Deltares

Enabling Delta Life

Definition study of Smart Waterways

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Summary
This report contains a definition study and an outline for the functional design of an advanced navigability monitoring and forecasting system, based on the echosounders that are normally mounted on the ships plying the river, a data acquisition and processing system, a hydrological low-water forecast model, a morphological bed-topography forecast model and data-assimilation techniques to use measured data for updating real-time navigability forecasts. The report identifies related projects and systems, provides boundary conditions and design targets and presents key components as well as an overall structure of the system as a first step towards a functional design. Special attention is paid to relevant stakeholders and potential partners in further development.

References
Appendix 11 to Krekt, A.H., T.J. van der Laan, R.A.E. van der Meer, B. Turpijn, O.E. Jonkeren, A. van der Toorn, E. Mosselman, J. van Meijeren & T. Groen (2011), Climate change and inland waterway transport: impacts on the sector, the Port of Rotterdam and potential solutions. Arcadis, Port of Rotterdam, Ministry of Infrastructure and the Environment, VU University of Amsterdam, Delft University of Technology, Deltares and TNO. Knowledge for Climate, project HSRR08, CfK/037/2011, ISBN/EAN 978-94-90070-434.

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Contents

1 Introduction

1.1 Background

Smart Waterways (Dutch: ‘Slimme Vaarweg’) is the provisional name for an advanced navigability monitoring and forecasting system under development. It will be based on the ecosounders that are normally mounted on the ships plying the river, a data acquisition and processing system, a hydrological low-water forecast model, a morphological bed-topography forecast model and data-assimilation techniques to use measured data for updating real-time navigability forecasts.

Although the name ‘Smart Waterways’ is used by different parties with some degree of diversity regarding the interpretation of what this system should really do, the common denominator in all cases is the principal idea of using up-to-date bed level data collected by transport vessels to obtain a better view on navigable water depths along inland waterways.

This appendix presents a definition study carried out within the present project under the Knowledge for Climate programme. A preliminary version has already resulted in follow-up actions. Rijkswaterstaat, ThyssenKrupp Veerhaven, Havenbedrijf Rotterdam, MARIN, Deltares and Delft University of Technology are preparing a 1.2 million euro project to develop the system, starting in January 2011.

1.2 Objective

The objective within the project under Knowledge for Climate is to execute a definition study and to set up an outline for a functional design of Smart Waterways. It is recognised from the start that this goal has to be attacked in two ways of equal importance: (1) to sketch a broad picture of technical feasibility of the information system, and (2) to evaluate the demands and the support for such a system among different stakeholders.

1.3 Activities carried out for this study

Tuning with possible partners was the main activity of this definition study. In practice these are mainly departments within Rijkswaterstaat and Deltares. The interviews with these partners largely consisted of discussing running projects with a certain degree of overlap with Smart Waterways. In fact, getting an overview of projects, (inter)national developments and trends touching upon the subject of operational systems in rivers turned out to be a vast task already.

Main components and interconnections were identified and described, thus making a start with a functional design of Smart Waterways.

Safety issues, acceptance issues and other risks were identified.

Extensive inventories of existing data acquisition techniques, existing operational database systems, available software, etcetera, have not been carried out. A good number of tips about how system components should function was nevertheless found. Naturally, expert knowledge on state-of-the-art techniques is needed to make the right decisions for what tools to use to set up the system.

Follow-up actions were specified and listed in a set of recommendations.

1.4 Reading guidance

Throughout this exploratory study, attention was paid to distinguish and devote more or less equal amounts of effort to both stakeholder support and technical feasibility. However, these two aspects are not discussed separately in this text, because in many contexts (such as project descriptions in Chapter 2) they are inevitably mixed.

This report is Appendix 11 to the main Knowledge-for-Climate report by Krekt et al (2011) on the impacts of climate change on the inland waterway transport sector and the Port of Rotterdam, elaborating one of the potential solutions. The structure of this appendix is as follows. Chapter 2 presents a list of related projects and systems that are currently under development. Then, based on input from several experts, Chapter 3 provides boundary conditions and design targets including some requirements of the system. Next, Chapter 4 introduces the key components of Smart Waterways. Chapter 5 presents a coarse outline of the system's structure. This can be seen as a first step towards a functional design. After this, Chapter 6 discusses some backgrounds on stakeholders and specific hurdles. Finally, the conclusions and recommendations of this study are given in Chapter 7.

As much of the nomenclature was originally formulated in Dutch, several translations into Dutch are added. When in practice only the Dutch name of a project is used, the translation into English is added between parentheses. A list of abbreviations is included in Chapter 8 and a list of references in Chapter 9.

1.5 People

Christiaan Erdbrink carried out this definition study. Erik Mosselman was the project leader. Christiaan consulted the following people at Deltares: Marc van Dijk, Kees Sloff, Daniel Twigt, Gerben de Boer, Henk Verheij, Maarten van der Wal and Arjen Luijendijk. Externally, he consulted the following people: Hendrik Havinga (Rijkswaterstaat ON), Marco Taal (Rijkswaterstaat ON), Therry van der Burgt (Rijkswaterstaat DID), Peter Stuurman (Rijkswaterstaat ON), Petra van den Konijnenburg (Rijkswaterstaat DVS) and Jan Hoskam (Rijkswaterstaat DVS).

2 Ongoing projects on information systems for inland navigation

2.1 Introduction

This chapter provides relevant projects (which are in varying stages of development) that one needs to know before making a start with setting up an operational information system for inland waterways.

Interviews executed in the period February-March 2010 form the basis of this chapter. Innumerable information systems for professional navigation exist. It has not been the goal to recover a list of these, to review these, or to completely scrutinize any of these. The order of treating the projects is arbitrary. It is recommended, however, to read all sections in the given order, in order to understand the specific terms and abbreviations.

2.2 BOS-Baggeren

In the daily practice of Dutch national river management, supplying information on the minimum water depths amounts to focusing on a limited number of river locations where critical shoals are found. The water depth at the most critical location is announced by Rijkswaterstaat Oost-Nederland (RWS ON) through publication of MGDs (‘Minst Gepeilde Diepten’). Inland water transport barge captains tune their cargo load on the MGD. This is especially relevant at low river water levels. For water depths more than 3.50 m, RWS ON issues no MGD values. Locations along the river where the MGD occurs are often notorious spots, known to the river manager, at which the water depths need to be checked frequently.

A bed level survey takes place as a routine activity over the the entire river section of the Waal, once every two weeks. This routine management sounding (‘beheerspeiling’) is principally motivated by RWS ON to check the river dredger’s perfomance. It consists of a survey of the full width of the fairway’s main channel (‘vaargeul’) plus an extra 25 metres on both sides. If the survey shows certain parts of the river bed to be above the required level, RWS ON imposes financial penalties to the dredging contractor.

In order to enable an efficient organisation of dredging and survey activities on the Waal, RWS ON commissioned WL | Delft Hydraulics to develop a supporting system. This was developed in the period 1998–2003. The resulting system is called BOS-Baggeren (Klaassen & Sloff, 2000; Sloff, 2001; Sloff & Ververs, 2002; Sprengers, 2000a,b,c; Stone, 2005; Ververs, 2003, 2005). The goal of the system was in principle to optimize dredging based on a crude 2-3 weeks morphological prediction.

BOS-Baggeren is essentially a GIS database (based on ArcGIS) that gives the user online access to a hydraulic map including data on bed level soundings and low-water depths, thus giving regional, graphical information on allowable cargo loads (by means of prescribing allowable vessel draughts). In this way it can be considered a precursor of Smart Waterways. Two types of Rijkswaterstaat river soundings served as data input: the fortnightly ‘beheerspeiling’ surveys and the wider multi-beam soundings of the whole river width (‘oriëntatiepeiling’), which are done less frequently.

BOS-Baggeren consists of a water level prediction model and a morphology prediction model. The former was based on a discharge prediction fed by a relatively simple hydrological model that applied a straightforward discharge rating curve based on measurement data.

The morphological model was basically just a predictor of river bed disruptions in a global sense. It simulated the sedimentation in time of dredged river sections (holes), based on assumed (parameterised) exponential decay functions. This served as an estimate of the time it takes for the dredged holes to fill back up with sediment again.

While the development of BOS-Baggeren was carefully tuned with both river manager (RWS ON) and dredging contractor in several workshop meetings, the closure of a new performance-based dredging contract in 2006 ('prestatiecontract') between these two parties made this supporting system somewhat obsolete. BOS-Baggeren still exists, but is not used intensively anymore today. At RWS ON, Wim Kornelissen is the contact person for information about BOS-Baggeren. At Deltares, Kees Sloff has been working on this.

An important concept in BOS-Baggeren is the OLR ('Overeengekomen Laagste Rivierstand'). This is a reference water level for the minimum water depths guaranteed by Rijkswaterstaat. Naturally, this is a vital element for inland shipping as this determines the (theoretical) cargo capacity. For the Rhine river section, which includes IJssel and Waal (which have a not-fixated level), the actual water level may on average not be lower than this OLR level 5% of the time, i.e. 18 days per year. This water level corresponds to a certain discharge at Lobith (of about 1020 m3/s). The river section of the Maas has a fixed water level that is controllable by weirs and sluices. For these rivers and inland channels with fixed levels, the OLR-requirement is more strict (not below 1% of the time). Once every five years, Rijkswaterstaat redefines the OLR. In 2006, Rijkswaterstaat extended the required water depth for navigation at OLR level from 2.5 m to 2.8 m. In 2011, the OLR will be determined again, which could possibly lead to new requirements. In the meantime, there is a yearly (unofficial) update of the OLR called the BRV ('baggerreferentievlak').

