship's behaviour and the tug assistance could be considered as 'good' to 'very good'.

After each run, the pilot was asked whether it would be advisable to carry out the manoeuvre in reality. Based on this assessment, the conditions were classified as 'acceptable', 'marginal' and 'unacceptable'; the results shown in Fig. 16.

Analysis based evaluation of the simulation runs

Taking account of the comments of the pilots on the simulated manoeuvres, it was clear that several criteria should be considered for assessing the bottom conditions. Two criteria concern the controllability of the ship controlled by own means, which is especially of importance during the last phase of the departure scenario, after turning the old mole with tug assistance:

- Is a departing ship able to develop a speed that is sufficient to compensate for the cross current acting beyond the breakwaters? Based on the pilots' qualitative assessment, a speed of 10 knots is acceptable; speeds under 8 knots are unacceptable. Situations leading to intermediate speeds are considered as marginal.
- Can a straight course be obtained without extreme use of rudder and propeller? Taking account of the pilots' evaluation, the standard deviation of the rate of turn of the ship appears to be an adequate indicator, with critical limits of 5 and 6deg.min^{-1}.

The third criterion concerns manoeuvrability with tug assistance: are the ship's control devices (rudder, propeller) and the tug assistance sufficient to perform the manoeuvres safely within acceptable time limits? In order to evaluate this property in a quantitative way, the impulse of steering force was introduced, being the time integral of the sum of the lateral rudder and tug induced forces. Similarly, the impulse of steering moment was defined as well. The values of these impulses were calculated for each sub-trajectory, and compared to the pilots' evaluation of the adequacy of tug assistance. In this way, it was not only possible to quantify the third criterion, but extrapolations to assistance by more or less powerful tugs could be made as well.

Results and future developments

The research project resulted into a new value for the critical density to define the nautical bottom. If a number of conditions are fulfilled, 1200kg.m^{-3} may be considered as a safe value:

- Assistance of at least two tugs of 45 ton bollard pull is required for deep-drafted container carriers.
- Navigability through lower density mud layers (1100kg.m^{-3}) is constrained to -7% of under keel clearance (Fig. 17, left).
- More tug power (2 x 60ton) reduces this constraint (to -12%), but does not affect the definition of the nautical bottom (Fig.17, right); on the other hand, if less tug power (2 x 30ton) is available, the ship should not contact the mud-water interface;
- The present situation in the access channel outside the breakwaters should not be changed;
- Pilots must receive updated information on the levels of the mud-water interface and the nautical bottom;
- Pilots must be aware of the modified controllability of a ship navigating with reduced or negative under keel clearance relative to the mud-water interface, and should receive an appropriate training.

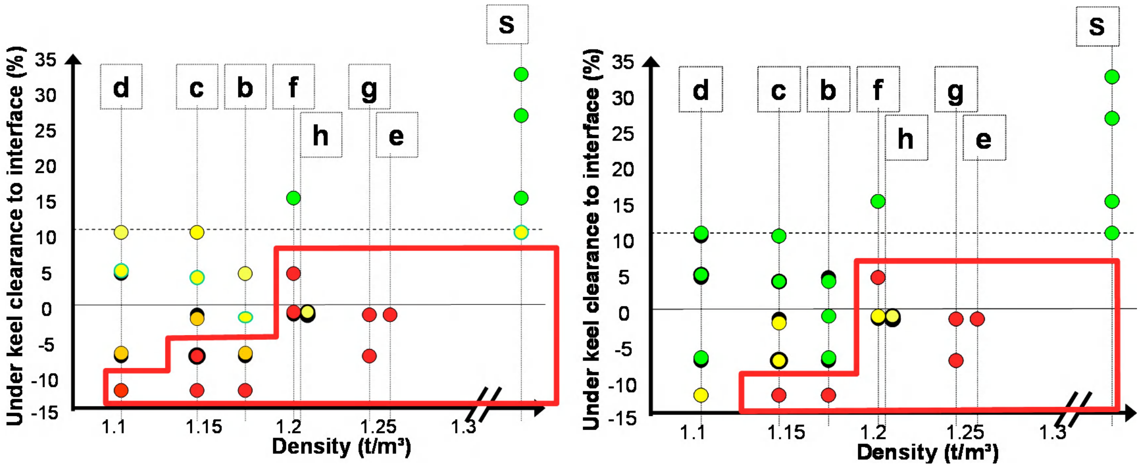

Fig. 17. Real time simulation program. Acceptability of manoeuvres taking account of all criteria, with assistance of 2 tugs with 45 ton (left) and 60 ton (right) bollard pull each.

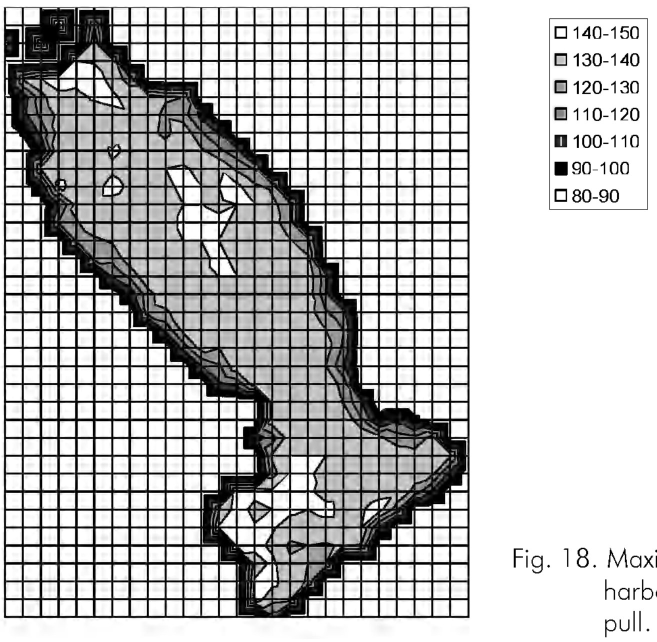

Fig. 18. Maximum allowable draft (in dm) in the outer harbour with tug assistance of 2*60 ton bollard pull.

At present, the conclusions mentioned above are implemented: the 1200kg.m^{-3} level is considered as the nautical bottom; the pilots tend to keep a 10% under keel clearance referred to this level, but also respect the maximum penetration of 7% of draft (typically 1m) into the mud layer. New efforts are presently carried out to take full advantage of the results of the current research project:

- A methodology to interpret bottom surveys in terms of navigability is being developed; as an example, Fig. 18 shows a map of the outer harbour of Zeebrugge indicating the maximum allowable draft at low tide.
- Detailed registrations of manoeuvres carried out with deep-drafted vessels at low tide are planned to validate the concept in general and the mathematical models in particular, as the latter are based on model tests carried out in a simplified environment.

- Additional simulation runs in a larger range of bottom and weather conditions will be carried out in order to improve the pilots' decision scheme. The involvement of a large group of pilots is important, as the human factor plays an important role in the simulation results.
- Training sessions will be organised for the Zeebrugge pilots to familiarise themselves to the specific ship behaviour.
- The realism of the simulations will be increased by adapting the mathematical simulation model so that transitions between several types of muddy bottoms will be allowed.
- Additional model testing is planned to extend the mathematical model to bow thruster assisted manoeuvres. Indeed, pilots criticized the lack of a bow thruster during the simulations.

Conclusion

A research project based on captive ship model tests, mathematical modelling and real-time simulation runs has resulted into an upper limit for the nautical bottom from a nautical viewpoint and to guidelines for the pilots concerning handling of deep-drafted container vessels in the muddy conditions of the harbour of Zeebrugge.

It should be emphasized that these specific conclusions are only valid for deep-drafted container carriers arriving at or departing from Zeebrugge harbour, as the mud layer characteristics, the environmental conditions (e.g. current) and harbour layout are typical for this area.
On the other hand, a similar methodology can be applied for assessing the limits for navigation in other harbours and waterways suffering from fluid mud deposits, provided that the local conditions (bottom, ship type, …) are covered by the experimental database and, therefore, the mathematical model. The present approach offers an important advantage: the new criterion for the nautical bottom is not merely based on one single physical property of the mud layer, but has been determined taking into account all significant factors such as harbour layout, bottom characteristics, ship behaviour, environmental conditions (current, wind), available tug assistance and human control.

Acknowledgements

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MORPHOLOGICAL MANAGEMENT IN ESTUARIES CONCILIATING NATURE PRESERVATION AND PORT ACCESSIBILITY

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Abstract

In 1999, Flanders and The Netherlands agreed to set up a common strategy for managing the Scheldt River in its estuarine reach. In 2002, both parties signed a memorandum of understanding in which was defined a 'Long Term Vision' strategy and its objectives. One of these is the preservation in the Western Scheldt of a dynamic and complex flood and ebb channel network, the so-called 'multi-channel system'. The present trend, a continuation of past natural morphological evolutions combined with human interference (poldering, dredging and other river works) may jeopardise this objective.

An expert team appointed by the Port of Antwerp proposed the idea of morphological dredging for curbing this negative trend, aiming at steering the estuarine morphology. In a first phase, sediment from dredging works could be used to reshape sandbars where needed. One case study is discussed in this paper, the aim being to reconstruct the eroded tip of a sandbar at a bifurcation so that the flood and ebb flows would be perseved, a condition to maintain the multi-channel system in the reach. The strategy would not only cut back on the ongoing degradation of the ecological and morphological values of the estuary, but it could also possibly help reducing the quantity of material to be dredged on the crossings by increasing the scouring or self-dredging capacity of the flow. A diffuser-type device was used to disperse the dredged material in a controlled way in shallow water along the sandbar edges.

In 2002-2003, the new disposal strategy has been investigated by Flanders Hydraulics Research as a pilot project (Plaat van Walsoorden). The research programme combined three tools: field measurements, physical scale models and 3D numerical models. The results of the research work confirmed the feasibility of the idea. However, the Port of Antwerp Experts concluded that a real life (*in situ*) disposal test was required to give final proof of the feasibility of this new disposal strategy.

At the end of 2004, 500,000m^3 of sand was disposed at the seaward tip of the shoal of Walsoorden using a diffuser. The main idea was to modify the morphology of this sandbar by disposing dredged material very precisely. The amount of 500,000m^3 was chosen because it is large enough to see an effect of the disposed sediment, while it is small enough to be reversible if something would go wrong. To evaluate the success of this *in situ* test, an extensive monitoring programme was set up, including bathymetric surveys, ecological monitoring, sediment tracing tests and sediment transport measurements.

After one year of monitoring the disposed sediments, it can be concluded that the experiment is very successful. The morphological monitoring showed that almost 80% of the disposed sediments is still on the disposal location after one year. The ecological monitoring did not reveal any significant negative impact, neither in the intertidal areas, nor in the subtidal areas. This *in situ* test confirmed the feasibility of the proposed disposal strategy. An estimated volume of 4 to 5 million m^3 could be disposed here to reach the proposed objectives, representing more than half of the volume dredged yearly in the Western Scheldt.

Keywords: Morphological dredging; Western Scheldt; Ecomorphology.

Introduction

The morphology of an estuary is continually changing, adjusting to the forcing processes which themselves are also changing. No estuary is therefore stable and habitats and the ecological functioning of the estuary will continually change from its present status even if man didn't intervene. This implies the need for a detailed conceptual understanding of the estuary system in question. Only such an understanding can lead to proper assessment of the effects of existing and future human activities, such as dredging and disposal, but also the construction of flow regulating structures and dikes. For any estuary there should be a holistic management plan, which takes into account the interests and effects of all uses and users of the estuary in an integrated way.

This paper focuses on the case of the Scheldt Estuary, where morphological management is used to conciliate nature preservation and port accessibility. The Scheldt is the aorta to the port of Antwerp, while it is one of the few remaining European estuaries covering the entire gradient from fresh to salt water tidal areas.

Overview of historical evolutions

Natural evolutions till 1000 AD

At the end of the Pleistocene, the last ice age, rivers in North-West Europe discharged in the Atlantic Ocean in the vicinity of the Doggersbank, far away from the present shores. With the warming up of the climate, the sea level rose very quickly over more than 100m from 20 Kyr BP to about 7 Kyr BP, then slower to become (comparatively) rather stable over the past two millenaries. The past rising sea level reshaped strongly the coastal areas and estuaries at the end of the Holocene. Many of these morphological changes are still ongoing. With the invasion of the street of Kales, tidal currents started to erode its banks, creating cliffs and feeding a littoral sediment transport that was at the origin of an almost continuous series of sandy bars and islands in front of the actual Belgian, Dutch and German coast (Fig. 1). An inner sea was formed, a kind of an extensive lagoon of which remains only the Wadden Sea. The sand barrier between lagoon and open sea was regularly breached during storms, scouring large channels deep into the inner sea. River sediments filled those parts of the lagoon receiving streams with large sand discharges, like the Rhine. In other parts receiving little and more silty sediment loads, like from the Scheldt River, tidal action penetrated progressively, developing further the sea branches. Import of marine sediments by the tidal currents formed large shoals in the lagoon. Sea branches not connected to a main river basin silted up (e.g. Zwin), while others like the Honte and the Eastern Scheldt expanded further as they were at that time connected to a river basin. Later on, the southern sea branch, the Honte, became dominant over the Eastern Scheldt and had now become the estuary of the Scheldt River. In the Southern part of the inner sea, shoals aggregated and channels enlarged. Around 1000 A.D., Zeeland had become a patchwork of islands, surrounded by a network of tidal channels. At that time, the River Scheldt discharged in the lagoon near Bergen op Zoom and both the Honte (present Western Scheldt) and the Eastern Scheldt were conducting the Scheldt River water to the North Sea. Till the 11th century, morphological evolutions were significant but fully natural, with almost no human impact.

Fig. 1. Situation during the Roman times.

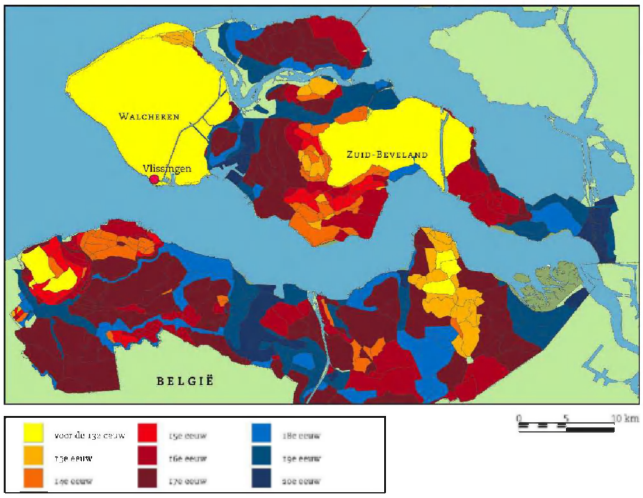

Fig. 2. Land reclamation from the 11th till the 20th century.

Human influence after 1000 AD

First signs of human impact on the estuary's environment become visible in the 11th century: locals reclaimed land that had silted up high enough and started to protect it against flooding (Fig. 2). However, inundations due to levee breaching during storm events returned repeatedly portions of land to the river. From the 16th century on, the poldering techniques had become more sophisticated and larger areas were permanently poldered (e.g. for eastern Zeeuws-Vlaanderen 50% of the total poldering occurred during the 17th century).

Poldering was less intensive during the 19th and 20th century because a large percentage of salt marshes had been reclaimed already. However, hydraulic works and storms continued to reshape the area. In 1867 and 1871, the two remaining links (Kreekrak and Sloe) between the Honte (Western Scheldt) and the Eastern Scheldt were cut off, modifying drastically the tidal channels network. A catastrophic storm with extensive inundation, in 1953, made the Netherlands decide about executing an extensive flood protection plan 'Delta'. From historical data can be concluded that these human impacts such as closure of secondary channels and poldering have strongly influenced the tidal regime of the Western Scheldt. Stronger tidal penetration enlarged the main navigation channel.

