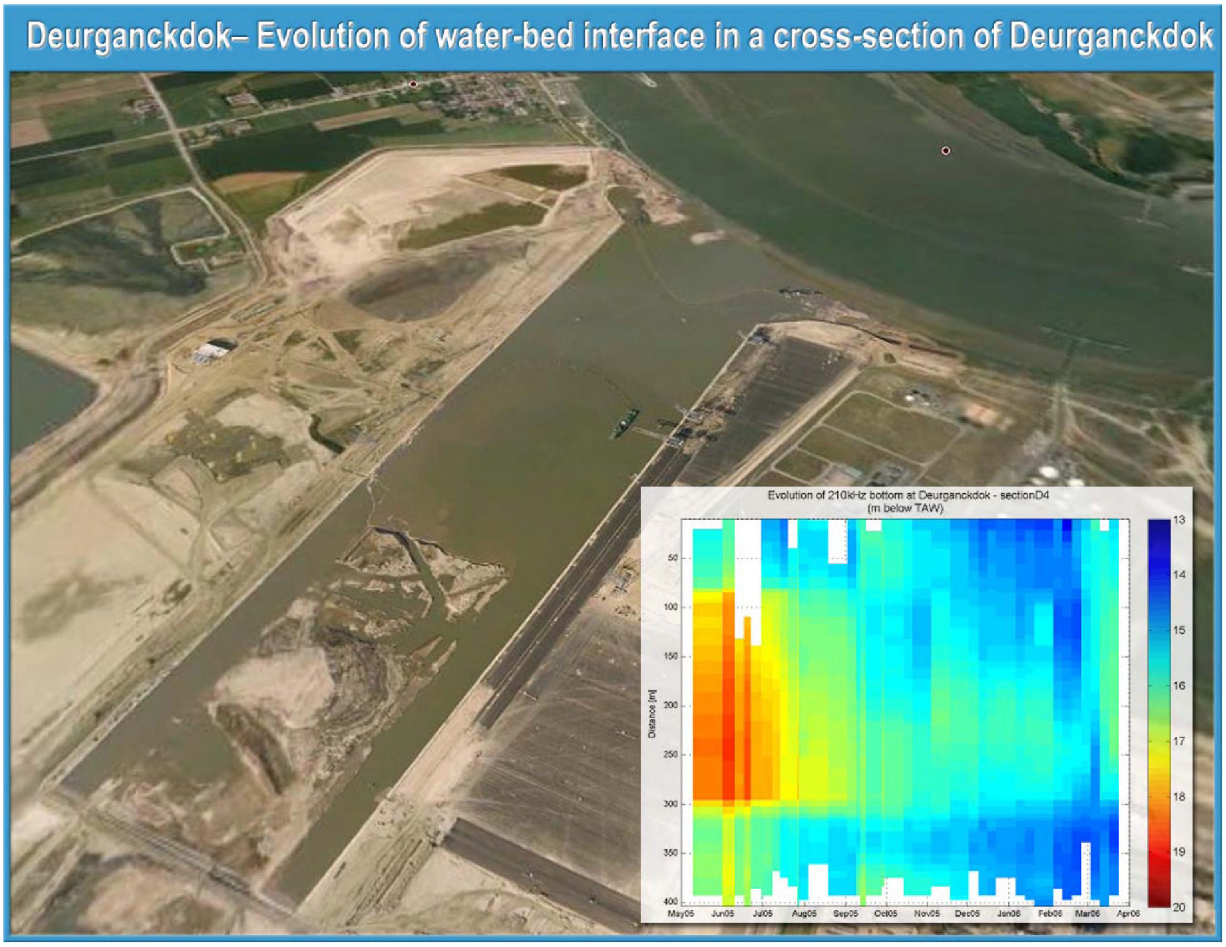
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DEPARTEMENT MOBILITEIT EN OPENBARE WERKEN
WATERBOUWKUNDIG LABORATORIUM

Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing

Bestek 16EB/05/04



Deelrapport 1.21 : Sedimentbalans 01/07/2008 – 30/09/2008

Report 1.21 : Sediment balance 01/07/2008 – 30/09/2008

24 April 2009

I/RA/11283/08.077/MSA

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GLOSSARY

BIS	Dredging Information System used in the Lower Sea Scheldt
d	Density of dredged sediment [kg/dm³]
DGD	Deurganckdok
HCBS	High Concentration Benthic Suspensions
M	mass of dry solids [ton]
ρ_s	density of the solid minerals [kg/dm³]
ρ_w	density of clear water [kg/dm³]
t_{0d}	Reference situation for densimetric analysis (empty dock)
t_{0e}	Reference situation for volumetric analysis (24 March 2006)
TDS	Ton of dry solids [ton]
V	volume of dredged sediment [m³]

1. INTRODUCTION

1.1. The assignment

This report is part of the set of reports describing the results of the long-term measurements conducted in Deurganckdok aiming at the monitoring and analysis of silt accretion. This measurement campaign is an extension of the study "Extension of the study about density currents in the Beneden Zeeschelde" as part of the Long Term Vision for the Scheldt estuary. It is complementary to the study 'Field measurements high-concentration benthic suspensions (HCBS 2)'.

The terms of reference for this study were prepared by the 'Departement Mobiliteit en Openbare Werken van de Vlaamse Overheid, Afdeling Waterbouwkundig Laboratorium' (16EB/05/04). The repetition of this study was awarded to International Marine and Dredging Consultants NV in association with WL|Delft Hydraulics and Gems International on 10/01/2006. The project term was repeated twice with an extra year from April 2007 till March 2008, and April 2008 till March 2009.

Waterbouwkundig Laboratorium– Cel Hydrometrie Schelde provided data on discharge, tide, salinity and turbidity along the river Scheldt and provided survey vessels for the long term and through tide measurements. Afdeling Maritieme Toegang provided maintenance dredging data. Agentschap voor Maritieme Dienstverlening en Kust – Afdeling Kust and Port of Antwerp provided depth sounding measurements.

The execution of the study involves a twofold assignment:

- Part 1: Setting up a sediment balance of Deurganckdok covering a period of three years
- Part 2: An analysis of the parameters contributing to siltation in Deurganckdok

1.2. Purpose of the study

The Lower Sea Scheldt (Beneden Zeeschelde) is the stretch of the Scheldt estuary between the Belgium-Dutch border and Rupelmonde, where the entrance channels to the Antwerp sea locks are located. The navigation channel has a sandy bed, whereas the shallower areas (intertidal areas, mud flats, salt marshes) consist of sandy clay or even pure mud sometimes. This part of the Scheldt is characterized by large horizontal salinity gradients and the presence of a turbidity maximum with depth-averaged concentrations ranging from 50 to 500 mg/l at grain sizes of 60 - 100 μm. The salinity gradients generate significant density currents between the river and the entrance channels to the locks, causing large siltation rates. It is to be expected that in the near future also the Deurganckdok will suffer from such large siltation rates, which may double the amount of dredging material to be dumped in the Lower Sea Scheldt.

Results from the study may be interpreted by comparison with results from the HCBS and HCBS2 studies covering the whole Lower Sea Scheldt. These studies included through-tide measurement campaigns in the vicinity of Deurganckdok and long term measurements of turbidity and salinity in and near Deurganckdok.

The first part of the study focuses on obtaining a sediment balance of Deurganckdok. Aside from natural sedimentation, the sediment balance is influenced by the maintenance and capital dredging works. This involves sediment influx from capital dredging works in the Deurganckdok, and internal relocation and removal of sediment by maintenance dredging works. To compute a sediment balance an inventory of bathymetric data (depth soundings), density measurements of the deposited material and detailed information of capital and maintenance dredging works will be made up.

The second part of the study is to gain insight in the mechanisms causing siltation in Deurganckdok, it is important to follow the evolution of the parameters involved, and this on a long and short term basis (long term & through-tide measurements). Previous research has shown the importance of water exchange at the entrance of Deurganckdok is essential for understanding sediment transport between the dock and the Scheldt river.

1.3. Overview of the reports

1.3.1. Reports

Reports of the project for the period April 2006 – March 2009 are summarized in Table 1-1.

Table 1-1: Overview of Deurganckdok Reports

Report	Description
Sediment Balance: Bathymetry surveys, Density measurements, Maintenance and construction dredging activities	
1.1	Sediment Balance: Three monthly report 1/4/2006 – 30/06/2006 (I/RA/11283/06.113/MSA)
1.2	Sediment Balance: Three monthly report 1/7/2006 – 30/09/2006 (I/RA/11283/06.114/MSA)
1.3	Sediment Balance: Three monthly report 1/10/2006 – 31/12/2006 (I/RA/11283/06.115/MSA)
1.4	Sediment Balance: Three monthly report 1/1/2007 – 31/03/2007 (I/RA/11283/06.116/MSA)
1.5	Annual Sediment Balance (I/RA/11283/06.117/MSA)
1.6	Sediment balance Bathymetry: 2005 – 3/2006 (I/RA/11283/06.118/MSA)
1.10	Sediment Balance: Three monthly report 1/4/2007 - 30/06/2007(I/RA/11283/07.081/MSA)
1.11	Sediment Balance: Two monthly report 1/7/2007 – 31/08/2007 (I/RA/11283/07.082/MSA)
1.12	Sediment Balance: Four monthly report 1/09/2007 – 31/12/2007 (I/RA/11283/07.083/MSA)
1.13	Sediment Balance: Three monthly report 1/1/2008 – 31/03/2008 (I/RA/11283/07.084/MSA)
1.14	Annual Sediment Balance (I/RA/11283/07.085/MSA)
1.20	Sediment Balance: Three monthly report 1/4/2008 - 30/6/2008 (I/RA/11283/08.076/MSA)
1.21	Sediment Balance: Three monthly report 1/7/2008 – 30/9/2008 (I/RA/11283/08.077/MSA)
1.22	Sediment Balance: Three monthly report 1/10/2008 – 31/12/2008 (I/RA/11283/08.078/MSA)

Report	Description
1.23	Sediment Balance: Three monthly report 1/1/2009 – 31/03/2009 (I/RA/11283/08.079/MSA)
1.24	Annual Sediment Balance (I/RA/11283/08,080/MSA)
Factors contributing to salt and sediment distribution in Deurganckdok: Salt-Silt (OBS3A) & Frame measurements, Through tide measurements (SiltProfiling & ADCP) & Calibrations	
2.1	Through tide measurement Siltprofiler 21/03/2006 Laure Marie (I/RA/11283/06.087/WGO)
2.2	Through tide measurement Siltprofiler 26/09/2006 Stream (I/RA/11283/06.068/MSA)
2.3	Through tide measurement Sediview spring tide 22/03/2006 Veremans (I/RA/11283/06.110/BDC)
2.4	Through tide measurement Sediview spring tide 27/09/2006 Parel 2 (I/RA/11283/06.119/MSA)
2.5	Through tide measurement Sediview neap tide (to be scheduled) (I/RA/11283/06.120/MSA)
2.6	Salinity-Silt distribution & Frame Measurements Deurganckdok 13/3/2006 – 31/05/2006 (I/RA/11283/06.121/MSA)
2.7	Salinity-Silt distribution & Frame Measurements Deurganckdok 15/07/2006 – 31/10/2006 (I/RA/11283/06.122/MSA)
2.8	Salinity-Silt distribution & Frame Measurements Deurganckdok 15/01/2007 – 15/03/2007 (I/RA/11283/06.123/MSA)
2.9	Calibration stationary equipment autumn (I/RA/11283/07.095/MSA)
2.10	Through tide measurement Siltprofiler winter (I/RA/11283/07.086/MSA)
2.11	Through tide measurement Salinity Profiling winter (I/RA/11283/07.087/MSA)
2.12	Through tide measurement Sediview winter (I/RA/11283/07.088/MSA)
2.13	Through tide measurement Sediview winter (I/RA/11283/07.089/MSA)
2.14	Through tide measurement Sediview winter (I/RA/11283/07.090/MSA)
2.15	Through tide measurement Siltprofiler (to be scheduled) (I/RA/11283/07.091/MSA)
2.16	Salt-Silt distribution Deurganckdok summer (21/6/2007 – 30/07/2007) (I/RA/11283/07.092/MSA)
2.17	Salt-Silt distribution & Frame Measurements Deurganckdok autumn (17/09/2007 - 10/12/2007) (I/RA/11283/07.093/MSA)
2.18	Salt-Silt distribution & Frame Measurements Deurganckdok winter (18/02/2008 - 31/3/2008) (I/RA/11283/07.094/MSA)
2.19	Calibration stationary & mobile equipment winter (I/RA/11283/07.096/MSA)
2.20	Through tide measurement Sediview DGD during neap tide Spring 2008 (I/RA/11283/08.081/MSA)

Report	Description
2.21	Through tide measurement Sediview DGD during spring tide Spring 2008 (I/RA/11283/08.082/MSA)
2.22	Through tide measurement Sediview DGD during neap tide Summer 2008 (I/RA/11283/08.083/MSA)
2.23	Through tide measurement Sediview DGD during spring tide Summer 2008 (I/RA/11283/08.084/MSA)
2.24	Through tide measurement Sediview DGD during neap tide Autumn 2008 (I/RA/11283/08.085/MSA)
2.25	Through tide measurement Sediview DGD during spring tide Autumn 2008 (I/RA/11283/08.086/MSA)
2.26	Through tide measurement Sediview DGD during neap tide Winter 2009 (I/RA/11283/08.087/MSA)
2.27	Through tide measurement Sediview DGD during spring tide Winter 2009 (I/RA/11283/08.088/MSA)
2.28	Through tide measurement ADCP eddy DGD Summer 2008 (I/RA/11283/08.089/MSA)
2.29	Through tide measurement Siltprofiler DGD Summer 2008 (I/RA/11283/08.090/MSA)
2.30	Through tide measurement Siltprofiler DGD Winter 2009 (I/RA/11283/08.091/MSA)
2.31	Through tide measurement Salinity Profiling DGD Winter 2009 (I/RA/11283/08.092/MSA)
2.32	Salt-Silt distribution Deurganckdok: Six monthly report 1/4/2008 - 30/9/2008 (I/RA/11283/08.093/MSA)
2.33	Salt-Silt distribution Deurganckdok: Six monthly report 1/10/2008 – 31/3/2009 (I/RA/11283/08.094/MSA)
2.34	Calibration stationary & mobile equipment Autumn 2008 (I/RA/11283/08.095/MSA)
Boundary Conditions: Upriver Discharge, Salt concentration Scheldt, Bathymetric evolution in access channels, dredging activities in Lower Sea Scheldt and access channels	
3.1	Boundary conditions: Three monthly report 1/1/2007 – 31/03/2007 (I/RA/11283/06.127/MSA)
3.10	Boundary conditions: Three monthly report 1/4/2007 – 30/06/2007 (I/RA/11283/07.097/MSA)
3.11	Boundary conditions: Three monthly report 1/7/2007 – 30/09/2007 (I/RA/11283/07.098/MSA)
3.12	Boundary conditions: Three monthly report 1/10/2007 – 31/12/2007 (I/RA/11283/07.099/MSA)
3.13	Boundary conditions: Three monthly report 1/1/2008 – 31/03/2008 (I/RA/11283/07.100/MSA)
3.14	Boundary conditions: Annual report (I/RA/11283/07.101/MSA)

Report	Description
3.20	Boundary conditions: Six monthly report 1/4/2008 – 30/09/2008 (I/RA/11283/08.096/MSA)
3.21	Boundary conditions: Six monthly report 1/10/2008 – 31/03/2009 (I/RA/11283/08.097/MSA)
Analysis	
4.1	Analysis of Siltation Processes and Factors (I/RA/11283/06.129/MSA)
4.10	Analysis of Siltation Processes and Factors (I/RA/11283/07.102/MSA)
4.20	Analysis of Siltation Processes and Factors (I/RA/11283/08.098/MSA)

1.3.2. Measurement actions

Following measurements have been carried out during the course of this project:

1. Monitoring upstream discharge in the Scheldt river
2. Monitoring Salt and sediment concentration in the Lower Sea Scheldt taken from on permanent data acquisition sites at Lillo, Oosterweel and up- and downstream of the Deurganckdok.
3. Long term measurement of salt distribution in Deurganckdok.
4. Long term measurement of sediment concentration in Deurganckdok
5. Monitoring near-bed processes in the central trench in the dock, near the entrance as well as near the landward end: near-bed turbidity, near-bed current velocity and bed elevation variations are measured from a fixed frame placed on the dock's bed.
6. Measurement of current, salt and sediment transport at the entrance of Deurganckdok for which ADCP backscatter intensity over a full cross section are calibrated with the Sediview procedure and vertical sediment and salt profiles are recorded with the SiltProfiler equipment
7. Through tide measurements of vertical sediment concentration profiles -including near bed highly concentrated suspensions- with the SiltProfiler equipment. Executed over a grid of points near the entrance of Deurganckdok.
8. Monitoring dredging activities at entrance channels towards the Kallo, Zandvliet and Berendrecht locks
9. Monitoring dredging and dumping activities in the Lower Sea Scheldt

In situ calibrations were conducted on several dates to calibrate all turbidity and conductivity sensors (IMDC, 2006f & IMDC, 2007l).

1.4. Structure of the report

This report is the sediment balance of the Deurganckdok for the period of 01/07/2008 to 30/09/2008. The first chapter comprises an introduction. The second chapter describes the project. Chapter 3 describes the methodology. The measurement results and processed data are presented in Chapter 4, whereas chapter 5 gives a preliminary analysis of the data.

2. SEDIMENTATION IN DEURGANCKDOK

2.1. Project Area: Deurganckdok

Deurganckdok is a tidal dock situated at the left bank in the Lower Sea Scheldt, between Liefkenshoek and Doel. Deurganckdok has the following characteristics:

1. The dock has a total length of 2750 m and is 450 m wide at the Scheldt end and 400 m wide at the inward end of the dock
2. The bottom of Deurganckdok is provided at a depth of –17m TAW in the transition zones between the quay walls and the central trench. The bottom in the central trench is designed at –19 m TAW.
3. The quay walls reach up to +9m TAW

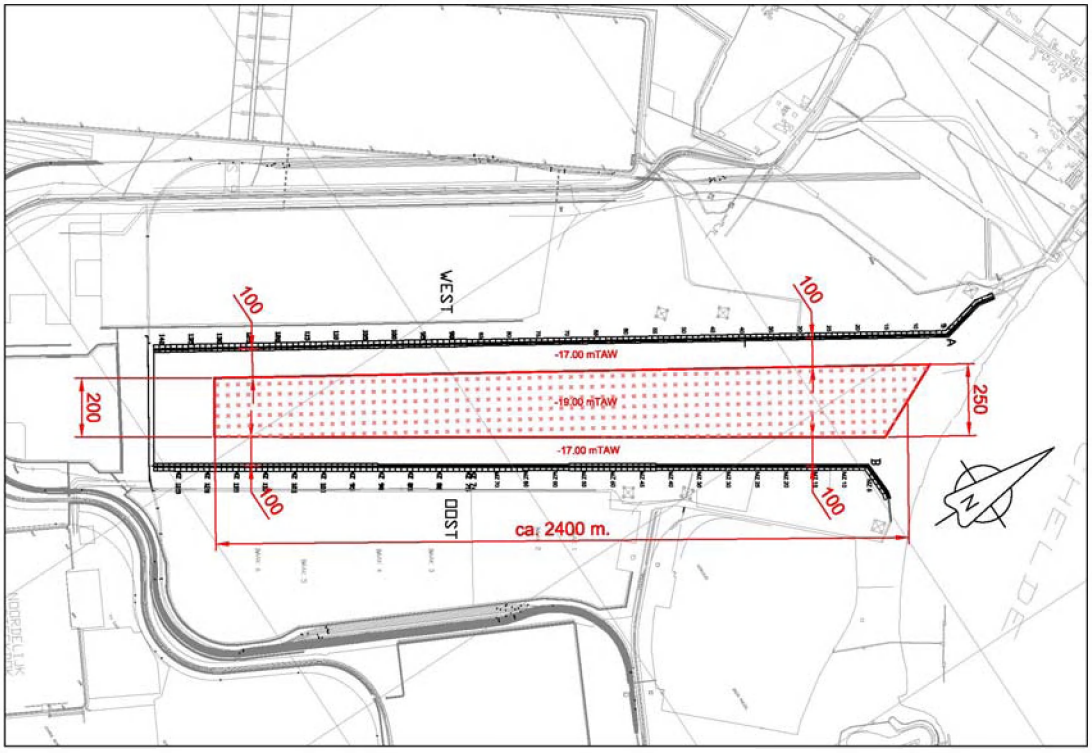


Figure 2-1: Overview of Deurganckdok

The dredging of the dock is performed in 3 phases. On 18 February 2005 the dike between the Scheldt and the Deurganckdok was breached. On 6 July 2005 Deurganckdok was officially opened. The second dredging phase was finalized a few weeks later. The first terminal operations have started since. In February 2007, the third dredging phase started and is finalised by February 2008.

2.2. Overview of the studied parameters

The first part of the study aims at determining a sediment balance of Deurganckdok and the net influx of sediment. The sediment balance comprises a number of sediment transport modes: deposition, influx from capital dredging works, internal replacement and removal of sediments due to maintenance dredging (Figure 2-2).

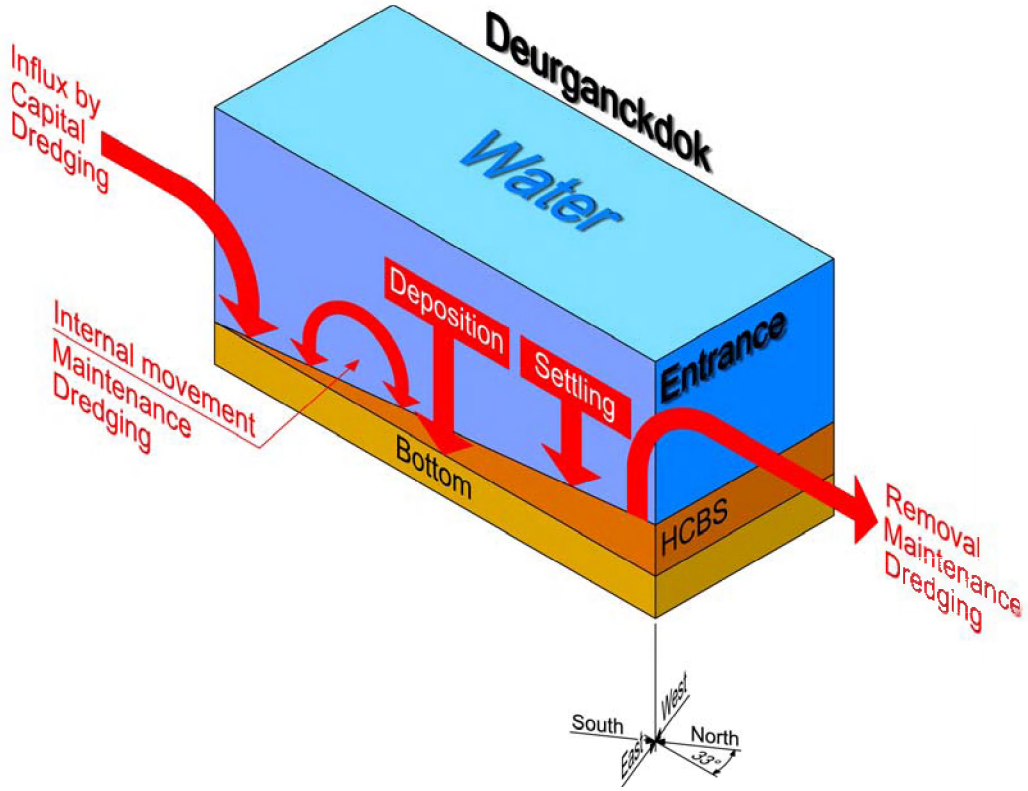


Figure 2-2: Elements of the sediment balance

A net deposition can be calculated from a comparison with a chosen initial condition t_0 (Figure 2-3). The mass of deposited sediment is determined from the integration of bed density profiles recorded at grid points covering the dock. Subtracting bed sediment mass at t_0 leads to the change in mass of sediments present in the dock (mass growth). Adding cumulated dry matter mass of dredged material removed since t_0 and subtracting any sediment influx due to capital dredging works leads to the total cumulated mass entered from the Scheldt river since t_0.

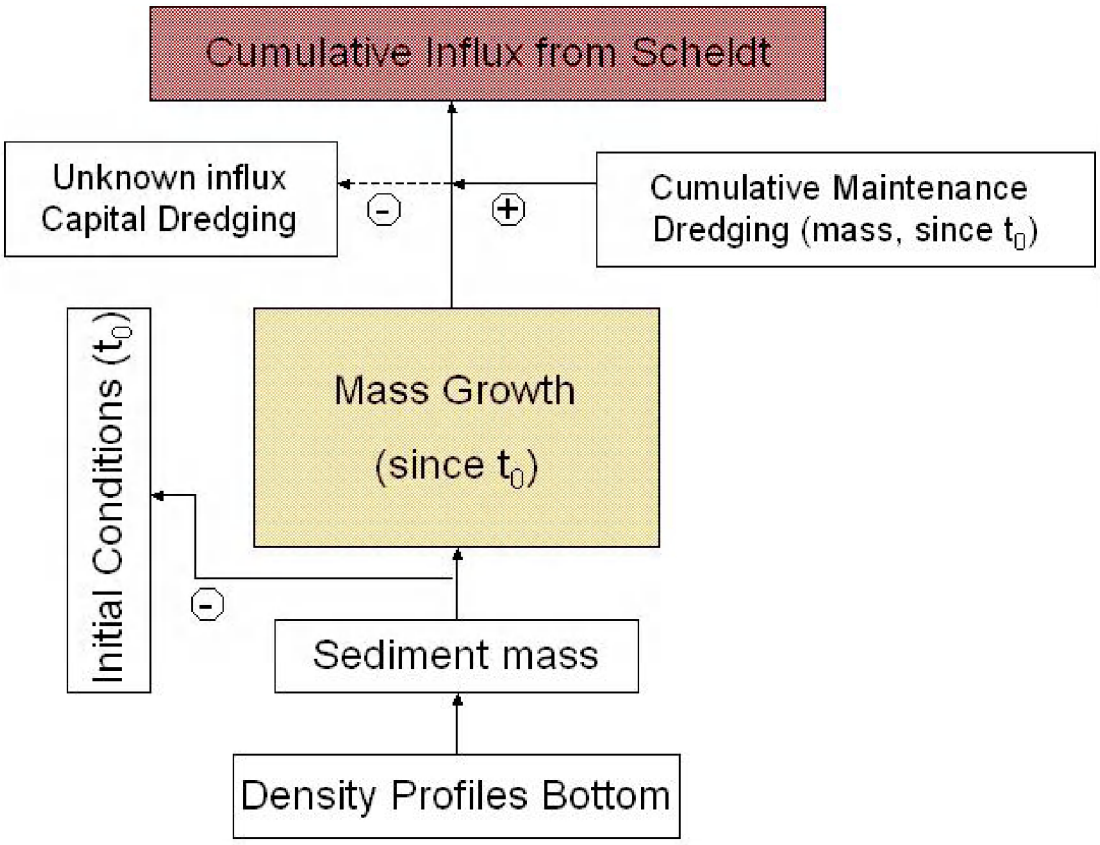


Figure 2-3: Determining a sediment balance

The main purpose of the second part of the study is to gain insight in the mechanisms causing siltation in Deurganckdok. The following mechanisms will be aimed at in this part of the study:

- Tidal prism, i.e. the extra volume in a water body due to high tide
- Vortex patterns due to passing tidal current
- Density currents due to salt gradient between the Scheldt river and the dock
- Density currents due to highly concentrated benthic suspensions

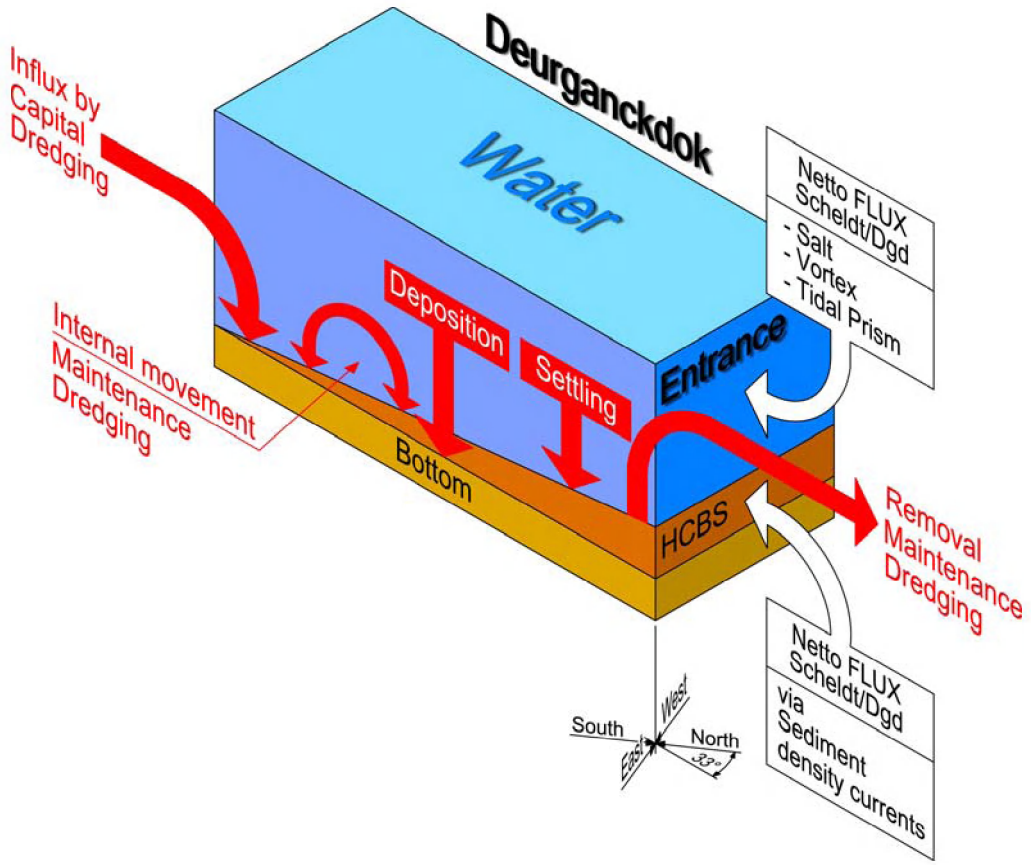


Figure 2-4: Transport mechanisms

These aspects of hydrodynamics and sediment transport have been landmarks in determining the parameters to be measured during the project. Measurements will be focused on three types of timescales: one tidal cycle, one neap-spring cycle and seasonal variation within one year.

Following data are being collected to understand these mechanisms:

- Monitoring upstream discharge in the Scheldt river.
- Monitoring Salt and sediment concentration in the Lower Sea Scheldt at permanent measurement locations at Oosterweel, up- and downstream of the Deurganckdok.
- Long term measurement of salt and suspended sediment distribution in Deurganckdok.
- Monitoring near-bed processes (current velocity, turbidity, and bed elevation variations) in the central trench in the dock, near the entrance as well as near the current deflecting wall location.
- Dynamic measurements of current, salt and sediment transport at the entrance of Deurganckdok.
- Through tide measurements of vertical sediment concentration profiles -including near bed high concentrated benthic suspensions.
- Monitoring dredging activities at entrance channels towards the Kallo, Zandvliet and Berendrecht locks as well as dredging and dumping activities in the Lower Sea Scheldt.
- In situ calibrations were conducted on several dates to calibrate all turbidity and conductivity sensors.

3. MEASUREMENTS

3.1. Depth soundings

The client executes dual-frequency echo-sounder measurements every week to every three weeks. F. De Cock (Agentschap voor Maritieme Dienstverlening en Kust – Afdeling Kust) communicated that these measurements are carried out with a 210-33 kC Echo sounder using Qinsy software. The depth sounding measurements are executed in a grid configuration, consisting of sections perpendicular and parallel to the quay wall.

Table 3-1: Overview of the available depth soundings suitable for analysis 01/07/2008 – 30/09/2008

date	*type of measurement*	*signal*	*Source*
13/03/2008*	dual frequency 210-33 kHz	210	Afdeling Kust
15/07/2008	dual frequency 210-33 kHz	210	Afdeling Kust
11/08/2008	dual frequency 210-33 kHz	210	Afdeling Kust
26/08/2008	dual frequency 210-33 kHz	210	Afdeling Kust
3/09/2008	dual frequency 210-33 kHz	210	Afdeling Kust
22/09/2008	dual frequency 210-33 kHz	210	Afdeling Kust

*= reference situation depth soundings: t_{0e}

To calculate a sediment balance it is necessary to analyse the measurements in stationary situation, with no alteration in boundary conditions being dredging operations. Every period is characterized by a depth sounding measurement before ('inpeiling') and one after ('uitpeiling').

A number of analyses were done using the depth soundings in Table 3-1. The raw depth sounding data was processed in ESRI ArcGIS. The 210 kC signal is used in the following analyses as it gives an indication of the water-bed interface.

A reference level was chosen from all depth sounding measurements. Previous reports used the earliest measurement as reference level, i.e. 24 March 2006. In February 2008, the capital dredging of the dock was finalized such that a significant larger measurement area became applicable. A new reference situation, initial condition t_{0e}, therefore seemed plausible for which the depth sounding of 13 March 2008 was selected.

A number of analyses were performed in ArcGIS 9 and a Matlab environment to produce maps, figures and tables with relevant information concerning elevation, elevation changes and volumetric growth (§4.2 to §4.4).

3.2. Density measurements

Density measurements are necessary to calculate a sediment balance of dry weight of sediment per surface unit. In order to measure bulk densities, two devices were used, i.e. the Navitracker and the Densitune. The former device was applied on 11 and 26 August 2008, whereas the Densitune was used on 11 September 2008. The application of different devices is related to a contract change for density measurements in the harbour of Zeebrugge. Some information on both devices are given below.

3.2.1. Navitracker

The Navitracker is a patented system to measure the density of fluid mud suspensions, by means of a gamma-density meter. It has been used by the Flemish authorities over 20 years to determine the nautical bed for the port of Zeebrugge.

The Navitracker system can be operated by a computer controlled winch to tow it through the mud (horizontal mode). The Navitracker is equipped with the following sensors:

- The Gamma ray density sensor, mounted on a fork-like tow fish, gives density information.
- The depth sensor gives information of the depth of the sensor.
- The position of the fish is calculated out of the length of the winch cable. Together with the position of the tow fish, following the density level, a dual frequency echo sounder is used to map the hard bottom and the top of the mud. With a speed of 2 to 3 knots, large areas can be covered.

For these measurements the Navitracker was used in a vertical profiling mode, with the probe in vertical position in order to penetrate the soft bottom. The vertical density profiler is used to measure density in thick mud layers with high densities.

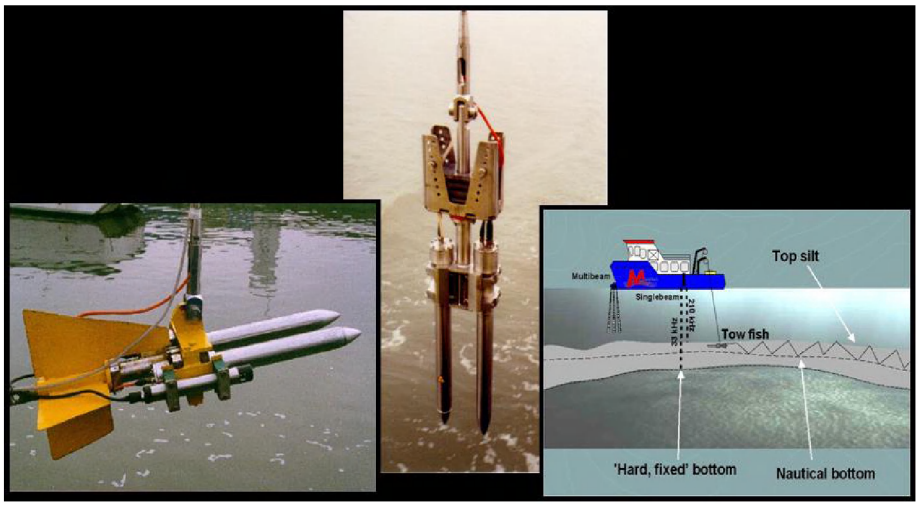


Figure 3-1: Navitracker

The Navitracker was calibrated in the laboratory for measuring high densities, formed by very dense water-mud mixtures. For this reason the Navitracker did not detect subtle variations in density caused by changes in salinity. The density deviated from 1.000 ton/m³ only in the presence of a high concentration of sediments.

The Navitracker has a sampling frequency of 10 measurements per second.

3.2.2. DensiTune

The DensiTune is a patented system to determine the internal density of liquid silt layers. The measurement system is based on the “tuning fork” principles. One of the legs vibrates with a specific frequency, and the other leg responds with a frequency which depends on the density of the medium in which the DensiTune is inserted. The system measures vertical density profiles in liquid silt layers while lowered.

3.2.3. Data analysis

The resulting density profiles were processed in a Matlab environment and visualized in Matlab and ESRI ArcGIS. Equal density layers were computed. Volume and density information was used to calculate masses of silt. All masses are given in ton of dry solids (TDS) characterized by a density of 2.65 kg/dm³. The water-bed interface is defined as the layer with a density of 1.03 kg/dm³.

In this measurement campaign, Navitracker density measurements have been performed on 11 and 26 August 2008, and DensiTune measurements were performed on 11 September 2008.

As a reference situation the empty dock will be used at the design depth. The design depths for the different zones are shown in Table 3-2. The different zones are described in §4.1.

Table 3-2: Reference Situation Density Measurements (t_{0d})

Zone	Design Depth (mTAW)
Central trench	-19
Berthing zones and transition zones to central trench	-17
Sill	-13.5
Transition sill to navigation channel	Not applicable

3.3. Maintenance Dredging Data

All maintenance dredging (except sweep beam) activities in Deurganckdok were collected in the BIS-system. This system gives a standardised output per week, that states the weight, volume and V'[1] removed/dumped in every 5*5m grid cell in the area. In case the density of the dredged sediment in the hopper bin is larger or equal to 1.6 kg/dm³, V' is equal to the volume in the bin. In case the density is smaller than 1.6 kg/dm³, V' is equal to the reduced volume which is defined as the volume the dredged sediment would have in case the density would be equal to 2 kg/dm³ (AWZ 2000). These dredged volumes are important to have an overall view on the sediment balance. Maintenance dredging occurred in the second half of August 2008.

The available data on sweep beam activity is not collected in the BIS-system. However, the mode of operation of the sweep beam is explained:

- On the sill (zone 1 & 2): the sediment is swept into the Lower Sea Scheldt
- Inside the dock: the sweep beam sweeps the berthing zones next to the quay walls and moves sediment into the central trench

Therefore, an overview is given of where and when sweep beam dredger was working in Deurganckdok (DGD) or on the sill of Deurganckdok (sill DGD).

Table 3-3: Sweep beam maintenance dredging activities in Deurganckdok and on the sill of Deurganckdok between July and September 2008 (source: Afdeling Maritieme Toegang)

From	Till	Duration (days)	Location
7/07/2008	7/07/2008	1	sill DGD
14/07/2008	14/07/2008	1	sill DGD + northern/southern quays (first third of dock from entrance)
16/07/2008	17/07/2008	2	sill DGD + northern/southern quays (first third of dock from entrance)
22/07/2008	26/07/2008	5	sill DGD + northern/southern quays (first third of dock from entrance)
28/07/2008	28/07/2008	1	Sill DGD
5/08/2008	5/08/2008	1	Sill DGD
11/08/2008	11/08/2008	1	Sill DGD

[1] V' = Reduced Volume

From	*Till*	*Duration (days)*	*Location*
18/08/2008	18/08/2008	1	Sill DGD
25/08/2008	30/08/2008	6	sill DGD + northern/southern quays (first half of dock from entrance)
1/9/2008	1/09/2008	1	Sill DGD
5/09/2008	6/09/2008	2	Sill DGD
8/09/2008	11/09/2008	4	Sill DGD
17/09/2008	20/09/2008	4	sill DGD + northern/southern quays (first half of dock from entrance)
22/09/2008	27/09/2008	6	sill DGD + northern/southern quays (first four-fifth of dock from entrance)

An overview of the total dredged mass in all zones (BIS data) is provided in APPENDIX I. The sweep beam tracks are shown in APPENDIX J. The loggings of the sweep beam tracks show the position and depth of the rake. From the up-down position of the rake and the ship's direction, it is possible to identify whether the ship is sweeping sediment into the Scheldt or not.

4. SEDIMENT BALANCE ANALYSES

4.1. Project Area: (Sub)Zones and Sections

To calculate volumes and masses for the sediment balance of Deurganckdok it is necessary to subdivide it into 5 zones:

- Zone 1: Between the sill and the navigation channel in the Lower Sea Scheldt.
- Zone 2: Sill at entrance DGD designed at –13.5 m TAW.
- Zone 3: Central trench in DGD with a design depth at –19 m TAW (including slope to –17 m TAW)
- Zone 4: Transition between central trench and berthing zones with a design depth at –17.00 m TAW: on both (North (N) and South (Z)) sides of DGD (55 m wide).
- Zone 5: Berthing zones next to quay walls on both (North (N) and South (Z)) sides of DGD (40 m wide)

Zones 3, 4 and 5 are subdivided into subzones A, B, C, D and E. This is shown in Figure 4-1.

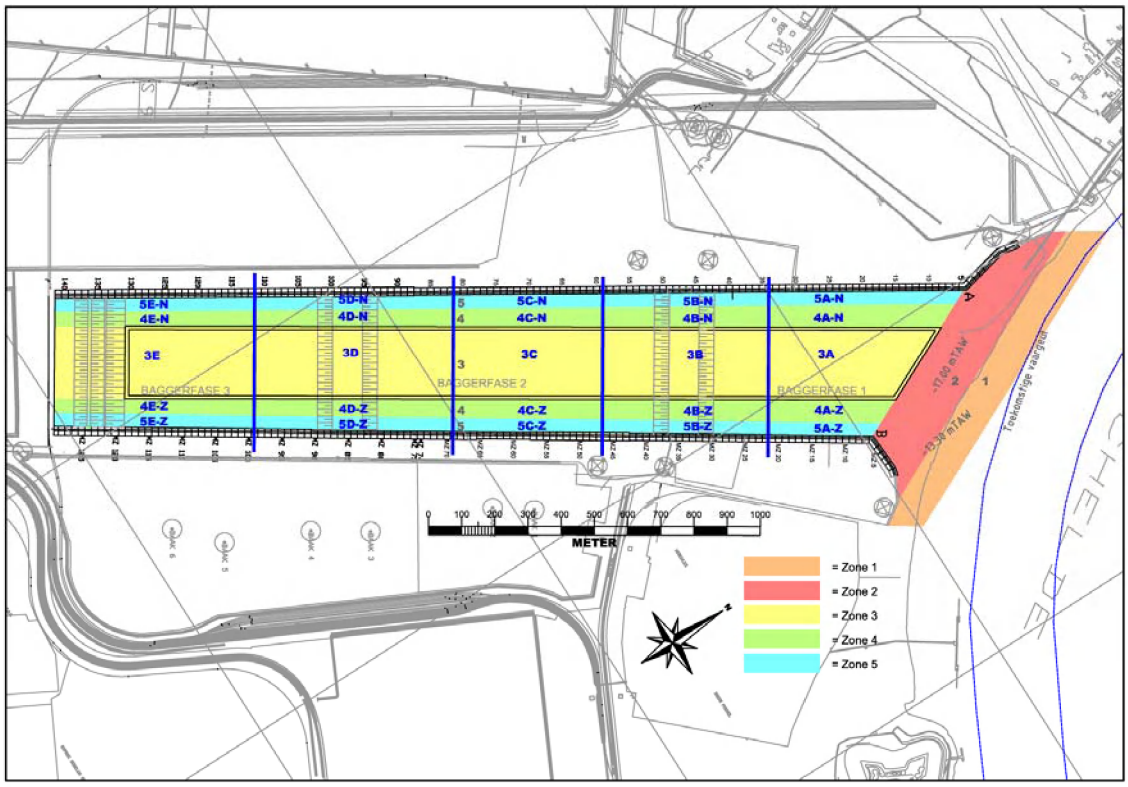


Figure 4-1: Deurganckdok: Zones and Subzones

Sections are defined for this whole area (Figure 4-2):

- D sections are oriented perpendicular to the quay walls inside the dock and parallel to the navigation channel outside the dock (sill and Scheldt). The origin of the sections is taken on the quay wall at the left bank (West side) looking outwards.
- L Sections are oriented along the centerline of the dock and run from the navigation channel towards the inland end of the dock, in anticipation of the realisation of the third phase of Deurganckdok. The origin is situated on the intersection between each L section and section D10.

The coordinates of these sections are given in Table 4-1.

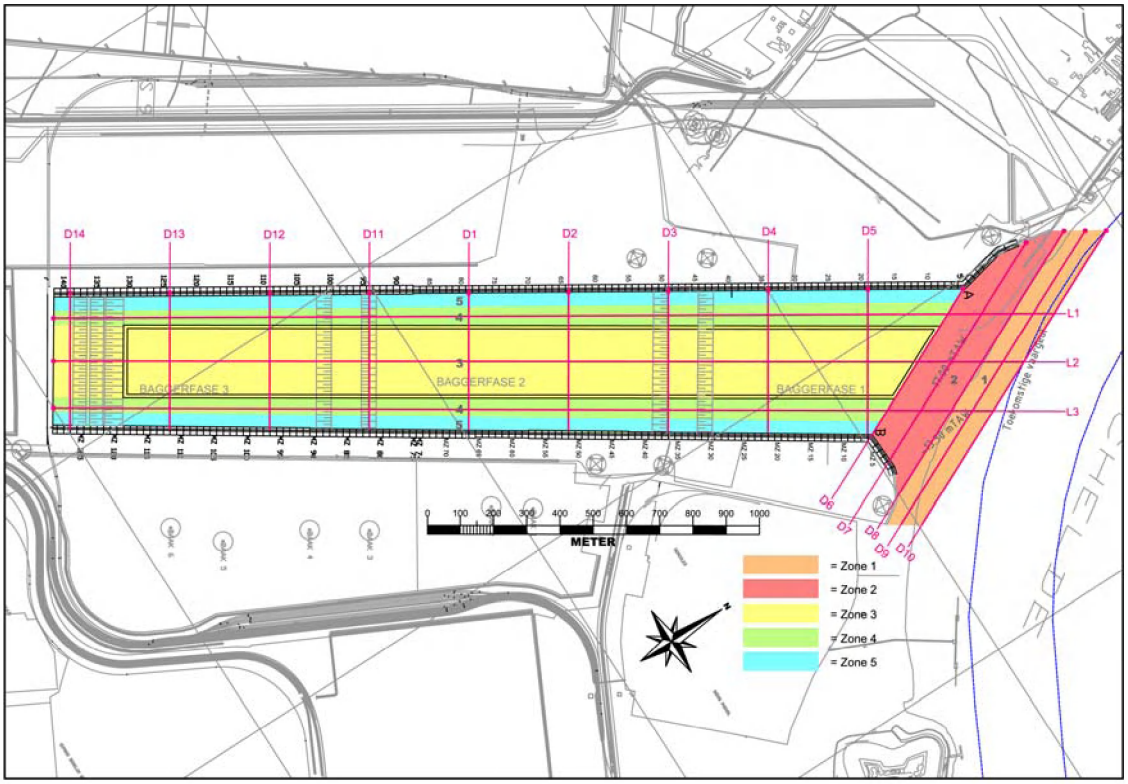


Figure 4-2: Deurganckdok: D and L Sections

Table 4-1: Coordinates of Sections [UTM ED50]

Name	***Origin***		***End***	
	Easting	***Northing***	***Easting***	***Northing***
D Sections				
D1	587773	5683253	588123	5683037
D2	587929	5683510	588283	5683290
D3	588084	5683767	588444	5683544
D4	588239	5684023	588604	5683797
D5	588394	5684280	588765	5684051
D6	588542	5684526	588772	5684062
D7	588521	5684761	588864	5684068
D8	588552	5684875	588972	5684027
D9	588585	5684930	589047	5683994
D10	588617	5684984	589081	5684047
D11	587615	5682997	587962	5682783
D12	587459	5682742	587802	5682529
D13	587300	5682487	587642	5682276
D14	587143	5682232	587482	5682023
L Sections				
L1	588748	5684720	587180	5682151
L2	588825	5684565	587290	5682082
L3	588901	5684410	587409	5682007

4.2. Depth of the water-bed interface (210 kC)

This is shown as a GIS grid map generated directly from the depth sounding data and is shown in APPENDIX A. An example is shown in Figure 4-3.

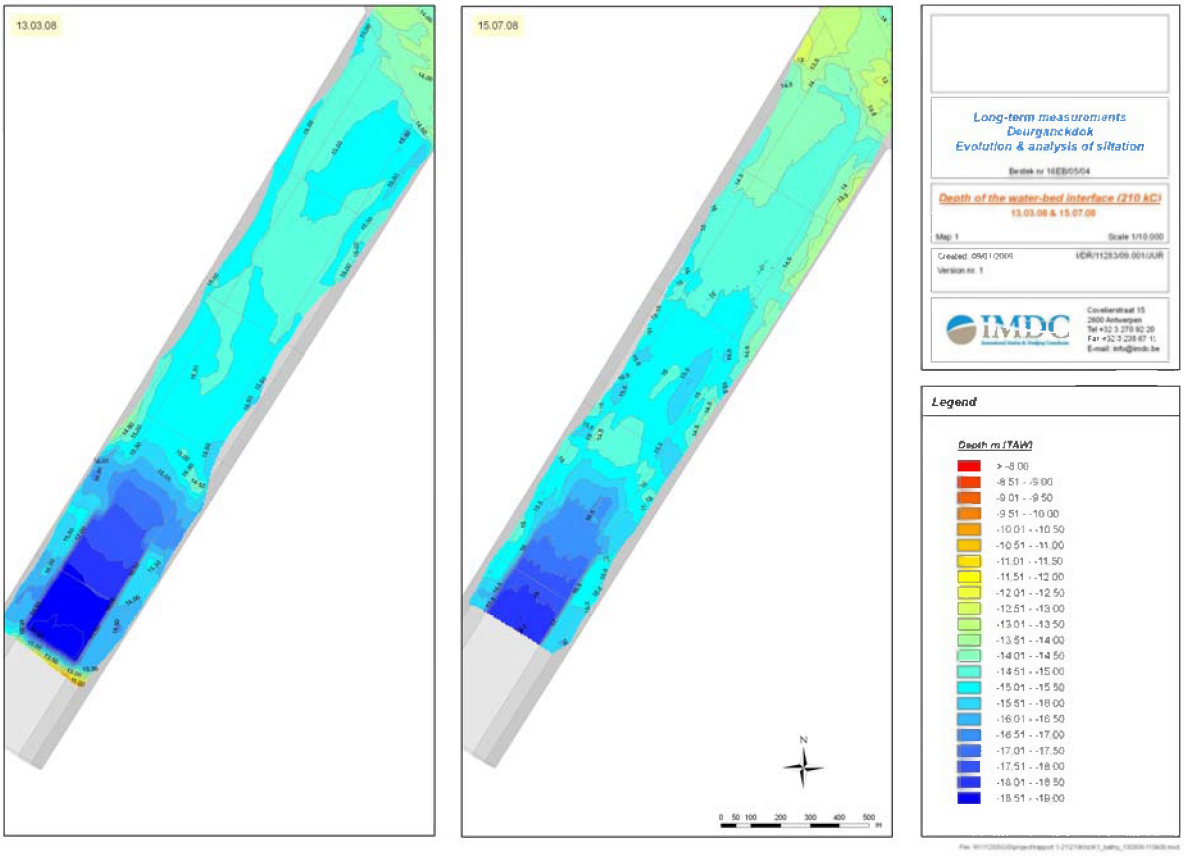


Figure 4-3: Example of a map showing depth of water-bed interface (210 kC) for 13/03/08 and 15/07/08

4.3. Evolution of water-bed interface (210 kC)

GIS grid maps show the difference charts for every depth sounding in relation to the reference situation (t_{0e}) and to the previous depth sounding (right). An example is shown in Figure 4-4.

The difference in depth between subsequent depth soundings for 210 kC measurements is also shown for all predefined sections. Graphs show a colour plot with Time in the X-axis, Distance to origin of section in the Y-axis and the depth of the top layer [m TAW] as a colour plot.

The origin for de the D sections is the northern quay wall. The origin of the L sections is the intersection between the L section with the Scheldt edge of zone 1. An example for sections is shown in Figure 4-5. The description of the sections is given in § 4.1.

Maps and graphs are shown in APPENDIX B.

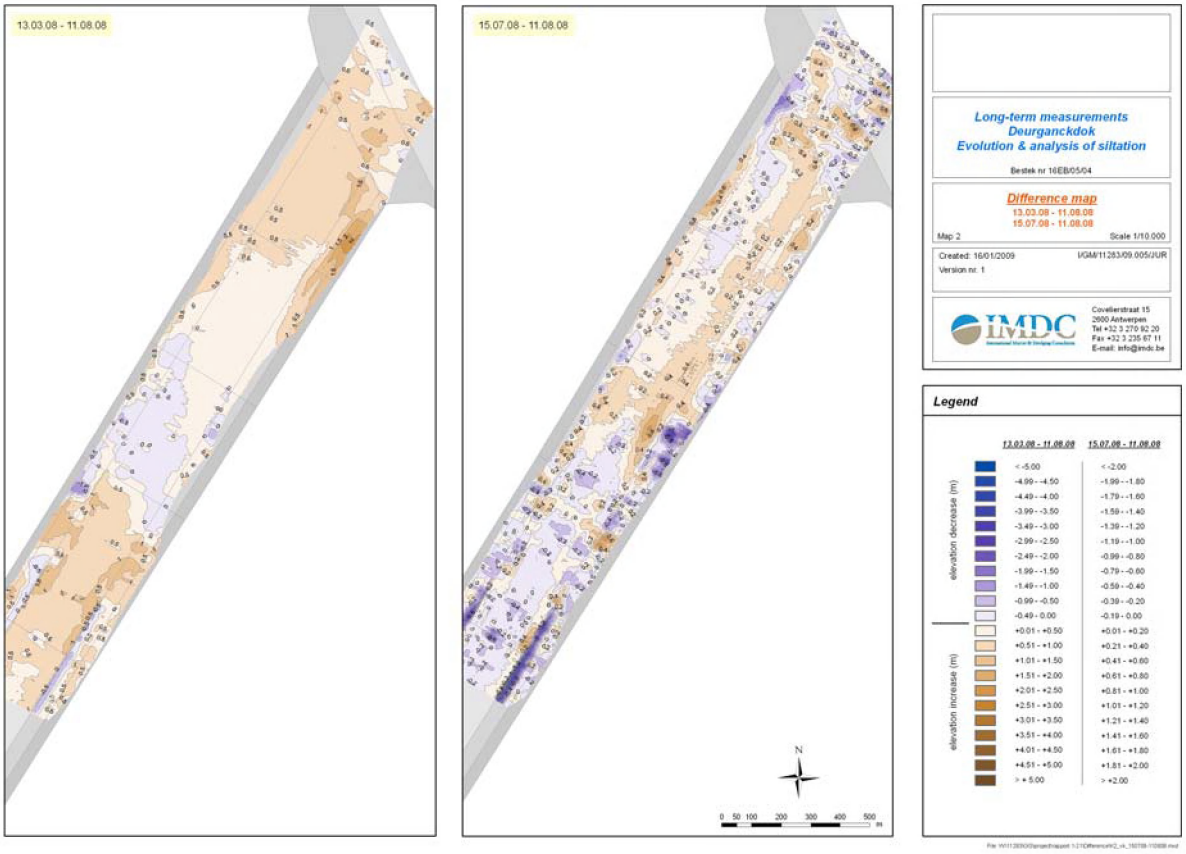


Figure 4-4: Difference charts of the depth sounding on 11/08/08: in reference to t_{0e} (left), and to the previous measurement (right) on 15/07/08

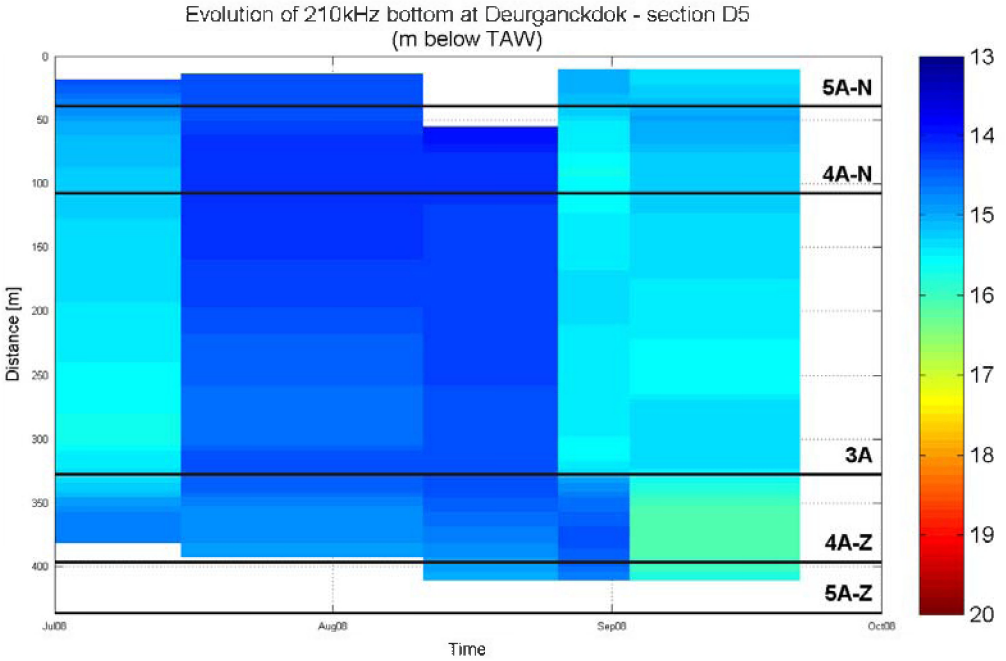


Figure 4-5: Graph of Evolution of the water-bed interface (210 kC) for section D5

4.4. Volumetric siltation rates [cm/day] in different zones and sections

A table with monthly average siltation rates for all (sub)zones is also given in APPENDIX C.

Graphs in APPENDIX C show two parameters:

- Average siltation rates [cm/day]: The average siltation rate is the difference in the depth of the water-bed interface and is calculated only for those zones and subzones that have at least a 50% surface area overlap between two subsequent depth soundings. This is done for all successive depth soundings. It is shown in the plots as a bar and is positive for sedimentation and negative for erosion or removal.
- Cumulative bed level change [m]: an initial situation (t_0) is used as baseline. Starting from this reference level the evolution of the average bed level elevation is shown for the particular (sub)zone.

Dredging events from the BIS system are marked on each of these graphs. This is computed for all zones, subzones, sections and Deurganckdok as a whole. As an example we show siltation rate and cumulative bed level change for zone 3a in Figure 4-6.

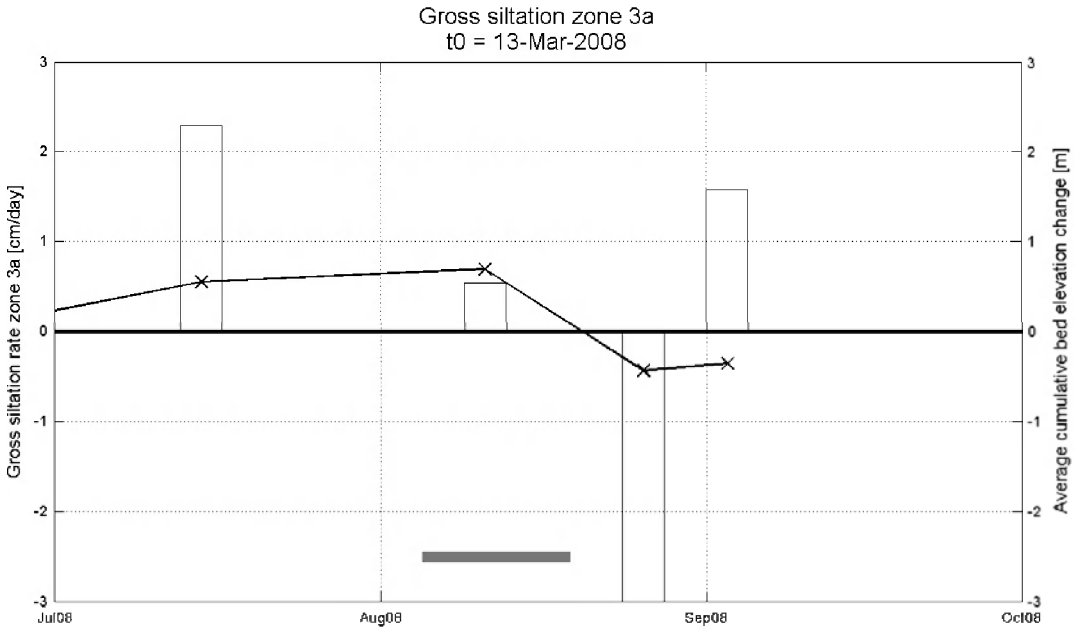


Figure 4-6: Volumetric siltation rate for zone 3a

4.5. Depth of water-bed interface (1.03 kg/dm³) and equal density layers

This analysis is based on density profile measurements from the Navitracker. Maps show the depth of water-bed interface and equal density layers (1.1, 1.2, 1.3 kg/dm³). The elevation of the water-bed interface is here defined as the depth at which the equipment encounters a density of 1.03 kg/dm³. This threshold is chosen since the maximum weight of salt and suspended sediment in the water column is estimated at 30 g/l, corresponding with a bulk density of about 1.03 kg/dm³. When the density passes this value, the equipment is assumed to reach the water-bed interface. The depth of the layers of constant density can be found in APPENDIX D, whereas APPENDIX E gives the density profiles for the different sections in Deurganckdok. An example for equal density

layers in section D4 is given in Figure 4-7. An example of a map is given in Figure 4-8. The description of the sections is given in § 4.1.

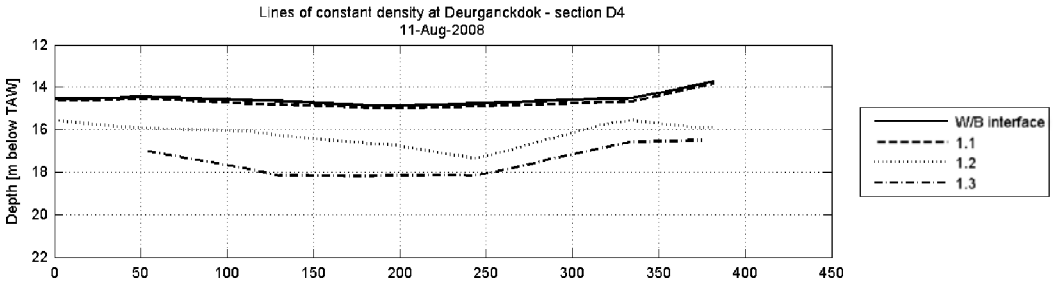


Figure 4-7: Depth of water-bed interface and equal density layers in section D4 on 11 August 2008

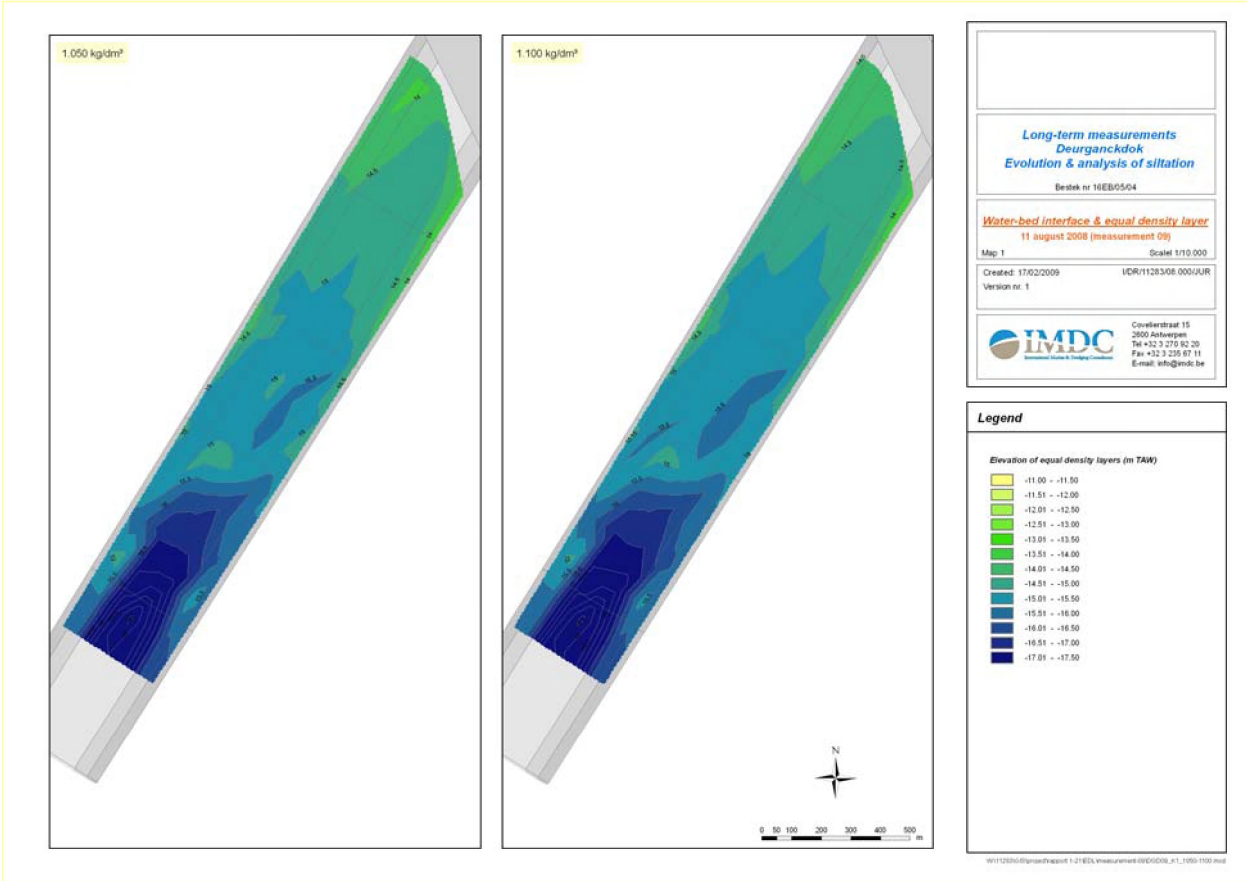


Figure 4-8: Map of the depth of the water-bed interface and equal density layers for 11/08/08

4.6. Evolution of water-bed interface and equal density layers elevation

The evolution of water-bed interface and equal density layers (1.1, 1.2 en 1.3 kg/dm³) are shown for all sections in APPENDIX F. The description of the sections is given in § 4.1. Note that the last measurement of the previous measurement campaign, i.e. 5 June 2008, is added to the present data series in order to have a good view on the density evolution. This makes 3 density measurements in total being used for this comparison. Sections of four different planes of constant

density are determined. These planes are determined by mapping the depths at which the specified densities have been encountered. For every measurement campaign the elevation of these planes across the sections has been plotted. An example is shown in Figure 4-9

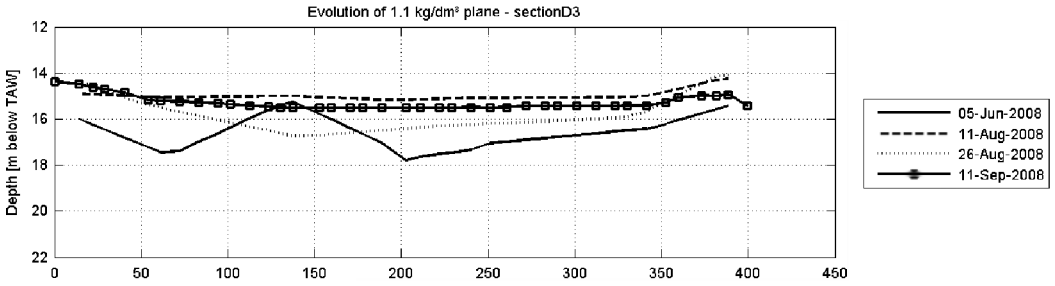


Figure 4-9: Graph of the evolution of 1.1 kg/dm³ plane in section D3

4.7. Measured mass maps

The measured mass in [TDS/m²] is calculated and visualized in maps for every measurement in reference to the empty dock at design depth (reference situation t_{0d}) (see §3.2). Every map is based on a density measurement.

These maps are shown in APPENDIX G.