2.3 River Information Services (RIS) and Fairway Information System (FIS)

The now (2010) running project Fairway Information System (FIS) is a sizable project concerning all of the Dutch inland fairways. The origin of this initiative is the European incentive called River Information Services (RIS), or RIS Directive, which follows the goal of enabling the expansion of the inland navigation transport sector in a controlled and safe way. RIS is an umbrella concept with the general aim of implementing information services to support the planning and management of river traffic and transport operations. All over Europe, information about and for transport vessels, for example their cargo and route, will in the future be exchangable in a standardized way. RIS actually comprises a multitude of measures to improve the quality and accessibility of information for inland navigation. This should make it much easier to get an overview (in the form of a digital map) of the inland fairway network including all conceivable additions ranging from the location of shipping locks (and their opening hours, contact info etcetera) to the most recent weather forecasts. FIS is one of those measures that are part of RIS. According to the European initiators, implementing RIS not only improves traffic safety and environmental protection but will also enhance the efficiency and security of transport operations and increase competitiveness.

Being one of the implementations of RIS, FIS should be interpreted as a project that is organised top-down. To be more precise, the European Committee has ordered the Dutch Ministry of Transport and Water Management (V&W), which instructs the DGLM directory ('Directoraat-Generaal Luchtvaart en Maritieme Zaken'), which in turn orders Rijkswaterstaat (RWS), to execute the work. Within RWS, the departments that are working on FIS are the Dienst Verkeer en Scheepvaart (DVS), the Scheepvaartverkeerscentrum (SVC), the Data ICT Dienst (DID) and the Waterdienst (WD).

FIS (the Dutch term is ‘vaarweginformatiesysteem’) encompasses the task of collecting all existing sources of navigational information relevant to inland water transport ship captains. At present many of these sources are scattered over various (online) databases and websites, making it hard to get a good picture of all items that are necessary to plan a navigation trip. FIS focuses on the integration of data sources relevant to ship captains and on presenting this at a single on-line location. Ship captains can thus quickly download their Electronic Nautical Charts (ENCs).

The RIS website (see list of references) describes FIS as follows (start of quote). FIS contains geographical, hydrological and administrative data that are used by skippers and fleet managers to plan, execute and monitor a journey. FIS provides dynamic information as well as static information about the use and status of the inland waterway infrastructure, and thereby supports tactical and strategic navigation decision making. FIS contains data on the waterway infrastructure only – excluding data on vessel movements – and therefore consists of one-way information from shore to ship/office. Traditionally these services are provided through nautical paper charts and one or more of the following services in national formats and in the national language: Notices to Skippers, TV and radio broadcasts, internet, VHF nautical information radio, e-mail subscription services and fixed telephones situated on locks. RIS will provide standardised electronic charts and standardised Notices to Skippers in a machine readable format and in eleven languages (end of quote).

The intended outcomes of FIS, according to the Rijkswaterstaat website, are better estimates of travel times, thereby making inland waterway transport more suitable for current logistics processes and supporting fuel economy and improved safety levels with automatically generated alarm messages. The Waterdienst (WD) is the manager of FIS in the Netherlands. The task of the DID consists of the ICT actions necessary to integrate different online sources into a single interface. In 2009, Deltares performed a small project for RWS DID aimed at developing an interface that links FEWS with MATROOS, as part of the ongoing development of FIS. The still realistic goal is to finish the implementation of FIS in the Netherlands before the end of 2010 and to have it fully operational by that time. Other EU countries are allegedly much later with their implementations – apart from Germany.

RIS is still under development. As a result it is not yet clear what the execution of many services will look like (what devices are necessary to get navigational information on board of a ship and how the information will be presented). An aspect that is ultimately essential to the success of FIS and RIS is the cooperation between European states to tune their national networks and navigation systems and to make these compatible in order to achieve standardization. So far, no definitive agreements were made on measures to harmonize the different systems.

2.4 IRIS-2

At present, RWS ON is involved in another RIS implementation: the EU-driven project called ‘IRIS-2’, under French leadership. This project involves the cooperation between several parts of RWS and comprises the elaboration of the ideas on how to incorporate up-to-date water depth information into digital fairway maps. One of the focal points here is to use echosounders mounted on inland transport vessels as a new source of bed level data, but also to look at predictive water level models. The purpose of providing more accurate water depth information, from the viewpoint of RWS ON, is to enable a ship captain to judge –during the trip– how to sail in the most fuel-economic way, i.e. by sailing over the deepest channels of the river. Furthermore, the role of a more reliable predictive water level model would be to facilitate decisions to carry more shipping cargo on the next trip, according to RWS ON.

Rijkswaterstaat ON acknowledges that data from echosounders mounted on inland transport vessels are not straightforward. Not all vessels will be suitable for this. Moreover, the use of these data is only useful when there is a way to get the data in a short time from the vessel, on which measurements took place, to the rest of the fleet. The water depth information has to be sent off the ship immediately. Collecting the data after having completed the voyage produces unacceptable delays. RWS ON sees the need not only to present depth data in a swift manner, but also the need to disregard insignificant bed level details. For example, 1 m wide local trenches are not of interest, whereas significantly deeper parts of the channel that continue for several kilometres, are. RWS ON has the intention to set up a competition to (ICT) companies to enable this type of data presentation in a proper way.

A clear complication regarding water level prediction, as identified by river manager RWS ON, stems from the present inaccuracies of predictive water level models as currently in use by RWS Waterdienst. Recent comparisons by RWS ON of predictions of the water level at Lobith with the actual measured water level at that location, show that for one-day-ahead predictions differences of 20 cm occur and for two-days-ahead predictions differences of 60 cm are no exception. This makes these water level predictions fairly impractical for purposes of tuning cargo loads, considering that, for ore transport, an extra draught of 10 cm corresponds to an extra cargo load of roughly 1000 metric tons. The river manager RWS ON has the mission to guarantee the navigability of the fairways and is thus concerned with the inaccuracies related to predictive models when using these as a source of information to base decisions on.

The following (sub)project leaders at Rijkswaterstaat work on IRIS-2:

- Cas Willems (DVS) and Jos van Splunder (SVC) (national project leaders);
- Peter Stuurman and Martin Faaij (ON) (leader for water depth and water level models);
- Erik Sprokkelreef (WD).

2.5 Effective dredging

Rijkswaterstaat ON and WD are interested in ways to quickly remove local shoals in rivers. This has led to the wish to structurally exploit a technique in which sediment accumulations on the river bed are being washed away by using the propellor jets of inland transport vessels. Although this idea is not new, there are physical uncertainties attached to it: what is the jet flow load on the bed and, ultimately, how effective is jet-induced dredging of river-bed material when done by propellor jets (i.e. not by specialised dredging vessels).

At Deltares this has landed in the TO (‘Toegepast Onderzoek’) project called ‘Effectief Baggeren’ (‘Effective Dredging’), commissioned by RWS WD. Kees Sloff leads the project. In addition to the topic of washing away shoals using transport vessels, this project also addresses innovative dredging techniques. In the course of 2010, an outline will be set up of field measurements that are to take place in 2011. These field tests aim at answering the question: how can propellor jets of ordinary transport vessels be applied for ad hoc dredging of impeding river shoals? Two things are measured in this campaign: the water flow velocities underneath the vessel and the amount of resulting sediment transport. RWS DID will also be involved in these tests.

2.6 Project 'Optimalisatie Aflaaddiepte' at MARIN

Research institute and nautical consultant MARIN's main activities are related to optimization of hull shapes (reducing resistance, among other things). Through Henk Blaauw, MARIN has contacts with ThyssenKrupp Veerhaven BV (abbreviated here to Veerhaven), a large shipping company of tug-pushed barges ('duwbotenrederij'). This company (and possibly others) wishes for more information on navigable water depths than is supplied by Rijkswaterstaat. Hence the joint project 'Optimalisatie Aflaaddiepte' ('Optimization of loading depth').

The MGDs, see Section 2.2, have a validity of 1-2 days while there is a growing desire from the transport sector for more current, more recent information. In other words, they need more frequent updates on navigable depths of the river. Good contacts of MARIN with Veerhaven are really valuable, because this gives the possibility to deploy inland transport vessels in field tests (nearly) free of costs, whereas normally using such vessels in field tests would be the chief costs of such field tests. The link of this project with Smart Waterways is the issue of navigable depths: it provides the functional foundation of a shoal forecasting system.

2.7 Research on flow around ships

The Deltares R&D programme about harbours and inland waterways is captured in the roadmap 'Toegang tot water en transport over water' (often colloquially called 'Havens en Scheepvaartwegen') and includes an item 'Smart Waterways'. This is then considered as an intermediate step –now planned around 2012– in research towards a set of practical computational tools with a broad range of nautical possibilities. Deltares staff involved are Martijn de Jong and Henk Verheij.

