memorandum

PR3317.20

Project : MMS Waddensea
Date : 10/03/2017
Subject : Full paper Hydro-international
From : Mattijn van Hoek
To : Hydro editorial board

Header

Proactive dredging in the Dutch Wadden Sea

Subheader

Morphological monitoring and forecasting through development of a maintenance management system

Introduction

The navigation channels in the Dutch Wadden Sea require continuous maintenance due to unceasing sedimentation of sand and mud. In this paper we describe the data management workflow and adopted technologies for a maintenance management system (MMS) used for morphological monitoring and forecasting of the various navigation channels. The Dutch Department of Waterways and Public Works awarded in 2016 a multiannual contract to contractor Gebroeders van der Lee to maintain the navigable waterways and harbours the Dutch Wadden Sea where HKV consultants provide support in development and maintenance of this MMS.

Study area

Since 2009 the Dutch Wadden Sea is inscribed on the UNESCO's World Heritage List and is therefore a protected nature reserve. It is a high dynamic system due to tidal effects in terms of biodiversity and morphology. The area is famous for its rich flora and fauna and there are multiple assigned protected locations for mussels seed banks, shell production sites and seal reserves. There is also economic activity in the region and multiple cable and pipelines are registered to be in place concerning data and telecom, electricity, gas and liquid with a total length of nearly 850km. Since the existence of numerous island from which five are accessible for the general public the region has a high recreational value.

These islands and mainland are connected by means of 11 harbours and 5 main navigation channels with a total length of 350km (see Figure 1). The channels are split into 100 dredge fields and 40 dumping locations. Where each dredge field has its unique declared minimum and maximum bed level.

The challenge of the project is to find a balance between the strict limitations of the works in terms of ecology, but simultaneously the huge economic impact of improper maintenance of the channels. Therefore it is of utmost importance to have continuous insight in the situation for well ahead and cost-efficient planning.