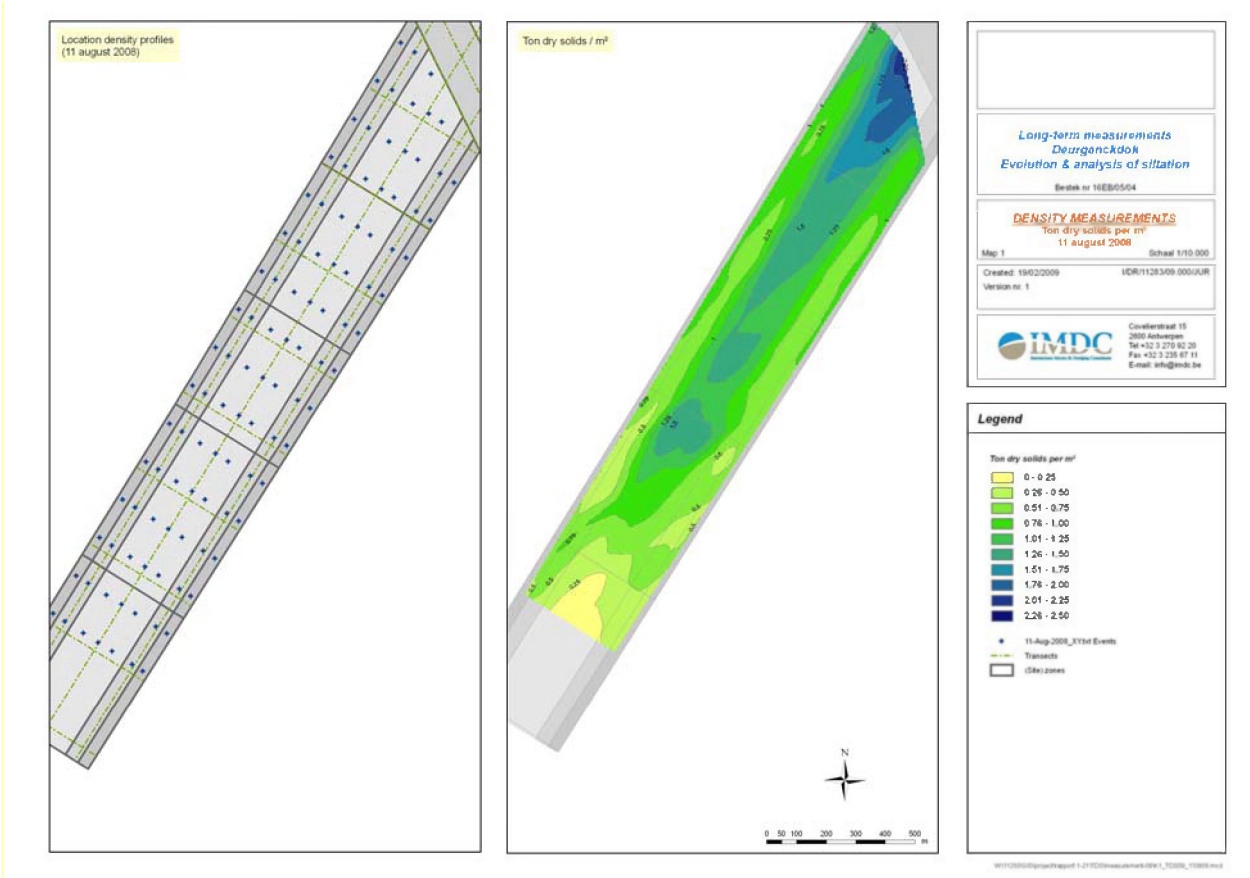


Figure 4-10: Map showing the location of the density profiles (left) and the calculation of TDS (right) on 11/08/08

4.8. Average net mass evolution

The average net mass growth [TDS/m²] in all zones and subzones is based on density profile measurements (measured sediment mass). The actual sediment mass present in the dock and measured by density profiling does not take the removed dredged material into account. The mass removed by dredging can be computed from BIS data (dredged material mass). Only zones spatially covered for 50% and more by density measurements are considered for sediment mass calculations. Unmeasured parts of these zones retrieve a value for the calculations (in order to close the mass balance of the zone), being the average mass per square meter based on the actual density measurements of the considered zone.

By adding measured mass to dredged material mass, the total accumulated mass and hence the growth can be shown (see Figure 4-11). In case this *total mass* can be computed for the complete dock (or a zone) for two subsequent measurements, an estimation of the net sediment flux into the dock (or zone) during the intermediate period is given by the difference of both total mass values. The net sediment flux into an area can also be defined as the net mass growth (kg/m² or Ton Dry Solids/m²). Division of the net mass growth of a zone by the number of days in between measurements leads to the averaged net mass growth rate. Note that the last measurement of the previous measurement campaign, i.e. 5 June 2008, is added to the present data series in order to have a good view on the net mass evolution.

Averaged net mass growth rate [kg/m²/day] is computed for each zone and subzone and is shown in APPENDIX H. An example is shown for zone 3C in Figure 4-12.

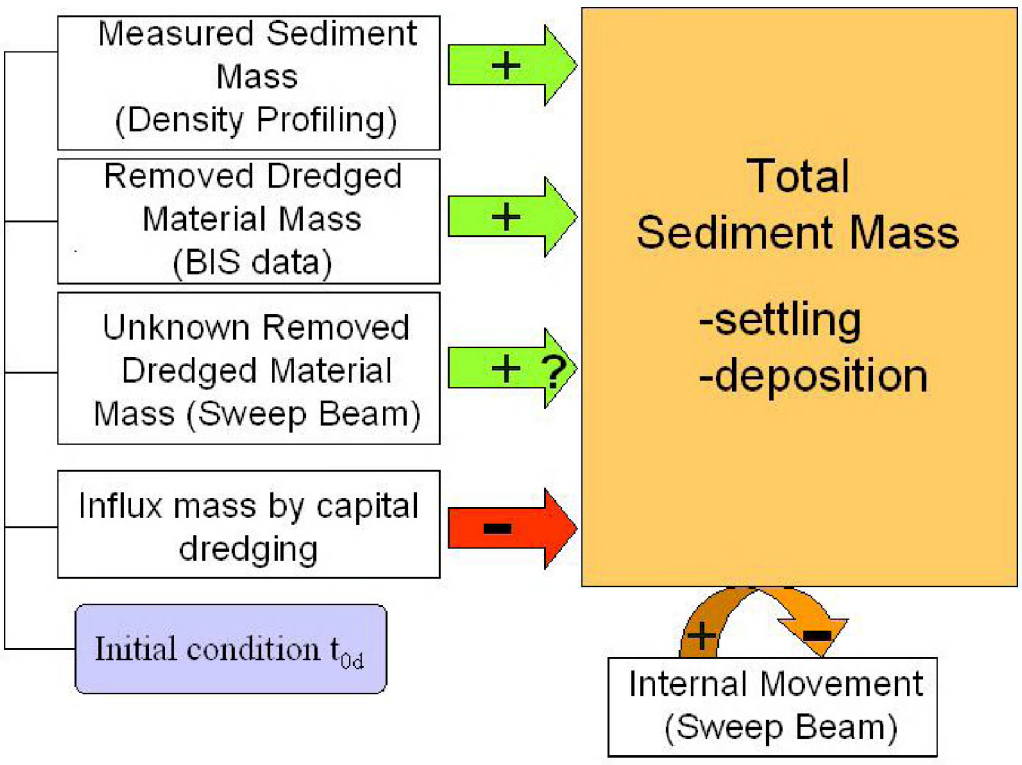


Figure 4-11: Flow chart with different elements contributing to total sediment mass for (sub)zones and total area

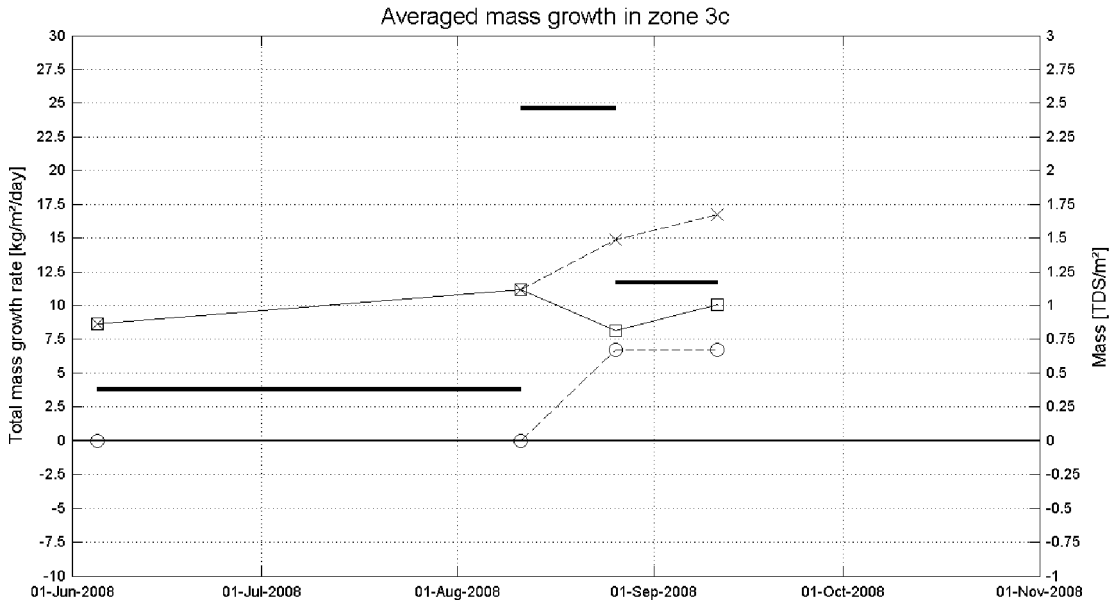


Figure 4-12: Example of averaged mass growth and mass evolution for subzone 3C

Clearly, the sediment mass balance is incomplete because sediment fluxes cannot be derived from the sweep beam data (of which no mass or volume information is available). Internal movements of sediment by the sweep beam (berthing zones to central trench) and removal of sediments from the sill into the Lower Sea Scheldt definitely influence the mass balance for (sub)zones and the total dock.

A table in APPENDIX H gives an overview for all zones and subzones for the following parameters, and this only if data is available for at least 50 % of this (sub)zone:

- Measured Sediment mass [TDS/m²]
- Dredged Material mass (absolute) [TDS]
- Total Sediment mass [TDS/m²]
- Growth rate [kg/m²/day]]
- Total area [ha]
- Covered area [ha]: area covered by density profiles
- Percent of zone covered [%]

5. PRELIMINARY ANALYSIS OF THE DATA

5.1. Volumetric analysis

Depth sounding data is processed to show the evolution of the average sediment volume per unit of surface, i.e. the average evolution of bed level as detected by a 210 kHz sounder. If more than 50% of the area of a (sub)zone is covered, an average siltation rate is calculated. For the period of July - September 2008, depth soundings were performed on 15 July, 11 and 26 August, and 3 and 22 September 2008. Whereas the depth soundings in July and August covered the entire dock, the data of September only covered the sill area and around half of zone A (see APPENDIX A). During the former measurements, an adequate coverage was obtained for subzones A-D for zones 2, 3 and 4.

The bathymetric measurements in APPENDIX A and the corresponding bathymetric difference maps in APPENDIX B show that the bed interface moves to decreasing depths between 11 and 26 August 2008. This was due to the dredging campaign between 11 and 24 August, which resulted in a bed deepening of 1.5 – 2.5 m in zones 3A-B.

From APPENDIX C, it is clear that a bed level increase was observed till the depth sounding of 26 August 2008. Between 5 June and 15 July siltation rates in the central trench were in the range of 0.6 - 2.3 cm/day. In the subsequent period (15 July – 11 August) volumetric siltation rates were much lower and measured slightly more than 0.5 cm/day in the central trench (zones 3A-C). The large siltation rates in the former period may still be the result of the maintenance dredging in the central trench at the end of June (i.e. the lowered sediment bed more effectively traps incoming sediment). The second period shows moderate siltation rates indicating a steady siltation of the central trench.

It could also be concluded for the period June-July 2008 that the siltation rates decreased when moving further inside the dock (starting from the entrance). This longitudinal trend is also in accordance to previous measurements (see e.g. IMDC, 2007n). When investigating the dock-transverse trend of the siltation rates, it could be seen that no significant difference occurred between the northern and southern quay.

5.2. Densimetric analysis

Hopper maintenance dredging occurred in the periods 11-17 and 18-24 August 2008. (see Table 5-1). BIS data revealed that more than 380x10³ TDS was dredged in this period. The amount of dredged mass increased over the two weeks of activity. The majority of dredged mass originated from zones 3A-C (more than 83%). The amount decreased when moving further inside the dock, which is in accordance to the natural siltation rates, i.e. siltation rates lower too when moving away from the Scheldt river inside the dock.

Table 5-1: Dredged sediment mass (TDS)

	11-Aug-08	18-Aug-08	
zone	**17-Aug-08**	**24-Aug-08**	**% Total**
1	39	0	0.0
2	483	346	0.2
3a	59941	80335	36.7
3b	33300	77573	29.0
3c	11229	55195	17.4
3d	3508	13759	4.5
4Na	11052	6768	4.7
4Nb	5866	2514	2.2
4Nc	1249	421	0.4
4Nd	0	75	0.0
4Za	8679	1918	2.8
4Zb	5103	2083	1.9
4Zc	487	803	0.3
4Zd	13	0	0.0

Total	140949	241789	382738
% Total	36.8	63.2	

From the measured vertical density profiles the temporal evolution of planes of constant density can be investigated. The results can be found in APPENDIX F. The lowering of these equal density planes by dredging is clear (cf. 5 June 2008).

These vertical density profiles have also been numerically integrated to calculate the mass of dry solids above a reference plane for each zone (i.e. the design depth of Deurganckdok t_{0d} (see §2.1)). This data availability also enables the use of the densimetric dredging data, cf. BIS data, in the mass balance calculations. Total sediment mass is only calculated for locations where 50% and more of the zone area is covered by density measurements. Adding up the measured and dredged masses leads to the total sediment mass as shown in APPENDIX H. Results show a mass growth rate in the central trench (zones 3A-D) in the range of 0.2 to 9.2 kg/m²/day for the period 5 June – 11 August 2008. These numbers are in the range of growth rates measured in previous measurement periods, e.g. 2 - 15 kg/m²/day for the period September 2007 - June 2008. The period of 11-26 August however showed extremely large growth rates, being related to dredging activities; these extremely large growth rates up to more than 45 kg/m²/day should be questioned though. Zones 4N-A, 4N-B and 4N-C showed growth rates in the range of 2.4 – 4.2 kg/m²/day, being comparable to those for the periods September–November 2007. Note that the DensiTune was applied on 11 September and not the Navitracker as in all previous measurements. The different device application certainly resulted in different density profiling and resulting sediment masses (see IMDC, 2008b). The trend analysis of the growth rates should therefore be looked at with scrutiny. The period of 26 August – 11 September indeed showed growth rates ranging from 7 kg/m²/day up to more than 22 kg/m²/day, which is larger than those growth rates valid for undredged periods and measured with the Navitracker.

An overview of the total mass settled over time, for all zones that have been covered for 100%, is shown in Table 5-2 and Table 5-3. From these figures, it is concluded that between early June and mid-August about 101x10³ tons of dry solids have settled in zones 3 and 4, subzones A-D. Instead, the subsequent two-weeks period showed 489x10³ tons of settled dry solids. This vast amount is

obviously a consequence of the large growth rates being calculated for the period 11-26 August 2008. Finally, the period of 26 August – 11 September resulted in 270x10³ tons of settled dry solids. Also here, this amount seems rather large seen the two-weeks period; a plausible cause may be the change of density profiling device.

Subdividing per subzone (Table 5-3), it is concluded that the settled mass in subzones A (nearest to river) was generally larger than the settled mass in subzones B and C. This confirms the hypothesis of a gradual decrease in siltation with distance from the Scheldt river.

Table 5-2: Total sediment mass (measured + dredged, in 10³ TDS) in some zones

zone	11-Aug-08	26-Aug-08	11-Sep-08
3a	159	227	260
3b	136	202	228
3c	111	147	166
3d	112	124	138
4Na	35	40	47
4Nb	23	27	30
4Nc	18	17	15
4Nd	18	20	14
4Za	23	24	33
4Zb	22	23	30
4Zc	16	17	19
4Zd	18	17	19

Table 5-3: Mass settled per subzone in zones 3 and 4 (measured + dredged, in 10³ TDS)

	05-Jun-2008 / 11-Aug-2008	11-Aug-2008 / 26-Aug-2008	26-Aug-2008 / 11-Sept-2008
subzone A	45	183	114
subzone B	30	180	86
subzone C	19	94	44
subzone D	6	32	26

6. REFERENCES

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IMDC (2007c) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 1.3 Sediment Balance: Three monthly report 1/10/2006 – 31/12/2006 (I/RA/11283/06.115/MSA)

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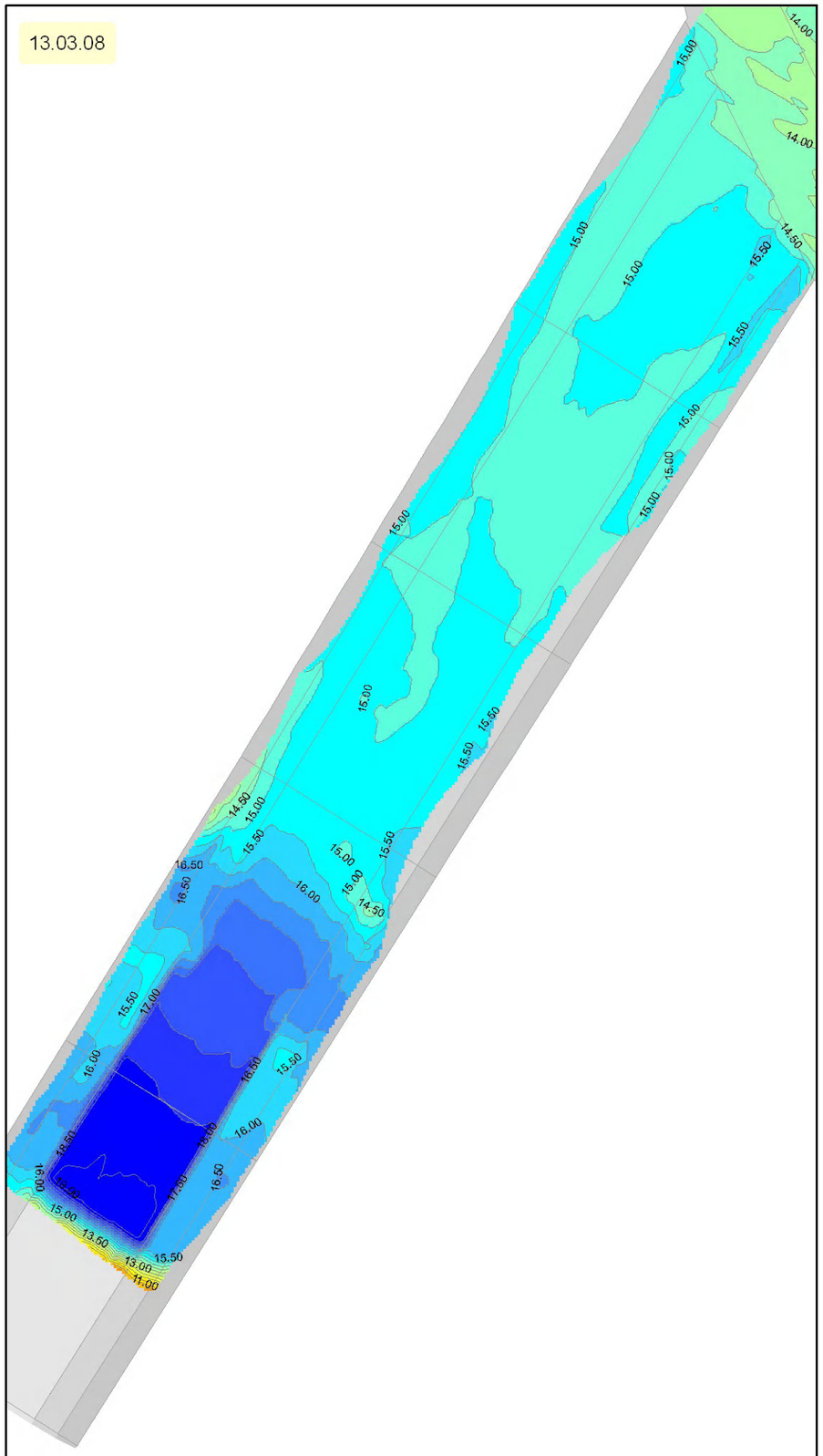
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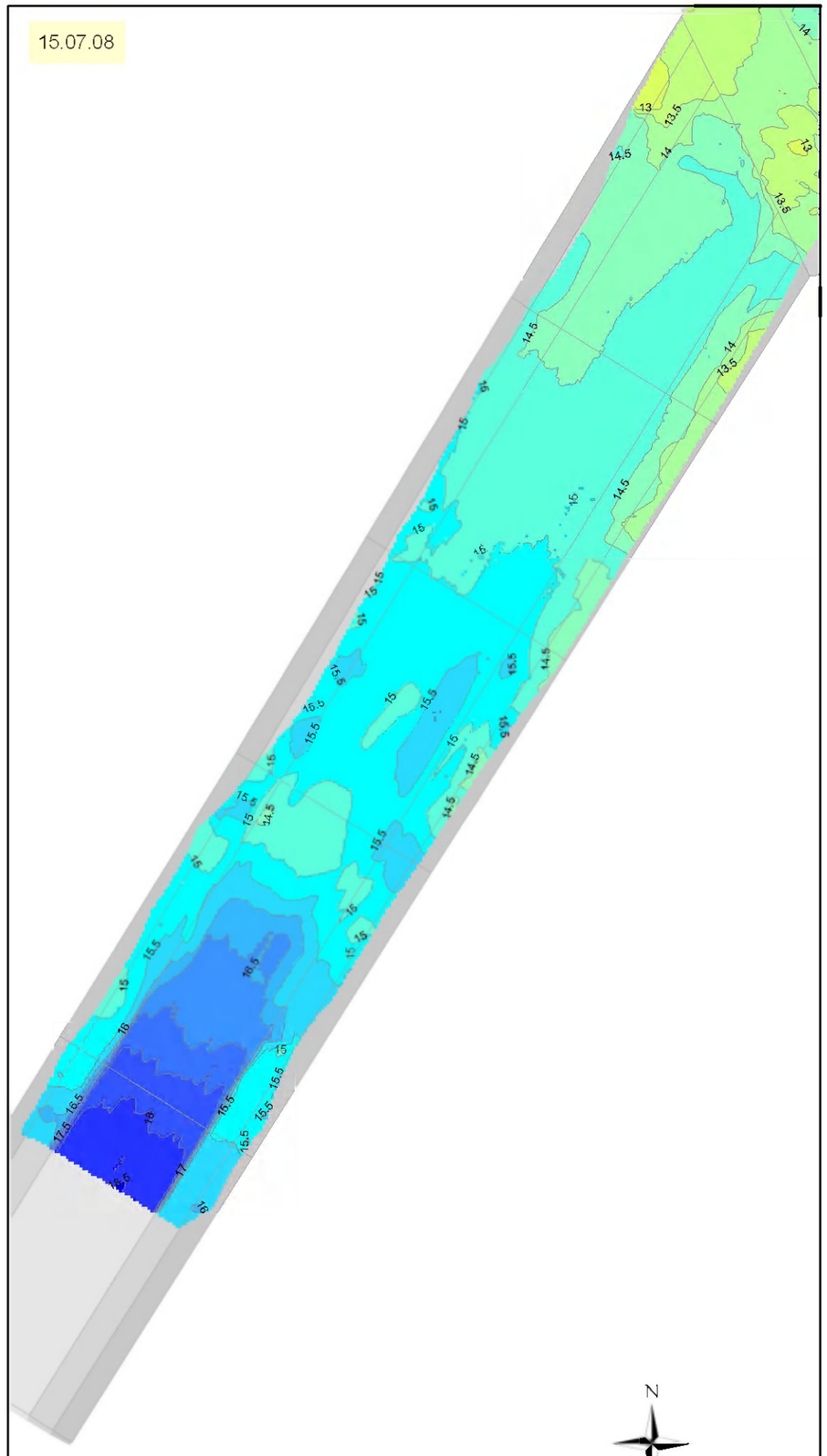
APPENDIX A.

DEPTH OF THE WATER-BED INTERFACE (210 KC)

13.03.08



15.07.08



Long-term measurements Deurganckdok Evolution & analysis of siltation

Bestek nr 16EB/05/04

Depth of the water-bed interface (210 kC)

13.03.08 & 15.07.08

Map 1 — Scale 1/10.000

Created: 09/01/2009 — I/DR/11283/09.001/JUR

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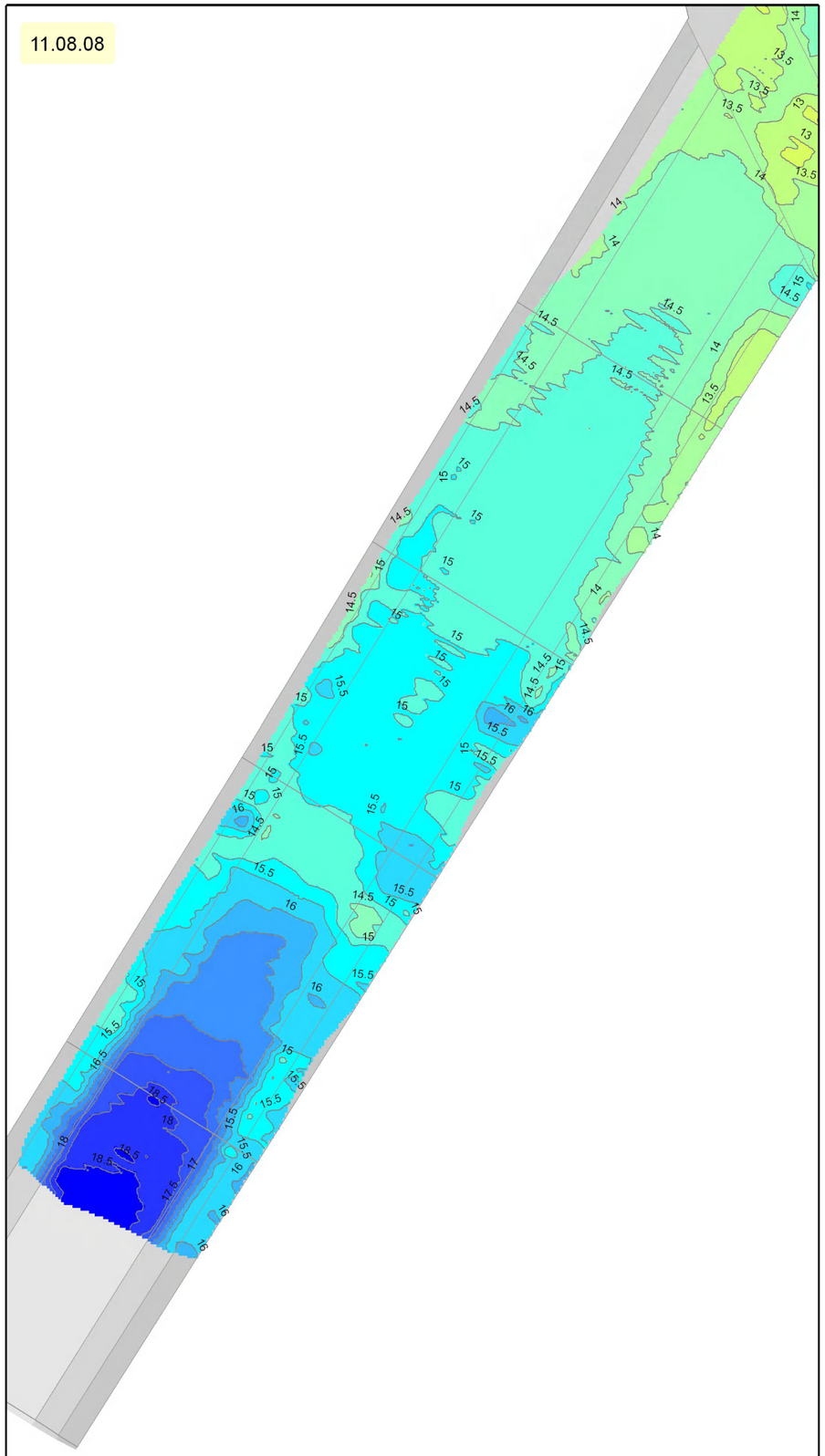
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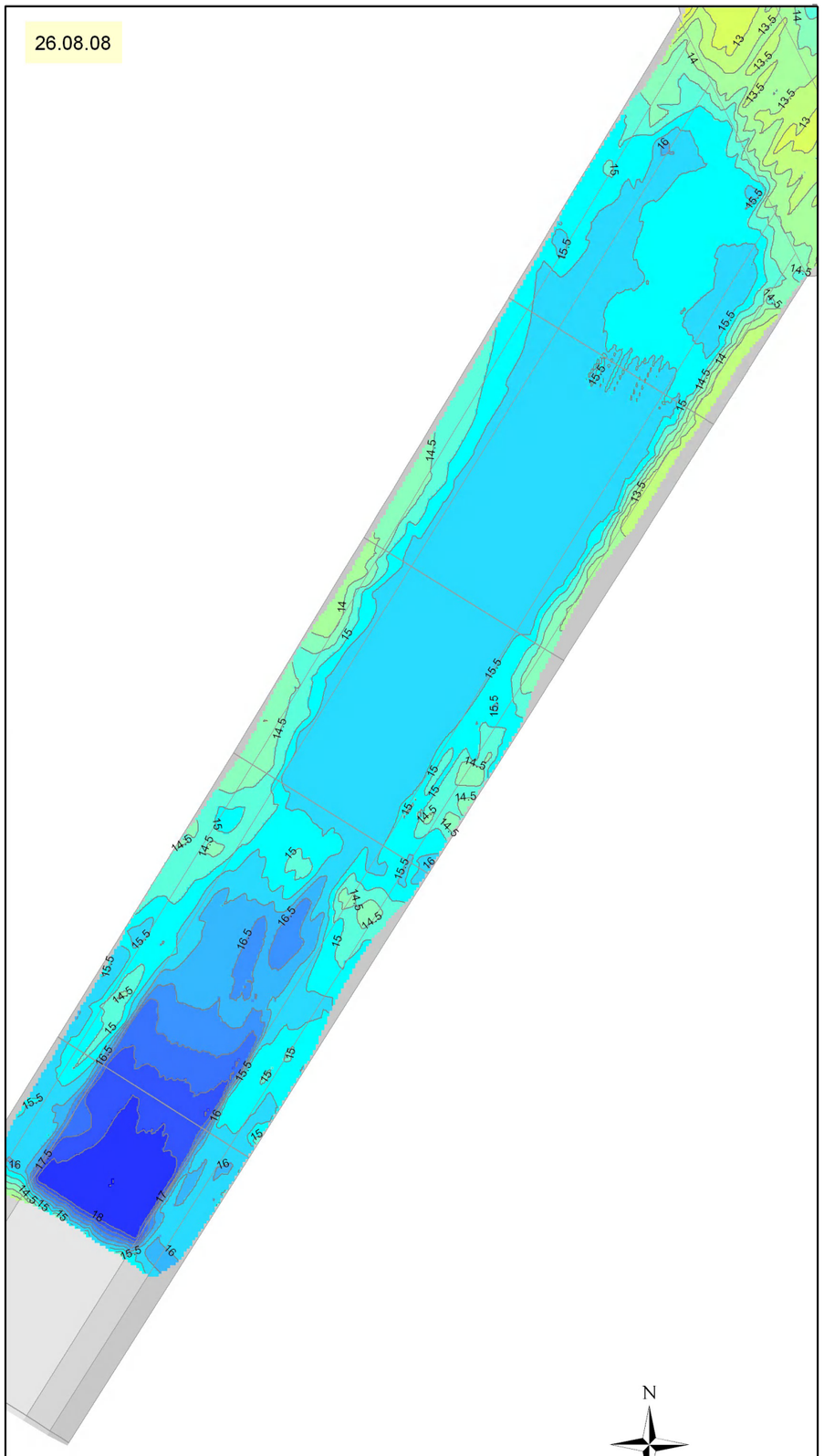
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- -18.01 - -18.50
- -18.51 - -19.00

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11.08.08



26.08.08



Long-term measurements Deurganckdok Evolution & analysis of siltation

Bestek nr 16EB/05/04

Depth of the water-bed interface (210 kC)

11.08.08 & 26.08.08

Map 2 Scale 1/10.000

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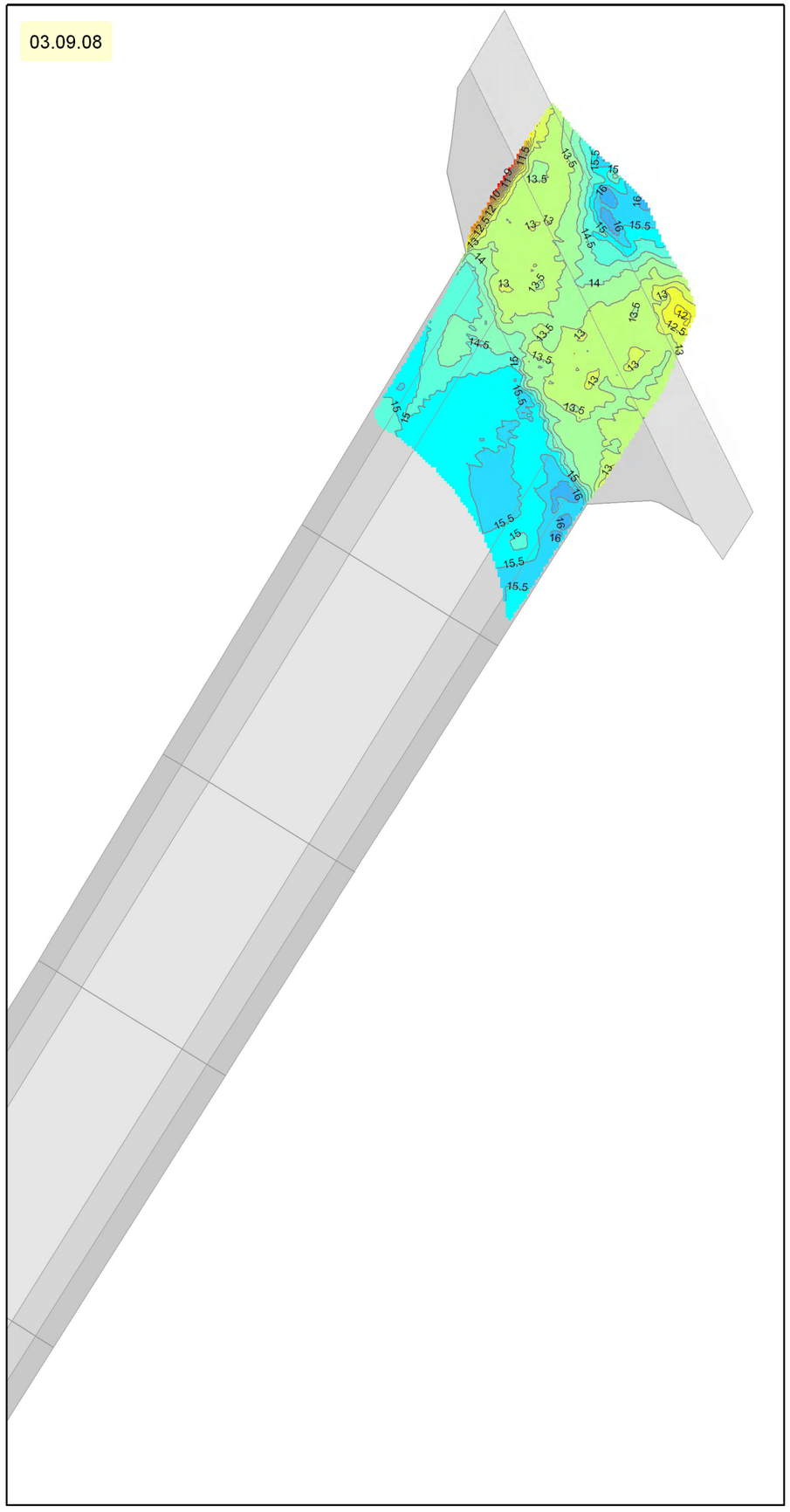
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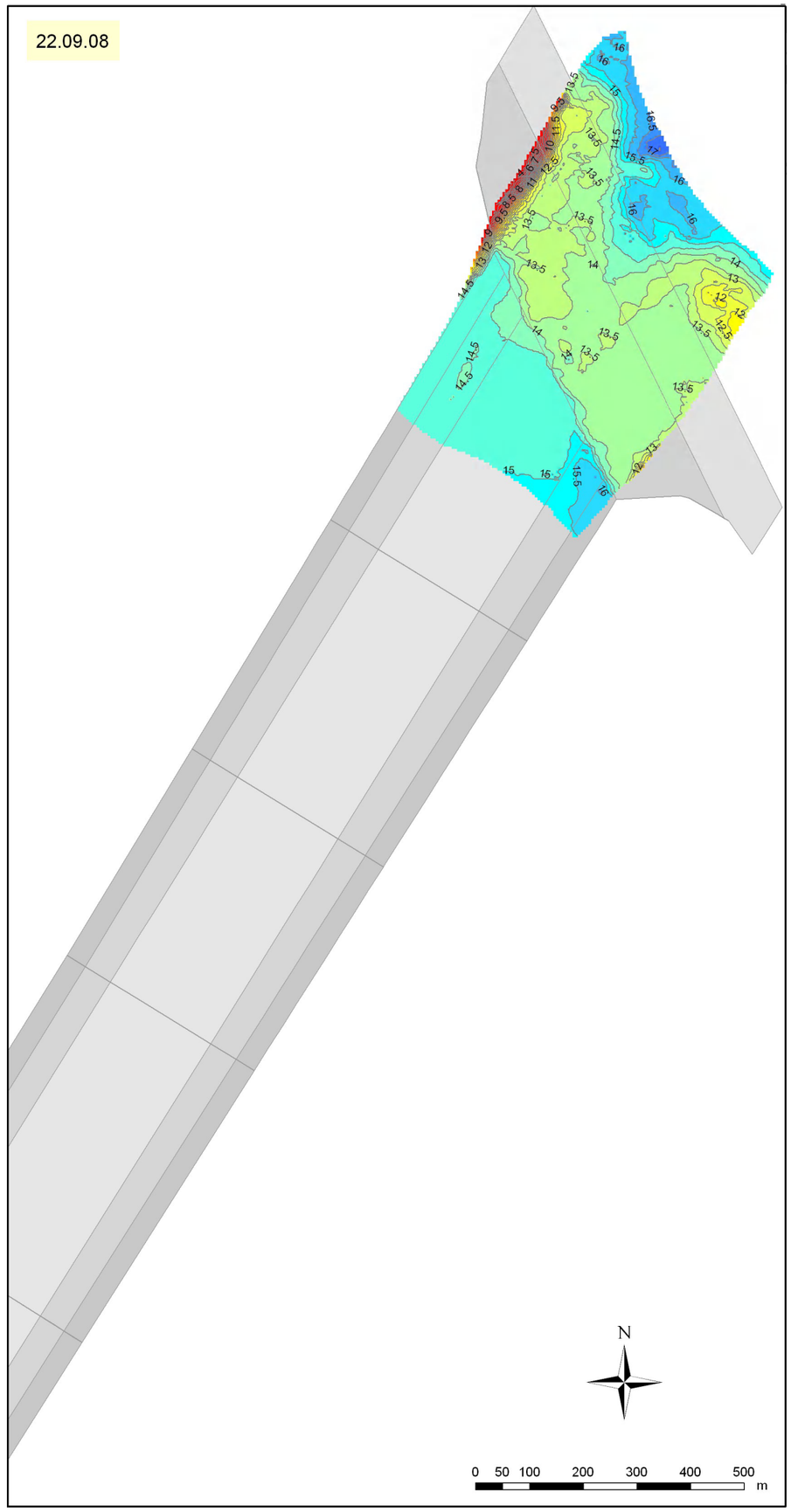
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03.09.08



22.09.08



Long-term measurements Deurganckdok Evolution & analysis of siltation

Bestek nr 16EB/05/04

Depth of the water-bed interface (210 kC)

03.09.08 & 22.09.08

Map 3 Scale 1/10.000

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Legend

Depth m [TAW]

- > -8.00
- -8.51 - -9.00
- -9.01 - -9.50
- -9.51 - -10.00
- -10.01 - -10.50
- -10.51 - -11.00
- -11.01 - -11.50
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APPENDIX B.

EVOLUTION OF DEPTH OF WATER-BED INTERFACE

(210 KC)

B.1 Difference maps

13.03.08 - 15.07.08



Long-term measurements Deurganckdok Evolution & analysis of siltation

Bestek nr 16EB/05/04

Difference map

13.03.08 - 15.07.08

Map 1 — Scale 1/10.000

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Legend

13.03.08 - 15.07.08

elevation decrease (m)

- < -5.00
- -4.99 - -4.50
- -4.49 - -4.00
- -3.99 - -3.50
- -3.49 - -3.00
- -2.99 - -2.50
- -2.49 - -2.00
- -1.99 - -1.50
- -1.49 - -1.00
- -0.99 - -0.50
- -0.49 - 0.00

elevation increase (m)

- +0.01 - +0.50
- +0.51 - +1.00
- +1.01 - +1.50
- +1.51 - +2.00
- +2.01 - +2.50
- +2.51 - +3.00
- +3.01 - +3.50
- +3.51 - +4.00
- +4.01 - +4.50
- +4.51 - +5.00
- > + 5.00

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13.03.08 - 11.08.08

15.07.08 - 11.08.08

N

0 50 100 200 300 400 500 m

Long-term measurements Deurganckdok Evolution & analysis of siltation

Bestek nr 16EB/05/04

Difference map

13.03.08 - 11.08.08
15.07.08 - 11.08.08

Map 2 Scale 1/10.000

Created: 16/01/2009 I/GM/11283/09.005/JUR
Version nr. 1

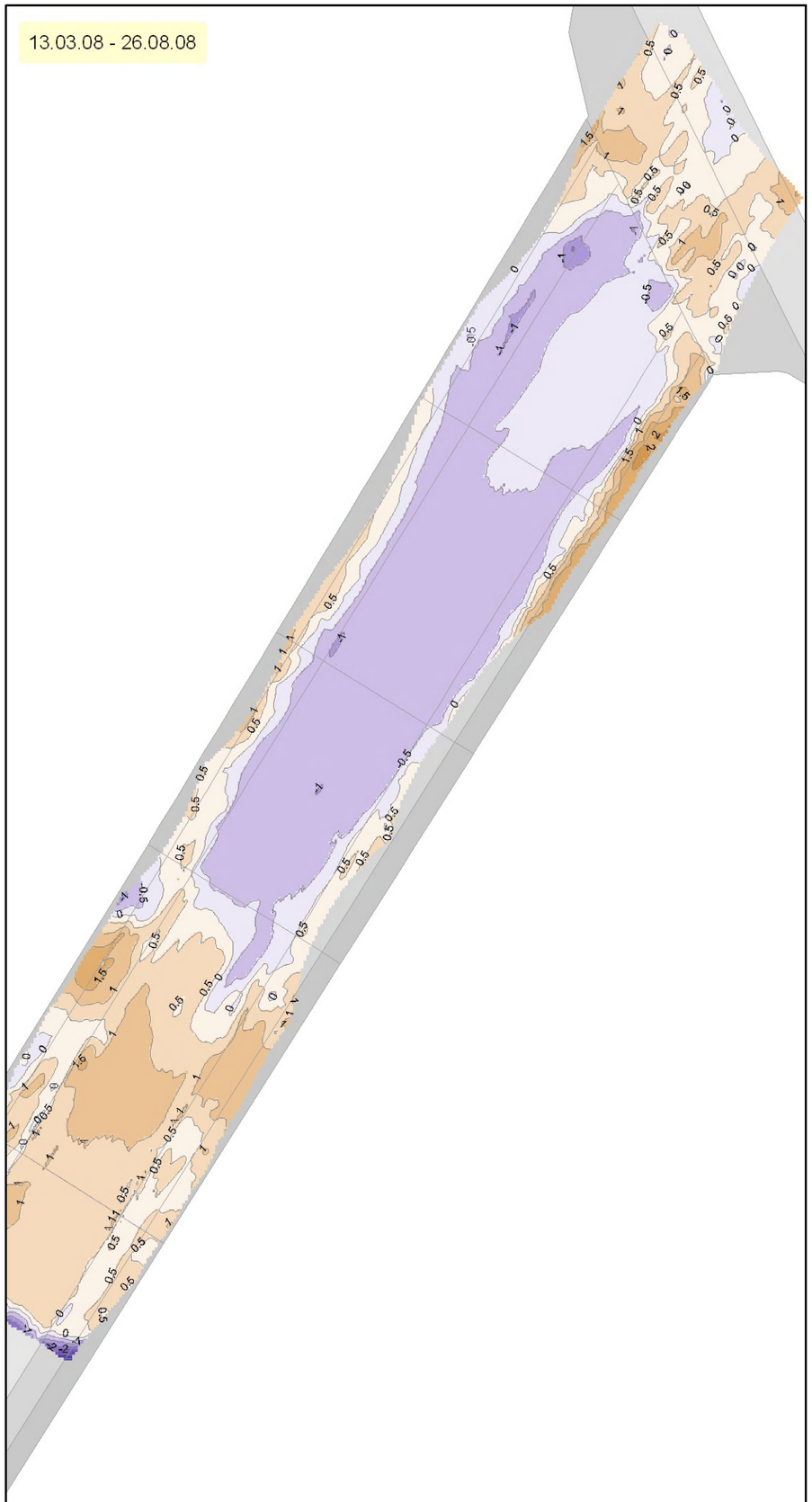
IMDC International Marine & Dredging Consultants
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E-mail: info@imdc.be

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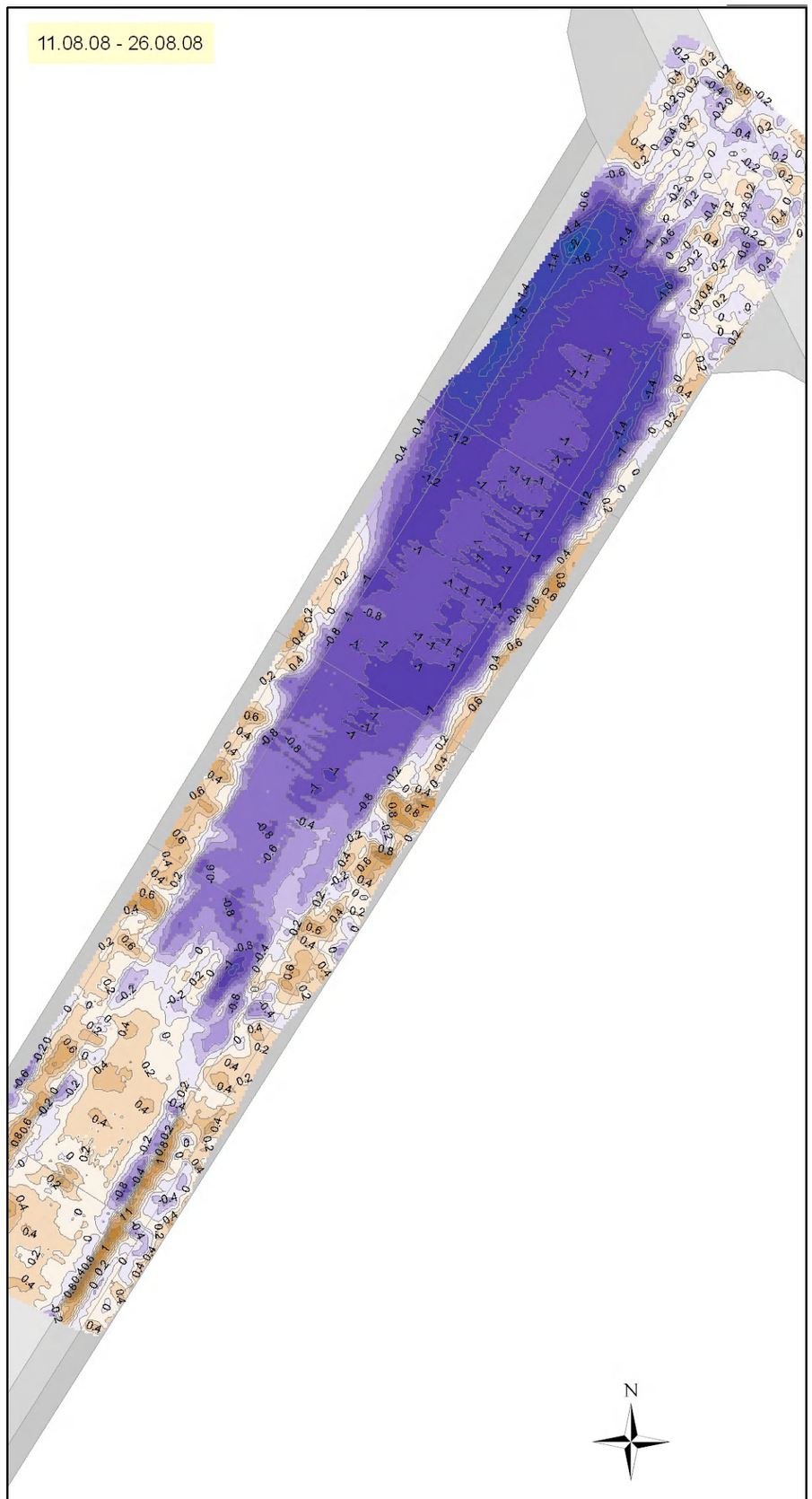
	13.03.08 - 11.08.08	15.07.08 - 11.08.08
elevation decrease (m)	< -5.00	< -2.00
	-4.99 - -4.50	-1.99 - -1.80
	-4.49 - -4.00	-1.79 - -1.60
	-3.99 - -3.50	-1.59 - -1.40
	-3.49 - -3.00	-1.39 - -1.20
	-2.99 - -2.50	-1.19 - -1.00
	-2.49 - -2.00	-0.99 - -0.80
	-1.99 - -1.50	-0.79 - -0.60
	-1.49 - -1.00	-0.59 - -0.40
	-0.99 - -0.50	-0.39 - -0.20
	-0.49 - 0.00	-0.19 - 0.00
elevation increase (m)	+0.01 - +0.50	+0.01 - +0.20
	+0.51 - +1.00	+0.21 - +0.40
	+1.01 - +1.50	+0.41 - +0.60
	+1.51 - +2.00	+0.61 - +0.80
	+2.01 - +2.50	+0.81 - +1.00
	+2.51 - +3.00	+1.01 - +1.20
	+3.01 - +3.50	+1.21 - +1.40
	+3.51 - +4.00	+1.41 - +1.60
	+4.01 - +4.50	+1.61 - +1.80
	+4.51 - +5.00	+1.81 - +2.00
	> + 5.00	> +2.00

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13.03.08 - 26.08.08



11.08.08 - 26.08.08



Long-term measurements Deurganckdok Evolution & analysis of siltation

Bestek nr 16EB/05/04

Difference map

13.03.08 - 26.08.08
11.08.08 - 26.08.08

Map 3 Scale 1/10.000

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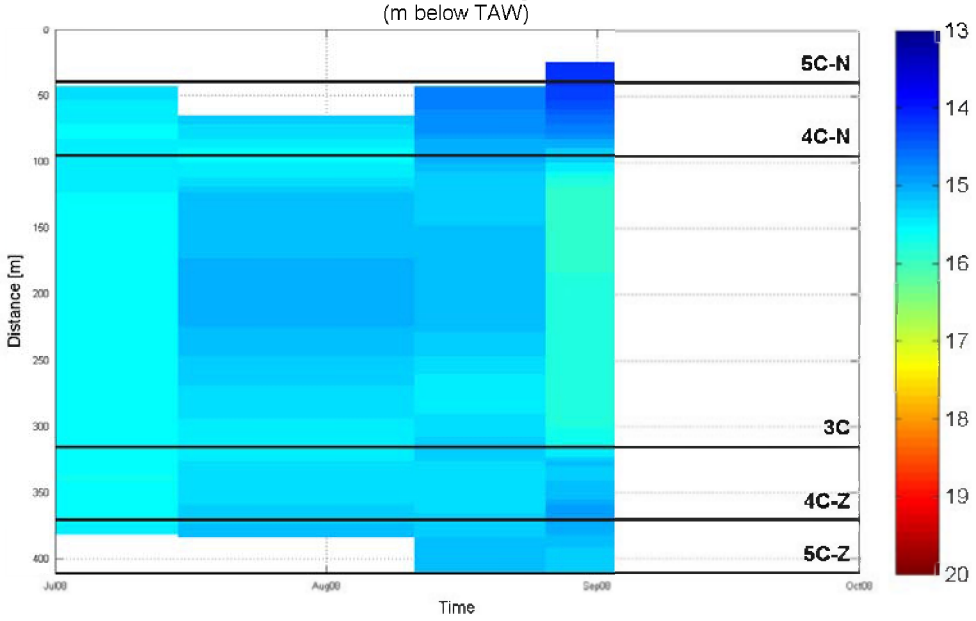
	13.03.08 - 26.08.08	11.08.08 - 26.08.08
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	-4.99 - -4.50	-1.99 - -1.80
	-4.49 - -4.00	-1.79 - -1.60
	-3.99 - -3.50	-1.59 - -1.40
	-3.49 - -3.00	-1.39 - -1.20
	-2.99 - -2.50	-1.19 - -1.00
	-2.49 - -2.00	-0.99 - -0.80
	-1.99 - -1.50	-0.79 - -0.60
	-1.49 - -1.00	-0.59 - -0.40
	-0.99 - -0.50	-0.39 - -0.20
	-0.49 - 0.00	-0.19 - 0.00
elevation increase (m)	+0.01 - +0.50	+0.01 - +0.20
	+0.51 - +1.00	+0.21 - +0.40
	+1.01 - +1.50	+0.41 - +0.60
	+1.51 - +2.00	+0.61 - +0.80
	+2.01 - +2.50	+0.81 - +1.00
	+2.51 - +3.00	+1.01 - +1.20
	+3.01 - +3.50	+1.21 - +1.40
	+3.51 - +4.00	+1.41 - +1.60
	+4.01 - +4.50	+1.61 - +1.80
	+4.51 - +5.00	+1.81 - +2.00
	> + 5.00	> +2.00

B.2 Bed elevation evolution per section

Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD

Evolution of 210kHz bottom at Deurganckdok - section D1
(m below TAW)

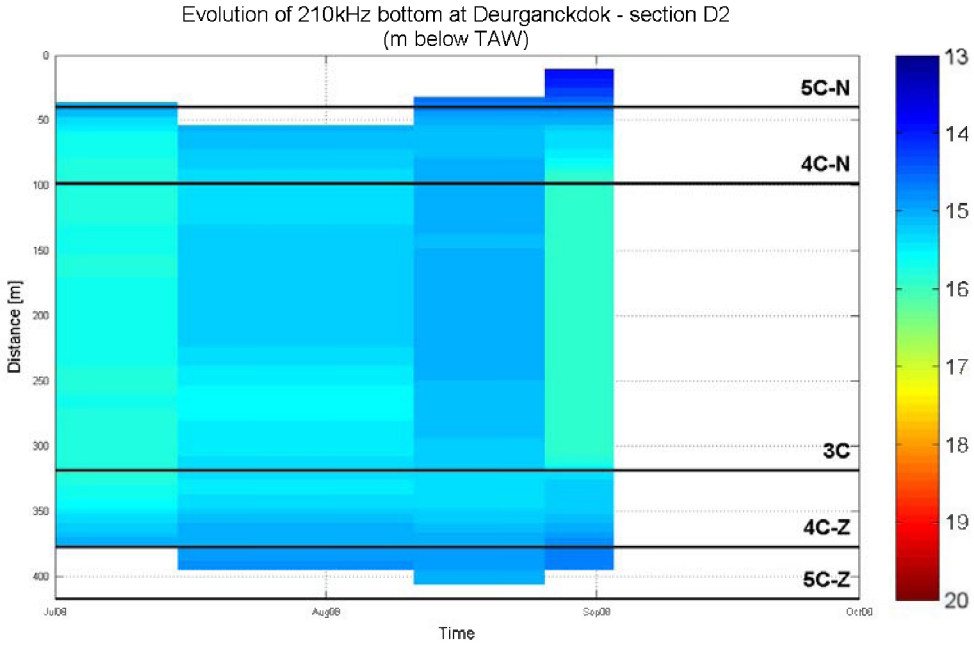


Data Processed by: IMDC
In association with : wl | delft hydraulics

I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

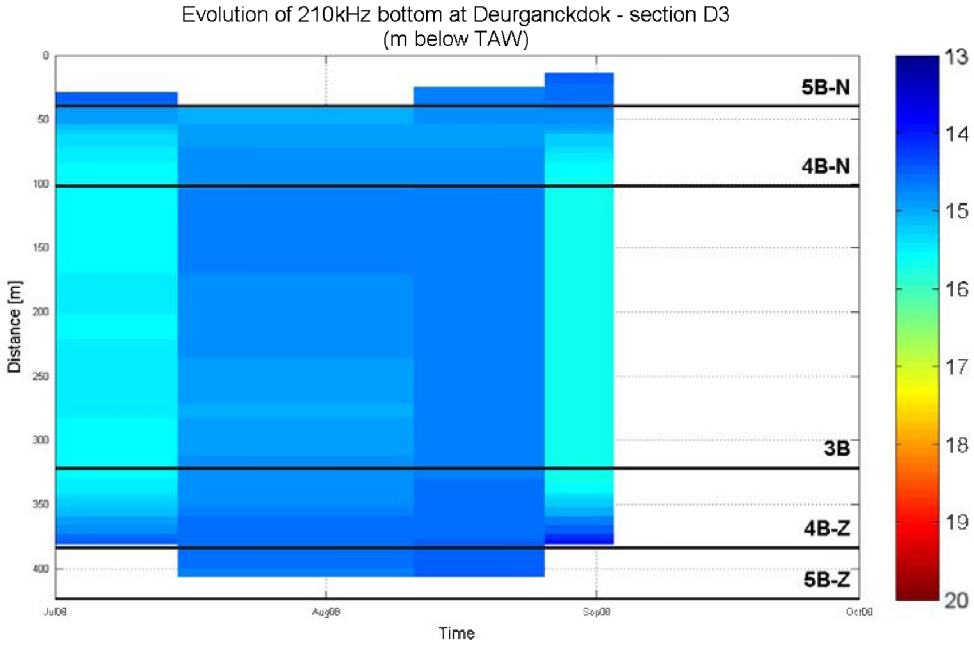
Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD



Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD

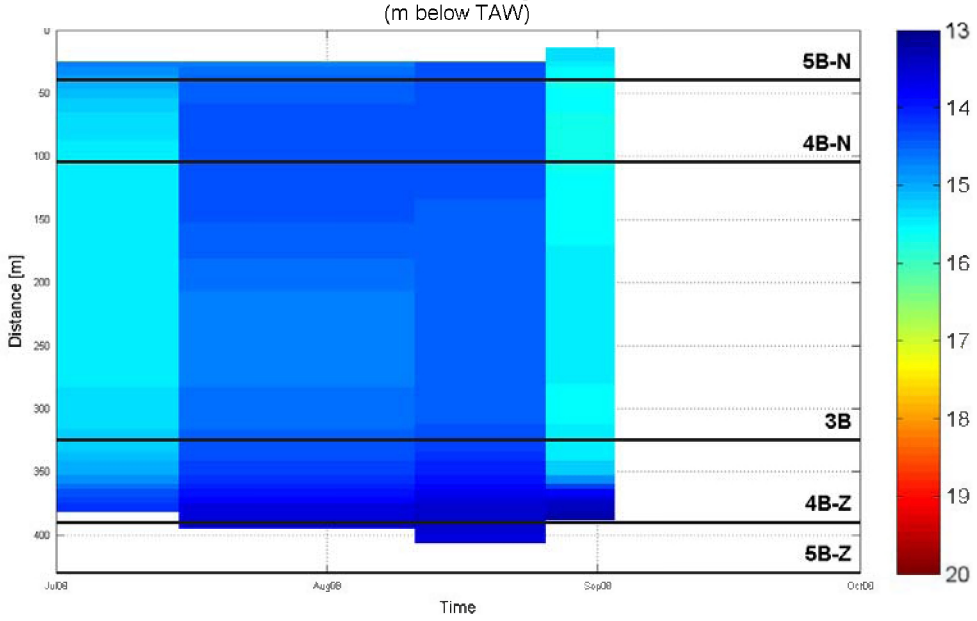


Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD

Evolution of 210kHz bottom at Deurganckdok - section D4
(m below TAW)

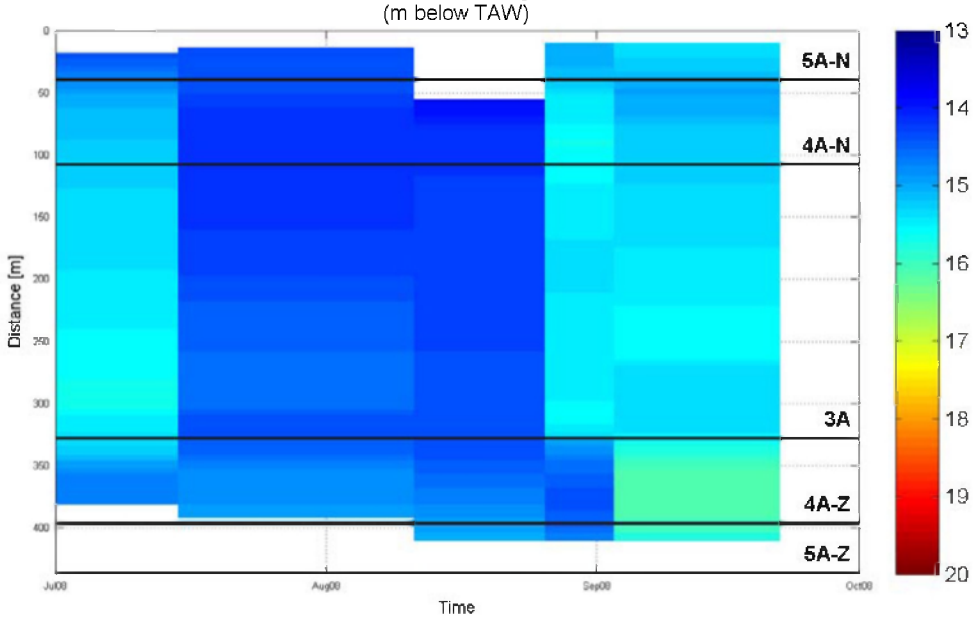


Data Processed by:
In association with :
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD

Evolution of 210kHz bottom at Deurganckdok - section D5
(m below TAW)



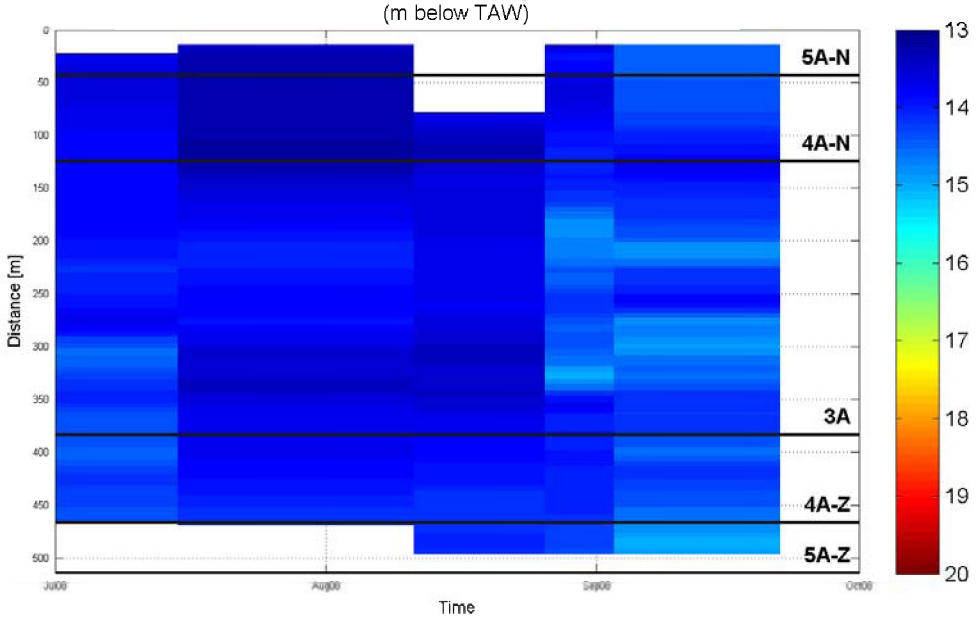
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In association with : WL | delft hydraulics

I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD

Evolution of 210kHz bottom at Deurganckdok - section D6
(m below TAW)

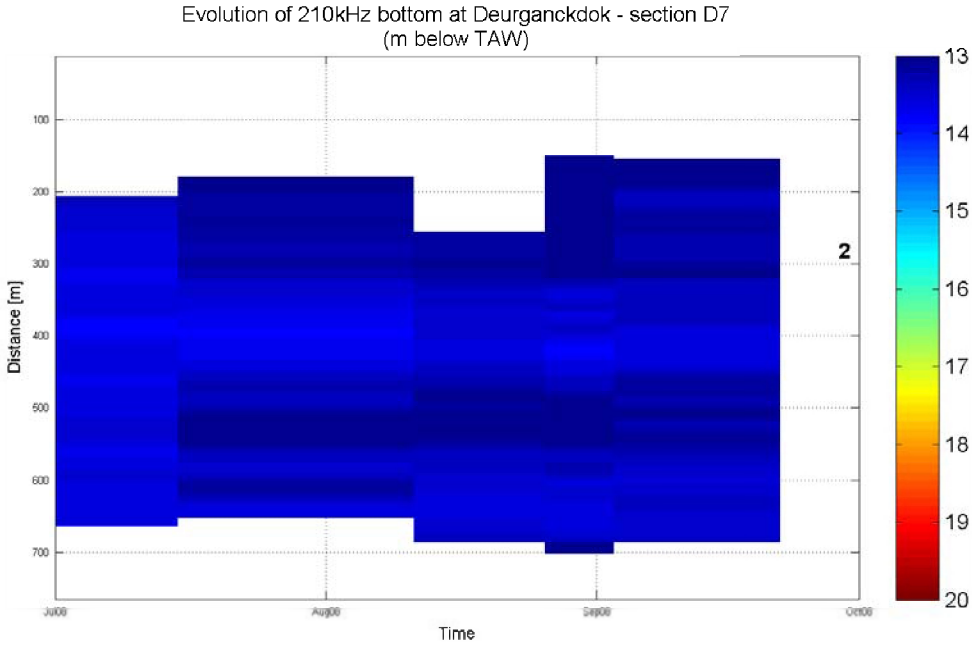


Data Processed by: IMDC
In association with : wl | delft hydraulics

I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

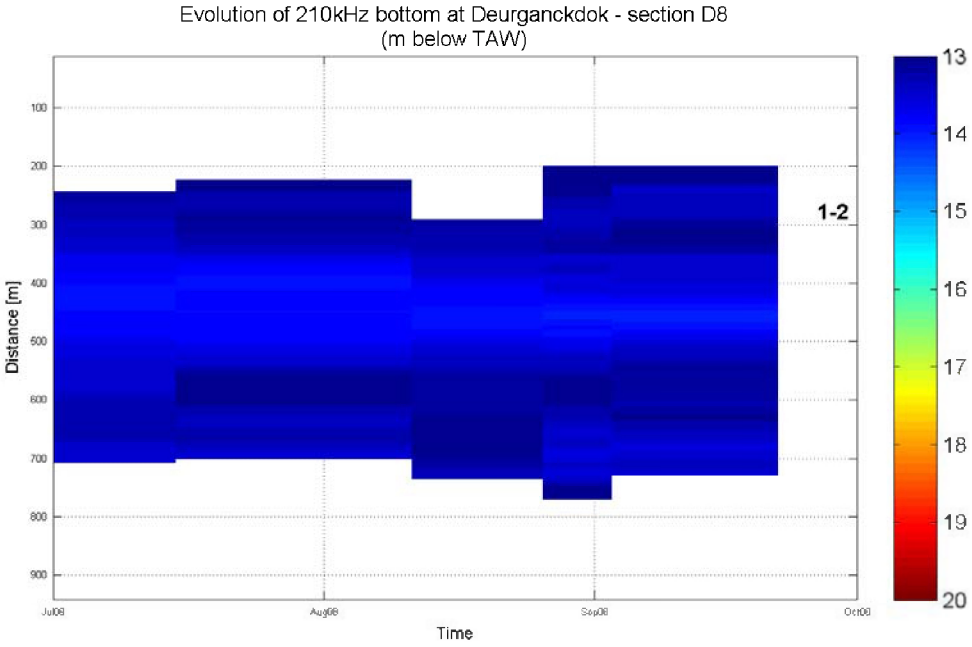
Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD



Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD

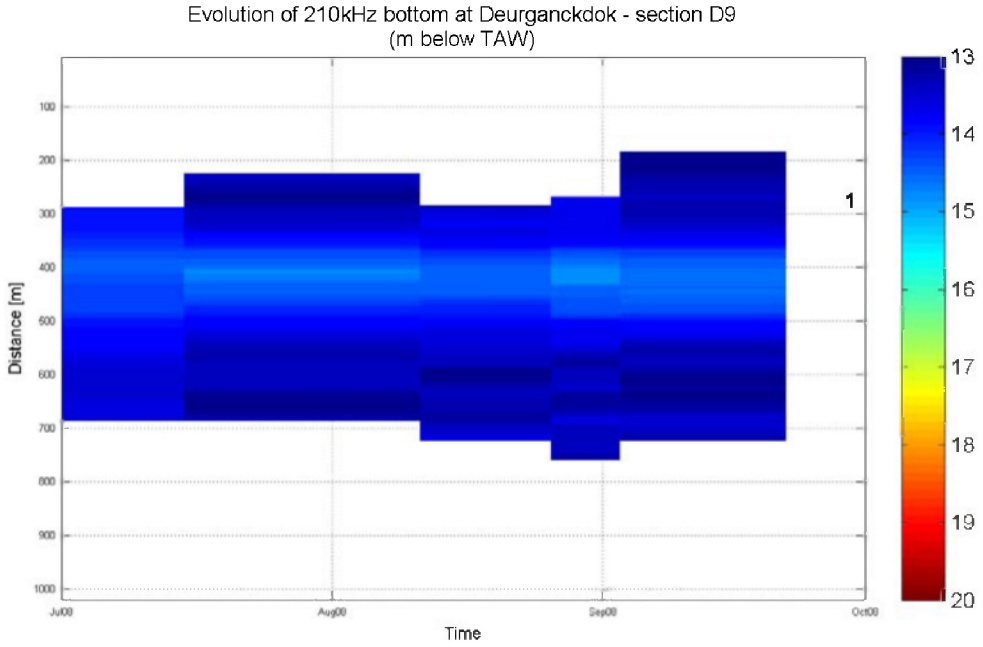


Data Processed by: IMDC
In association with : WL | delft hydraulics

I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD

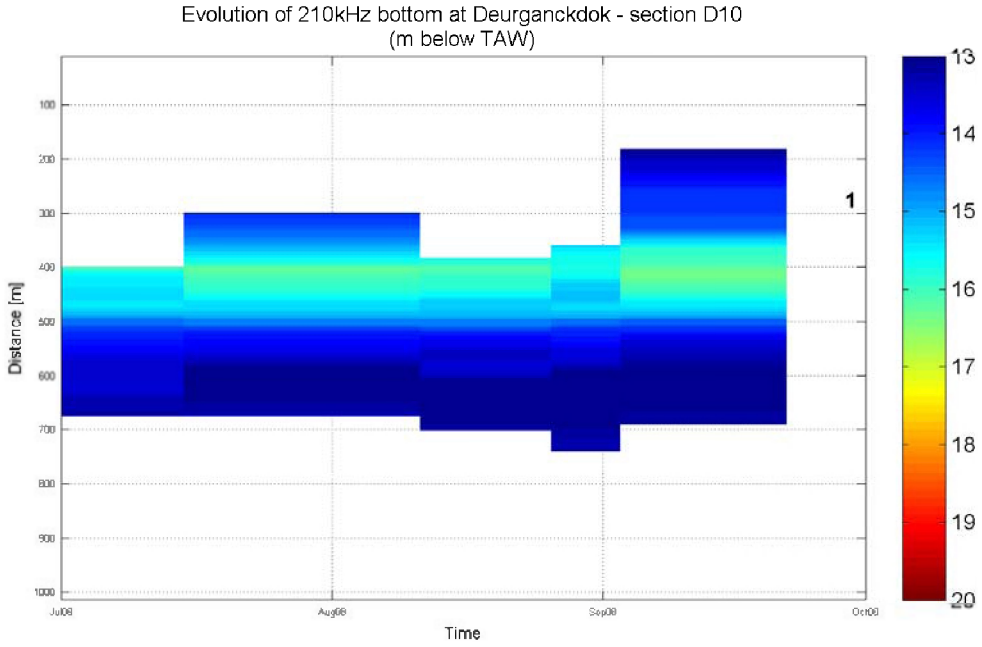


Data Processed by: IMDC
In association with : wl | delft hydraulics

I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

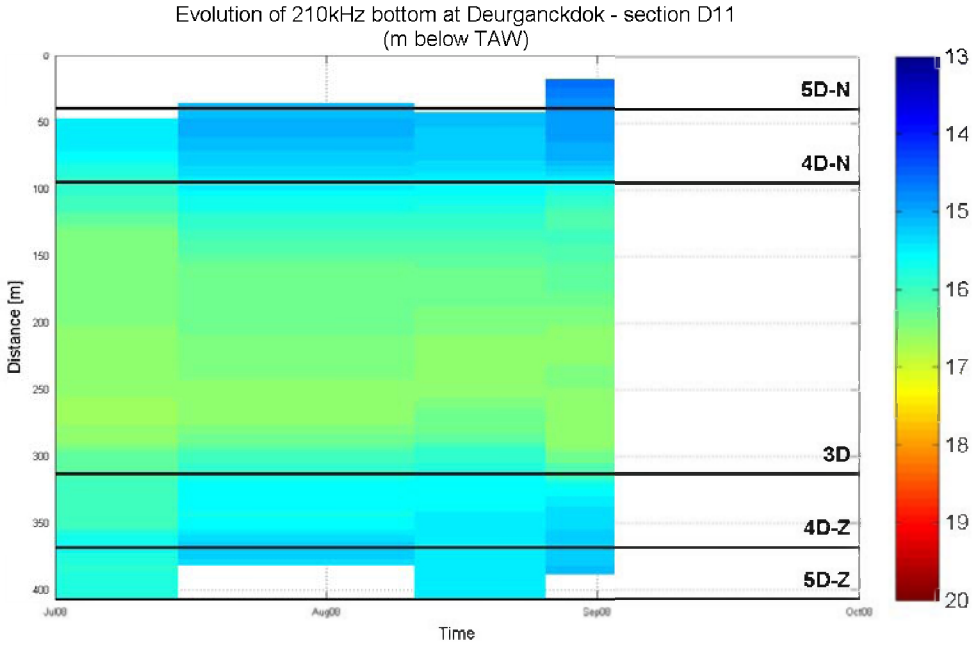
Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD



Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD



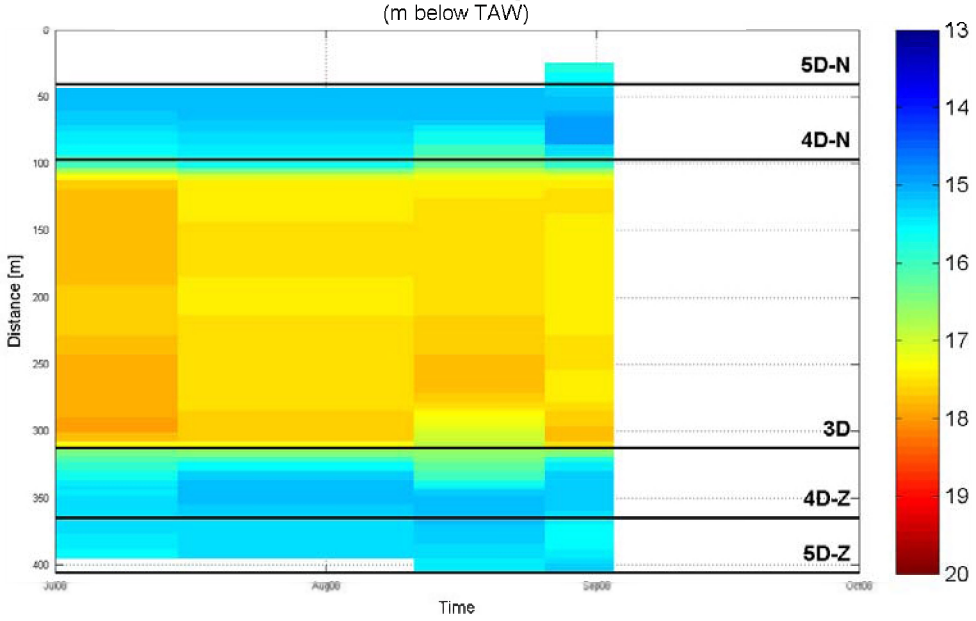
Data Processed by: IMDC
In association with : WL | delft hydraulics

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Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD

Evolution of 210kHz bottom at Deurganckdok - section D12
(m below TAW)

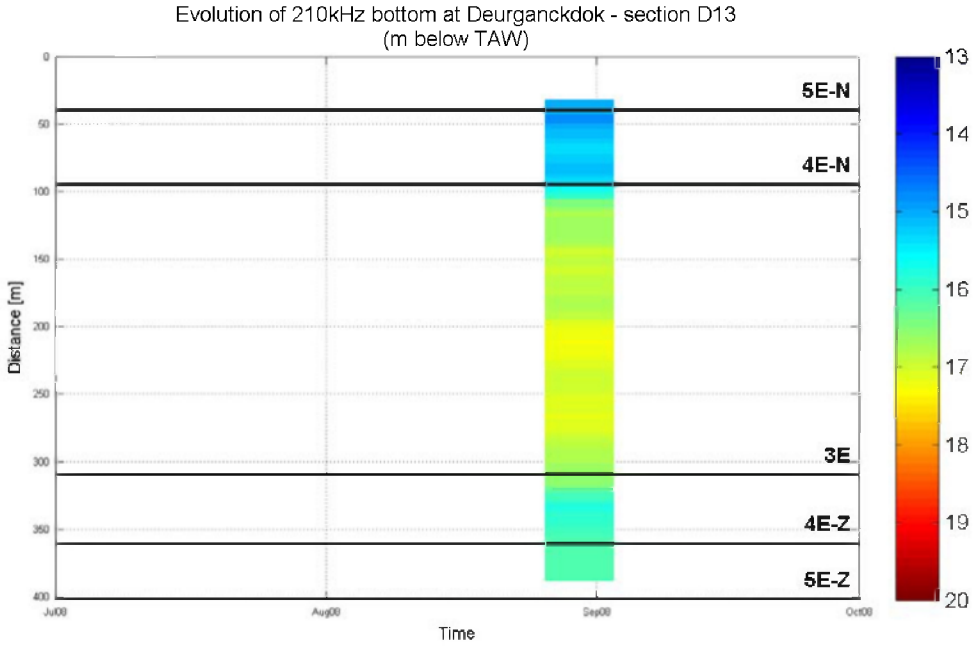


Data Processed by: IMDC
In association with : wl | delft hydraulics

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Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD

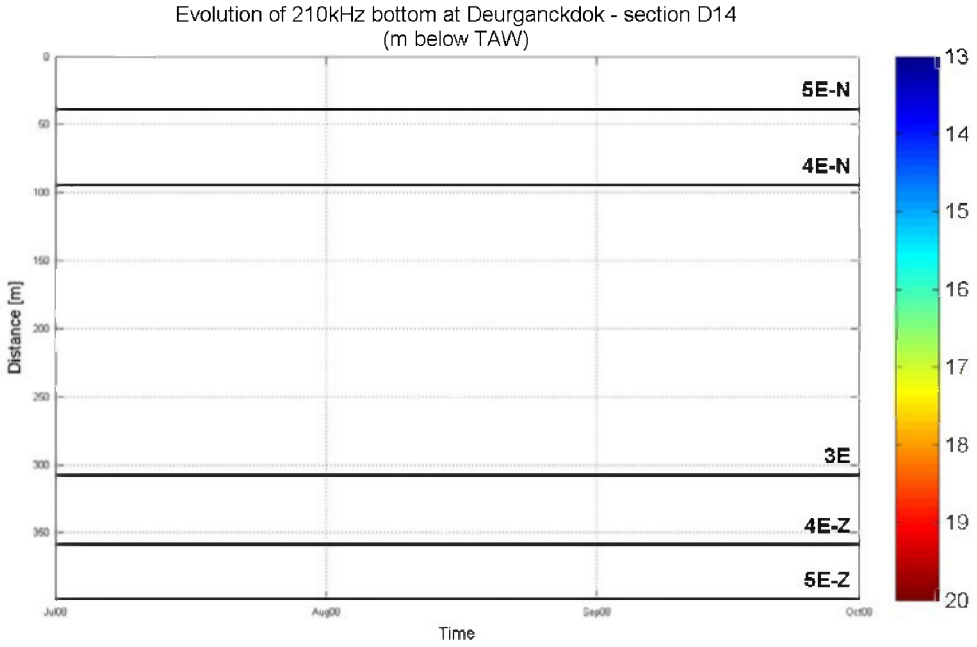


Data Processed by: IMDC
In association with : WL | delft hydraulics

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Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD

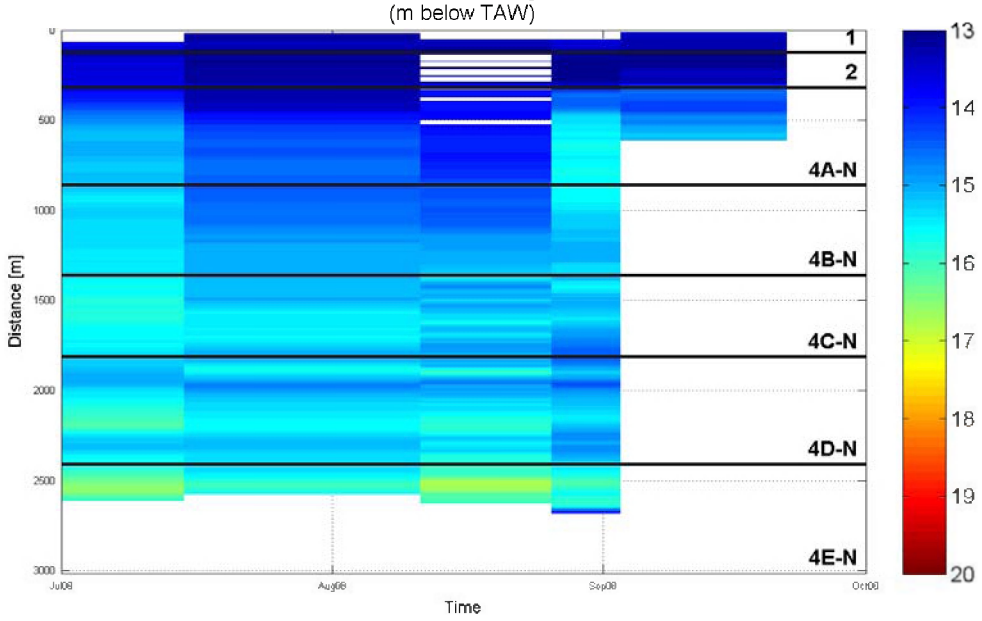


Data Processed by: IMDC
In association with : WL | delft hydraulics
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Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD

Evolution of 210kHz bottom at Deurganckdok - section L1
(m below TAW)



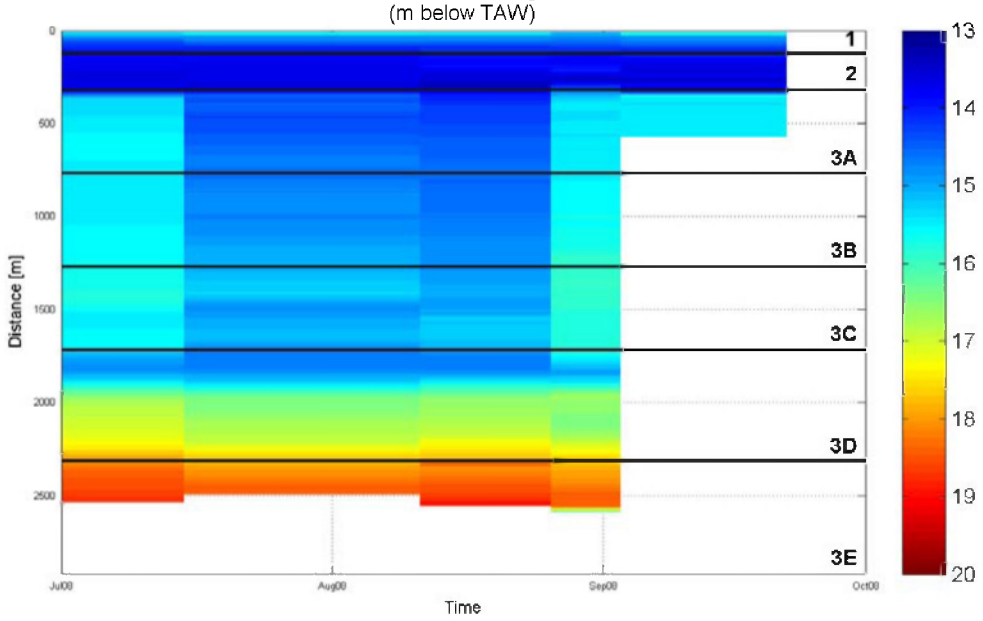
Data Processed by:
In association with :

I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD

Evolution of 210kHz bottom at Deurganckdok - section L2
(m below TAW)



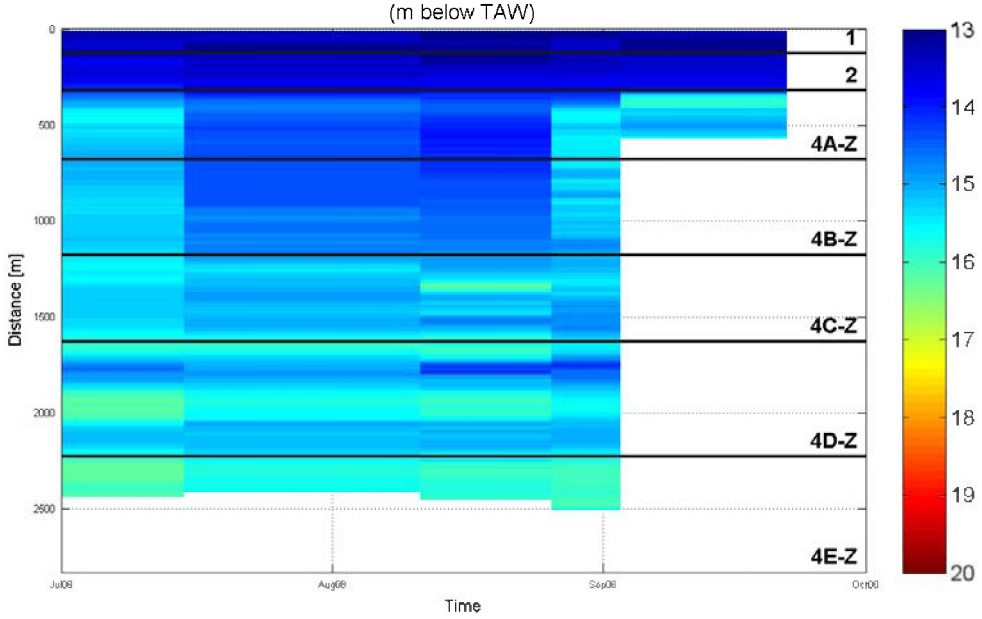
Data Processed by: IMDC
In association with : WL | delft hydraulics

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Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD

Evolution of 210kHz bottom at Deurganckdok - section L3
(m below TAW)



Data Processed by: IMDC
In association with : WL | delft hydraulics

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APPENDIX C.

VOLUMETRIC SILTATION RATES IN DIFFERENT ZONES AND SECTIONS

C.1 Siltation rates (tabular)

1/ Per zone (cm/day)

	15-Jul-08	11-Aug-08	26-Aug-08	03-Sep-08	22-Sep-08
1	-	-	-	-	0.10
2	0.46	0.04	1.21	-1.69	0.92
3a	2.29	0.53	-7.53	1.58	-
3b	1.67	0.54	-6.66	-	-
3c	0.96	0.56	-4.64	-	-
3d	0.56	-0.08	-0.63	-	-
3e	-	-	-	-	-
4Na	1.66	0.07	-7.98	6.24	0.77
4Nb	1.23	0.38	-4.05	-	-
4Nc	0.59	0.78	-0.03	-	-
4Nd	0.50	-0.32	2.02	-	-
4Ne	-	-	-	-	-
4Za	1.75	0.79	-5.58	-5.53	-
4Zb	1.41	0.37	-3.74	-	-
4Zc	0.67	-0.43	1.27	-	-
4Zd	0.39	-0.31	1.75	-	-
4Ze	-	-	-	-	-
5Na	-	-	-	-	0.56
5Nb	-	-	-	-	-
5Nc	-	-	-	-	-
5Nd	-	-	-	-	-
5Ne	-	-	-	-	-
5Za	-	0.14	-0.04	-24.25	-
5Zb	-	0.26	-	-	-
5Zc	-	-	2.13	-	-
5Zd	-	0.36	1.06	-	-
5Ze	-	-	-	-	-

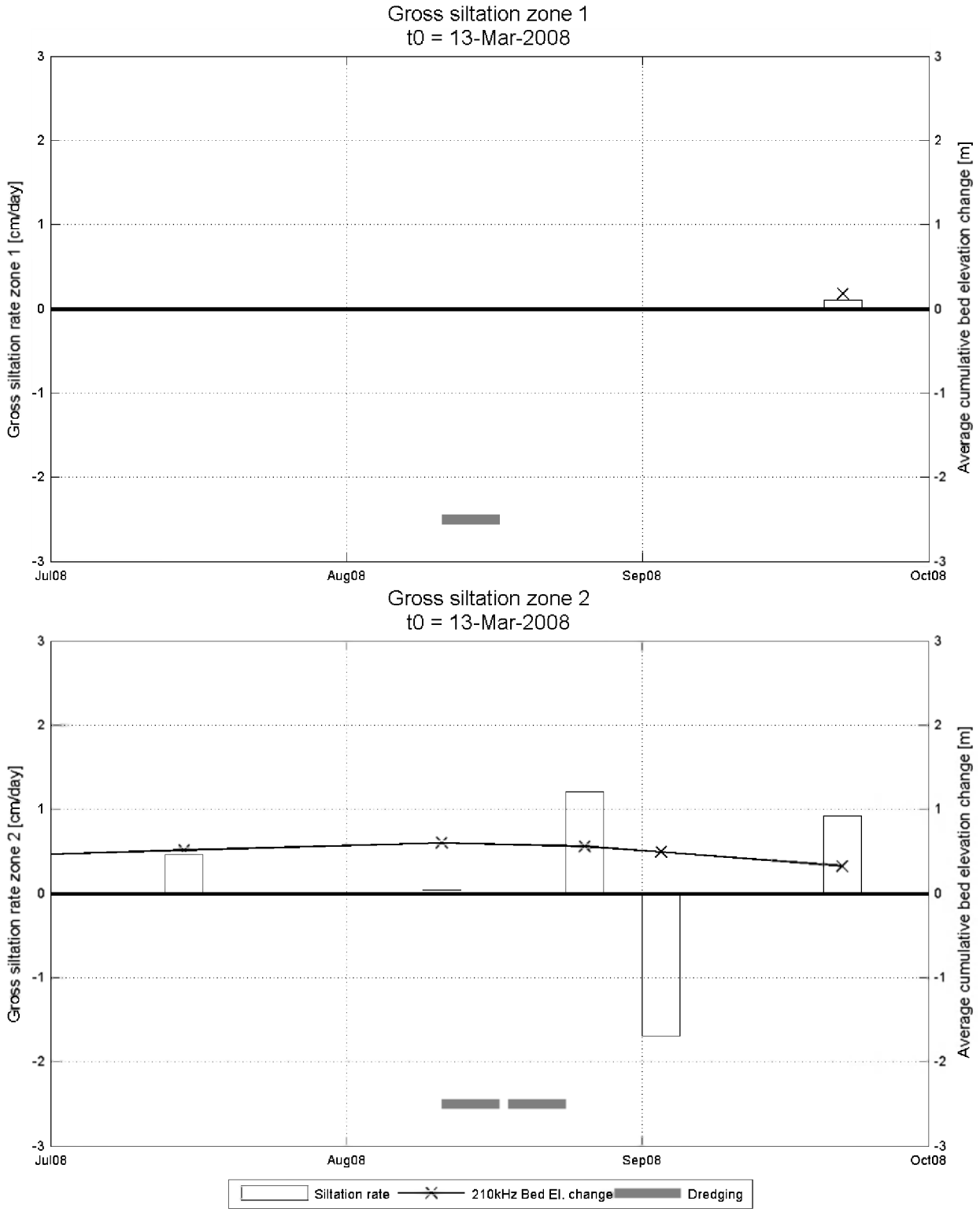
2/ Per section (cm/day)

	15-Jul-08	11-Aug-08	26-Aug-08	03-Sep-08	22-Sep-08
D1	0.70	0.25	-1.21	-	-
D2	0.88	0.75	-2.83	-	-
D3	1.32	0.46	-4.44	-	-
D4	1.99	0.43	-6.93	-	-
D5	1.98	0.24	-5.97	-2.91	2.34
D6	0.92	-0.27	-3.02	-2.34	0.27
D7	0.63	-0.07	2.54	-3.05	0.80
D8	-	-	-	-0.46	0.92
D9	-	-	-	-	-0.23
D10	-	-	-	-	0.49
D11	0.68	0.07	0.33	-	-
D12	0.47	-0.14	0.79	-	-
D13	-	-	-	-	-
D14	-	-	-	-	-
L1	1.20	-0.42	-1.04	-	-
L2	1.28	-0.24	-3.44	-	-
L3	0.97	0.11	-1.74	-	-

C.2 Water-bed interface evolution for ali zones

Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD



Reference level: depth sounding 13-Mar-2008

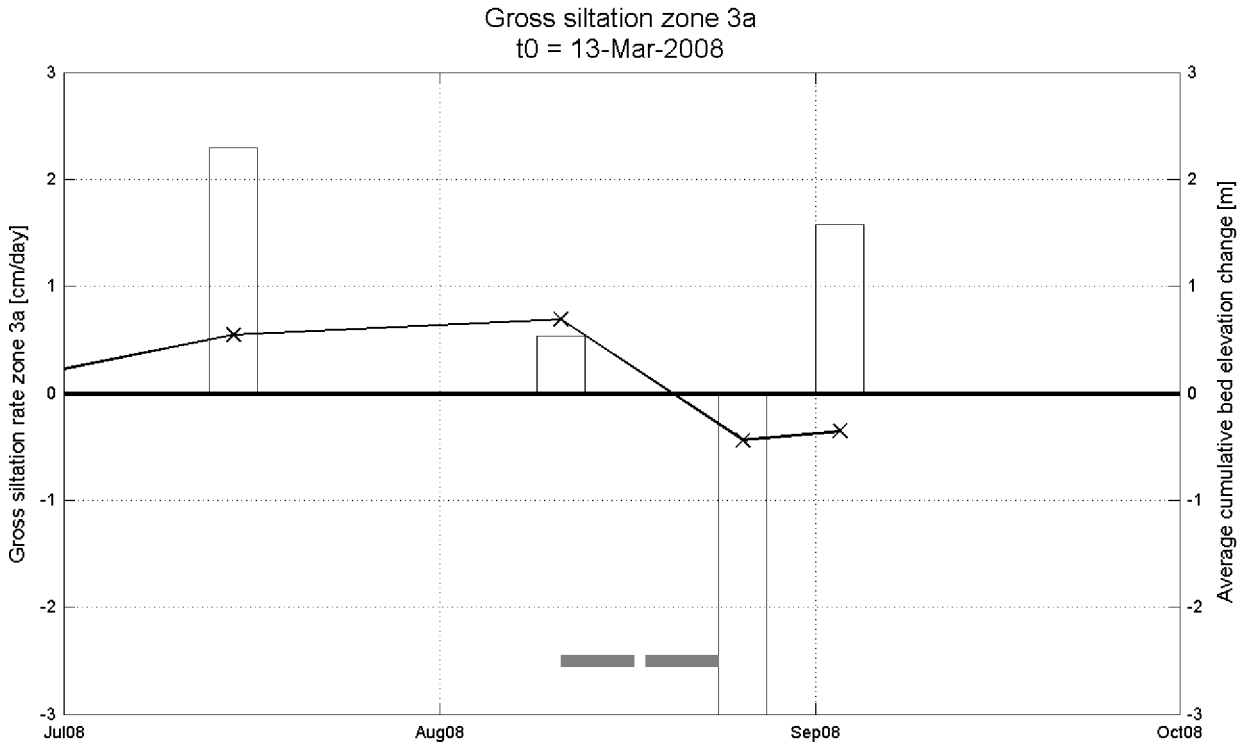
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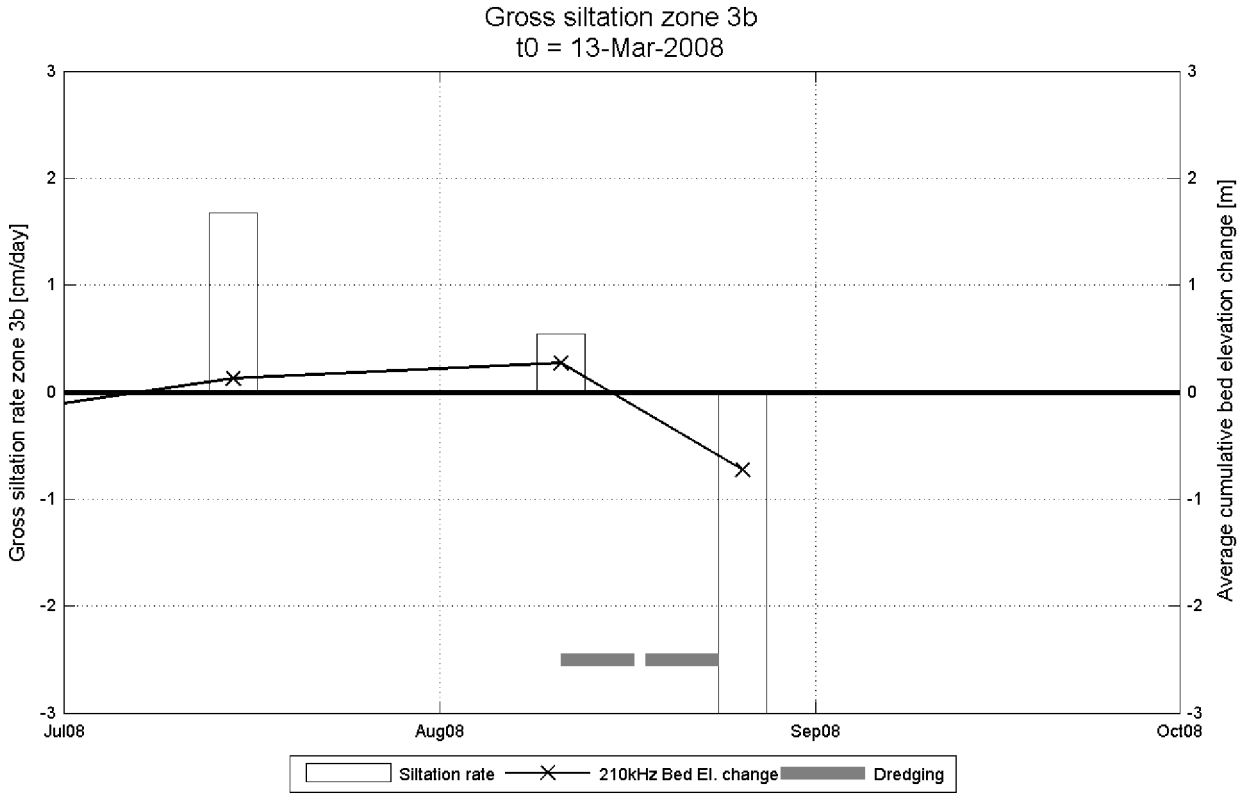
In association with : WL | delft hydraulics

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Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD





Reference level: depth sounding 13-Mar-2008

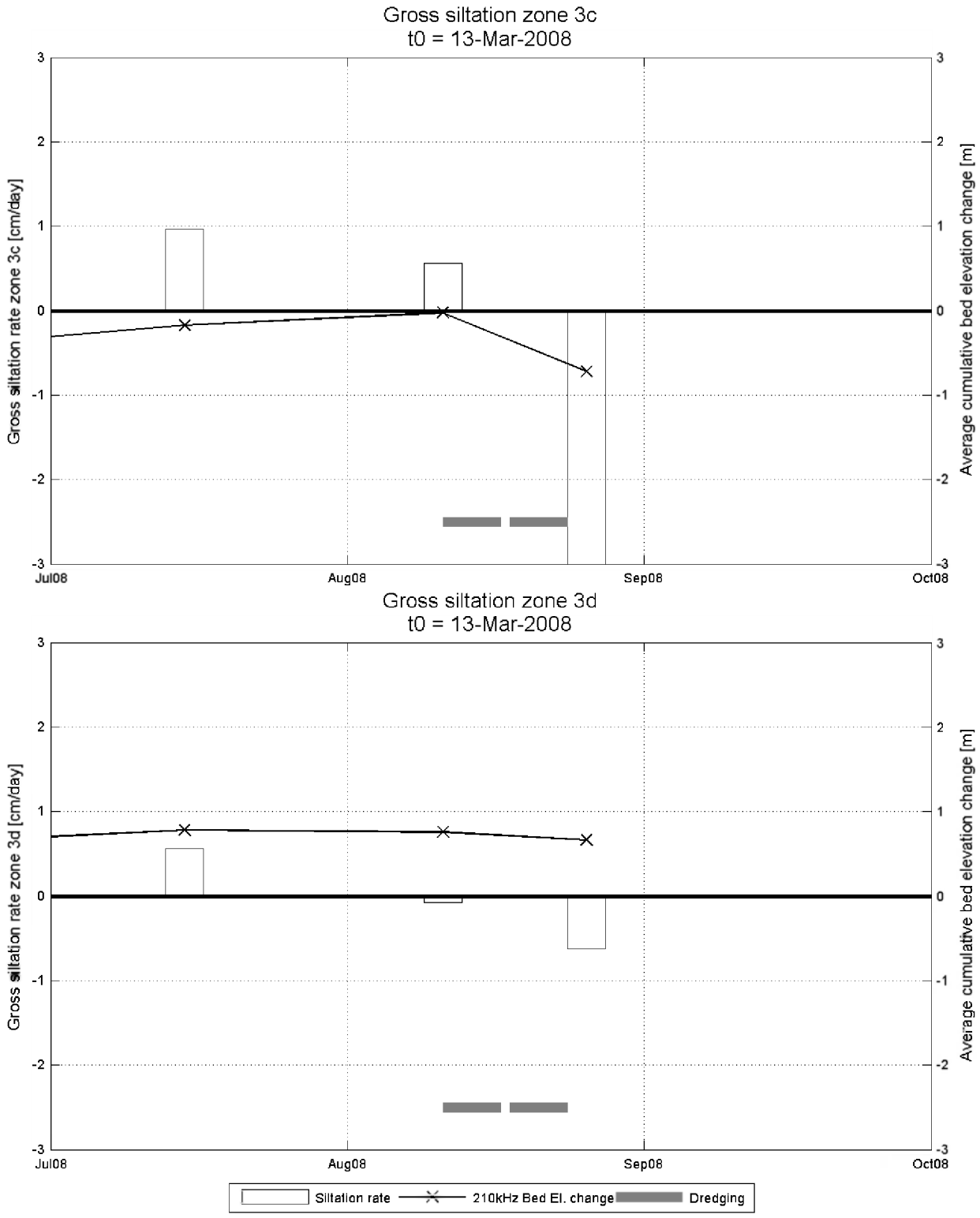
Data Processed by: IMDC International Marine & Dredging Consultants

In association with : WL | delft hydraulics

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Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD



Reference level: depth sounding 13-Mar-2008

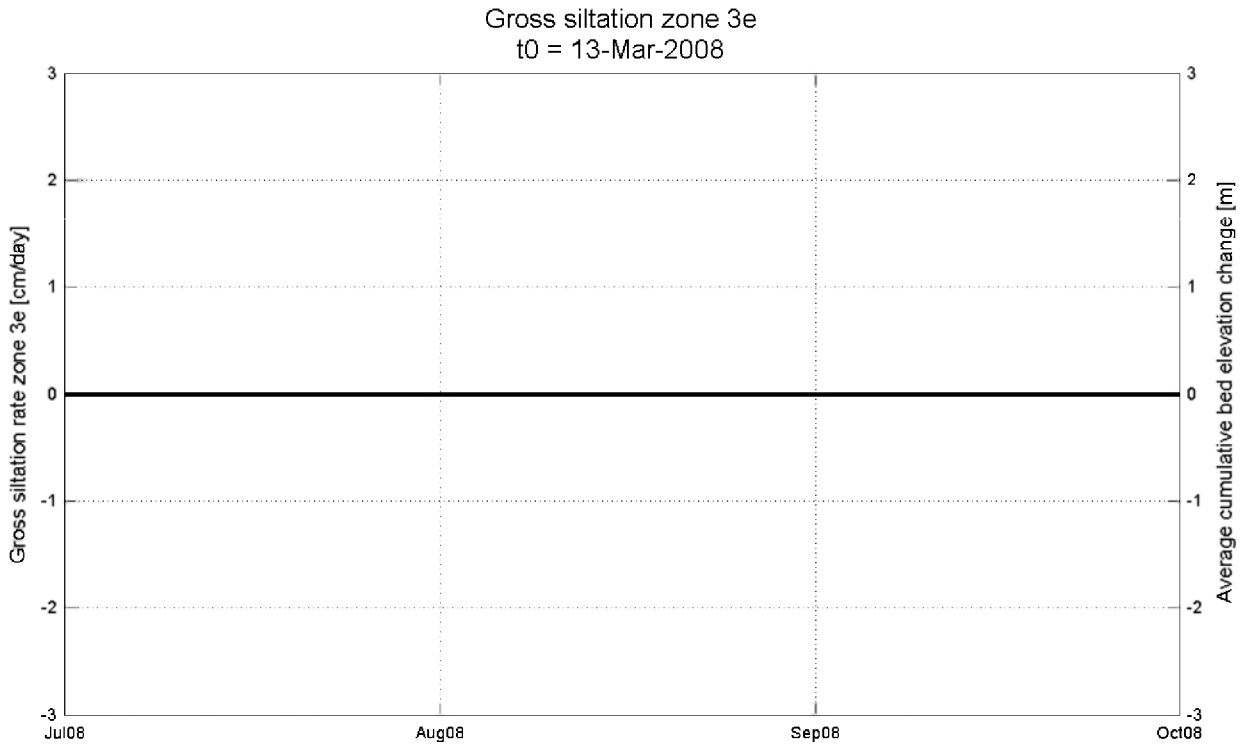
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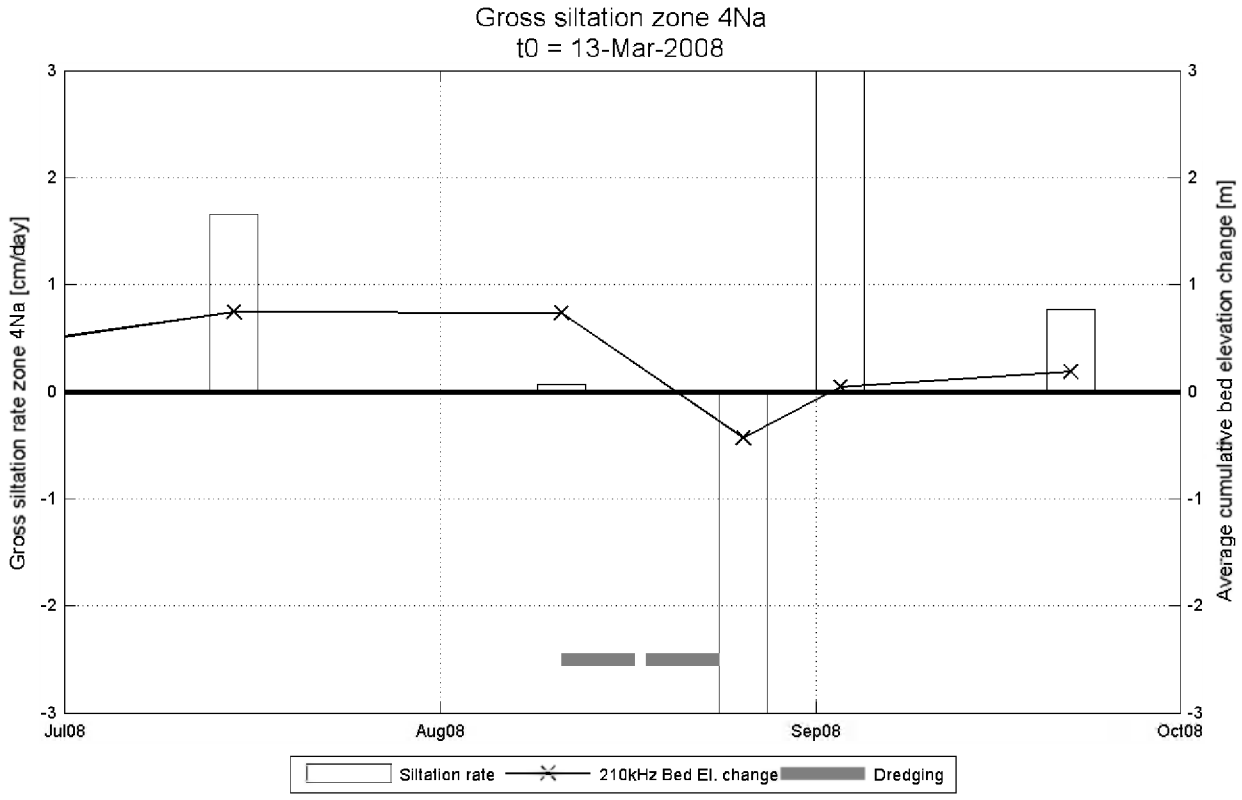
In association with : WL | delft hydraulics

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Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD





Reference level: depth sounding 13-Mar-2008

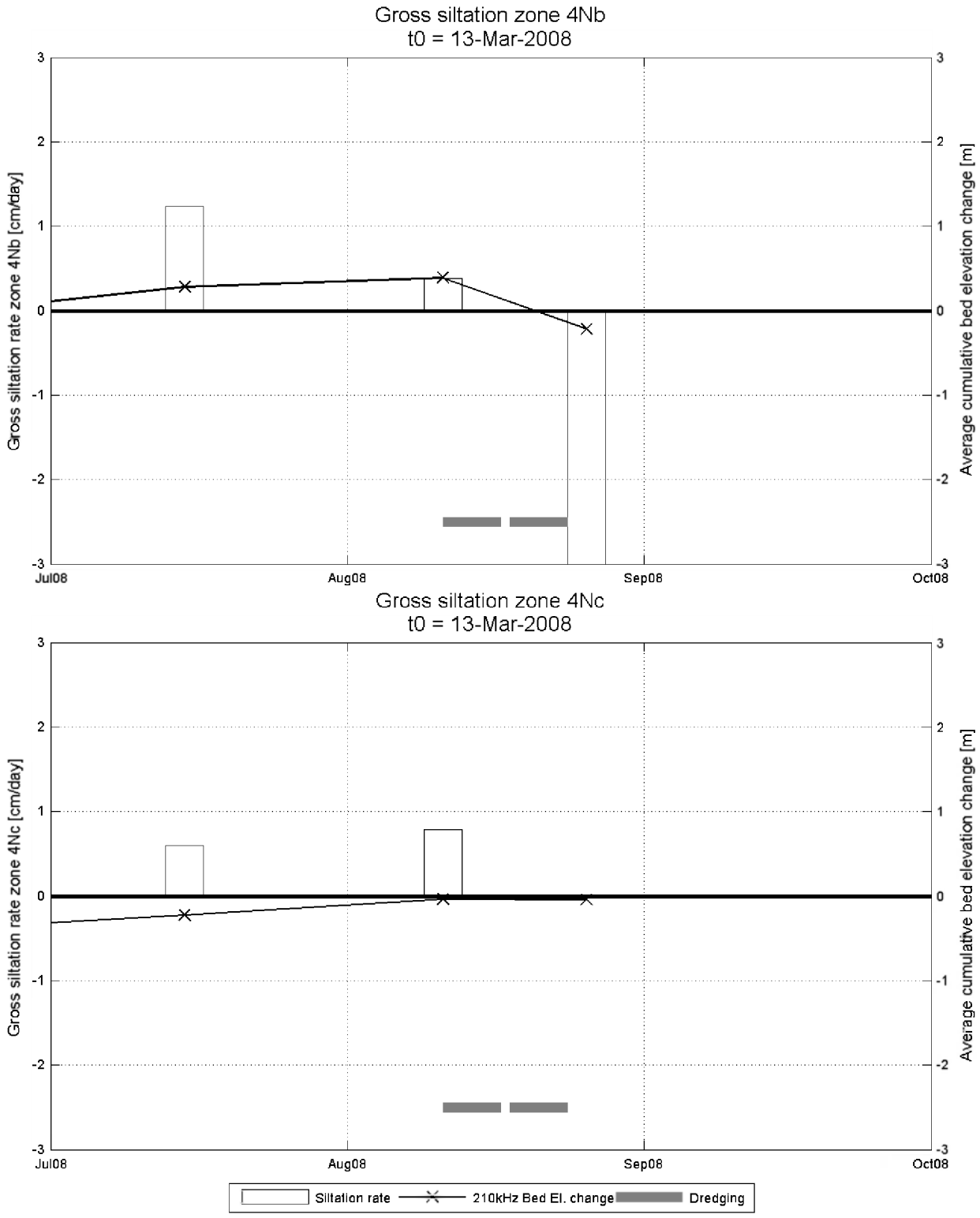
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In association with : WL | delft hydraulics

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Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD



Reference level: depth sounding 13-Mar-2008

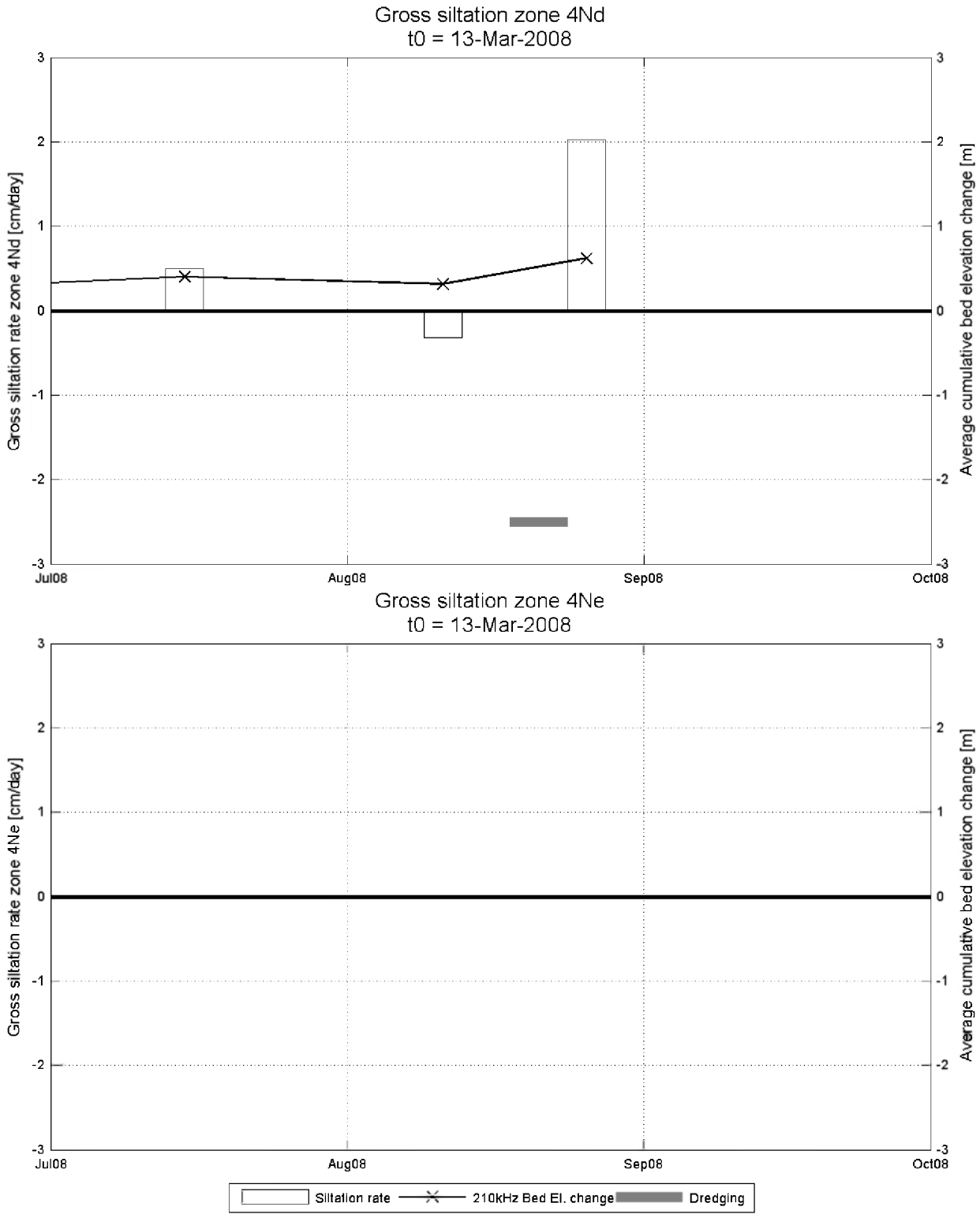
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Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD



Reference level: depth sounding 13-Mar-2008

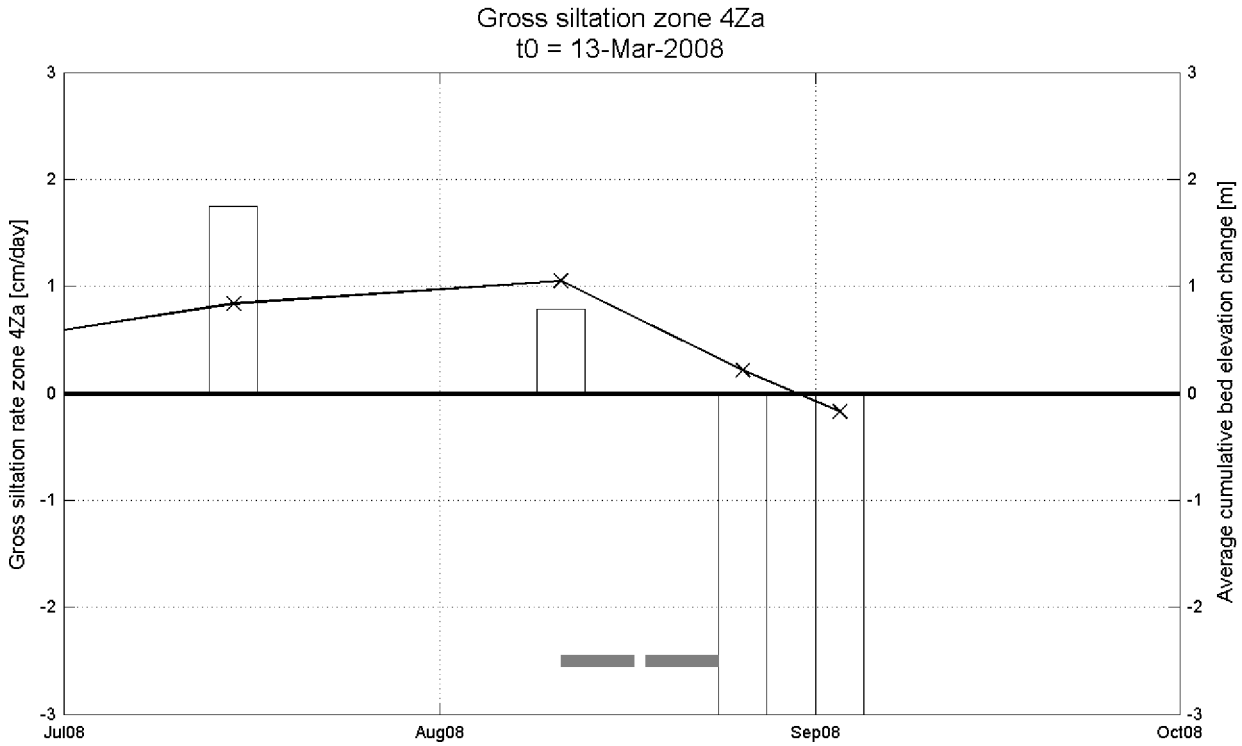
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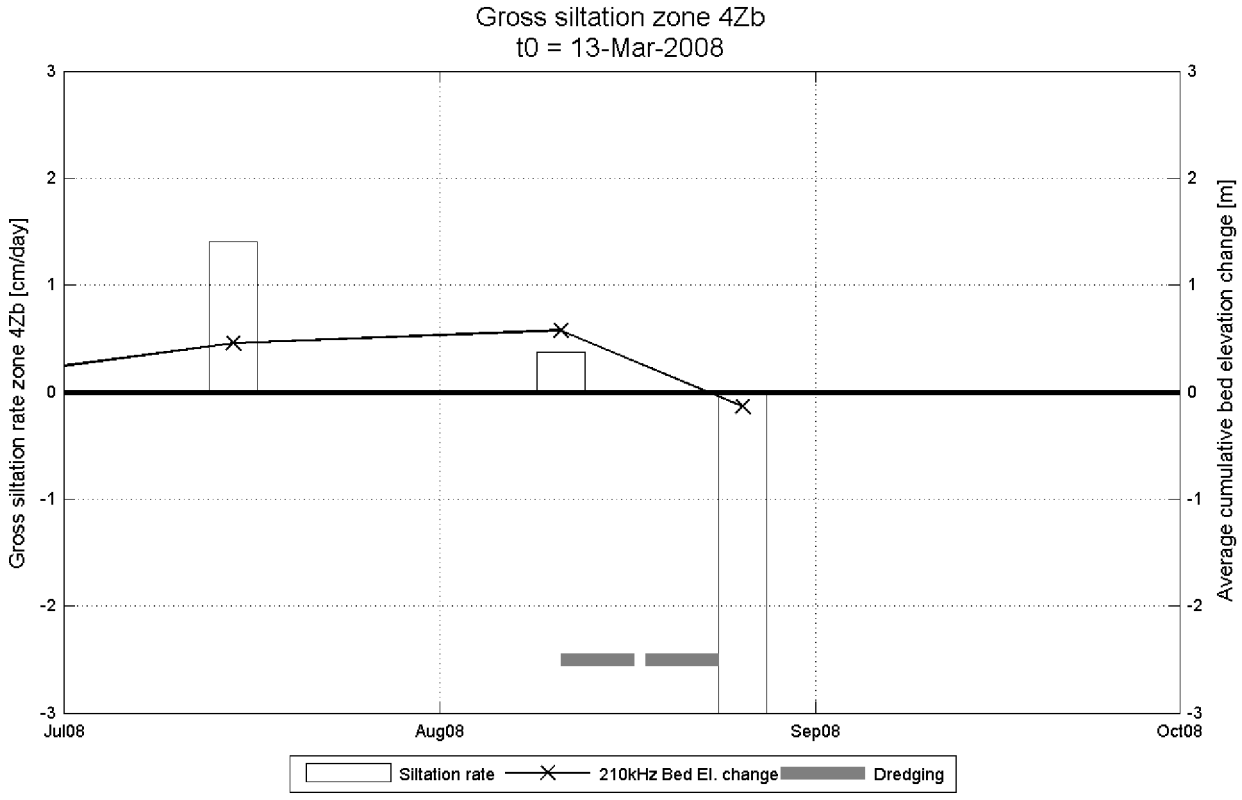
In association with : WL | delft hydraulics

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Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD





Reference level: depth sounding 13-Mar-2008

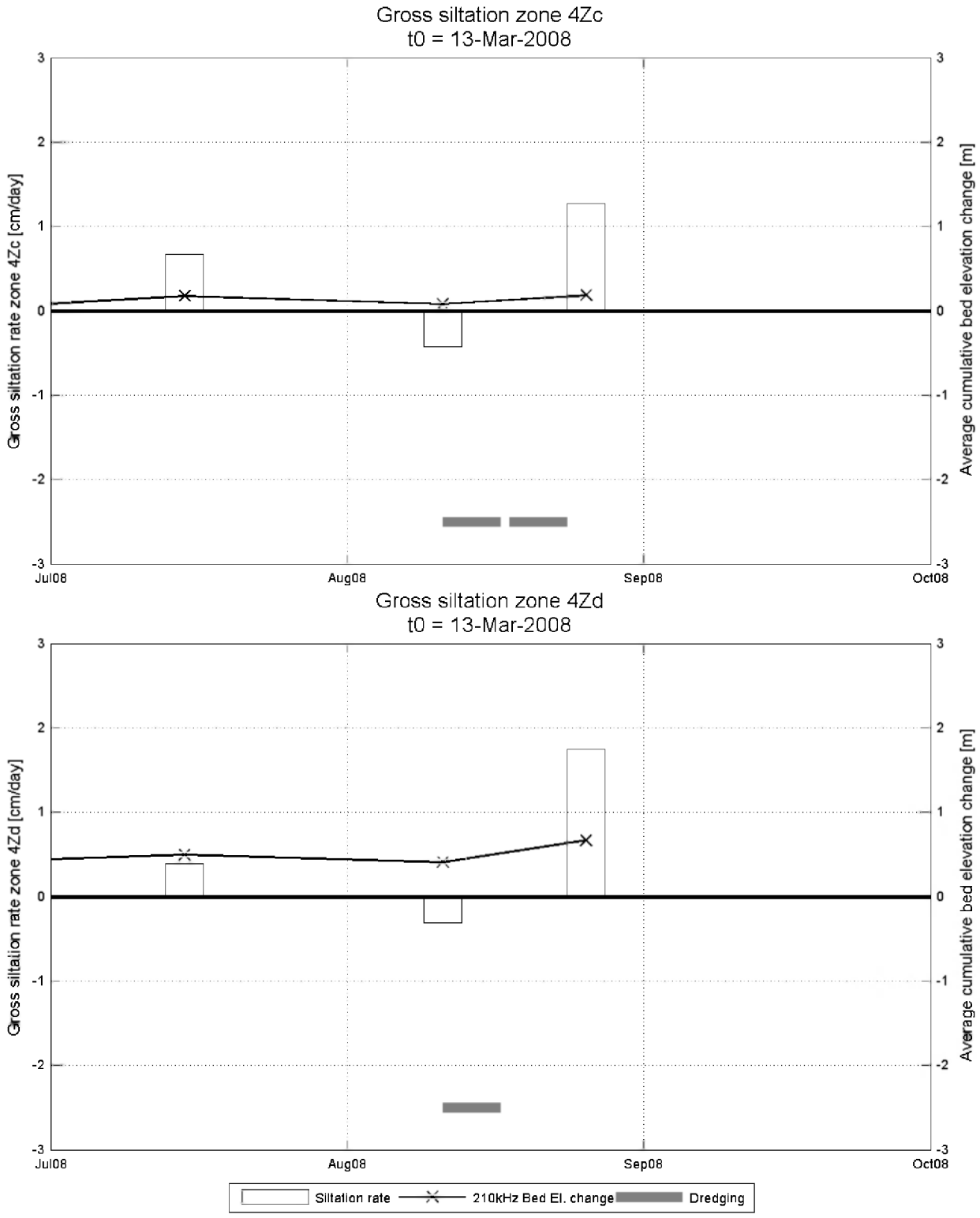
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Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD



Reference level: depth sounding 13-Mar-2008

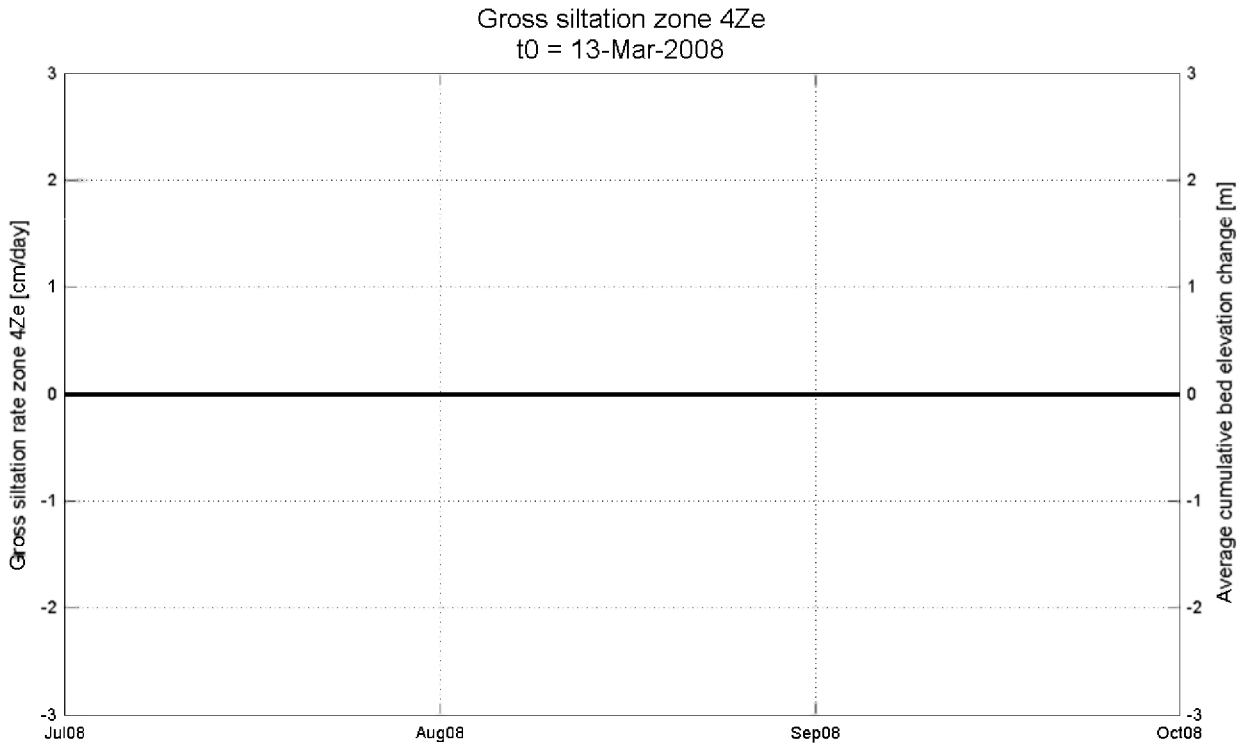
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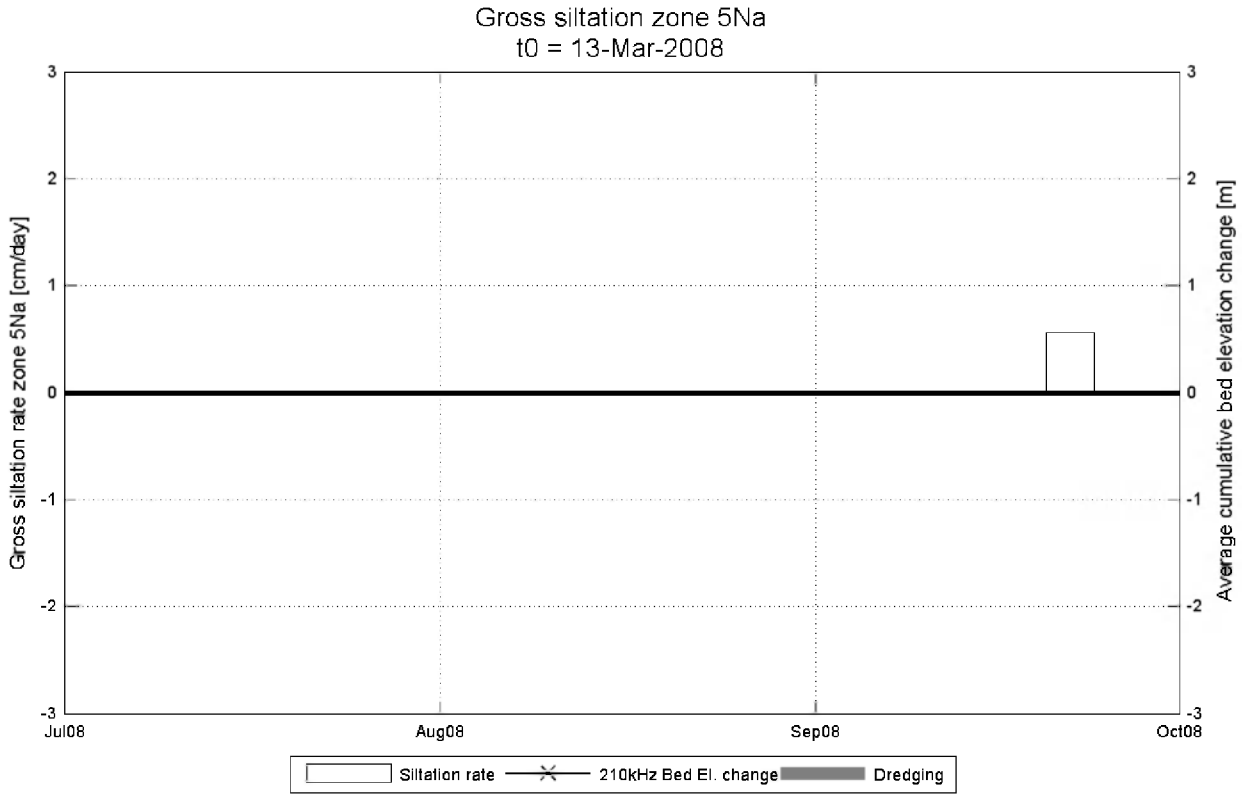
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Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD





Reference level: depth sounding 13-Mar-2008

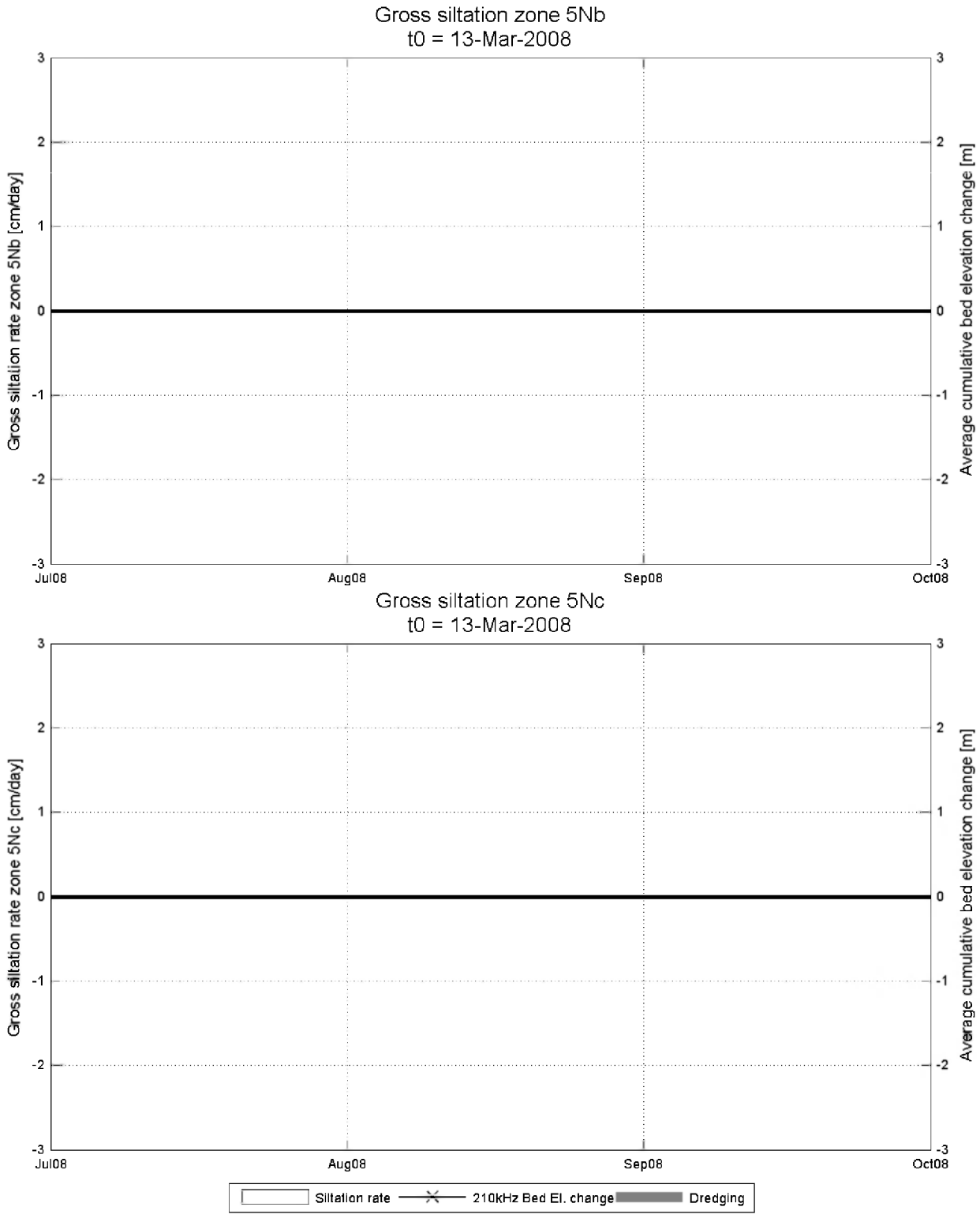
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Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD



Reference level: depth sounding 13-Mar-2008

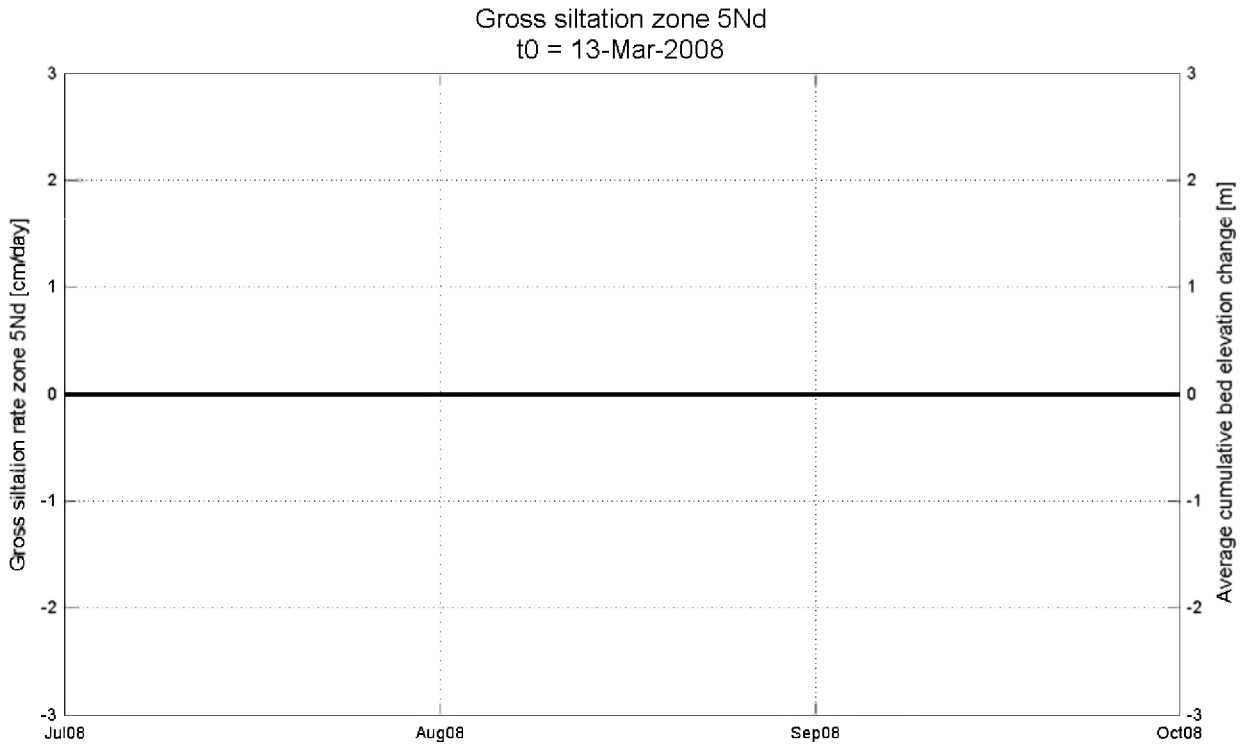
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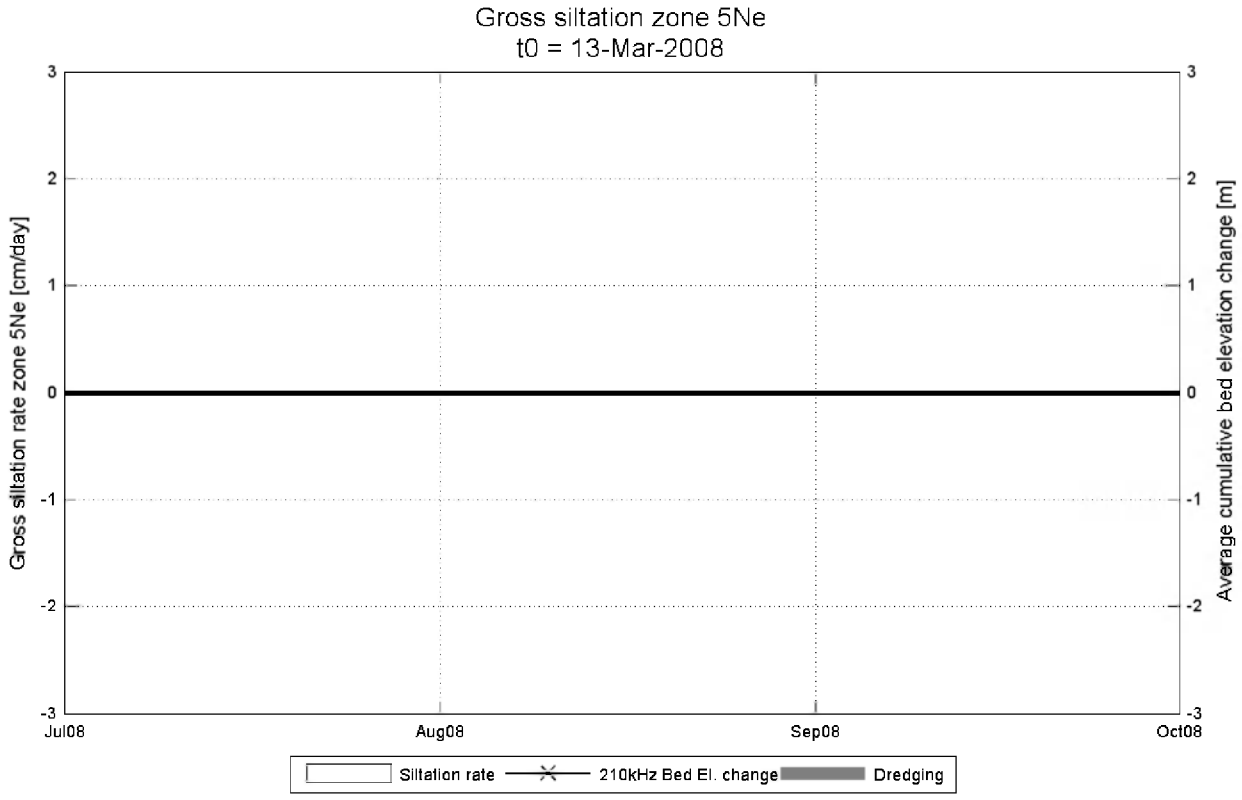
In association with : WL | delft hydraulics