This R&D roadmap programme is also tuned and agreed upon by the faculty of Civil Engineering and Geosciences at Delft University of Technology. The plan, written down in a proposal to NWO dated April 2010, is to involve one PhD student (from China, starting end of 2010), one postdoc and perhaps also MSc students to work specifically on the hydrodynamical aspects. Additionally, Rijkswaterstaat Dienst Infra (RWS DI, formerly RWS Bouwdienst) has been informed; they are mainly interested in bank stability problems caused by jets.

From next year (2011) onwards, a series of prototype scale field measurements has been scheduled to investigate flows around moving vessels. This campaign will definitely produce a unique and valuable data set which will become central to further understanding of the impact of ship-induced flows in inland waterways. These are the same tests as mentioned in Section 2.5.

There are direct links between this project, the MARIN project and the 'Effective dredging' project. RWS ON has contracts with small dredging companies for maintaining the navigable depths. These are not always capable of removing all shoals on a short term, and therefore the use of transport vessels for blowing away shoals is being investigated. Since the MARIN-based project and 'Effective dredging' have a common goal and interest, and require fundamental knowledge on the flow physics, there is a mutual agreement to try to make a single large project out of these three projects spanning 3-4 years, consisting of several sub-projects including an as yet unspecified navigable depth forecast system and the study on flow around vessels.

2.8 FEWS-based system for Maasvlakte 2

Deltares recently set up a predictive system based on monitoring data to provide information for port navigation on changing currents during the various construction stages of the large Dutch land reclamation project ‘Maasvlakte 2’. Daniel Twigt is the contact person for this project at Deltares. Measurements used for this system consist of: an ADCP placed at one fixed location off shore, Seadarq measurements of the entire port entrance and monthly ADCP measurements by a survey vessel. For Deltares, the client of this project was HMCN (Hydro Meteo Centrum of RWS Noordzee). Activities by HMCN include making predictions of water levels, currents and waves for the entire North Sea, Waddensea and ‘Noordelijk Deltabekken’. HMCN protects continuity and content of the measuring system of the North Sea (‘Meetnet Noordzee’).

The Maasvlakte 2 (MS2) system is a FEWS system. A snapshot is shown in Figure 1. The users of this system are the harbour pilots (‘loodsen’) of the Port of Rotterdam. It gets its data from MATROOS, which functions as the database and obtains its data from HMCN. The system’s main application is a data viewer. A new interface was created which is suitable for data presentation that is being offered to the vessels and easy to interpret by the harbour pilots. The actual processing of the measurement data is not done by the part of the system that was designed by Deltares; the MATROOS database can be considered as an external data source. The MS2 system can be considered as a hybrid system in the sense that it stands between a client-server system (that incorporates automatic updates real-time to the client based on new measurement data) and a stand-alone system (that does not have automatic updates). HMCN operates the computational models and transfers the output data to MATROOS. The stand-alone FEWS-system then readily extracts the necessary data from MATROOS.

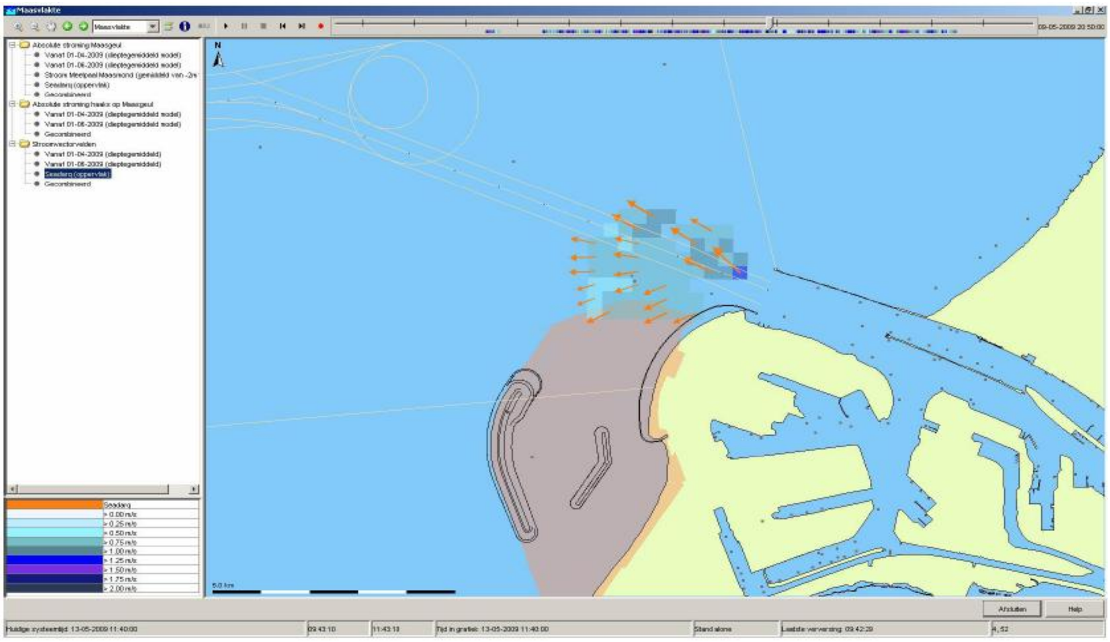

Figure 1. Snapshot of Maasvlakte 2 system.

The system shows the flow for the situation at the start of the month and the predicted situation at the end of the month which includes the scheduled dredging reclamation works for that period. The system gives a flow forecast for a few days.

The model schematization with the changed bathymetry is being updated manually once every month. A general description of FEWS has been included in the next chapter.

2.9 Automatic Identification System (AIS)

A novel source of information for inland shipping has become available with the introduction of Automatic Identification System (AIS). When used for inland navigation this system is usually called ‘Inland-AIS’. This is a notable addition to the existing traffic management by traffic regulation posts (‘verkeersposten’) of RWS and to existing ship-to-ship communication.

AIS is based on the use of onboard transponders. Transponders are electronic devices that automatically send and receive messages. These transponders placed on ships will continuously send out information about the ship’s identity and position. This means that traditional VHF communication by means of ‘marifoon’ can be reduced in the future. The fairway manager will now automatically have an overview of sailing ships – ship captains do not have to announce their positions anymore.

AIS recognises the presence of another vessel only if that vessel also uses AIS. Consequently, AIS does not make the radar system obsolete and should not be seen as a replacement of radar. However, in contrast to radar, AIS has the advantage of being able to ‘see around corners’ and is not impeded by bridges and tall buildings. With the spreading of AIS, traffic regulation posts (‘verkeersposten’) at Wijk bij Duurstede and Nijmegen will in due course probably become obsolete and cease to exist.

Several pilots are currently running to test AIS; these started in October 2009. The introduction of AIS on a larger scale is aimed to take place from 2010 onwards. Eventually, it will become compulsory to use AIS. The remaining problem is the costs of the AIS device. These are around 2000 Euros and should be paid by the ship captains themselves. One of the preliminary results of the AIS pilot is that a certain inaccuracy in ship location has to be accepted.

2.10 Waterway of the Future

Rijkswaterstaat DVS is involved in issues on national traffic management, both on land and on waterways. A large ongoing project at DVS is called ‘Vaarweg van de Toekomst’ (‘Waterway of the Future’). Anno 2010 this is led by Petra van den Konijnenburg. This project runs continuously; no end date has been set. It is one of the four themes of the wider Rijkswaterstaat innovation programme ‘Wegen naar de Toekomst’ (WnT, ‘Roads to the Future’). This programme concentrates on drawing up visions of the future and results in proposals for pilot projects. For the Waterway of the Future theme, the leading question is how the desires of all users of the waterways in 2030 can be met. This project contains several focal points. Most interestingly for Smart Waterways, one of these is the issue of optimizing maintenance of the waterways. For the question of how to use transport vessels to remove shoals, the DVS does not actively develop new ideas, however. They have indicated to merely keep an eye on new developments via contacts with Arjan Sieben (Rijkswaterstaat WD).

The same holds for the position of DVS towards the Smart Waterways project. They have indicated that they do not see a shoal forecast system as an item to include in Waterway of the Future, but they are interested in staying informed about what happens in terms of research and development. So they do like to know what is going on, but DVS is at present not willing to contribute –financially or otherwise– to the development of a forecasting system for the waterways in this framework.

Conversely, for the parties that are developing Smart Waterways it is informative to keep an eye open to ideas and pilots developed in the Waterway of the Future project. One of these entails the role of providing logistic information for container vessels on the waterways between the ports of Amsterdam and Antwerp. For example: what is the capacity of a shipping lock and when can an approaching vessel expect to obtain permission to enter the locks? When a ship captain knows this in advance, he can adjust his approaching speed, thus minimising both fuel consumption and waiting times at the locks.

2.11 River studies at RWS

When discussing river-related initiatives on a national level, it is good to know about (the existence of) previous projects at RWS. In addition to the present projects already described, the following prominent projects executed in the past are worth mentioning.