Sediment mining for providing building material started at the end of the 19th century. Since 1958, about 1 to 2 million cubic meters of sediment was mined per year, on average.

At the end of the 19th century, dredging activities (Fig. 3) were required to improve the accessibility of the port of Antwerp. Until the 1920's, these activities were concentrated on the Belgian territory ($2Mm^3.yr^{-1}$). From 1920 till 1960 the quantities on Belgian and Dutch territory were comparable ($2 + 2Mm^3.yr^{-1}$). The first large deepening campaign happened in the early 1970's, the main part of dredging works on Dutch territory ($3 + 10Mm^3.yr^{-1}$). Nonetheless, the increased dredging in the Dutch part did not apparently result in significant changes of the trend in morphology or tidal action. During the late 1990's, a second dredging campaign for improving the navigation conditions was conducted. The impact of the deepening by 4 feet is monitored (MOVE programme), but no significant negative impact was noticed yet.

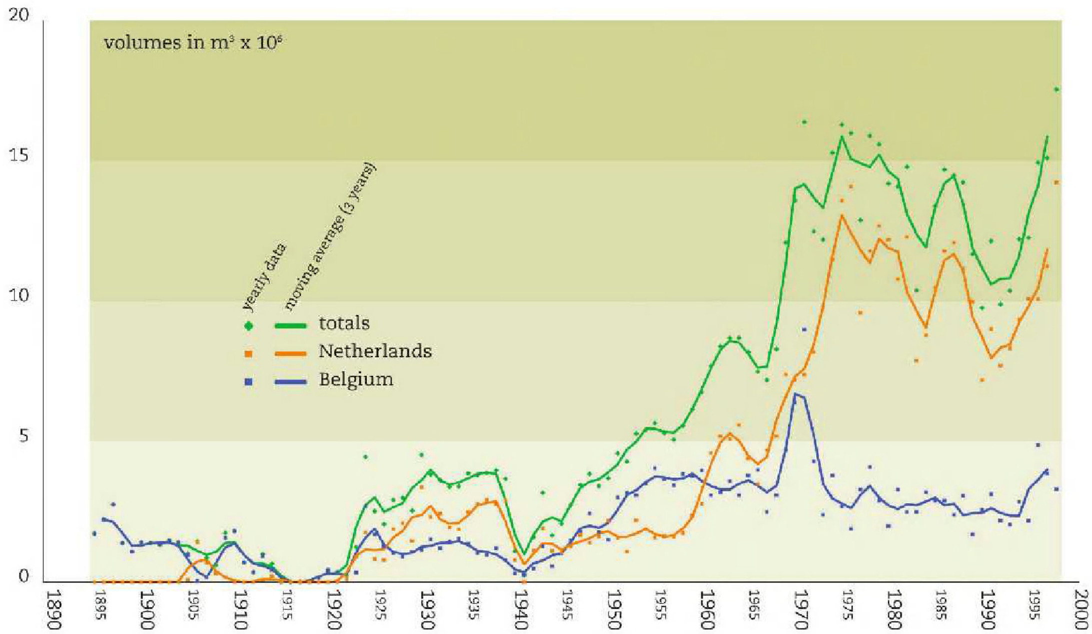

Fig. 3. Dredging activities in the Scheldt Estuary since 1895.

Maintaining navigation conditions in a morphological dynamic estuary

The morphological evolution of the estuary between 1800 and 2000 (Fig. 4) is one of further shoal aggradation and enlargement of the main channels. The estuary has been described as a typical multiple flood and ebb channel network. The main and deeper ebb channels have usually sills at the seaward end where they join together with the flood channels. These ones are shallower and have a sill at the landward side, where they join the main ebb channel. There are also many minor channels, the 'chute' channels, sometimes called 'short-cut' channels connecting the major ebb and flood channels. Historical maps reveal that the ebb or flood function of channels is not always obvious and sometimes even unclear. Ebb channels may turn into flood channels, and vice versa (see middle part of the estuary on Fig. 4). The reducing mobility of the channels and shoals is for a large part due to the hard bordering of the estuary (levees, bank protections, groynes, jetties and harbours); sandbars are rising too high, channels deepen, shallow water areas diminish.

A Dutch-Belgian Technical Scheldt Commission was set up in 1948 to manage technical issues such as the works needed for ensuring the access to the Port of Antwerp. Till 1970, dredging was restricted to maintaining depths on crossings in the navigation channel, formed by the main ebb channels. Traditionally, the sediments were disposed in the flood channels with the idea that it would take a rather long time before coming back into the main ebb channel.

With the demand for increased navigation depth, a first deepening started in 1970 and the dredged sediments were still disposed in flood channels. The disposal sites were decided in common by the Dutch and the Belgium administrations on the basis of the assessment of the ongoing morphological changes. The procedures were adjusted due to the increasing concern about environmental aspects and with the regionalisation making the Flanders region responsible in Belgium for public works and infrastructure. In 1995, Flanders and The Netherlands reached an agreement to deepen further the Western Scheldt shipping route. Works were executed in 1997 and 1998. However, the amount of sediment disposed in the eastern part of the Western Scheldt was reduced when aggradation was observed in some flood channels, supposedly because too much sediment had been disposed there. This siltation could eventually jeopardise the existence of the multi-channel system in that reach. Therefore, from 1997 on, more material was moved to disposal sites in the western reach of the estuary.

In 1999, the Dutch and Flemish governments decided to set up a Long-Term Vision (LTV) project with three objectives: to ensure maximum safety against flooding, optimal accessibility of the ports within the estuary and optimal nature development. These three subjects are all related to the morphology of the estuary. Directly concerned by these issues, the autonomous Port of Antwerp, independent from the Flemish administration, requested a group of experts (called Port of Antwerp Expert Team, or 'PAET') to give an opinion about the prospects for a further deepening and widening of the navigation route, mainly needed for the larger container ships. One of the main questions considered in LTV was where to dispose the large volumes needed for such an enlargement? Dutch researchers had claimed that flood channels would disappear if too large quantities of sediment were to be disposed there. Their conclusions were based on some assumptions and calculations with modelling tools, of which one is based on the so-called 'cell-theory' (Wang *et al.,* 1995; Winterwerp *et al.,* 2001). A 'cell' is composed of an ebb channel and a flood channel and the enclosed inter-tidal flats. According to this theory, sediment circulates in 'cells', with a net landward movement in the flood channels and a net seaward one in the ebb channels. The Port of Antwerp experts consider this schematisation as too simplistic. Based on their analysis of past morphological changes in general and of the (temporary?) decay of some flood channels, they stated that not (only) disposal of sediments was to be blamed, rather the always more stringent immobilisation of the main channels and shoals. To revert the reduction in dynamic morphological behaviour of the estuary, it was proposed to steer the development of channels and shoals. Recent studies show that the disposal of dredging materials has a much larger impact on the estuarine morphology than the deepening of the channels (ProSes, 2004). The main attention should therefore go to new strategies for disposal, although the Port of Antwerp expert team believes that dredging may also be beneficial for morphology, e.g. rectifying the shape of sandbars.

In 2002, the Dutch and Flemish governments signed a memorandum of understanding to implement together the Long-Term Vision programme. They set up jointly an organisation called ProSes (Project Direction for the Development Scheme of the Western Scheldt Estuary) funded by both regions and which main task was to establish for 2004 the development scheme with the objectives to be reached in 2010. Part of the research referred to in this paper was conducted within the frame of ProSes, though many activities were financed directly by the Flemish government and the Port of Antwerp.

Morphological management of the Western Scheldt

Morphological management of a river

Morphological management of rivers aims at finding measures to have their morphology evolving to a situation that is considered as 'desirable', which is obviously rather subjective as the goals may be very different. A river engineer may have very different views from an environmentalist or a biologist. Nevertheless, there is a growing interest in the 'management' approach versus the 'engineering' or 'river taming' approach, especially because of past negative experiences with river training.

In 1968, Flanders Hydraulics Research faced the challenge to improve the maritime access on the Congo River. It could profit from a very long experience with dredging in such a powerful river with very high discharges and sediment transport rates: the so-called 'Directed Dredging Method' [Méthode des Dragages Dirigés, (*in French*)], based on a thorough analysis of field data.

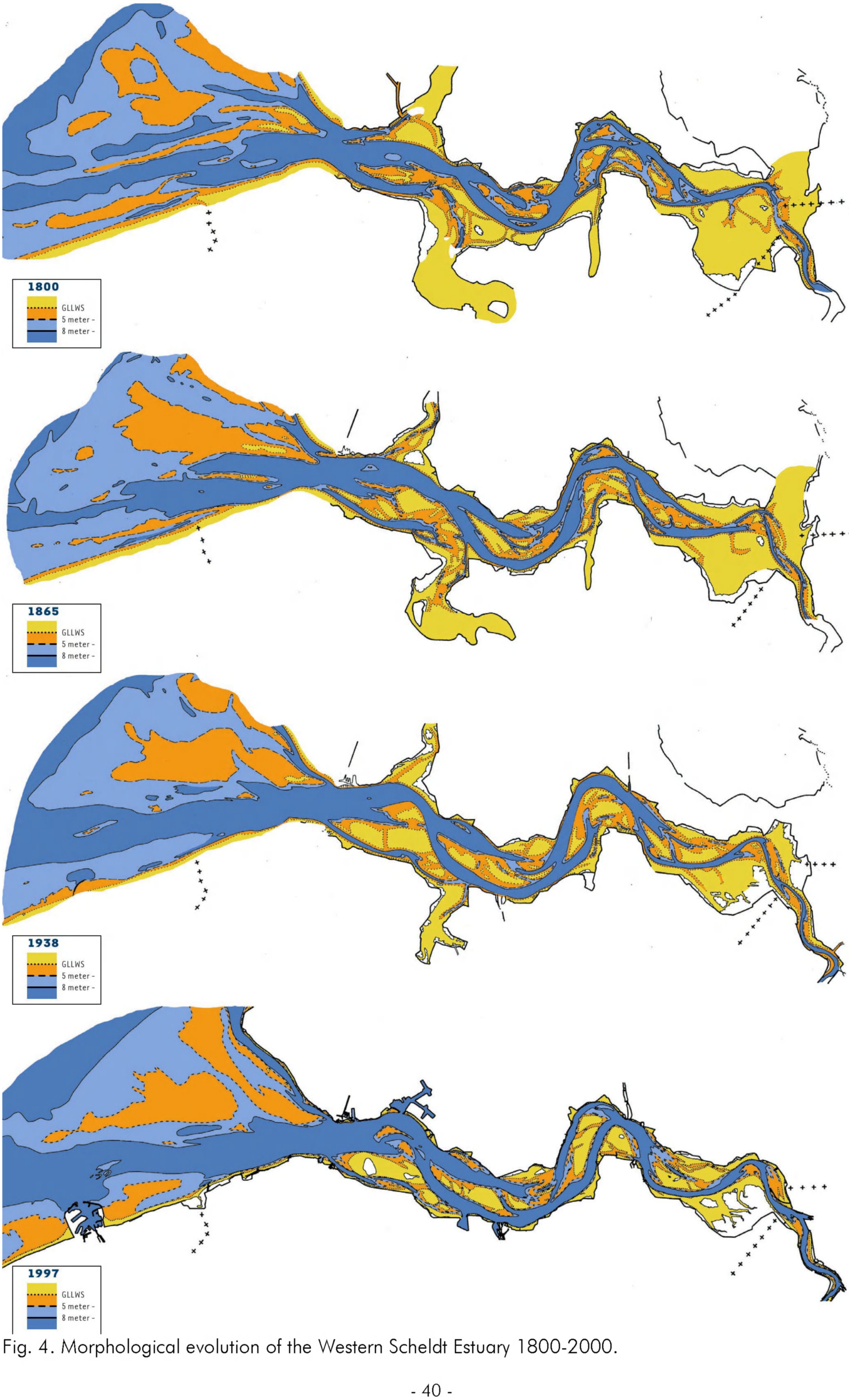

Fig. 4. Morphological evolution of the Western Scheldt Estuary 1800-2000.

This method was further developed carrying out scale model studies and extensive field surveys, to become the 'Morphological Dredging Method' (Peters and Wens, 1991). The idea of morphological management was further developed in other projects on very different rivers, such as the Pirai in Bolivia (Peters, 1994) and the Ichilo River, also in Bolivia (Peters, 1998). The same philosophy was applied: understanding the river behaviour and working with the river, not against nature, using simple and cheap methods. In the first case of the Pirai River, the traditional way to protect against flooding with high levees and strong bank protections was replaced by lighter protections in combination with adaptation of the river plan form. In some cases, the river shore alignment was changed with excavations so that the flow would not attack the banks. The strategy was based on a continuous monitoring. In the second case of the Ichilo River, the occurrence of a natural cut-off was halted with light guiding structures, which aimed at orienting the flow away from the meander bottleneck. In this way, it was possible to save time for designing artificial cut-off's, which allowed the river to remain along the Puerto Villarroel harbour, of major importance for the transport of goods from and to the Bolivian Amazone region. In all cases, a follow up has shown that the methodology of river management was feasible and could be successful, at the condition it was based on the best possible understanding of the physical (morphological) behaviour of the rivers. It also showed the advantage of using recurrent measures, such as dredging or excavations.

Morphological dredging

During a meeting with the LTV's working group on morphology, in the year 2000, the Port of Antwerp experts suggested 'morphological dredging' as an alternative to the present dredging strategies. It is based on the principles developed for the maintenance and the capital dredging in the navigation route in the Congo inner delta, for example by redistributing the sediment transport and using dredging and disposal to change the plan form of the river.

Disposal is a way to redistribute the sediment in the Western Scheldt, so as to feed, as an example, areas eroding too much, not only in the flood channels, also on some parts of shoals. The Port of Antwerp expert team worked out a proposal to restore the western tip of Walsoorden plate that erodes since several decades. Several millions of cubic meters of sediment could be stored at that place (Fig. 5 – white hatching). The technique could be applied in other places along the estuary. One advantage of the proposal is that the additional volumes produced by the capital dredging required for a further improvement of the navigation route could be kept within the estuary instead of exporting it out of the estuary, into the sea. Nobody knows today what would result for the Western Scheldt from such an export in terms of tidal propagation and environmental impact. The estuary is said to have very little sediment exchange with the sea and the quantity of sediment supplied by the river is rather small, limited to very fine material, mainly silt and clay.

The second part of morphological dredging is to correct the shape of shoals when this impacts negatively on the overall flow and sediment patterns. This may be illustrated by the example of the sand spit at the seaward end of the ebb channel at Walsoorden (at the Southwest end). It is formed by the combined action of flood and ebb and, together with the protruding groyne and the levee on the left bank, it constricts too much the flow during the end of the ebb flow. It may be that this results in a less effective flow on the crossing of Hansweert, just west of the tip of the Walsoorden sandbar. In that case, modifying the shape of the sand spit by disposing dredged sediments might improve the self-dredging capacity of the crossing, reducing finally the dredging effort.

Modifying the hard bordering of the estuary

The Port of Antwerp expert team considers that the layout of the hard bordering is not always beneficial for achieving the objectives set out in LTV. The development of shoals and channels is controlled by levees and other hydraulic structures. The plan-form layout of these levees was not planned; they were established erratically, often by building new levees after breaches occurred during extreme storms. Some brutal changes in the orientation of the levees create hard points protruding into the estuary and controlling the position and shape of sandbars. The analysis of the Walsoorden test-site lead to the conclusion that the piers of the Hansweert lock access channel (on the right bank), protruding in the main channel, affect the orientation of the flood flow towards the Walsoorden plate, enhancing its erosion. More than thirty years ago, a dike protruding in the river at Walsoorden (on the left bank) was modified to improve the morphology so that dredging would diminish on the nearby crossing of Hansweert. However, the overall morphology in the river stretch changed meanwhile so that this dike could have today a negative impact on the crossing. PAET decided to make an inventory of similar situations, for analysis of possible solutions.