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Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD





Reference level: depth sounding 13-Mar-2008

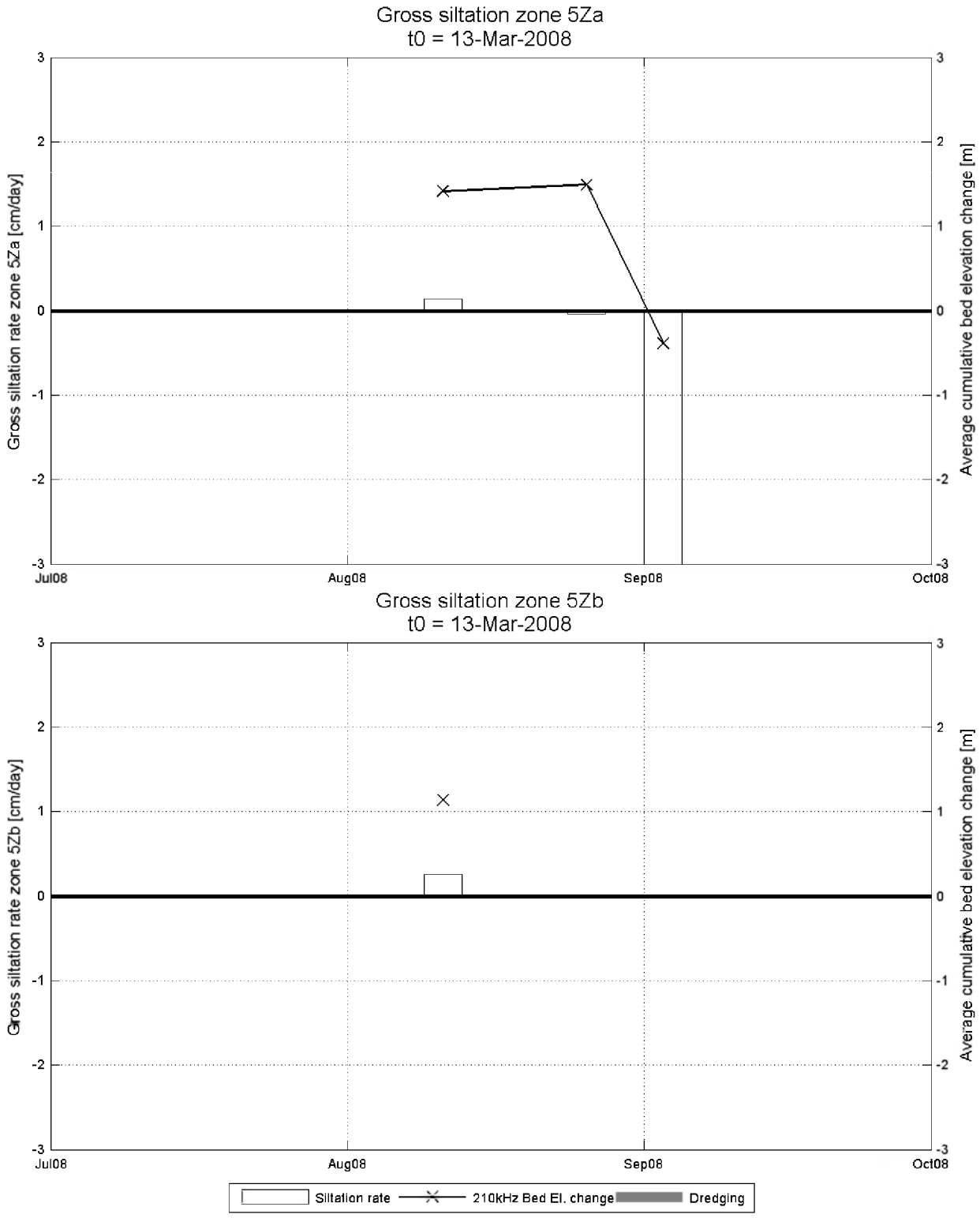
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Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD



Reference level: depth sounding 13-Mar-2008

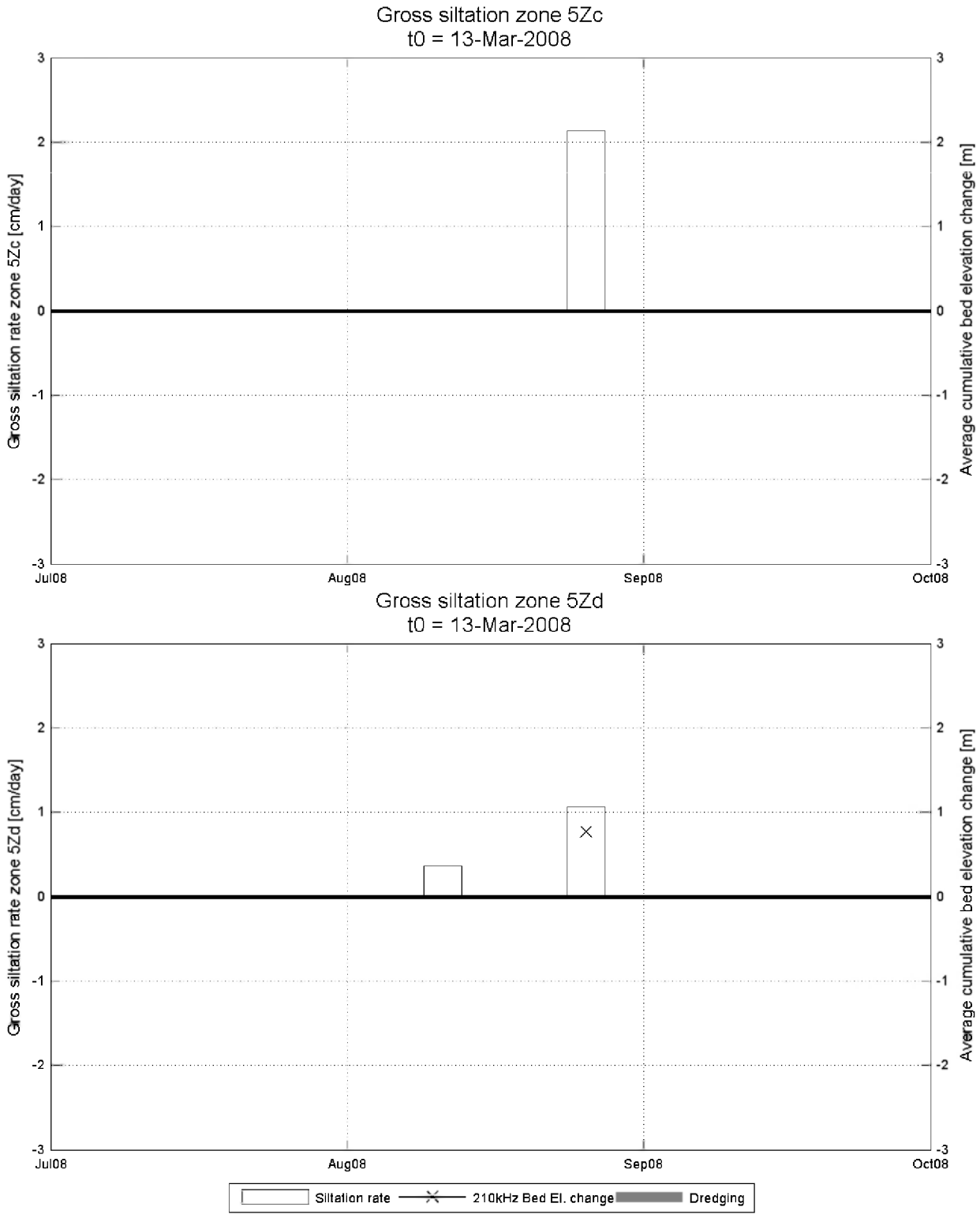
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Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD



Reference level: depth sounding 13-Mar-2008

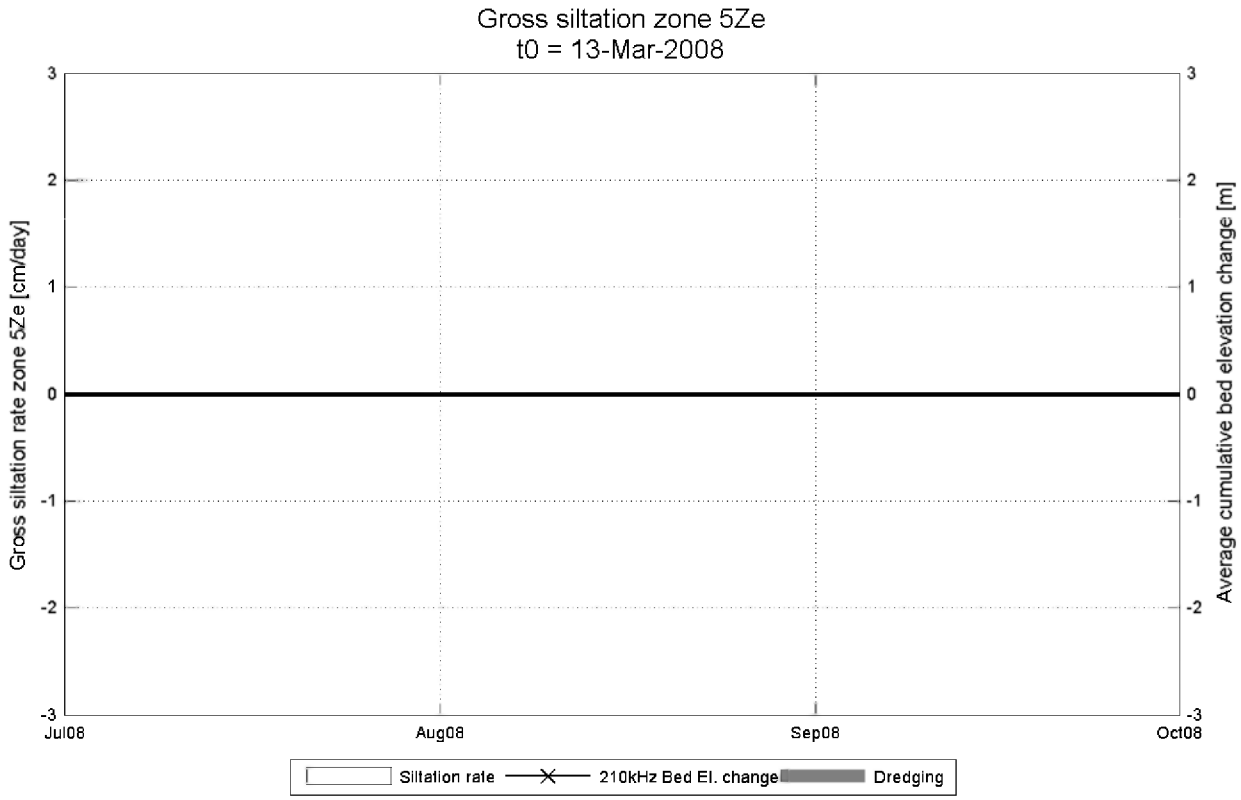
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Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD



Reference level: depth sounding 13-Mar-2008

Data Processed by:

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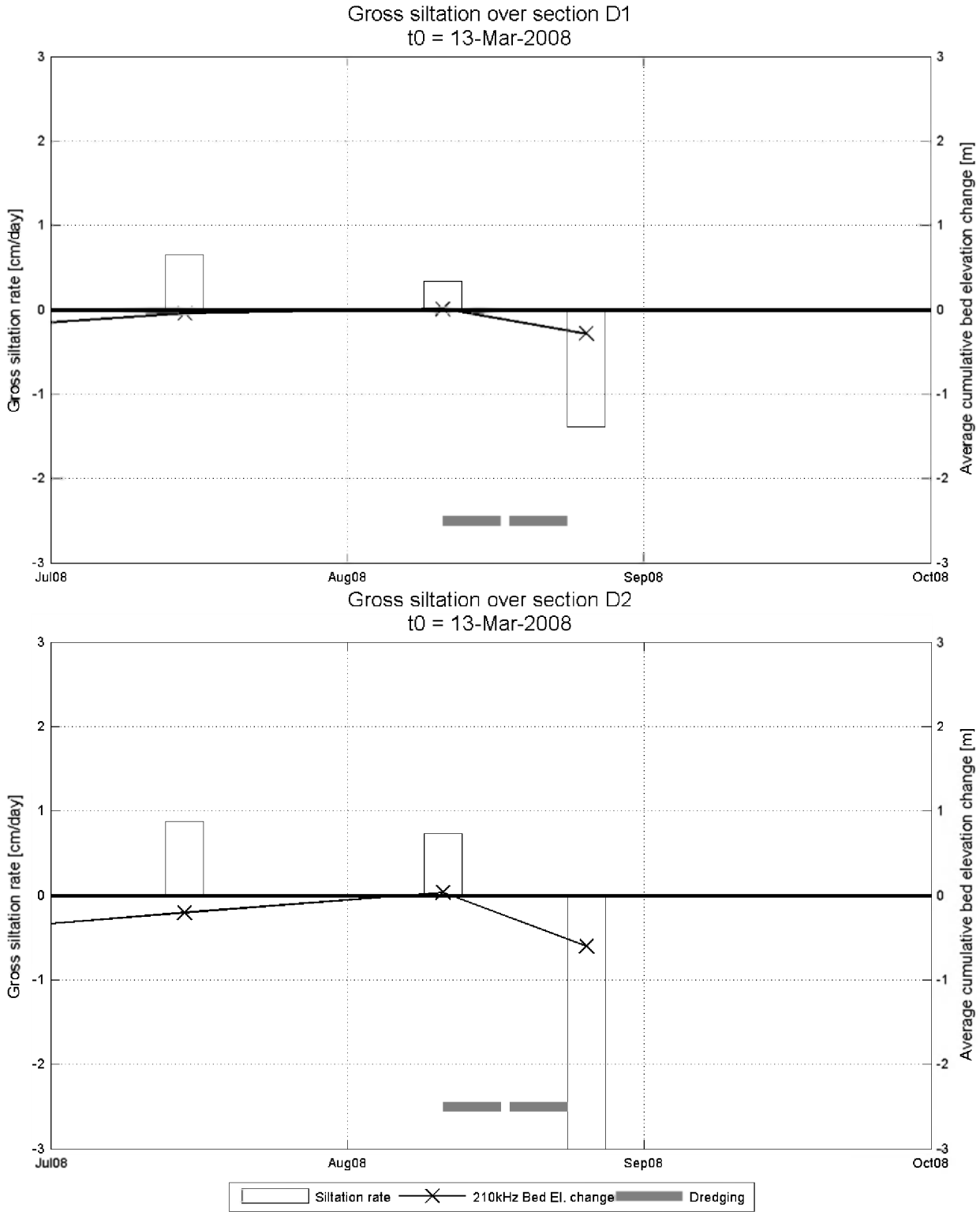
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C.3 Water-bed interface evolution for all sections

Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD



Reference level: depth sounding 13-Mar-2008

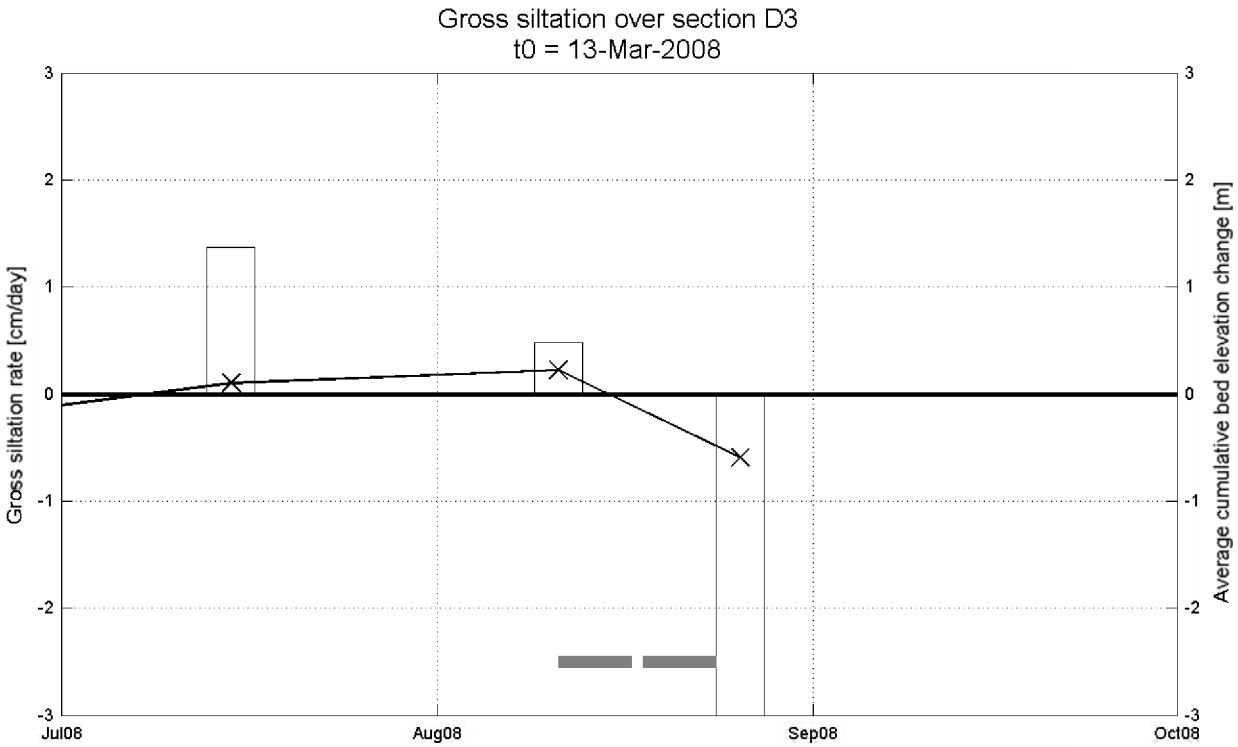
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Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD





Reference level: depth sounding 13-Mar-2008

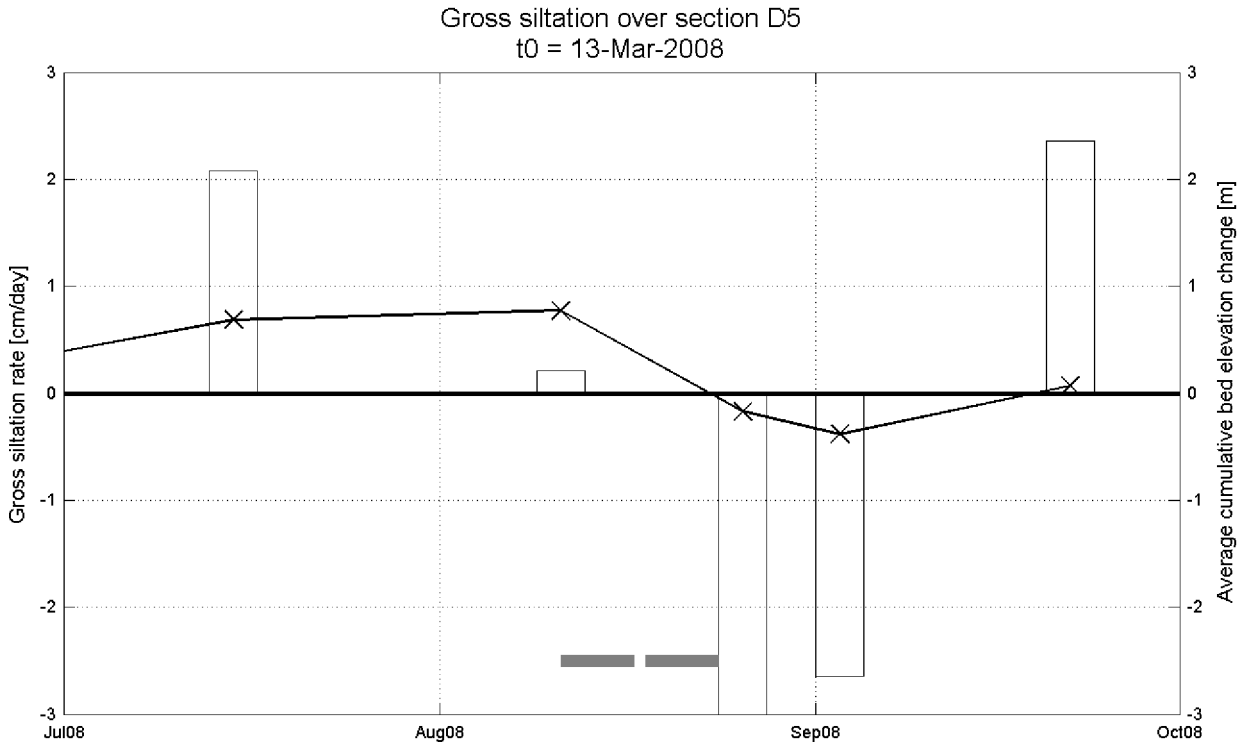
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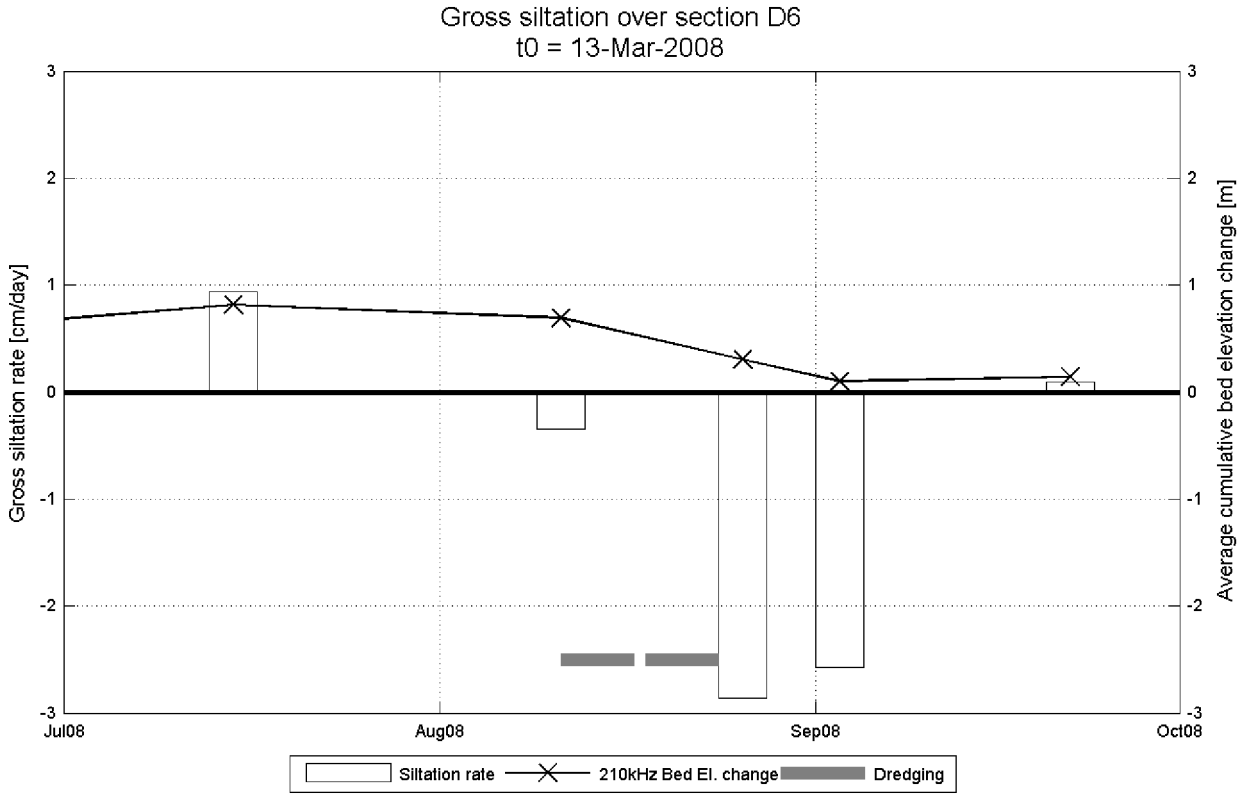
In association with : WL | delft hydraulics

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Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD





Reference level: depth sounding 13-Mar-2008

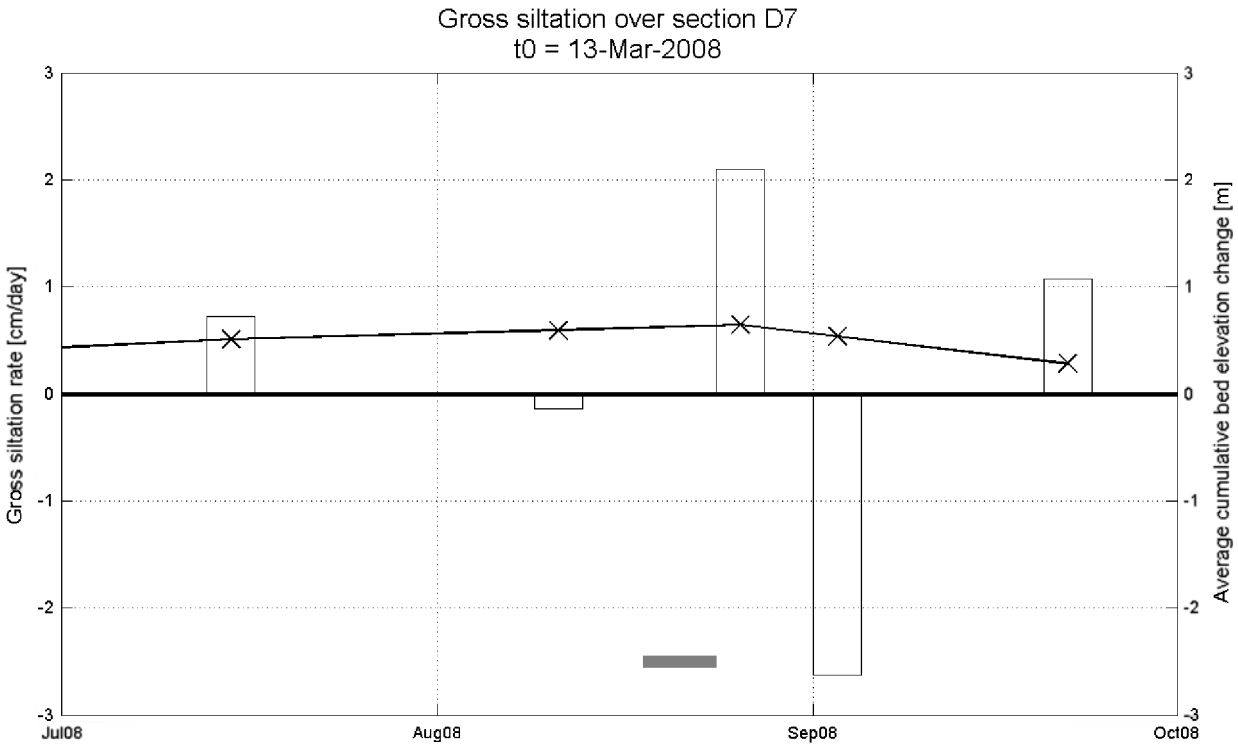
Data Processed by: IMDC International Marine & Dredging Consultants

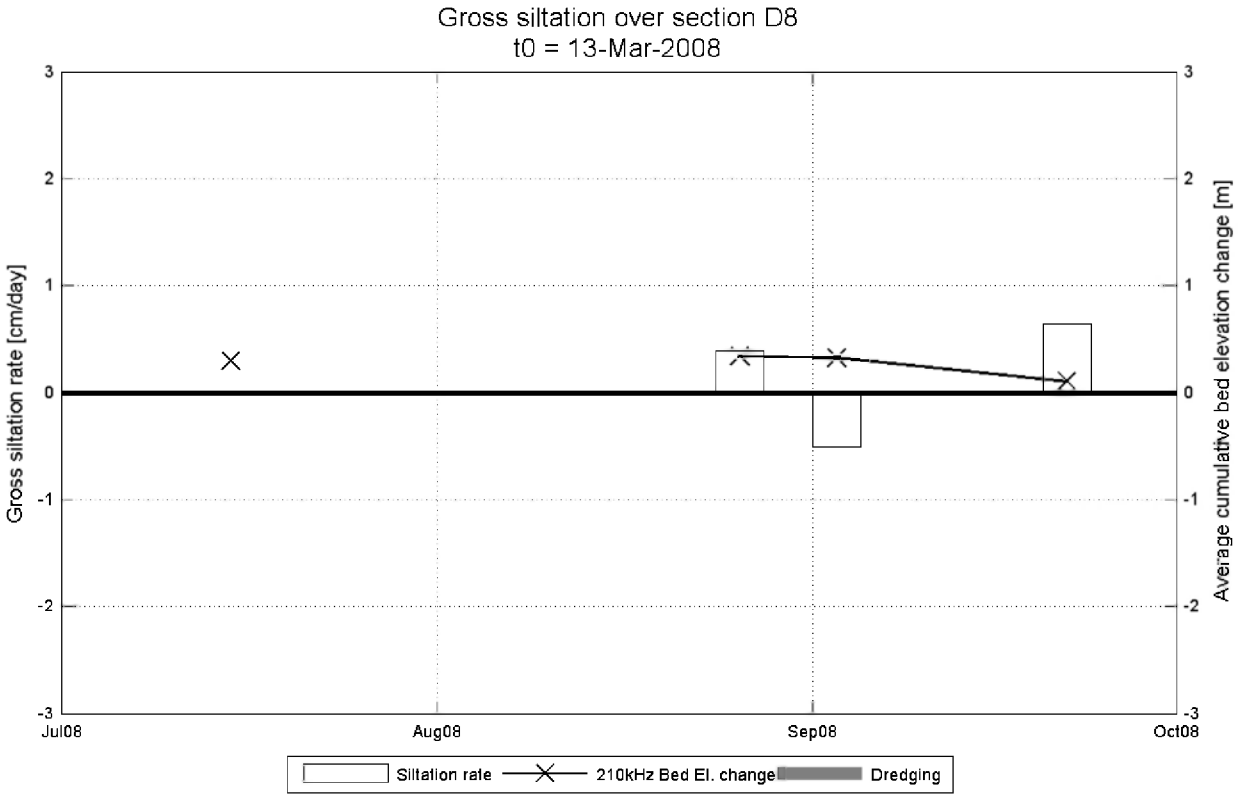
In association with : WL | delft hydraulics

I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD





Reference level: depth sounding 13-Mar-2008

Data Processed by: IMDC International Marine & Dredging Consultants

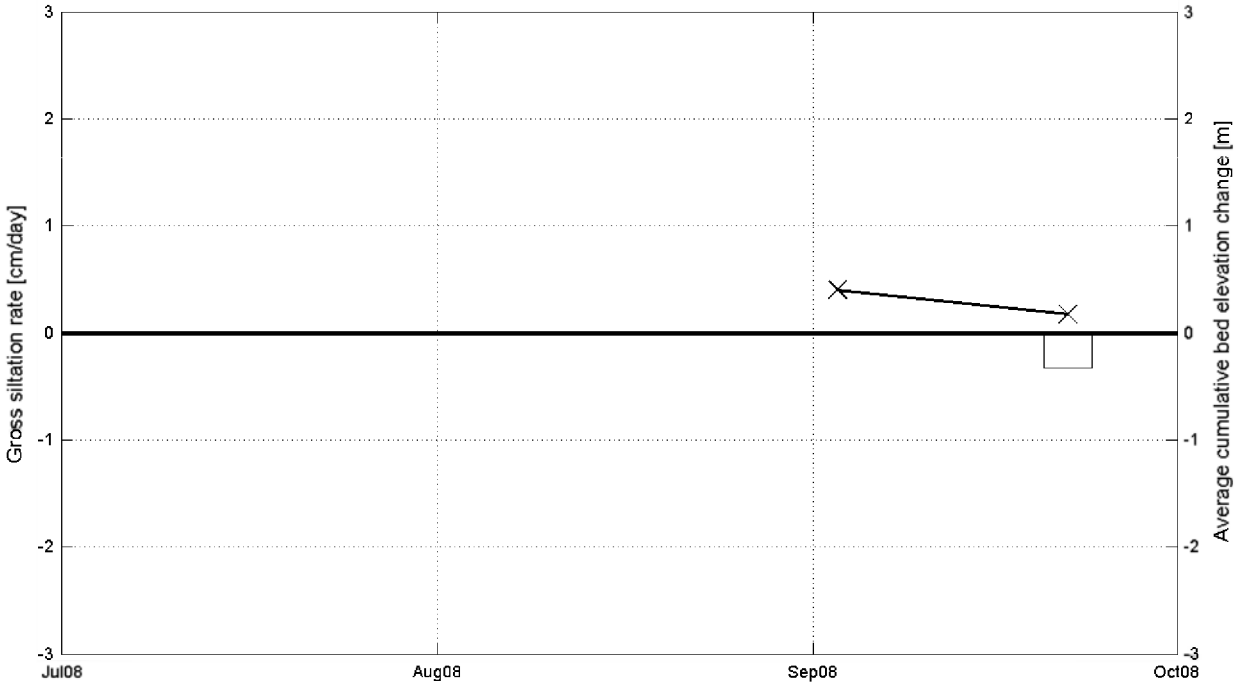
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I/RA/11283/08.077/MSA

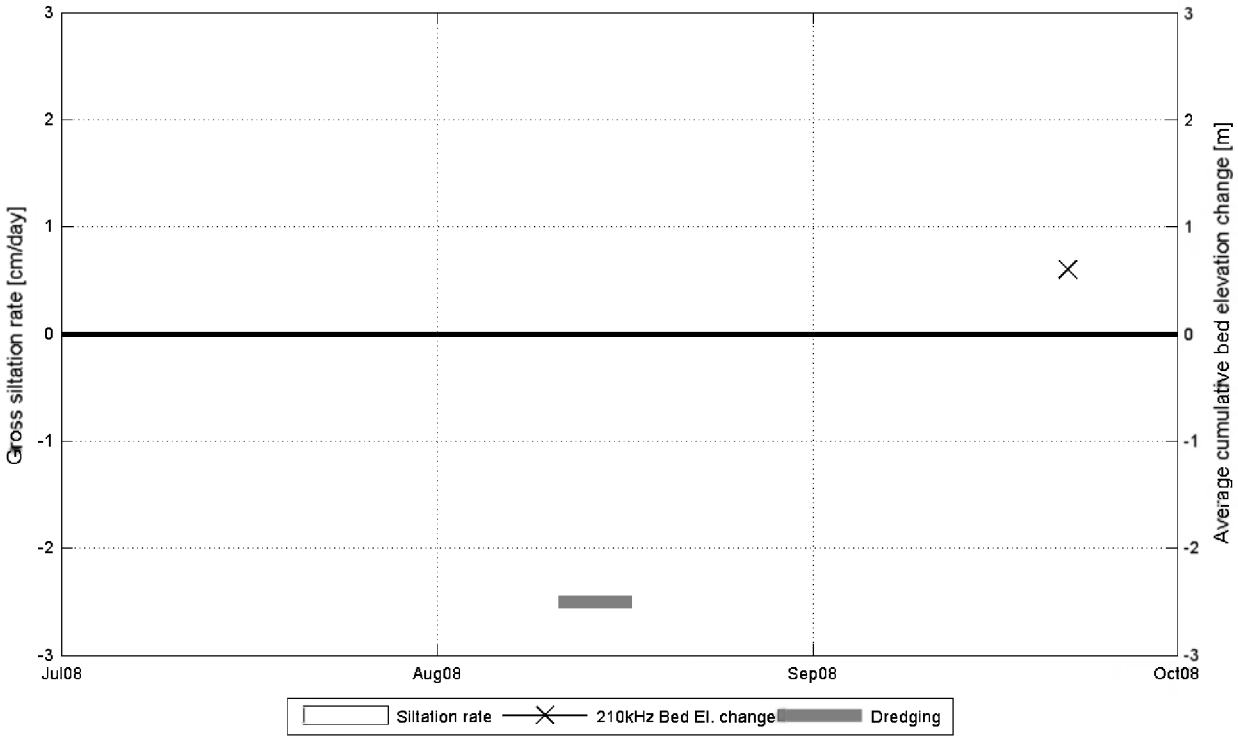
Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD

Gross siltation over section D9
t0 = 13-Mar-2008



Gross siltation over section D10
t0 = 13-Mar-2008



Reference level: depth sounding 13-Mar-2008

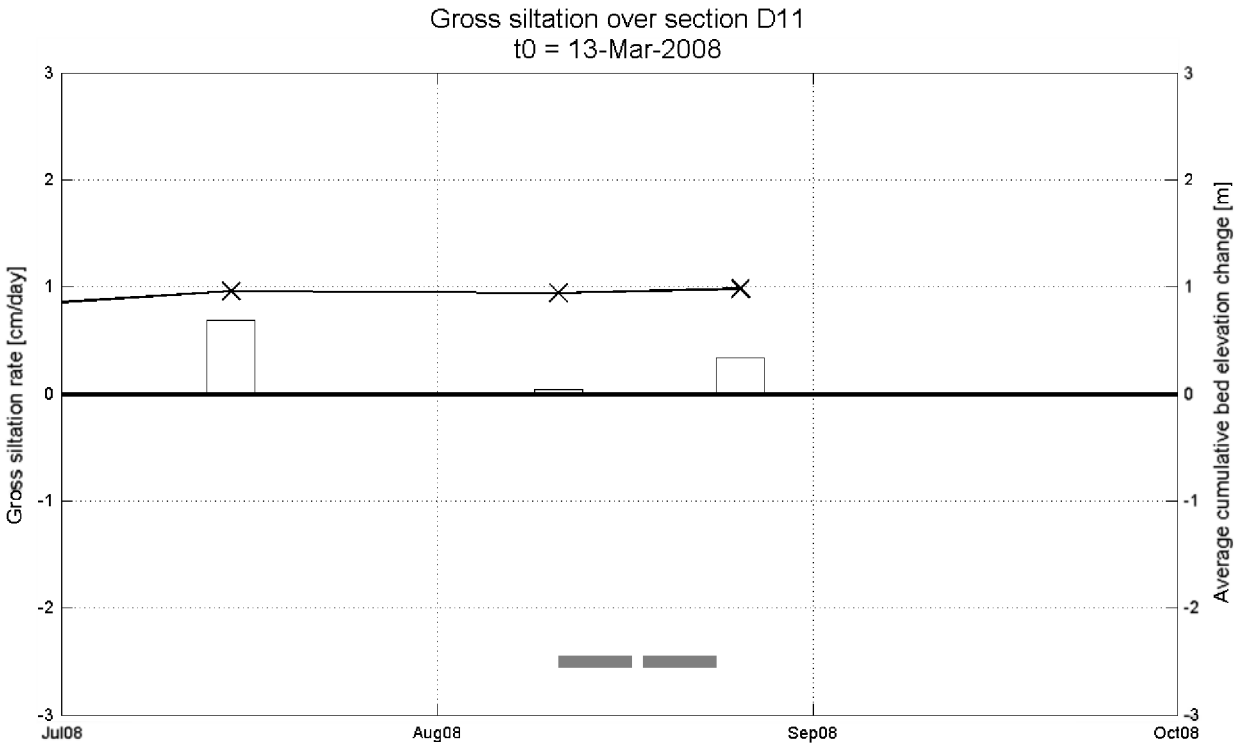
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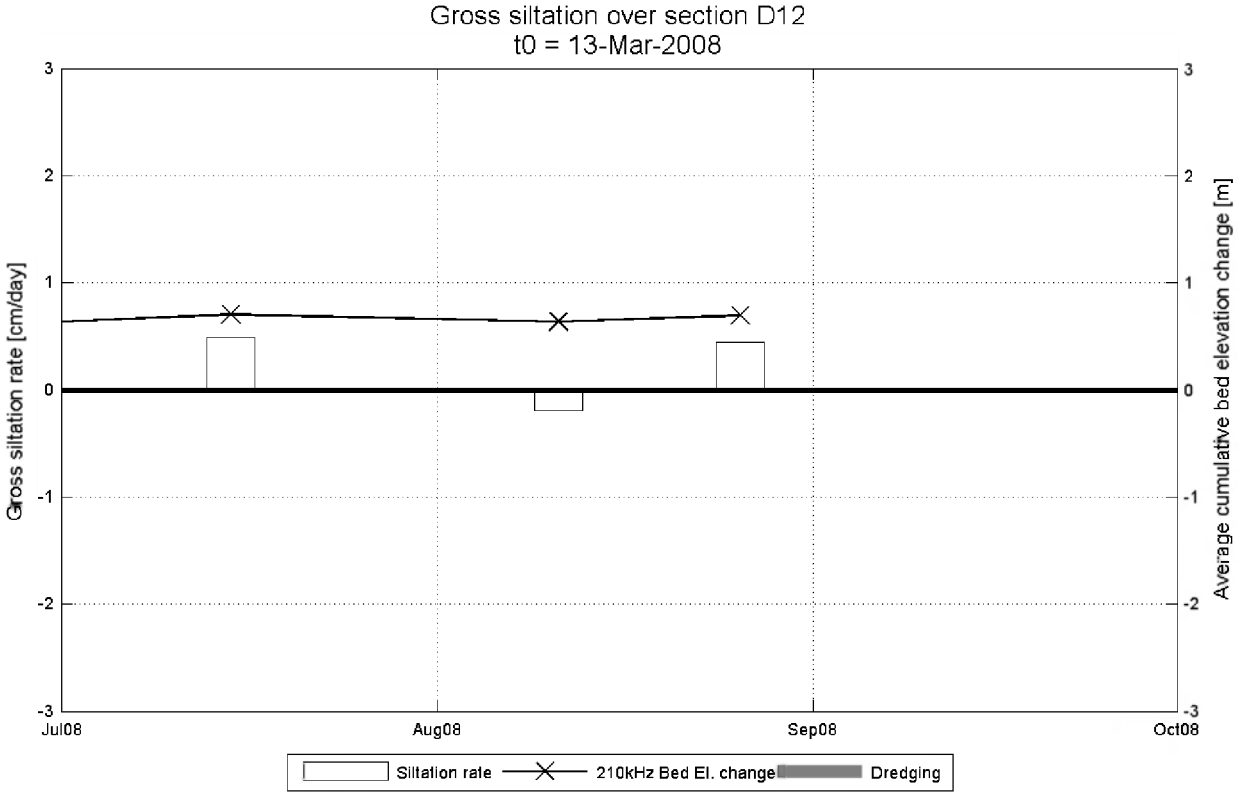
In association with : WL | delft hydraulics

I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD





Reference level: depth sounding 13-Mar-2008

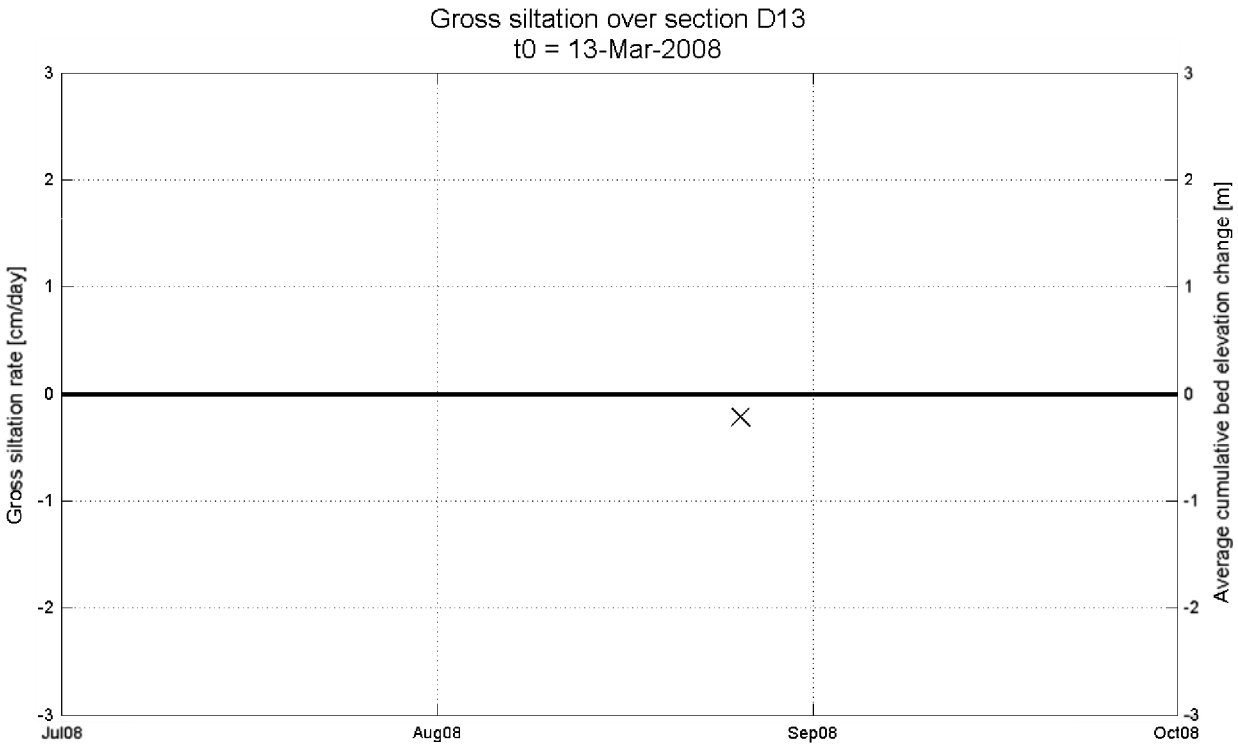
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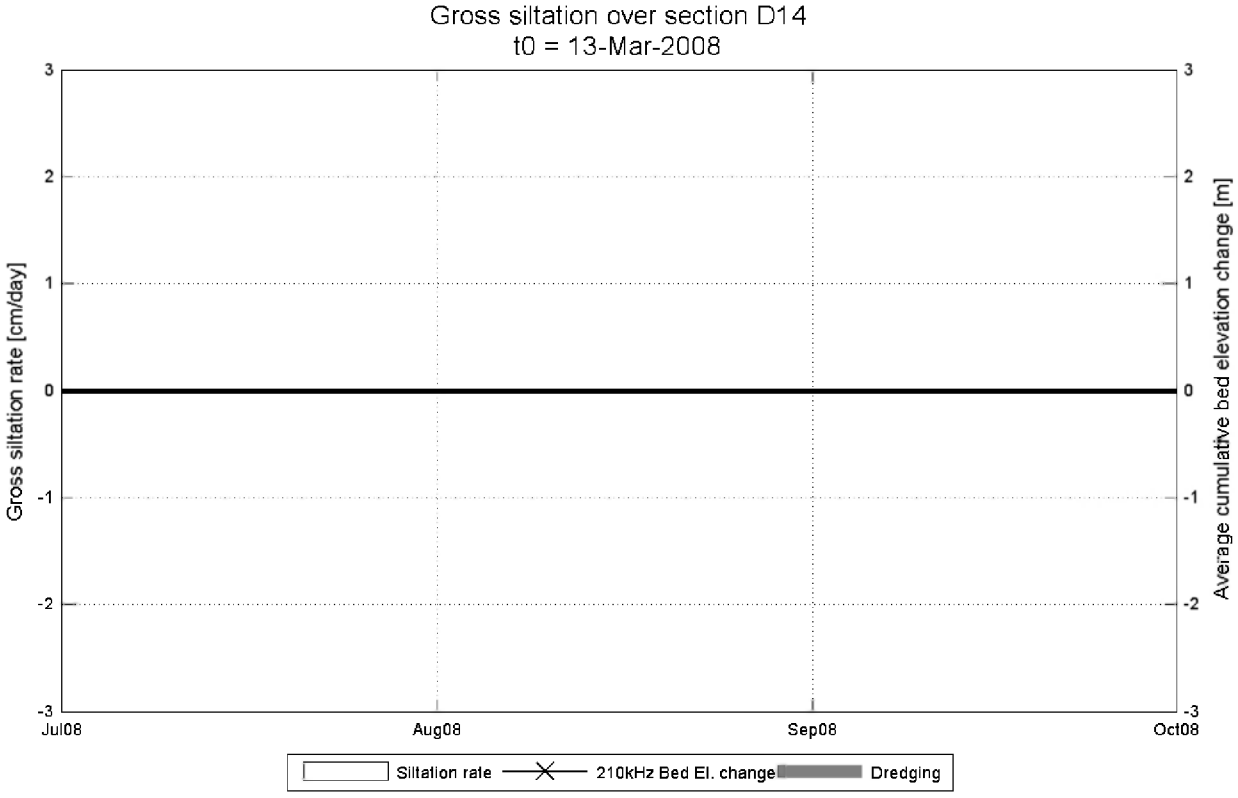
In association with : WL | delft hydraulics

I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD





Reference level: depth sounding 13-Mar-2008

Data Processed by: IMDC International Marine & Dredging Consultants

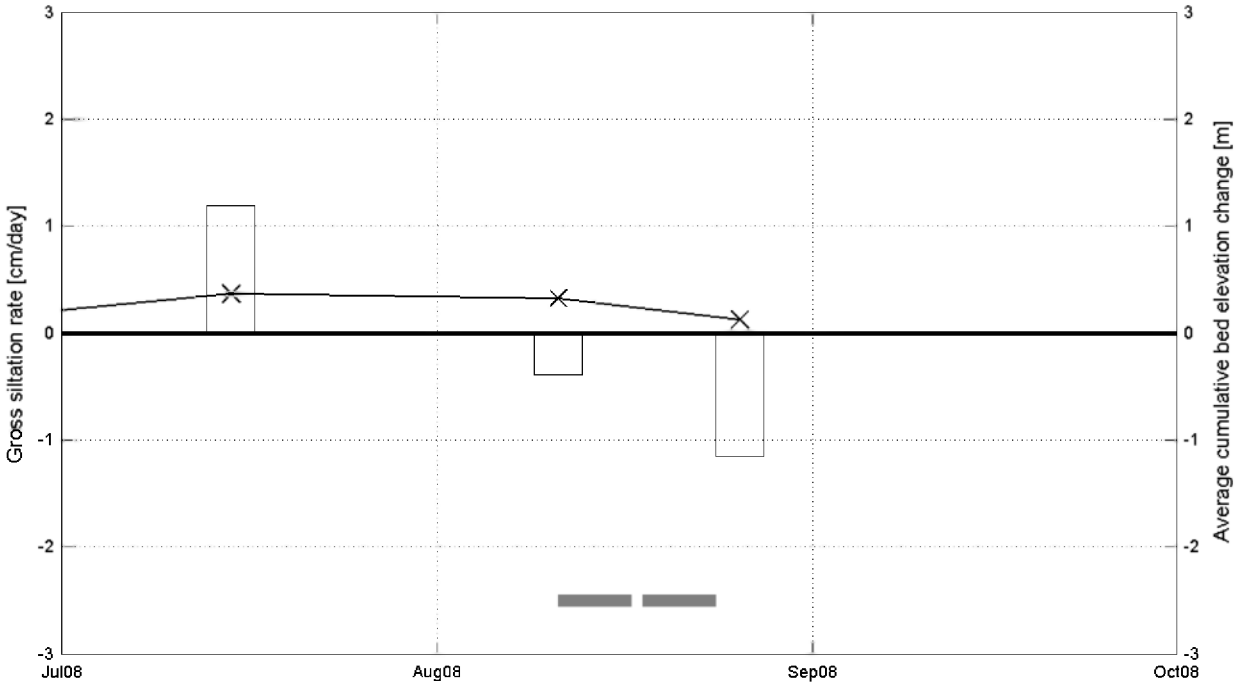
In association with : WL | delft hydraulics

I/RA/11283/08.077/MSA

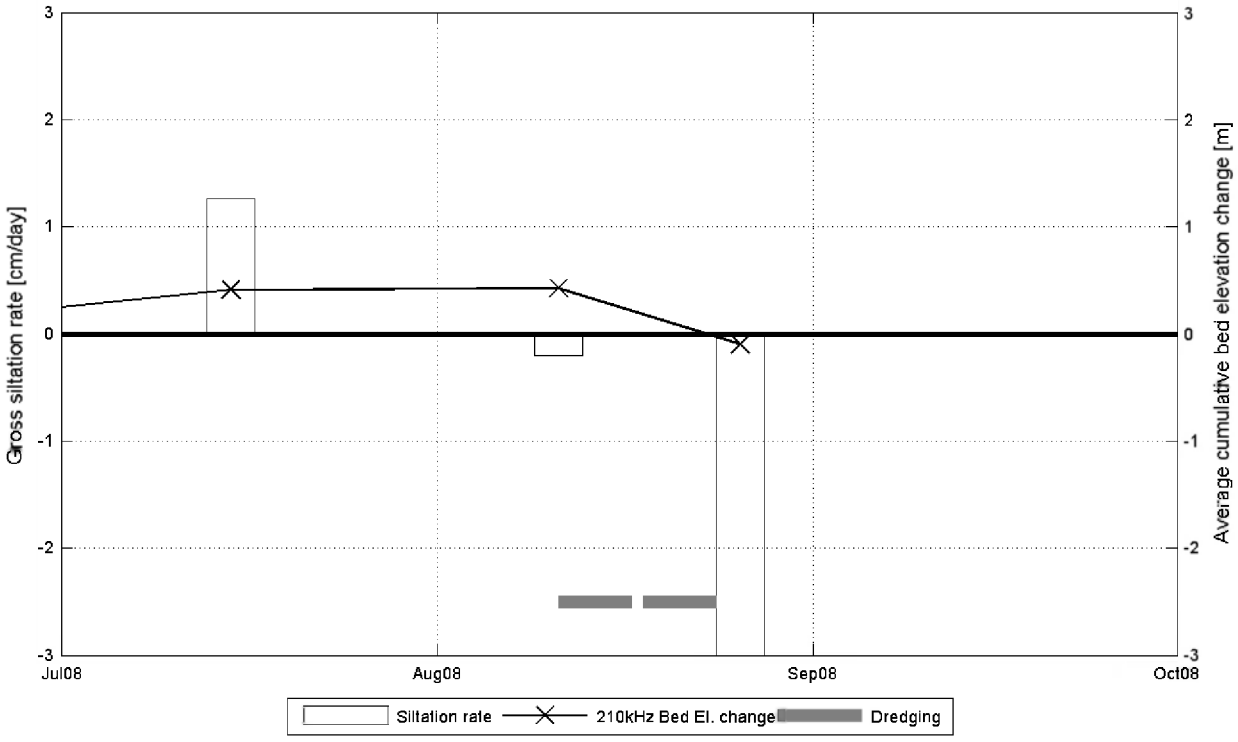
Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD

Gross siltation over section L1
t0 = 13-Mar-2008



Gross siltation over section L2
t0 = 13-Mar-2008



Reference level: depth sounding 13-Mar-2008

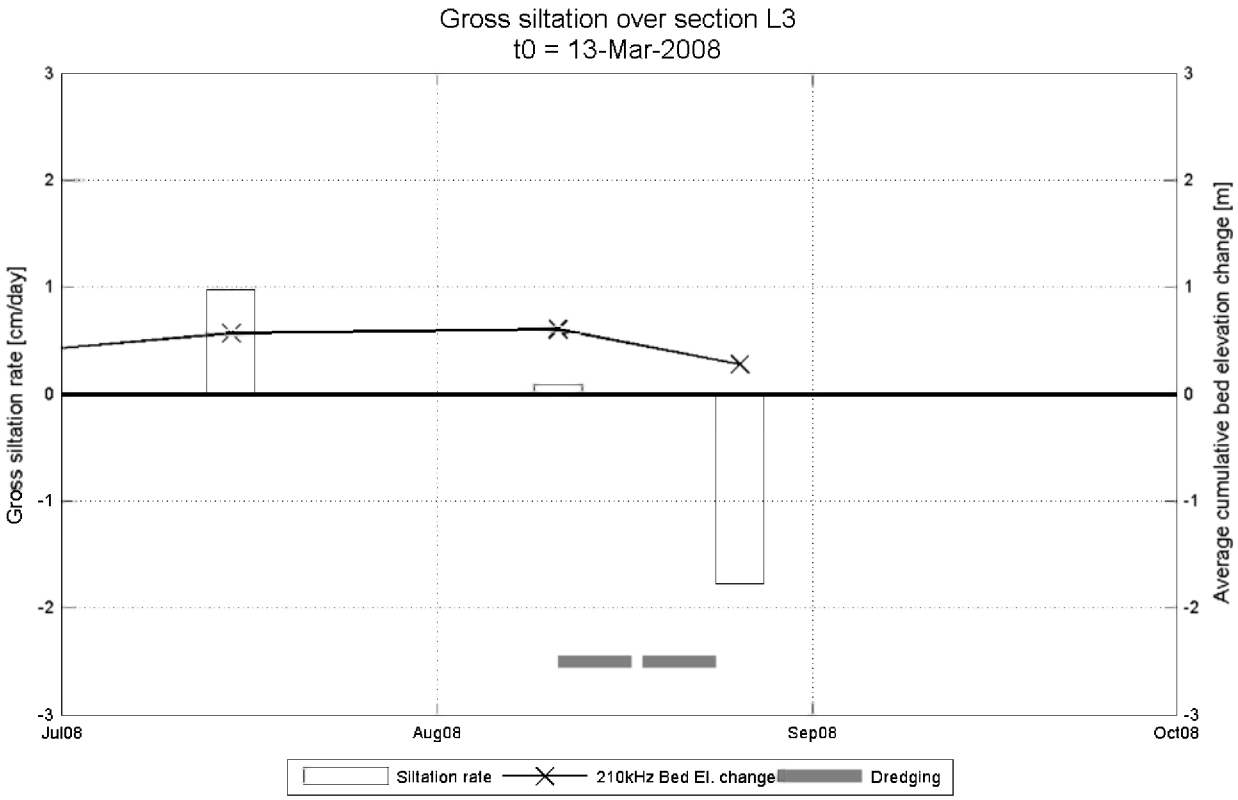
Data Processed by: IMDC International Marine & Dredging Consultants

In association with : WL | delft hydraulics

I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD



Reference level: depth sounding 13-Mar-2008

Data Processed by:

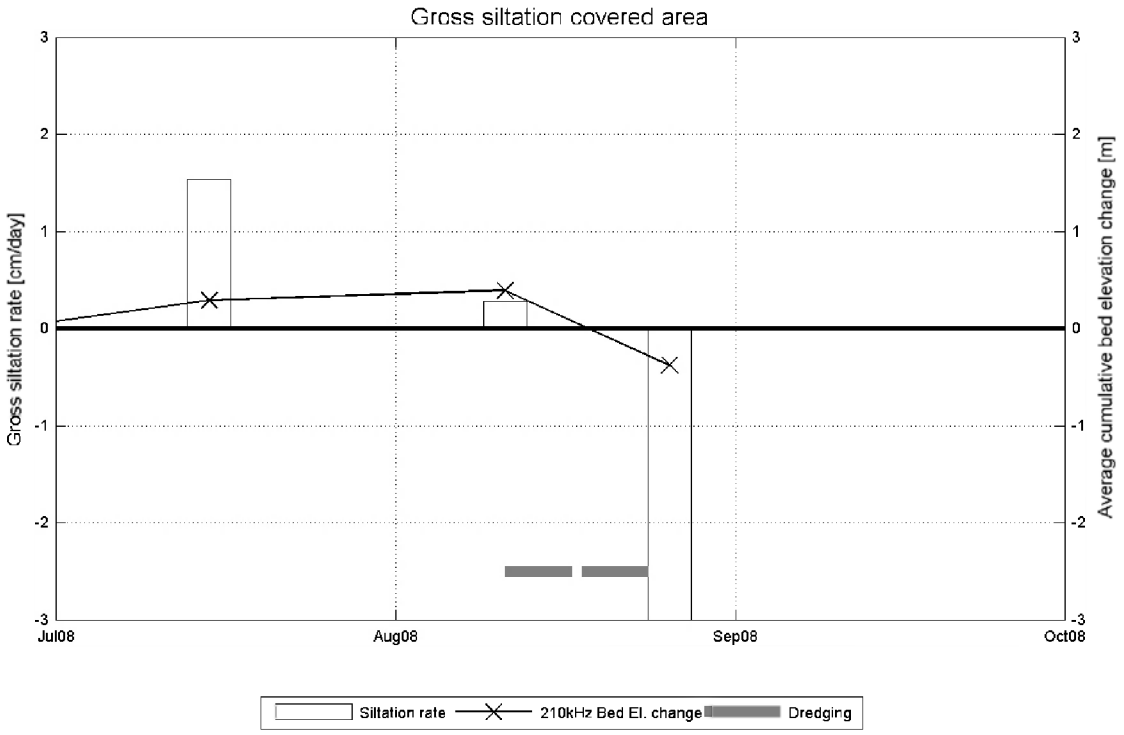
In association with :

I/RA/11283/08.077/MSA

C.4 Siltation rate complete Deurganckdok

Long-term monitoring siltation Deurganckdok

Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD



Reference level: depth sounding 13-Mar-2008

Data Processed by: IMDC International Marine & Dredging Consultants

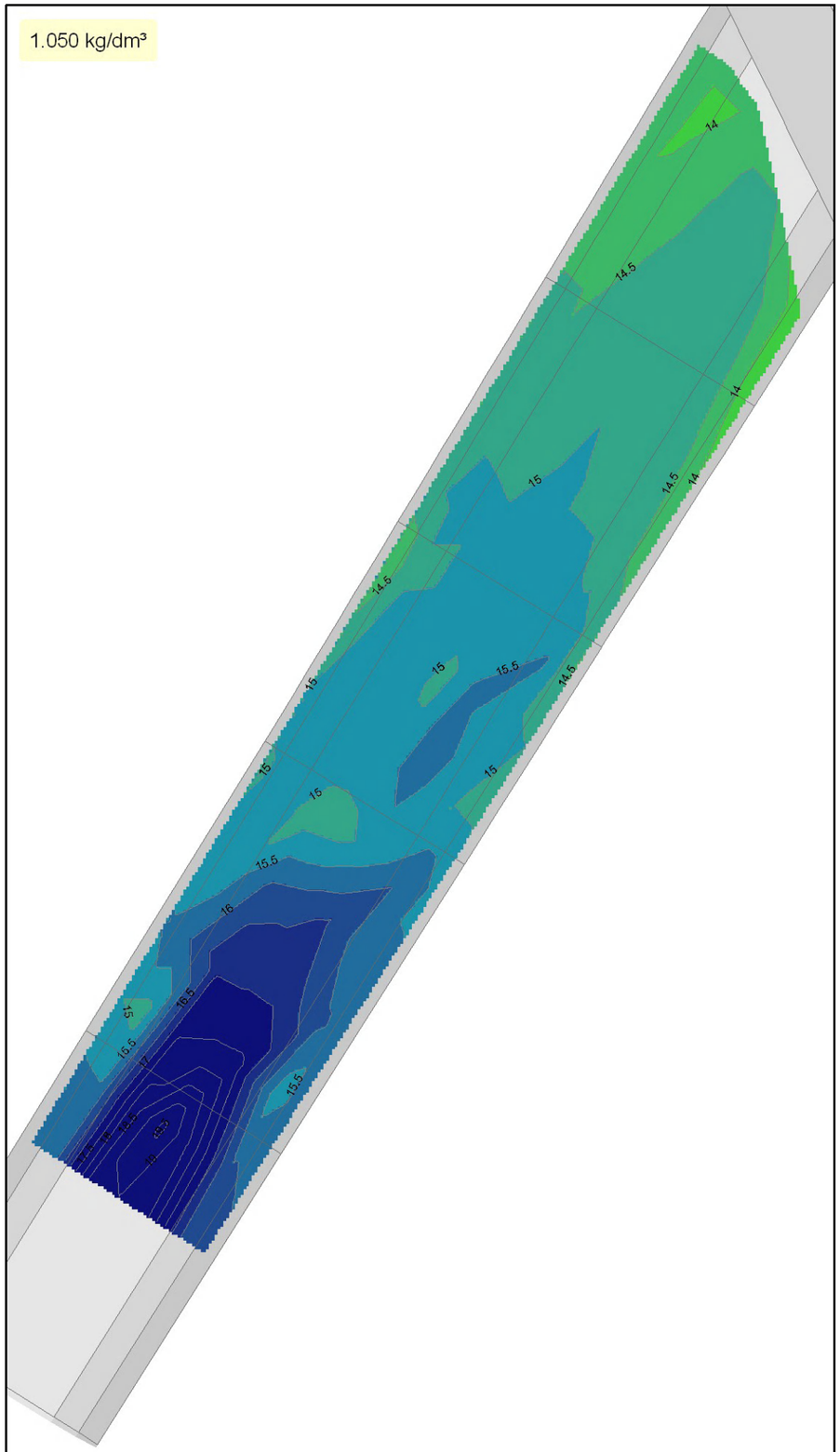
In association with : WL | delft hydraulics

I/RA/11283/08.077/MSA

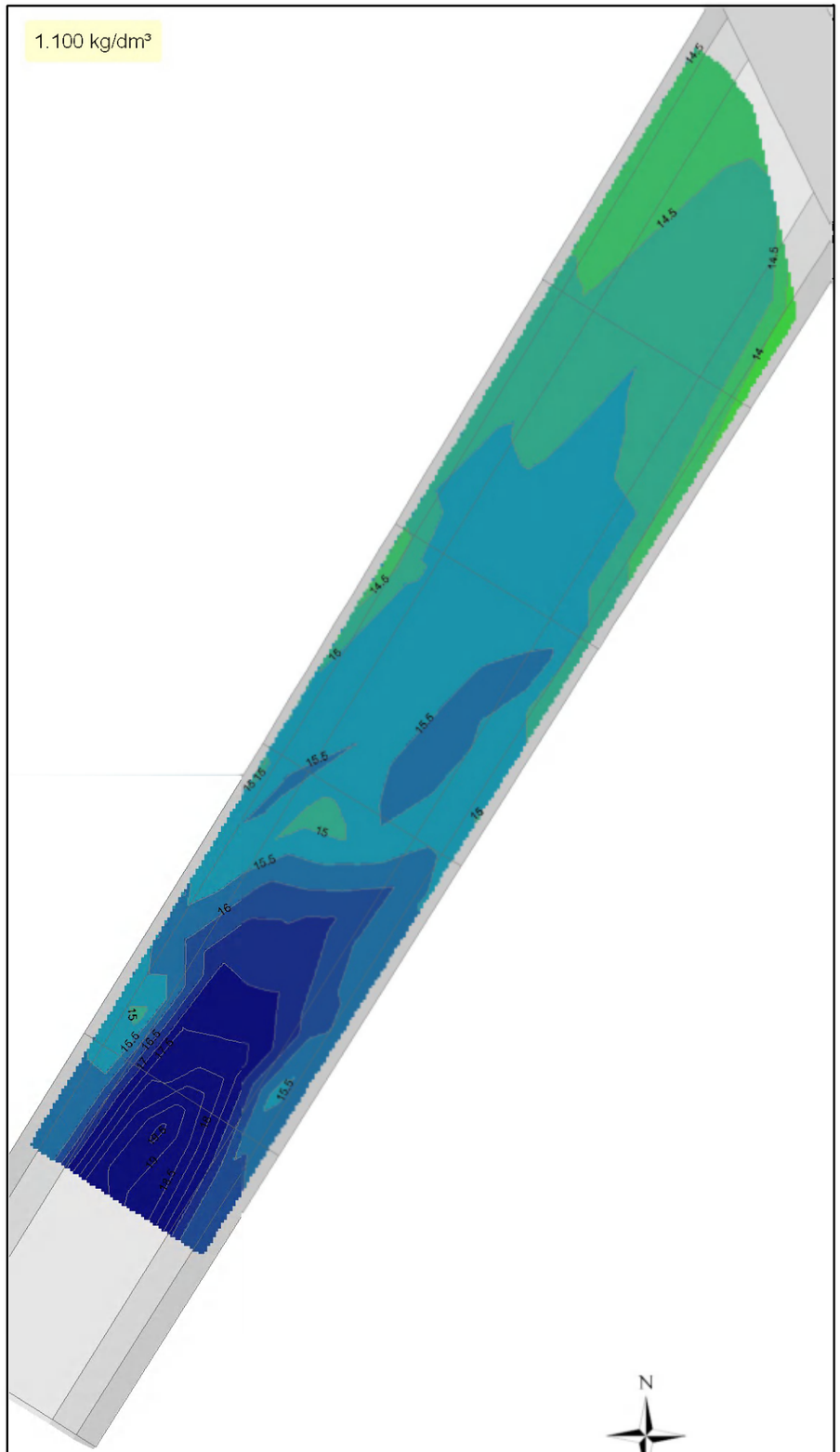
APPENDIX D.