1960s:	Various projects by Rijkswaterstaat ON (previously: DON) on finding the optimal fairway called 'Optimale Vaarweg'.
1990s:	Studies on the river Waal called 'Hoofd Transportas Waal'.
2000s:	DVR ('Duurzame Vaardiepte Rijndelta') has the aim of ensuring long-term navigability on Dutch rivers by means of morphological studies concerning large-scale river bed level changes.
2000-2010s:	Room for the River (RvR, 'Ruimte voor de Rivier') comprises the design and execution of a set of measures along the Dutch rivers aimed at lowering water levels at the design flood discharge.

In the context of navigability it should be noted that DVR and RvR influence each other and are in some ways connected, but essentially strive for contradictory goals. Local measures of the RvR programme might lead to irregularities in the bed level and hence cause shoals. The precise effects of, among other measures, groyne lowering and the construction of secondary channels on river morphology are not known accurately and have to be monitored closely.

2.12 Conclusion of inventory of projects

Apparently several parties are occupied with new systems that provide information of some kind for inland shipping. It is not needed to achieve a synthesis between all these different lines of approach. Related projects are evidently very helpful to learn from. An important observation is that there is a need by the inland water transport sector to know more than just the MGD. Is the critical water depth formed by a single local shoal or are the depth restictions caused by numerous long, shallow sand bars?

The conclusion from the inventory is furthermore that the integration of the 'Effective Dredging' project, the research project about flows around ships and the MARIN project on optimizing cargo loading, as mentioned in Section 2.7, covers a major amount of relevant topics and incentives – including the idea of a Smart Waterways system. A meeting in Brielle on April 8th 2010 gave a new push in this direction. People from Deltares, RWS ON, RWS DVS and Veerhaven were present at this meeting and were informed on the Smart Waterways definition study in the present Knowledge for Climate project.

The interviews carried out for the study show that most Rijkswaterstaat parties are already quite well informed about the Smart Waterways concept. Future talks with for example RWS ON need not cover the system or its contents as such, but should rather be about solving the traffic management and safety issues.

The large Rijkswaterstaat river projects in past and present (Sections 2.2, 2.3, 2.4, 2.9, 2.10 and 2.11) provide background information on the river manager’s concerns. RIS and all its subimplementations, most notably FIS and IRIS-2, can be seen as indications of the international trend towards incorporating a greater variety of data into information systems for inland water transport ship captains. Navigable water depth predictions would be an appropriate addition to FIS.

Let us now proceed and have a look at the objectives of Smart Waterways. What do we want to achieve with the Smart Waterways system? This is addressed in Chapter 3.

3 Functions and aim of Smart Waterways

3.1 Introduction

The cross-relations with projects listed in the previous chapter, as well as with other (past and future) initiatives, will play a role in the articulation of the overall aim of the Smart Waterways system. The project descriptions of the previous chapter have yielded an identification of mutual elements that lead to a good idea on preferred properties of the system. In coming to a logical structure for this operational system, it is essential to establish aim and intended applications.

3.2 Aim of the system

This section addresses the aim of the system by a two-way approach, namely by first looking at the general objectives of the Smart Waterways system (overall aim) and by subsequently looking at the requirements for the actual implementation of Smart Waterways (executive aim).

Overall aim:

An expression of the aim in general terms should make it directly clear what the significance of Smart Waterways is for fairway management and inland water transport, without too many details.

The intended overal aim of the operational monitoring and forecast system of shoals called 'Smart Waterways' is threefold:

(i) To improve navigational safety on inland waterways;
(ii) To enable more economic cargo transportation over inland waterways;
(iii) To promote inland water transport in a more environmentally conscious way.

Re (i):
Safety on inland waterways could be improved by providing more elaborate bed level information to the captains of (large) transport vessels, because this can make it easier for them to navigate. Difficulties in manoeuvering in inland waterways can be caused by width constraints (mainly in river bends) as well as by depth constraints (mainly in straight sections) in the cross-section. Sailing with a small keel clearance or at a small distance from a lateral side wall is known to reduce the steering effect of the rudder. Also, the effect of an irregular return flow resulting from reduced keel clearance can influence steering. If a captain has access to information on locations of shallow and narrow river sections, he or she can anticipate to this in a more appropriate manner. Ongoing and planned research projects (e.g. in the cooperation between Delft University of Technology and Deltares) have the goal of developing more knowledge on phenomena related to flows around a vessel.

Re (ii):
Having the ability to know the water depth limitations of a planned trip in advance allows better determination of the cargo to be loaded on board. A large increase in cargo mass carried by a transport vessel leads to a relatively small increase in the vessel's draught. Naturally, the more cargo is transported in a single voyage, the less trips are needed. And thus the direct economic benefit is immediately clear. In the present situation, without exact knowledge about water depths encountered on the future trip, transport vessels apply

conservative safety margins for their keel clearance and hence the amount of cargo carried on board. Secondly, bed level information that makes it possible for the skipper to sail through the deeper river sections for long distances, instead of through the shallower parts, will result in a more efficient –and thus more economic– use of fuel. Sailing through shallow and narrow cross-sections is accompanied by more resistance on the hull of the ship and this requires more energy. Another aspect in saving fuel consumption is based on knowledge of flow strengths in the river. This may at first seem slightly off topic within the Smart Waterways discussion, but it is useful to know about this. Ship captains often want to, and try to, make use of the weaker currents near groynes when sailing in upstream direction. Conversely, they strive for sailing on the parts of the river that contain high flow velocities when sailing in downstream direction (these are usually the deeper channels in the rivers). This navigation aspect regularly leads to unsafe situations. Transport barges are known to literally sail into the underwater part (the slope) of groyne heads, when they try to sail as close as possible along the groyne heads. Providing information on the distribution of flow velocities in the river could be a way of enabling more fuel-efficient navigation, while making the fairway safer at the same time.

Re (iii):
The awareness of the need to have clean waterways has grown considerably in the past decade. In 2006, the former department DGTL ('Directoraat-Generaal Transport en Luchtvaart') of the Dutch Ministry of V&W initiated a study concerning the supervision on emission of greenhouse gases by inland shipping traffic (Inspectie Verkeer en waterstaat, 2006). Since 1 July 2008, the DGTL department is called DGLM ('Directoraat-Generaal Luchtvaart en Maritieme Zaken'). The aspect of noise reduction is also part of these studies. Other ecological river elements that can be improved by more conscious shipping traffic include the waves caused by passing ships. Here holds the rule: the less intense, the better.

It is self-evident that the economic aim coincides with the aim of a more environment-friendly use of inland waterways: reduction of fuel consumption indeed implies reduction of a substantial part of the transport costs and reduction of emission of harmful gases.

Note that 'optimisation' can refer to several things. A specification is needed: optimisation of cargo loading, of fuel consumption, of total transport costs, etcetera.

Executive aim:

The executive aim of the Smart Waterways project is to set up an operational monitoring and forecast system of shoals in the Dutch rivers Waal and Boven-Rijn. This is motivated in particular by recent progress in the application of operational data processing systems plus the ongoing improvements in morphological numerical modelling at Deltares. Next to the data processing and software components, the strength of Smart Waterways lies in continuous data acquisition measurements by echosounders on board of inland transport vessels and immediate sharing of these bed level data. Generally put, the Smart Waterways forecast system would function as a guidance tool for inland navigation and river managers alike.

3.3 Applications

The obvious observation that a system with the above aims is simply applied to produce forecasts requires some further elaboration, especially on the question of how the system is practically applied. The following two ways of applying the system are distinguished:

(i) By a sailing vessel. The Smart Waterways forecast system is applied to determine the optimal sailing route regarding the position of the vessel in the river's cross-section.
(ii) By a moored vessel. The Smart Waterways forecast system is applied to determine the cargo to be loaded for the next voyage.

Applying the system cannot be seen separately from the users and future stakeholders of this project. The above applications assume the inland water transport sector as the main user. See also Section 6.2 on stakeholders.

3.4 Terms of Reference

It is part of this study to give a first push towards designing the navigability forecast system. Defining exact terms of reference is not possible yet at this stage of the project. Only a few points are listed:

- Water depth predictions should have a maximum inaccuracy of 10 cm.
- Model output should give predictions of 1 to 3 days ahead.
- The model should make use of the most recent measurement data from ships, i.e. the delay between data acquisition and presentation of processed data should not exceed 24 hours.
- The minimum frequency of model output is one prediction per day.
- A good depth profile resolution over the width of the river is necessary. The exact desired level of detail or resolution of the presented bed level information is still to be determined.

4 Smart Waterways system components

4.1 Introduction

This chapter introduces the chief components that are thought to be indispensible for an operational shoal forecast model by giving a 'bird's eye view' of relevant information about these components. This is merely intended as a background that will be helpful for further discussions on the structure of Smart Waterways. Section 4.2 describes the FEWS system in general, based on an edited text from public Wiki pages of Deltares. Although originally developed for flood forecasting, FEWS is equally suited for low water level forecasts. Section 4.3 provides some information on morphological modelling – the actual computation of the forecast. Finally, Section 4.4, adds some remarks on acquiring measurement data from vessels.

This chapter presents individual components, whereas Chapter 5 provides a proposal for the overall system structure and the links between the various components.

