Monitoring of settling and consolidation of mud after water injection dredging in the Calandkanaal

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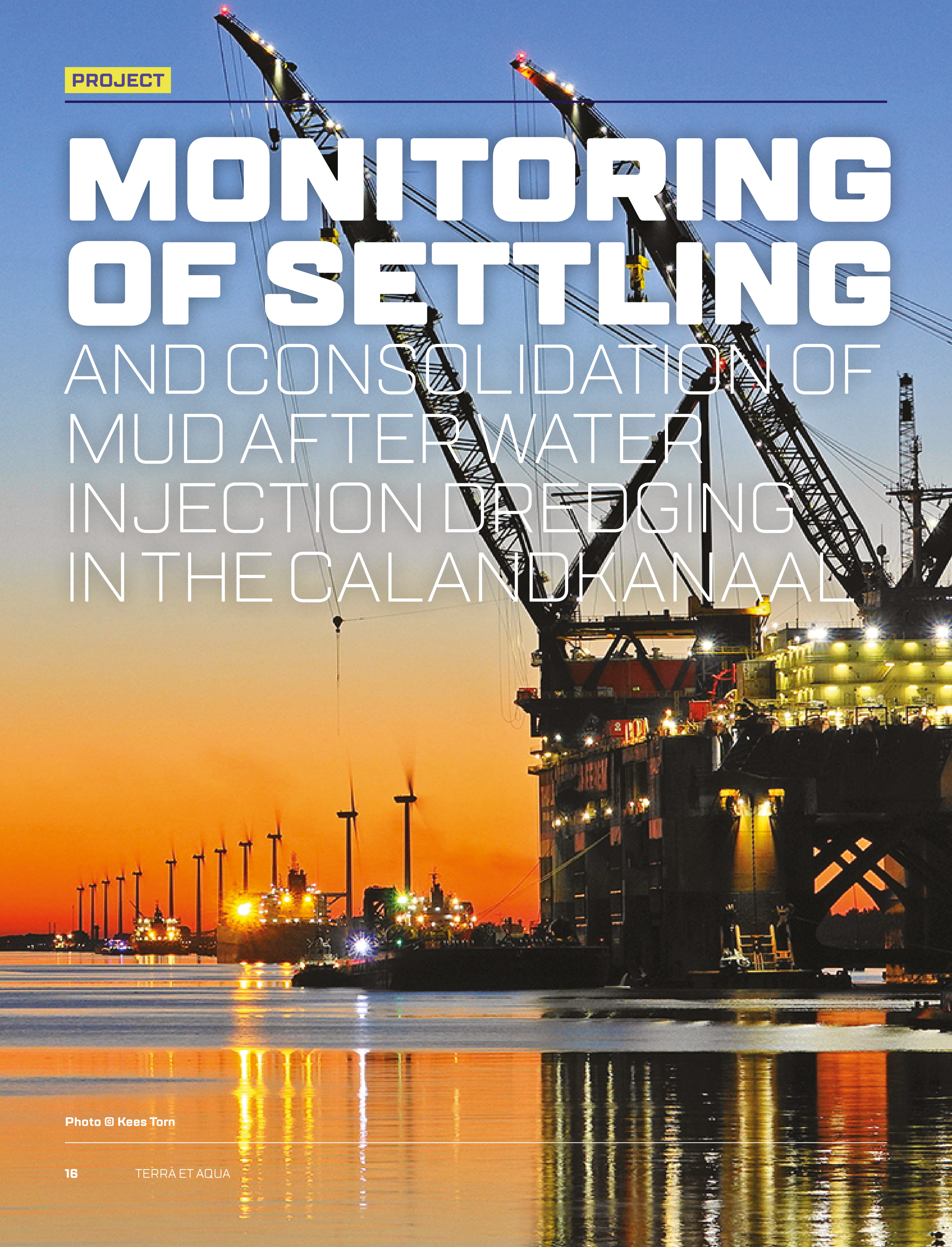
MONITORING OF SETTLING

AND CONSOLIDATION OF MUD AFTER WATER INJECTION DREDGING IN THE CALANDKANAAL



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As regular maintenance and relocation of sediment deposits are highly expensive, Port authorities seek more efficient solutions for reducing the costs and CO2 emissions of maintenance dredging. One solution, water injection dredging (WID), is carried out for maintaining the sediment deposits which predominantly consist of clay and silt. WID has been proven to be a cheaper solution by leaving the sediment in place, eliminating substantial costs for relocation of the dredged sediment.

In order to keep ports and waterways at Port of Rotterdam accessible, more than 11 million m³ of deposited sediment were dredged in 2017.

Introduction

Navigation in ports and waterways must be safeguarded by maintenance dredging, which removes sediments deposited by tide, river flows and currents. The volumes of dredged sediment have been substantially increased in the Port of Rotterdam (PoR) over the last five years (see Figure 1). In order to keep ports and waterways accessible, more than 11 million m³ of deposited sediment were dredged in 2017. The dredged volumes are almost doubled in comparison with the volumes dredged in 2011. The sediment depositions in these areas consist mainly of fine cohesive minerals forming mud layers, which are periodically dredged by a Trailer Suction Hopper Dredger (TSHD). As maintenance dredging and consequent relocation of mud can be highly expensive, port authorities seek for tailor-made solutions that can help to reduce the maintenance costs as well as CO2 emissions and at the same time guarantee safe navigation in the port.

There are various measures that can potentially help to reduce maintenance costs and CO2 emissions. For instance, revising the intervention protocols can bring additional short- and long-term benefits. In the long-term instead of removing sediment, its presence may be accepted since ships are – under certain conditions – able to sail through fluid mud. Local sediment conditioning may be required to avoid that mud layers become consolidated to allow sailing through them.

A conventional way for estimating the navigability in ports and waterways with fluid mud layers is done through the calculation of the nautical depth. This approach ensures that vessels can safely navigate through areas, where thick layers of fluid mud are detected. For practical reasons, a critical density (1200 kg/m³) is typically used for estimating the nautical depth within PIANC's nautical bottom approach (PIANC, 2014). However, it has long been recognised, that a practical definition of the nautical depth should be based on considerations not only of density but should also include the so-called rheological properties of the water-sediment mixture (Wurpts and Torn, 2005, Kirichek et al., 2018b). Currently, a rheological parameter (100 Pa yield stress) serves as a criterium for estimating the nautical depth in the Port of Emden.