DEPTH OF WATER-BED INTERFACE AND EQUAL DENSITY LAYERS

1.050 kg/dm³



1.100 kg/dm³



Long-term measurements Deurganckdok Evolution & analysis of siltation

Bestek nr 16EB/05/04

Water-bed interface & equal density layer

11 august 2008 (measurement 09)

Map 1 — Scalel 1/10.000

Created: 17/02/2009 — I/DR/11283/08.000/JUR

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E-mail: info@imdc.be

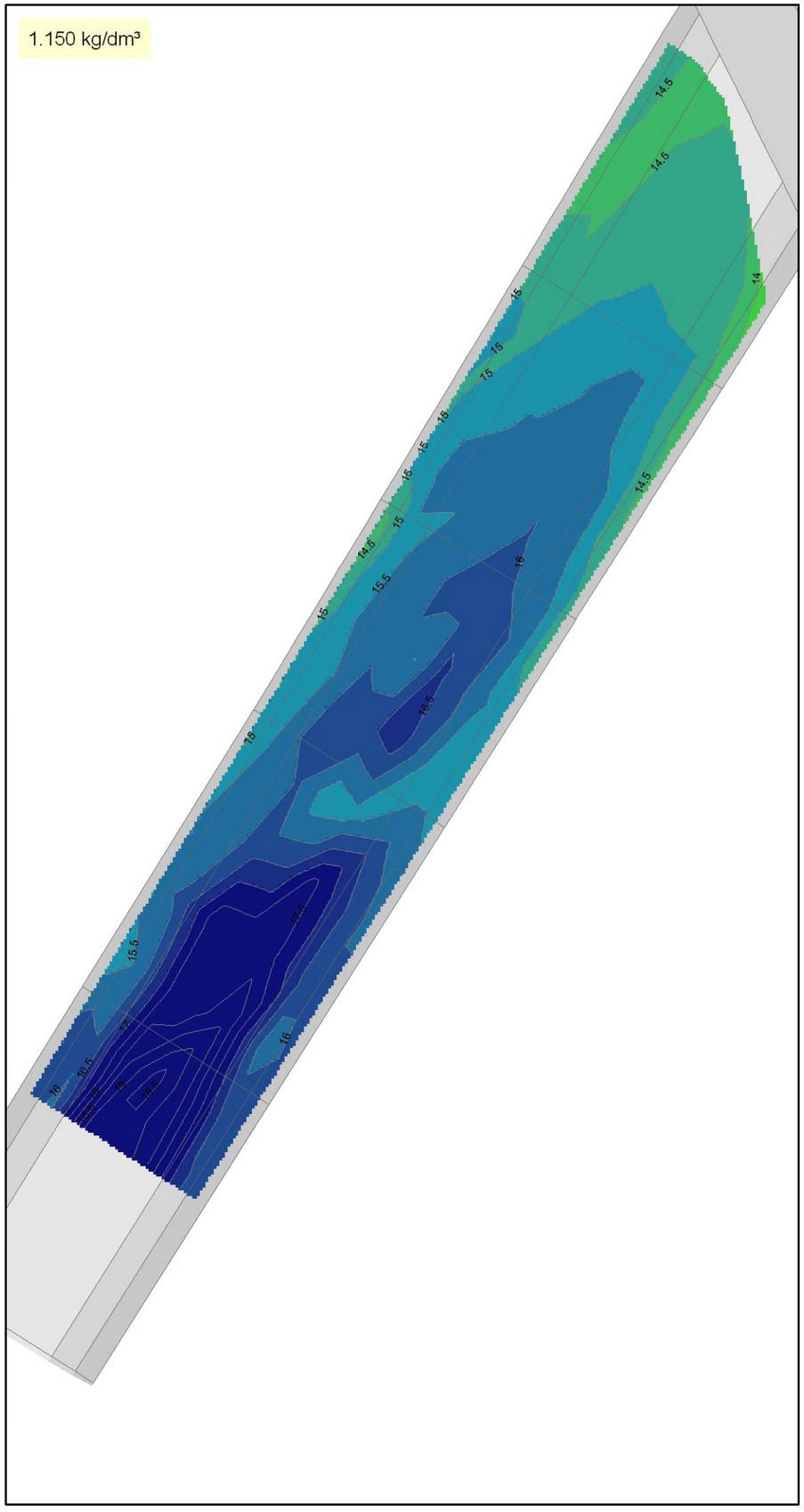
Legend

Elevation of equal density layers (m TAW)

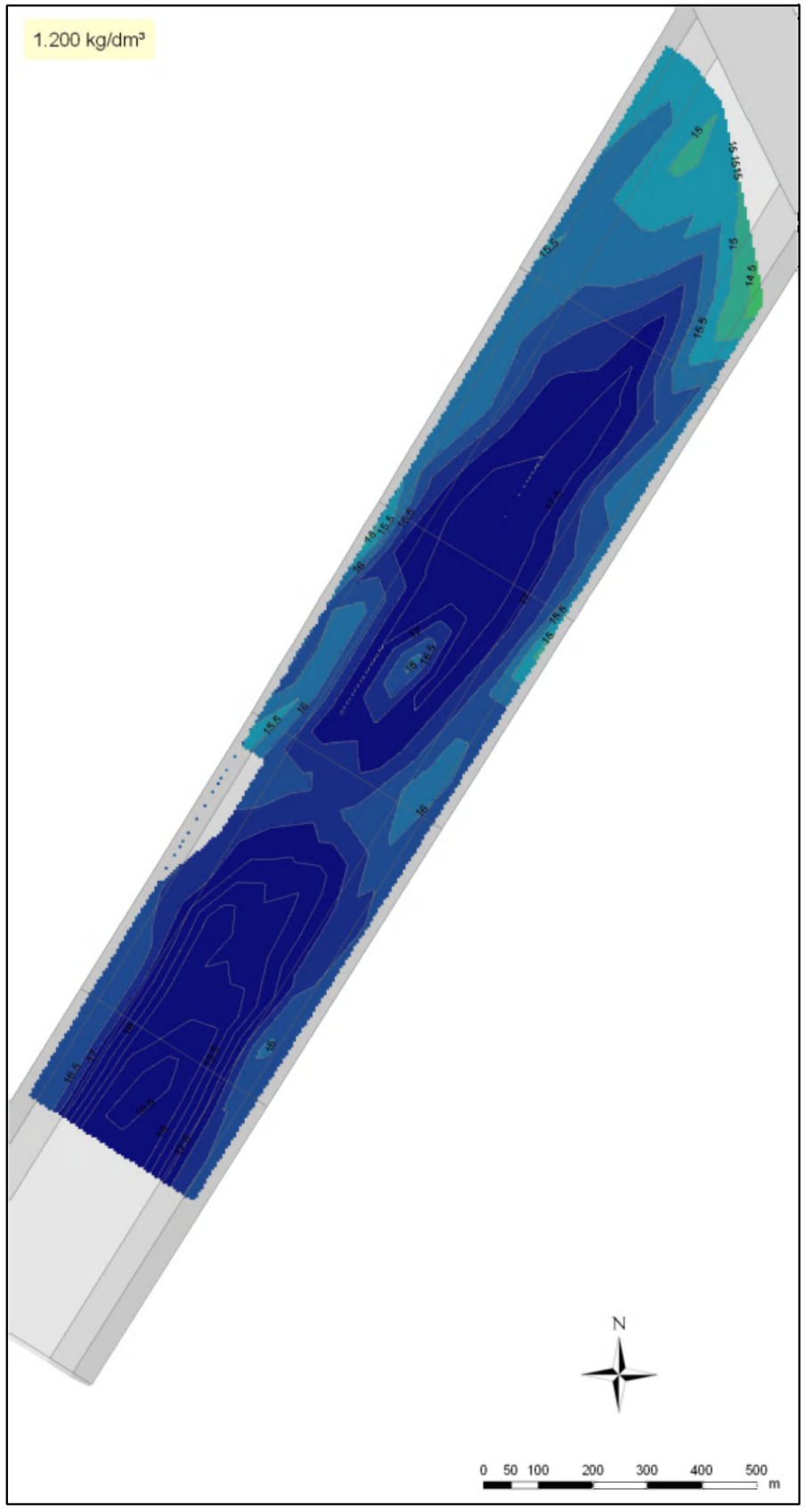
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- -14.51 - -15.00
- -15.01 - -15.50
- -15.51 - -16.00
- -16.01 - -16.50
- -16.51 - -17.00
- -17.01 - -17.50

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1.150 kg/dm³



1.200 kg/dm³



Long-term measurements Deurganckdok Evolution & analysis of siltation

Bestek nr 16EB/05/04

Water-bed interface & equal density layer

11 august 2008 (measurement 09)

Map 2 Scalel 1/10.000

Created: 17/02/2009 I/DR/11283/08.000/JUR

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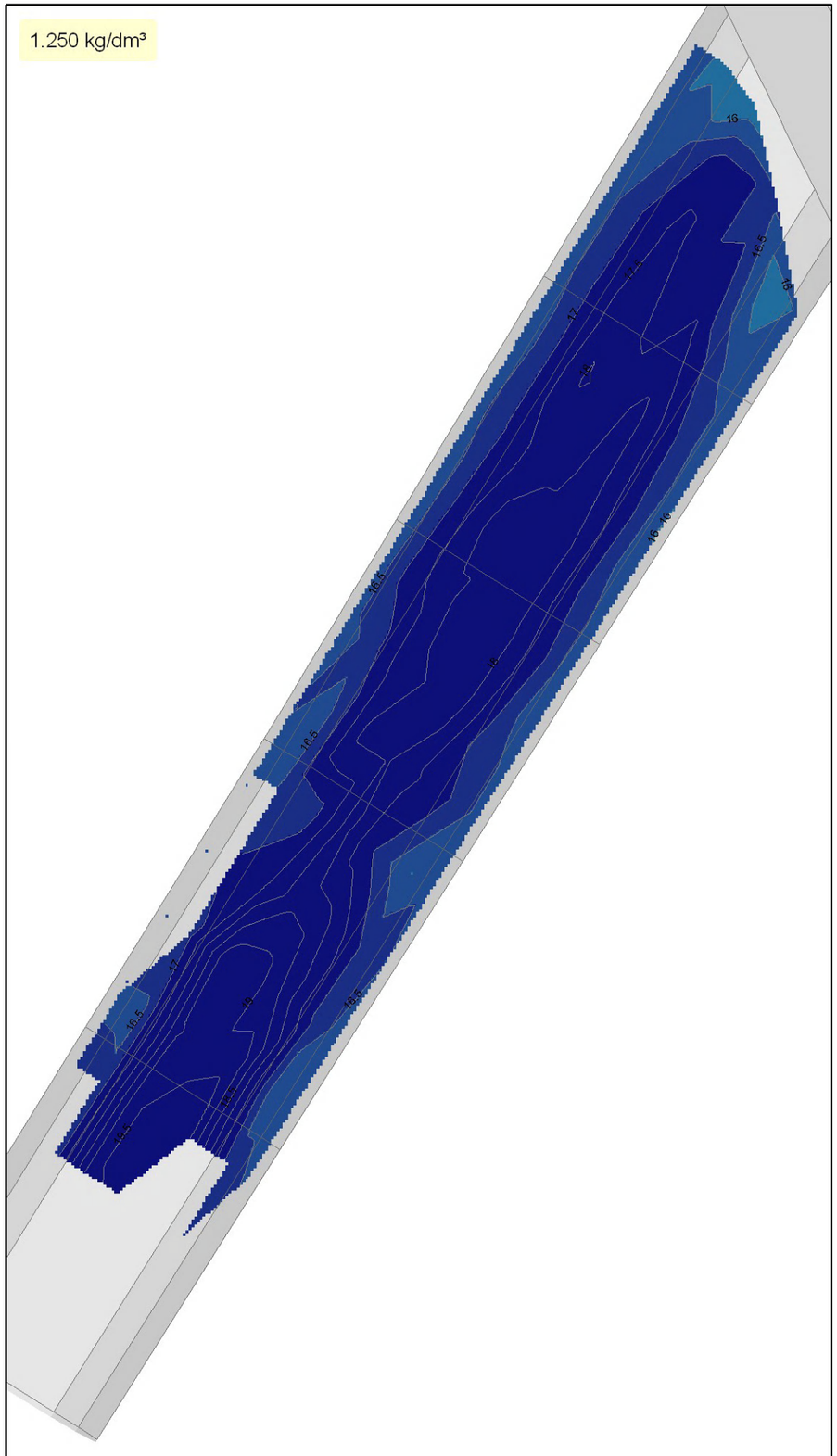
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Elevation of equal density layers (m TAW)

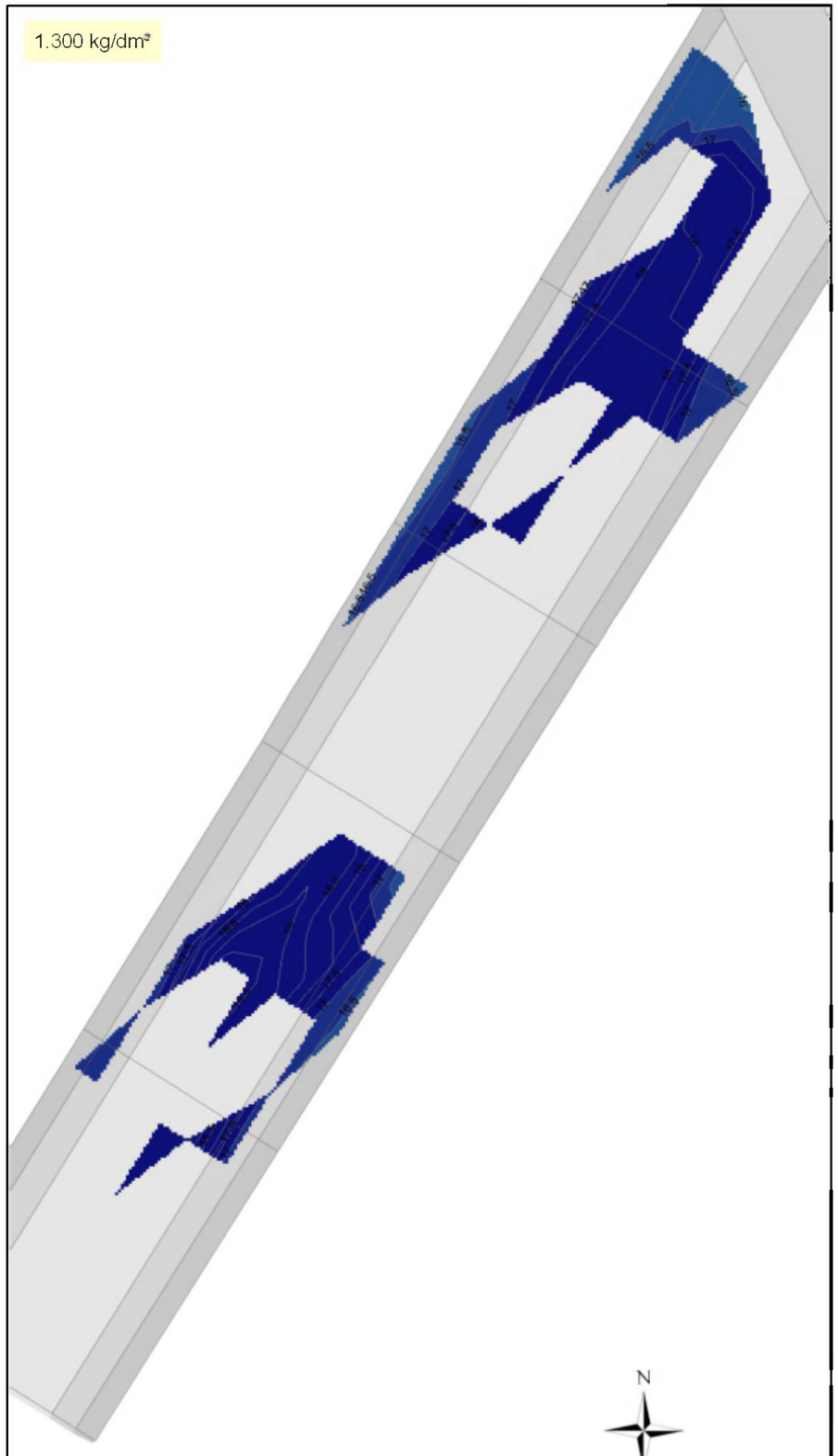
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- -14.51 - -15.00
- -15.01 - -15.50
- -15.51 - -16.00
- -16.01 - -16.50
- -16.51 - -17.00
- -17.01 - -17.50

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1.250 kg/dm³



1.300 kg/dm³



Long-term measurements
Deurganckdok
Evolution & analysis of siltation

Bestek nr 16EB/05/04

Water-bed interface & equal density layer

11 august 2008 (measurement 09)

Map 3 Scalel 1/10.000

Created: 17/02/2009 I/DR/11283/08.000/JUR

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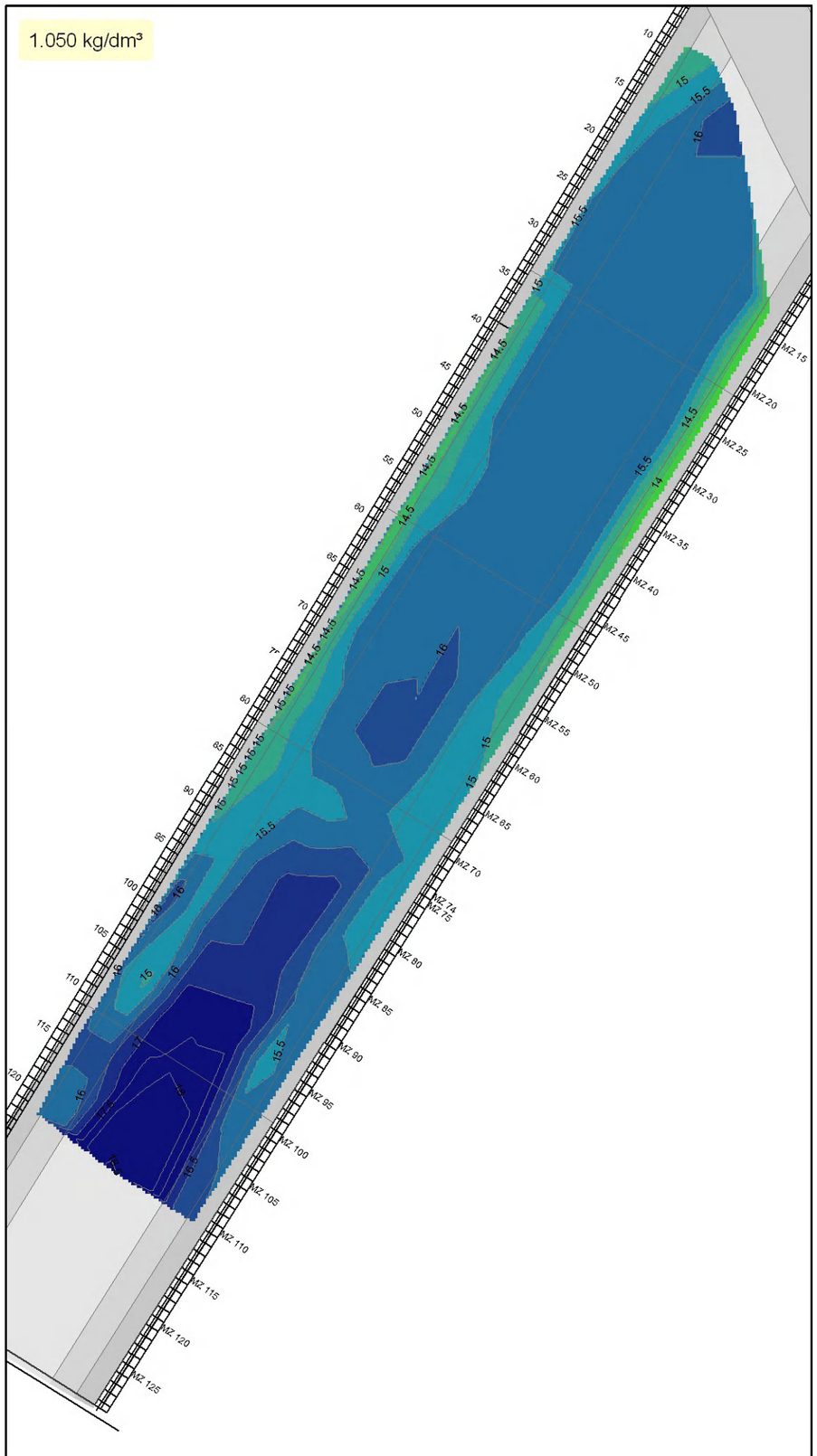
Legend

Elevation of equal density layers (m TAW)

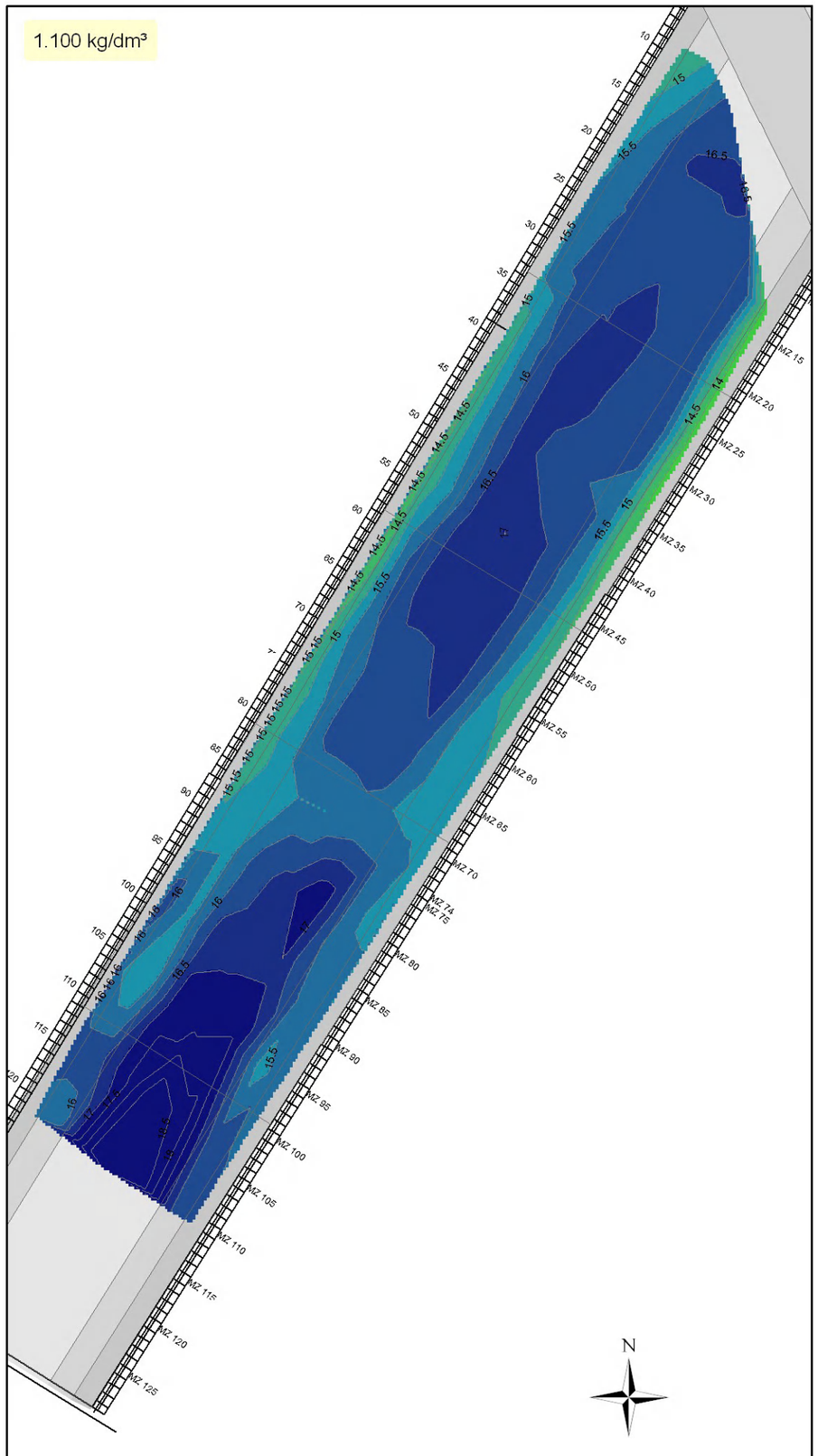
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- -16.51 - -17.00
- -17.01 - -17.50

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1.050 kg/dm³



1.100 kg/dm³



Long-term measurements Deurganckdok Evolution & analysis of siltation

Bestek nr 16EB/05/04

Water-bed interface & equal density layer

26 august 2008 (measurement 10)

Map 1 Scalel 1/10.000

Created: 17/02/2009 I/DR/11283/08.000/JUR

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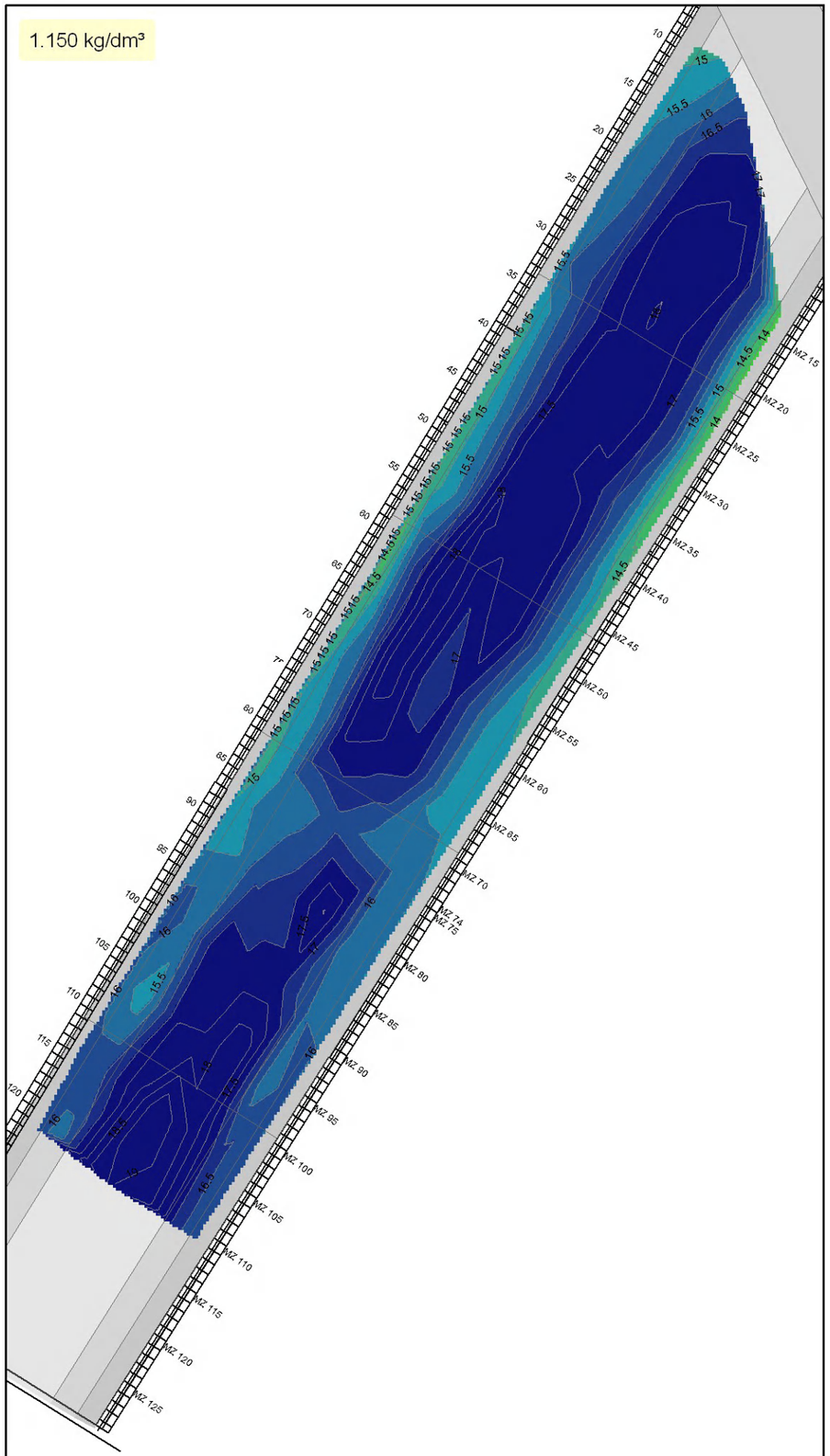
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Elevation of equal density layers (m TAW)

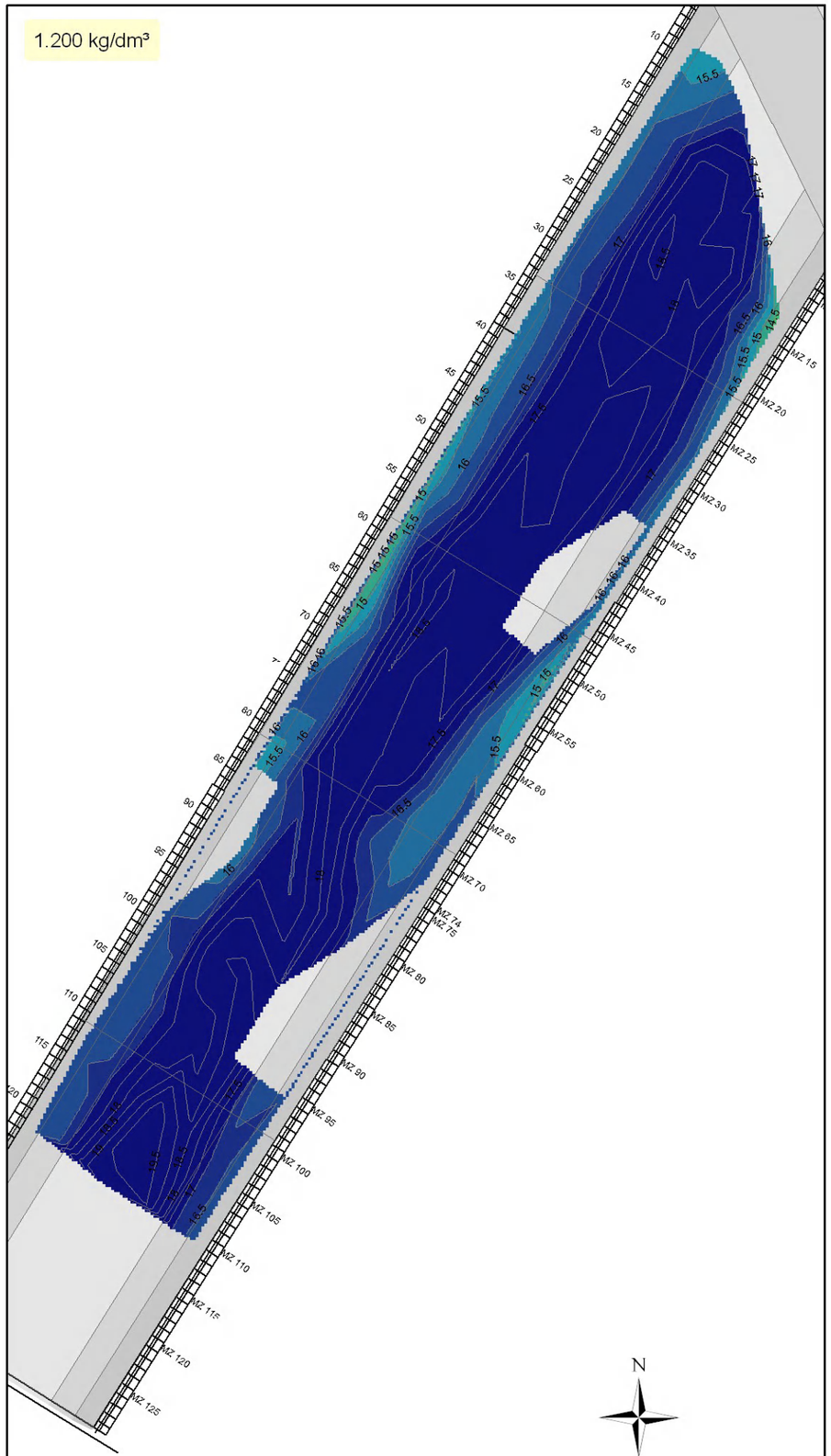
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- -15.51 - -16.00
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- -16.51 - -17.00
- -17.01 - -17.50

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1.150 kg/dm³



1.200 kg/dm³



Long-term measurements Deurganckdok Evolution & analysis of siltation

Bestek nr 16EB/05/04

Water-bed interface & equal density layer

26 august 2008 (measurement 10)

Map 2 Scalel 1/10.000

Created: 17/02/2009 I/DR/11283/08.000/JUR

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Fax +32 3 235 67 11
E-mail: info@imdc.be

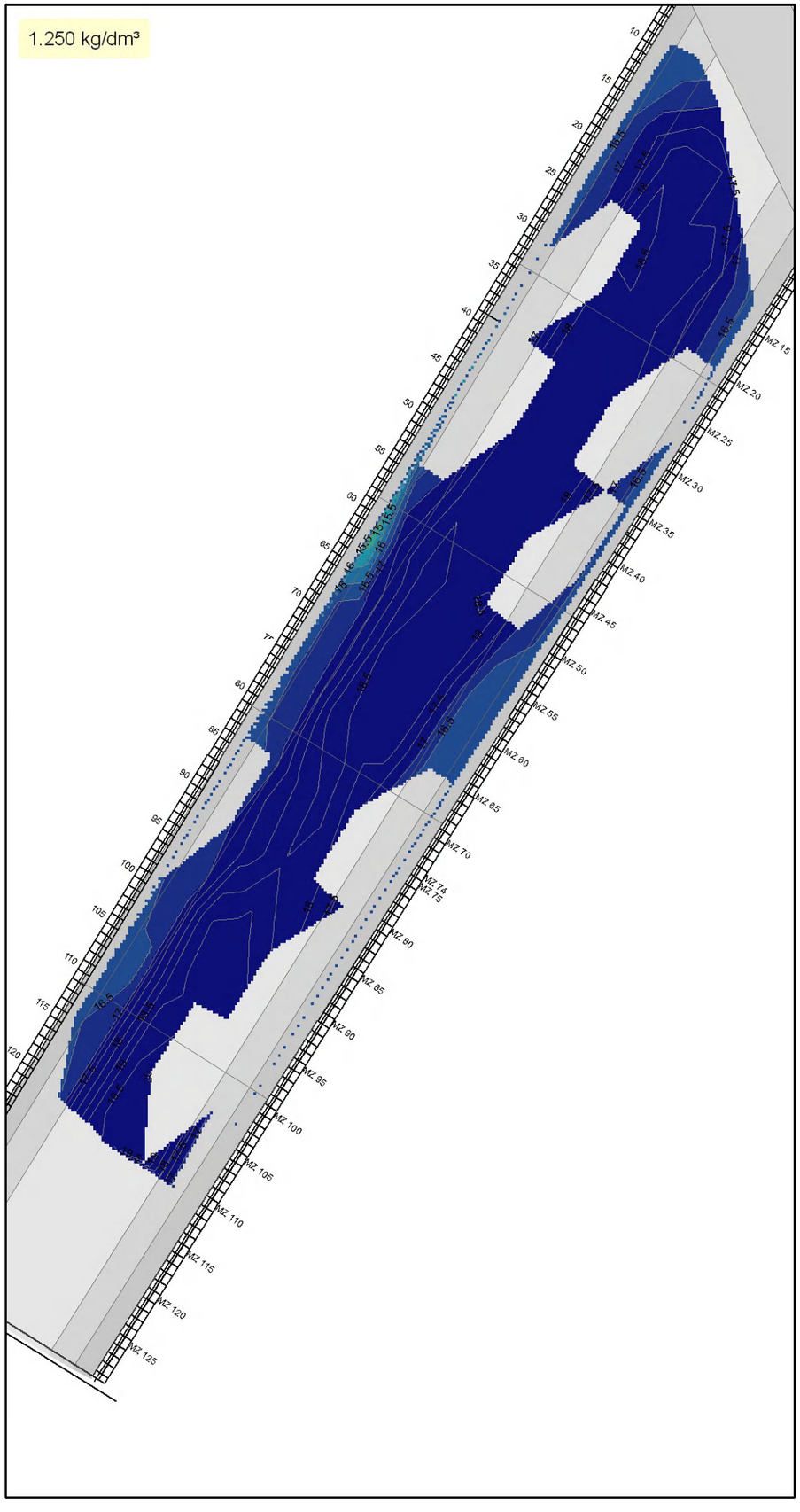
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Elevation of equal density layers (m TAW)

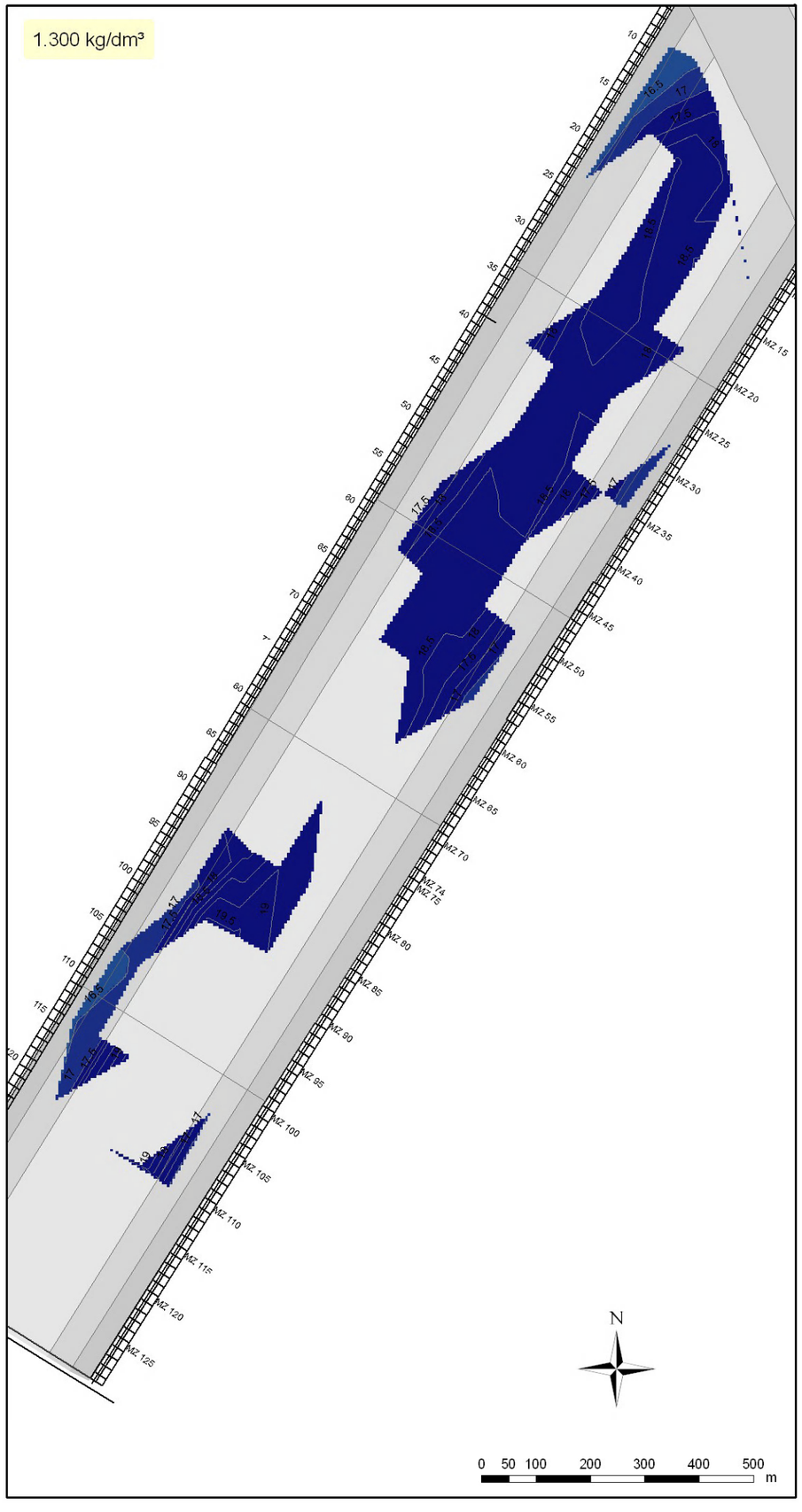
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- -14.51 - -15.00
- -15.01 - -15.50
- -15.51 - -16.00
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- -16.51 - -17.00
- -17.01 - -17.50

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1.250 kg/dm³



1.300 kg/dm³



Long-term measurements Deurganckdok Evolution & analysis of siltation

Bestek nr 16EB/05/04

Water-bed interface & equal density layer

26 august 2008 (measurement 10)

Map 3 Scalel 1/10.000

Created: 17/02/2009 I/DR/11283/08.000/JUR

Version nr. 1

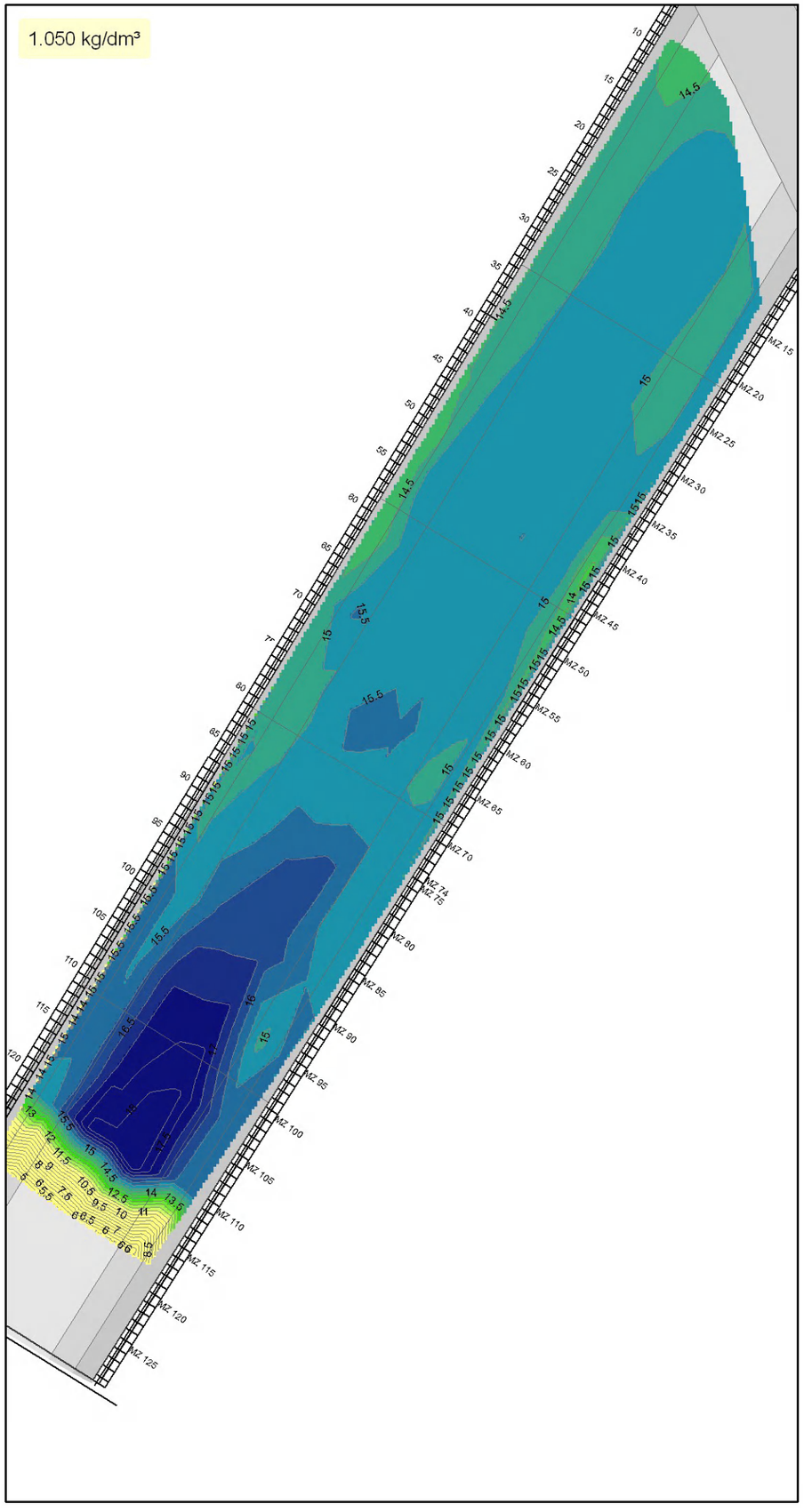
IMDC International Marine & Dredging Consultants
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E-mail: info@imdc.be

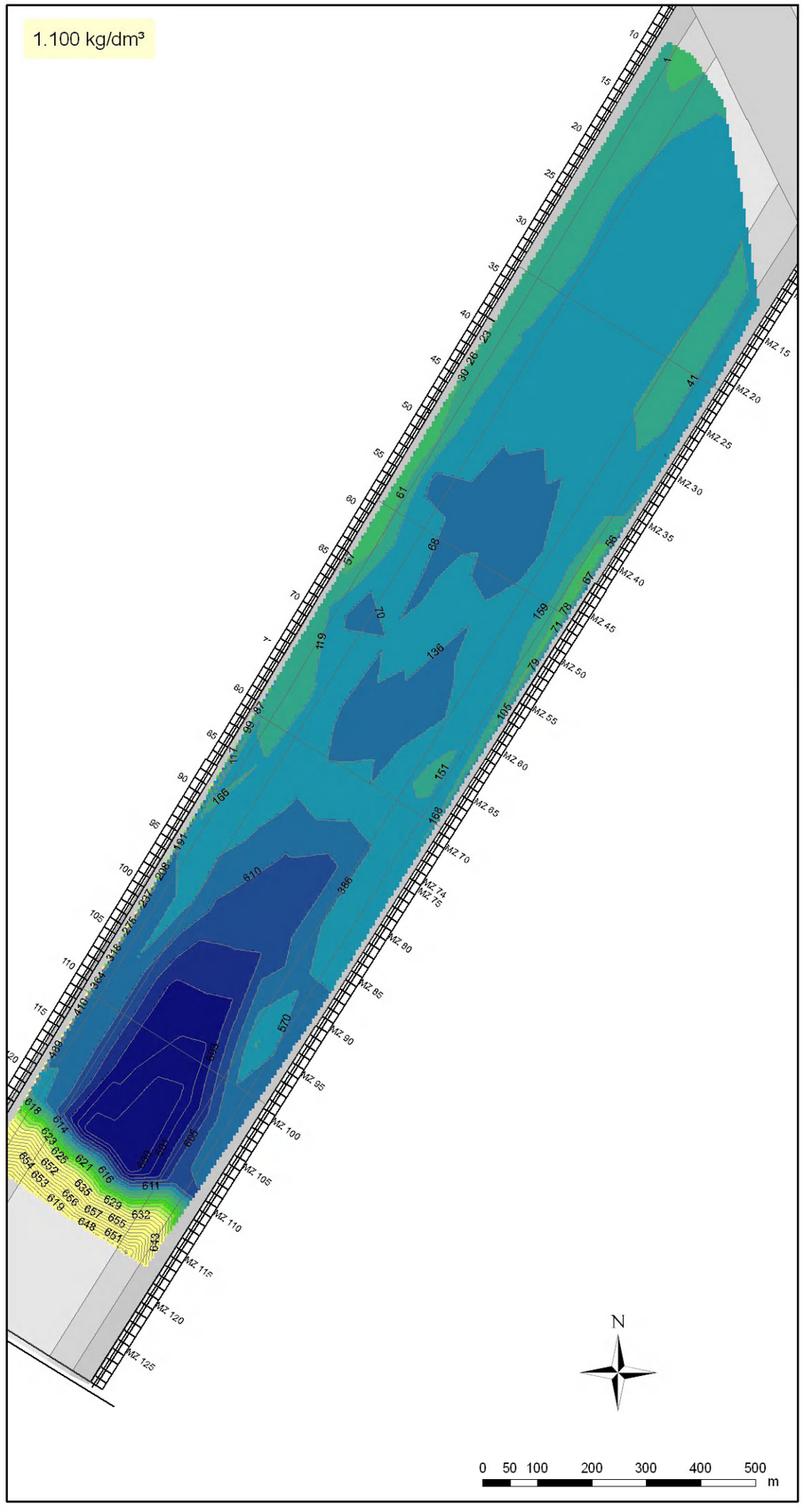
Legend

Elevation of equal density layers (m TAW)

- -11.00 - -11.50
- -11.51 - -12.00
- -12.01 - -12.50
- -12.51 - -13.00
- -13.01 - -13.50
- -13.51 - -14.00
- -14.01 - -14.50
- -14.51 - -15.00
- -15.01 - -15.50
- -15.51 - -16.00
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- -16.51 - -17.00
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Long-term measurements Deurganckdok Evolution & analysis of siltation

Bestek nr 16EB/05/04

Water-bed interface & equal density layer

11 september 2008 (measurement 11)

Map 1 — Scalel 1/10.000

Created: 17/02/2009 — I/DR/11283/08.000/JUR

Version nr. 1

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Fax +32 3 235 67 11
E-mail: info@imdc.be

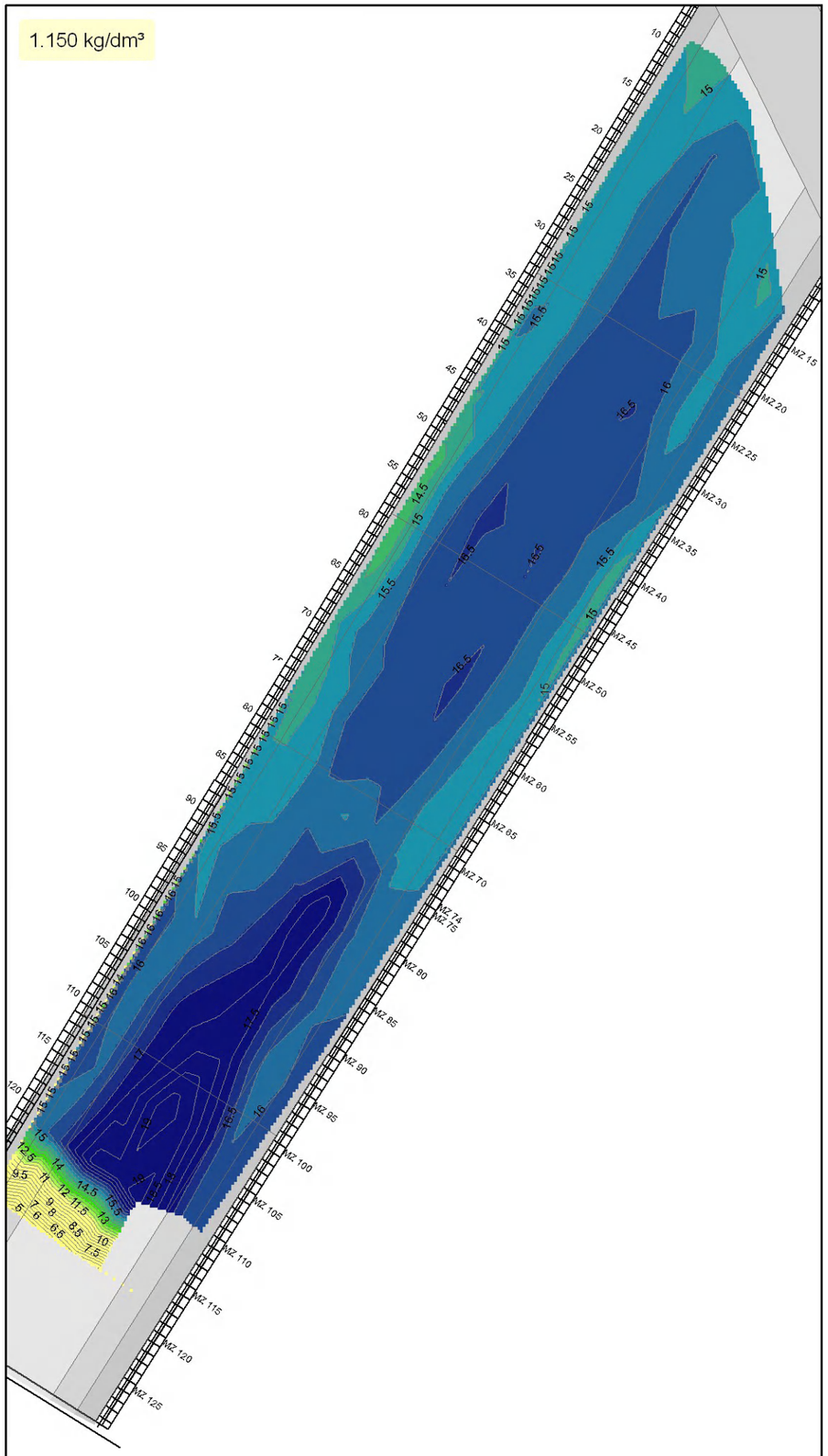
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Elevation of equal density layers (m TAW)

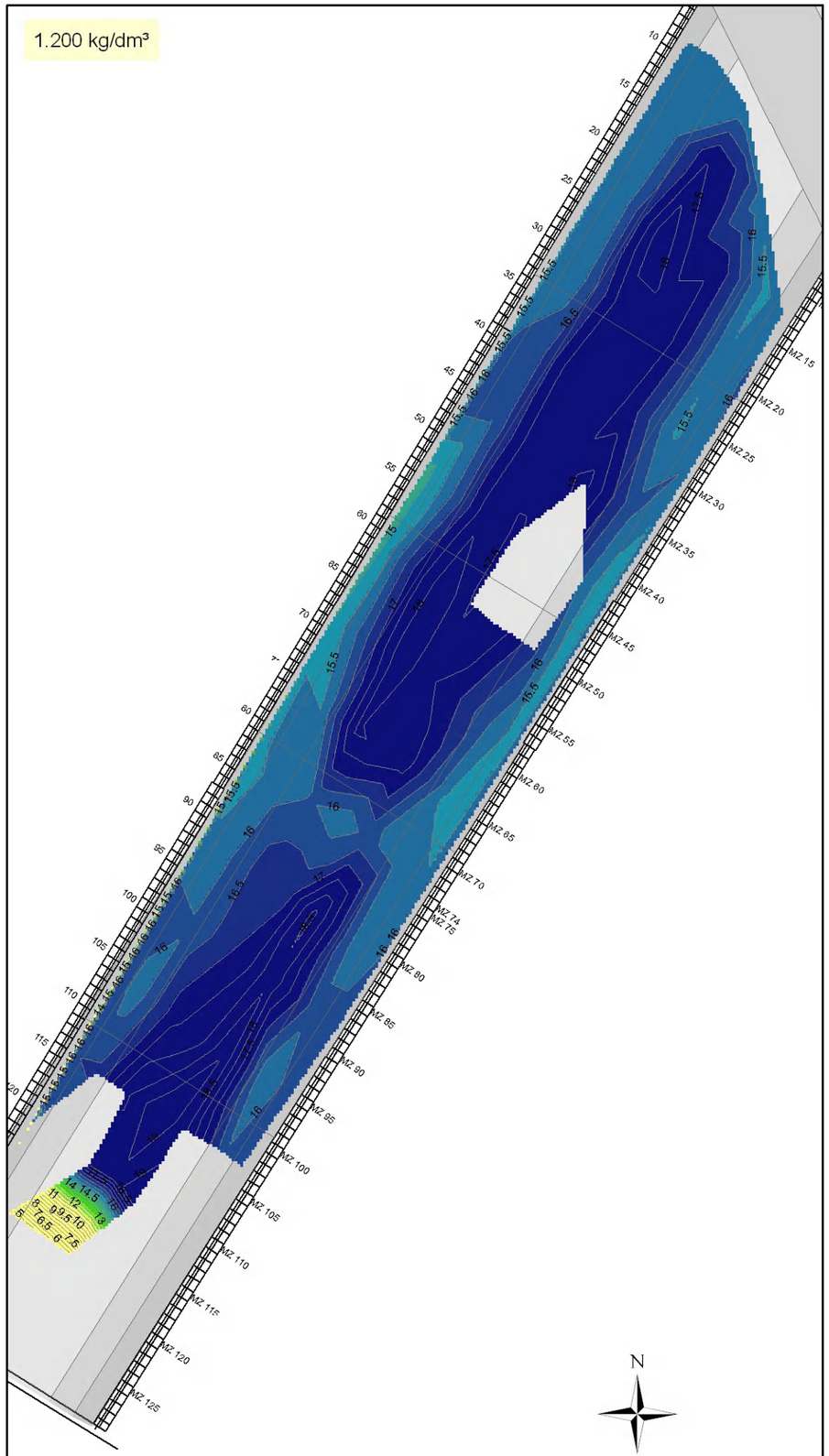
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- -16.51 - -17.00
- -17.01 - -17.50

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1.150 kg/dm³



1.200 kg/dm³



Long-term measurements Deurganckdok Evolution & analysis of siltation

Bestek nr 16EB/05/04

Water-bed interface & equal density layer

11 september 2008 (measurement 11)

Map 2 Scale1 1/10.000

Created: 17/02/2009 I/DR/11283/08.000/JUR

Version nr. 1

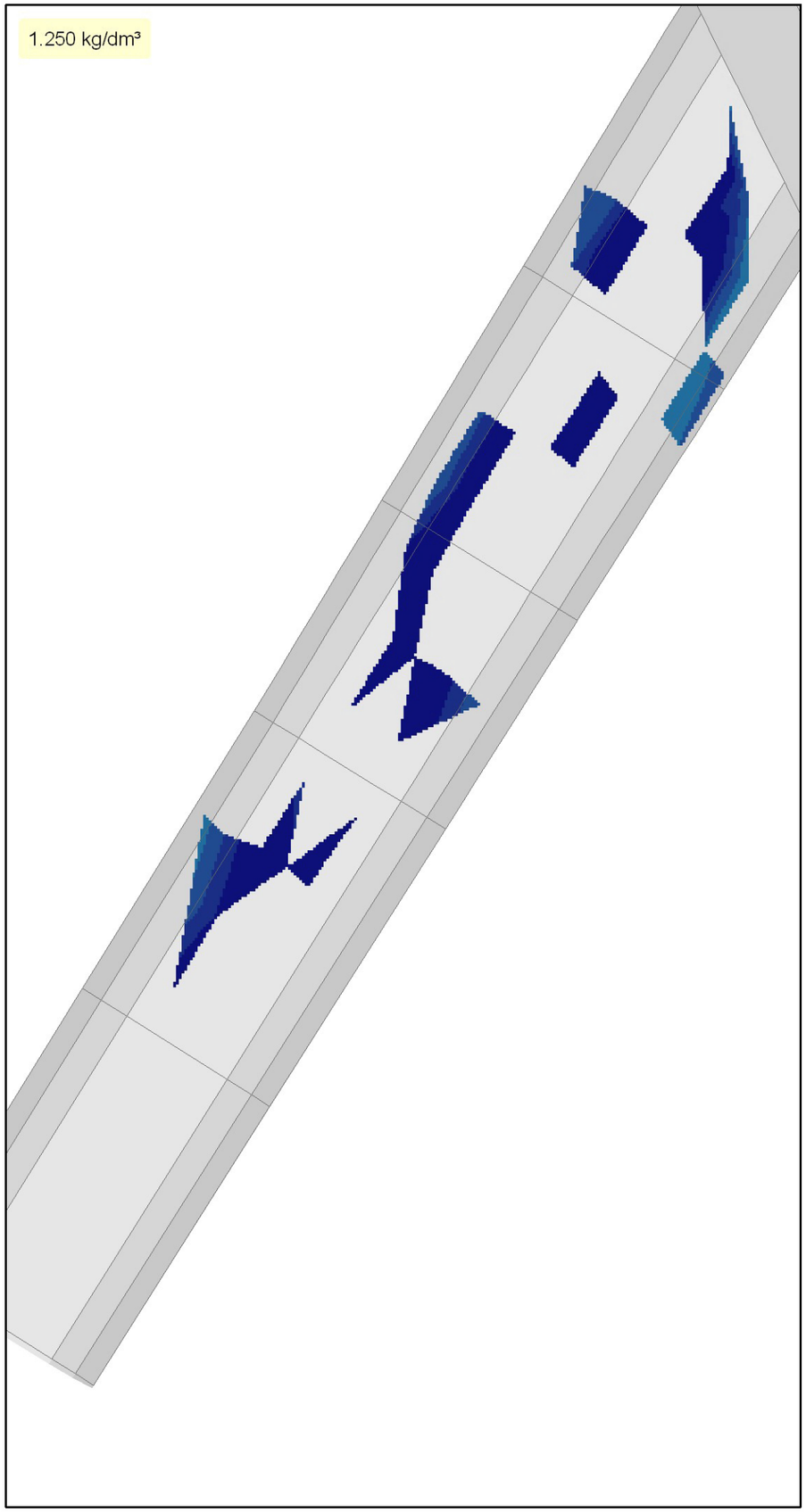
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2600 Antwerpen
Tel +32 3 270 92 20
Fax +32 3 235 67 11
E-mail: info@imdc.be

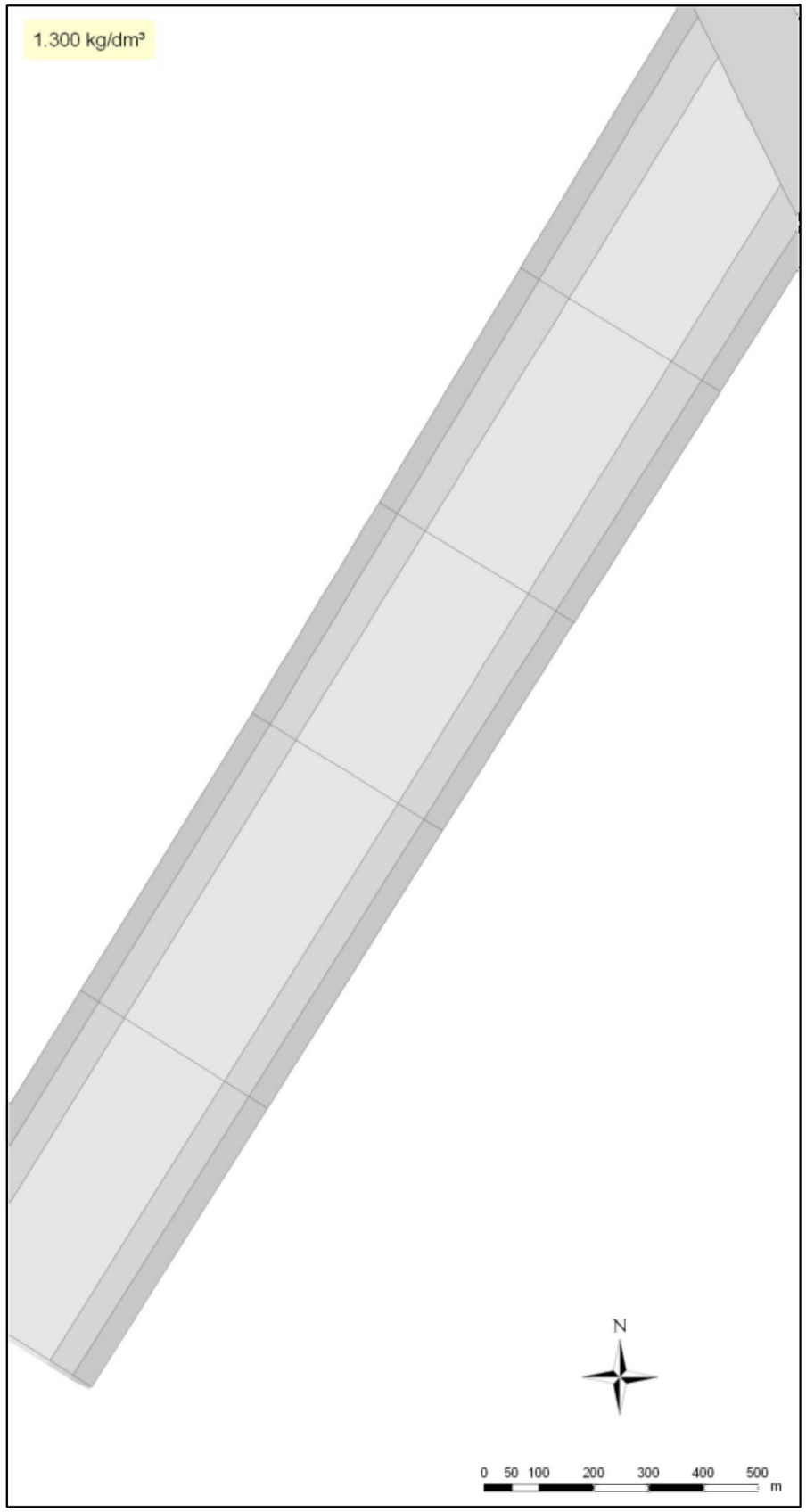
Legend

Elevation of equal density layers (m TAW)

- -11.00 - -11.50
- -11.51 - -12.00
- -12.01 - -12.50
- -12.51 - -13.00
- -13.01 - -13.50
- -13.51 - -14.00
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Long-term measurements Deurganckdok Evolution & analysis of siltation

Bestek nr 16EB/05/04

Water-bed interface & equal density layer

11 september 2008 (measurement 11)

Map 3 Scalel 1/10.000

Created: 17/02/2009 I/DR/11283/08.000/JUR

Version nr. 1

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International Marine & Dredging Consultants
Coveliersstraat 15
2600 Antwerpen
Tel +32 3 270 92 20
Fax +32 3 235 67 11
E-mail: info@imdc.be

Legend

Elevation of equal density layers (m TAW)

- -11.00 - -11.50
- -11.51 - -12.00
- -12.01 - -12.50
- -12.51 - -13.00
- -13.01 - -13.50
- -13.51 - -14.00
- -14.01 - -14.50
- -14.51 - -15.00
- -15.01 - -15.50
- -15.51 - -16.00
- -16.01 - -16.50
- -16.51 - -17.00
- -17.01 - -17.50

W\11283\GIS\project\rapport 1-21\EDL\measurement-11\DGD11_K3_1250-1300.mxd

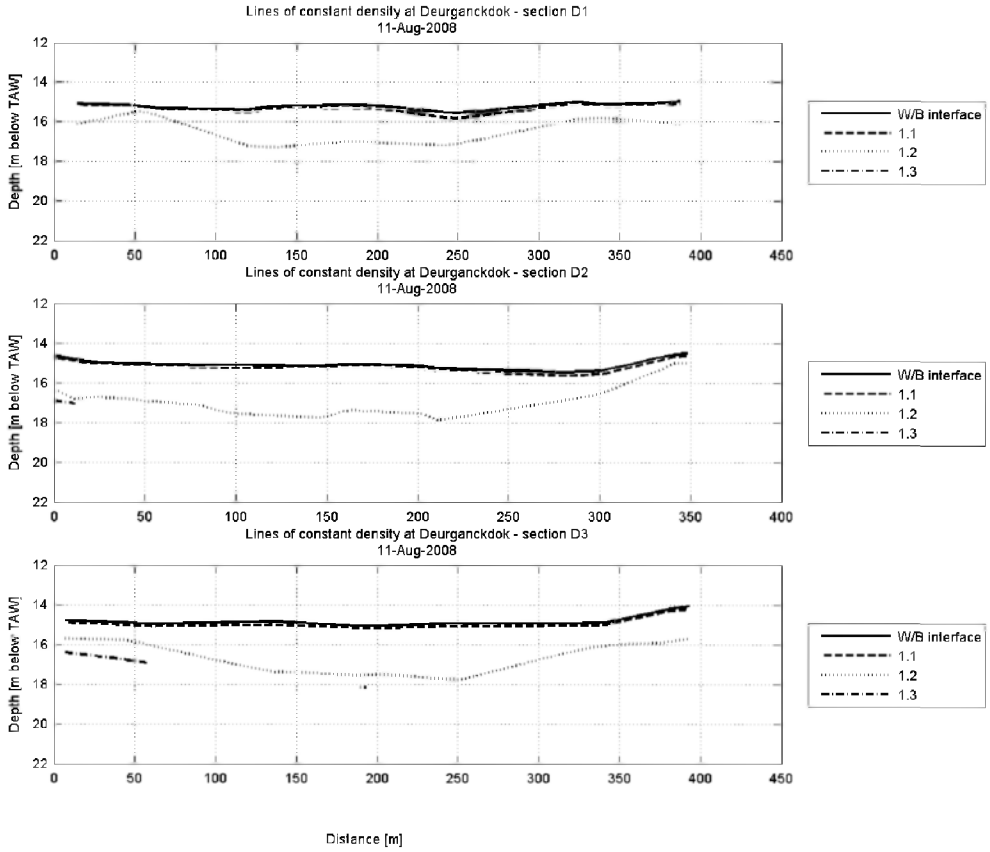
APPENDIX E.