4.2 Description of FEWS

General information on FEWS

Recent developments in numerical weather prediction, radar data and on-line meteorological and hydrological data collection have resulted in an increasing focus on data import and processing within flood warning. Together with the progress in database development, hydrological and hydraulic model development, and on-line data availability, the challenges for developing a modern flood forecasting and warning system is found in the integration of large data sets, specialised modules to process the data, and open interfaces to allow easy integration of existing models capacities. In response to these challenges, Deltares' Flood Early Warning System (Delft-FEWS) provides a state of the art flood forecasting and warning system. The system is a sophisticated collection of modules designed for building a flood forecasting system customised to the specific requirements of an individual flood forecasting agency.

The philosophy of the system is to provide an open shell system for managing the forecasting process and handling time series data. This shell incorporates a wide range of general data handling utilities, while providing an open interface to a wide range of forecasting models. The modular and highly configurable nature of Delft-FEWS allows it to be used effectively for data storage and retrieval tasks, in simple forecasting systems and in highly complex systems utilising a full range of modelling techniques. Depending on the situation, one can choose to apply FEWS as a client-server or a stand-alone application.

Connecting Delft-FEWS to external data sources

An efficient connection to external data sources is of paramount importance in an operational flood forecasting system. Delft-FEWS provides an import module that allows import of on-line meteorological and hydrological data from external databases. These data include for example time series obtained from telemetry systems such as observed water levels, observed precipitation, but also meteorological forecast data, radar data, etc. Data are imported using standard interchange formats, such as XML, GRIB (for Numerical Weather Predictions) and ASCII. The import of external data also supports ensemble weather predictions.

Validating, interpolating and transforming data
Particular emphasis is placed in Delft-FEWS on quality checking of data obtained from external sources, with extensive validation options to check data and serial interpolation (gap-filling) abilities to complete data series where required. Data hierarchy options allow alternative data sources to be used as a fallback in the forecasting process should the nominal sources be unavailable. The use of these options will ensure the continuity of the flood forecasting process, even if available real-time data is incomplete or inconsistent.

Another set of utilities is available to provide support in transforming data with disparate spatial and temporal scales. This includes geo-statistical spatial interpolation to derive for example areal weighted precipitation from spatially distributed point sources, or from spatial data such as radar data and numerical weather prediction models.

The data transformation utilities also include methods for temporal aggregation and disaggregation, evaluation of simple equations and typical hydrological functions such as stage-discharge relationships and evaporation calculations.

Finally, a useful asset of FEWS is the application of what is called ‘ensemble forecasting’, in which smart choices are being made to combine multiple numerical predictions into one forecast.

Note that FEWS is principally an operational system and not explicitly suited to act as a large database. For this a system such as MATROOS is more suitable.

MATROOS
The MATROOS system mainly acts as a database containing a variety of hydraulic data of coastal and oceanic, but also inland water areas in the Netherlands. In this way it is used by operational systems to provide the necessary data. A future use of this database system is to act as an archive for FEWS data. Moreover, MATROOS itself also acts as an operational sea model.

From the website of Matroos: (start of quote) MATROOS stands for Multifunctional Access Tool foR Operational Oceandata Services. MATROOS gives you easily access using your internet browser to all recent and historical model and monitoring data relevant to the storm surge forecasts. MATROOS offers also the facility of an international near-real time multi-model forecast analysis: water level forecasting data and weather forecasting data from the NOOS partners around the North Sea can be intercompared. MATROOS is optimized for fast retrieval of the most popular and recent data just like the common internet search engines. Visualization of data is as time histories or as spatial maps. Statistical parameters relevant to the storm surge warning service or any interested oceanographer can be analysed with MATROOS as well. MATROOS gives the authorities access to recent model data for trajectory analysis of spills and for safe guidance of ship traffic. The learning effect of MATROOS will be substantial, thus leading to a further reduction of risks of flooding and environmental calamities (end of quote).

4.3 Morphological modelling
With the ever increasing computer power becoming available to engineers over the last decades, numerical hydrodynamical and morphological models have become more and more sophisticated. This means that nowadays bigger models and finer grids are applied than ever before. But computing power is not the only change; new insights into physical processes are being presented. Also, at the time of BOS-Baggeren, there was no proper schematisation

available for a 2D-model model. Setting up such a model would nowadays be an easier, though by no means trivial task. One of the key points, furthermore, is that predictions are requested on a short term instead of a long term. For short-period predictions, a denser model (smaller grid size) is necessary than is used in most model applications. This is especially important for the prediction of local morphology. Moreover it will be desirable to model the absolute bed elevation, as opposed to the relative (difference) levels that are simulated in projects such as Room for the River (RvR, 'Ruimte voor de Rivier').

Figure 2. Area near Vianen for which the Delft3D shoal predictor explained the grounding of a ship (Sloff, 2006).

The main point of any morphological model for the Dutch river system applied for shoal forecasting is to describe the physical processes that cause critical shoals and that can incidentally also cause the washing away of the shoals. River shoals generally form in inner bends, as a result of river dunes, in front of groyne fields (the so-called 'kribvlammen') and at locations where water leaves the main channel to enter the floodplain during floods. Combinations may give rise to the shoals that actually give problems for navigation. Delft3D simulates the underlying processes spatially and temporally.

A challenge lies in the accuracy of such a Delft3D model. Absolute bed level computations are sometimes considered (albeit at relatively large scales), but the model outcomes should still be seen as approximations. The question is how absolute bed levels can be computed within the order of accuracy in which shoals occur. This requires a different model treatment. Now the critical shoals appear in simulations as a time-average model outcome. The shoals in present Delft3D models do not emerge in short-term day-to-day simulations and their exact location and the exact moment they arise are not simulated well. Luckily, modelling tricks are proposed to make more accurate short-term simulations and hence predictions. One of these involves a comparison between the simulated 'dune-averaged' or equilibrium bed level and the bed level according to the most recent multi-beam measurements.

The difference between these two bed levels, the 'disturbed bed level', will act as input into Delft3D (next to the equilibrium level that was already simulated) and the development of this disturbed bed then gives the forecast.

Once some experience is gained with this type of simulations (by getting to know the behaviour of dune processes described by typical time-scales per river location, for instance), simplified short-cut calculations could be introduced based on parametrisations of the 2D model, that will speed up the forecasting process. In other words, Delft3D eventually would not need to be run from A to Z for every prediction. This building-blocks type of approach ('blokkendoos') is just an idea that could make it easier to maintain the operational system. The more straightforward alternative would be to keep the 2D model running continuously, a more costly option.

Another point is how often the model's schematisation will require an update. The ongoing river engineering interventions for Room for the River (RvR) will inevitably mean that the model schematisation needs frequent updating. And also, one can sometimes choose to run only a selected subset of the model, for example the part where new measurement data have become available, or the most morphologically active part. In order to do this, someone has to make decisions; this can be done be an operator or perhaps semi-automatically using certain criteria.

Interestingly, as a definitive token of suitability, there is a remarkable example of the capabilities of Delft3D as a shoal predictor. During a numerical river study by Sloff (2006), an inland transport vessel grounded in a river bend near Vianen. The Delft3D simulations were able to immediately explain the location of the shoal – and to identify its physical cause, viz. the relatively large distances between the river groynes. This is a noteworthy indication of the possibilities and feasible predictive power of Delft3D as a tool to identify shoals in critical river sections.

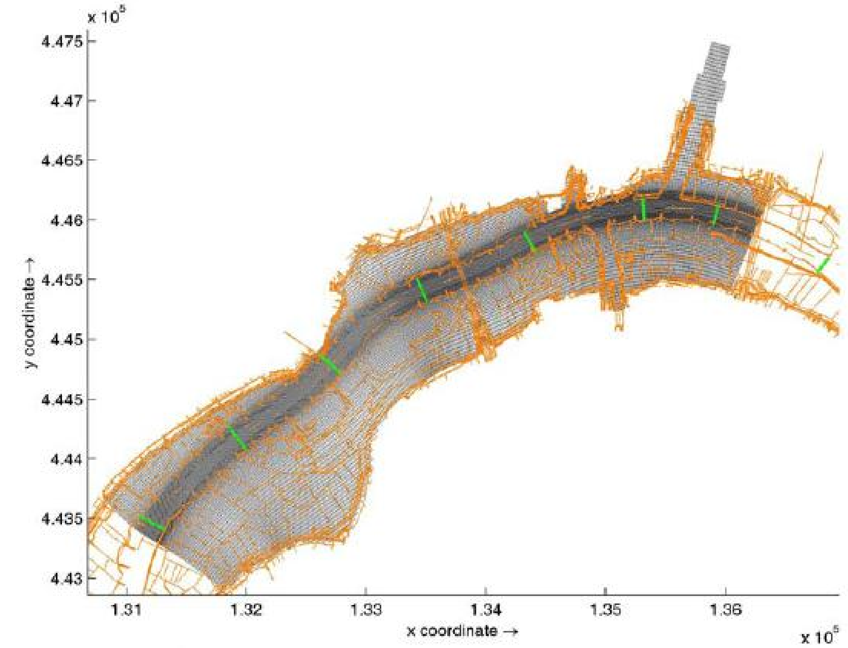

Figure 3. Computational grid of Delft3D shoal predictor that explained the grounding of a ship near Vianen (Sloff, 2006).