Criteria for selecting disposal areas

The selection of disposal areas must be based on several requirements, related to safety against flooding, accessibility and nature preservation: producing a morphology reducing the maintenance dredging effort, maintaining a dynamic multi-channel system in which tidal energy could be dissipated as much as possible, ensuring the preservation of a variety of ecotopes. All these criteria are linked to the morphological development of the estuary, to be steered by dredging and disposal of dredged materials.

Monitoring

Our understanding of the morphological processes in rivers and estuaries is not sufficient to predict very precisely the response induced by dredging and disposing the sediment in specific places. Morphological dredging and disposal is reversible up to a certain point. Selection of disposal sites must be flexible and it must be possible to halt operations if unwanted morphological changes are observed. Therefore, a comprehensive monitoring programme is absolutely needed. This includes, among other: flow measurements, topo-bathymetric observations (among other with multibeam charts and LIDAR observations), bottom sampling for sediment size and biological data acquisition, sediment transport measurements and possibly sediment tracking.

Technology for morphological dredging

The dredging companies contacted for advice about the disposal of material in controlled way close to the riverbed have developed a system by which the sediment is disposed quietly with a diffuser in shallow water (Fig. 6). This technique has already successfully been applied in coastal areas (Goossens and Bosschem, 2002).

Potential benefits for the environment

A careful choice of disposal sites, based on good field data and possibly completed with modelling, may produce a selective spatial dispersion of the sediments along the sandbar. Some particle fractions will preferentially move in the deeper areas, other moving towards the shallower ones, possibly up to the top of the bar. During the process, the change in morphology by aggrading up some parts of the bar will change the flow patterns and modify consequently the local sediment transport capacities. This will obviously also change the sedimentation pattern, also of the finest particles moving in suspension in the water column. The segregation of sediment fractions of both disposed and natural sediments will result in the formation of different substrata, some more silty than other, creating a variety of ecotopes.

In a common meeting of the ProSes working groups on morphology and ecology, it was decided to involve biologists and ecologists in the Walsoorden test disposal, monitoring closely the physical, chemical and biological parameters. Surveys would take place before, during and after the test disposal. However, the rigid conditions for the disposal of dredged materials delayed the test for several months.

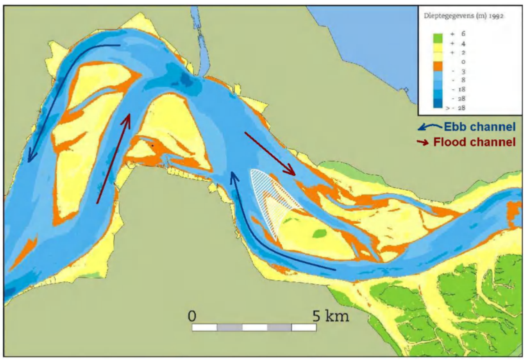

Fig. 5. Walsoorden area.

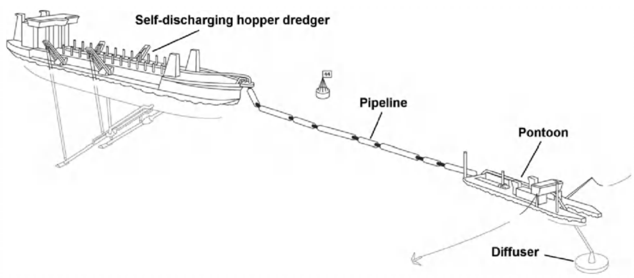

Fig. 6. Schematisation of disposal technique.

Research on the Walsoorden test case

Tools and tests

The PAET has stated from the beginning of the Walsoorden project proposal (Peters and Parker, 2001) that field measurements and physical and numerical models needed to be combined, as each of these study tools has advantages and limitations. They must be seen as complementary tools for the assessment of the alternative dredging and disposal strategy. The research programme included a field measurement campaign (floats, sediment transport), physical, fixed bed scale model tests for both the flow and the bed sediment movement and hydrodynamic numerical model simulations. Flanders Hydraulics Laboratory (Ministry of Environment and Infrastructure) executed this programme with the support of the Port of Antwerp and its expert team.

Field measurements provide an insight in the processes as they occur in nature. Due to changes in natural conditions (e.g. tidal variations), a measurement campaign may only give information limited to the prevailing conditions. Measuring techniques have obviously also their limitations.

DGPS tracked floats supplied information on flow patterns during the tide. These flow patterns were measured during a full spring-neap tidal period and provided on one hand information about the *in situ* flow conditions and on the other a series of data that were used to calibrate and validate the models. Sediment transport rates were measured during one tidal cycle, using both Delft Bottle (DB12) and Acoustic Sand Transport Meter (ASTM), in three points at the seaward tip of the Walsoorden sandbar (Fig. 8 – yellow dots). The bottom topography was measured near the tip of the plate using multi-beam (Fig. 8 – green area).

A second tool used in the project is the physical scale model. With best possible scales according to scaling laws, processes such as flow and bed load transport are well represented. Models present the possibility to control and change the testing conditions. Errors may become problematic when horizontal and vertical scales differ too much in a distorted model. Though the distortion is rather high (but not exceptional) for the Western Scheldt-model (horizontal scale = 1/400 ⇔ vertical scale 1/100), exaggeration of some processes – such as secondary currents – in the model induces discrepancies with reality. They seem however acceptable for the objective of the model tests on disposal of dredged material.

The hydrodynamic experiments in the scale model made use of small floats aiming at reproducing the measured float tracks in nature. Cameras registered the flow patterns. A second series of tests simulated the behaviour of disposed sediment in front of the tip of the plate. Therefore it was found that polystyrene (with a median diameter of 450μm) was the most appropriate material for the scale model. This material allowed a good reproduction of the moment of initiation of movement, nevertheless the transport rates weren't simulated correctly.

Finally, numerical models were used. These also have a high flexibility because test conditions can easily be adapted. Restrictions arise in the numerical representation of natural processes, for which the physics is still not always well understood, as is the case for sediment transport. This makes the applicability of morphological processes in numerical models doubtful. For some model parameters the physical meaning is rather low and they have to be calibrated.

A global 2Dh model of the whole tidal influenced zone of the River Scheldt was set up in SIMONA-software (as used by Rijkswaterstaat) to simulate the tidal propagation and horizontal salinity gradient. This model generated boundary conditions for a detailed model of the study area (Terneuzen – Schelle) which was set up in Deflt3D software (WL|Delft Hydraulics, 2003). In a first approach the detailed model was set up as a 2Dh model. Complex secondary currents (produced by ebb-flood-channel bifurcations, as well as salinity gradients) required a 3D approach. Sensitivity analysis allowed to conclude that the use of a 3D model with at least 10 layers was best suited to produce the most reliable flow fields.

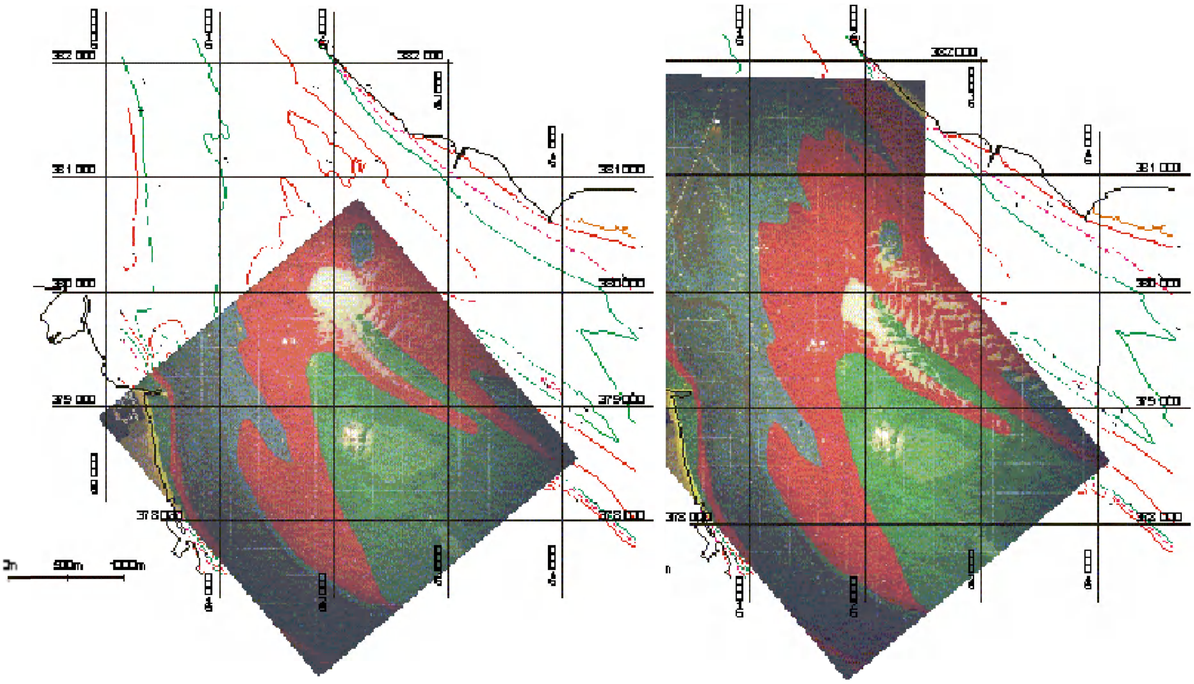

Fig. 7. Disposal experiment near the tip of the plate of Walsoorden in the physical scale model.

Results

The field measurements revealed that the two secondary flood channels, located at each side of the Walsoorden sandbar tip, have a different hydrodynamic behaviour (Fig. 8 – float tracks during flood). The northern sand spit clearly guides the flow during the well-developed flood and ebb flow. The southern sand spit does not guide very much the flow, neither during flood or ebb phases. Nevertheless, it remains in place since long and its existence is likely linked to secondary flow structure (due to hard bordering of the left bank) and to bed load paths. Interesting to note is the significant ebb flow effect along the northern border of the Walsoorden sandbar in the main flood channel.

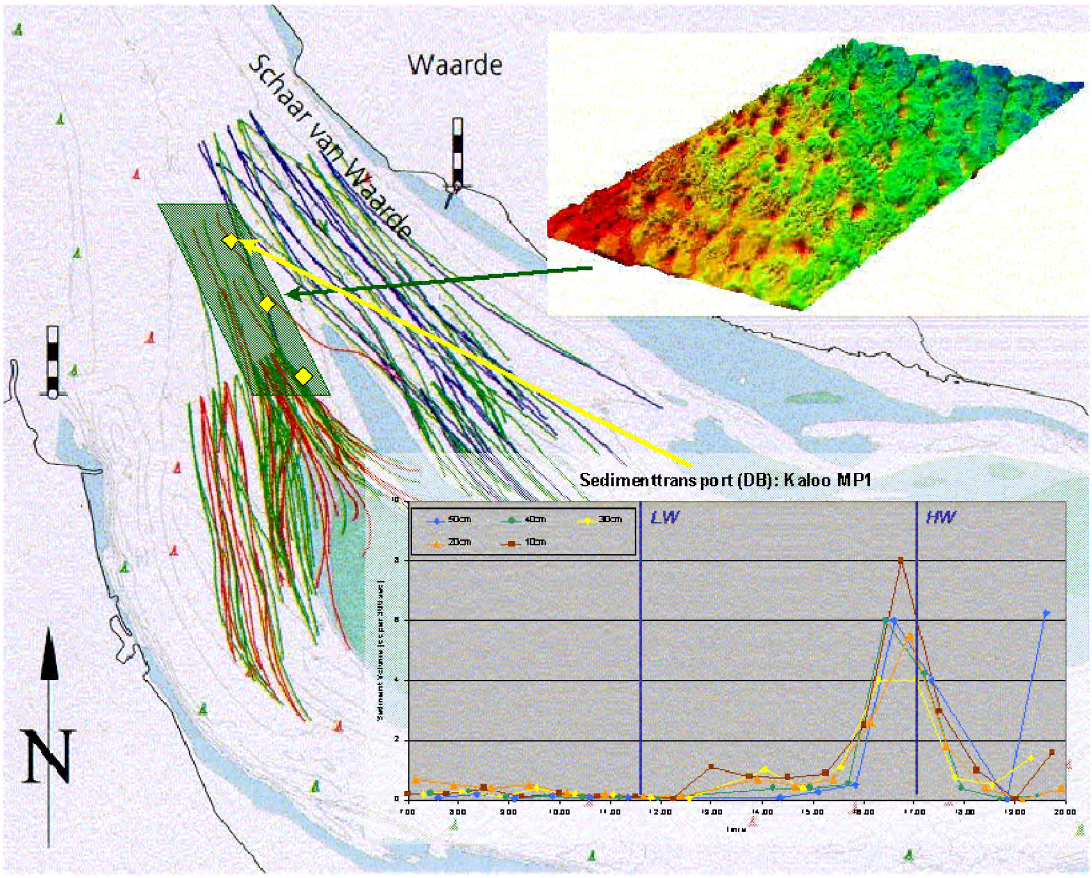

Fig. 8. Field measurements (background: floats; right top: multi-beam; right bottom: sediment transport).

The sediment measurements revealed that sediment transport takes place during the first ebb phase and during the flood phase (Fig. 8). After the initial ebb phase, when the water level has dropped, the tip of the sandbar is located in the shadow of the Walsoorden sandbar and sediment transport is very low. During flood, both DB12 and ASTM data show that the transport rate is the lowest at the location closest to the plate. At the start of the flood, higher transport rates are observed furthest from the sandbar, but the difference with middle location is very small. In contrast, the highest rates during the maximum flood occur in the middle location.

As far as hydrodynamics is concerned, it can be said that the comparisons between the results observed in scale model and those computed on the one hand, and with the measurements on the other hand are rather encouraging (Fig. 9 – top). The results indicate to date that the overall flow patterns are quite well reproduced, though differences were found, mainly during slack low water and early flood period (Fig. 9 – bottom). This positive statement does not mean that the numerical simulation models are in any way 'validated' or 'calibrated' and that from now on they can be used and trusted for all purposes. More specifically, in our opinion they should not be used without precaution or limitation, as an operational tool to study the alternative disposal strategy at Walsoorden.

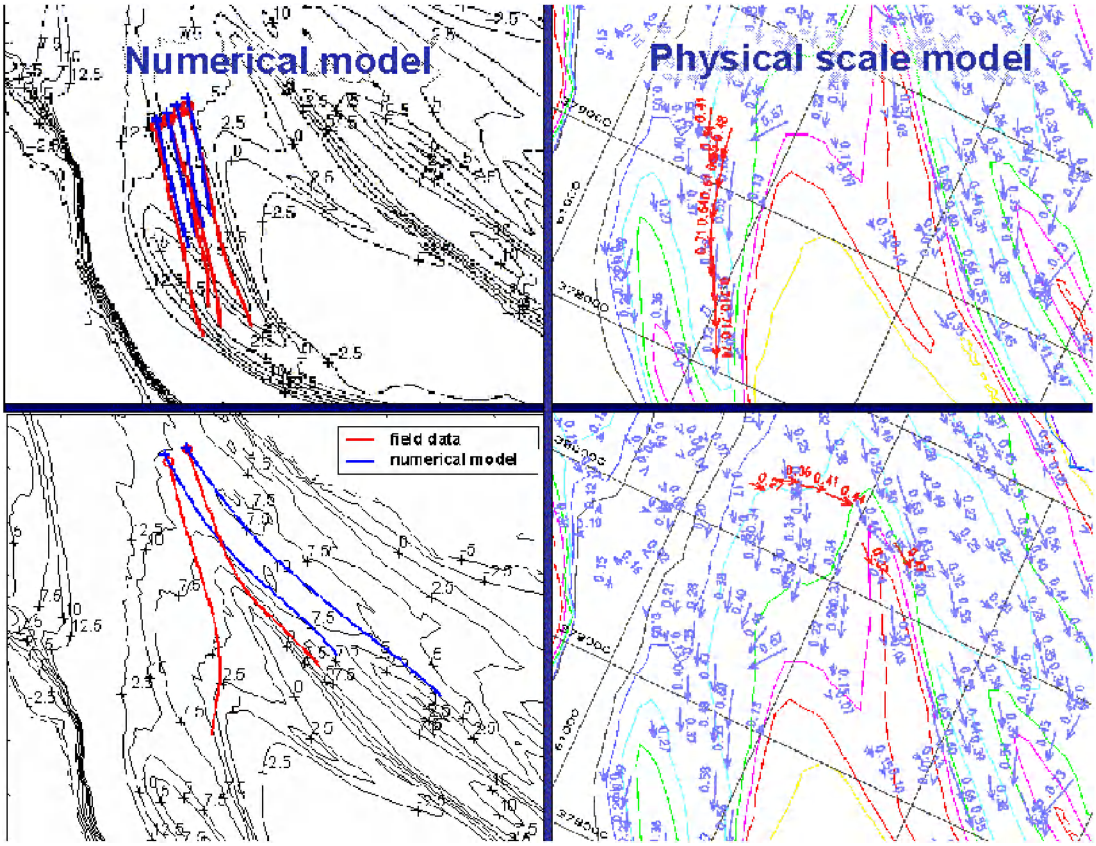

Fig. 9. Modelling results (red: field data; blue: modelling result).