DEPTH OF PLANES OF CONSTANT DENSITY

E.1 Measurements August 11th, 2008

Long-term monitoring siltation Deurganckdok

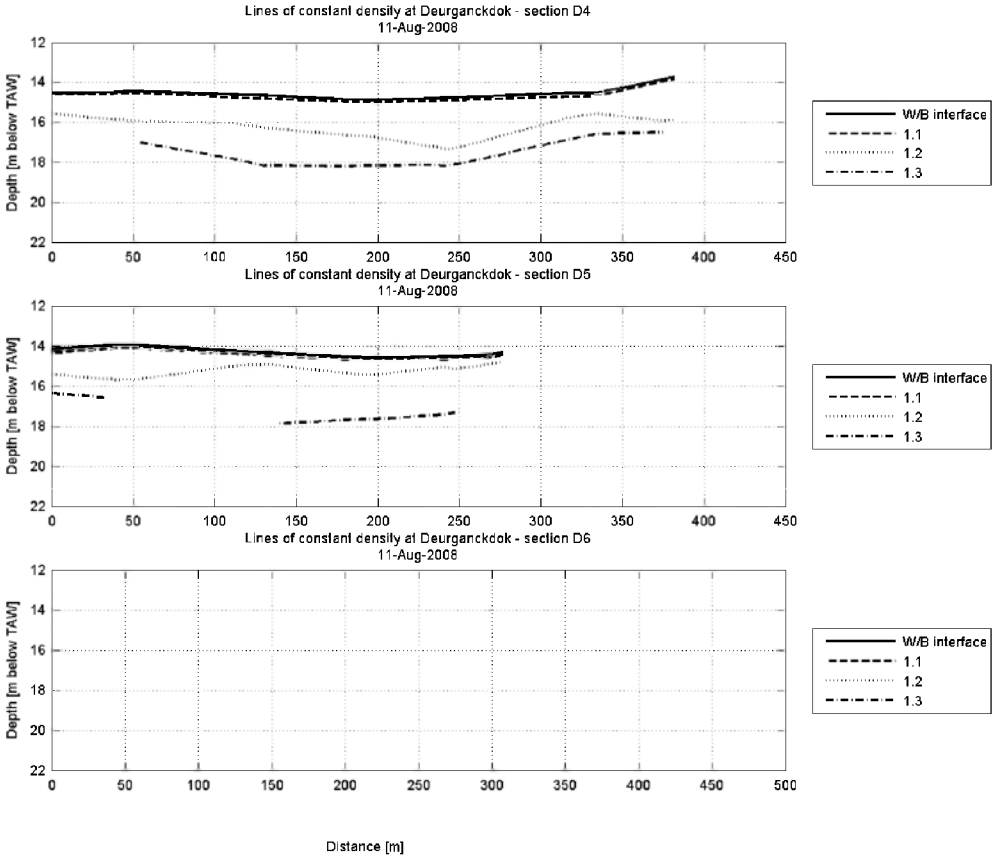
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by:
In association with :
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

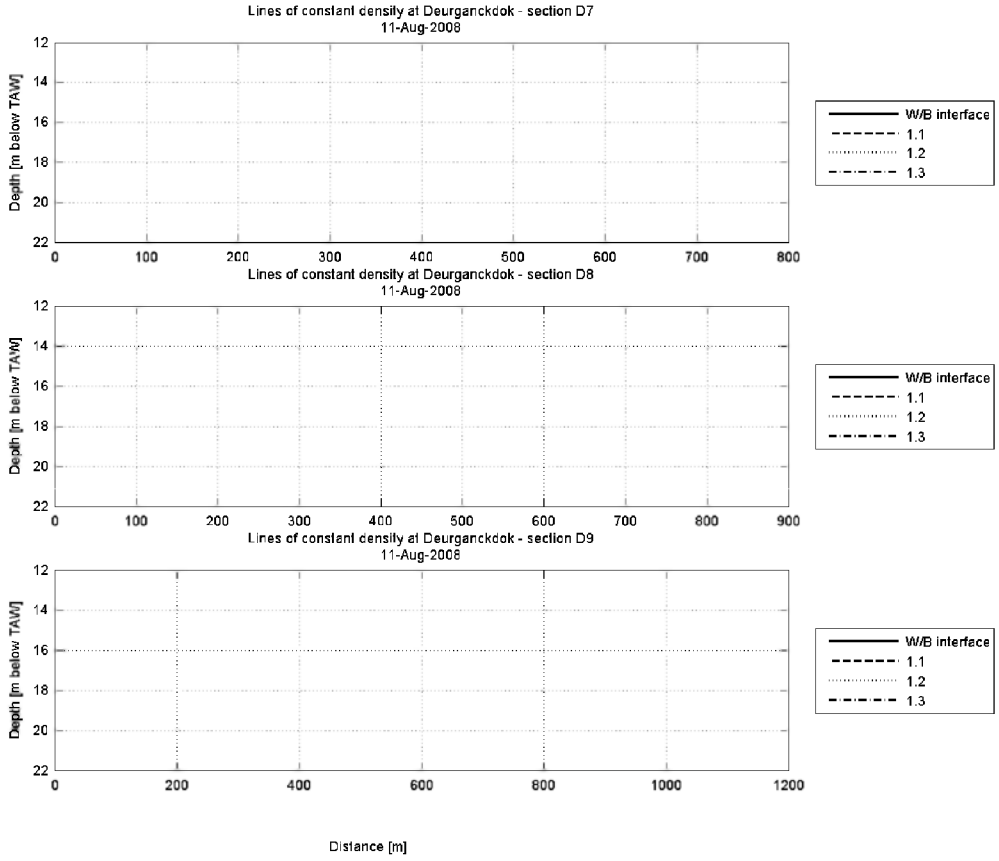
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC
In association with : wl | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

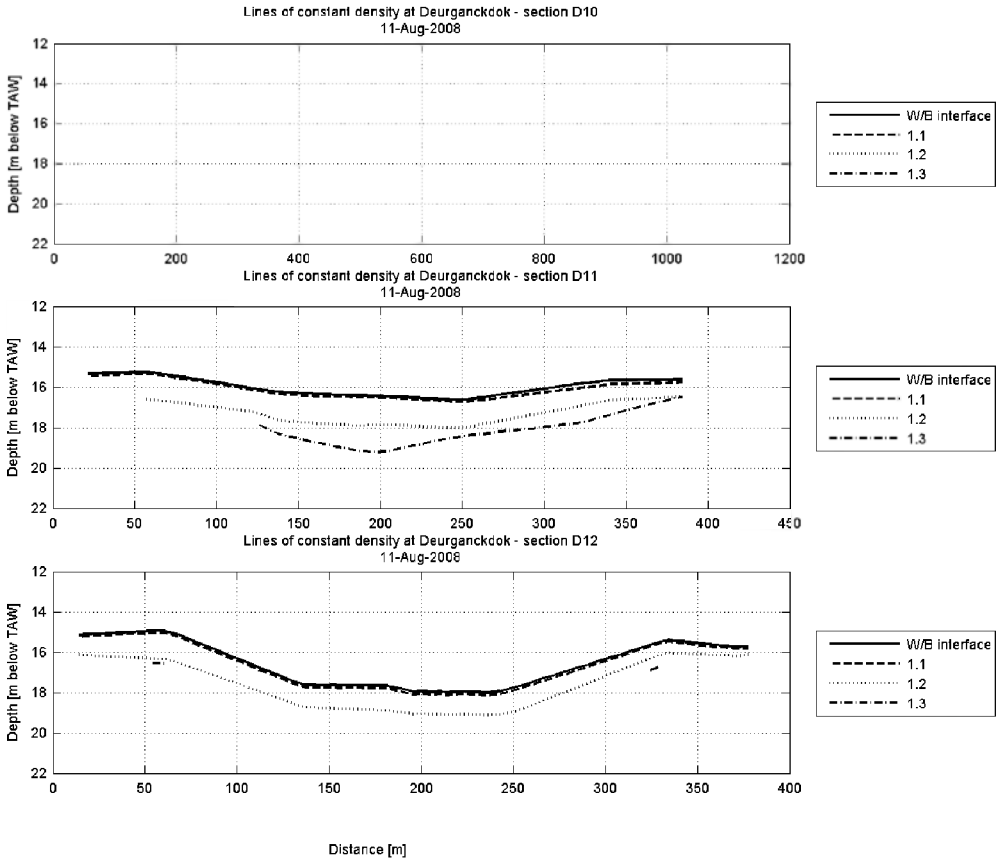
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by:
In association with :
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

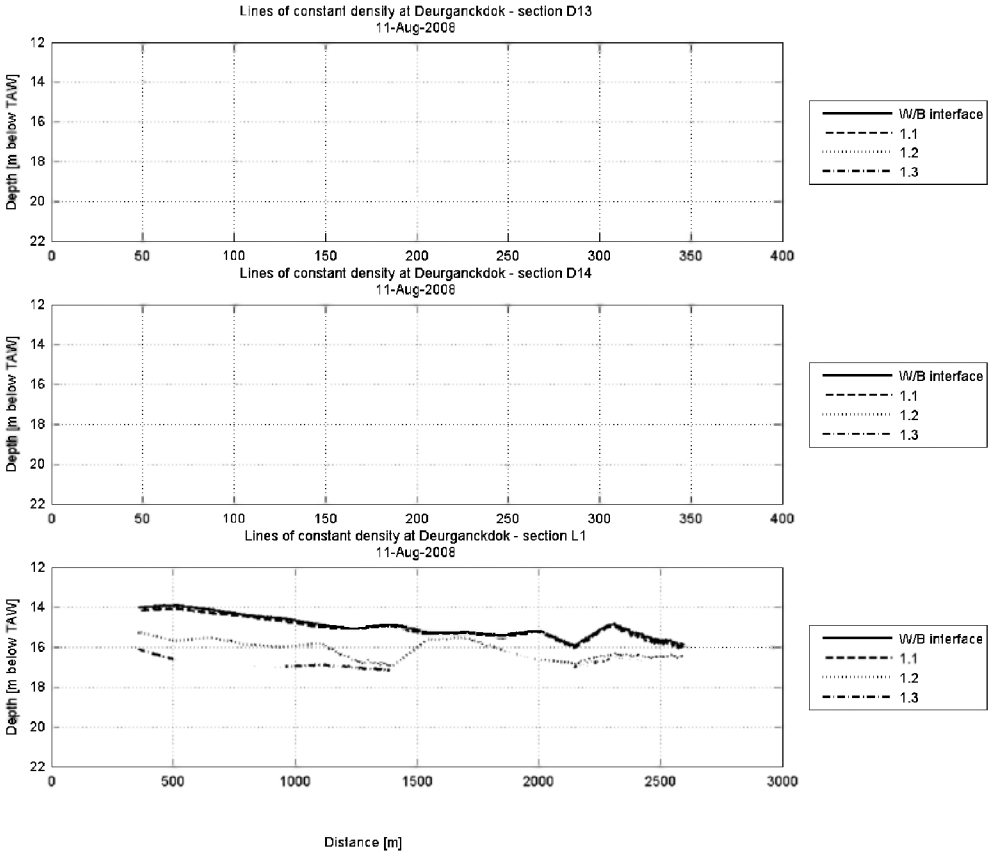
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC
In association with : wl | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

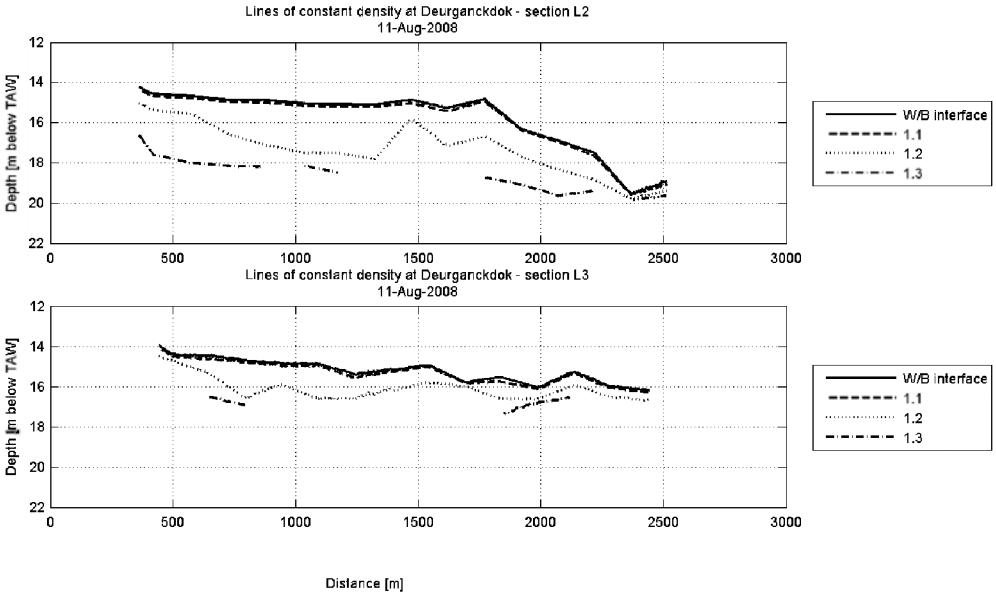
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by:
In association with :
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD

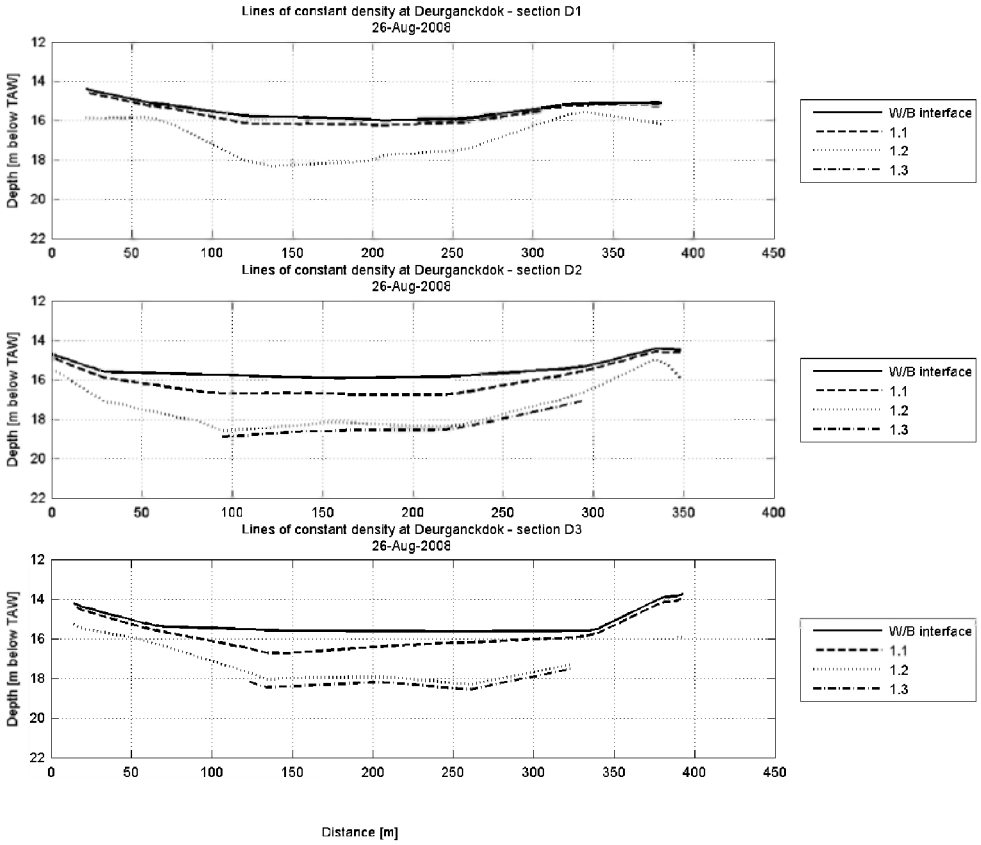


Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.077/MSA

E.2 Measurements August 26th, 2008

Long-term monitoring siltation Deurganckdok

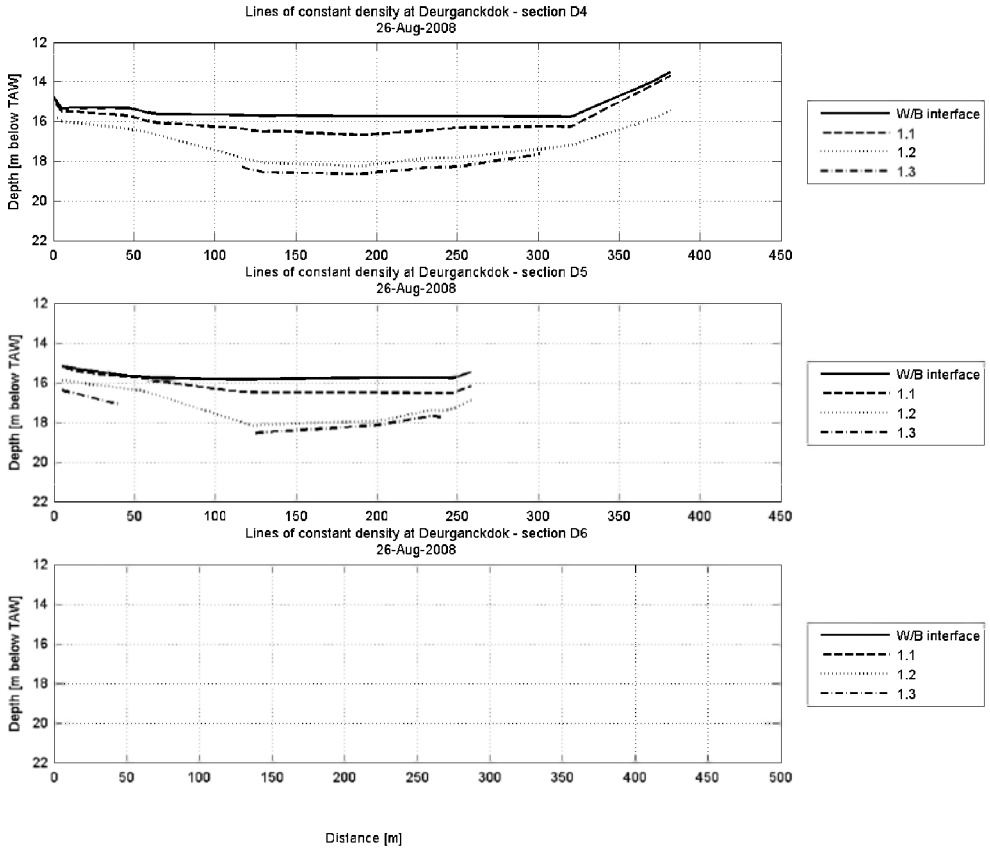
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

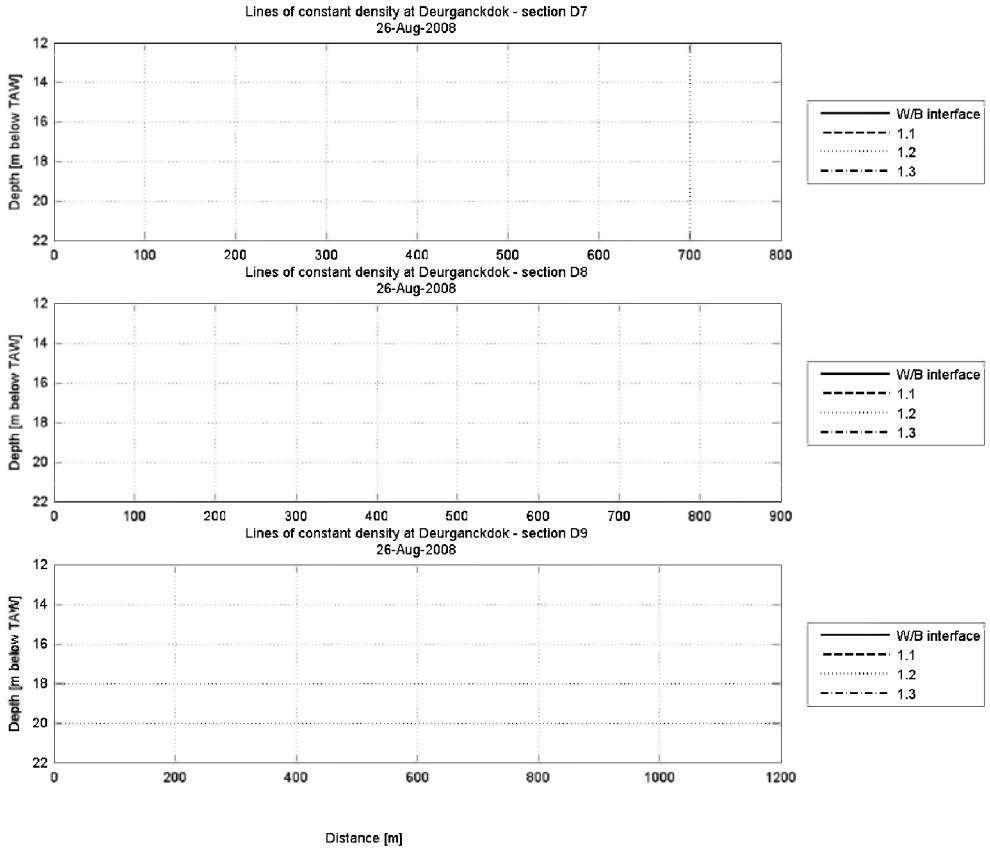
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC
In association with : wl | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

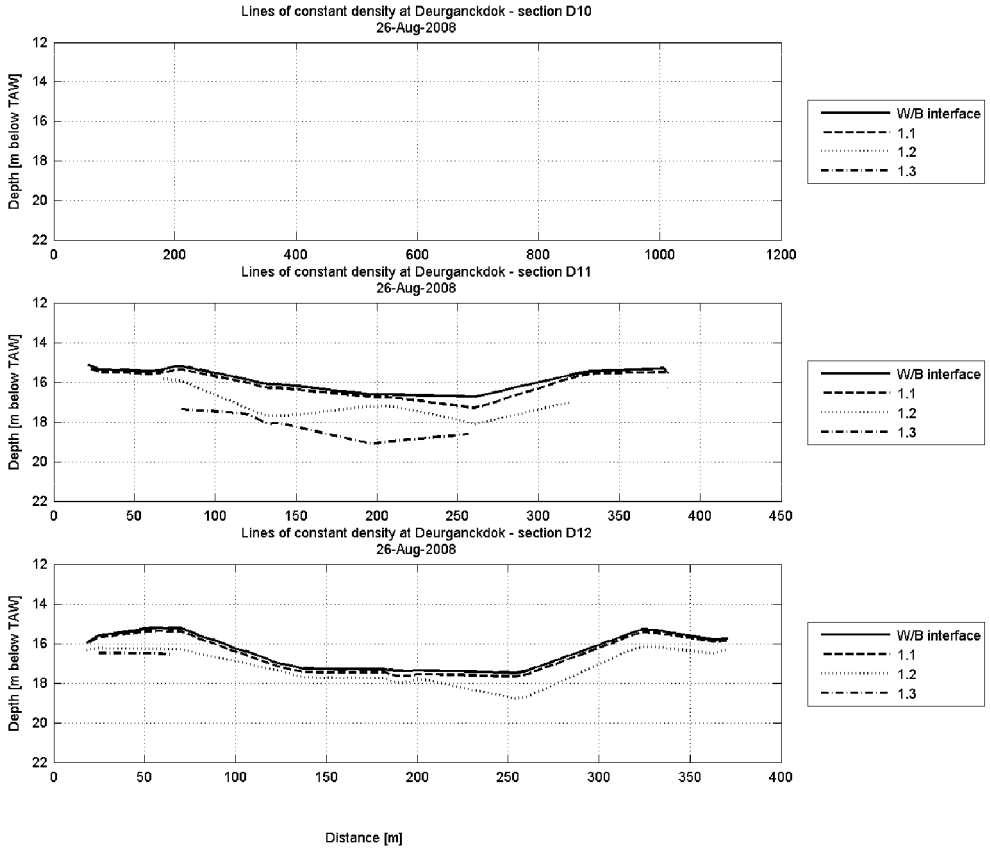
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC
In association with : wl | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

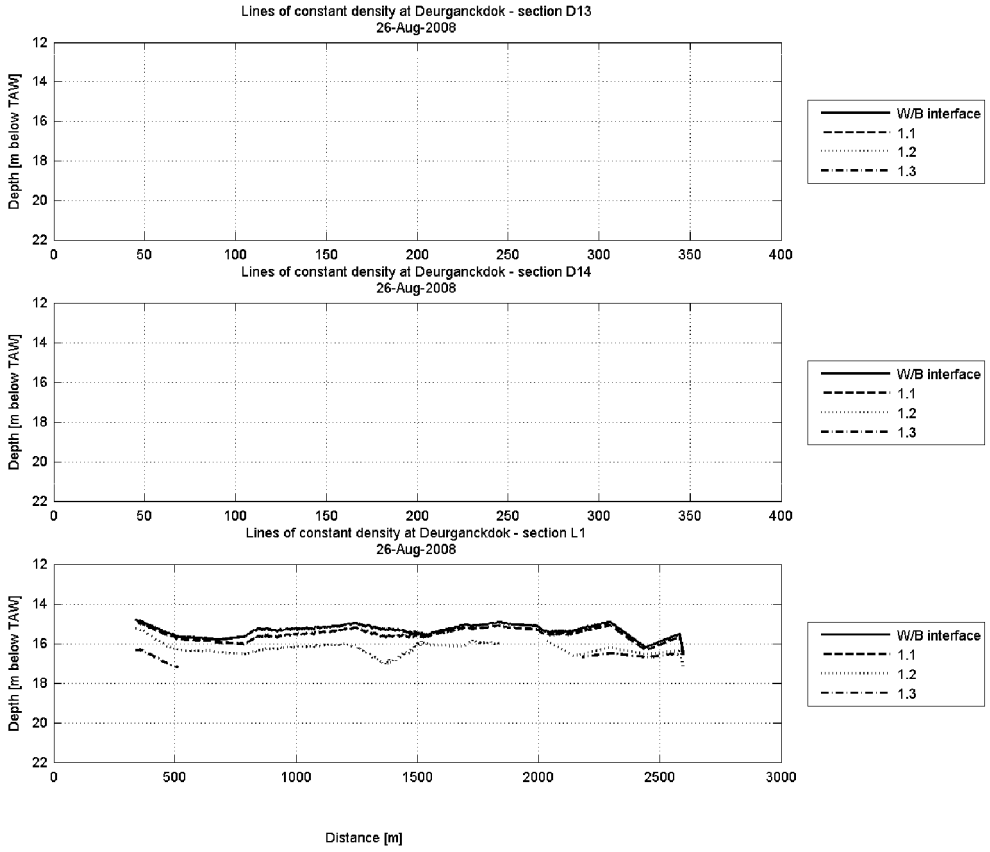
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC
In association with : wl | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

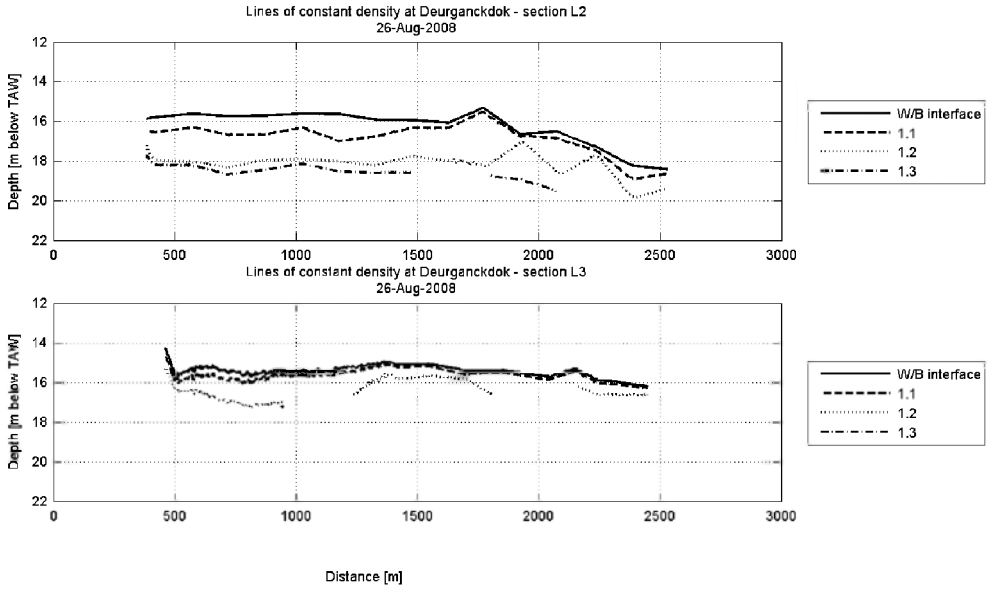
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC
In association with : wl | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD

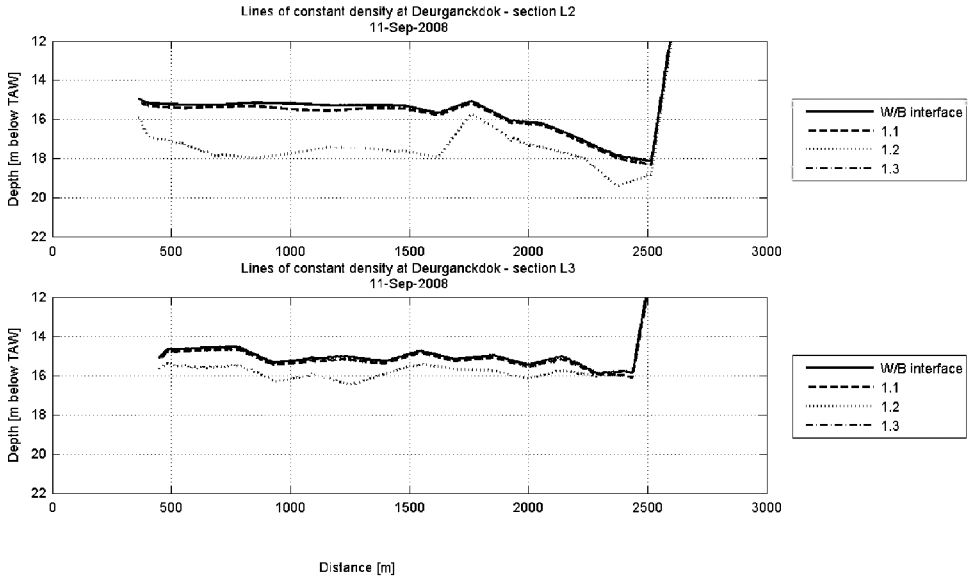


Data Processed by:
In association with :
I/RA/11283/08.077/MSA

E.3 Measurements September 11th, 2008

Long-term monitoring siltation Deurganckdok

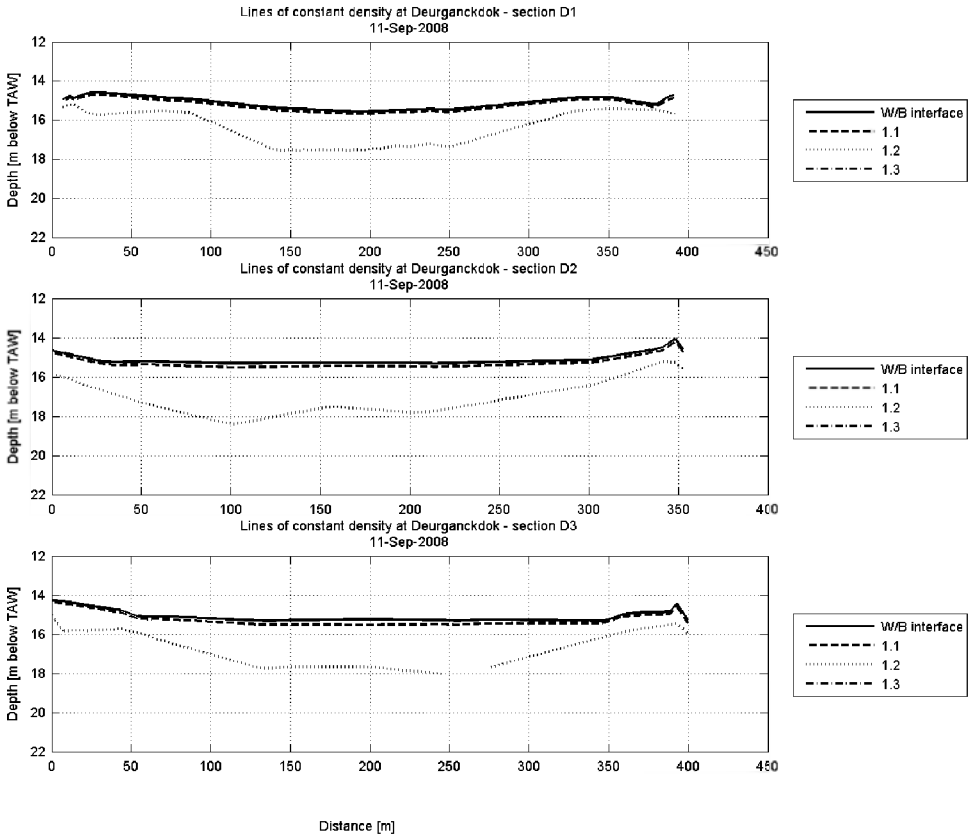
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC
In association with : wl | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD

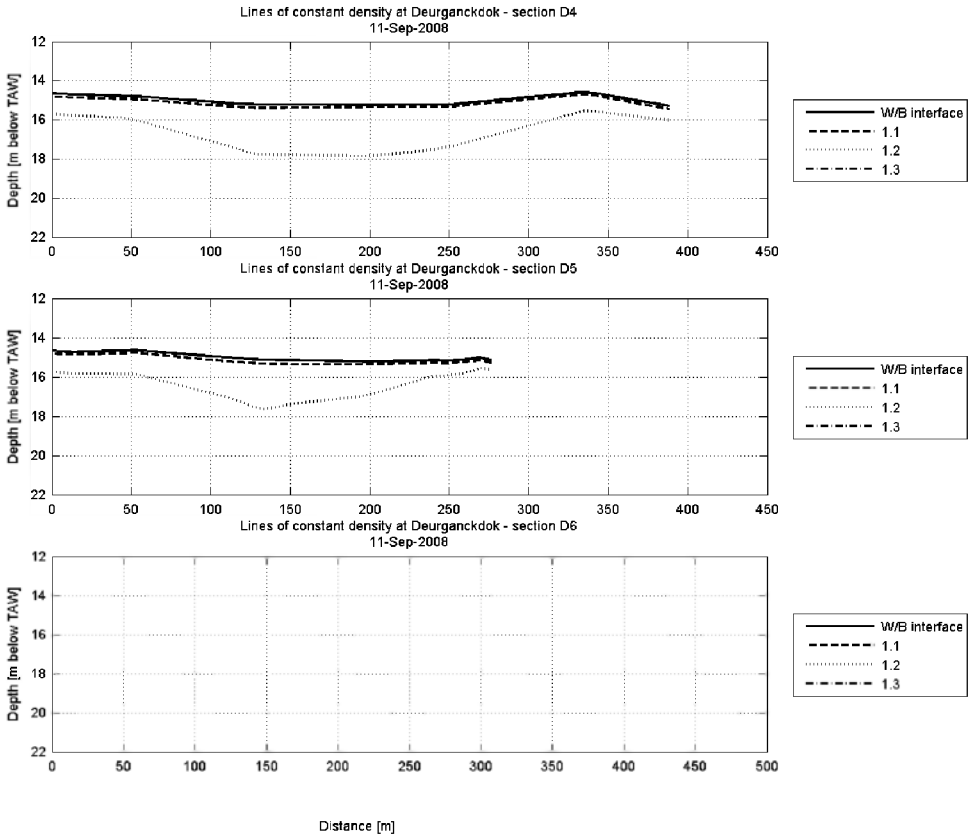


Data Processed by: IMDC
In association with : WL | delft hydraulics

I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

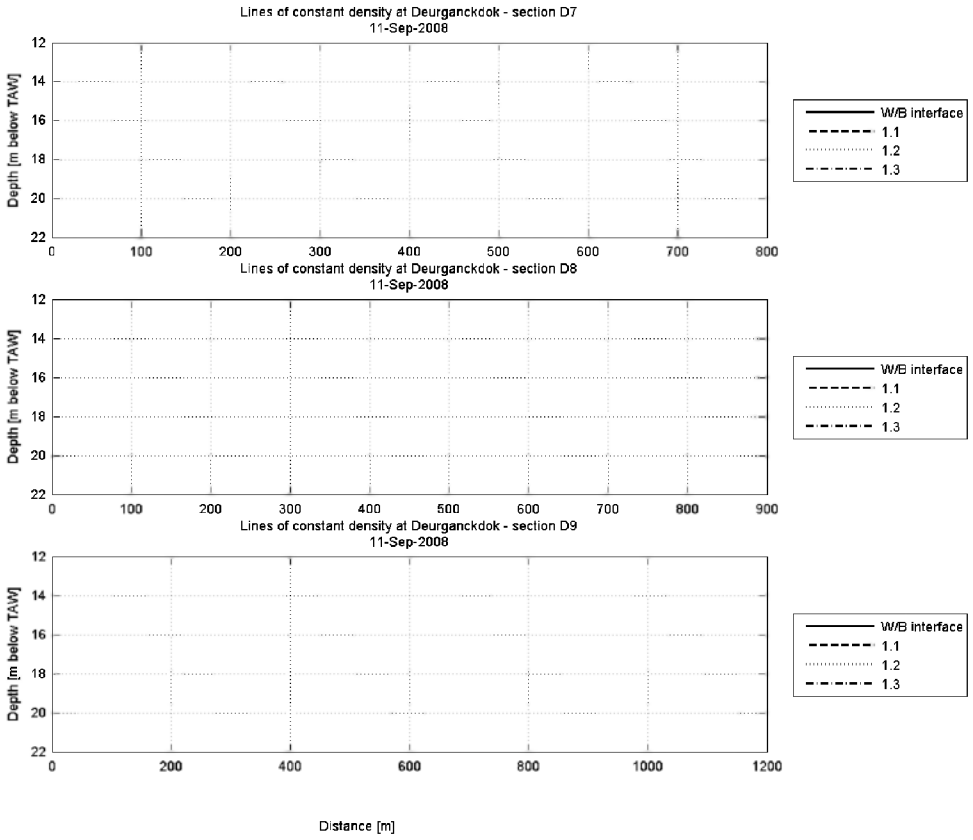
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC
In association with : wl | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD

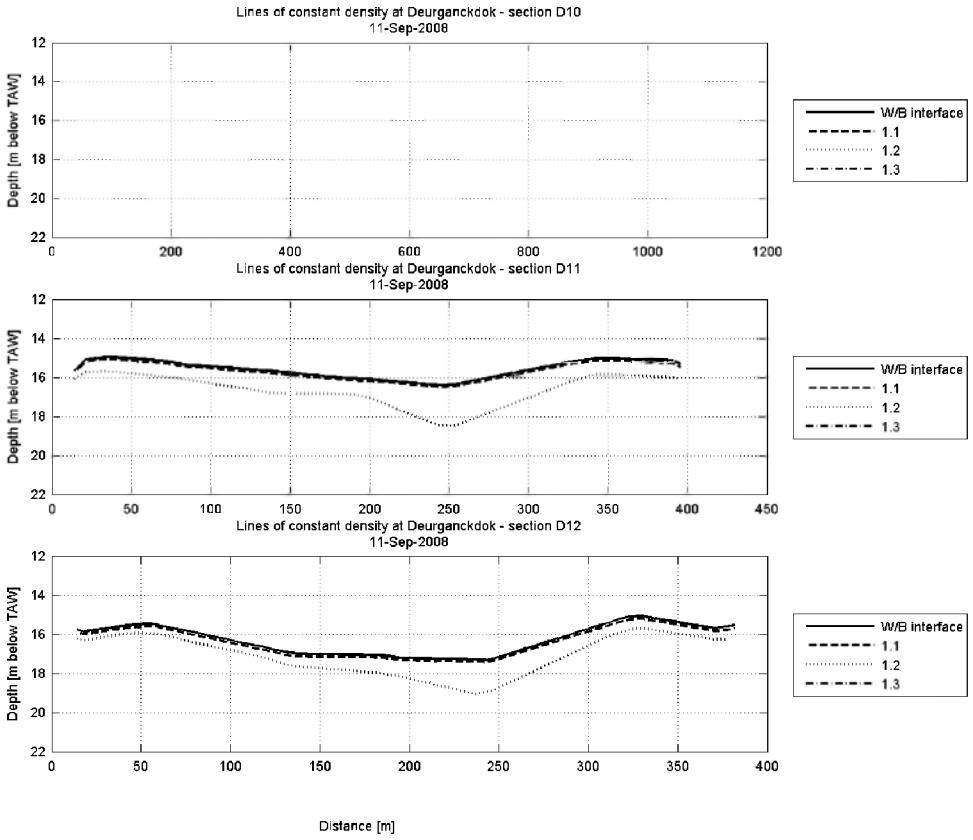


Data Processed by: IMDC
In association with : wl | delft hydraulics

I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

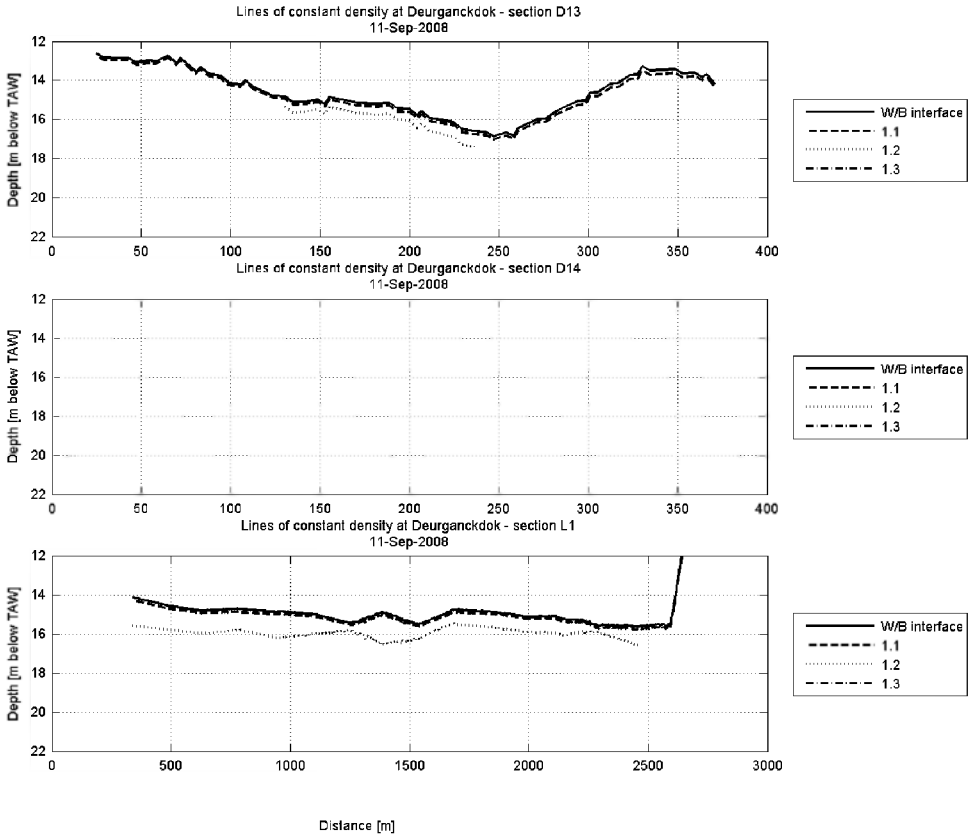
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC
In association with : wl | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC
In association with : wl | delft hydraulics

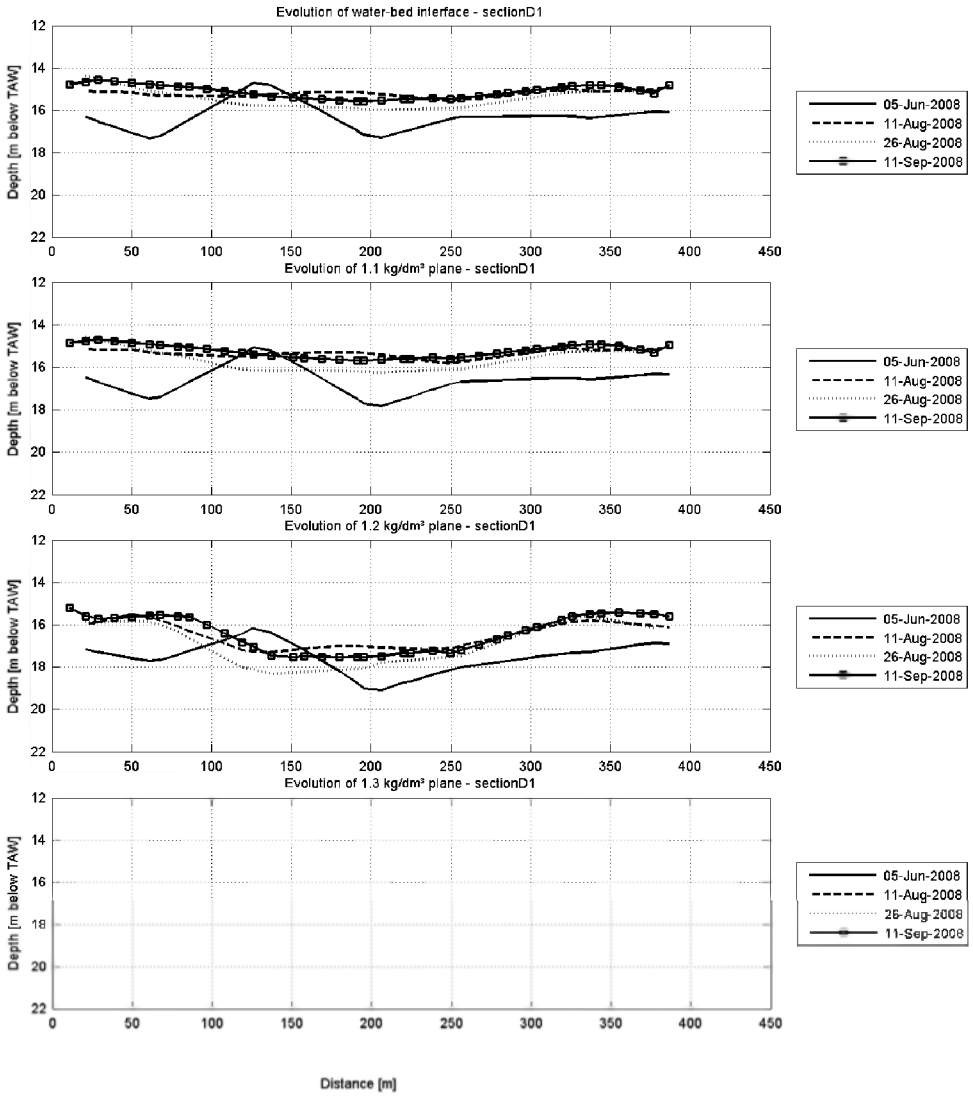
I/RA/11283/08.077/MSA

APPENDIX F.

DEPTH EVOLUTION OF PLANES OF CONSTANT DENSITY

Long-term monitoring siltation Deurganckdok

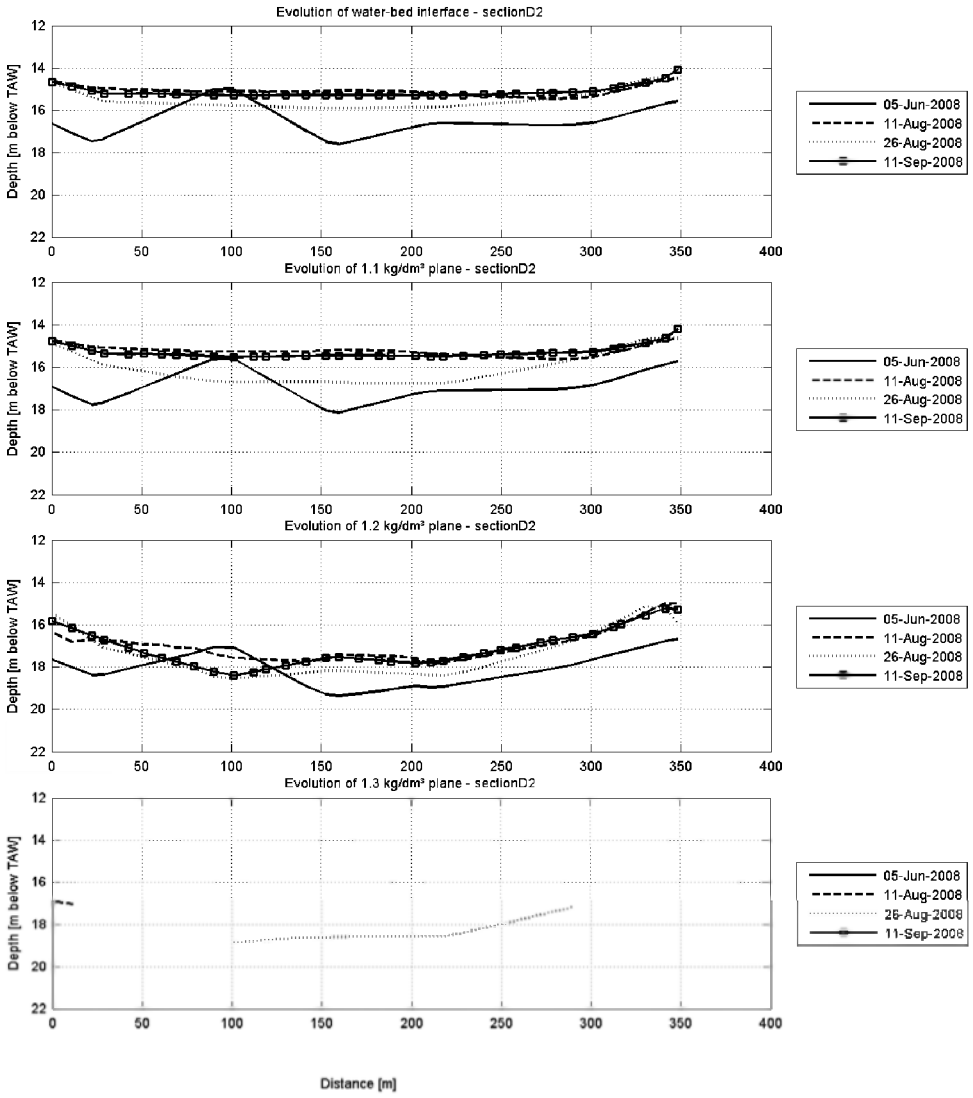
Evolution of planes of constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC
In association with : wl | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

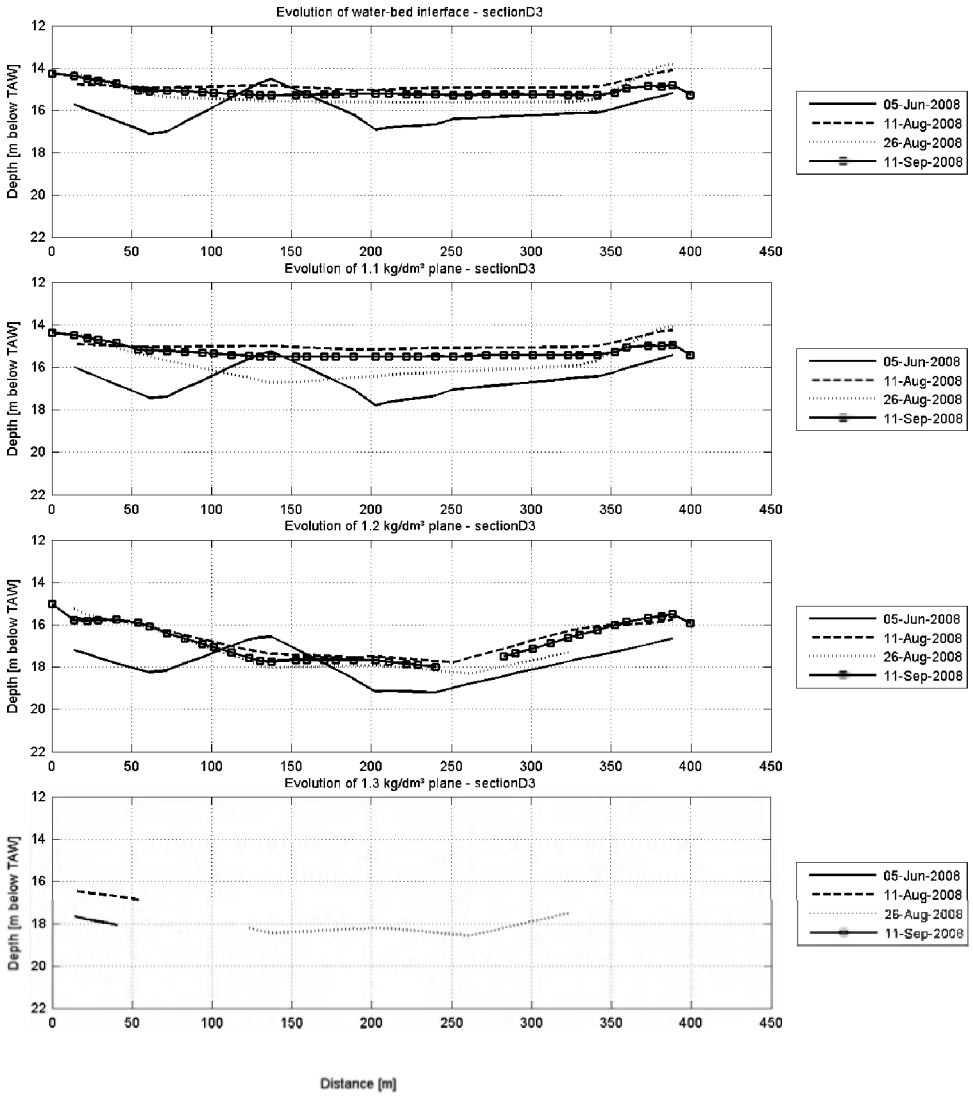
Evolution of planes of constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC
In association with : wl | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

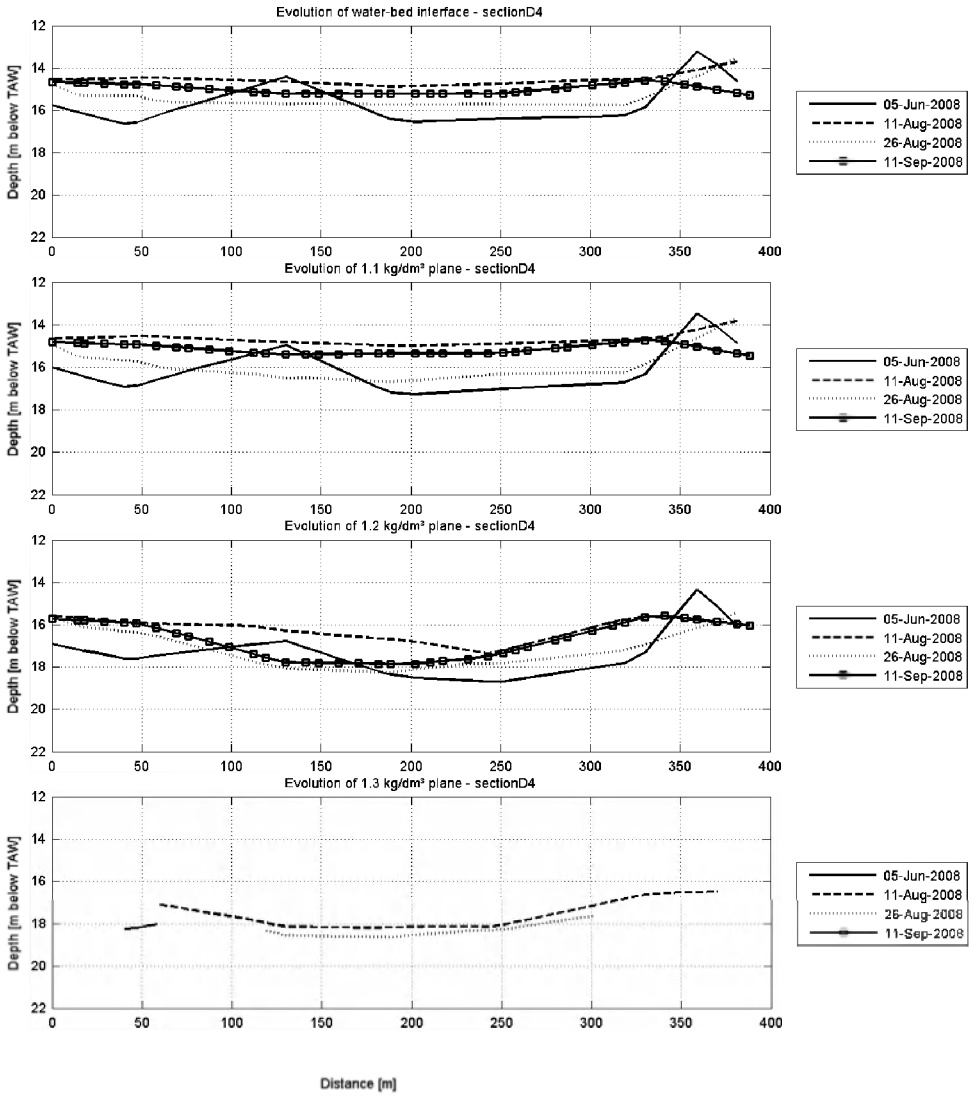
Evolution of planes of constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

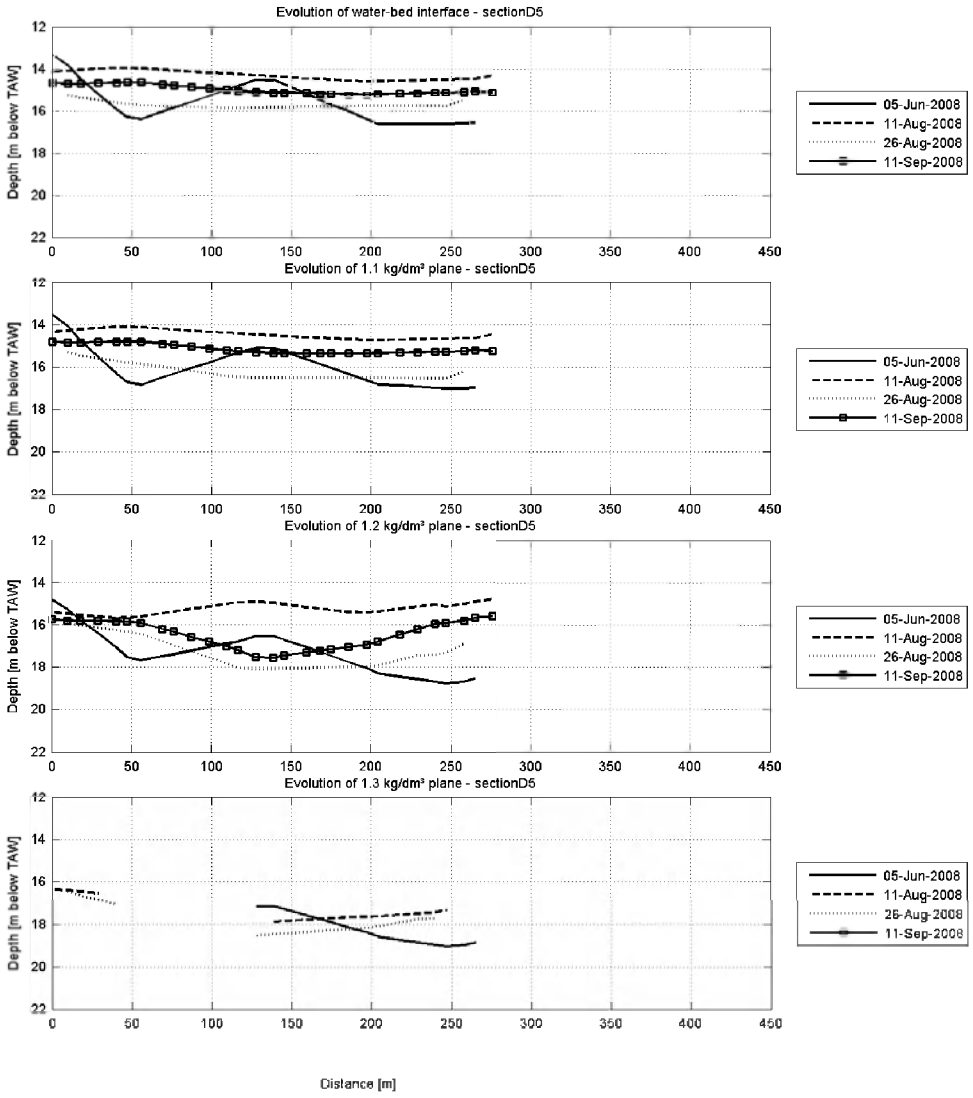
Evolution of planes of constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

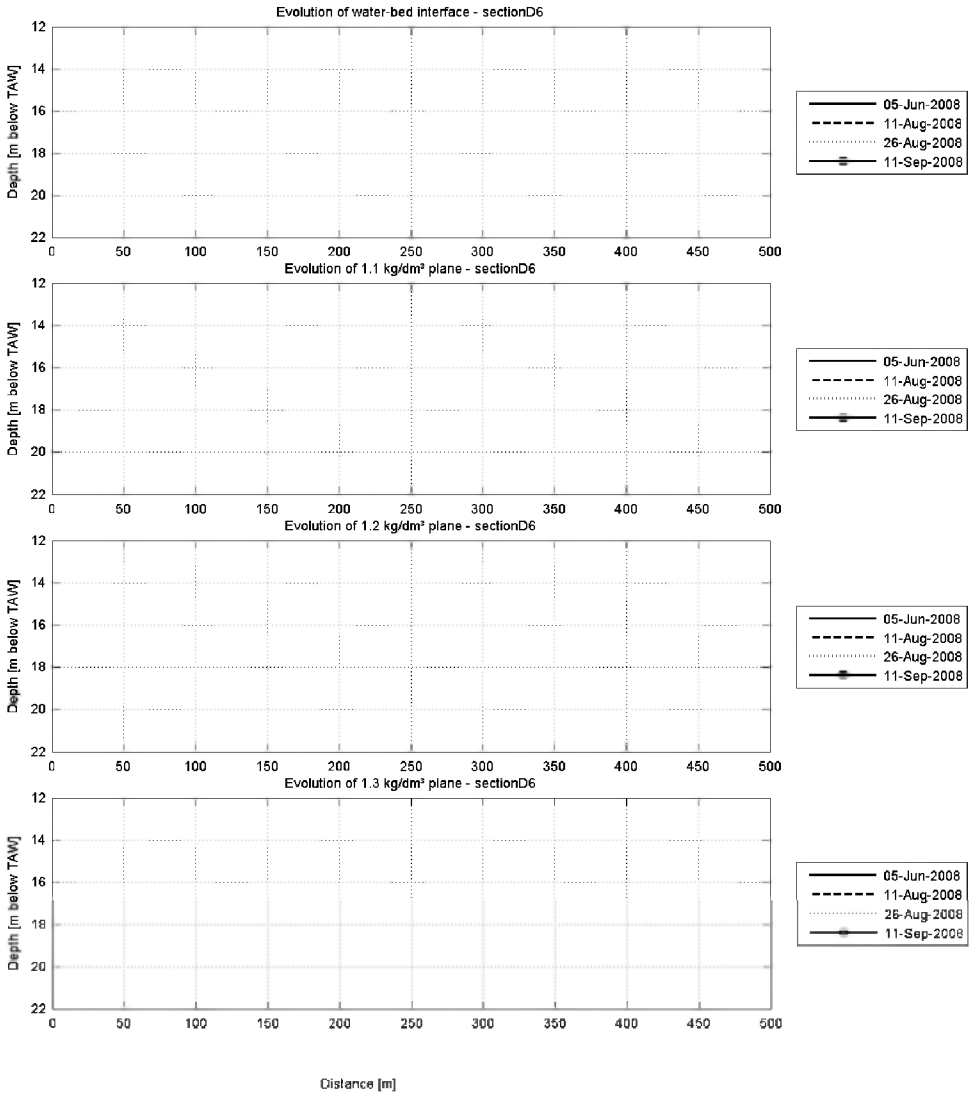
Evolution of planes of constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

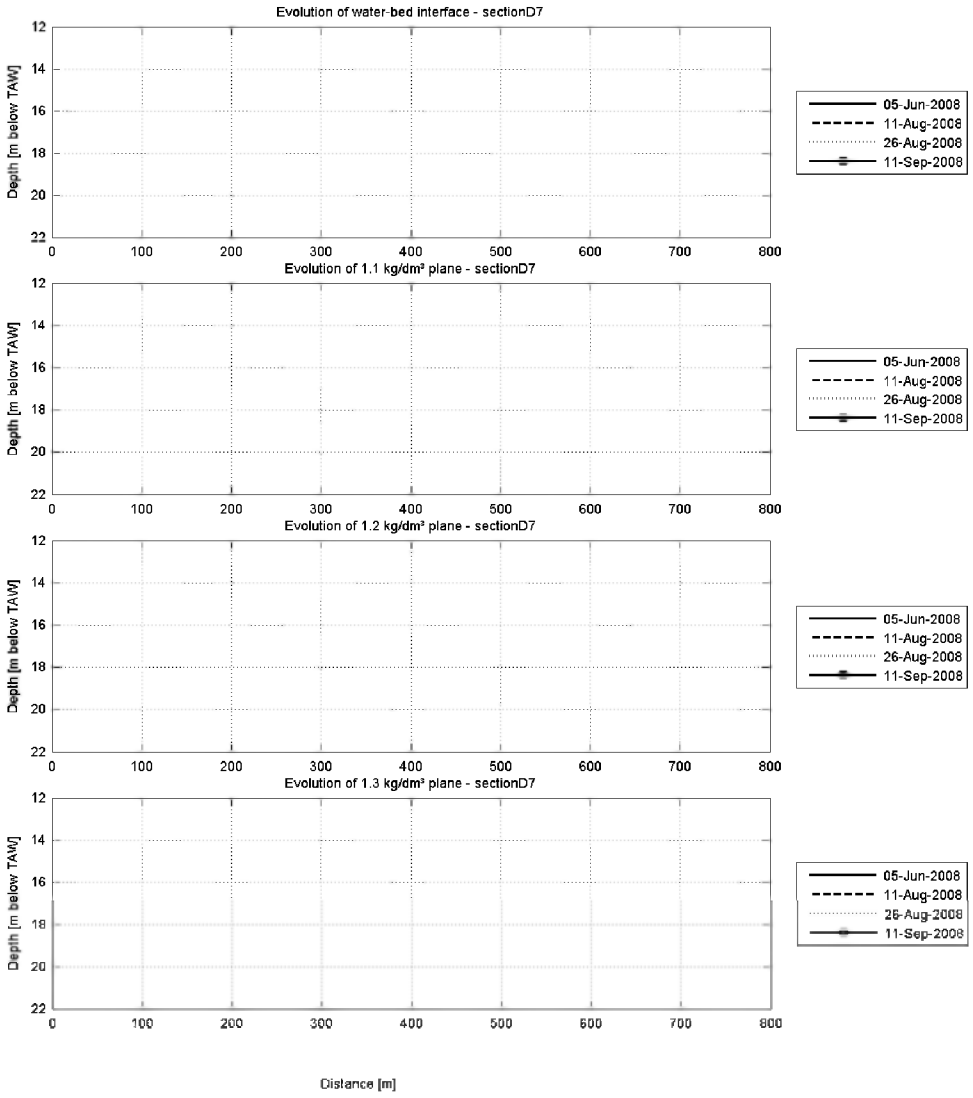
Evolution of planes of constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

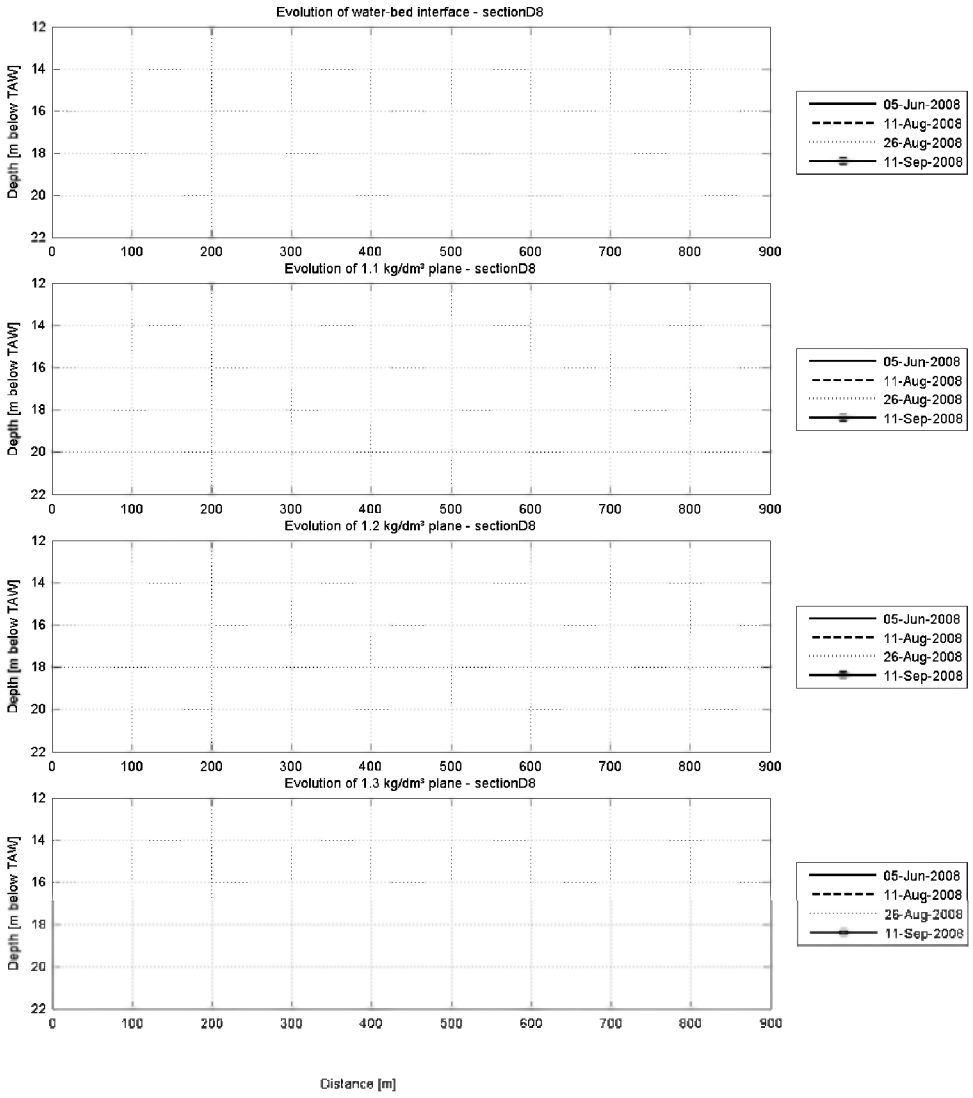
Evolution of planes of constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