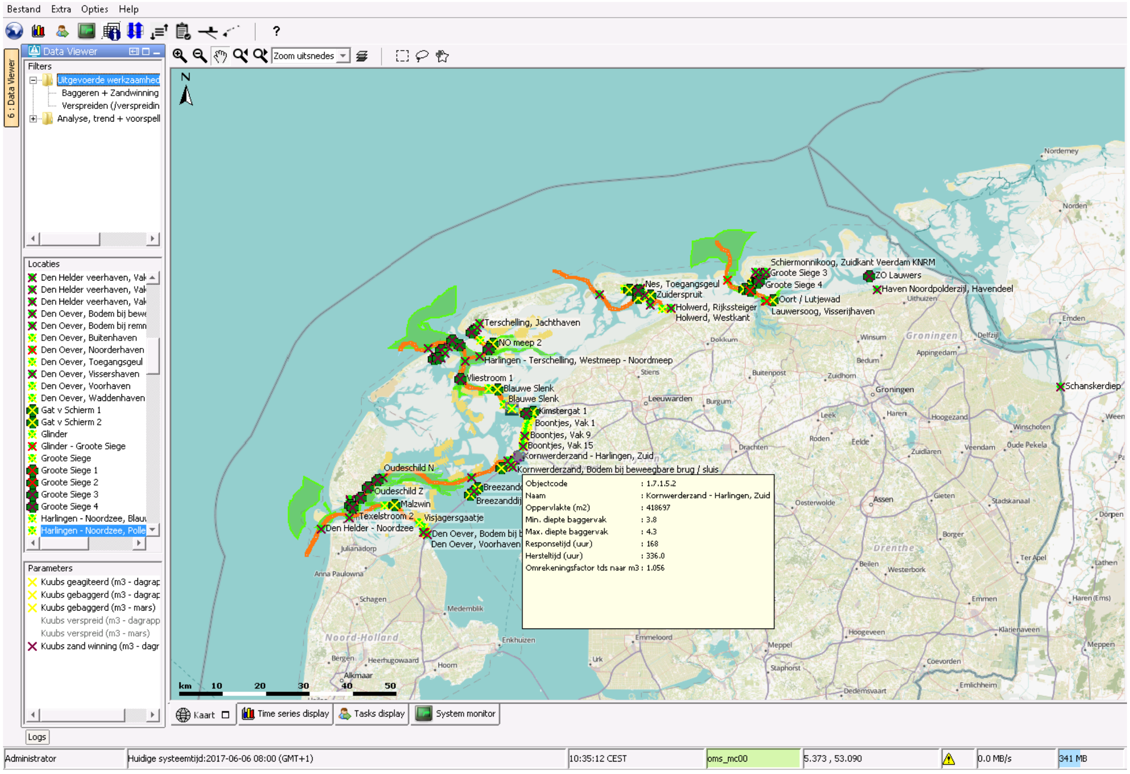


Figure 1 Geographical overview map of the MMS where point specific information is visible through tooltips.

Materials

The vessels adopted by the contractor for its maintenance activities are a dredge vessel, trailing suction hopper dredger, plough vessel, water injection vessel and a survey vessel equipped with multi-beam echo sounders.
While some surveys are undertaken every other month, such as the dredge fields containing little dynamic in seabed changes, others require a high intensive survey frequency (on weekly basis) as these dredge fields might contain significant shoaling. The multiple ferries active on the different navigation channels (will) provide depth level measurements by means of single-beam echo sounders.

In parallel the trailing suction hopper dredger is equipped with a Monitoring And Registration System (MARS) capable of automated measuring of dredged and dispersed volumes Tons Dry Solids (TDS) of every trip.

Each of these numerical measurements are presented to the MMS servers in a standardized fashion so they can be processed automatically.

Monitoring of the actual bed level

All multi-beam echo sounder data presented to the MMS server have passed the QA/QC and have a spatial resolution of 1 by 1 meter, but since the exact location of measurements are unknown from textual description all echo sounder data are processed and mapped to a custom made tiling scheme overcoming spatial and temporal variances. The tile scheme follows the navigation channels including a minimal buffer of 50 meter. In total there are currently 500 tiles defined and updated daily (1 tile ~ 500x500 pixels x 4 byte (float32) = 1MB/day/tile). In the daily process of creating a complete coverage of the most actual bed level for all navigation channels we consider all provided echo sounder data in the last 30 days, since the process of data acquisition and passing all QA/QC checks is allowed by contract to take multiple weeks. In other words it is a daily process that retroactively consider changes in the last 30 days. Using the actual bed level several deriatives are computed (see Figure 2) such as the volume, percentage and average depth above and below the minimum and maximum declared bed level.