Conclusion about the feasibility study of the Walsoorden test site

Although a number of aspects of the study, that were indicated by the PAET as being essential for assessing the feasibility of the proposed disposal strategy, were not undertaken – specifically additional sediment transport measurements – the results derived from the studies concerning hydrodynamics and sediment transport (Flanders Hydraulics Research, 2003) indicate that the placement of material as proposed for the morphological dredging strategy can likely be used to influence the estuarial morphology (PAET, 2003). Degraded areas and their associated biotopes could be regenerated. PAET insisted on having a small scale *in situ* disposal test to gain final evidence that the proposed strategy is feasible.

The analysis of the data has also shown that all investigative tools were needed to reach this conclusion and that morphological assessment of the Western Scheldt should not be based on modelling alone. One should realise that our knowledge about and understanding of the physical processes governing morphological changes is still not sufficient to set up trustworthy models. Combining different tools is the only way to reduce the uncertainties.

Where most of the research occurred within the scope of ProSes, a second opinion team was asked to give their comments on the methodology used for and the results gathered from the research. They confirmed that the idea to use dredged material to restore sandbars is very valuable and that an *in situ* disposal test is necessary to remove the remaining uncertainties about the proposed strategy.

The walsoorden *in situ* disposal test

Execution of the disposal test

The execution of an *in situ* disposal test had to bring final proof of the feasibility of the alternative disposal strategy. The idea of the *in situ* test was to dispose quietly and precisely 500,000m³ of sand with a diffuser on the bottom. The dredging vessel (self-discharging hopper dredger) was connected to a floating pipeline through which the sand is transported to a pontoon 'Bayard II' (Fig. 6). On this pontoon the sand is pumped to a diffuser (Fig. 10) that disposes the sediment in a precise way on to the bottom. The use of the diffuser required an adjustment of the disposal license. The amount of 500,000m³ was chosen because it is on one hand large enough to affect significantly the bottom morphology, however on the other hand small enough to be reversible if something would go wrong. The choice of the disposal location was based on the results of the feasibility study. The float measurements, the results of the numerical simulations and the physical scale model tests with moveable material on fixed bed indicated that an area between the northern sand spit and the tip of the plate was most suitable for an *in situ* disposal test (Fig. 11). From 17 November to 20 December 2004, 500,000m³ of sand was almost continuously disposed in the proposed area.

Fig. 10. Detail of the diffuser.

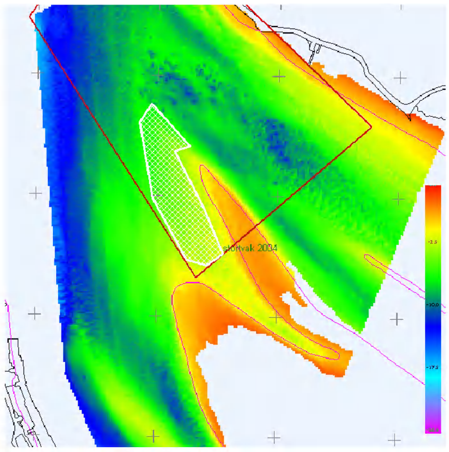

Fig. 11. Licensed disposal area (red) and disposal test area (white).

Monitoring of the disposal test

To evaluate the success of the test an extensive monitoring programme was set up. This programme, which was executed over a period of one year, included bathymetric surveys, ecological monitoring, sediment tracing tests and sediment transport measurements. Several criteria were defined before the test for evaluating its success. One of them stated that two weeks after finishing the disposal execution of the test, at least 80% of the disposed sediment should stay within the control area (this was defined as the disposal area, extended slightly towards the sandbar of Walsoorden). Also the ecological parameters should not indicate a change in ongoing natural trends.

Bathymetric surveys

The bathymetric surveys were executed using the multibeam-technique, producing high resolution bathymetric charts. From the start of the experiment (November 2004) until March 2005, weekly surveys were executed in an area around the disposal location (area ~ 900ha). From March until June 2005 the measurement frequency was reduced to one survey every 2 to 3 weeks, while from June 2005 until January 2006 one survey per month was executed. Beside this possible impact area, a larger zone was measured every two months, to capture possible larger scale influence of the *in situ* test. These surveys allowed volume computations for the control area. The evolution of the sediment volume is shown in Fig. 13. The amount of disposed sediment should be corrected due to the differences in density in the hopper and *in situ*. Therefore a correction factor 0.9 was applied to the hopper volumes. As can be seen in Fig. 13 the first survey after the execution of the disposal test shows a smaller volume measured *in situ* than what was disposed. This small difference (25,000 m^3) represents the sediment losses during the disposal of the sand, where a fraction (finer sands) was transported by the currents.

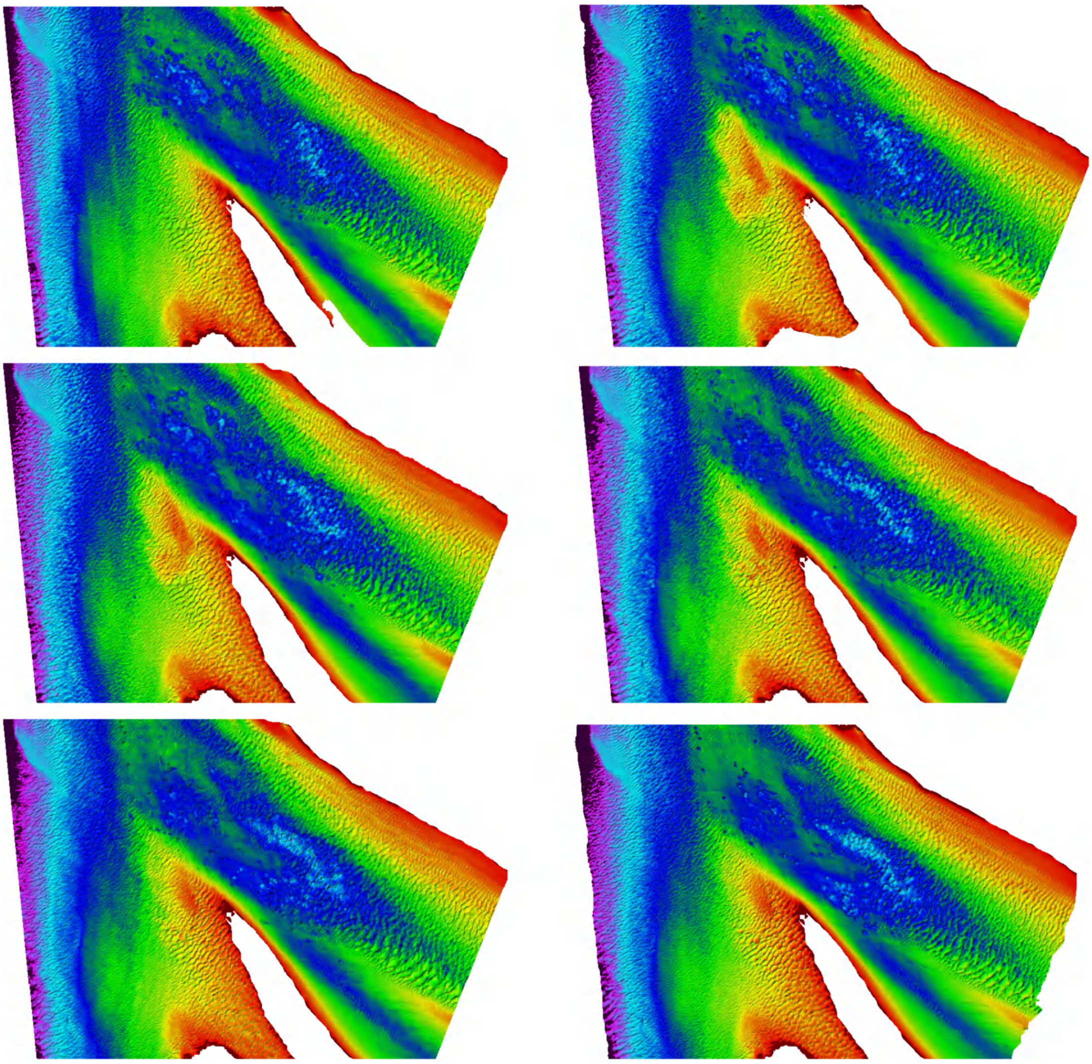

Fig. 12. Evolution of bathymetry [November–December 2004 (top); March-June 2005 (mid); September–December 2005 (down)].

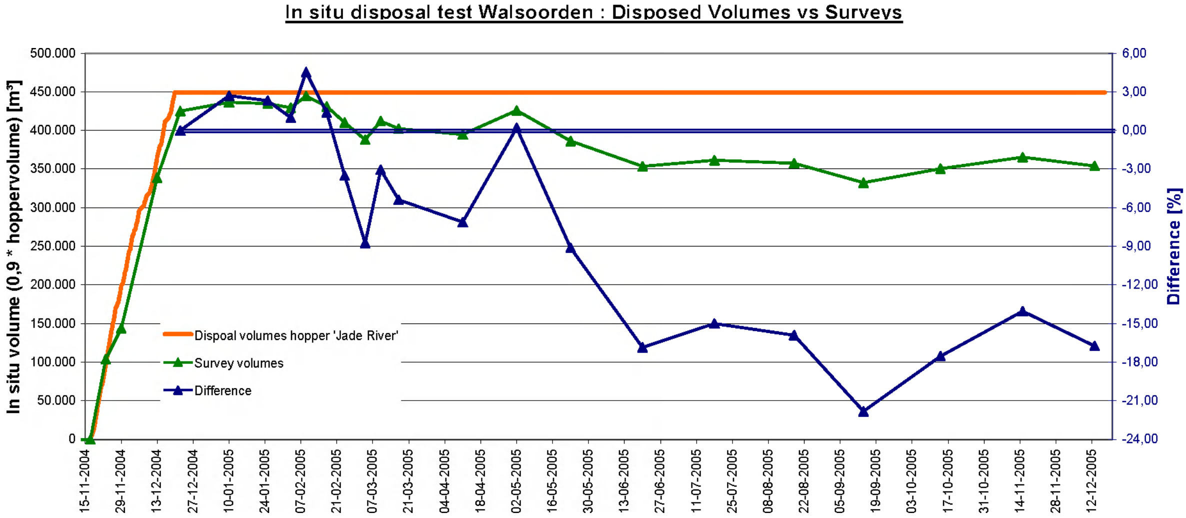

Fig. 13. Evolution of measured volumes.

During the first two months the volume within the control area was even higher than after execution of the test, probably due to natural processes. Afterwards a decrease of volume was measured, a loss of ~ 10% after six months, almost 20% after one year. The main part of the eroded sand is transported during flood towards the Walsoorden sandbar. This evolution is in agreement with the predictions of the feasibility study. Fig. 14 presents the evolution of a longitudinal section through the disposal area. The bedforms, present before the test (red), were flattened out by the disposal of the sediments with the diffuser (green). Immediately after the test, new bedforms started to develop in the disposal area, resulting in a new pattern (yellow) some three months after the test. After six months, the new bedforms are well developed (blue). Sediment is eroded from the down-estuary side (400-600m) of the disposal area and transported with the flood flow towards the up-estuary side (1000m). It may be concluded that the disposed sediments stay well in place, and the imposed criterion was successfully fulfilled.

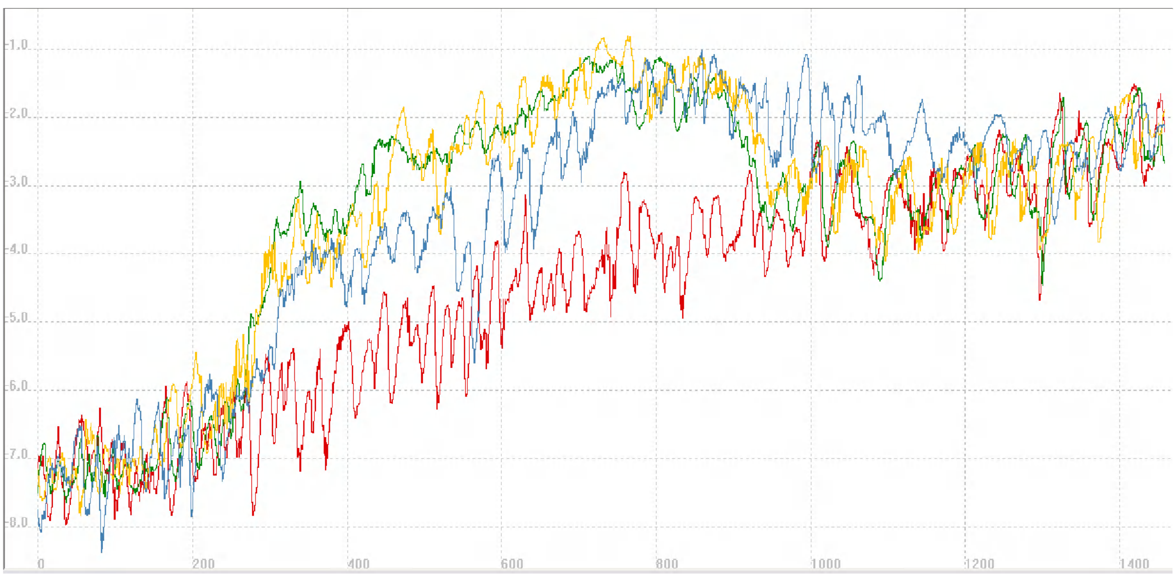

Fig. 14. Longitudinal profile through disposal area (red = November 2004; green = January 2005; yellow = March 2005; blue = June 2005).

Ecological monitoring

The ecological monitoring programme included both intertidal as subtidal measurements. Ecologists feared increased sedimentation, especially of coarser sediment on the sandbar, which could have a negative impact on its biotopes. The intertidal monitoring comprised of several stations on the Walsoorden sandbar where erosion-sedimentation, sediment composition and macrobenthos was measured. None of the results from this monitoring indicated that the *in situ* disposal test was responsible for a significant change in ongoing trends. The subtidal monitoring was focussed on sediment composition and macrobenthos samples, using the BACI-technique (Before-After-Control-Impact). Beside the disposal area (yellow area on Fig. 16), two control areas were chosen: one at the traditional disposal site 'Schaar van Waarde' (green area), the other (red area) where no influence from disposal activities should be expected.