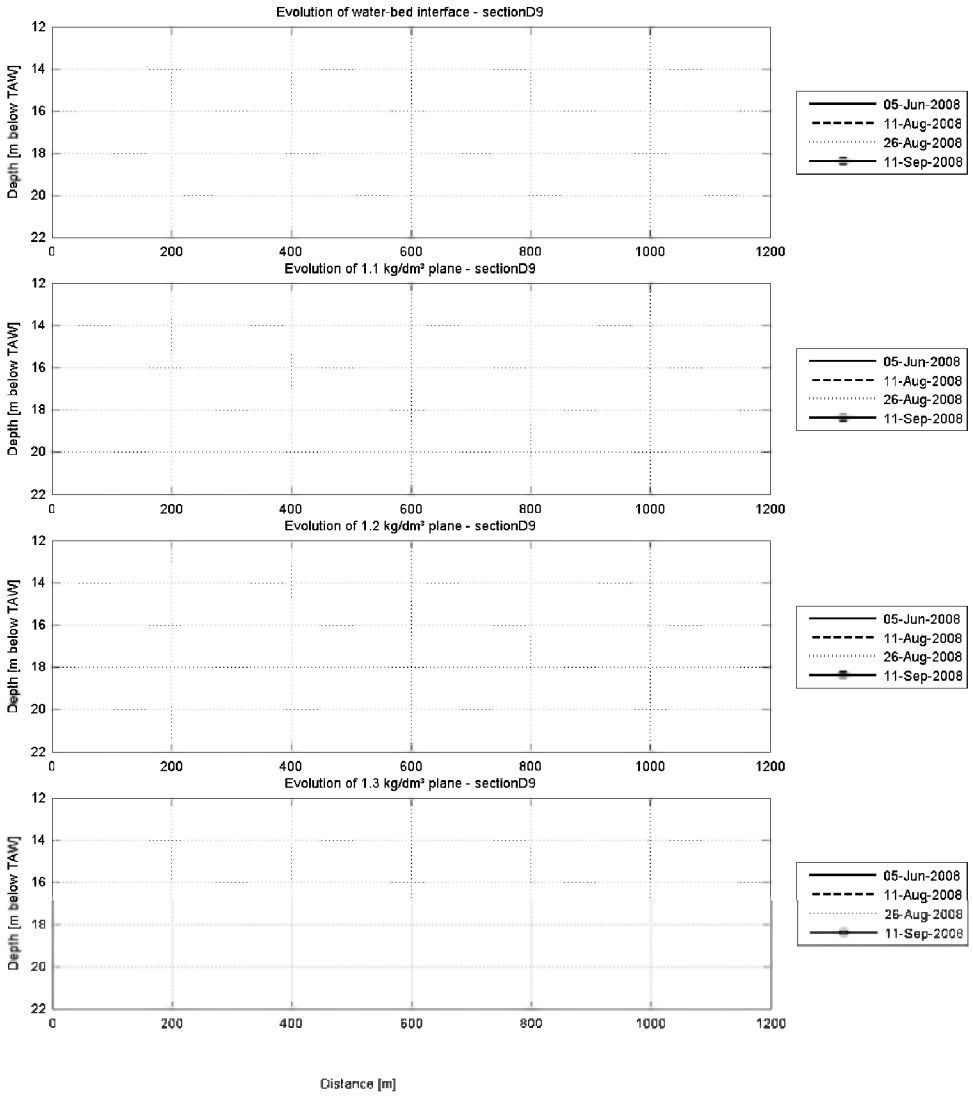
Evolution of planes of constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

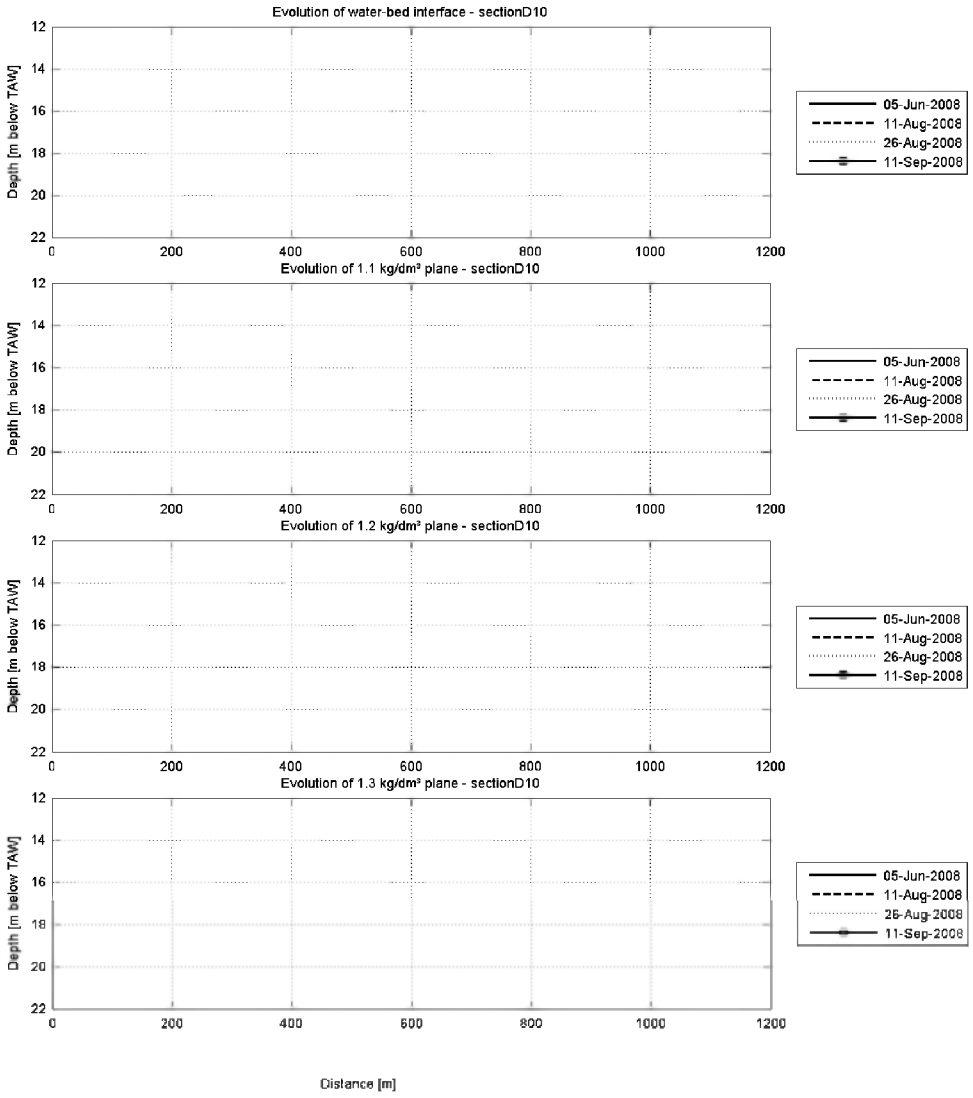
Evolution of planes of constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

Evolution of planes of constant density	Equipment(s): NaviTracker
	Location: DGD

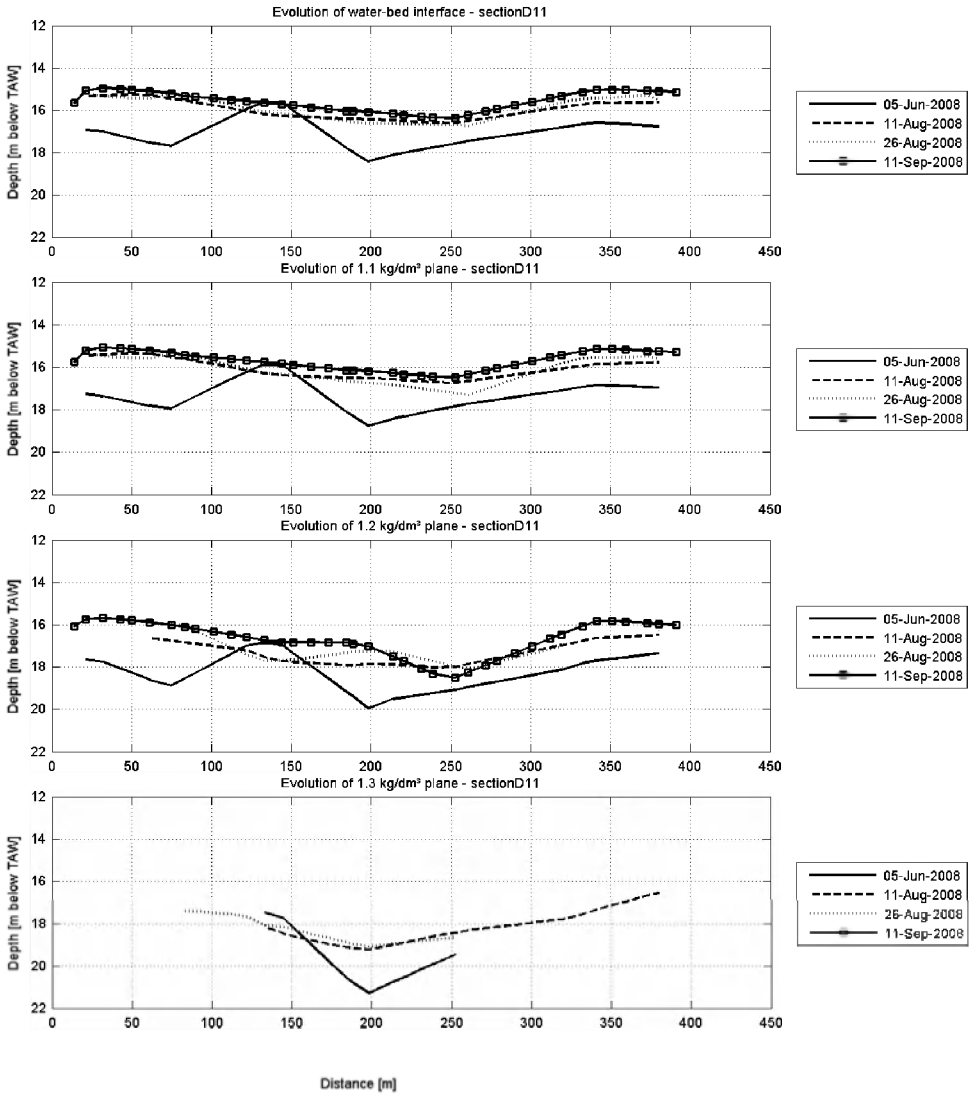


Data Processed by: IMDC
In association with : WL | delft hydraulics

I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

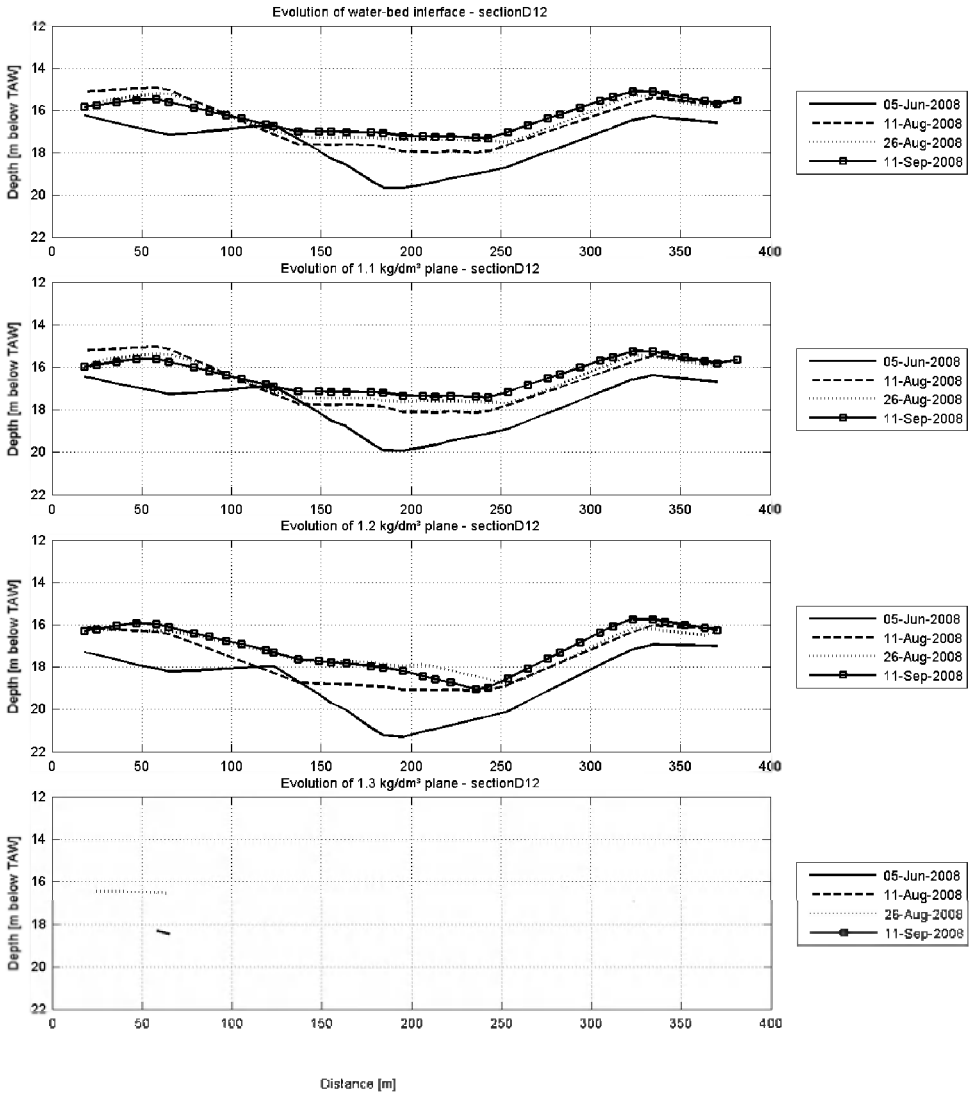
Evolution of planes of constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC
In association with : wl | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

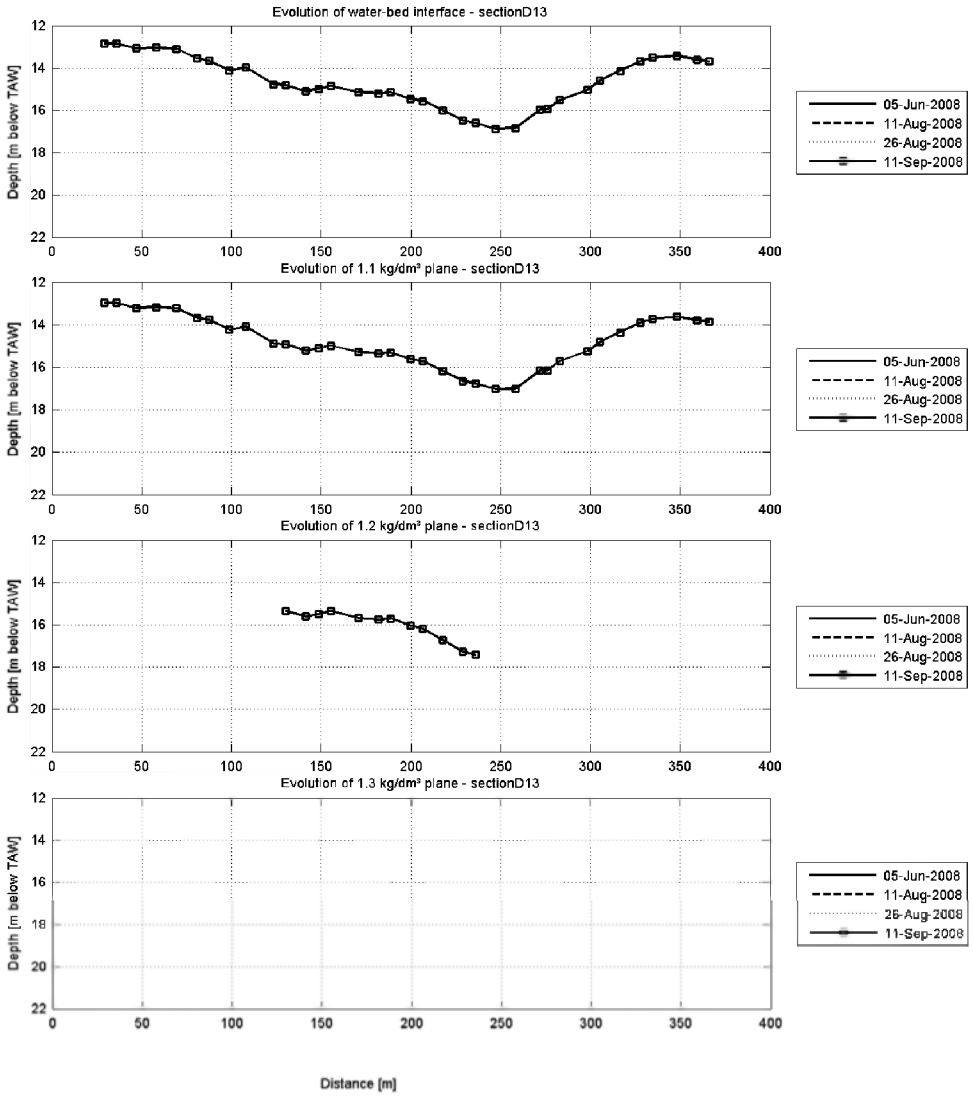
Evolution of planes of constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

Evolution of planes of constant density	Equipment(s): NaviTracker
	Location: DGD

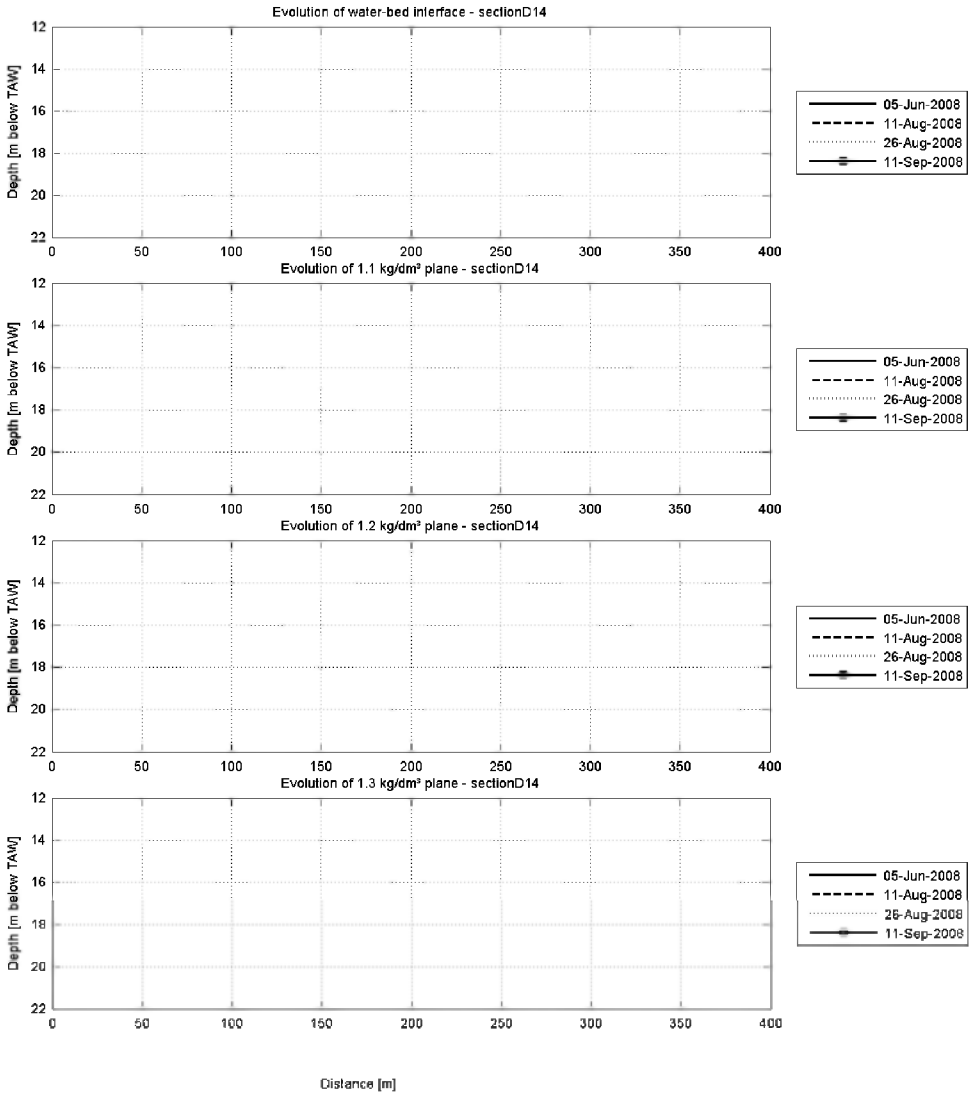


Data Processed by: IMDC
In association with : WL | delft hydraulics

I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

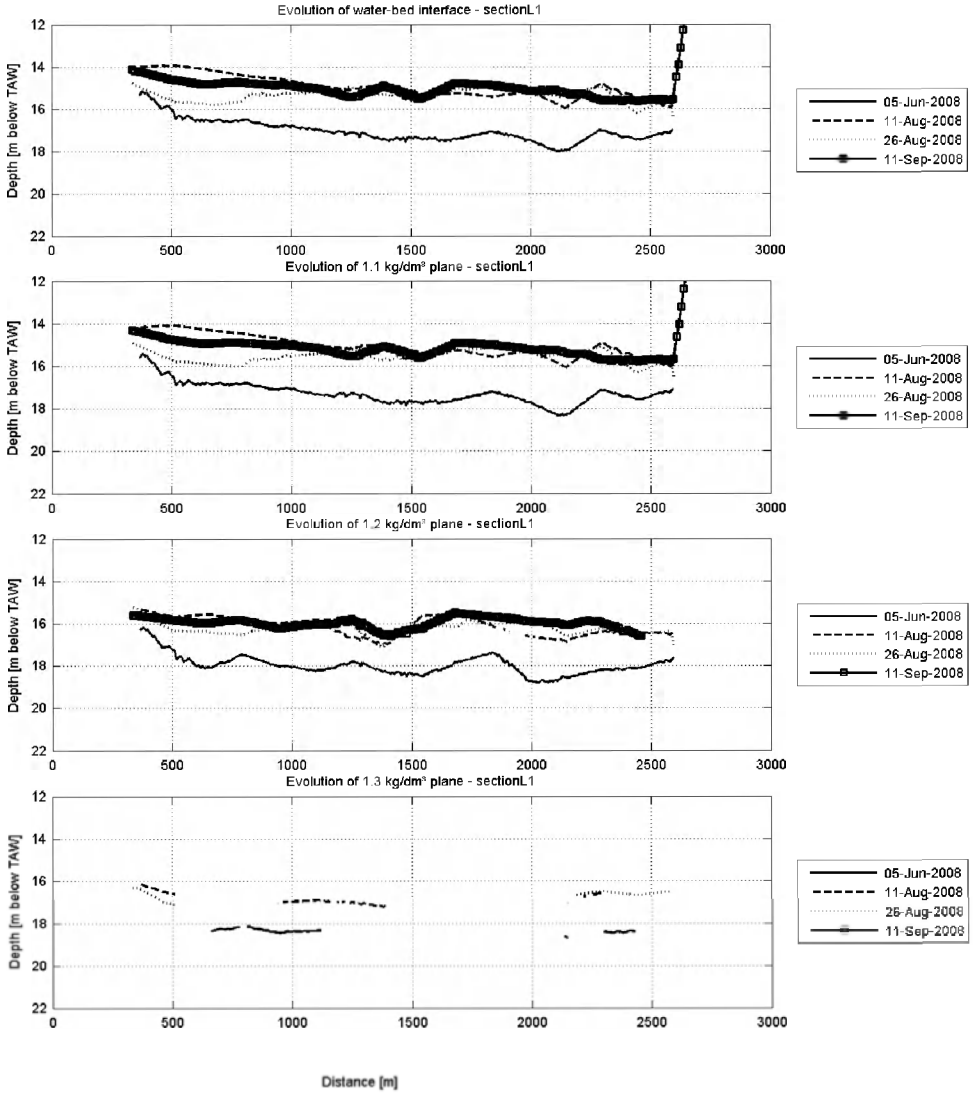
Evolution of planes of constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

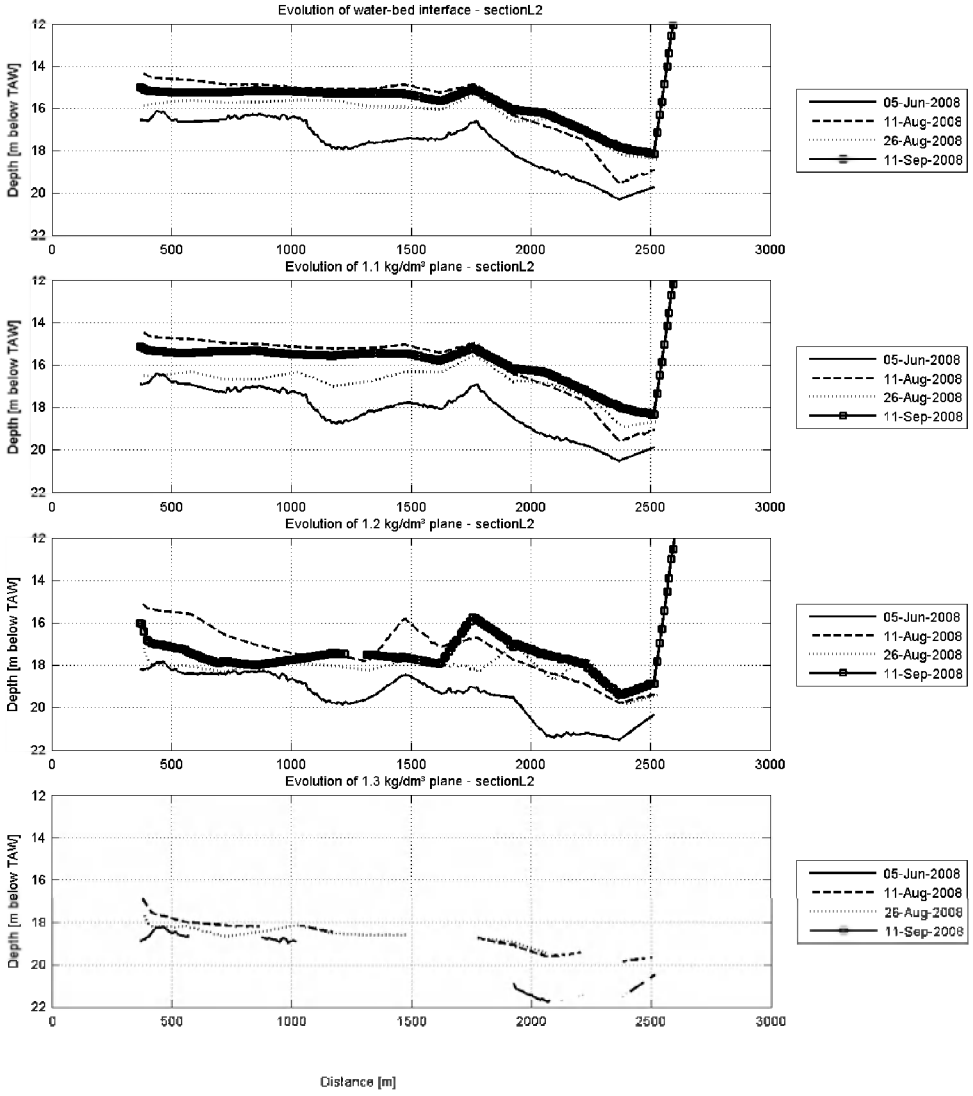
Evolution of planes of constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

Evolution of planes of constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC
In association with : WL | delft hydraulics

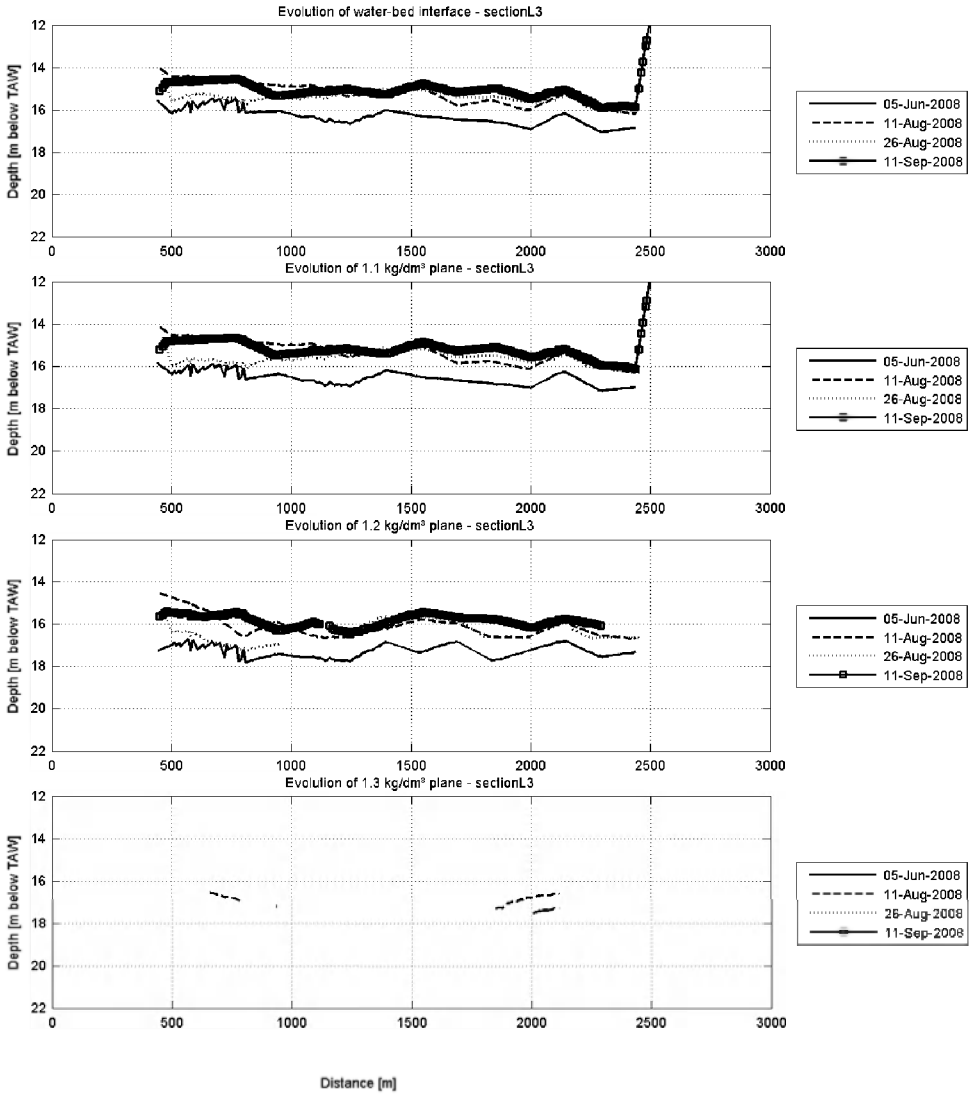
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

Evolution of planes of constant density

Equipment(s):
NaviTracker

Location:
DGD



Data Processed by: IMDC
In association with : WL | delft hydraulics

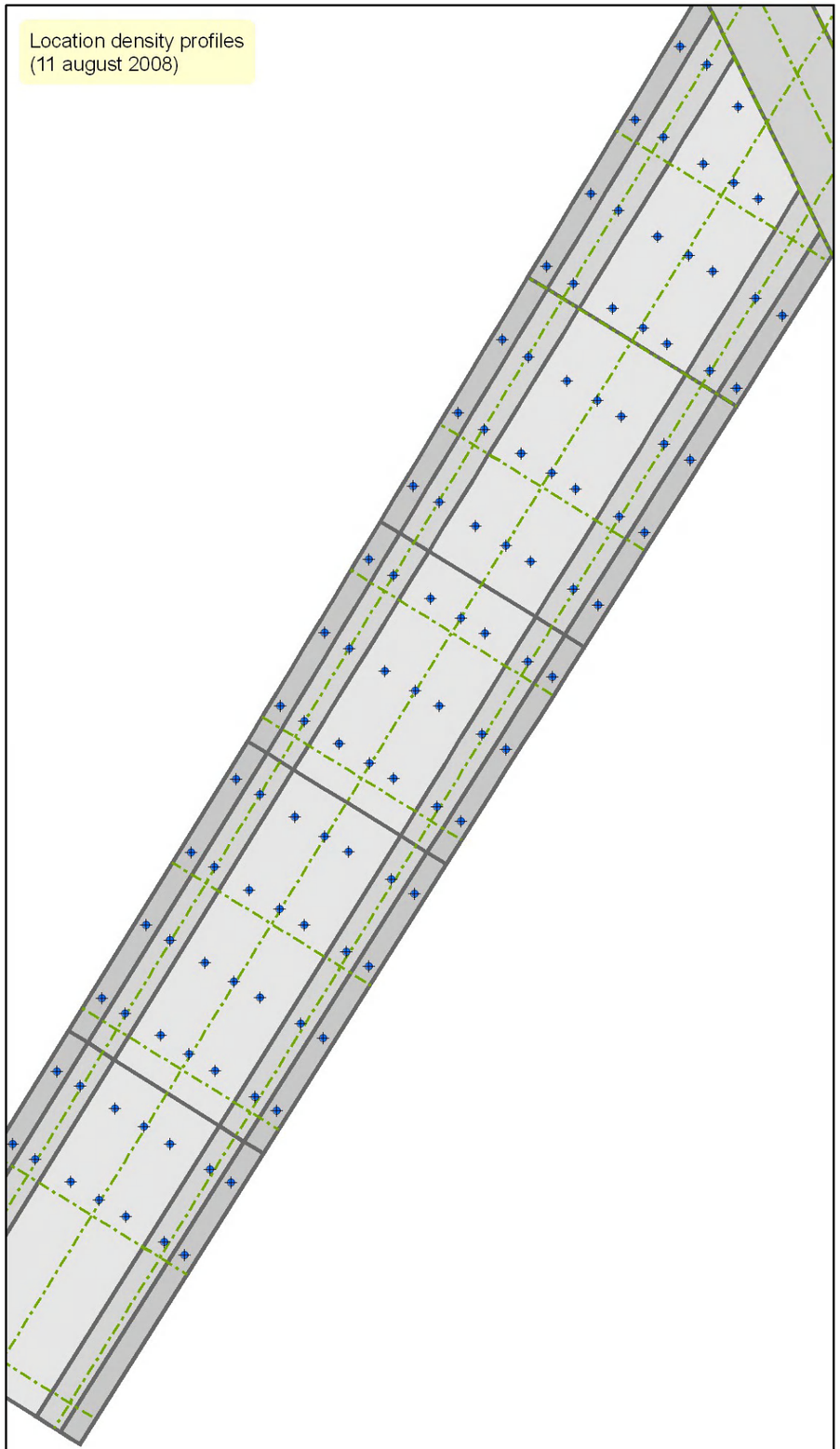
I/RA/11283/08.077/MSA

APPENDIX G.

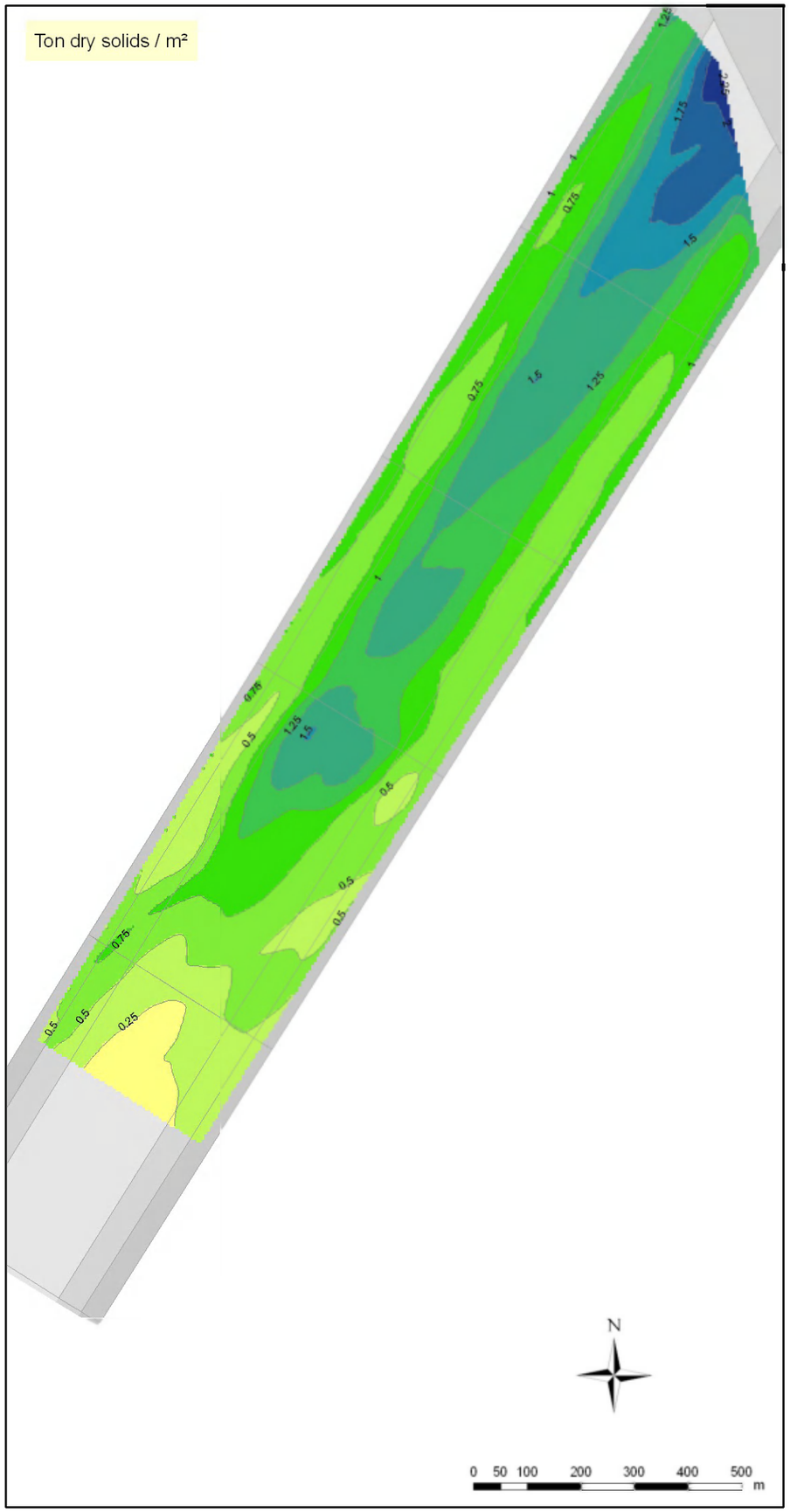
SEDIMENT MASS DISTRIBUTION IN

DEURGANCKDOK

Location density profiles
(11 august 2008)



Ton dry solids / m²



Long-term measurements
Deurganckdok
Evolution & analysis of siltation

Bestek nr 16EB/05/04

DENSITY MEASUREMENTS
Ton dry solids per m²
11 august 2008

Map 1 Schaal 1/10.000

Created: 19/02/2009 I/DR/11283/09.000/JUR
Version nr. 1

IMDC
International Marine & Dredging Consultants
Coveliersstraat 15
2600 Antwerpen
Tel +32 3 270 92 20
Fax +32 3 235 67 11
E-mail: info@imdc.be

Legend

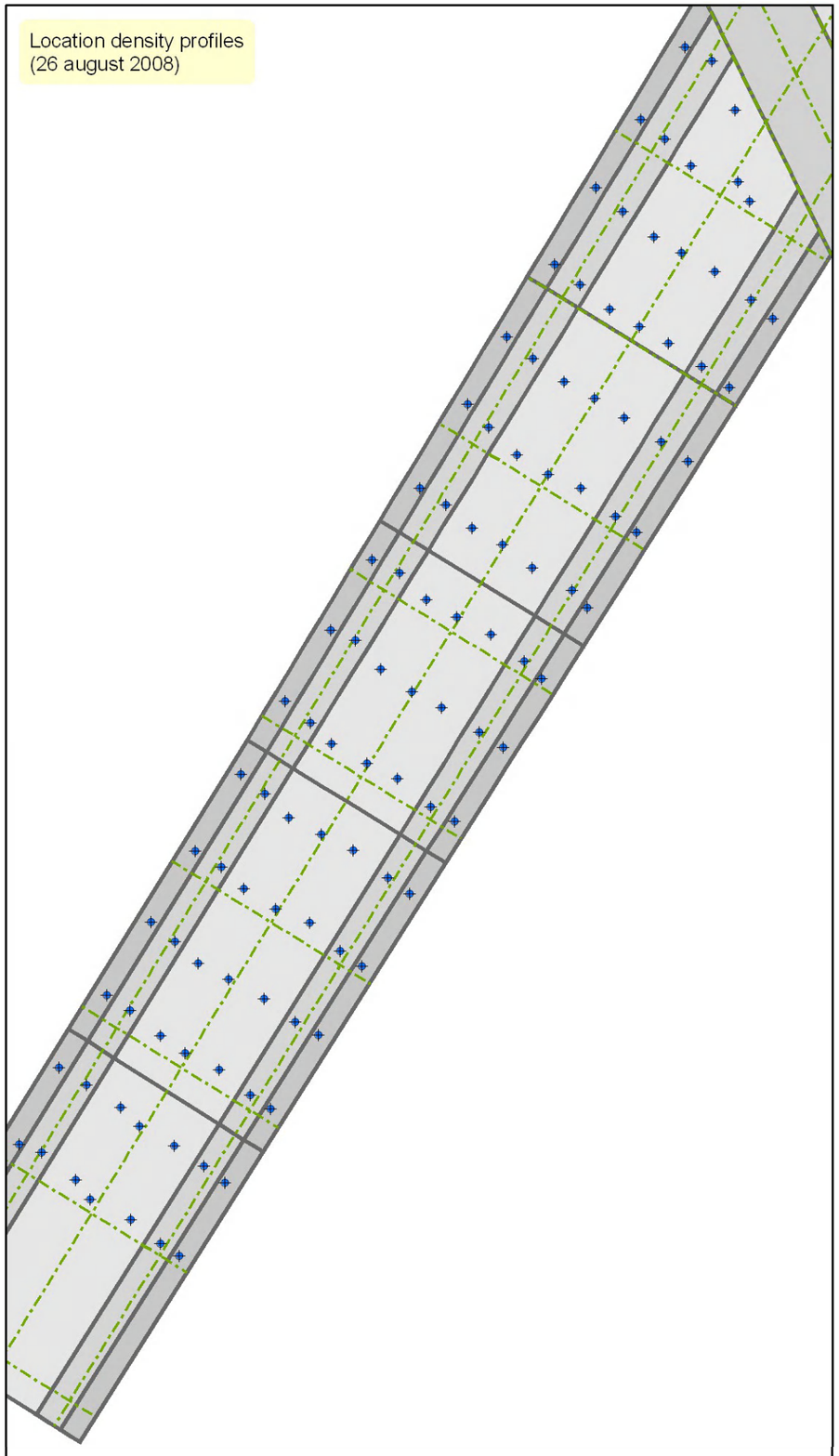
Ton dry solids per m²

- 0 - 0.25
- 0.26 - 0.50
- 0.51 - 0.75
- 0.76 - 1.00
- 1.01 - 1.25
- 1.26 - 1.50
- 1.51 - 1.75
- 1.76 - 2.00
- 2.01 - 2.25
- 2.26 - 2.50

- 11-Aug-2008_XY.txt Events
- Transects
- (Site) zones

W:\11283\GIS\project\rapport 1-21\TDS\measurement-09\K1_TDS09_110808.mxd

Location density profiles
(26 august 2008)



Ton dry solids / m²



Long-term measurements
Deurganckdok
Evolution & analysis of siltation

Bestek nr 16EB/05/04

DENSITY MEASUREMENTS
Ton dry solids per m²
26 august 2008

Map 1 Schaal 1/10.000

Created: 19/02/2009 I/DR/11283/09.000/JUR
Version nr. 1

IMDC
International Marine & Dredging Consultants
Coveliersstraat 15
2600 Antwerpen
Tel +32 3 270 92 20
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E-mail: info@imdc.be

Legend

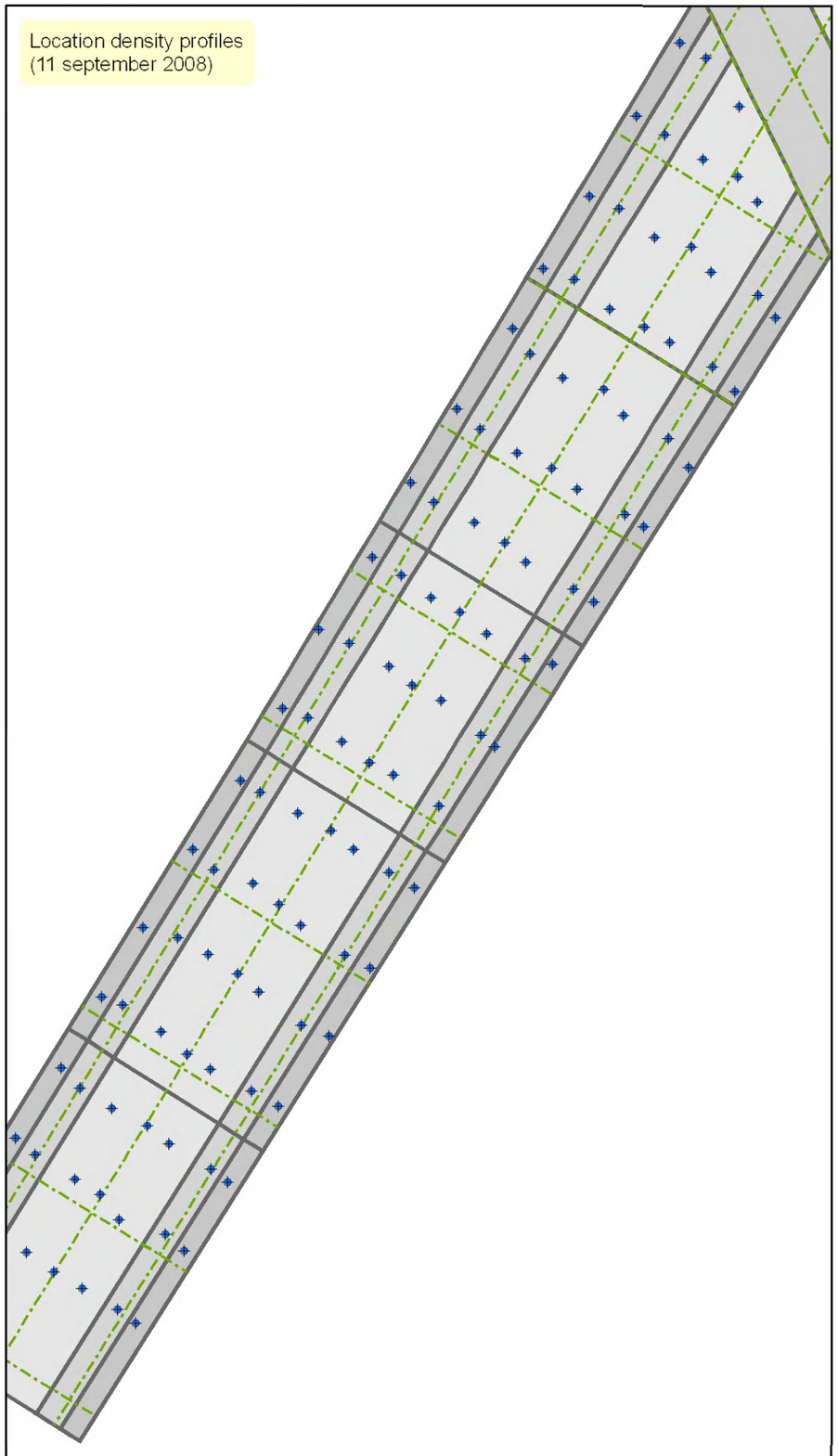
Ton dry solids per m²

- 0 - 0.25
- 0.26 - 0.50
- 0.51 - 0.75
- 0.76 - 1.00
- 1.01 - 1.25
- 1.26 - 1.50
- 1.51 - 1.75
- 1.76 - 2.00
- 2.01 - 2.25
- 2.26 - 2.50

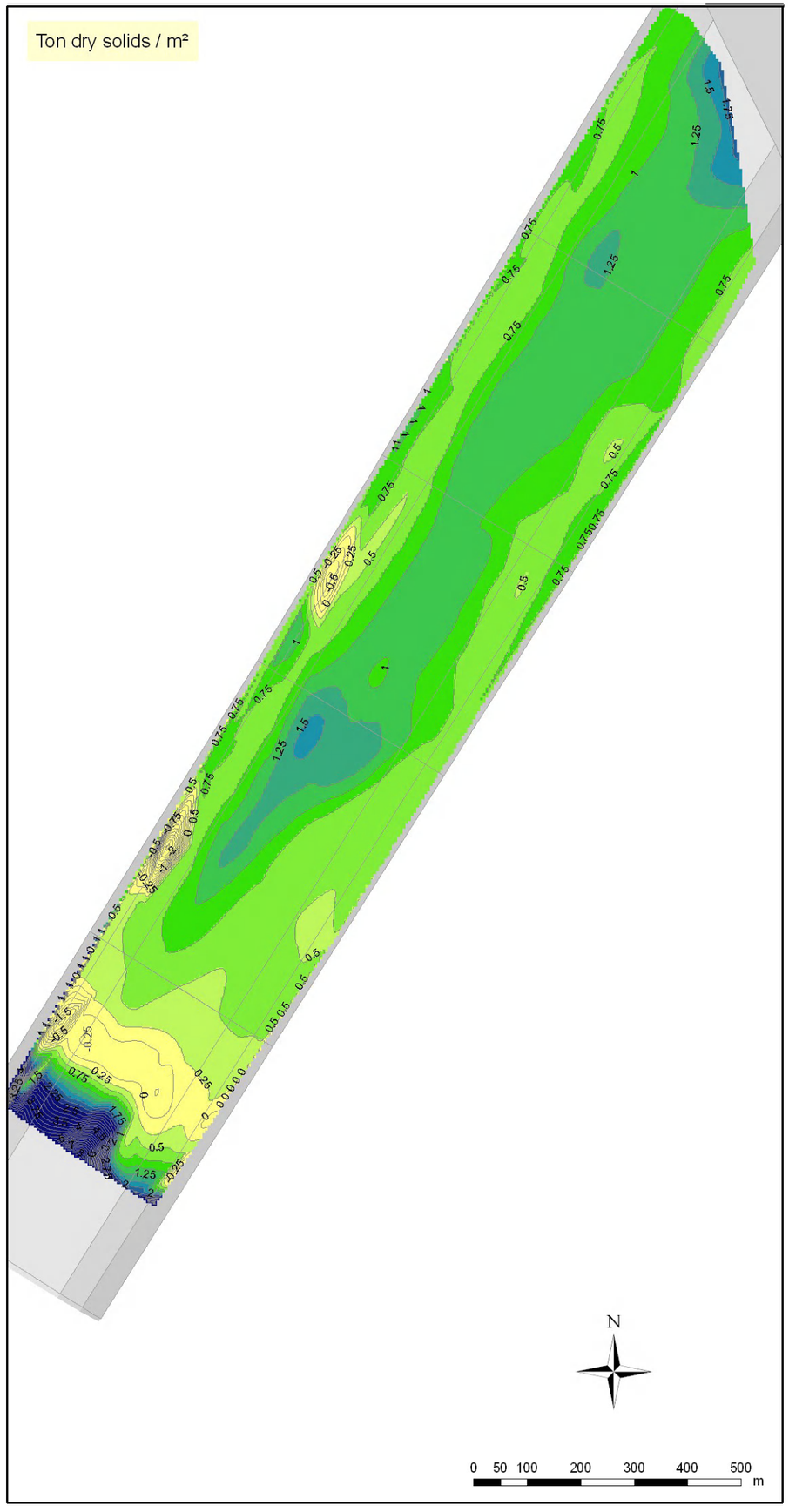
- 26-Aug-2008_XY.txt Events
- Transects
- (Site) zones

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Location density profiles
(11 september 2008)



Ton dry solids / m²



Long-term measurements
Deurganckdok
Evolution & analysis of siltation

Bestek nr 16EB/05/04

DENSITY MEASUREMENTS
Ton dry solids per m²
11 september 2008

Map 1 Schaal 1/10.000

Created: 19/02/2009 I/DR/11283/09.000/JUR
Version nr. 1

IMDC
Immerse, Marine & Dredging Consultants
Coveliersstraat 15
2600 Antwerpen
Tel +32 3 270 92 20
Fax +32 3 235 67 11
E-mail: info@imdc.be

Legend

Ton dry solids per m²

- 0 - 0.25
- 0.26 - 0.50
- 0.51 - 0.75
- 0.76 - 1.00
- 1.01 - 1.25
- 1.26 - 1.50
- 1.51 - 1.75
- 1.76 - 2.00
- 2.01 - 2.25
- 2.26 - 2.50

11-Sep-2008_XY.txt Events
Transects
(Site) zones

W:\11283\GIS\project\rapport 1-21\TDS\measurement-11\K1_TDS11_110908.mxd

APPENDIX H.

AVERAGE MASS GROWTH AND GROWTH RATE

H.1 Tabular results

**Measured Mass (TDS/m²)

	05-Jun-08	11-Aug-08	26-Aug-08	11-Sep-08
1	-	-	-	-
2	-	-	-	-
3a	1.00	1.62	0.88	1.20
3b	0.87	1.24	0.83	1.07
3c	0.86	1.12	0.82	1.01
3d	0.85	0.86	0.82	0.93
3e	-	-	-	0.99
4Na	0.70	0.98	0.60	0.80
4Nb	0.50	0.74	0.59	0.69
4Nc	0.51	0.68	0.59	0.54
4Nd	0.39	0.55	0.60	0.43
4Ne	-	-	-	0.83
4Za	0.60	0.97	0.56	0.92
4Zb	0.53	0.69	0.52	0.74
4Zc	0.50	0.62	0.62	0.68
4Zd	0.42	0.54	0.52	0.57
4Ze	-	-	-	0.55
5Na	-	-	-	0.76
5Nb	0.52	0.81	-	0.79
5Nc	0.46	0.74	0.84	0.52
5Nd	0.23	0.51	-	0.20
5Ne	-	-	-	-
5Za	-	-	-	-
5Zb	0.73	0.83	0.87	0.77
5Zc	0.44	0.68	0.73	0.71
5Zd	0.23	0.51	-	0.54
5Ze	-	-	-	-

Trench area mean	0.89	1.18	0.83	1.04

**Cumulative dredged mass in covered area (TDS)

	05-Jun-08	11-Aug-08	26-Aug-08	11-Sep-08
1	0	0	39	39
2	0	0	829	829
3a	0	0	140275	140275
3b	0	0	110873	110873
3c	0	0	66424	66424
3d	0	0	17267	17267
3e	0	0	0	0
4Na	0	0	17820	17820
4Nb	0	0	8380	8380
4Nc	0	0	1670	1670
4Nd	0	0	75	75
4Ne	0	0	0	0
4Za	0	0	10597	10597
4Zb	0	0	7185	7185
4Zc	0	0	1289	1289
4Zd	0	0	13	13
4Ze	0	0	0	0
5Na	0	0	0	0
5Nb	0	0	0	0
5Nc	0	0	0	0
5Nd	0	0	0	0
5Ne	0	0	0	0
5Za	0	0	0	0
5Zb	0	0	0	0
5Zc	0	0	0	0
5Zd	0	0	0	0
5Ze	0	0	0	0

Total	0	0	382738	382738

**Total cumulative mass(TDS/m²)

	05-Jun-08	11-Aug-08	26-Aug-08	11-Sep-08
1	-	-	-	-
2	-	-	-	-
3a	1.00	1.62	2.30	2.62
3b	0.87	1.24	1.84	2.08
3c	0.86	1.12	1.49	1.68
3d	0.85	0.86	0.95	1.06
3e	-	-	-	0.99
4Na	0.70	0.98	1.09	1.29
4Nb	0.50	0.74	0.86	0.96
4Nc	0.51	0.68	0.66	0.60
4Nd	0.39	0.55	0.60	0.43
4Ne	-	-	-	0.83
4Za	0.60	0.97	1.00	1.36
4Zb	0.53	0.69	0.75	0.97
4Zc	0.50	0.62	0.67	0.73
4Zd	0.42	0.54	0.52	0.57
4Ze	-	-	-	0.55
5Na	-	-	-	0.76
5Nb	0.52	0.81	-	0.79
5Nc	0.46	0.74	0.84	0.52
5Nd	0.23	0.51	-	0.20
5Ne	-	-	-	-
5Za	-	-	-	-
5Zb	0.73	0.83	0.87	0.77
5Zc	0.44	0.68	0.73	0.71
5Zd	0.23	0.51	-	0.54
5Ze	-	-	-	-

Trench area mean	0.89	1.18	1.60	1.81

**Growth rate (kg/m²/day)

	05-Jun-2008 / 11-Aug-2008	11-Aug-2008 / 26-Aug-2008	26-Aug-2008 / 11-Sept-2008
1	-	-	-
2	-	-	-
3a	9.19	45.39	20.18
3b	5.54	39.91	14.94
3c	3.83	24.65	11.76
3d	0.22	5.98	6.95
3e	-	-	-
4Na	4.22	7.27	12.41
4Nb	3.63	7.55	6.41
4Nc	2.67	-1.81	-3.56
4Nd	2.36	3.52	-10.65
4Ne	-	-	-
4Za	5.57	1.99	22.55
4Zb	2.42	3.87	13.56
4Zc	1.88	3.21	3.30
4Zd	1.82	-1.69	3.53
4Ze	-	-	-
5Na	-	-	-
5Nb	4.39	-	-
5Nc	4.15	6.38	-20.10
5Nd	4.13	-	-
5Ne	-	-	-
5Za	-	-	-
5Zb	1.55	2.29	-5.96
5Zc	3.57	3.54	-1.02
5Zd	4.14	-	-
5Ze	-	-	-

Trench area mean	4.39	27.59	13.02

**Covered Area

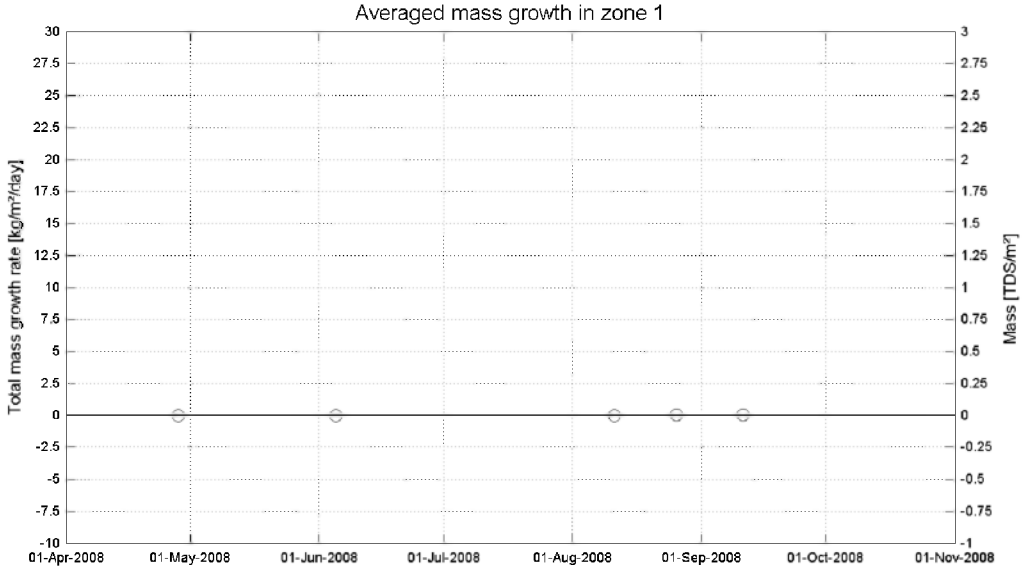
	05-Jun-08		11-Aug-08		26-Aug-08		11-Sep-08	
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
1	0.00	0	0	0	0	0	0	0
2	0.00	0	0	0	0	0	0	0
3a	8.35	85	8.46	86	8.21	83	8.53	86
3b	10.99	100	10.99	100	10.99	100	10.99	100
3c	9.91	100	9.91	100	9.91	100	9.91	100
3d	13.06	100	13.06	100	13.06	100	13.06	100
3e	4.94	38	4.8	37	4.97	38	8.05	62
4Na	3.14	86	3.22	89	3.28	90	3.29	90
4Nb	3.12	100	3.12	100	3.12	100	3.12	100
4Nc	2.57	100	2.57	100	2.57	100	2.57	100
4Nd	3.28	100	3.28	100	3.28	100	3.28	100
4Ne	1.25	38	1.21	37	1.21	36	2.02	61
4Za	1.56	64	1.59	66	1.44	59	1.53	63
4Zb	3.12	100	3.12	100	3.12	100	3.12	100
4Zc	2.59	100	2.59	100	2.59	100	2.59	100
4Zd	3.23	100	3.23	100	3.23	100	3.23	100
4Ze	1.17	38	1.16	37	1.21	39	1.93	63
5Na	0.87	38	1	44	0.7	31	1.15	50
5Nb	1.13	57	1.11	55	0.91	46	1.37	69
5Nc	1.10	61	1.06	59	0.92	51	1.38	76
5Nd	1.32	55	1.31	55	1.16	49	1.54	65
5Ne	0.30	12	0.42	17	0.3	12	0.69	29
5Za	0.38	29	0.44	33	0.28	21	0.43	33
5Zb	1.10	55	1.13	56	1.1	55	1.48	74
5Zc	1.04	58	0.99	55	0.91	50	1.37	76
5Zd	1.20	50	1.24	52	1	42	1.73	72
5Ze	0.36	15	0.44	18	0.32	13	0.69	29
Total	81.05	62	81.41	63	79.75	60	89.01	70

H.2 For each zone

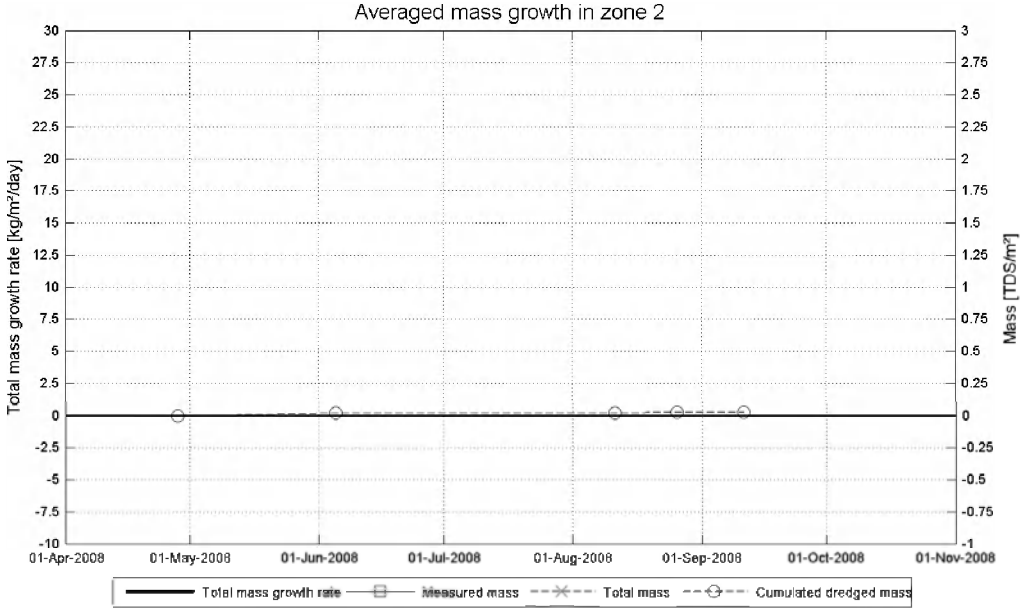
Long-term monitoring siltation Deurganckdok

Measured/Dredged/Total Mass	Equipment(s): NaviTracker
	Location: DGD

Averaged mass growth in zone 1



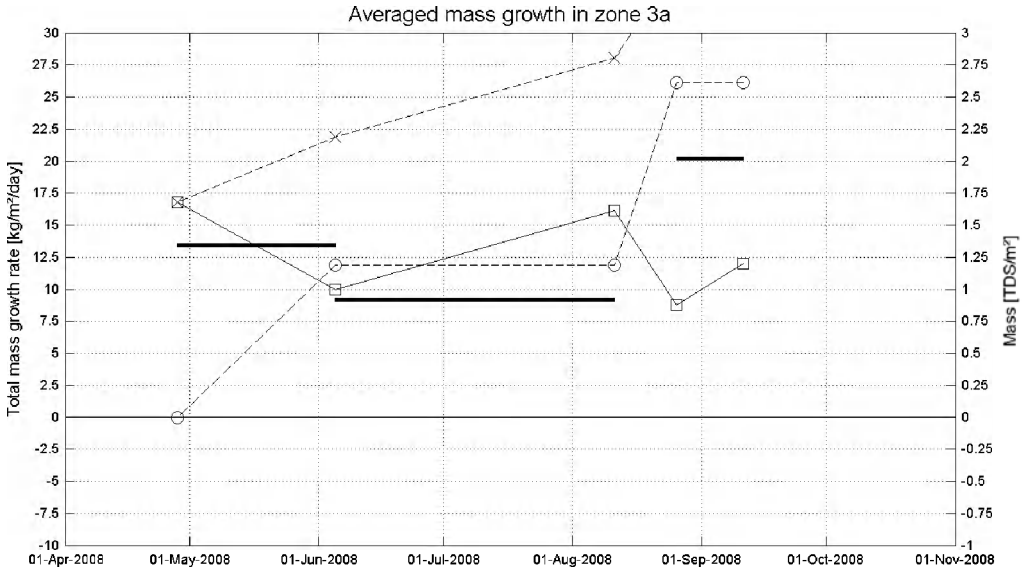
Averaged mass growth in zone 2

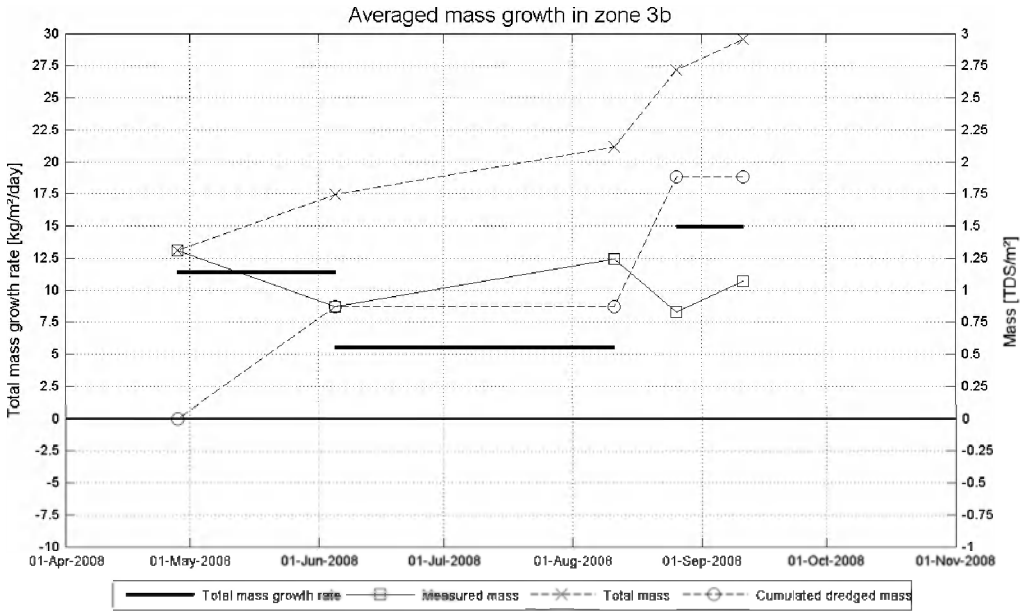


Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

Measured/Dredged/Total Mass	Equipment(s): NaviTracker
	Location: DGD

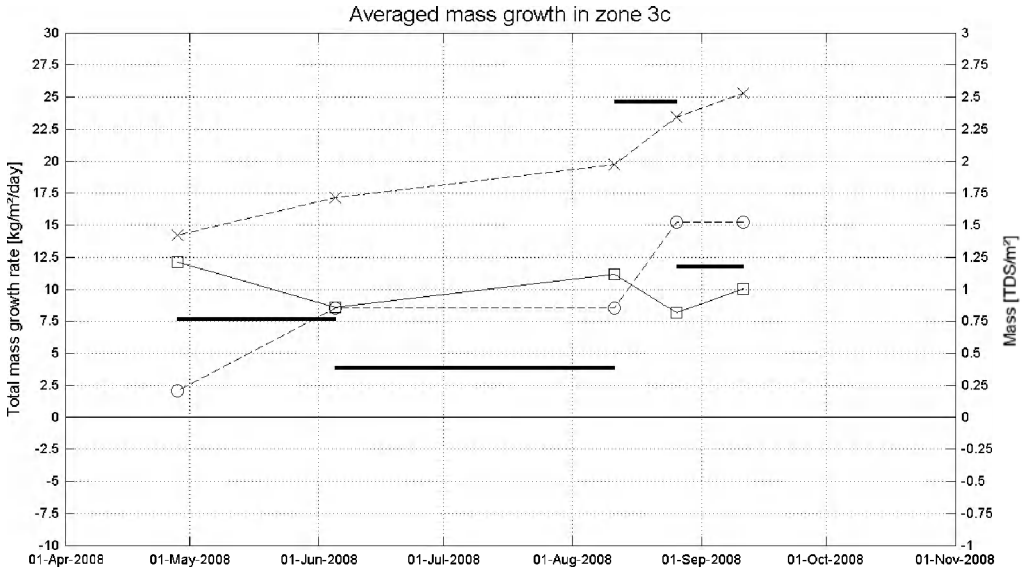


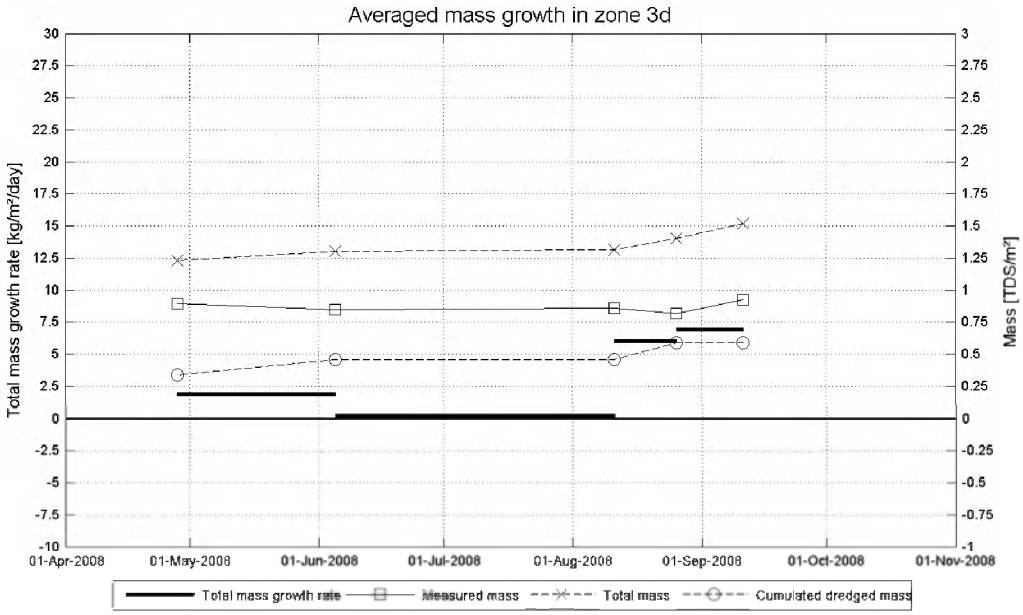


Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

Measured/Dredged/Total Mass	Equipment(s): NaviTracker
	Location: DGD



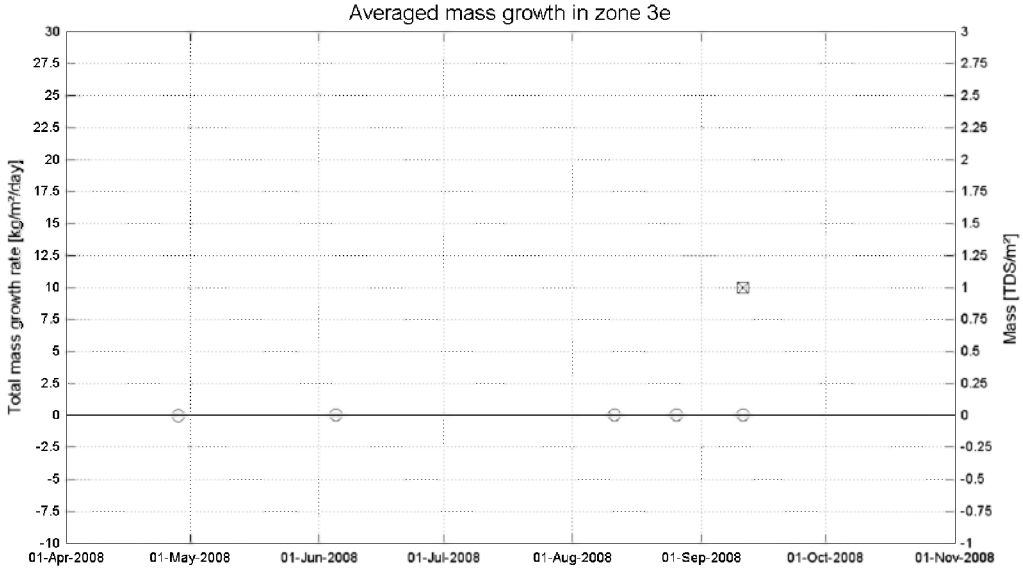


Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.077/MSA

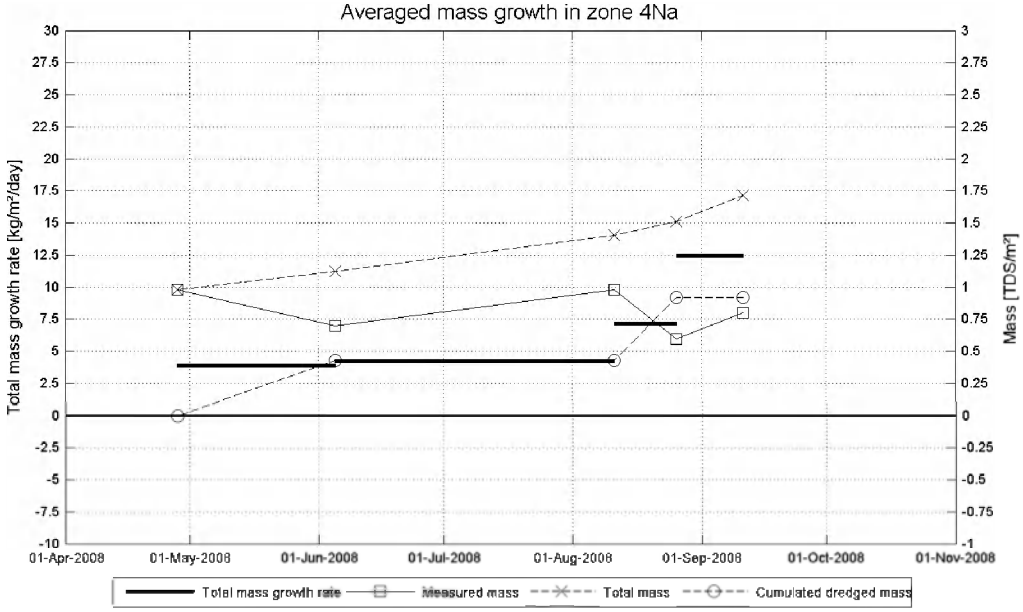
Long-term monitoring siltation Deurganckdok