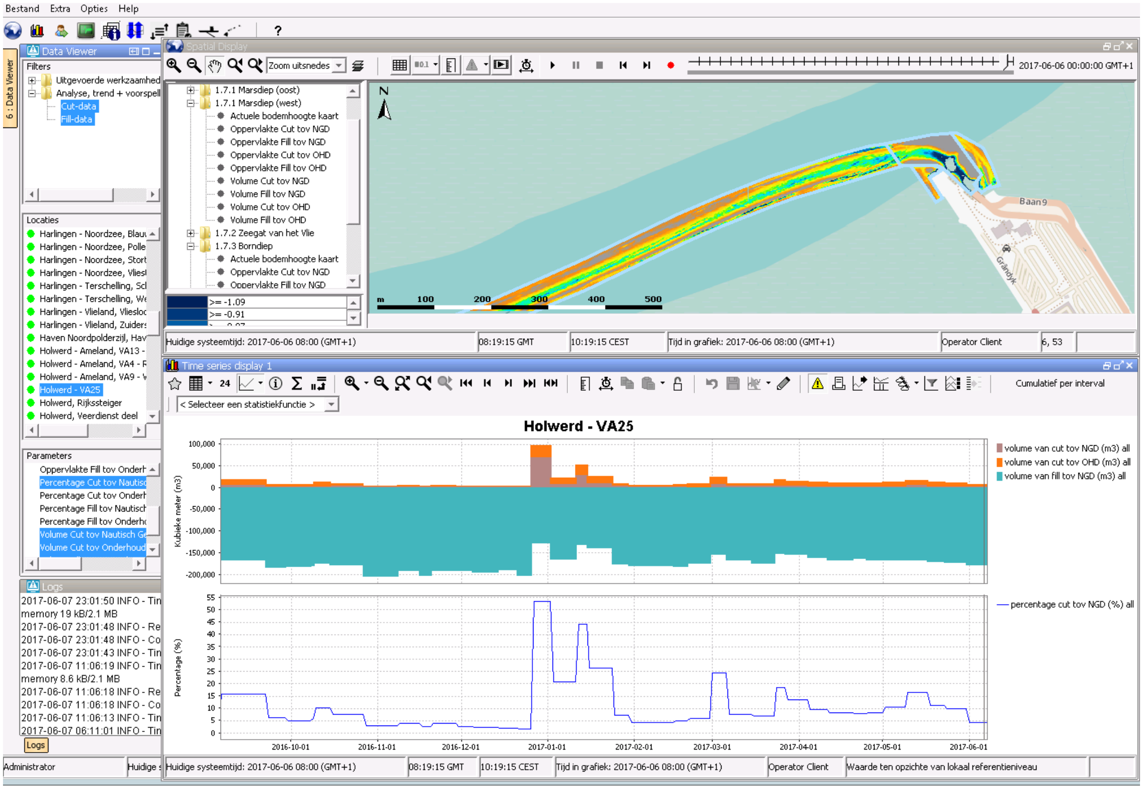


Figure 2 Derivative results from the daily computed bed level used for creating the weekly dredging planning

Forecasting of the bed level 10 day ahead

Multiple approaches have been considered for forecasting.

Firstly we tried to adopt a trend analysis of data reported by the previous contractor. These data could not be validated by its source and was aggregated to monthly values. For computation of speed of shoaling in cm/day this is in insufficient. Since the data is monthly based it is hard to correlate the dredged volumes with wind directions.

Secondly we tried to adopt an existing hydrodynamic sludge shoaling model (SOBEK 3D). This model was calibrated for January-March 2009, where grid had a spatial resolution of 400 meter. Using this model we tried to find a sludge shoaling speed using the dynamic variables wind speed, wind direction and reported dredged volumes.

We were able to downscale the results to 200 by 200 meter spatial resolution, but this is still too coarse when comparing these with the measured spatial resolution of 1 meter from current multi-beam echo sounders. The period of 3 months (90 data points) is too short to cover all wind directions and wind speed has no direct influence on the shoaling speed, it is mainly the direction that is important.

Thirdly we redid the trend analyses based on validated data collected within the first year where dredged and dispersed volumes of each trip were recorded and bed level measurements were available with a spatial resolution of 1 meter. The results showed that we still have insufficient data to create regressions for each wind direction. South-western wind is the most dominant wind direction for shoaling, but the quality of the prediction and direction (increasing or decreasing shoaling trend by increasing wind power) differs greatly for the 100 dredge locations.

Automatic report generation and permit monitoring

Multiple automatic report functionalities have been created to assist the contractor in fulfilling his obliged duties regarding their client. The reports are a notification email including links to the raw data of recently measured echo sounder data. Weekly overviews in chart and tabular format of the dredged and dispersed volumes for each location. Monthly overviews of all registered trips and automatic generation of CAD layout (A0) of raw echo sounder data.

All dredge fields and dumping locations are subject to multiple permit licenses regarding the allowance, quality and quantity of dredging activities (both loading and dumping). Since all these permits are provided through multiple authoritative departments where each permit has a different expiry date it is important to provide warnings in-time if a permit is subject to renewal.