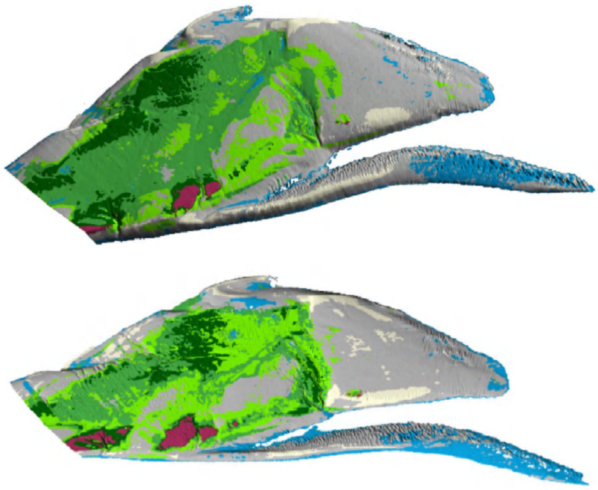

Fig. 15. Remote sensing image Walsoorden sandbar (top: 2004; bottom: 2005).

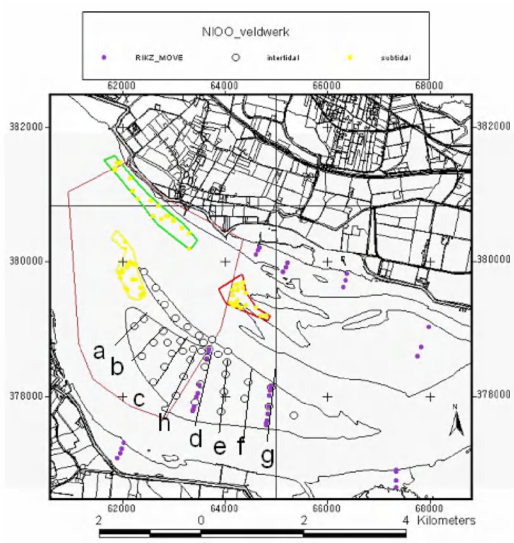

Fig. 16. Sampling stations ecological monitoring programme.

For the subtidal samples an increase in grain size was found for the impact area. This is explained by the coarser sediment (d50 ~ 250μm) that was disposed compared to the local sediment (d50 ~ 200μm) before the test. The macrobenthos samples did not show deterioration (biomass, diversity and density) for the impact area compared to the two other control areas. It should be noticed that the quality of macrobenthos samples in the subtidal areas was significantly worse than to the intertidal macrobenthos samples. Summarizing: no significant negative ecological impact could yet be detected from the *in situ* disposal test near the Walsoorden sandbar.

Tracer experiment

A sediment tracer test was executed to get an idea of the sediment transport patterns. The tracer material was an industrial glass-granulate (SiO_2) whereto 0.05 weight percent of IrO_2 was added in melted state. After cooling down, the mixture was grinded to obtain a grain size comparable to that of the disposed sediments (~ 250μm). Afterwards a fluorescent coating was added. In total 500kg of tracer material was prepared. The fluorescence allows already a first indication of available tracer material in the samples taken in the field. Afterwards the positive samples are activated in the laboratory so that the concentration of tracer material can be determined. A first tracer experiment was executed in February 2005 with 500kg of tracer material. The material, packed in small containers (50kg each), was lowered down to 0.50m above the bottom during slack where they were opened. Five sampling campaigns were planned, using the Van Veen grab to collect approximately 50 samples during each campaign. The first samples did not contain any tracer material. Possible explanations could be either that bedforms covered the tracer or that the tracer material was too fine and dispersed during a storm in the weeks after the injection. A second campaign using vibro-core sampling technique did not produce better results. Therefore a new injection was executed in September 2005. This time the tracer material (500kg) was mixed in advance with 500kg sand with grain size comparable to the deposited sediments. The injection was executed by a diver, who placed the sediments onto the bottom. A first sampling campaign, the day after the injection, revealed some transport of the tracer material in up-estuary direction (Fig. 17). In a second campaign tracer material was found in several points of the sampling grid (Fig. 18). The highest concentrations were found near the injection point, with the predominant transport indicating mainly an up-estuary movement towards the sandbar. In a third sampling campaign (November 2005), no significant concentrations of tracer material were found. The question remains why no concentrations were found. This may sustain the hypothesis of bedforms covering up the tracer material. Despite the limited recovery of tracer material, the initial results confirm the trends from the bathymetric surveys: the disposed material that is eroded, is transported in the up-estuary direction towards the sandbar.

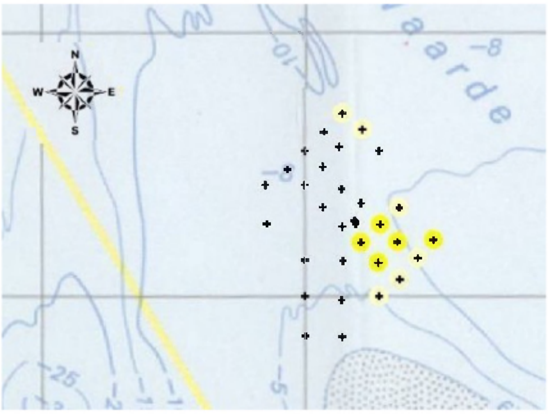

Fig. 17. Tracer concentration one day after injection.

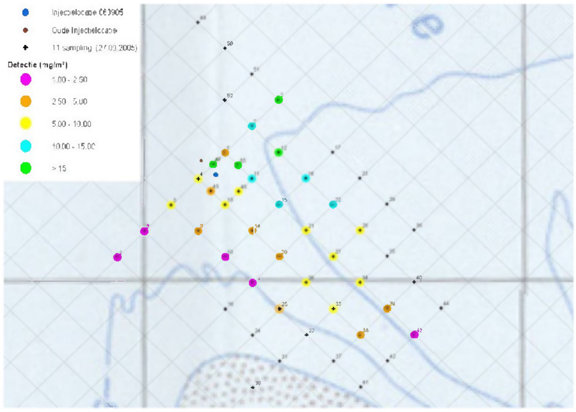

Fig. 18. Tracer concentration one month after injection.

Monitoring of flow and sediment transport

Sediment transport and flow velocity were measured during a full tidal cycle in several stations near the Walsoorden sandbar. A first campaign was conducted in June 2003, before the disposal test, with three stations (1, 2, 3) down-estuary from the Walsoorden sandbar. In September 2004, a second campaign was realized, also in three locations: station 2, the proposed disposal area and stations 4 and 5, both control points (places that could be influenced by the disposal test, one on each side of the bifurcation produced by the sandbar). These two control points were also measured during (December 2004) and after (May 2005) the execution of the disposal test. Velocities were measured using acoustic techniques (Aanderaa), while sediment transport was measured with the Delft Bottle, on a frame for near bed transport, suspended on several depths for suspension transport. This sediment trapping has the benefit that larger sediment samples can be collected over a longer sampling time, producing a good average transport rate and sufficient sediment to be analysed afterwards on grain size.

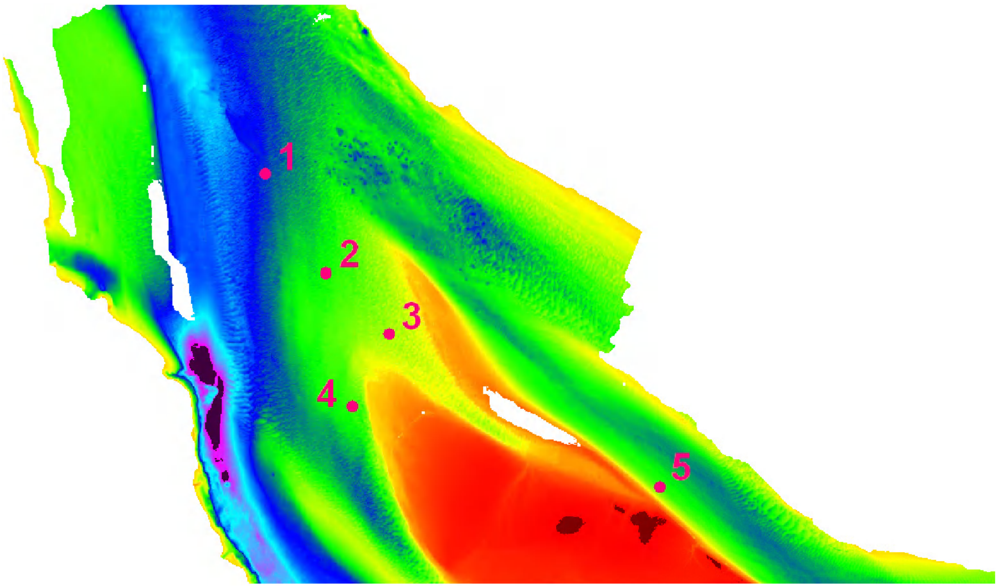

Fig. 19. Sediment transport and flow velocity measurement locations.

The results of the sediment transport measurements (Flanders Hydraulics Research, 2006) show no significant changes in the two control points. The pattern for these two locations is different. For point 4 the main sediment transport takes place from HW-2h to HW. During the ebb period only limited sediment transport was found. For point 5 there is a first peak near the end of the flood (cf. point 4), but at the start of the ebb strong sediment transport was measured. Despite being situated in the so-called flood channel, strong ebb currents occur in this channel. For the other points (1 to 4) the Walsoorden sandbar creates a 'shadow zone' for the ebb flow, with limited velocities and therefore limited sediment transport during the ebb.

Conclusions* in situ *disposal test

From morphological point of view, it can be concluded that the experiment using a diffuser for modifying the morphology of the sandbar by disposing precisely dredged material was very successful. The ecological monitoring did not reveal any significant negative impact, neither in the intertidal areas, nor in the subtidal areas. This *in situ* test confirmed the feasibility of the proposed disposal strategy. A second disposal started at the beginning of 2006, however not with the diffuser technique but with the commonly used disposal technique. An estimated volume of 4 to 5 million m^3 could be disposed here to reach the proposed objectives, representing more than half of the volume dredged yearly in the Western Scheldt.

Conclusion and recommendations

For a long time dredging operations have been considered as producing only negative impacts on the environment. Flanders Hydraulics Research (at that time the Belgian National Laboratory) had acquired experience in using dredging for influencing morphological evolutions in the Congo river, improving the accessibility of the maritime ports. This experience was used on the

Scheldt Estuary. The Western Scheldt is one of the last relatively natural estuaries with a dynamic multi-channel system and exceptionally valuable eco-systems. A management with broader objectives that include accessibility, safety and nature preservation progressively replaces the past management of the maritime access route to the Port of Antwerp, which was based almost exclusively on an engineering approach. In 2001 an international expert team appointed by the Port of Antwerp authorities, set forward new ideas about the morphological management of the estuary by using dredging and disposal of dredged material to steer the morphological behaviour of the estuarine multi-channel system.

As a pilot project, to demonstrate this new disposal strategy, the location at the sandbar of Walsoorden was selected by the Port of Antwerp Expert Team on the basis of expertise. The western tip of the Walsoorden plate has been eroded since decades. Reshaping the tip of this sandbar by morphological dredging might improve the self-dredging capacity of the crossing of Hansweert, reducing finally the dredging effort. The feasibility of this project was studied by Flanders Hydraulics Research, combining desk studies, scale modelling, numerical modelling and field surveys. None of the results of this extensive study opposed the feasibility of the proposed disposal strategy at the Walsoorden sand bar.

To finally prove the proposed disposal strategy, an *in situ* disposal test was conducted. At the end of 2004, 500,000m^3 of sand was disposed at the seaward tip of the Walsoorden sandbar. The experiment was intensively monitored, both on morphology as on ecology. More than one year after completion of this test, it can be concluded that a new morphological dredging and disposal strategy could be successfully embedded in the future morphological management of the Western Scheldt. However, as stated by the Port of Antwerp Expert Team, the new ways of dredging and disposing sediments should be combined with other measures, such as adapting the hard bordering of the estuary and finding alternatives to the traditional protection works of banks and shoals.

The Walsoorden experiment also confirmed the need for building the capacity of the professionals in morphological assessment techniques, giving sufficient room to expertise and visual analysis of charts, maps and remote sensing observations. A further collaboration between engineers, biologists and ecologists is needed to develop further the idea of morphological dredging and the strategies to manage the morphology of estuarine systems.

Acknowledgement

The research presented was conducted through a close collaboration between Flanders Hydraulics Research and the Port of Antwerp Authority, partly as a project under the Dutch-Flemish ProSes direction. It was funded by ProSes and by the Flemish Ministry of Environment and Infrastructure. Surveys were organised with the collaboration of the Flemish Administration of Maritime Access, the Dutch Rijkswaterstaat and the contractors. The authors acknowledge the effective support of the Port of Antwerp Authority, which funded the expert team, also the participation of the other members of the Port of Antwerp expert team, Reginald Parker from the UK, Jean Cunge from France, Bob Meade and Michael Stevens from USA.

Related websites

DELFT3D-software: http://www.wldelft.nl/soft/d3d/intro/index.html
MOVE-programme: http://www.scheldenet.nl/ (MOVE)
PROSES: http://www.proses.nl/
SIMONA-software: http://www.minvenw.nl/rws/rikz/projecten/simona/index.html

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NEW DEVELOPMENTS IN (LOCAL) MARINE METEOROLOGY

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Weather at sea is an essential boundary condition for safe navigation. Therefore, forecasting the weather state at sea delivers a strategic benefit. The air-sea interaction makes this forecasting more complicated. Marine meteorological forecasting not only encloses wind, visibility, precipitation, temperature, but also waves and tides.

The Flemish coastal zone is characterized by a complex of sandbanks influencing waves and currents. The shipping channels leading to the port of Zeebrugge, the port of Ostend and the Western Scheldt, the access-river to the port of Antwerp, have a limited depth. Deep draught vessels have to use tidal windows. To provide the nautical authorities with accurate marine meteorological forecasts, in order to optimize vessel traffic, a 'Hydro-Meteo System' was set up.

For the production of these forecasts the actual meteorological situation and state of the sea has to be known. Therefore the monitoring network 'Vlaamse Banken' was installed. The monitoring network consists of measuring platforms, wave-measuring buoys, tidal stations along the coast and a meteopark at the port of Zeebrugge.

The Oceanographic Meteorological Service (OMS) is the marine meteorological forecast centre. A highly skilled team of marine meteorologists produces several forecasts a day concerning wind, visibility, wave-sea, swell, tides and general atmospheric conditions for the coastal zone and the shipping channels.

The marine meteorological forecasts, also called hydro-meteo forecasts, are distributed to dedicated users (division Vessel Traffic Assistance, DAB Pilotage, DAB Fleet, Port Authorities, the storm-warning service of the division Coast, …).

MRCC OOSTENDE: NEW TECHNOLOGIES FOR A SAFER NORTH SEA

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Abstract

On 1 June 2006, a new Maritime Rescue Coordination Centre (MRCC) will be commissioned by the Shipping Assistance Division of the Ministry of the Flemish Community, offering a state-of-the-art and integrated platform for Vessel Traffic Monitoring, Incident Management and Search & Rescue functionalities to ensure safety and to coordinate rescue actions at sea. This paper gives a preview of the advanced Traffic Monitoring functionalities as they will be available in the MRCC.

Introduction

The challenge to monitor and guarantee the safety and efficiency of shipping at sea, requires a continuous effort from maritime authorities and coastguard organisations. Dramatic accidents like on 13 December 2005 the capsizing of the fishing boat Z.122 Noordster in British waters, always remember us that efficient deployment and quick coordination of rescue actions at sea are of vital importance. The recent incident with the Panamese container vessel MSC Eleni and the RoRo vessel Kaduna in front of the Flemish coast on 23 May 2005, again draws the attention of governmental maritime administrations and authorities to their responsibilities. These responsibilities to constantly guarantee and monitor the safety at sea, require a continuous improving and investing in the best available technologies.