Measured/Dredged/Total Mass	Equipment(s): NaviTracker
	Location: DGD

Averaged mass growth in zone 3e



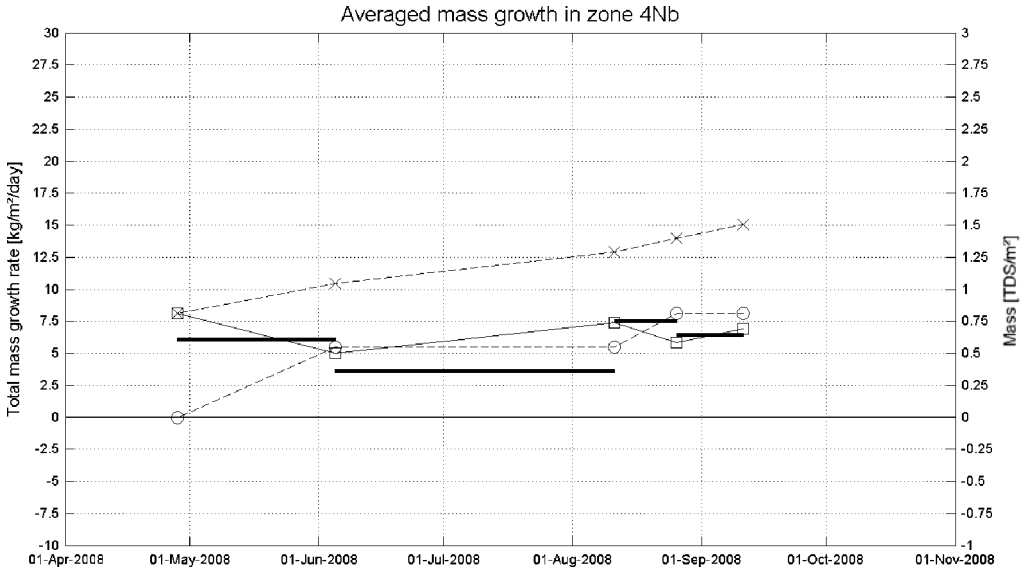
Averaged mass growth in zone 4Na

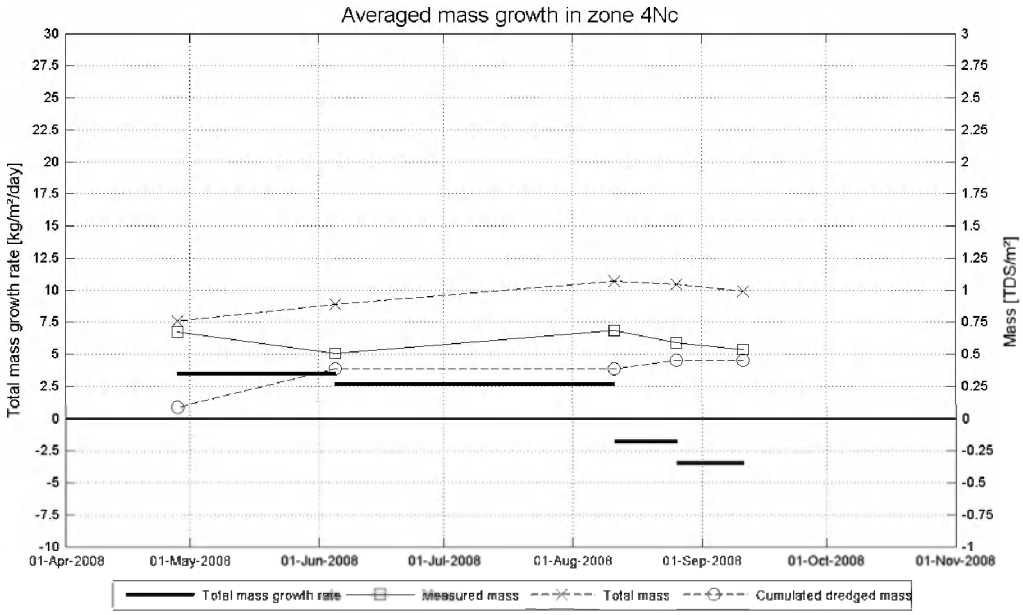


Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

Measured/Dredged/Total Mass	Equipment(s): NaviTracker
	Location: DGD

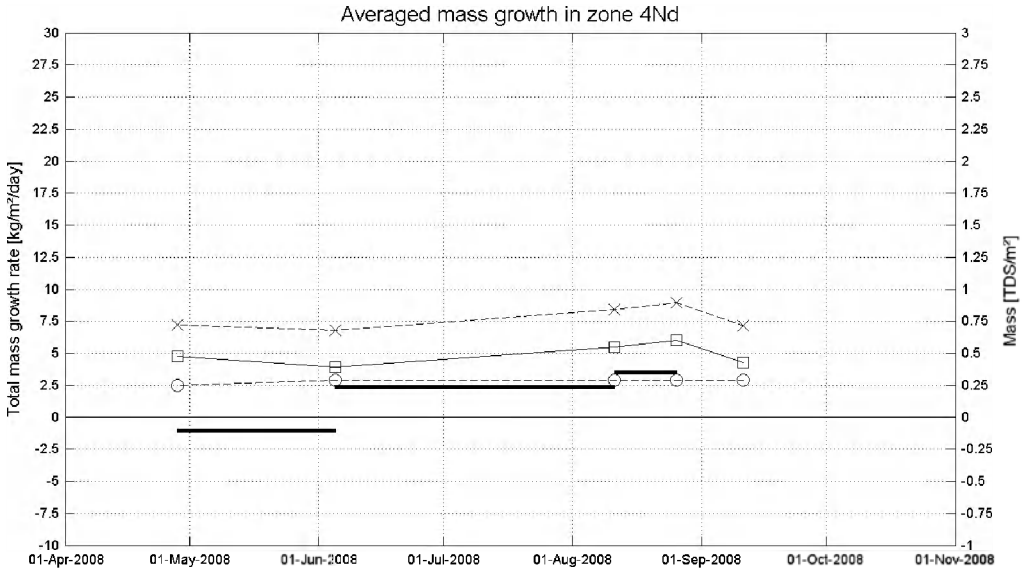


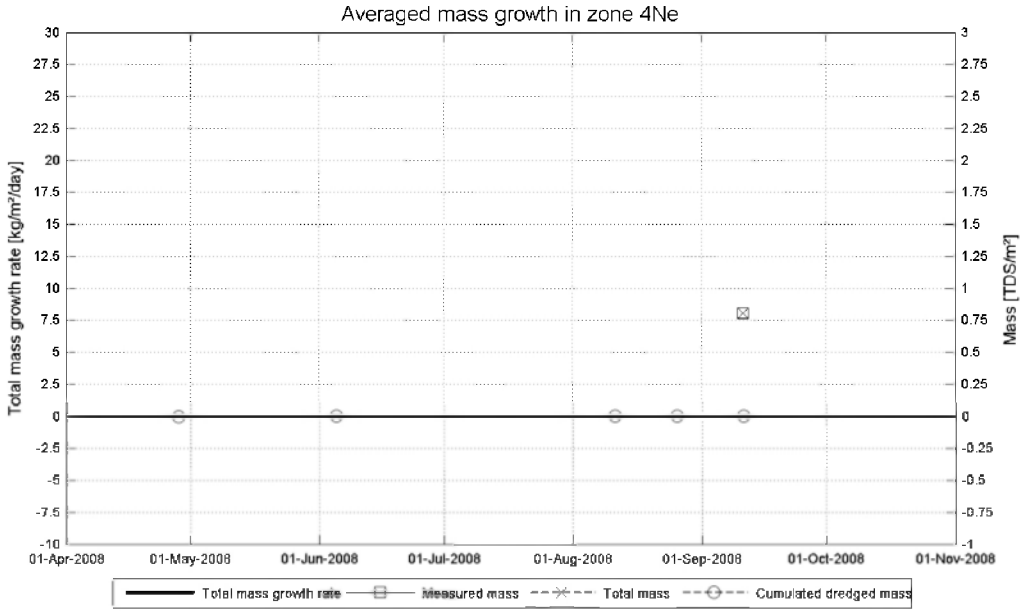


Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

Measured/Dredged/Total Mass	Equipment(s): NaviTracker
	Location: DGD

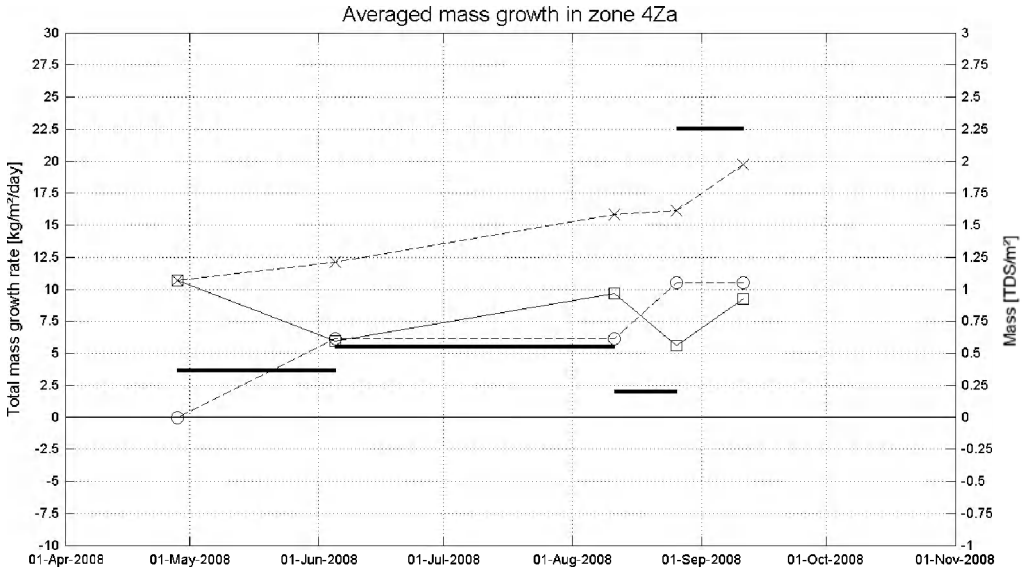


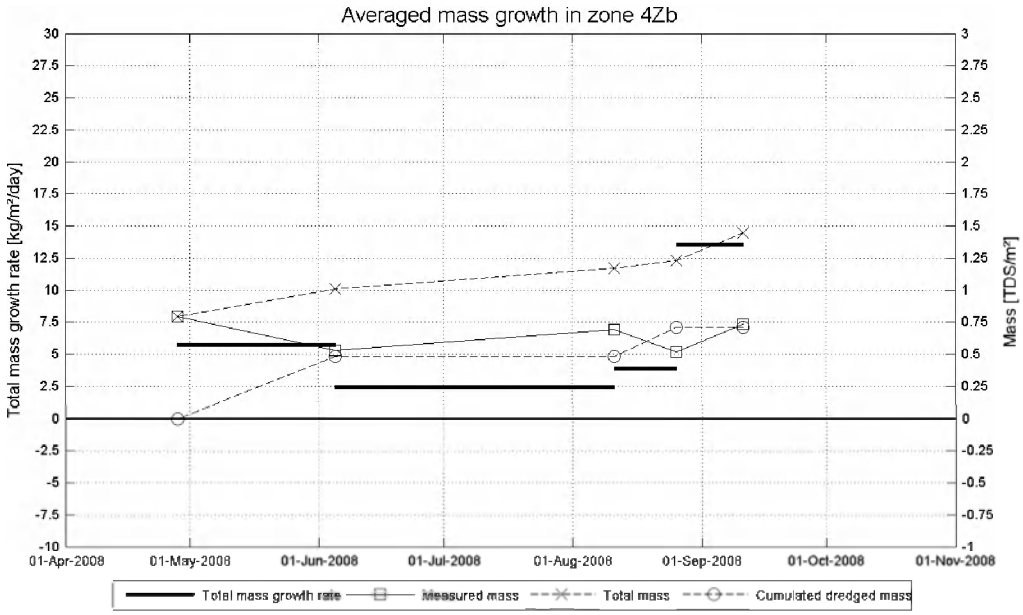


Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

Measured/Dredged/Total Mass	Equipment(s): NaviTracker
	Location: DGD

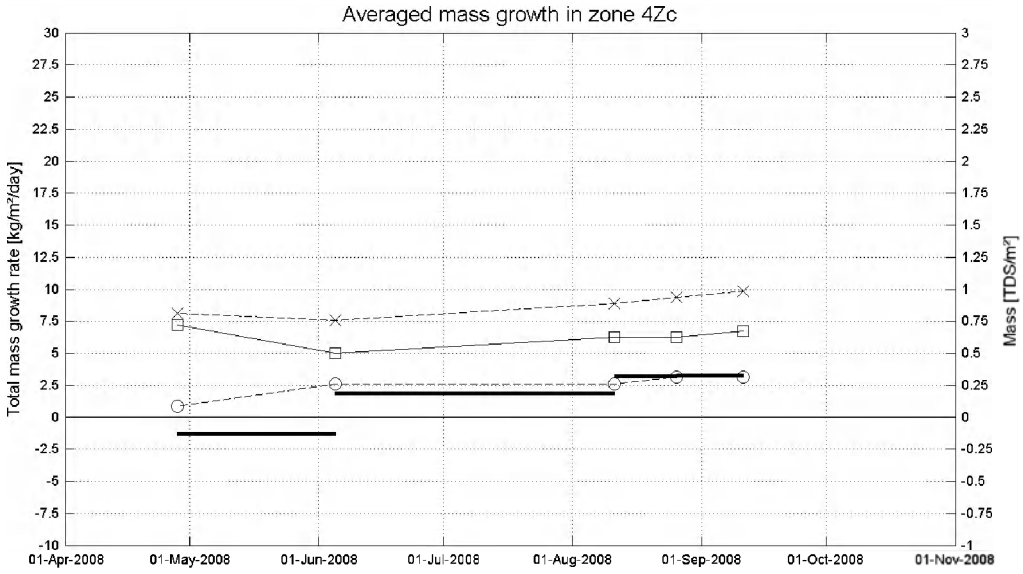


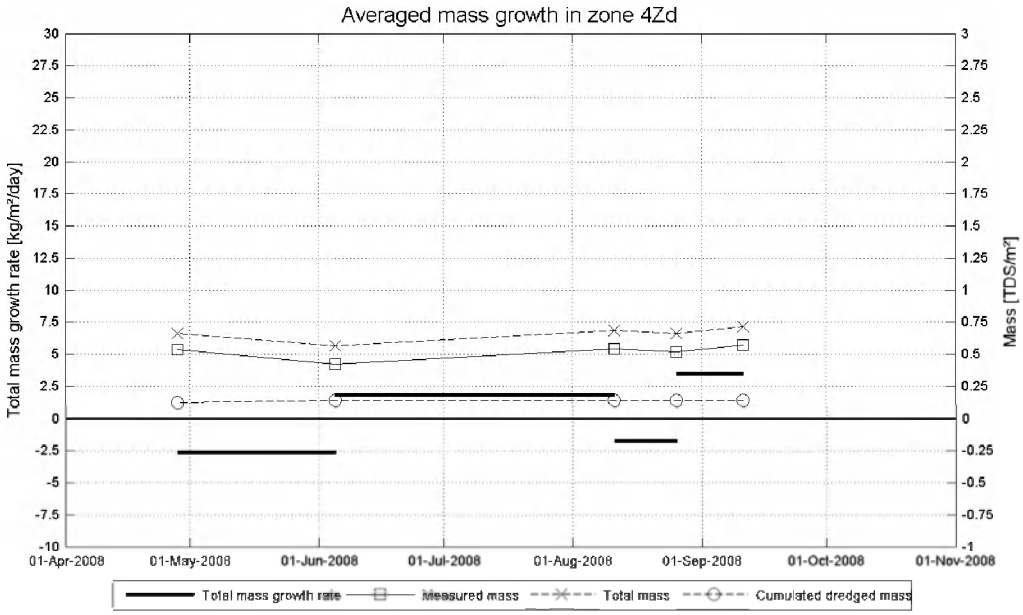


Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

Measured/Dredged/Total Mass	Equipment(s): NaviTracker
	Location: DGD

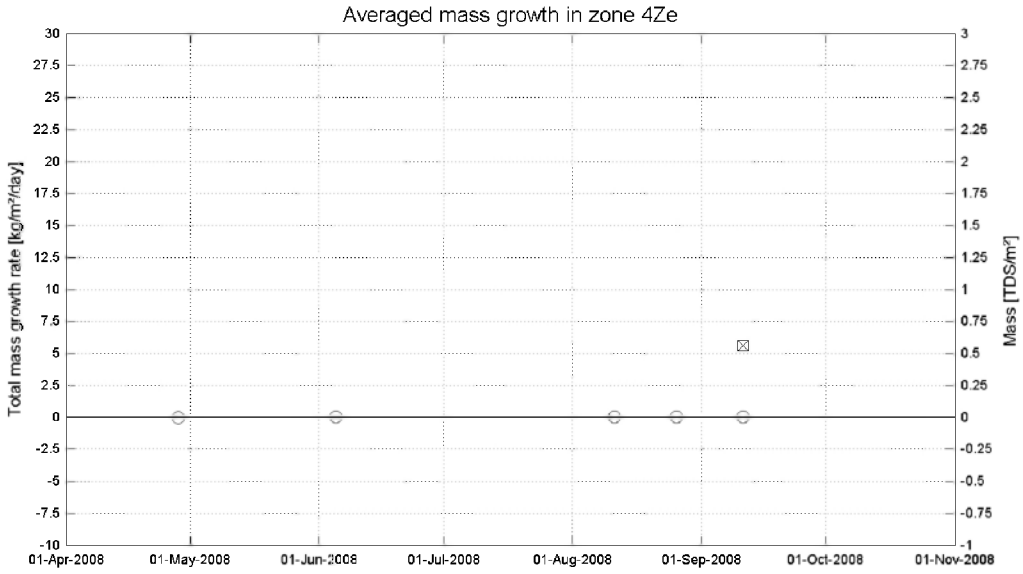


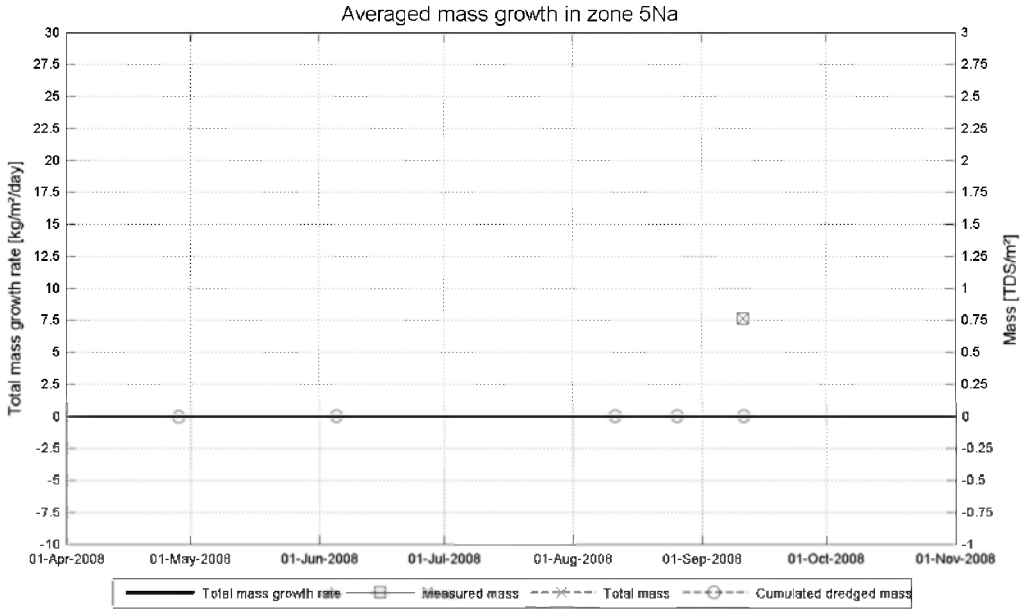


Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

Measured/Dredged/Total Mass	Equipment(s): NaviTracker
	Location: DGD

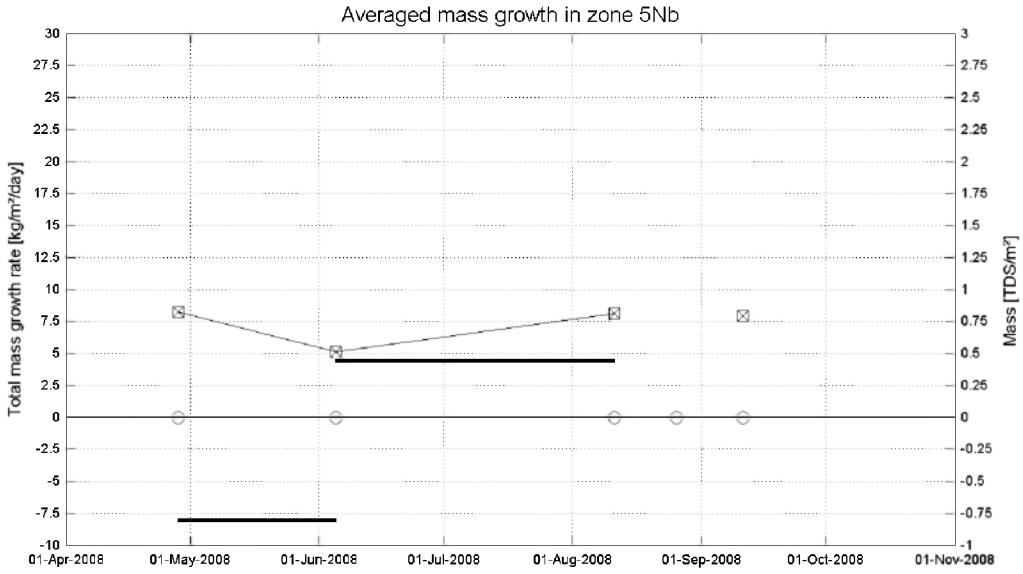


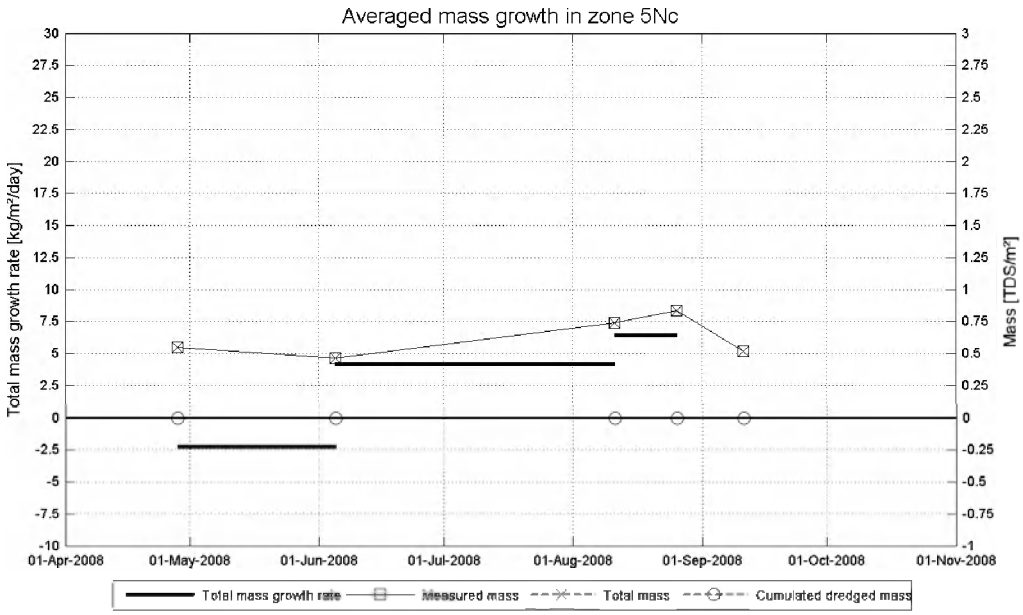


Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

Measured/Dredged/Total Mass	Equipment(s): NaviTracker
	Location: DGD

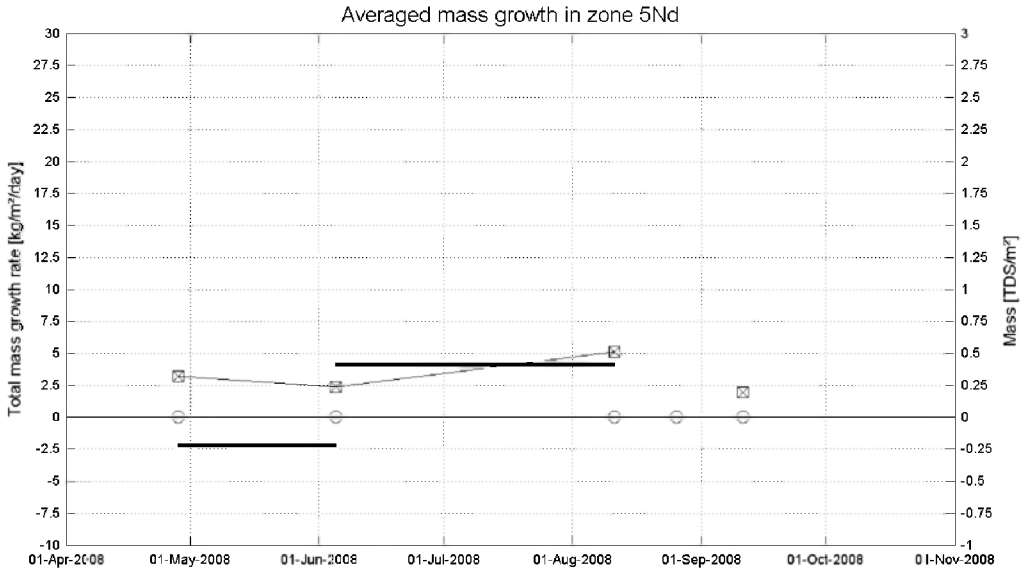


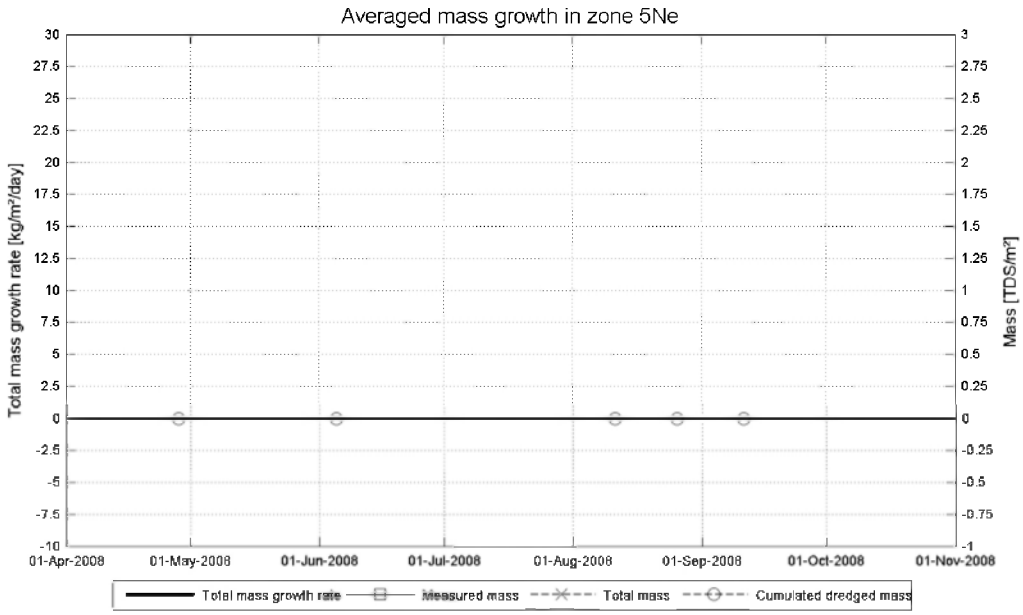


Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

Measured/Dredged/Total Mass	Equipment(s): NaviTracker
	Location: DGD

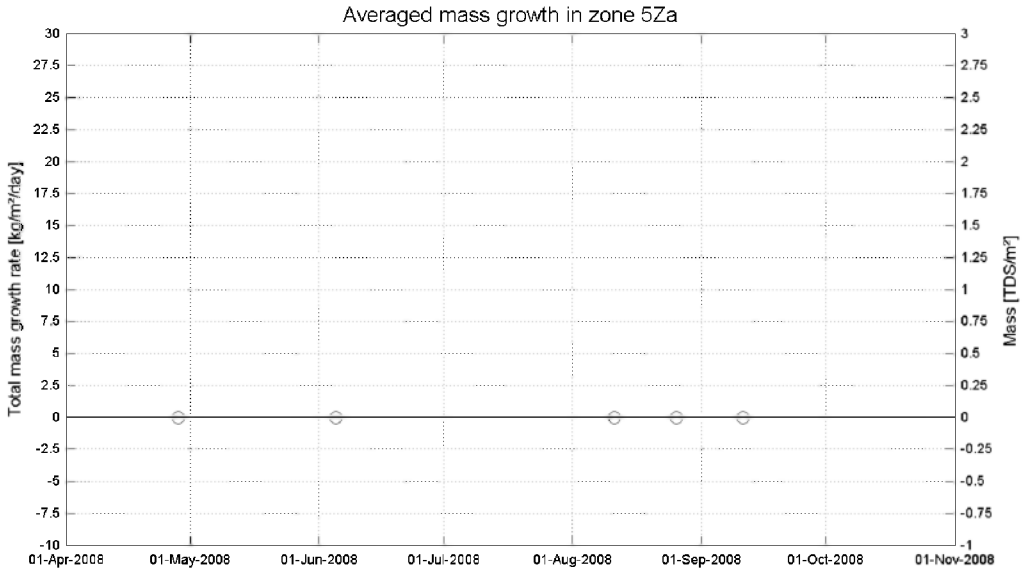


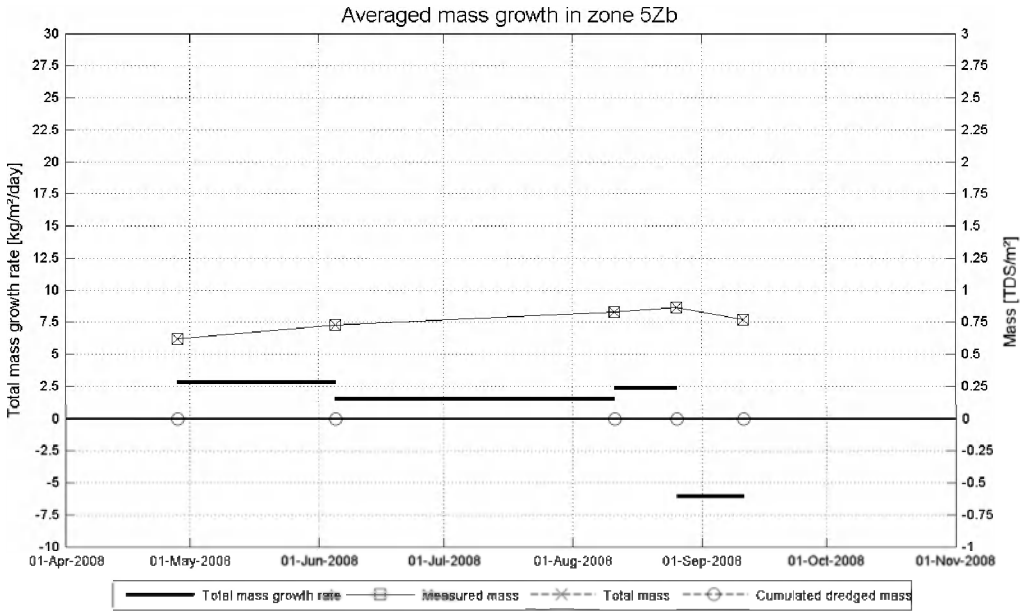


Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

Measured/Dredged/Total Mass	Equipment(s): NaviTracker
	Location: DGD

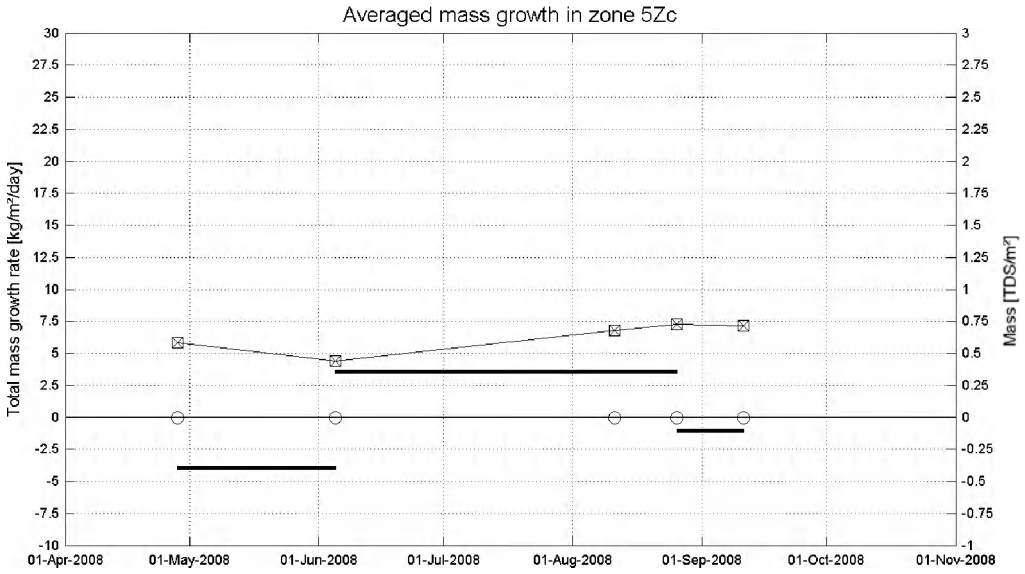


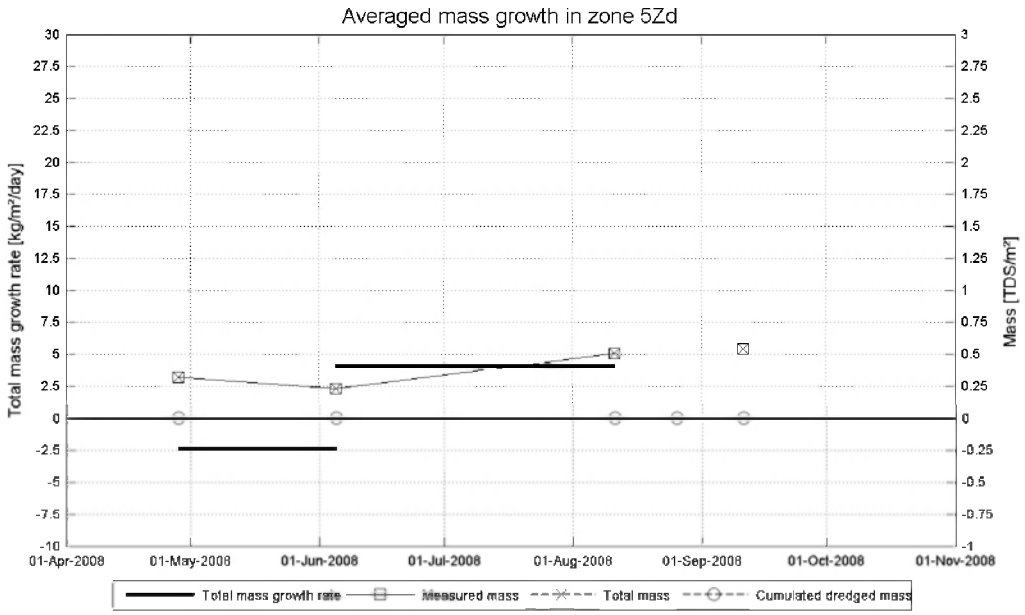


Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

Measured/Dredged/Total Mass	Equipment(s): NaviTracker
	Location: DGD

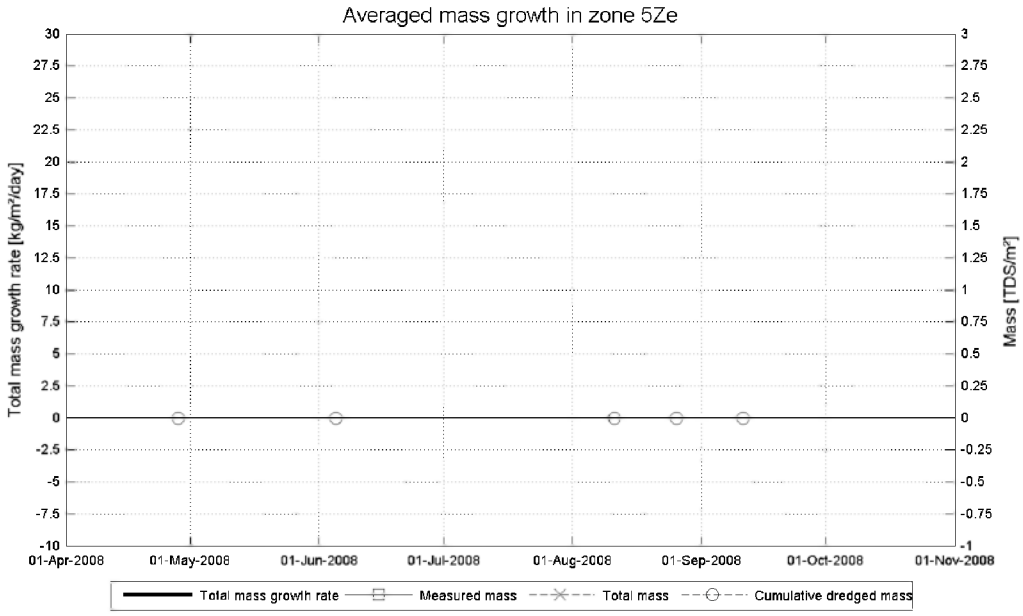




Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.077/MSA

Long-term monitoring siltation Deurganckdok

Measured/Dredged/Total Mass	Equipment(s): NaviTracker
	Location: DGD

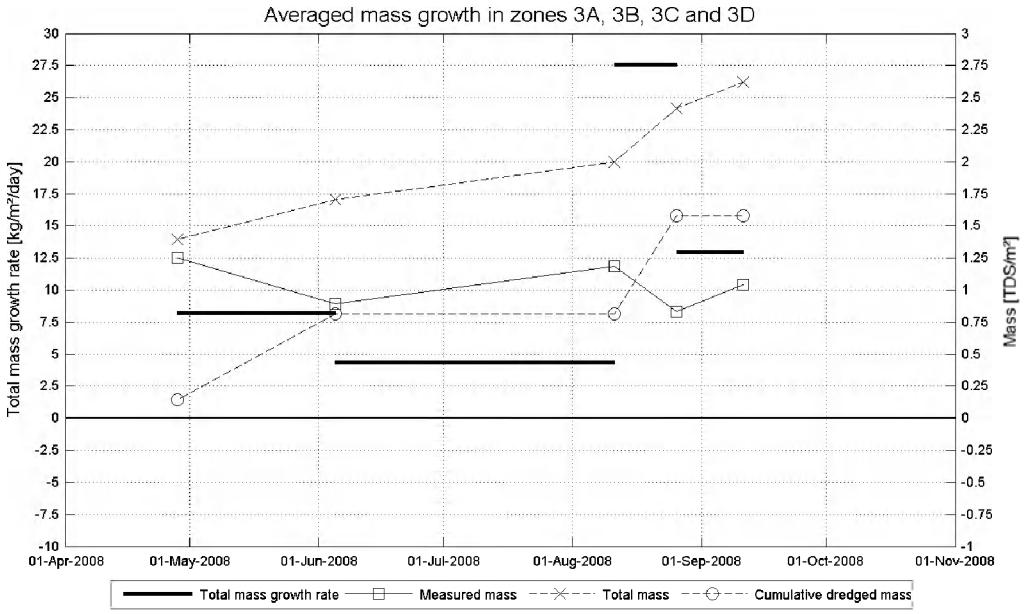


Data Processed by:
In association with :
I/RA/11283/08.077/MSA

H.3 For complete Deurganckdok

Long-term monitoring siltation Deurganckdok

Measured/Dredged/Total Mass	Equipment(s): NaviTracker
	Location: DGD



Data Processed by:
In association with :
I/RA/11283/08.077/MSA

APPENDIX I.

DREDGING DATA

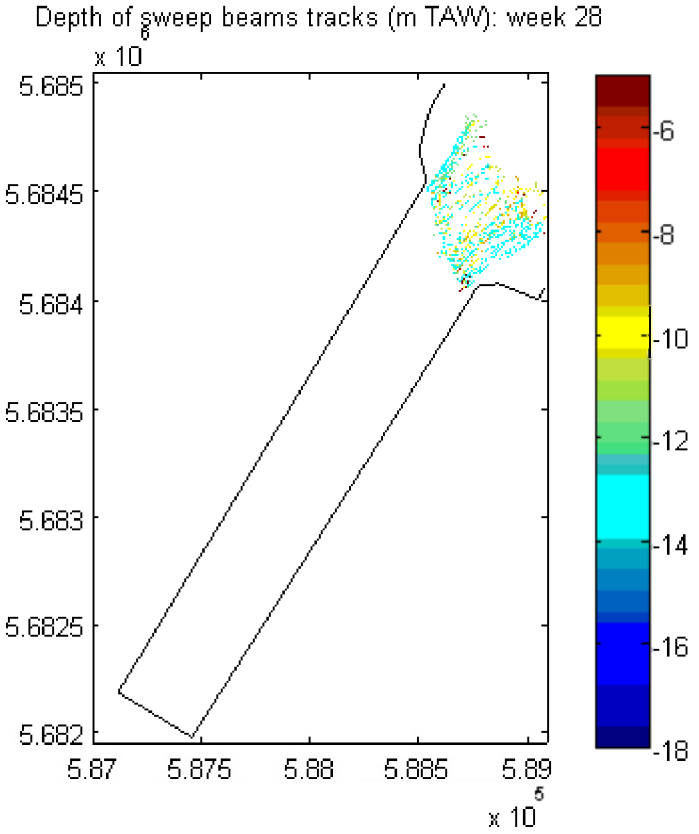
**Cumulative dredged mass in covered area (TDS)

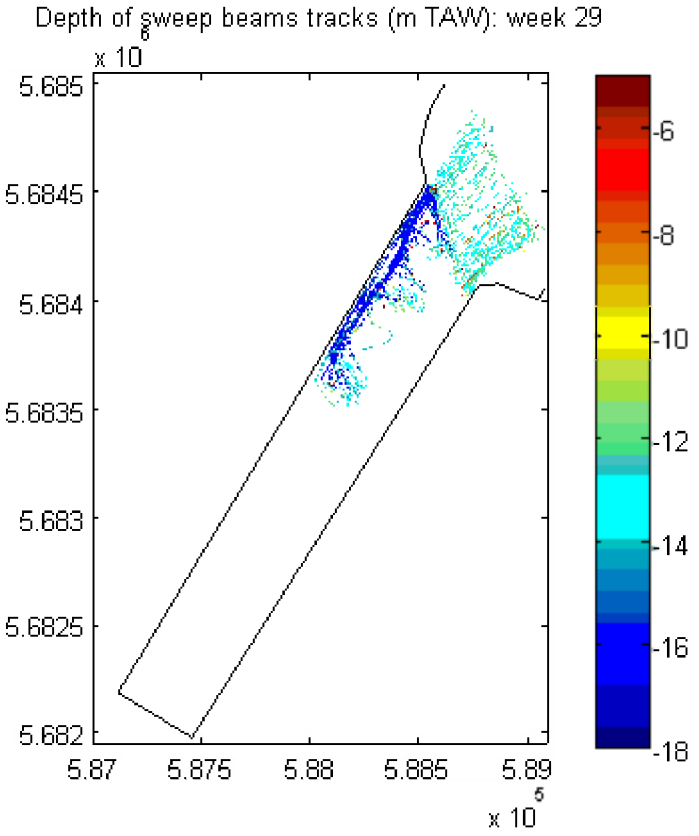
	11-Aug-08	18-Aug-08	
zone	17-Aug-08	24-Aug-08	% Total
1	39	0	0.0
2	483	346	0.2
3a	59941	80335	36.7
3b	33300	77573	29.0
3c	11229	55195	17.4
3d	3508	13759	4.5
4Na	11052	6768	4.7
4Nb	5866	2514	2.2
4Nc	1249	421	0.4
4Nd	0	75	0.0
4Za	8679	1918	2.8
4Zb	5103	2083	1.9
4Zc	487	803	0.3
4Zd	13	0	0.0

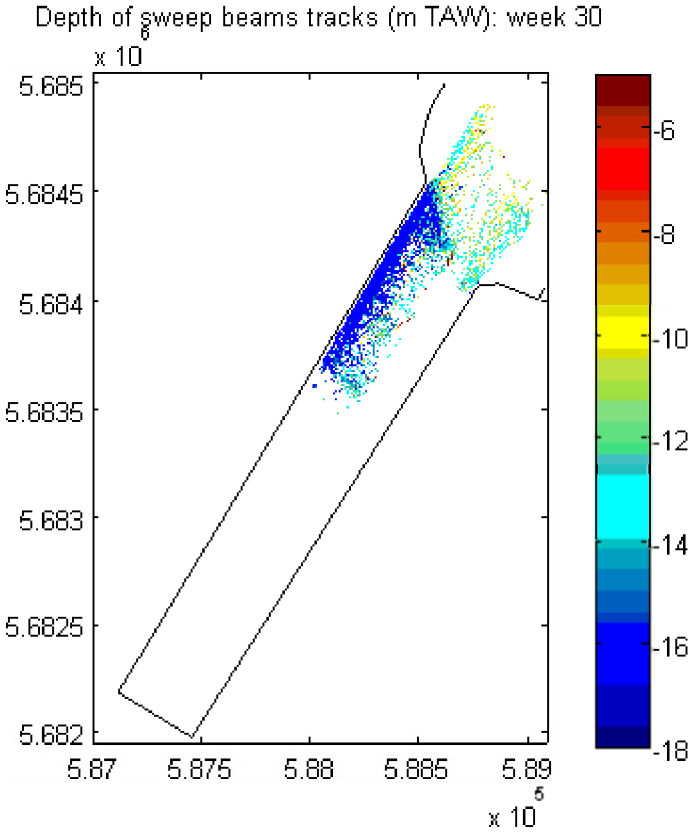
Total	140949	241789	382738
% Total	36.8	63.2	

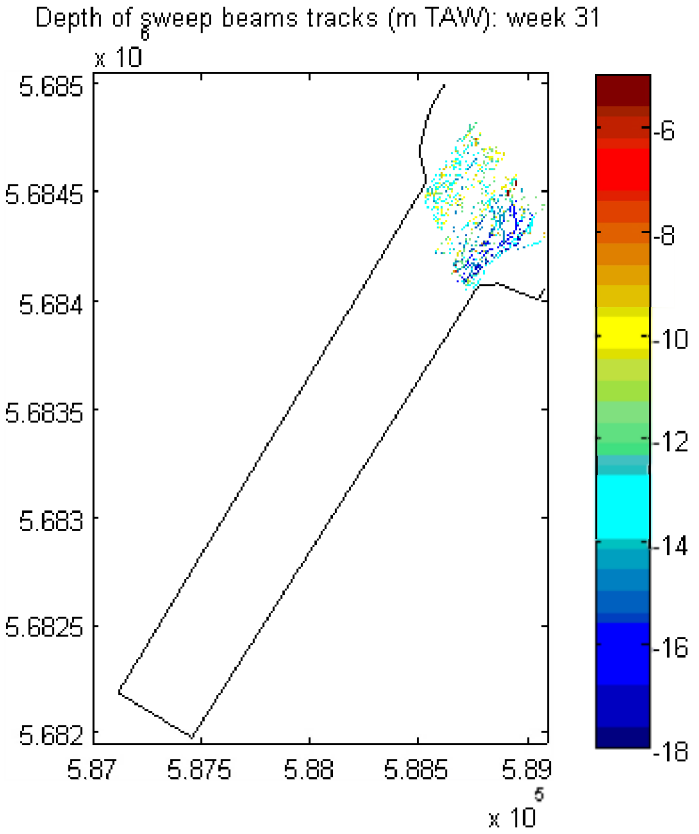
APPENDIX J.

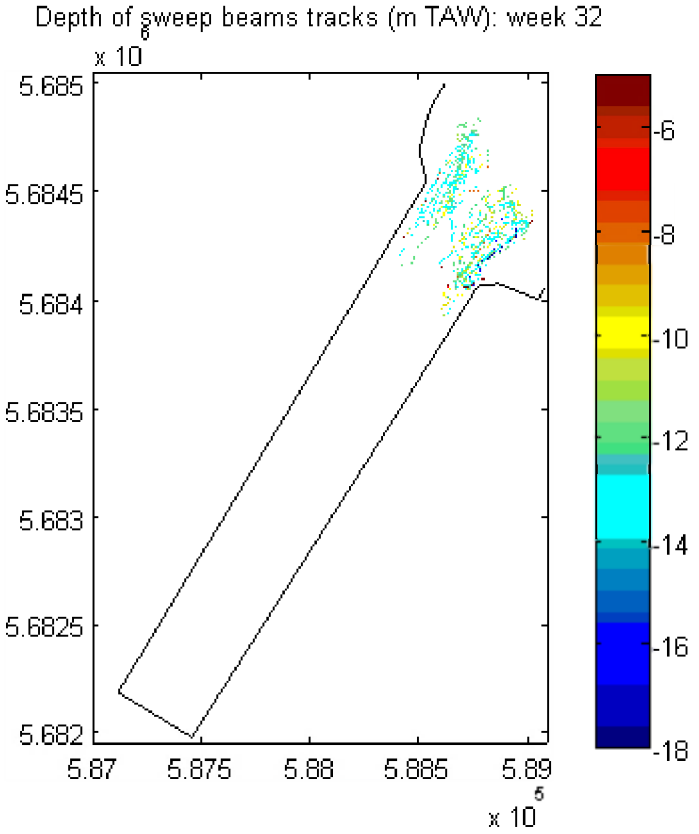
SWEEP BEAM DREDGING DATA

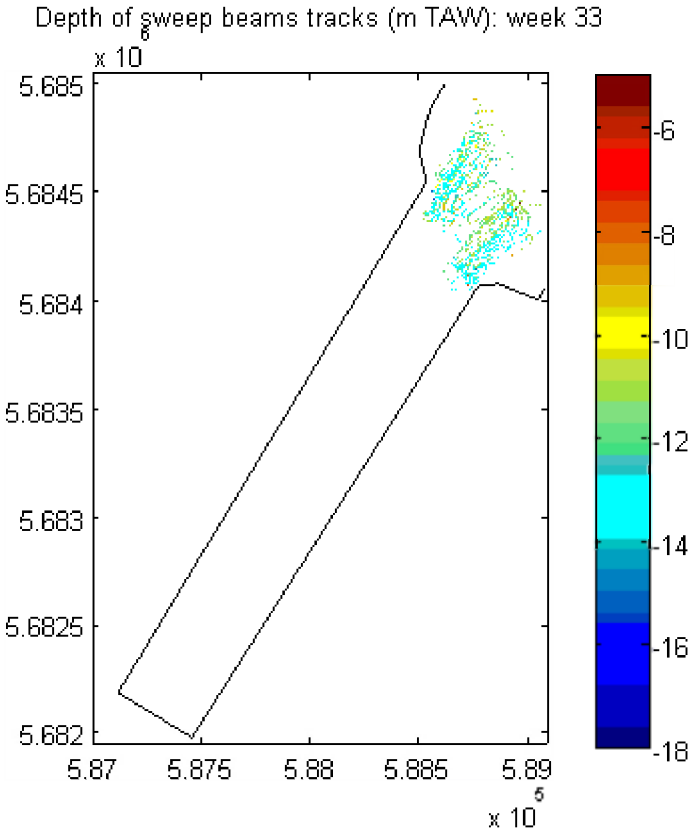

Depth of sweep beams tracks (m TAW): week 28
x 10^6
5.685
5.6845
5.684
5.6835
5.683
5.6825
5.682
5.87
5.875
5.88
5.885
5.89
x 10^5
-6
-8
-10
-12
-14
-16
-18

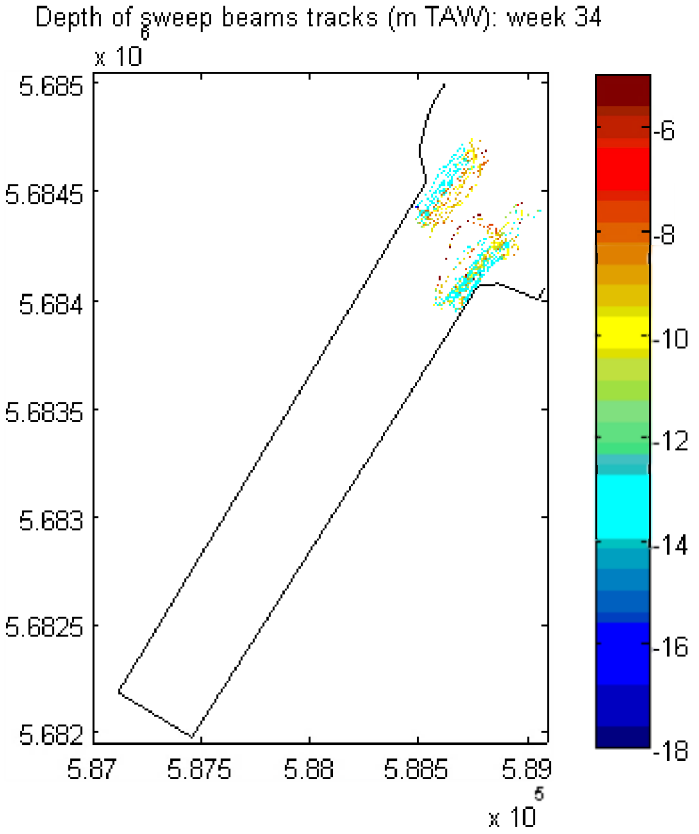

Depth of sweep beams tracks (m TAW): week 29
x 10^6
5.685
5.6845
5.684
5.6835
5.683
5.6825
5.682
5.87
5.875
5.88
5.885
5.89
x 10^5
-6
-8
-10
-12
-14
-16
-18

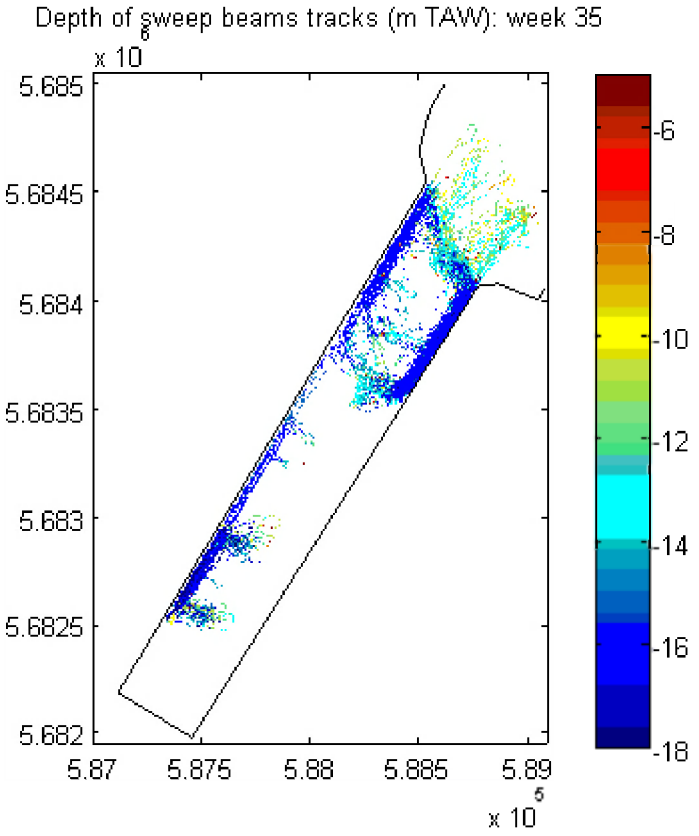

Depth of sweep beams tracks (m TAW): week 30
x 10^6
5.685
5.6845
5.684
5.6835
5.683
5.6825
5.682
5.87
5.875
5.88
5.885
5.89
x 10^5
-6
-8
-10
-12
-14
-16
-18

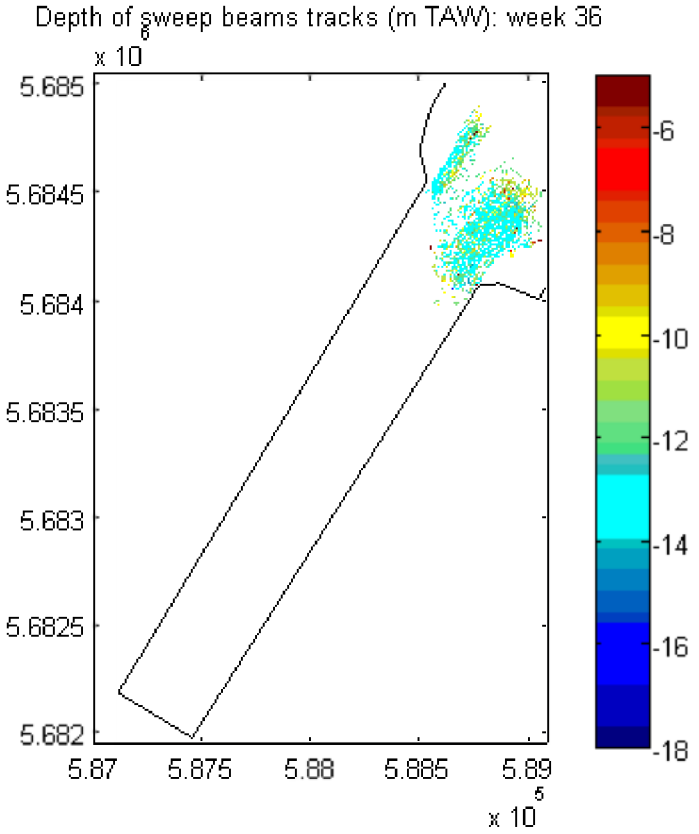

Depth of sweep beams tracks (m TAW): week 31
x 10^6
5.685
5.6845
5.684
5.6835
5.683
5.6825
5.682
5.87
5.875
5.88
5.885
5.89
x 10^5
-6
-8
-10
-12
-14
-16
-18

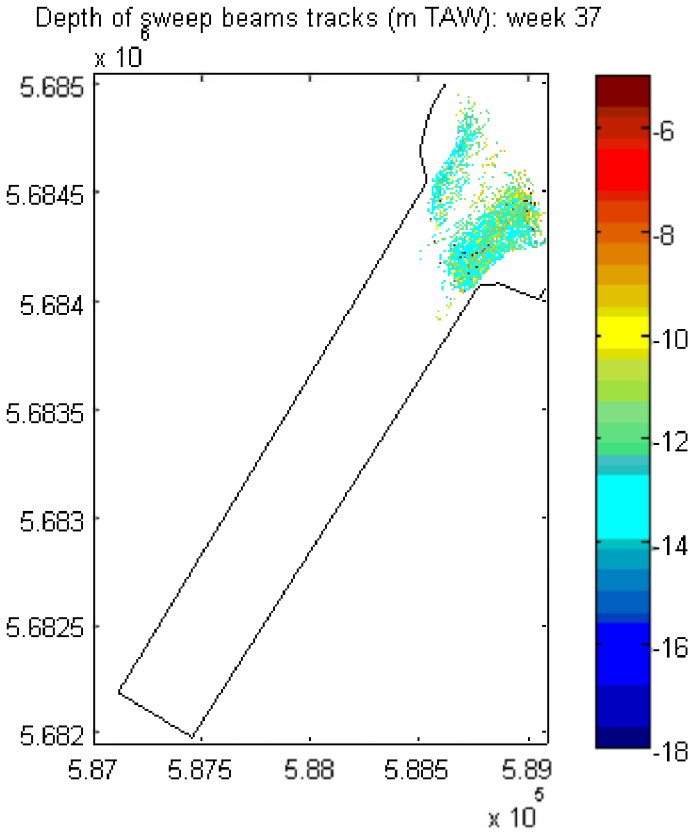

Depth of sweep beams tracks (m TAW): week 32
x 10^6
5.685
5.6845
5.684
5.6835
5.683
5.6825
5.682
5.87
5.875
5.88
5.885
5.89
x 10^5
-6
-8
-10
-12
-14
-16
-18

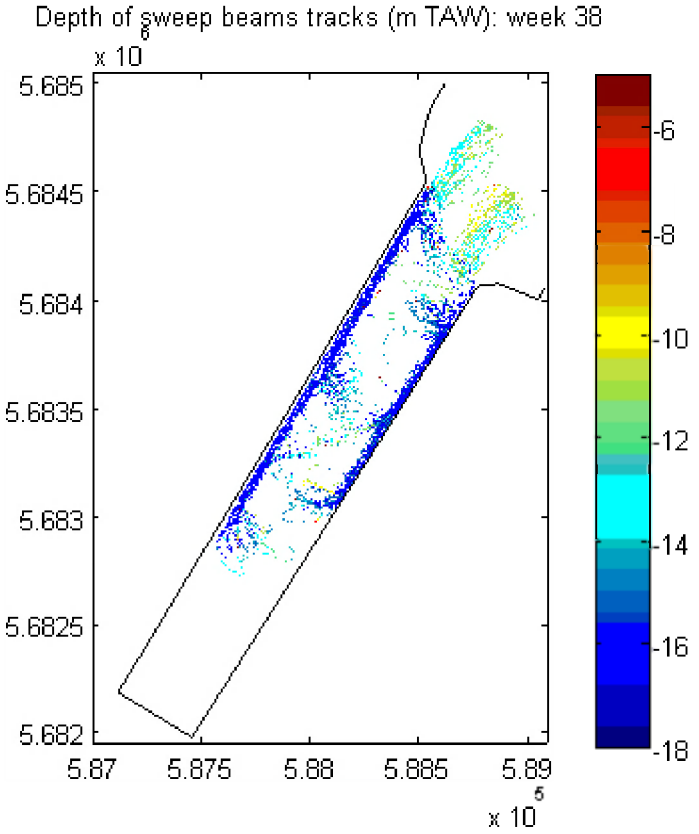

Depth of sweep beams tracks (m TAW): week 33
x 10^6
5.685
5.6845
5.684
5.6835
5.683
5.6825
5.682
5.87
5.875
5.88
5.885
5.89
x 10^5
-6
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-12
-14
-16
-18

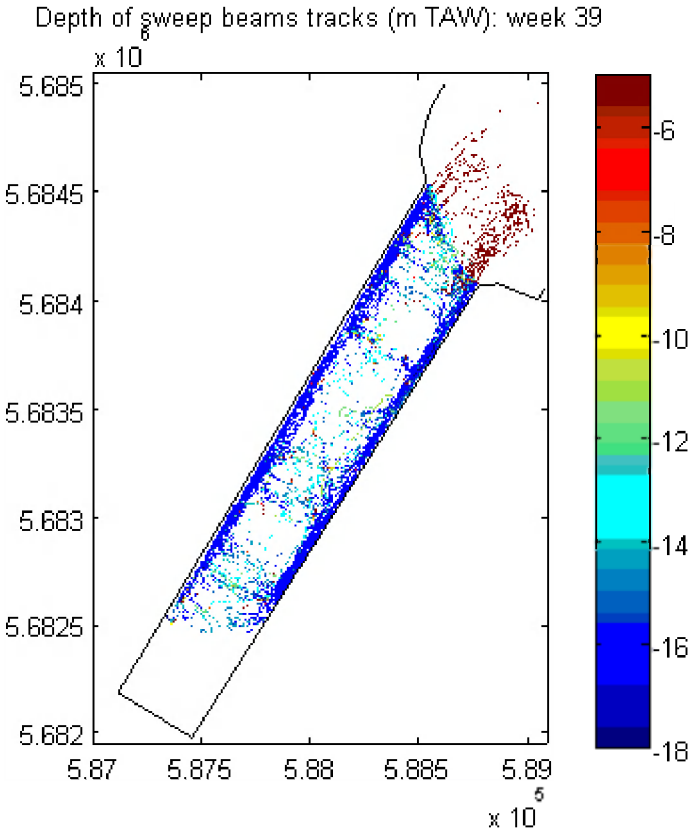

Depth of sweep beams tracks (m TAW): week 34
x 10^6
5.685
5.6845
5.684
5.6835
5.683
5.6825
5.682
5.87
5.875
5.88
5.885
5.89
x 10^5
-6
-8
-10
-12
-14
-16
-18


Depth of sweep beams tracks (m TAW): week 35
x 10^6
5.685
5.6845
5.684
5.6835
5.683
5.6825
5.682
5.87
5.875
5.88
5.885
5.89
x 10^5
-6
-8
-10
-12
-14
-16
-18


Depth of sweep beams tracks (m TAW): week 36
x 10^6
5.685
5.6845
5.684
5.6835
5.683
5.6825
5.682
5.87
5.875
5.88
5.885
5.89
x 10^5
-6
-8
-10
-12
-14
-16
-18


Depth of sweep beams tracks (m TAW): week 37
x 10^6
5.685
5.6845
5.684
5.6835
5.683
5.6825
5.682
5.87
5.875
5.88
5.885
5.89
x 10^5
-6
-8
-10
-12
-14
-16
-18


Depth of sweep beams tracks (m TAW): week 38
x 10^6
5.685
5.6845
5.684
5.6835
5.683
5.6825
5.682
5.87
5.875
5.88
5.885
5.89
x 10^5
-6
-8
-10
-12
-14
-16
-18


Depth of sweep beams tracks (m TAW): week 39
x 10^6
5.685
5.6845
5.684
5.6835
5.683
5.6825
5.682
5.87
5.875
5.88
5.885
5.89
x 10^5
-6
-8
-10
-12
-14
-16
-18