Optimising current maintenance strategies can substantially reduce the costs and CO2 emissions. Water injection dredging (WID) can be efficiently applied for fluidising and transporting the sediment within the port area. By applying WID, it is proposed to keep port

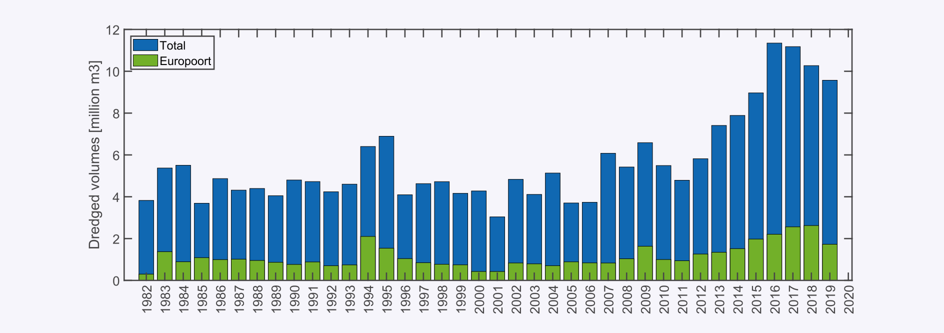

FIGURE 1

Dredged sediment volumes at the Port of Rotterdam from 1982 till 2020 (adapted from Kirichek et al., 2018a).

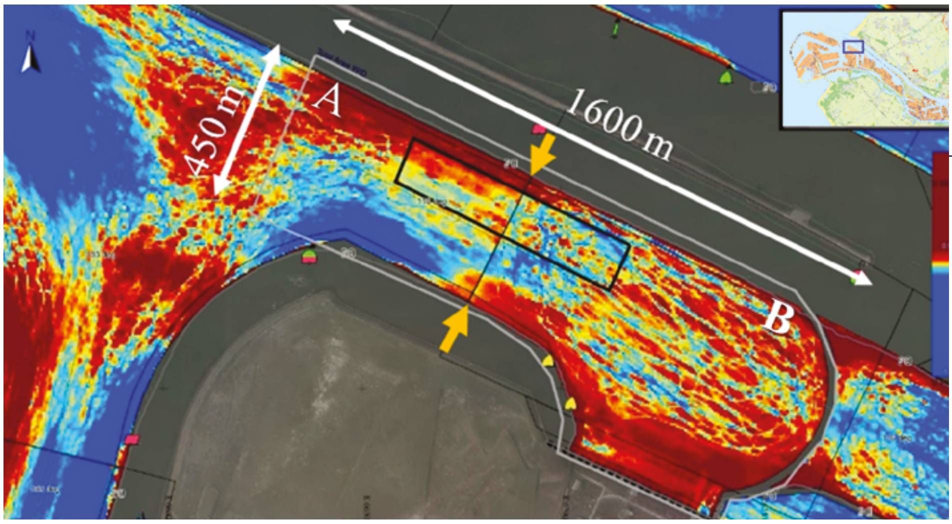

FIGURE 2

Location of the sediment trap in the Calandkanaal. Black rectangle shows the location of the sediment trap. Orange arrows indicate a boundary between Rijkswaterstaat's (A) and the PoR's (B) maintenance areas within the WID pilot location (gray contour). Based on the measured and simulated data, the western part of Europoort was chosen for the WID pilot.

locations, which are not easily accessible by TSHD, at required nautical depth. Fluidising the sediment by water injection creates homogeneous fluid mud layers of a substantial thickness (up to 2 m). These fluid mud layers have a weak shear strength (yield stress), therefore they can be easily transported as gravity currents by natural forces and/or by WID.

This paper presents the results of testing WID at the Calandkanaal. The efficiency of WID was compared to TSHD maintenance in the Calandkanaal. Available historical dredged volumes and CO2 emissions from the fuel consumption data from the last two years were analysed in order to assess the cost and CO2 efficiency of WID and TSHD for maintenance in the area of the investigation.

Descriptions of the pilot

Location

Several conditions had to be considered before location of the WID pilot was finally chosen. First, there should be enough sediment to fluidise and transport in the area. This sediment should be cohesive by its nature so that WID fluidising processes result in formation of fluid mud layers, which can be transported to the sediment trap.

Second, the sediment trap should be located further away from the berths to avoid any ship-induced entrainment that can affect settling processes in the sediment trap. Third, the hydrodynamic conditions are expected to be favorable for trapping the sediment, therefore preliminary hydrodynamic modelling was done in order to find a right location for the sediment trap.

Sediment trap and WID actions

Figure 2 shows the location, where the sediment trap was designed and WID was carried out. The sediment trap was made by a TSHD on the northern bank in the Calandkanaal. The dimensions of the trap are 600 m over 120 m. The over depth of the sediment trap varies from 1 m to 1.3 m.

WID was conducted for fluidising the deposited sediment in the area of the sediment trap over the length of 1600 m, so that the fluidised mud layers would flow into the sediment trap. The WID area is shown by the grey line in Figure 2.

Monitoring plan and attributes

The main objectives of monitoring surveys were to capture settling and consolidation behaviour of mud after WID and to compare yield stress (100 Pa) and density (1200 kg/m^3) levels for applying the nautical depth in the area of the investigation. In addition, sediment dynamics during WID (see Figure 3) was recorded.

The monitoring plan is given in Table 1. WID was performed during day 1. A preliminary survey was conducted before WID. The measurements from this survey were used as a reference. The monitoring campaign was carried out every Wednesday on a weekly basis starting from day 1 until day 84 with occasional surveys afterwards.