Existing radar and traffic information systems, procedures and working methods as available in VTS or MRCC coastal monitoring centres are being challenged with new technologies like the introduction of AIS, the information exchange with the European maritime information network SafeSeaNet, and the adoption of new ICT technologies and software tools. Furthermore, existing infrastructure has to be constantly renewed and new technology should always call for new opportunities. From the legal aspect as well, new regulations, recommendations and directives from both an international level (IALA & IMO) and a European level (EC) offer new perspectives and have implications on the VTS and MRCC operating procedures and systems.

Moreover, the amount and complexity of new activities a maritime administration is being challenged with in the coastal zones, is constantly increasing. These new activities include safety monitoring, risk assessment, coastal zone management, trans-national information exchange, etc. As well, special attention must be given to the monitoring of ships and navigation in the vicinity of windfarm areas in construction or in exploitation. Safety issues related to shipping routes alongside these constructions are a major issue for maritime authorities: the VTS and MRCC traffic monitoring systems will play an essential role to perform this task.

This paper gives a practical demonstration on how the challenges mentioned above are being tackled within the organisation of a MRCC (Maritime Rescue Coordination Centre). A renewed MRCC will be commissioned in Oostende (Belgium) in June 2006. This state-of-the-art MRCC will be linked to and will be exchanging information with maritime authorities (port and VTS authorities, the EC/EMSA,…) or with other partners in the Belgian Coastguard Organisation.

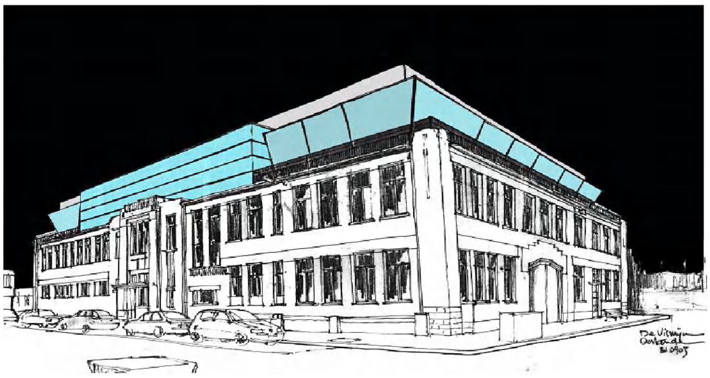

Fig. 1. MRCC Oostende.

MRCC Oostende system overview

The major task of a MRCC is to coordinate Maritime Search and Rescue Operations within the Belgian SAR zone (geograhically identical to the EEZ zone). This task involves search and rescue of human life at the sea and the tasks related to combating sea pollution, and results from International Conventions such as the International Convention on Maritime Search and Rescue established in Hamburg on April 27, 1979 (The SAR Convention) such as:

- constant readiness to immediate search and rescue action;
- preparation of search action plans;
- co-ordination of the SAR operations;
- cooperation with foreign SAR services;
- cooperation during the SAR service with other organisations such as all other partners within the Belgian Coastguard organisation.

Therefore a MRCC system comprises three main applications which are relying on the exchange of data and information as shown in Fig. 2.

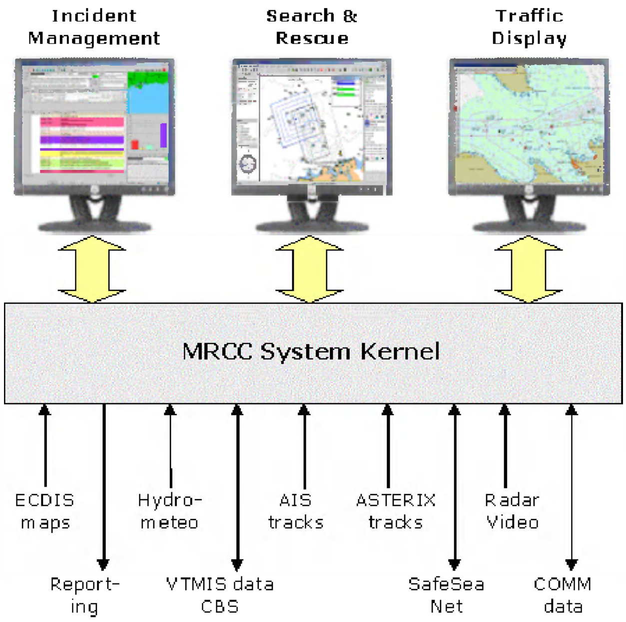

Fig. 2. MRCC software architecture.

Incident Management System (IMS)

The IMS system supports and enhances all operational activities in an Emergency Control Room like a Maritime Rescue Coordination Center (MRCC). It helps to manage the core tasks of communications, resource deployment and incident management such as:

- call logging and history;
- incident recording;
- resource deployment and monitoring;
- incident management;
- information and message handling.

The integration will be achieved through the use of some of the latest developments in IT including Voice over IP, CTI (Computer Telephony Integration) and spatial databases.

The IMS uses a Graphical User Interface (GUI) and includes a scrolling window, a hot key, a radio log, message catalogue addressee list, incident log presentation and mapping. Many of the message input forms (including the incident logging form, broadcasts, standard incident messages) are user-designed and hence can be laid out as required. These forms are created/updated using tools provided in the IMS system. This facility will allow a MRCC to collect and present information in exactly the format as required.

'Action Plans' can be compiled through the system. These action plans can then be called up to provide guidance and an audit trail throughout the running of an incident. The action plans as prepared for the MRCC, will be covering all SAR actions and MRCC communication flows with other partners of the Belgian Coastguard organisation, as described in common procedures for cooperation between all different Belgian Coastguard partners and services.

Search and Rescue System (SAR)

The Search and Rescue Information System is a software tool concerned with the accurate determination of search areas for lost people, vessels and objects at sea together with allocation of SAR resources to systematically searching those areas. It is compliant with the UK Coastguard CG3 methodology used by many organisations throughout the world, including NATO.

The SAR planning tool application is summarised in the following features list:

- SAR Model Configuration
- SAR Visualisation
    - Model Output and Reporting
    - SAR Target Probability of Detection (POD)
    - 'drag and drop' allocation of SAR resources to search areas
    - Pre-configured databases of SAR targets and SAR resources
    - Graphical manipulation of search areas
    - Automatic re-calculation of SAR information
- Integrated GIS
- Current Flow Data Visualisation

MRCC – Integration of applications

The integration of the various MRCC applications is being managed by an integrated VTS/ECDIS application. The Traffic Monitoring display is interfacing to the SAR application to integrate search areas, patterns and target objects for the support of SAR operations, calamities and the follow-up of daily tasks. The necessary SAR information is transferred and visualized by the VTS/ECDIS application. The integration is mainly done by exchanging application specific information such as search areas or incident states. The core integration is done by the VTS/ECDIS application which is also responsible to serve the web-based access with the integrated information. Map data (S57) is used in all three applications.

Advanced radar detection tools

The radar information, which is available in the MRCC, could be used for other applications useful for other coastguard or maritime partners. An example is the possibility to detect oil spills on the water-level, currents and wave directions of the sea level, or even the topography of the sea bottom. Based on the systems and radar information available in the new MRCC, tests will be carried out at the end of 2006 to investigate the technological possibilities to provide additional information that could be of value to other maritime partners or coastguard partners.
Early detection and recovery of the oil spill is one possible future example of this advanced radar software technology. Detection and combating sea pollution is very important as public awareness is high after several accidents with oil vessels in the near past. Therefore, efficient oil spill detection during day and night conditions, based on existing VTS and MRCC systems could be an asset for the coastguard organisation in the future, as an additional source of information, complementary to the already available technologies or procedures for oil slick detection. Combined with information about current predictions this would greatly help to coordinate respective actions.

These radar software technologies increase efficiency and safety at sea and on board. Illegal oil spills can be detected through existing VTS radar infrastructures. The conditions of an incident, like currents, sea bottom topography, water level, etc. can be reconstructed because raw radar data can be stored and made available. In man over board situations, a search and rescue operation can be more efficient because current vectors can be measured, providing an accurate prediction of water movement in time, allowing accurate determination of the position of the person.

Integration of this radar software processing tools in an existing MRCC system, could be of added-value to provide more information to other coastguard partners.

Windfarm risk assessment and decision-making tools

The real-time traffic image of the North Sea as available in the MRCC, together with chart information of activities in specific zones of the Belgian EEZ zone, offers opportunities to add extra software tools for management-level decision-making tools in case of incident management, action plan assessment or incident investigation.

Specifically for the risk assessment, planning and coordination of vessel manoeuvering or rescue actions in the vicinity of a windfarm area, a software tool Rembrandt is foreseen in the new MRCC.

'Rembrandt' is a real- and fast-time ship-handling and manoeuvring simulator. It is principally designed for the following applications:
- manoeuvre rehearsal;
- ship performance and operational assessments;
- assessment of port arrangements (berths, channels, etc.);

- assessment of tug requirements;
- ship-handling training;
- incident investigations.

This tool will be used in the risk assessment of ship manoeuvering and rescue operations within or in the vicinity of windfarm areas in the Belgian North Sea, and will be integrated as extra functionality onto the MRCC software platform.

Maritime communication platform

Apart from the advanced Traffic Monitoring functionalities, the MRCC will be equipped with a state-of-the-art Maritime Communication platform from Frequentis. This fault tolerant and fully digital platform will be integrated with external information sources such as DSC (Digital Selective Calling) calls and Navtex messages in order to guarantee maximum safety at sea. This communication platform offers an easy-to-use and integrated touch-screen user application to the MRCC operator, allowing quick communication in case of incidents or rescue actions.

Conclusions

MRCC Oostende technologies

The renewal of the MRCC Oostende was awarded after a European tender procedure to a multi-disciplinary consortium formed by the companies Barco, Fabricom GTI and Tein Telecom. The new MRCC will be commissioned on 1 June 2006 by the Shipping Assistance Division of the Ministry of the Flemish Community and will replace the current monitoring system to become an integrated, state-of-the-art rescue and co-ordination centre.

The MRCC Oostende traffic monitoring technologies and systems integrate an advanced version of VTS systems (OPScenter VTS from Barco, Belgium) with an Incident Management System (VISION from Fortek Ltd., UK) and a Search & Rescue module (SARIS from BMT Renewables Ltd., UK).

With the new system, operators will be able to display traffic data from different external sensor sites. The MRCC system solution includes the integration of data from an existing AIS network, information from existing hydrological and meteorological measuring systems and databases, voice communication facilities, combined radar video, track and voice recording and replay functionalities, information exchange on regional level with Port and VTS authorities (Central Broker System), information exchange on European level using the SafeSeaNet (SSN) network, and allows browser-based access to an integrated traffic image and SAR incident logging for coastguard partners.

If there is an incident, the MRCC can rely on a lean, reliable and state-of-the-art solution, which fully supports all port control and maritime rescue activities and fulfils the role of a National Competent Authority (NCA) within the European context of SafeSeaNet. In this way, the MRCC Oostende will be able to comply with all obligations as set out in the EU Monitoring Directive (2002/59) and as followed up by the European Maritime Safety Agency (EMSA).

Along with its role as rescue coordination center, the new MRCC will also provide a separate incident management crisis meeting room and press information center. For this purpose, a large-scale high-resolution videowall is foreseen in the crisis meeting room, providing 24/7 operational capability with multiple inputs and adjustable screen layout functionalities. Videoconferencing functionalities as well are foreseen in this crisis meeting room to allow all members of a MRCC crisis meeting in Oostende to communicate with other essential partners in the Belgian Coastguard Organisation, from which the Navy base in Zeebrugge and the national Rescue Coordination Centre in Brussels are two major key partners alongside the MRCC.

Future vision

Advanced Traffic Monitoring solutions today are no longer stand-alone systems reserved for major ports, waterways and maritime authorities, but are becoming increasingly significant for maritime rescue coordination and incident management. Integrated traffic management systems and solutions will more and more have to offer a high-performance and highly reliable maritime service to other maritime partners or customers based on the gathered and consolidated information. This is especially the case for an MRCC in the coordinating service it has to offer to quickly and adequately inform other Coastguard partners in case of an incident or rescue action, enabling them to perform their tasks and responsibilities as efficiently as possible.

Traffic Management solutions should focus on integrating traffic management with rescue coordination services and external information sources and databases supporting a common-operational-picture visualization for ports, waterways, coastal and maritime safety and security. The nature of maritime crisis management means that different authorities or organisations, like all coastguard partners, search and rescue or safety-related authorities, emergency response services, security-related or anti-terrorist authorities, port authorities,... are dispersed in virtual organisations. All partners and authorities work together (e.g. in the Belgian Coastguard organisation) to look at situations, assess the risks, identify potentially critical situations that may develop into crises, develop strategies for avoidance, mitigation or aid, plan for these and then implement.

Continuous re-planning and updating based on integrated information support is essential as the situation changes. For this purpose, all information data as captured and consolidated in the MRCC, will be made available to partners on an operational level, to ensure a high degree of group awareness of how the situation is managed in order to support timely, accurate and effective decisions to be taken by each partner throughout critical situations.

Next generation of integrated solutions

In the future an integrated solution should not just cover the integration at the presentation level but also at the database level. This will allow integration of a large range of data sources, real-time information and models. These simulation & training tools will support the persons behind the systems (not only persons on the operator-level, but also on the managerial or decision-making level) by helping to compliment their experience and knowledge in the best way.

Functionality	Name	Forecast timeframe						Example maritime use
		History	Real time	Hours	Days	Weeks	Years	
Vessel Traffic Services	**VTS**	X	X	X				Collision avoidance
Automatic Identification Systems	**AIS**	X	X	X				Ship and cargo identification
Incident Management	**VISION**	X	X	X				Incident response
Search and Rescue Planning	**SARIS**		X	X	X			Search and rescue response
Oil Spill Information	**OSIS**			X	X	X		Oil spill dispersal response
Traffic Simulation and Forecasting	**Rembrandt**			X	X	X	X	Long term growth in traffic and collision risk
Search and Rescue Resource Planning	**SRMD**						X	Long term need for search and rescue resources

Fig. 3. Integrated traffic monitoring solutions and functionalities.

A true surveillance environment as such in a Maritime Rescue Coordination Center (MRCC) is designed to provide a real-time collaborative work environment for monitoring, response dispatching/co-ordination, access/flow control, recording and overall systems control for 24/7 operations.

The MRCC Oostende is offering a highly advanced and integrated system platform, supporting state-of-the-art vessel traffic monitoring, incident management and search and rescue functionalities, and is ready to cope with the challenges of the future.

BRIDGING THE GAP BETWEEN KNOWLEDGE CREATION AND PRACTICAL IMPLEMENTATION IN MULTIMODAL TRANSPORT – VIL AS MATCH MAKER

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Abstract (Dutch)

De brug slaan tussen kenniscreatie en praktische implementatie in multimodaal achterlandvervoer. De brug slaan tussen theorie en praktijk vormt steeds een grote uitdaging. Het Vlaams Instituut voor de Logistiek (VIL) heeft deze missie op het vlak van logistiek. Het VIL wil de logistieke sector in Vlaanderen duurzaam ondersteunen en versterken in haar competitiviteit. Het wil een platform zijn met concrete antwoorden op relevante logistieke vraagstukken. Zo wil het VIL de brugfunctie vervullen tussen enerzijds de kennis die gecreëerd wordt aan de traditionele kennisinstellingen, zoals universiteiten of hogescholen, en anderzijds de concrete problematiek die zich stelt in het werkveld. Het VIL wil uitgroeien tot een centrum dat logistieke kennis opbouwt, verzamelt en verspreidt. Het innoveert en moedigt innovatie aan. Het stuwt de promotie van de Vlaamse logistiek en van de logistiek in Vlaanderen. Het VIL is voortdurend op zoek naar instrumenten om theorie te vertalen naar de praktijk. Dat kan via een toegankelijk rapport (VIL-Series), een handleiding (bvb. om de meest geschikte modal split te achterhalen), een stappenplan (bvb. om een samenwerking onder logistieke dienstverleners op te zetten),… maar ook via best practices. Via verspreiding van deze testimonials kunnen logistieke actoren warm gemaakt worden voor bepaalde logistieke concepten. Zo kan bijvoorbeeld een multimodale ontsluiting van een haven gepromoot worden. Er wordt een kloof waargenomen tussen vraag en aanbod in de vervoermarkt. Een afstemming tussen vraag en aanbod is nodig voor een goed afgewogen modaliteitskeuze. Verladers nemen nog te vaak beslissingen op basis van een incompleet of gekleurd beeld van de beschikbare dienstverlening van de verschillende modaliteiten. Daarnaast hebben vervoerders en transportoperatoren te weinig voeling met de verzuchtingen van de verladende sector. In de paper wordt ingegaan op de methodiek die het VIL hanteert om de brug te slaan tussen vaak uit elkaar gegroeide werkvelden.