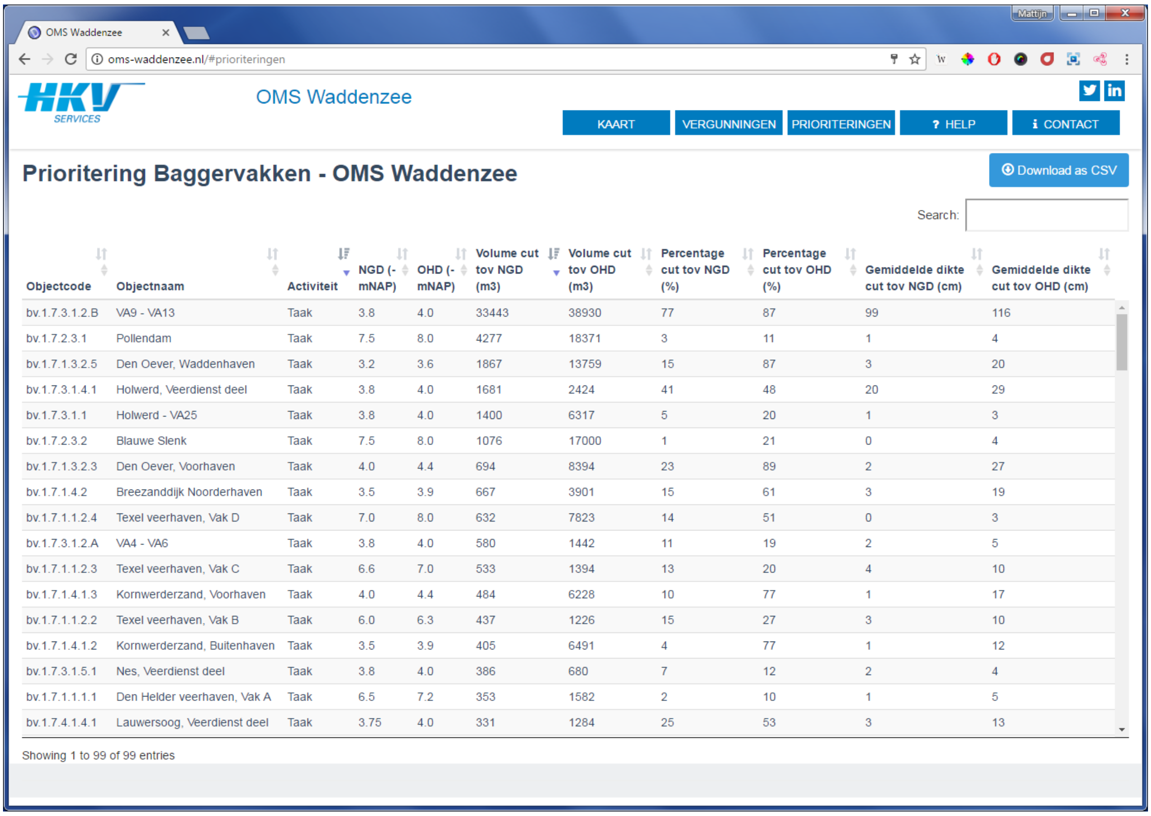
Apart from the automatic generated reports and validity of permits, the collected dredged and dispersed volumes are also validated against currently known maximums mentioned in the permits, where an warning for example is provided if the dumping locations are reaching their maximum based on the permit provided volume and the dispersed volumes registered.

Communication with stakeholders

As all data from multiple sources are processed, analysed, distributed and visualized from a centralized repository the system also becomes an important place for other stakeholders apart from the contractor hired specialists. We therefore set up an interactive web-based interactive dashboard with multiple derived datasets used for view purposes.

The dashboard is currently of great usage for:

- Creating the weekly planning by daily recalculation of the priorities based on the newly collected bathymetrical information that are translated into volumes/percentages/average thickness based on the minimum and maximum declared bed level depth of each dredge field (see Figure 3).
- The people on board the dredge vessels to identity in detail where within the dredge field should be most detail given based on the interactive single meter spatial resolution map provided by means of an optimized web mapping service (WMS, Figure 4) for both the maximum and minimum declared bed level depth *('nautical guaranteed depth'* and *'maintenance depth'* respectively).
- The contractors client to have quick insight in the weekly aggregated dredged and dispersed volumes for all locations as is shown in Figure 5.