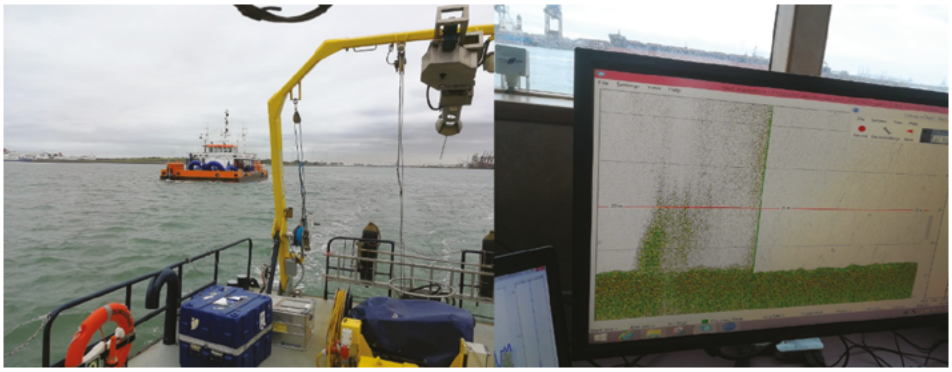

FIGURE 3

Monitoring during WID actions.

TABLE 1

Monitoring plan for the pilot.

	Week number	42	43	44	45	46	47	48	49	50	51	52	1	2	3	4	5
	Day	**0**	**1**	**7**	**14**	**21**	**28**	**35**	**42**	**49**	**56**	**63**	**70**	**77**	**84**	**91**	**98**
I.	Multibeam	▨	▨ WID	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	SILAS	▨	▨ WID	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
II.	DensX		WID	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨				▨
	Rheotune	▨	▨ WID	▨		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	Gaviprobe	▨	▨ WID	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
III.	Frahmlot	▨	▨ WID	▨		▨	▨			▨				▨	▨		
	Slib Sampler	▨	▨ WID	▨		▨	▨			▨				▨	▨		
	MARS Haake	▨	▨ WID	▨		▨	▨			▨				▨	▨		

Table 2 provides the list of monitoring attributes which were used during the monitoring campaign. The monitoring attributes can be divided into three groups:

1. Acoustic/seismic tools;
2. Penetrometers;
3. Laboratory analysis.

There are two tools in Group I. These tools provide a 2D and 3D high resolution bathymetry and shallow subsurface profiles. Teledyne RESON SeaBat 7101 multibeam echo-sounder with Septentrio Asterx-U VRS GNSS positioning, Ixblue Hydrins motion sensor and Stema SILAS system are mounted on the survey vessel that was used for monitoring (see Figure 3). These two systems are used by the PoR surveyors for day-to-day surveys. The high-frequency multibeam echo-sounder is used for mapping the water-sediment level (200 kHz) and low-frequency (38kHz) SILAS system is employed in the port areas with mud layers, where the density-based (1200 kg/m^3) nautical bottom approach is applied for mapping the nautical guaranteed depth (NGD) on the nautical charts (Kirichek et al., 2018b).

TABLE 2

Monitoring tools used in the pilot.

Tool	Output	Unit
Multibeam	Water-mud level	m
SILAS	100 Pa and 1200 kg/m^3 levels	m
Graviprobe	Undrained shear strength	Pa
Rheotune	Density, Bingham stress vertical profiles	Pa, kg/m^3
DensX	Density vertical profile	kg/m^3
Frahmlot	Mud samples	-
Slibsampler with Anton Paar	Density vertical profile	kg/m^3
MARS Haake Rheometer	Yield stress	Pa

> **The monitoring campaign was carried out every Wednesday on a weekly basis starting from day 1 until day 84 with occasional surveys afterwards.**

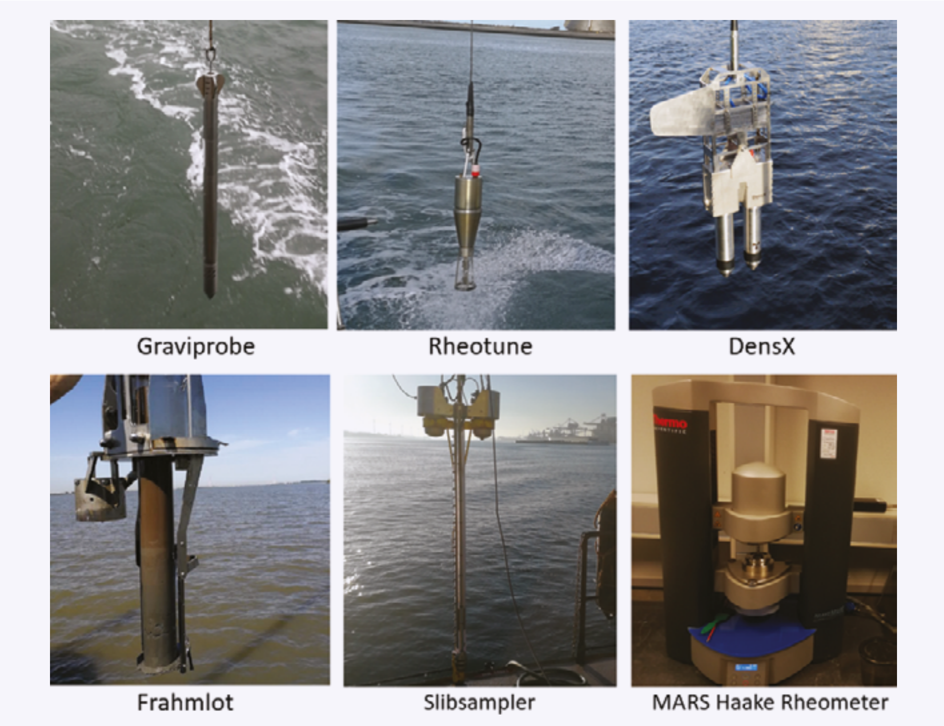

FIGURE 4

Vertical profilers and the rheometer that were used for characterising the mud layers.