Abstract (English)

The Flanders Institute for Logistics (VIL) is continuously searching for opportunities to bring together the various logistics actors. The main role of the VIL is often the one of match-maker. A match should be made between transport demand and supply, between users and providers of transport. Knowledge and experience about the different transport modes has to be distributed towards potential users. Transport providers, on their side, should be given insight in the shippers' requirements. Through best practices and a manual elaborated in the field of multimodal transport one supports this matching goal. A match should also be looked for between on one hand the ports with their maritime activities (i.e. loading and unloading sea vessels) and on the other hand customers in the hinterland searching for appropriate connections with the ports. Several improvements can be worked on. Often one of the most critical success factors seems to be the ability to bring together the right players. The VIL, as a neutral party, has often a facilitating or coordinating role in collaboration projects. Finally one should match the academicians with the practitioners. There often seems to be a knowledge gap between these two different worlds. The Flanders Institute for Logistics (VIL) has the mission to develop and to apply several tools in order to bridge these various gaps.

Introduction

The Flanders Institute for Logistics (VIL) started in May 2003 and was an initiative of a few logistics service providers with financial support from the Flemish government. It immediately filled a gap.

Flanders takes a prominent place in the logistics environment of Europe. That position is gained by this region through its prime location, dense and integrated multimodal transport infrastructure and its well trained, multilingual and productive employees. Foreign investors discover in Flanders an ideal location for a European Distribution Centre, as is confirmed by the European Distribution Report of Cushman & Wakefield Healey & Baker (2004).

Since the above-mentioned advantages are of a temporary nature and in order to maintain and improve its position, the logistics sector in Flanders has to innovate continuously. Moreover, sufficient attention has to be given to value added activities and innovative concepts and technologies that can anchor and further strengthen the logistics future of Flanders. Creating, spreading and encouraging innovation for logistics belongs to the main task of the Flanders Institute for Logistics (VIL).

The logistics sector in Flanders has to fulfil an important role in the global, fast changing logistics market. This means that Flanders needs to have a platform to permanently unite the three interested parties involved, namely the companies in the logistics sector, the Flemish institutions of knowledge (e.g. universities) and the Flemish government. The intense cooperation between companies with logistics activities, researchers and experts, and the government, is the best guarantee to realise continuous improvement in the Flemish logistics sector, partially through technological and conceptual innovation, in order to develop Flanders as the 'logistics region of excellence' in Europe. To materialise this cooperation and as a consequence to bridge the gap between the different logistics actors, the VIL has a task as knowledge base. It has to formulate specific answers to relevant questions and issues in the Flemish logistics sector.

In this paper first the research methodology of the VIL is explained. The different knowledge pillars and research levels are presented. Further the paper focuses on multimodal transport and its challenges. Looking for appropriate tools in order to match supply and demand in transport is one of these challenges. Another is matching the port community with the logistics actors in the port hinterland through efficient hinterland connections. Finally some promising innovative concepts are presented and the role of the VIL here in.

Research methodology

Knowledge development of the VIL is structured in two dimensions. In the first dimension there are four pillars, that make a first division of the various research projects. Of these four pillars there are three knowledge pillars (Multimodal Transport, Value added concepts and Technologies, Partnerships) and one supporting pillar (Benchmarking of Flanders). In the pillar 'Benchmarking of Flanders' projects are set up to map logistics in Flanders quantitatively and qualitatively. For projects developed within the knowledge pillars, knowledge creation is the main goal as well as the support of the competitiveness of the logistics sector.

Within each of these knowledge pillars projects are set up when they meet predefined criteria such as the magnitude of the user basis, the innovative character and the support and interest from the sector. In this topic selection, criteria such as the clear identification of the target group, the contribution to the competitive position in Flanders and the strengthening of the image of logistics in Flanders are taken into consideration.

These projects can, in a second dimension, be divided according to research level. We can identify four types of projects:

1. Feasibility studies
2. Strategic projects
3. Pilot-projects in cooperation with companies
4. Contract research

Feasibility studies

A feasibility study (http://www.vil.be/en/standvzaken.htm) is the first introduction to a topic. It describes a current status of research and practice of this chosen topic. Different players, expertise and relevant work on this topic is mapped. Bottlenecks, opportunities and solid cases are listed. Existing patents and licences are verified. The throughput time of such study is generally four to six months. The findings of a feasibility study are collected and presented to the VIL members, with whom feedback sessions are organised.

With the feedback of the sector it is then decided if a strategic project is initiated. A feasibility study will always result in a publication, in most cases a VIL-series.

Strategic project

A strategic project (http://www.vil.be/en/strategischewg.htm) aims at an in-depth study of a (niche of) a research topic and the start-up of innovative knowledge in this domain. The taskforce, of which the project period can last up to 12 months and more, is divided into phases and presented to a steering committee. This steering committee, assembled from academic experts and logistics players, acts as a soundboard that follows up and steers the course of a project. The project is rounded up with an actual realisation in which the new concepts are applied.

Pilot-projects in cooperation with companies

Generic knowledge is developed within a strategic project. This knowledge, crystallized in a manual and a step-by-step plan, can be applied by a wide range of companies and industrial sectors. The VIL also wants to be active in a more specific context through counselling companies (clusters) in the practical development of the developed knowledge. In pilot projects the tools developed in strategic projects are used and further validated. Companies are willing to invest (financial) resources in the pilot. Practical results are translated by the VIL into generic lessons relevant for a broader target group.

Contract projects

A fourth type of project is contract research. This involves collaboration between (a group of) companies and the VIL as partners, whereby each party has input and the results are shared. Important is the social relevance of the project assignment, whereby the neutral and advising position of the VIL is essential. In this contract research the VIL will have a coordinating and supervising role and specific external expertise will be consolidated and integrated through consultants or knowledge centres. Breakthrough, innovation, neutrality and quality are kept high in these projects. The VIL was already involved in different contract research projects, e.g. BIAC (Airport Zaventem), CEPA (Head office for employers at the harbour of Antwerp) and the Administration of Customs and duties of the FOD Finance.

Multimodal transport

In this paper we focus on the VIL knowledge pillar Multimodal Transport. Often multimodal transport, considering the different modes of transport in transport decisions, is named one of the sustainable solutions for crucial mobility issues. Both public and private actors are looking for solid initiatives and innovations in this domain. The ultimate goal should be to use in an optimal way the available capacities of the transport networks (roads, rails, inland waterways, terminals,…). A well developed multimodal transport system is assessed as the critical success factor for the continuation and expansion of Flanders as logistics top region.

The VIL started mid 2004 with an exploration phase on the domain of multimodal transport. The goal of this exploration phase was mapping the bottlenecks and opportunities in multimodal transport. A modus neutral position is taken. Multimodal has the following meaning to the VIL: on the basis of sufficient knowledge of the various transport modes for the type goods concerned, choosing the most appropriate means of transport. This implies that a solution can be either uni-modal or intermodal.

In August 2004 an information meeting was organised where a wide group of actors was invited. The intent was to check the role of the VIL in this multimodal context. A steering committee for multimodal transport was formed that overlooks this knowledge pillar of the VIL and that is able to offer that feedback useful to validate the created knowledge on multimodal transport.

Via various, well-chosen in-depth interviews with 'prominent witnesses' this exploration phase was conducted.

The exploration phase brought about seven multimodal challenges**:**

1. Matching demand and supply in transport
2. Working on a fair market –a level playing field- for transport
3. Optimising hinterland connections for the ports
4. Revitalising rail traffic
5. Optimising the use of all available network capacity
6. Total logistics optimisation
7. Analysis of innovative transport concepts

The VIL is determined to follow up these seven themes. In order to guarantee the vigour of the VIL and a structural research approach in this knowledge pillar multimodal transport, one should focus on a limited number of topics. The following three priority projects were chosen**:**

1. Matching demand and supply in transport
2. Optimising hinterland connections for the ports
3. Analysis of innovative transport concepts

The first two projects are drawn in a generic research project (strategic project). The third one is research in various separate (pilot) projects.

Matching tools in the multimodal transport market

Introduction

Because of growing congestion problems and environmental and safety concerns in road transport, freight transportation becomes more and more a key issue in logistics in particular and in the whole industrial process in general. Nowadays a large majority of freight flows are going by road haulage. Multimodality is more and more presented as the option to deal with the above-mentioned transport problems. In a multimodal transport context the decision maker is able to consider different transport modes and to eventually choose the most appropriate solution. This can be a uni-modal or an intermodal one. An intermodal journey combines different transport modes with transhipment in between. Shippers often admit they have a lack of knowledge and experience about the different transport modes. On the other hand transport suppliers are not always aware of the specific requirements of the transport user. Often there appears a wide gap between transport demand and supply.

Listing matching opportunities

An abundance of matching tools are suggested in academic and funded project work environments. The step towards implementation and commercialisation is often either neglected or underestimated. The Flanders Institute for Logistics (VIL) has carried out a thorough analysis of the matching opportunities in the transport market. A clustering exercise resulted in an exhaustive and unambiguous list of matching opportunities, from creating awareness through information providing (e.g. promotion, best practices,…) to supporting decisions by means of various tools (simulation tools, route planners, communication platforms,…). Based on a SWOT analysis of the different opportunities a roadmap for further initiatives has been developed. This resulted in concrete tools for logistics decision makers. A manual describing the different steps in the modal split process in a user-friendly way is such a tool. It helps industrial actors to make mature multimodal decisions. Such a tool is developed, made available and promoted by VIL after an extended validation among logistics decision makers.

Industry relevance

Many logistics managers regularly face the choice between different transportation modes: road haulage, inland navigation, rail transport, short sea shipping, etc... The transportation mode choice is still often made in a rather irrational way. Recently this problem was merely a cost minimisation problem; cost was mainly understood as ‘out of pocket’ cost. The increasing pressure for fast delivery of small batches (cf. JIT), the possibility of direct and flexible access to the final customer (responsiveness) and various other reasons have favoured road transportation in the years past. Congestion, environmental damage, accidents and the threatening re-regulation make that industrial actors at least should examine the opportunities of alternative transport modes. Nowadays, one decides to apply alternative transport for spreading of risks. Logistics decision makers admit they often have not enough background to choose the most appropriate transport solution. They are searching for tools to support transport decisions in a multimodal context. It is part of the VIL mission to anticipate that need.

The VIL role

The VIL has the role of match maker in multimodal transport. Beside the developed manual supporting decision makers in their modal split decisions (see above), one has chosen for best practices or testimonials about a certain issue in multimodal transport. The aim is that logistics actors will learn something by reading these structured cases or will come to new insights. Perhaps this can help these logistics decision makers to realise a modal shift. At least they become aware of the opportunities of alternative transport concepts and in this way they get a mental shift. About 30 well-chosen best practices are offered on the VIL-website. Again, this is a way to decrease the gap between shippers and transport providers.

Optimising hinterland connections of Flemish ports

The developments in multimodal networks take place in a fast changing economic context with important logistics and maritime evolutions, that equally have an impact on the logistics organisation of the hinterland network. Ports are hereby mainly focussed on loading and unloading sea vessels. The strong increase of the total volume handled in the Flemish seaports, mainly under the impulse of the fast growing container traffic in the port of Antwerp, poses new demands to the multimodal hinterland connection. Hereby is recognized that smooth connections from the Flemish ports to the hinterland are crucial to safeguard the competitive position of these ports.

In this strategic project the VIL has focussed on the bottlenecks of hinterland connections and the requirements of users of these connections to ports. The first objective is to search for organizational aspects in a current existing infrastructural context with a final goal of optimal use of the capacity in the existing hinterland network across borders of the individual modes.
The following phases were completed:

Bottleneck analysis

Enumeration of bottlenecks through about 30 in-depth interviews with interested actors within the hinterland connections such as port authorities, forwarding agents, shipping companies, (inland) terminal operators, logistics service providers (LSPs) and shippers.

Best practices

Fifteen best practices according to a fixed structure were worked out. The cases describe mainly organizational but also technical improvements in the optimisation of hinterland connections.

Requirements analysis

The (logistics) requirements of transport applicants, primarily shippers but also LSPs and terminal operators, were mapped qualitatively through in-depth interviews. On the basis of the findings of these interviews, a survey was composed that ensured a quantitative check at the shippers' side.

Improvement projects

From the synthesis of bottlenecks and requirements of hinterland connections in combination with inventarised best practices, a long list of improvement opportunities was created, mainly focussing on market players. After evaluation on the basis of two criteria, the opportunity for success and the final effect on multimodal transport, six favourable improvements projects were selected whereby the role of the VIL was stated:

1. Set-up of a neutral multimodal information desk
2. Encouragement of collaboration within the multimodal transport chain actors
3. Stimulation of technological development and innovation in multimodal transport
4. Creation of a basis for increasing opening hours of seaport terminals
5. Improvement of the insight in total logistics costs
6. Study of opportunities in the development of an integrated multimodal network

In most of these improvement tracks the VIL again has a role of coordinator or facilitator. There is often lack of a neutral partner who is able to bring together the necessary actors and who is guarding a *level playing field* among the different players.

Transport innovation

The Flanders Institute for Logistics (VIL) has the objective to search for new opportunities and innovation in transport. Not only introducing new modes of transport, but also applying new concepts making use of existing transport modes is part of the VIL mission. Two examples are given here in order to illustrate the VIL innovative approach.

Transport of pallets through inland navigation

In the *Distrivaart* project (2002-2004) the opportunities were investigated to transport pallets with fast moving consumer goods via inland waterways. This innovative logistics concept was elaborated in the Netherlands. The concept is innovative in the sense that it is focused on non-traditional flows for inland navigation, i.e. neither bulk nor containers. Line services are offered for palletized goods wherein several vessels fulfil a fixed journey.

The objective is to attract palletized fast moving consumer goods (FMCG), with the aim to establish economies of scale and scope through collaboration. Retail organizations like Albert Heijn, Schuitema and Laurus and manufacturers like Heineken, Interbrew, Grolsch, Unilever, Coca Cola, and Kimberly-Clark participated in the pilot project. In the implementation phase both technical and economical problems appeared.

Nowadays, in Flanders a project has been started to explore the opportunities of a similar concept. A trade-off should be made between on one hand the ease to implement such pallet transport and on the other hand the economies of scale and network effects obtained by that concept. This study should result in concrete pilot projects implementing such innovative concepts in inland navigation. After the first phase collaboration among actors in construction materials seems to be promising in order to attain the necessary volumes. Again, the VIL can play the role of *consolidator*.

Barge shuttle

Congestion is not only a problem on roads, but also more and more in ports. Ports are trying to optimise the handling operations at the sea terminals. They are focused on loading and unloading the often huge sea vessels. Handling inland barges comes on the second place. One of the improvement options is trying to avoid the small call and drop sizes of the inland container barges in the port. A barge shuttle service might be useful for the collection and distribution of containers between the different sea terminals in the port or between different transhipment points in a certain region in the hinterland. As a result high volume line services can be organised between the port on one hand and the hinterland hubs on the other hand.