OMS Waddenzee

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Prioritering Baggervakken - OMS Waddenzee

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Search:

Objectcode	Objectnaam	Activiteit	NGD (-mNAP)	OHD (-mNAP)	Volume cut tov NGD (m3)	Volume cut tov OHD (m3)	Percentage cut tov NGD (%)	Percentage cut tov OHD (%)	Gemiddelde dikte cut tov NGD (cm)	Gemiddelde dikte cut tov OHD (cm)
bv.1.7.3.1.2.B	VA9 - VA13	Taak	3.8	4.0	33443	38930	77	87	99	116
bv.1.7.2.3.1	Pollendam	Taak	7.5	8.0	4277	18371	3	11	1	4
bv.1.7.1.3.2.5	Den Oever, Waddenhaven	Taak	3.2	3.6	1867	13759	15	87	3	20
bv.1.7.3.1.4.1	Holwerd, Veerdienst deel	Taak	3.8	4.0	1681	2424	41	48	20	29
bv.1.7.3.1.1	Holwerd - VA25	Taak	3.8	4.0	1400	6317	5	20	1	3
bv.1.7.2.3.2	Blauwe Slenk	Taak	7.5	8.0	1076	17000	1	21	0	4
bv.1.7.1.3.2.3	Den Oever, Voorhaven	Taak	4.0	4.4	694	8394	23	89	2	27
bv.1.7.1.4.2	Breezanddijk Noorderhaven	Taak	3.5	3.9	667	3901	15	61	3	19
bv.1.7.1.1.2.4	Texel veerhaven, Vak D	Taak	7.0	8.0	632	7823	14	51	0	3
bv.1.7.3.1.2.A	VA4 - VA6	Taak	3.8	4.0	580	1442	11	19	2	5
bv.1.7.1.1.2.3	Texel veerhaven, Vak C	Taak	6.6	7.0	533	1394	13	20	4	10
bv.1.7.1.4.1.3	Kornwerderzand, Voorhaven	Taak	4.0	4.4	484	6228	10	77	1	17
bv.1.7.1.1.2.2	Texel veerhaven, Vak B	Taak	6.0	6.3	437	1226	15	27	3	10
bv.1.7.1.4.1.2	Kornwerderzand, Buitenhaven	Taak	3.5	3.9	405	6491	4	77	1	12
bv.1.7.3.1.5.1	Nes, Veerdienst deel	Taak	3.8	4.0	386	680	7	12	2	4
bv.1.7.1.1.1.1	Den Helder veerhaven, Vak A	Taak	6.5	7.2	353	1582	2	10	1	5
bv.1.7.4.1.4.1	Lauwersoog, Veerdienst deel	Taak	3.75	4.0	331	1284	25	53	3	13

Showing 1 to 99 of 99 entries

Figure 3 Overview of the daily regenerated prioritization in interactive tabular form sorted by volumes to dredge to comply with minimal required depths per location.

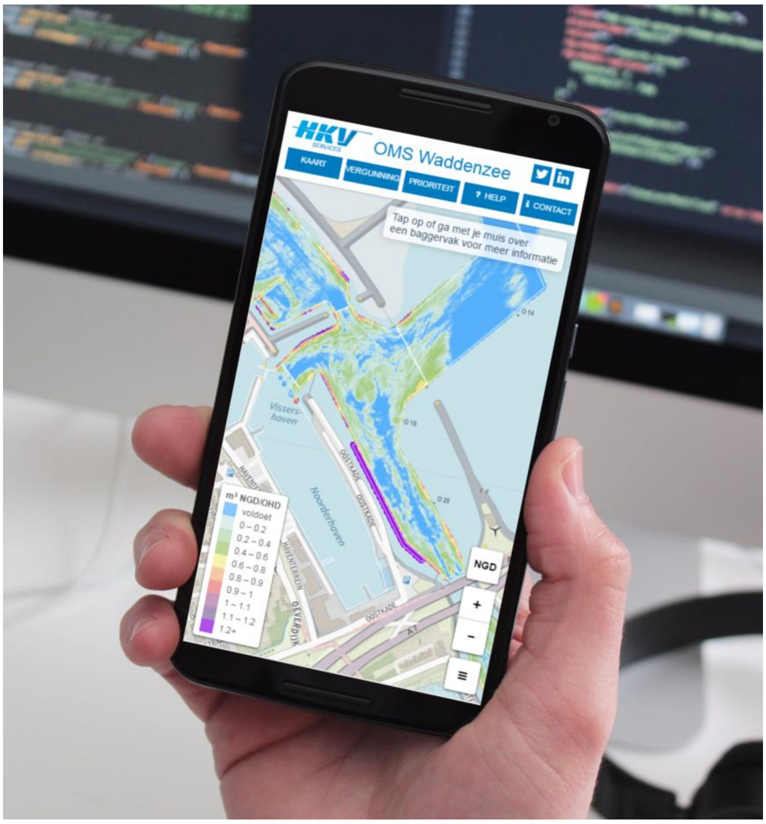

Figure 4 The most actual bed level subtracted the declared maximum bed levels depth visualized spatially in very high resolution accessible by hand-held devices such as smartphones.