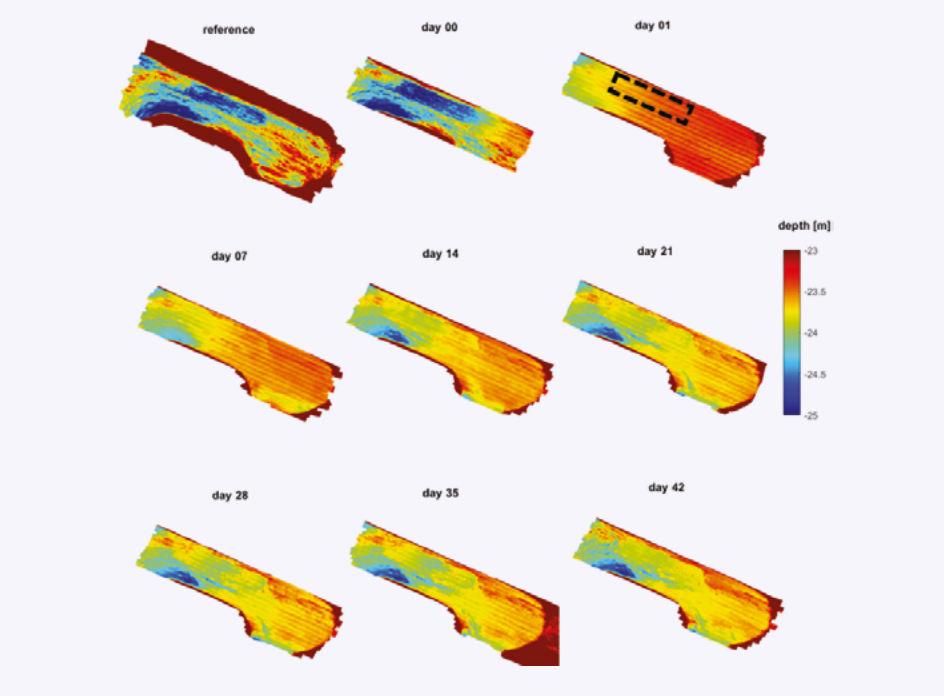

FIGURE 5

Development of bathymetry (water-mud level) before (reference) and after (day 01-day 42) WID. Black rectangle on 'day01' shows the location of the sediment trap.

Group II consists of three penetrometers, that measure physical parameters in the water-mud column. These tools are shown in Figure 4. DensX provides the vertical profile of density. The measurements of this device are based on X-ray scattering. At this moment, DensX measurements are used by Rijkswaterstaat and the PoR to measure densities of mud for SILAS calibration process, that allows applying 1200 kg/m^3 level for the nautical depth. Rheotune provides Bingham yield stress and density vertical profiles in water-mud columns. This tool correlates the amplitudes, that are triggered by mechanical vibrations at resonance frequencies, to either density or Bingham yield stress datasets, which are collected on various mud samples of different physical properties in laboratory. Graviprobe provides the vertical profile of the undrained shear strength, which is determined from the measured acceleration/deceleration of the instrument, that is acquired during a free-fall of Graviprobe.

Laboratory analysis was conducted by using the equipment in Group III. Initially, the sediment samples were collected using Slibsampler or Frahmlot. The former collects sediment core samples by using cylindrical tube with openings on the lateral side. The openings can be used for collecting a fluid mud samples from the core, that can be analysed directly on-board using Anton Paar density meter. The latter has a cylinder, that is connected to Frahmlot, and enables to collect soft sediment core samples up to 1 m in length and 0.1 m in diameter. The collected core is then subsampled and transported to a laboratory for further characterisation. The density and yield stresses of collected samples were measured in the laboratory. Anton Paar density meter was used for estimating the density of samples. As for rheology, MARS Haake Rheometer was utilised for analysing the yield stresses of mud samples. Newly developed time-efficient protocols (Shakeel et al., 2019) were applied for measuring the yield stresses.

Results and discussion

The monitoring results showed that state-of-the-art monitoring and surveying methods can provide us with useful information on development of mud layers due to WID and subsequent settling and consolidation processes. The monitoring tools from Group I gave a high-resolution spatial image during and after WID. Figure 5 shows the bathymetry before (reference, day 00) and after (day 01–day 42) WID. The indicated depth corresponds to the depth of water-mud interface. By comparing the measurements that were recorded before and after WID actions (day 00 and day 01, respectively), it was concluded that about 2 m of fluid mud was collected by the sediment trap. Further analysis showed that the mud layer settled in the sediment trap. This conclusion was justified by the fact that the contours of the sediment trap became more pronounced on the data acquired on day 42 comparing to the measurements collected on day 7. One might argue that the sediment didn't settle but eroded, however the sediment depositions around the sediment trap (see day 42) suggested that the settling process indeed took place at the sediment trap.

Figure 6 shows seismic profiles produced by the SILAS system. Typically, the processed data was used for correlating the density to seismic measurements in order to obtain density-based nautical bottom levels. Vertical blue and red lines are the Bingham yield stress and the density profiles that were measured by Rheotune. The change in seismic amplitudes (from light green to dark green) showed that there was no density gradient indication on the seismic data of the top sediment layer (Day 7, depth above 24.5m), suggesting that the top mud layer was homogeneous which is expected from fresh fluid mud layer.

The horizontal red line shows 1200 kg/m^3 levels, which were obtained by correlating the vertical density profiles given by Rheotune to seismic data acquired by SILAS system. The 1200 kg/m^3 level was in a proximity to a sharp color gradient (Day 7, depth of 25m), which could serve as an indication of the fluid mud – natural bed interface. However, a good correlation was only observed for a fresh fluid mud layer that was produced by WID (Day 7). Subsequent data (Day 21 and Day 42) showed a poor correlation between the 1200 kg/m^3 level and the sharp color gradient because of consolidation of fluidised mud.

Figure 7 shows the spatial variation of 1200 kg/m^3 levels during and after WID. The colour map corresponds to the depth, where sediment has a density of 1200 kg/m^3. The observation suggested that the fluidised sediment consolidated in the sediment trap

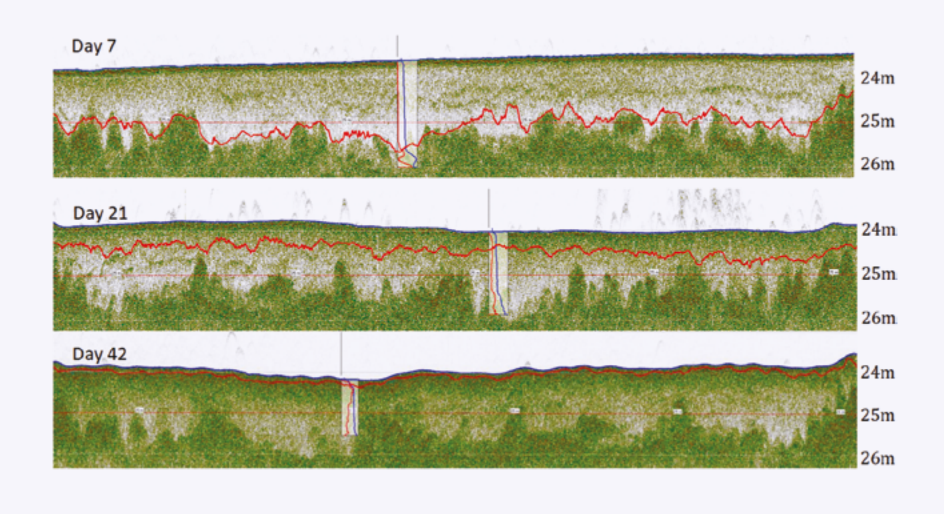

FIGURE 6

Vertical seismic profiles measured after WID at the Calandkanaal. Red line shows the 1200 kg/m^3 level.