4.4 Echosounding data and depth surveys

The novel idea is to mount high-quality echosounding equipment on the hulls of transport vessels. Most vessels already have a depth meter of some kind, in order to locally see the keel clearance during their trip, but the essence of this new idea is to let travelling transport ships collect more and more accurate depth data and to make these data available, somehow, to other users.

Standard echosounders acquire bed level data on single, discrete points in a narrow region along the fairway. This means there are obvious omissions (lacking data at locations between these points) and a lot of data processing may be necessary to get a fitting, complete spatial picture of the bed level. The use of sidescanners and multi-beam sensors is therefore a much better –if not essential– additional way of measuring required to get a more complete picture of the bed levels.

Another issue that needs attention is the computational correction that has to be applied to the measured data in order to compensate for the ship's draught and the water level differences due to the movement of the ship. This might hardly be an issue anymore nowadays, with the increased accuracy of GPS, but this has to be checked with experts. What is the accuracy in vertical direction, for example?

Rijkswaterstaat Meet- en Informatiedienst (sometimes simply 'Meetdienst') is responsible for carrying out regular surveys (of bed levels, water levels, and to a smaller extent also flow discharges and velocities) along the river. In the outside world, there is unfortunately a limited view on the activities of the Meetdienst. It can generally be stated that views on the relevance and practical value of monitoring vary in time, but also vary from person to person. In due time it has to become clear how the regular Rijkswaterstaat surveys will fit into the Smart Waterways system, but the primary source of measurement data of the system will come from the transport vessels.

More information remains required on the way how exactly to use data acquisition tools such as multibeams on the hull of transport vessels. In a next stage of developing Smart Waterways, better insight is desired into (1) the installation, calibration and practical use of these devices and (2) the necessary data treatment in order to make the raw field data compatible for use in numerical engineering models.

5 Concise outline of functional design

5.1 Introduction

This chapter can be interpreted as a draft version of a functional design of the Smart Waterways system. Section 5.2 provides a graphical representation. Subsequently attention is paid to the question of how to set up each of the system components and what difficulties are identified. Sections 5.3 to 5.6 give descriptions of the various system components based on three questions: (1) What is the main function of this component? (2) What is the proposed way to develop this? (3) What major bottlenecks can be identified? Note that the answers to these questions given here are still far from complete.

5.2 Proposed set-up of Smart Waterways system

Figure 4 shows the relation between the main Smart Waterways components. This flow chart, however crude, depicts the basic idea of how the operational system could – not necessarily should – be set up.

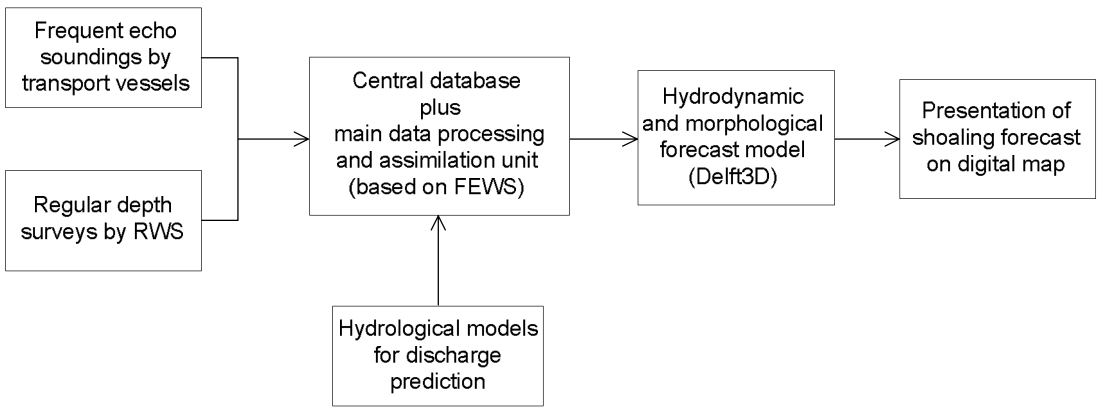

Figure 4. Schematic set-up of Smart Waterways system showing main components.

The arrows between the components do not depict straightforward input/output data flows, but represent steps of data assimilation and data processing that are not to be taken for granted. In fact, these are possibly the most challenging parts of the system.

Note that the relevance of the morphological model component for determining the navigable depth becomes limited in times of low river discharge. Below a certain discharge threshold level, it is possible to cancel the morphological model completely. The discharges coming from the hydrological models together with the most recent bed level data then fully determine the water depths at that time. Water levels resulting from these discharges still need to be calculated in the hydrodynamic model, of course.

5.3 Component 1: Measurements and surveys

What is the main function of this component?

The main function of measurements and surveys is to collect reliable and easy-to-process bed level data and to make these data quickly available to a central database system. The Waal is surveyed once every fortnight and this is thought of as a given source of data.

The success of Smart Waterways will be highly dependent on the complementary bed level information acquired by transport vessels.

What is the proposed way to develop this?
Several executive bodies are involved in the collection of field data concerning water depths on navigational fairways. Contact with the RWS Meetdienst is needed. Also, there are various different sounding devices. The desire in the framework of central data collection for Smart Waterways is to work towards a more uniform, standardised way to measure depth profiles from sailing transport vessels. The correction for load and water displacement effects should also be tackled in an appropriate and uniform way. Note that for a choice of measurement device, it is very important to know exactly what the desired requirements are, such as resolution, surface to be covered, sample frequency, etcetera.

The idea for a pilot, in which a data collection device is mounted on a number of container vessels, may definitely be a good start. Rijkswaterstaat ON is already considering this as a part of IRIS-2. It is proposed to follow such tests closely and to use the conclusions in further steps.

What major bottlenecks are identified?
Will echosoundings from transport vessels provide bed level data on all relevant locations of the fairway? If all vessels sail over the same track, this could result in a lot of blind spots, i.e. depth contours that are not captured by the echo loadings. These might precisely be the interesting, shallow parts of the cross-section.

Is the overall quality of the depth measurement systems on transport vessels sufficiently good?
Older echosounding devices may not be suitably calibrated and have large uncertainty bands.

Which ships are suitable for taking a data acquisition device on board that can send out reliable online bed level information?
Push barges ('duwbakken') are perhaps not suitable candidates because the barges in front of them have greater draught and may distort the data collection.

How to make the measurement data '(semi-)online' available, that is: how to send the measured data immediately from the ships to a collecting database system?
QINCY is an example of a file format that is in use to store measurement data from echo soundings. Several other formats exist. It has to be investigated which file types can be used by a FEWS system. These should ideally be uniformized as much as possible within the Smart Waterways system. The Data department of RWS DID can be asked for advice on this.

Processing can be considerably time-consuming as this involves combining many discrete data points to make a full (3D) spatial image. Both extrapolation and interpolation are tricky: what to do with areas without any bed level information at all? These parts, eg. close to the banks, are just as interesting (if not more) than other parts. And what to do with different bed levels measured by different vessels around the same time and at the same location?

5.4 Component 2: central FEWS-like operational system

What is the main function of this component?

The main function of the FEWS-like operational component is to provide efficient data assimilation by integrating measurement data with hydrological discharge model data into a format that is usable by the morphological model.

What is the proposed way to develop this?
To develop this component, FEWS experts can set up a custom-made system. It is paramount that, before this step is initiated, it is completely clear what the agreed set of requirements is. It cannot be developed independently of the connecting components.

What major bottlenecks are identified?
Various data sources imply various data types. Measurement data are very different from the hydrological data. Beside data format and content, also data quality will vary. This requires specialized processing and interpolation techniques. In short: how does the available data compare to the data format needed by the morphological model?

The measuring points are data input points for the operational system. FEWS generally requires these points to be on specific predetermined locations. For fixed measuring systems (fixed ADCP for example) this will not be a problem, but moving measurement points attached to vessels are certainly more difficult. Are the exact locations known at the moment of measuring?

The SOBEK-models running in a standard FEWS system are now focused on high discharges. The Smart Waterways system needs to operate equally well in all discharge situations.

5.5 Component 3: Morphological model

What is the main function of this component?
The main function of the morphological model is to calculate absolute bed levels and water levels within the required accuracy and allowable simulation time.

What is the proposed way to develop this?
It will require some model development to adequately set up a 2D morphological model in Delft3D for short-term predicitions. However, such a model is indeed feasible and benefits from tricks and techniques originating from extensive modelling experience at Deltares, for instance with using simplified parametrisations to speed up the calculation process.

What major bottlenecks are identified?
As already outlined in Section 2.3, the ultimate accuracy of the water depth prediction is an important issue. This relies of course on the quality of the measurement data and on the output from the hydrological models, but for a great part this relies on the performance of the morphological model. Predictions of river bed dune heights currently apply more to average heights rather than to the more unpredictable local dune heights.

Incidentally, considering the comparison between water level predictions and measurements as mentioned in Section 2.3, it has to be said that focusing on a single fixed location is a difficult thing. Loading draughts (‘aflaaddieptes’) are based on water levels at Lobith for the Dutch Bovenrijn and on water levels at Ruhrort for the German part. These locations are still used today, mostly for historical reasons. Perhaps it is useful to define new, more representative locations or sections as references for determining the loading draught.

5.6 Component 4: Presentation

What is the main function of this component?

The main function of this component is to present the navigable depth data in an orderly fashion, in line with existing ways of presenting waterway information.