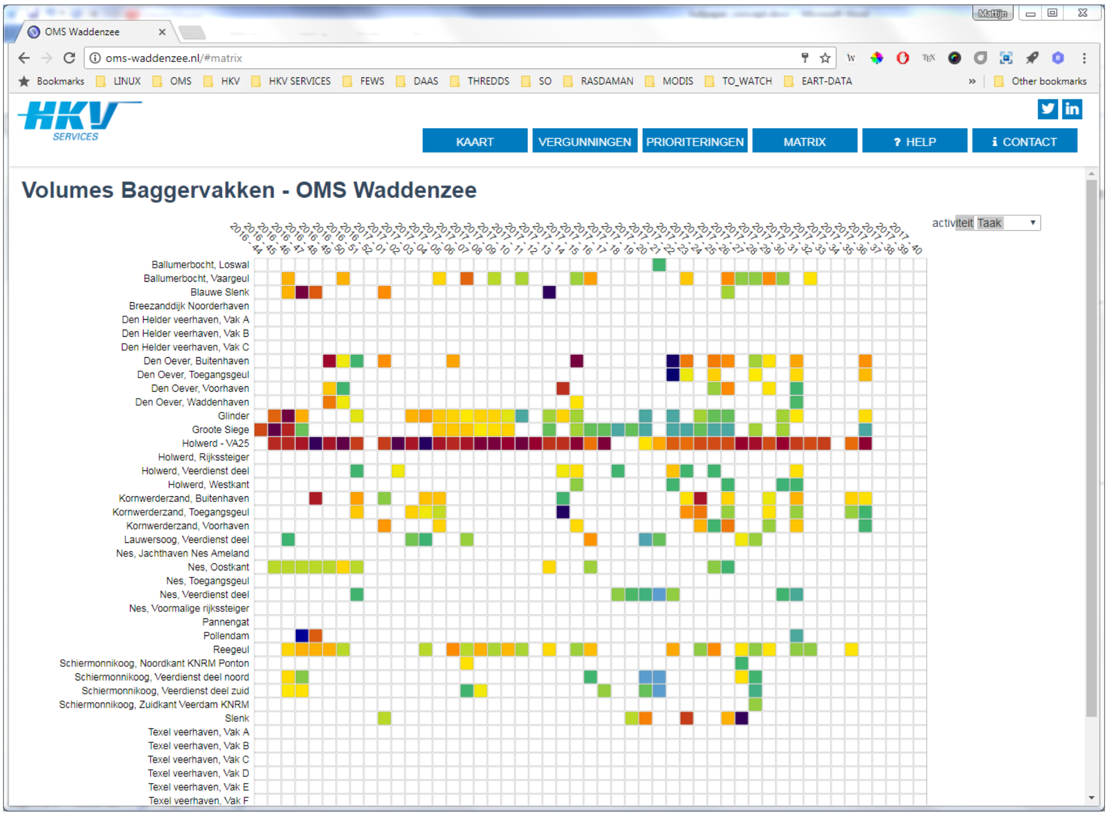

Figure 5 Interactive matrix overview within the dashboard presenting aggregated dredged volumes with dredge fields on the y-axis and weeks on the x-axis.

Conclusion

The developed MMS is in operation and provides in essential information for day-to-day activities on the dredge vessels, the week-to-week activities such as planning and month-to-month activities such as detailed overviews of dredged and dispersed volumes.
Forecast information are still subject to further investigation from which the confidence is likely to increase year by year as more data becomes available.
The adopted method for the developed MMs presents capability of producing alerts and warnings before bottlenecks become critical, where the interactive dashboard is received with great interest of all actors within the project.
Future developments will focus on improved automatic report generation and the adoption of remote sensing imagery for turbid plume detection, as a proxy for shoaling