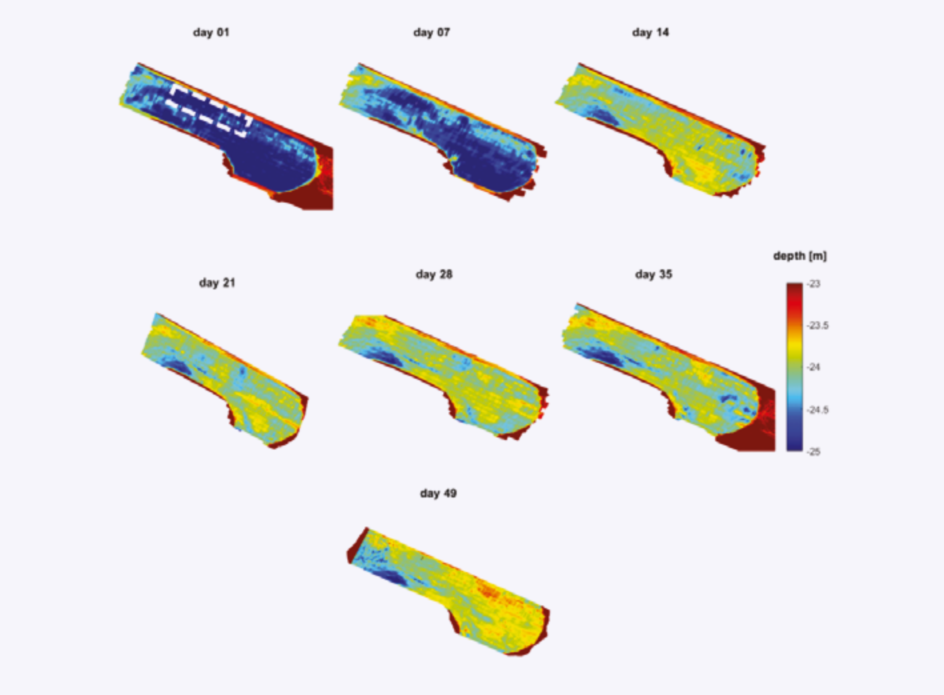

FIGURE 7

Development of 1200 kg/m^3 level after WID (day 01–day 49) at the Calandkanaal. White rectangle on 'day 01' shows the location of the sediment trap.

and in the surrounded area. However, the sediment did not consolidate at the South-West area, because this area was eroded due to hydrodynamic conditions. The eroded area was also clearly observed in the bathymetry data (see Figure 5).

The water-mud and 1200 kg/m^3 levels over the cross-section (see Figure 2) of the Calandkanaal are shown in Figure 8. The development of 1200 kg/m^3 level showed that mud layers in the sediment trap reached 1200 kg/m3 densities in 2-6 weeks suggesting that the over depth of the sediment trap can be used by arriving vessels for up to 6 weeks after WID if the density-based nautical bottom approach is applied.

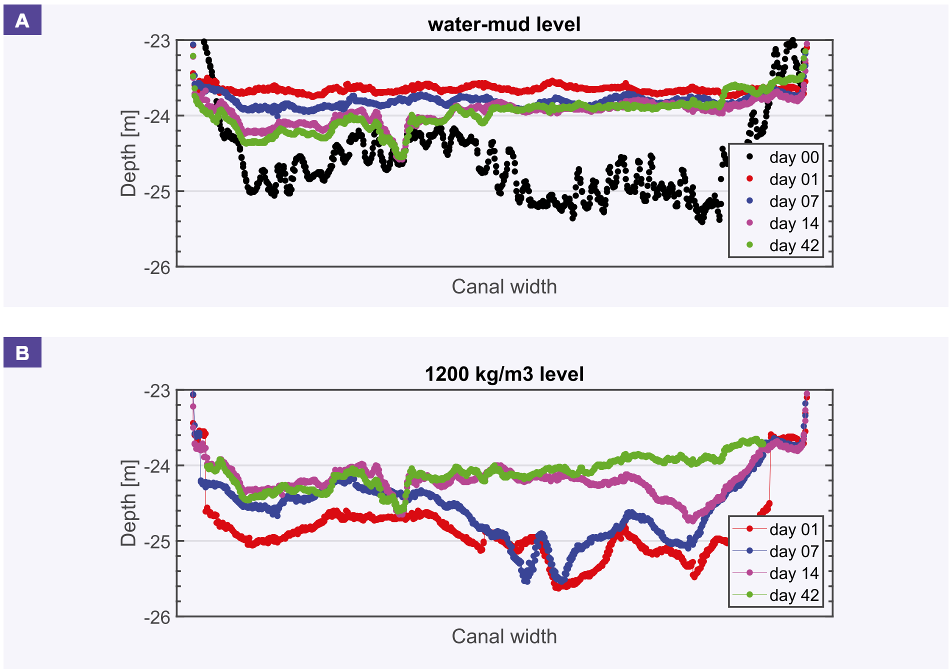

FIGURE 8

Development of water-mud level (A) and of 1200 kg/m^3 level (B) in time over the cross-section of the Calandkanaal (shown by orange arrows in Figure 2).

