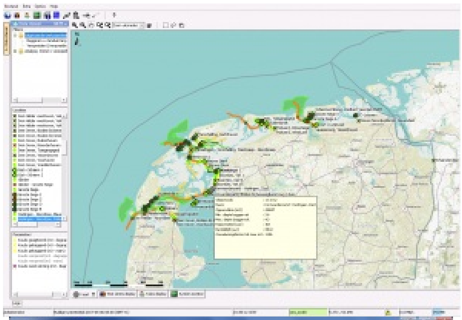
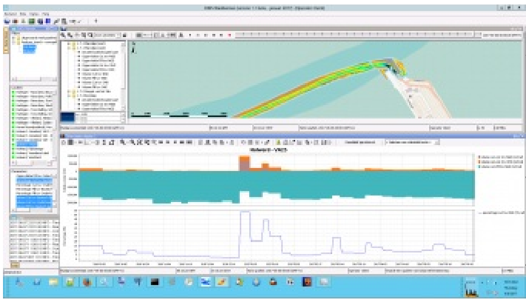
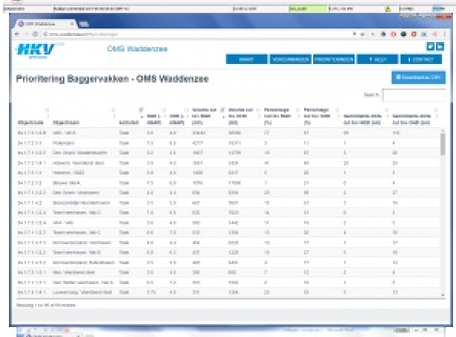
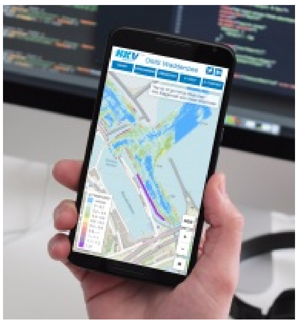
MORPHOLOGICAL MONITORING AND FORECASTING THROUGH DEVELOPMENT OF A MAINTENANCE MANAGEMENT SYSTEM

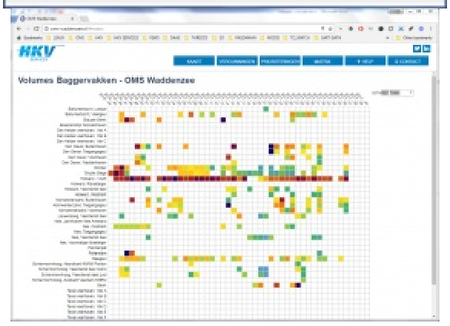
Proactive Dredging in the Dutch Wadden Sea











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

The challenge of working in these conditions is to find a balance between the strict limitations of the work 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 into the system, where adoption of the MMS results in the ability to pinpoint dredging activities, while reducing calamities and sharpening operational capabilities to reduce and optimise costs.

Study Area

The Dutch Wadden Sea has been on the UNESCO's World Heritage List since 2009 and is therefore a protected nature reserve. It is a highly dynamic system in terms of biodiversity and morphology due to tidal effects. The area is famous for its rich flora and fauna and there are multiple designated protected locations for mussel seed banks, shell production sites and seal reserves.

There is also economic activity in the region and multiple cables and pipelines are registered to be in place for data and telecom, electricity, gas and liquids, with a total length of nearly 850 kilometres. As numerous islands are also present, five of which are accessible for the general public, the region is also of great recreational value.

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

Figure 1: Geographical overview map of the MMS where location 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 multibeam echo sounders.

While some surveys are conducted every other month, such as the dredge fields with little dynamics in the seabed changes, others require a highly intensive weekly survey frequency as these dredge fields might contain significant shoaling. The multiple ferries active on the different navigation channels provide or will provide depth level measurements using single-beam echo sounders.

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

Each of these numerical measurements are entered into the MMS servers in a standardised fashion so they can be processed automatically.

Monitoring of the Actual Bed Level

All multibeam echo sounder data presented to the MMS server are validated and have a spatial resolution of 1 by 1 metre. As the exact location of measurements is unknown from the 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 metres. In total, 500 tiles are currently 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 validation checks is, by contract, allowed to take a number of weeks. In other words, computation of the actual bed level is a daily process that retroactively considers changes in the last 30 days. Using the actual bed level several derivatives are computed (see Figure 2) such as the volume, percentage and average depth above and below the minimum and maximum declared bed level. This is the main input data for planning and monitoring the dredging activities and reports for the contractor's clients.

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

Forecasting of the Bed Level 10 Days 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 based on monthly information 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 the grid had a spatial resolution of 400 metres. 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 metre spatial resolution, but this is still too coarse when comparing these with the measured spatial resolution of 1 metre from current multibeam 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 of wind that is important.

Thirdly, we carried out the trend analyses again based on validated data collected within the first year of the current contractor where dredged and dispersed volumes of each trip were recorded and bed level measurements were available with a spatial resolution of 1 metre. The results showed that we still have insufficient data to create regressions for each wind direction. A southwesterly 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) still differs for the 100 analysed dredge locations.

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

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 following reports were reported through notification emails:

- Recently measured echo sounder data, including links to the raw 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.

Apart from the automatically generated reports and validity of permits, the collected dredged and dispersed volumes are also validated against currently known maximums mentioned in the permits, where a warning is provided if the dumping locations reach their maximum based on the permit allowed volume.

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 by a number of 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.

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

Communication with Stakeholders

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

The dashboard is currently very useful for:

- Creating the weekly planning by daily recalculation of the priorities based on the newly collected bathymetrical information that is 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 of the dredge vessels to identity in detail where in the dredge field most detail should be given based on the interactive single metre spatial resolution map provided by means of an optimised web mapping service (WMS, Figure 4) for both the maximum and minimum declared bed level depth (‘nautical guaranteed depth’ and ‘maintenance depth’ respectively).
- The contractor’s client to have quick insight into the weekly aggregated dredged and dispersed volumes for all locations as shown in Figure 5.

Conclusion

The developed Maintenance Management System provides capabilities to proactively pinpoint dredge activities, reducing both calamities and total dredged volumes in the Dutch Wadden Sea. Detailed tracking of permits, and the dredged and dispersed volumes sharpens operation capabilities and reduce and optimise costs. The MMS has been in operation for nearly two years and provides essential information for day-to-day activities on the dredge vessels, week-to-week activities such as planning and month-to-month activities such as detailed overviews of dredged and dispersed volumes.

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 by all actors within the project.

Forecast information is still subject to further investigation but for which the confidence is likely to increase year by year as more data becomes available. 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.

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.