What is the proposed way to develop this?

Possibilities of presenting the data in practical digital map formats, especially integrated into Electronical Nautical Charts (ENCs), should be evaluated.

The central information portal of FIS could provide a good place for presenting the predictions of the Smart Waterways system. The output results of Smart Waterways could be incorporated into the FIS website and interface. FIS presents nautical information that can be collected (downloaded) by the user (the skipper) before departure. Nowadays, many inland shipping vessels have the possibility to access the internet before leaving, i.e. while they are in a harbour or along a quay in urban areas. Internet access is likely to become even more widespread in the future.

What major bottlenecks are identified?

The 'Maasvlakte-2' project showed it is important that the end-users will trust the presented data. Special training and briefing sessions for the users, as was the case for the 'Maasvlakte-2' project, are at first sight unfeasible considering the large number of users. This has a lot to do with proper interpretation of the data. A good interpretation is absolutely not self-evident when removing the intermediate step of expert judgement, which is usually included when results from a Delft3D model are presented.

6 Discussion

6.1 The system as a whole and organisation

Even if the components of the previous section can be developed with the indicated means, challenges still remain in order to successfully unite these components into a single workable system. Four aspects (not all technical) are recognised.

Firstly, a great part of the technical task lies in streamlining data flows and data processing between the various components. A complication in this respect could be the required co-operation between developers of two adjacent system components. They need to translate the overall system requirements into specific requirements for their components, yet make sure compatibility between the components is attained.

Secondly, the informational system output should become widely available in order to have maximum benefit. If only a limited number of vessels is able to have access to the Smart Waterways model output (whilst in harbour prior to departure or during their trip), this could result in much smaller economic benefits.

Thirdly, a shared, well-formulated goal has to be clear to all participants in the development of this system. The more specifically the ultimate functional aim is articulated, the better. Recall that the objectives outlined in Chapter 3 only give a kick-off. Formulating the central goal also implies considering long-term trends in waterway management. This element includes for instance a view on future dredging contracts, agreements with inland shipping companies ('rederijen'), international trends in fairway control (including RIS), economic (EU) trends, etcetera.

The fourth aspect regards the organisation of system development. Several parties have been mentioned. Especially the establishment of links between components requires apt co-ordination and organisational management. A central source of funding and, hence, a central 'mastermind' controlling the progress and keeping an overview are considered essential. In other words, if different parties individually work on the separate system components without clear overview of the final goal, it will be very hard to efficiently achieve a well functioning forecast system.

6.2 Stakeholders

The relations of various stakeholders with the Smart Waterways project are briefly listed here.

Rijkswaterstaat ON
Rijkswaterstaat Oost Nederland should be seen as major actor, as it is responsible for managing most of the Rhine branches and for giving guarantees about navigable depths. Rijkswaterstaat ON already embraced the idea of going beyond the simple issuing of MGDs. More information about bed levels and water depths enables more detailed and more efficient river management. This makes RWS ON a key stakeholder in the development of Smart Waterways. The year 2011 will see the signing of a new dredging contract between river dredging contractors and RWS ON, possibly following new OLR levels. No substantial changes are expected with respect to the current performance-based contract.

Other departments of Rijkswaterstaat.

Rijkswaterstaat WD is the primary partner for any large research project in which central RWS funding plays a role. The morphological module of Smart Waterways is to be developed in agreement with WD specialist and contact person Arjan Sieben.

Rijkswaterstaat DVS is, at the moment, not directly interested in participating actively, see Section 2.10.

Rijkswaterstaat DID could play a role in facilitating possible integration of Smart Waterways into FIS and give advice on how to interpret and use sounding data.

Rijkswaterstaat DI ('Dienst Infrastructuur') is interested in the impact of propeller jets on banks of waterways.

Inland water transport sector
The inland water transport companies are considered to be the stakeholders with the most significant interests in Smart Waterways. Shipping company ThyssenKrupp Veerhaven holds active contacts in the integrated research project, see Chapter 2. Contacts with the companies are important first of all for giving input for requirements to the Smart Waterways system. Secondly, the companies may co-fund the project as they will benefit from the results. Thirdly, they can also contribute to the development of Smart Waterways by giving the opportunity to carry out field tests, for example tests with measurement equipment on board of transport vessels.

It is worth noting that not all ship captains will support the project. Smaller transport vessels with smaller draughts can become limited in their freedom to sail in the deeper parts of the river when these parts are fully occupied by the vessels with larger draughts. The small vessels thus would not profit from sailing over the fuel-efficient deeper channels. Again, coming to a good agreement and making appropriate regulation is important.

Dredging companies
Local river dredging companies are not interested in Smart Waterways. They have their own methods to select shoals that need to be dredged and a better actual overview of current bed levels is not in their interest as it might even expose flaws in their dredging performance. Moreover, a system that can follow and track down every move of a dredging vessel might give unwanted privacy violations.

Deltares
For Deltares, Smart Waterways could give a boost to developing the link between FEWS and Delft3D. For FEWS development, setting up the Smart Waterways data assimilation component builds on recent experiences in similar projects, but equally so provides new challenges. For Delft3D, it is an interesting step forwards to apply the latest knowledge on river morphodynamics into a short-term operational predictive model.

Delft University of Technology (TU Delft)
TU Delft's faculty of Civil Engineering and Geosciences carries out joint research with Deltares on flows around vessels. This framework can easily be extended to include research on Smart Waterways. TU Delft could contribute to Smart Waterways in particular by research on new ways of data acquisition and processing.

Port of Rotterdam.

As users of the Maasvlakte-2 flow monitoring system, the Port of Rotterdam ('Havenbedrijf Rotterdam') could provide valuable feedback on how users experience working with such an operational data system.

MARIN
Tuning with MARIN is valuable for (i) the contacts they have with shipping companies, and (ii) the planned research on flows around vessels. MARIN has wide knowledge on (loading of) vessels, (measuring) navigable depth, etcetera: all factors that are important for the development of Smart Waterways.

European Union
Although the European Union started the RIS directive and has thus shown a drive to promote the inland water transport sector, it is unclear how fruitful it would be to have the EU as a partner for the development of the shoal forecast system. The EU is in the short run presumably not the easiest financial partner to work with for Smart Waterways.

6.3 Challenges

Chapter 5 lists a few technical challenges that have to be met in order to set up this operational system. There are also non-technical challenges. Even if the Smart Waterways system would technically be ready for use today, it still would not be straightforward to implement it. Some examples of non-technical obstacles are given below.

Liability
A major issue concerning implementation of an inland shoal forecast system could be liability. What if the forecast provided by the Smart Waterways system is inaccurate and accidents occur as a result of this? The model developer does not want to be confronted with law suits, but on the other hand a water depth prediction is useless for the inland water transport sector if there is no clear view on the accuracy of the prediction. So how to attain a workable situation in which responsibilities are clear without the constant threat of legal issues?

Risks
Several safety risks related to a different use of the fairway by inland shipping traffic will have to be addressed. Rijkswaterstaat ON is deeply concerned with this. Three risks are explained below.

Firstly, knowing the exact shoal positions might lead to more dangerous sailing, as ship captains might undertake uncommon manoeuvres to avoid the shoals. Additionally, large, fully loaded vessels are more likely to encounter one another head-to-head as they both make use of the same deep and narrow parts of the fairway. Moreover, vessels with less cargo on board, and generally the smaller vessels, will perhaps be forced (against their will) to avoid the busier deep channel sections. Rijkswaterstaat ON sees this potential increase in the number of traffic conflicts as a reason to hold reservations on supplying online water depth information to the inland water transport sector.

Secondly, by giving them information, ship captains are encouraged to use that information for optimal loading. In doing so they are limiting their keel clearance and greater risks of running aground can occur as a consequence of this. This is in fact the central challenge inherently linked to the two overall aims as set out in Section 3.2. Nonetheless, a clear presentation of accurate and up-to-date bed level information by the Smart Waterways system would still act as a reliable guidance for safe navigation.

Lastly, the traffic regulations for inland shipping will have to be updated for a possible situation where some vessels sail in selected deep parts of the fairway while other vessels do not. Ships with minimum keel clearance sailing in the deeper sections may not be able to give way (according to reigning traffic regulations) to other vessels at all, because they will run aground if they do so. One-on-one communication between approaching vessels is of course a natural way to solve confrontations, but clearly, principal traffic rules are necessary.

Rijkswaterstaat ON is currently working on river management issues such as these. The three risks mentioned here have a strong legal and liability component from the point of view of the river manager. To give an example of a possible solution in relation to the first of the three risks mentioned, one possible outcome is to expand the navigable depth guarantee into two fairway lanes instead of a single lane. There would then be one wider fairway lane in the river with a relatively shallow navigable depth, and within that one a second, narrow fairway with a deeper navigable depth. A complete assessment of potential risks and finding apt solutions has to be made in due course. The question remains to what extent the system developers should be involved in this.

6.4 Alternative operational systems

A number of additions to the Smart Waterways system is conceivable. These will result in models with a somehow adapted aim. One possibility is an operational model that predicts flow velocities and local currents and presents these in the digital maps. Another additional feature could be a computation module of the expected fuel use, to be calculated before and during the voyage.