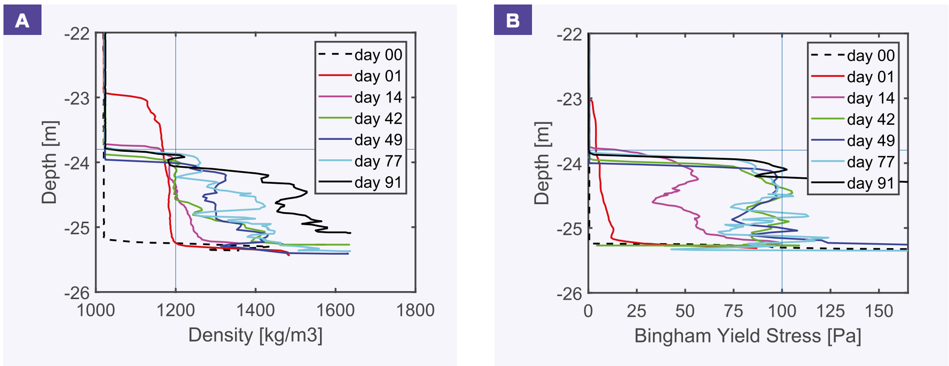

FIGURE 9

Density (A) and Bingham Yield Stress (B) profiles measured by Rheotune before (day 00) and after WID (day 01 – day 91) at the Calandkanaal.

The development of density and yield stress profiles measured by Rheotune in the sediment trap are shown in Figure 9. The measurements were conducted before (day 00) and after WID (day 01 – day 91). Day 00 shows the reference. Clearly, there was no fluid mud layers on the reference profiles (day 00). The measurements that were carried out right after WID (day 1) showed that the WID produced a fluid mud layer of about 2 m height. This fluid mud layer had a weak strength (the Bingham yield stress was less than 10 Pa) and the density was less than 1200 kg/m^3.

Two weeks after WID (day 14), the density of mud reached 1200 kg/m^3 at the bottom of the layer due to consolidation process. The Bingham yield stress of the settled layer was less than 60 Pa, suggesting that mud still had a weak strength.

Six weeks after WID (day 42), the density level reached 1200 kg/m^3, but the Bingham yield stress level of the layer was less than 100 Pa. Laboratory analysis showed that collected mud hadn't reached its consolidated phase and might be in a transition from fluid to consolidated phase. In addition, laboratory measurements showed a good correlation between laboratory and Rheotune's measured densities and Bingham yield stresses (Kirichek et al, 2020).

The density measurements conducted almost two months after WID (day 77), showed that mud had densities closer to 1300 kg/m^3 and the Bingham yield stresses of about 100 Pa.

DensX and Graviprobe measurements were used to confirm respectively the density and shear strength development of mud layer in the sediment trap. Figure 10 shows density and undrained shear strength profiles measured by DensX and Graviprobe before (day 01) and after WID (day 01 – day 98).

The DensX density profiles (Figure 10A) were in an acceptable agreement with the Rheotune density profiles (Figure 9A) in the density range of 1000-1250 kg/m^3. For the densities above 1250 kg/m^3, Reotune's profiles had more noise in the dataset.

The development of shear strength measurements provided by Graviprobe was consistent with the ones of Rheotune. From the Graviprobe measurements in the sediment

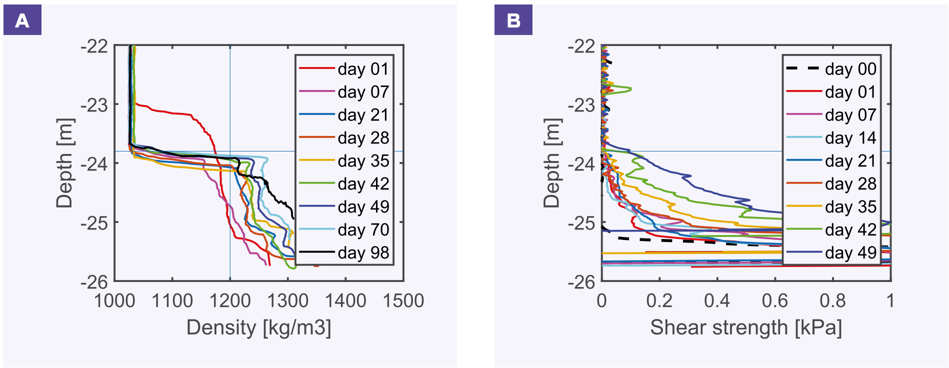

FIGURE 10

Density and undrained shear strength profiles measured by DensX and Graviprobe before (day 00) and after WID (day 01 – day 98) at the Calandkanaal.

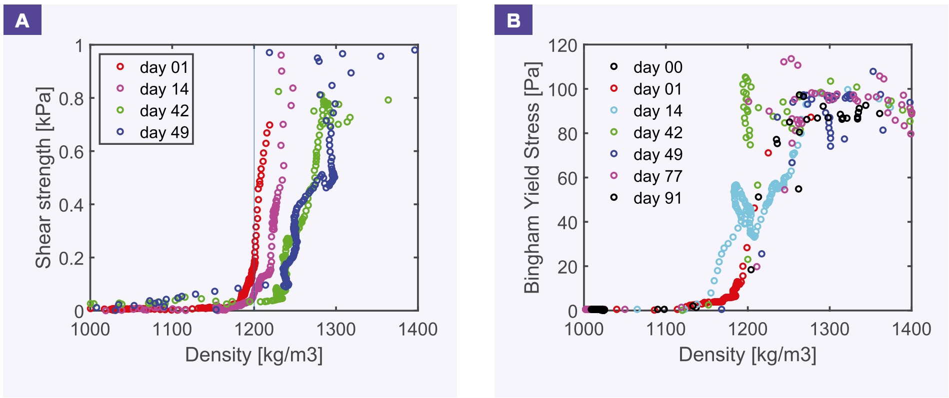

FIGURE 11

Density – yield stress/shear strength relationship measured (A) by DensX and Graviprobe, and (B) by Rheotune.