Nowadays, individual actors already offer such a service. Opportunities are examined in which several shippers use a common barge shuttle service. There are examples where a crane is connected on the vessel (e.g. the AMS crane-vessel in the port of Amsterdam). In the latter concept transhipment infrastructure can be avoided on the quays. The critical success factor as almost always is a high enough volume. Through collaboration one can consolidate freight flows and as a consequence a structured line service might be viable. The VIL is asked by some actors from the petrochemical sector to examine the opportunities in this field.

Conclusion

The Flanders Institute for Logistics (VIL) is continuously searching for opportunities to bring together the various logistics actors. The main role of the VIL is often the one of match-maker. A match should be made between transport demand and supply, between users and providers of transport. Knowledge and experience about the different transport modes has to be distributed towards potential users. Transport providers, on their side, should be given insight in the shippers' requirements. Through best practices and a manual elaborated in the field of multimodal transport one supports this matching goal. A match should also be looked for between on one hand the ports with their maritime activities (i.e. loading and unloading sea vessels) and on the other hand customers in the hinterland searching for appropriate connections with the ports. Several improvements can be worked on. Often one of the most critical success factors seems to be the ability to bring together the right players. The VIL as a neutral party has often a facilitating or coordinating role in collaboration projects. Finally one should match the academicians with the practitioners. There often seems to be a knowledge gap between these two different worlds. The Flanders Institute for Logistics (VIL) has the mission to develop and to apply several tools in order to bridge these various gaps.

THE USE OF DIGITAL MAPPING IN MARITIME AND COASTAL RELATED PROJECTS

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From GIS to map production

For more than 15 years, Aquaterra has been involved in projects related to digital mapping, cartography and photogrammetry. In these GIS-related activities the main effort was the production of geo-information and combining data of several GIS-formats (e.g. Esri, MapInfo, Intergraph, AutoCAD, etc.).

In the early nineties, Aquaterra developed the necessary know-how and software capabilities to bring GIS-data into the map-printing environment. At that time GIS-systems were used for map creation and screen display; output was limited to plotting or printing to computer connected peripherals.

Bringing the map results to a real cartographic layout and output was very difficult and nearly impossible. Offset printing could only be achieved through long and painful conversion of data or through some very expensive raster based products.

In 1987 the Apple-Macintosh computer was the first personal computer environment providing a solution for desktop publishing helped by Adobe's postscript language. This revolutionised the world of publishing and printing and would be the breakthrough for most of today's printing capabilities. Today no printing is possible without the use of a postscript RIP.

In desktop publishing, a RIP or Raster Image Processing is the process and the means of turning vector digital information such as a PostScript file into a high-resolution raster image. The RIP takes the digital information about fonts and graphics that describes the appearance of the file and translates it into an image composed of individual dots that the imaging device (or printer) can output.

The RIP is the translator between the computer data and the printer solution. In today's offset printing industry the graphic layout is no longer written to film but directly to the printing plates in the four CMYK color components.

Fifteen years ago this procedure was unthinkable; the printing of a GIS-based map was impossible without very dedicated file translation. It was in this domain that Aquaterra developed know-how and tools to bring GIS-data to postscript. Once the map conversion finished, they could go to offset printing and publishing.

Today a great variety of tools and procedures are needed to bring digital maps into the clients' approved layout and representation. Digital cartography requires a permanent research to satisfy the ever-increasing quality requirements and to maintain cost control.

Aquaterra has been involved in many map productions for a wide variety of projects in tourism, mobility, urban planning, environment, real estate, ecology, photogrammetry, etc.

In the maritime and coastal environment Aquaterra had the opportunity to do a number of mapping projects. In each of them different methods and production schemes were used. We will discuss a few examples based on our experience in these fields.

The Coastal Atlas of Belgium ('De Kustatlas')

The Atlas was initiated by the Coordination Cell for Coastal Management ('Coördinatiepunt voor Geïntegreerd Beheer van Kustgebieden').

It was aimed at bringing an inventory of the coastal aspects in areas such as:

- physical environment (hydrography, climate, tides and waves, etc.)
- nature
- tourism
- industry
- fishery
- culture
- architecture
- coastal defense and management

The Atlas was aimed at a large public distribution; in this way a great number of maps, graphics and tables should bring the many aspects of the coastal area to a clear overview.

The Atlas synthesizes the results of many researches and survey activities initiated by coastal and maritime organisations, universities, and government institutes.

Initial data for this project was provided in digital (photos, GIS-data, maps, graphics) as well as analogue (maps, reports, sheets, etc.) form. Some new maps had to be digitised and geo-referenced to combine them with other sources. Existing GIS-data needed reprojection to new map-projections for publishing.

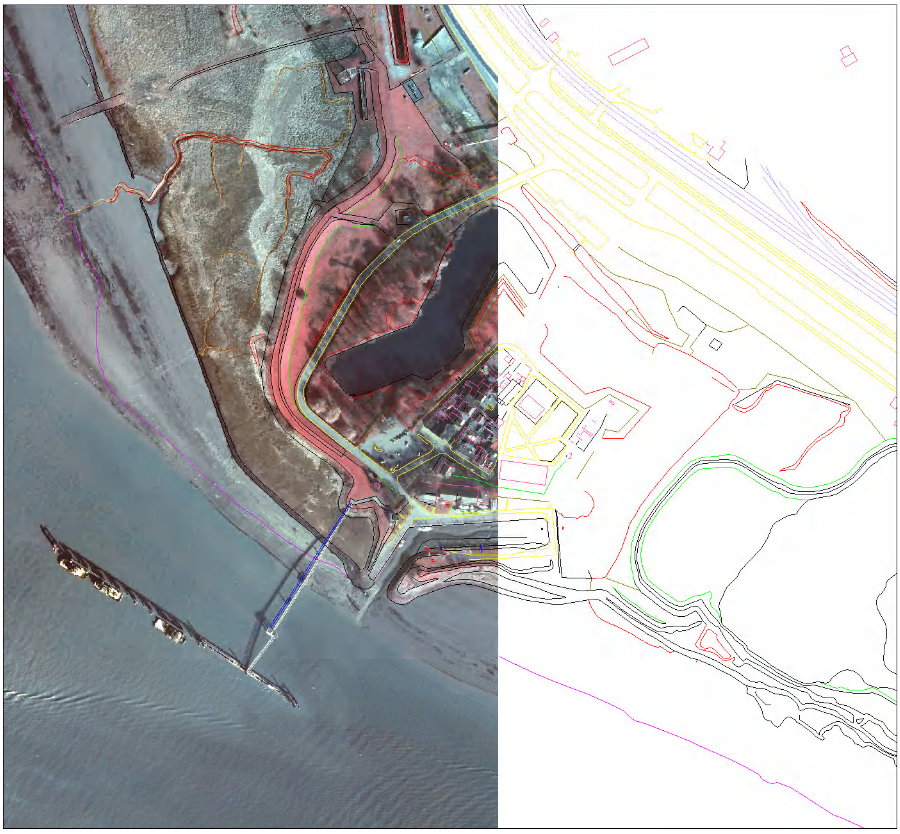
The overall layout as well as the layout for each chapter had to be discussed in detail. Each coastal field needed a specific approach to its content and characteristics. All maps and graphics had to be accompanied by text that was both synoptic and technically accurate.

The Atlas production was done fully digital and would also enable a web-version that was created afterwards. It proved to be a great success to the general public as well as the expert readers in these fields.

Mapping of the Schelde Estuary

In 2003 the Western Schelde Maritime Services (AWZ- Dienst Zeeschelde) needed monitoring the vegetation along the dikes, embankments and shoals of the Schelde River between the city of Gent and the Belgian-Dutch frontier; this also included the Rivers Durme and Rupel .

In order to monitor such vast tidal river embankment it was decided to create orthophotos of infrared aerial photography of the total river bank at different time intervals. Infrared (IR) photos allow a much better observation and differentiation of vegetation classes than (RGB) colour photos. Orthophotos are photomaps that allow accurate measurements and extraction of data on the images itself. A normal (aerial) photograph generates a conical projection of the image area and is only accurate near the photo-centre. 'Draping' the image over the terrain relief (or DTM) produces the orthos. Aerial photographs were taken at a (flight) scale of 1/5000 and on different time intervals (winter/summer) to observe vegetation changes.



Photogrammetric restitution of the stereo images (60/30% overlap) allowed the DTM creation. The digital processes needed a lot of data control in order to comply with quality criteria of both the DTM and the orthos. The orthos were subject to further radiometric corrections in order to make a homogeneous image representation of the river.

The result was an IR coverage of approximately 170km of riverbanks with photo-tiles of 1x1km and a ground resolution of 25cm per pixel image. The data was now used for vegetation mapping in a GIS-environment. Finally the images were combined into atlases of the whole River Schelde providing a practical working instrument for the government authorities.

Photo atlas of the Belgian coastline

The Belgian coastline is only 65km long but it represents a major economic factor and tourist attraction. With an average of more than 17 million tourists per year this small stretch of coastline has created a great variety of beach and recreation activities, hotel accommodation, restaurants and shopping areas. In summertime the beaches top more than 240.000 visitors per day!

The Belgian coast also generated an important real estate market; it varies from small apartments and holiday homes to very wealthy residential areas such as in Knokke-Zoute.
To visualise this important coastal area, Aquaterra decided to create an atlas of aerial photography covering the 65km of coastline from to beach up to 2km inland. This area really represents the major coastal residences and activities.

The photographs were taken with one of the first digital cameras for aerial photography. The high resolution digital photographs allowed the production of orthophotos with a ground resolution of 20cm/pixel.

An astonishing bird's-eye overview of the entire coastline was created in a page layout representing both 1x1km images and corresponding city maps.

The atlas also enabled the production of a virtual fly-over of the Belgian coast with some dedicated computer software. The great interest for this product by both private and local authorities as well as the coastal residents proved the necessity of such photographic inventory.

These projects were the result of synergy in different fields of digital mapping technologies.

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C-POWER NV – PERSPECTIVES FOR OFFSHORE WIND ENERGY

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C-Power is the sole fully authorised offshore wind farm in front of the Belgian coast. C-Power obtained all permits required for the construction of this wind farm, being the concession permit, the building and environmental permit, the offshore cable permit, the onshore cable permit and the grid connection permit.

The project consists out of 60 turbines of 3.6 up to 5MW on the Thornton sandbank, 27km in front of the Belgian coast. Water depths are ranging from 12 to 24.5 meters. The permits compel the project to start with a Demonstration Phase, consisting of: six turbines in water depths ranging from 15.5 to 22.5m.

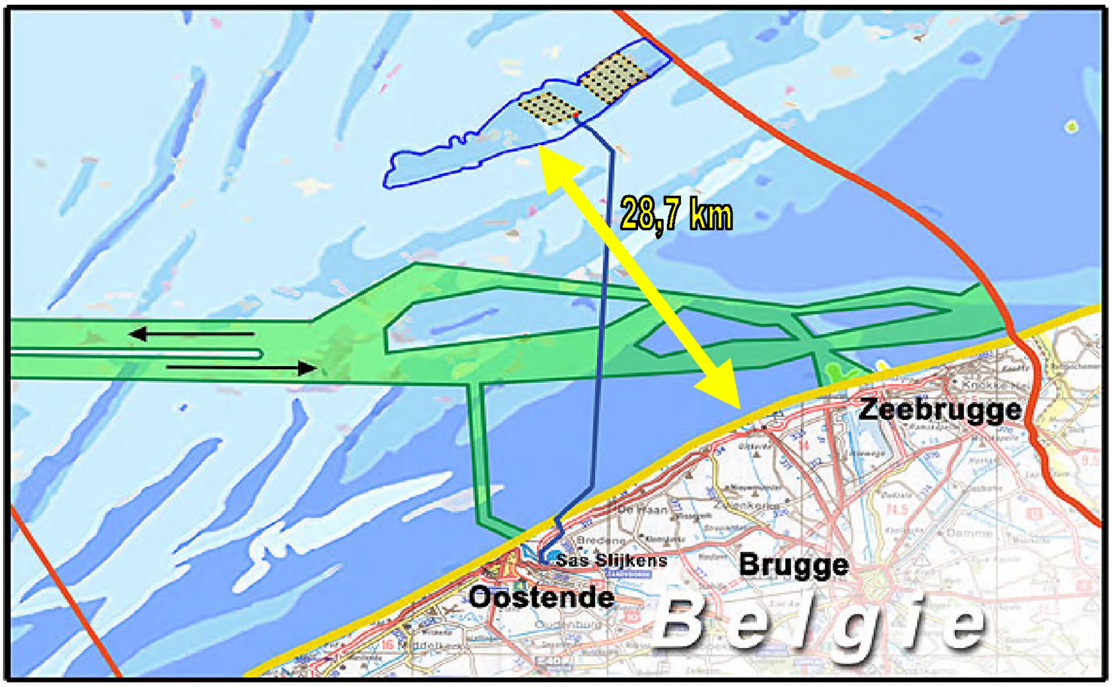

Fig. 1. Location of the C-Power offshore wind energy project.

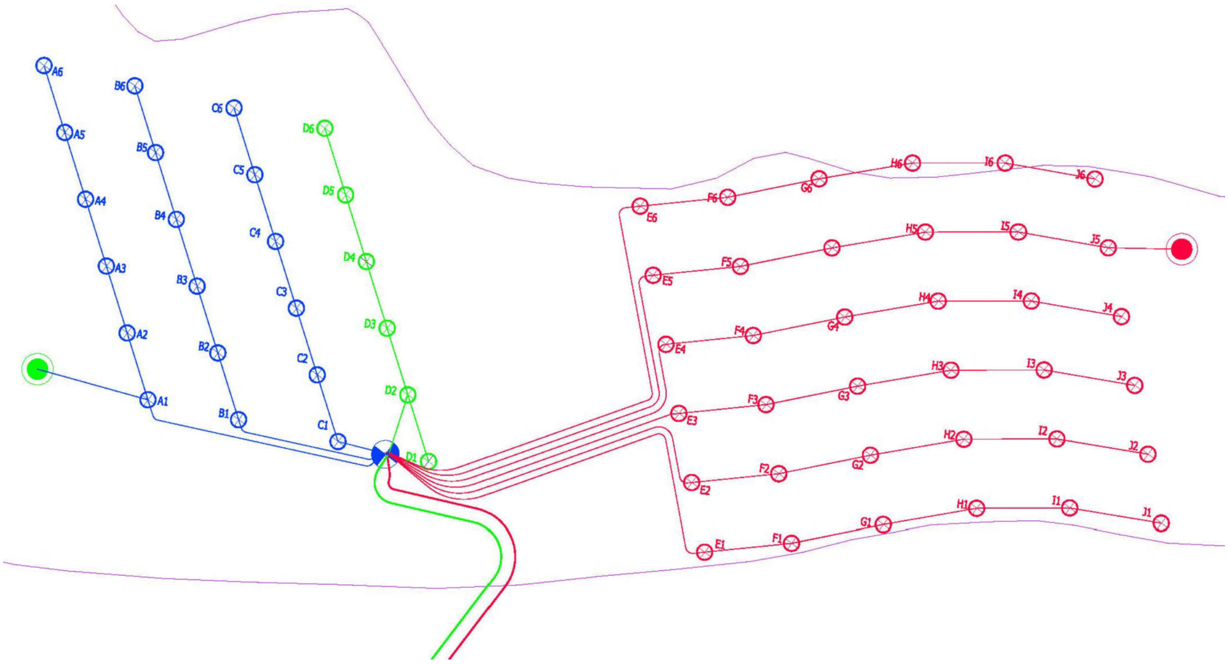

Fig. 2. Project planning.

2006-2007:

Demonstration phase: 6 wind turbines, 1st windmetmast, 1st offshore grid connection cable: 150kV (40km)

2008-2009:

18 wind turbines and the offshore transformer station

2010:

36 wind turbines, 2nd windmetmast, 2nd offshore grid connection cable: 150kV (40km)

All relevant information about the project (including all permits) is available on the website www.c-power.be.