6.5 Ecological application

The EU Water Framework Directive will require monitoring of river ecology. Independently of Smart Waterways, ideas have risen to set up a FEWS-like operational system that yields information on side channels, main channels and vegetation along the rivers. The development of such a system might be linked with the development of Smart Waterways.

7 Conclusions and recommendations

7.1 Findings of the definition study

A navigability monitoring and forecasting system serves several purposes with substantial economic interests. Reliable short-term prediction of shoals and water depths enables inland waterway ship captains to optimise cargo loads. Up-to-date bed level contours allow more fuel-efficient and hence environmentally friendly use of the fairway.

A series of interviews has yielded an inventory of current projects related to the subject of information systems for rivers. Most interesting for Smart Waterways are the implementations of the EU-driven project RIS by different departments of Rijkswaterstaat and the integrated project by Deltares, MARIN and TU Delft on navigable depths and the hydrodynamics and morphodynamics around vessels.

From the viewpoint of technical development of operational systems, the Smart Waterways system offers an attractive step ahead in more than one way. A schematisation has been set up of the various components that are needed. Up-to-date multibeam echosounder data acquired by transport vessels have to be combined with regular survey data, as well as with discharge predictions by hydrological models, into one central operational component. The data processing and assimilation involved form a considerable yet feasible challenge, ideally to be tackled by a FEWS-like approach. Output from this central database is used as input for the hydrodynamic and morphological model. The morphological predictive model component will benefit from new insights in the morphodynamics of the river bed and ongoing implementation of these in the Delft3D software. For the presentation of the modelling results, it is recognised that correct interpretation by ship captains is not self-evident.

Rijkswaterstaat ON is aware of trends to use depth data in order to optimize cargo loading. They indicate that safety issues concerning sailing through narrower fairway channels and with a smaller keel clearance require careful consideration. Moreover, traffic regulations need to be adapted to allow for changed sailing when bed level data become available to ship captains.

The organisation of setting up Smart Waterways would greatly benefit from closer involvement of the inland water transport companies. They could step forward and act together as a main stakeholder, since they are the main future users of the system. Furthermore, a single well formulated objective shared by all parties is essential for a converging development within an acceptable time horizon.

Within Deltares, the development of Smart Waterways does not need to await completion in 2012 of the studies on flow and sediment transport around ships. The operational Smart Waterways components can initially be developed independently of this research. Synergy with the ‘nautical tools’ applications about washing away shoals with transport ships will be possible in the framework of the R&D roadmap item of 2012.

7.2 Recommendations derived from the general findings

It is recommended that the development of Smart Waterways will be co-ordinated and funded by a single main financier. As long as various different parties keep exploring their own ideas on what the system should do, each based on their individual viewpoints, it will be hard to achieve the full potential of this system within an acceptable time span.

This effect is fostered by decentralization of funding. Ultimately, the whole should become more than the sum of its parts.

It is recommended that future developers of Smart Waterways keep a good and up-to-date view on the central aim and terms of references of this system. Once the system requirements have been laid down, in accordance with a complete set of detailed demands from the stakeholders, this should be the leading document for all developers – rather than to have each developing party putting in its own ideas during the process of development.

It is paramount for the key stakeholders to stay in contact with each other, and to integrate their ideas to enable a single collective (combined) system. This holds especially in the initial stages.

It is recommended that the parties currently involved keep momentum and do not wait too long with making further steps. Delays would slow down the process enormously, for instance because key people will change positions and budget priorities will change. Waiting and starting anew in a few years time means that most of previous efforts are wasted.

It is recommended to closely follow all scheduled field measurement tests of both flow and bed level data acquisition devices on board of container transport vessels.

Co-operation with Germany has not been investigated in this study. It is recommended, however, to look at possibilities of approaching German partners in an early stage.

7.3 Recommendations for further development

It is recommended to develop the Smart Waterways system via a three-step strategy as follows:

1 Visualisation of monitoring results. As a first step, start with handling and presenting the measured bed level data. This simplified system, according to the diagram in Figure 5, merely has the function of integrating newly measured data from the multibeam echosounders mounted on transport vessels. Setting up this system already requires one to tackle the chief complications of how to process the field data into an operational system. A presentation unit is useful for showing the results, but does not need not to be fully developed yet in this step. When this simplified Smart Waterways is ready to be shown and hence tested, it can serve as a pilot or demonstration model. This first step of system development could be carried out by FEWS experts at Deltares and data acquisition experts at Rijkswaterstaat Meetdienst and DID. TU Delft could play a role in solving fundamental problems.

2 Addition of input from hydrological models. Now the data from the hydrological models is also fed into the processing unit. It is here that the operational FEWS component is fully used. This requires more complicated data assimilation. Perhaps, a simple 1D SOBEK model can be coupled temporarily to the system, to see if the data ouput from the central database meets the right conditions for use in a hydrodynamic model. The resulting system is effectively Smart Waterways minus the morphological model. In this stage, the presentation unit could also be developed further.

3 Addition of morphological predictive model. The final step of development is to add the morphology model. This results in the model scheme of Figure 4. This step contains all difficulties of how to set up the morphological model, such as making the computational grid, calibrations, etcetera. The Deltares freshwater morphology group will be the main developer here. Furthermore, it could be linked with the Deltares Eureka initiative called

‘Near real-time support-modelling for efficient monitoring of bed changes’ by Arjen Luijendijk. His idea is to develop a short-term morphological prediction model for optimising surveys of dredging reclamation works in coastal regions of the Dutch North Sea.

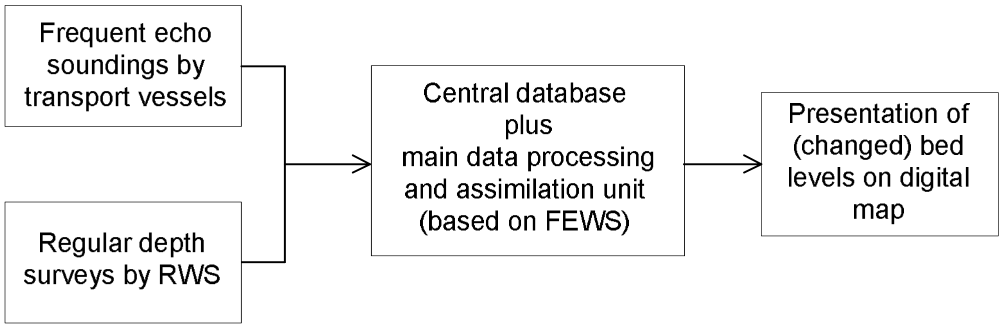

Figure 5. Simplified system, as a first step in the development of Smart Waterways.

Two considerations underly the suggested approach of developing Smart Waterways in separate steps. Firstly, this yields a structural process in setting up the system: the components will each receive optimal technical attention and benefit from new physical and computational insights along the way. Secondly, regarding the acceptance of the detailed information that will be provided to the ship captains, it would also be good to gradually present them more and more bed level data rather than immediately provide full 3D bed level data. This gives them time to get used to the information and to understand and interpret it correctly.

8 List of abbreviations

AIS	Automatic Identification System
DEWS	Drought Early Warning Systems
DGLM	Directoraat-Generaal Luchtvaart en Maritieme Zaken
DI	Dienst Infrastructuur, formerly Bouwdienst
DID	Data ICT Dienst
DVS	Dienst Verkeer en Scheepvaart
ENC	Electronic Nautical Chart
FEWS	Flood Early Warning System
FIS	Fairway Information System
HMCN	Hydro Meteo Centrum of RWS Noordzee
MATROOS	Multifunctional Access Tool foR Operational Oceandata Services
NWO	Nederlandse Organisatie voor Wetenschappelijk Onderzoek
ON	Dienst Oost-Nederland
PAWN	Policy Analysis of Water management for the Netherlands
RIS	River Information Services
RvR	Ruimte voor de Rivier
RWS	Rijkswaterstaat
SO	Strategisch Onderzoek
SVC	Scheepvaartverkeerscentrum
TO	Toegepast Onderzoek
WD	Waterdienst
WnT	Wegen naar de Toekomst

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9.2 Online references (URLs of consulted websites)

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http://www.wldelft.nl/soft/fews/int/index.html
http://public.wldelft.nl/display/FEWSDOC/Home

RIS:
http://europa.eu/legislation_summaries/transport/waterborne_transport/l24239_en.htm

FIS:
http://www.rijkswaterstaat.nl/water/veiligheid/scheepvaartverkeersbegeleiding/ris/FIS/

http://tentea.ec.europa.eu

AIS:
http://www.rijkswaterstaat.nl/water/veiligheid/scheepvaartverkeersbegeleiding/ris/AIS/

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MATROOS:
http://matroos.deltares.nl/

Waterway of the Future:
www.wegennaardetoekomst.nl

ThyssenKrupp Veerhaven BV:
www.veerhaven.com

Note that at present, searches by Google using the terms and abbreviations as used in this memo may give erroneous and confusing information. The following sites have nothing to do with the Smart Waterways system discussed in this study:

- ✗ http://www.smartwaterways.com/
- ✗ http://www.smartwaterways.org/
- ✗ http://tifac.org.in/index.php?option=com_content&view=article&id=460&Itemid=205
- ✗ http://www.melbourneaquarium.com.au/