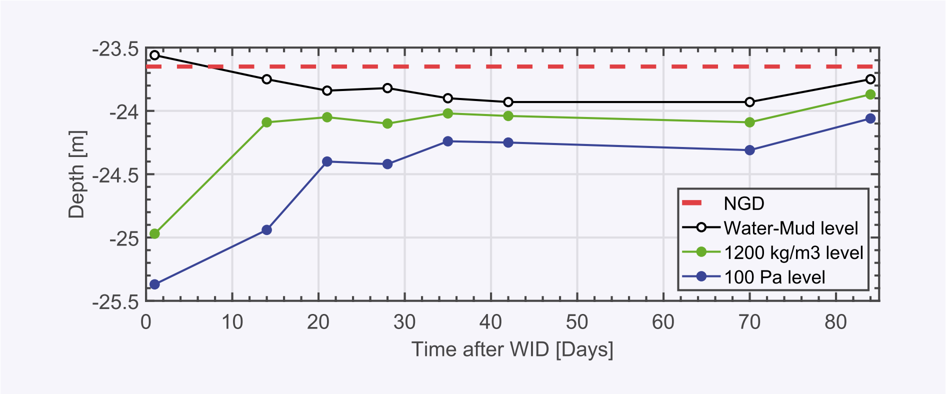

FIGURE 12

Development of measured water-mud level (black circles), 1200 kg/m^3 level (green circles) and 100 Pa level (blue circles) after WID at the Calandkanaal. Red dashed line shows the Nautical Guaranteed Depth at the area of the investigation.

trap, it was concluded that the sediment gained 0.2 kPa undrained shear strength in two months (day 49). This is in line with the Rheotune measurements of the Bingham yield stress profiles shown in Figure 9.

Figure 11 shows a non-linear relationship between density and strength, that was measured by Rheotune (see Figure 11A) and by DensX and Graviprobe (see Figure 11B). This figure demonstrates, that the density of mud does not provide any information about the strength because the strength of mud is time-dependent. The density-strength relationship that was measured by DensX and Graviprobe had less scatter of the data than the one measured by Rheotune (see Figure 11B), especially at densities above 1200 kg/m^3. This was most probably because DensX and Graviprobe
can penetrate mud with densities above 1200 kg/m^3 easier than Rheotune.

In-situ strength and density profiles can be useful for improving maintenance strategies in ports in waterways. For instance, the measurements collected after WID can potentially be combined with consolidation modeling (Kirichek et al, 2020). Using density and strength profiles as input parameters for numerical models can provide a valuable tool for estimating a time line for the next maintenance cycle. Furthermore, knowledge of the density of deposited sediments can help to determining the volumes that should be dredged by WID or TSHD. Finally, the density and strength measurements can be used for estimating the navigable depth. Figure 12 shows the comparison of a regular bathymetry-based criterium for navigation to the yield stress and density based nautical depths, which correspond to 100 Pa and 1200 kg/m3 levels, respectively. Applying the nautical bottom approach in the area of the investigation resulted in additional 2 m and 1.5 m of nautical depth right after WID (day 1) in case of applying 100 Pa and 1200 kg/m3 criteria, respectively. As mud settled, the density of mud built up faster than the yield stress, therefore the 1200 kg/m^3 level was always higher than the 100 Pa level. Furthermore, the 1200 kg/m3 level reached the equilibrium in 2 weeks after WID, but it took about 5 weeks for reaching a constant depth over time for the 100 Pa level. After 1 month, the difference between 1200 kg/m3 and 100 Pa levels were about 20-30 cm in favor of

An initial impression of the efficiency of the WID pilot at the Calandkanaal was analysed by comparing the historical data on dredged volumes of dry matter at the area of the investigation.

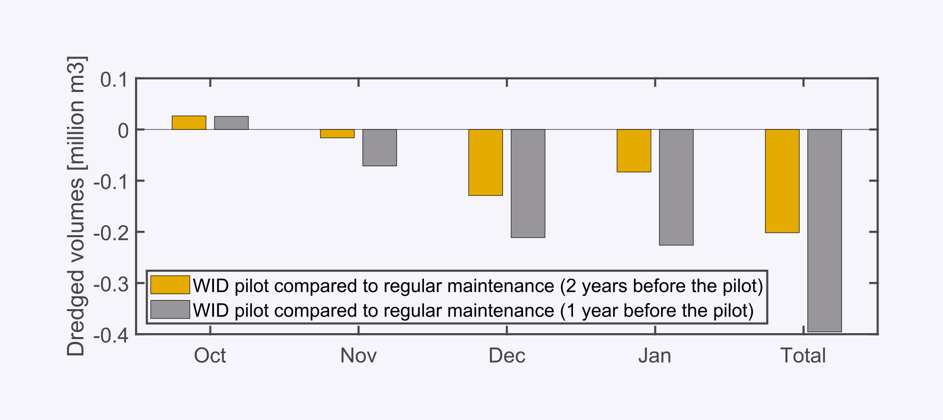

FIGURE 13

Difference of the dredged volumes during the WID pilot (Oct 2018 – Jan 2019) and the volumes that were dredged at the same area one year before the WID pilot (Oct 2017 – Jan 2018) is shown in grey bars. Difference of the dredged volumes during the WID pilot (Oct 2018 – Jan 2019) and the volumes that were dredged two years before the pilot (Oct 2016 – Jan 2017) is shown in orange bars.

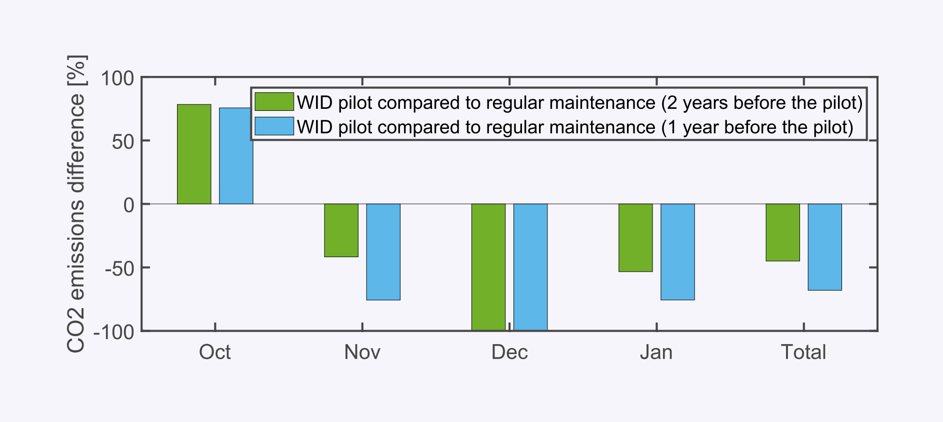

FIGURE 14

Difference of the CO2 emissions from the fuel consumption of dredging vessels during the WID pilot (October 2018–January 2019) and the CO2 emissions at the same area one year before the pilot (October 2017–January 2018) is shown in blue bars. Difference of the CO2 emissions during the WID pilot and the CO2 emissions two years before the WID pilot (October 2016–January 2017) is shown in green bars.

yield stress based nautical depth. Finally, the regular maintenance was conducted in the area almost in 3 months after WID, which is a positive outcome because normally the area of the investigation is maintained every month by a regular maintenance.

Initial impression of cost implications of CO2 emissions

An initial impression of the efficiency of the WID pilot at the Calandkanaal was analysed by comparing the historical data on dredged volumes of dry matter at the area of the investigation. For this analysis, the dredged volumes data from the PoR's maintenance area (see Figure 2) was used. The comparison is done for the period of the WID pilot (Oct 2018 – Jan 2019), one year (Oct 2017 – Jan 2018) and two years (Oct 2016 – Jan 2017) before the WID pilot. The data on the dredged volumes for earlier periods is not considered in the analysis because of infrastructural changes in the vicinity of the WID pilot area.

Figure 13 shows the differences of the dredged volumes that were obtained by subtracting the volumes that were dredged one year ago and two years ago from the dredged volumes during the WID pilot.

In general, the dredged volumes for the first month (October) were higher for the WID pilot because of additional dredging actions needed for making a sediment trap. After the first month, the volumes dredged during the WID pilot were much lower because regular maintenance was not needed after WID. By analysing the total difference of the dredged volumes, it could be concluded that the WID pilot was able to keep sediment in place and to prevent dredging of about 200,000–400,000 m^3 in the area of the investigation in the Calandkanaal. However, more detailed study has to be conducted in order to refine the outcome of the pilot. For instance, more knowledge on the sediment balance will help to analyse the impact of the WID pilot on the sedimentation in other areas of the port.

The CO2 emissions estimates from the fuel consumption of dredging vessels for the period of the WID pilot (October 2018–

January 2019) were compared to the CO2 emissions at the same area one year ago (October 2017–January 2018) and two years ago (October 2016–January 2017). The CO2 emissions were determined from the data of dredged volumes, dredging cycles, durations and fuel type consumed by WID and TSHD vessels. Figure 14 shows the results of the comparison. The CO2 emissions during the first month (October) of the WID pilot were about 75% higher than the CO2 emissions one and two years ago because more dredged volumes were needed for making a sediment trap and additional CO2 emissions from the WID vessel. However, the subsequent emissions for the period of the WID pilot were much lower than those of one and two years ago. For instance, in December the CO2 emissions during the WID pilot were 100% lower than those of one year and two year ago because no maintenance was needed during the WID pilot during this month. For the total duration of the pilot, the WID pilot was more CO2 efficient than the regular maintenance helping to reduce the CO2 emissions by 45-65%.

Conclusions

The effect of WID in the Calandkanaal was monitored for three months by means of measuring the development of density and strength (yield stress) during settling and consolidation of fluidised mud layer. It was concluded that in-situ data can be useful for estimating settling and consolidation time of mud after WID. Furthermore, measured yield stress and density profiles were used for PIANC's nautical bottom applications, where 1200 kg/m^3 and 100 Pa levels were adapted for estimating the nautical depth.

Utilising the nautical bottom approach brought an additional 2 m and 1.5 m of nautical depth right after WID in case of applying 100 Pa and 1200 kg/m^3 criteria, respectively. The 1200 kg/m^3 level was always higher and built up faster than the 100 Pa level. The regular maintenance was conducted almost in 3 months after WID implying a successful outcome of the WID pilot since the area of the investigation is normally maintained every month by a TSHD.

The efficiency of the WID pilot was compared to the regular maintenance in the area of the investigation in the Calandkanaal. An initial impression of cost implications obtained from the analysis of historical dredged volumes showed that during the WID pilot dredged volumed decreased by 200,000-400,000 m^3 comparing to the volumes dredged 2 and 1 years before the WID pilot at the same location and the same time of year. However, an additional analysis on the sediment balance should be carried out in order to refine the outcome of the WID pilot in the Calandkanaal and to study the impact of the WID pilot on the other areas of the port.

The CO2 emissions from the fuel consumption of dredging vessels were determined for the period of the WID pilot and for the regular TSHD maintenance conducted one and two years before the WID pilot at the same area and the same time of year. The CO2 emissions were estimated from the data on dredged volumes, dredging cycles, durations and fuel type consumed by WID and TSHD vessels. It was determined that the WID pilot was more CO2 efficient than the regular maintenance helping to reduce the CO2 emissions by 45-65% during the total duration of the pilot.

Based on the results of the WID pilot, it was concluded that new CO2 and cost efficient port maintenance strategy is feasible in the ports and waterways with mud layers.

Summary

Regular maintenance and relocation of sediment deposits are highly expensive causing Port authorities to seek more efficient solutions for reducing the costs and CO2 emissions of maintenance dredging. Water injection dredging (WID) is a solution utilised for maintaining the sediment deposits which predominantly consist of clay and silt, and is proven to be cheaper than hopper dredging by leaving the sediment in place. This eliminates substantial costs for relocation of the dredged sediment.

At the end of 2018, the utility of WID was investigated in the Calandkanaal at Europoort in Rotterdam. As a first step, the sediment trap was made in the Calandkanaal. Next, the WID was carried out for fluidising the sediment in close vicinity of the sediment trap and transporting the fluidised mud layer into the sediment trap.

The effect of WID was monitored by means of multibeam and SILAS system, that measured water-mud interface and fluidised mud layer thickness, respectively. After WID, the WID area was regularly surveyed for three months. Shear strength, yield stress and density of mud were measured in order to monitor settling and consolidation of fluidised mud layer. Furthermore, measured yield stress and density profiles were analysed as criteria for PIANC's nautical bottom applications, where 1200 kg/m^3 and 100 Pa limits have been applied for estimating the nautical depth.

The efficiency of WID was compared to regular maintenance in the Calandkanaal. Based on the analysis of historical dredged volumes and CO2 emissions from the fuel consumption data, it was concluded that WID is a more cost and CO2 efficient maintenance method than the regular maintenance in the area of the investigation.

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