



REPORT

**Flemish Government - Department of
Mobility and Public Works**

Maritime Access Division



International Marine & Dredging Consultants

in collaboration with

Deltares

Enabling Delta Life



**Evaluation of the external effects on the
siltation in Deurganckdok (2012 - 2014)**

Report 1.09: Annual sediment balance in survey
year 7: April 2012 - March 2013

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0. SUMMARY

This report presents the mass balance of Deurganckdok for the year April 2012 – March 2013 (or survey year 7). Based on bathymetric and densimetric measurements, the density, volume and mass evolution of the dock are presented in figures and tables. Natural siltation rates are estimated from periods without dredging activities. The year April 2012 – March 2013 is the second full year after the construction of the Current Deflecting Wall (CDW) near the northern entrance of the dock, which was finished in August 2011. Limited information about the natural siltation rate and a 21% decrease of dredged sediment mass compared to the previous year, has made it very difficult to make a significant conclusion about the effect of the CDW.

1. INTRODUCTION

1.1 THE ASSIGNMENT

This report is part of a set of reports concerning the project 'Evaluation of the external effects on the siltation in Deurganckdok (2012 - 2014)'. The terms of reference were prepared by 'Department of Mobility en Public Works of the Flemish Government, Maritime Access Division (16EF/2011/28). Part 1 of the study was awarded to International Marine and Dredging Consultants NV in association with Deltares on 3 February 2012.

This study is a follow-up study on the study 'Evaluation of the external effects on the siltation in Deurganckdok' (2009 - 2012) and the study 'Aanslibbing Deurganckdok (2006 -2009)'.

The data and information that are used in this project are carried out or collected by Flanders Hydraulics Research, Maritime Access Division and the Agency for Maritime Services and Coast. Flanders Hydraulics Research provided data on discharge, tide, salinity and turbidity along the river Scheldt. Maritime Access Division provided maintenance dredging data. Agency for Maritime Services and Coast – Coast Division provided depth sounding and density profile measurements.

1.2 AIM OF THE STUDY

The purpose of this study entails evaluating the external effects on the siltation in the Deurganckdok (DGD). External effects are those effects caused by recent or near-future human operations near Deurganckdok:

- The deepening and widening of the navigational channel in the Lower Sea Scheldt between the entrance of the Deurganckdok and the access channels to the locks of Zandvliet-Berendrecht (2008 - 2010);
- The deepening of the entrance to the Deurganckdok by removing the sill at the entrance (2009 - 2010);
- The construction of the Current Deflecting Wall downstream of the entrance of the Deurganckdok (2010 - 2011);
- The change in maintenance depth or strategy;
- Construction of the second Waaslandlock at the landward end of DGD (started in 2011)

1.3 OVERVIEW OF THE STUDY

This study constitutes of 2 parts:

- Reporting and analysis of existing documents and delivered measurement data.
- Execution of specific measurement campaign to determine the siltation and salinity rates at the entrance of DGD.

Reports of the project 'Evaluation of the external effects on the siltation in the Deurganckdok (2012 -2014)' are summarized in Table 1-1. The numbering of the reports is based on the previous project that ran between 2009 and 2012.

Table 1-1: Overview of the project 'Evaluation of the external effects on the siltation in Deurganckdok (2012 - 2014)'

Report	Description
I. Analysis and Reporting	
I.1 Annual Sediment Balance: Bathymetry surveys, Density measurements, Maintenance and construction dredging activities	
1.09	Annual Sediment Balance in survey year 7: 01/04/2012-31/03/2013 (I/RA/11406/13.143/JCA)
1.10	Annual Sediment Balance in survey year 8: 01/04/2013-31/03/2014 (I/RA/11406/13.144/JCA)
I.2 Boundary Conditions: Upriver Discharge, Salt concentration Scheldt, Bathymetric evolution in access channels, dredging activities in Lower Sea Scheldt and access channels	
1.11	Boundary Conditions in survey year 7: 01/04/2012 – 31/03/2013 (I/RA/11406/13.145/JCA)
1.12	Boundary Conditions in survey year 8: 01/04/2013 – 31/03/2014 (I/RA/11406/13.146/JCA)
I.3 Analysis of the boundary conditions	
1.13	Analysis of the boundary conditions in survey years 3 and 4: 01/04/2008 – 31/03/2010 (I/RA/11406/13.054/MGO)
1.14	Analysis of the boundary conditions in survey years 5 and 6: 01/04/2010 - 31/03/2012 (I/RA/11406/13.062/MGO)
1.15	Analysis of the boundary conditions in survey years 7 and 8: 01/04/2012 – 31/03/2014 (I/RA/11406/13.147/JCA)
I.4 Analysis: evaluation of external effects on siltation in Deurganckdok	
1.16	Analysis of external effects on siltation processes and factors (I/RA/11406/13.147/JCA)
II. Longterm salinity and turbidity measurement campaign at the entrance Deurganckdok	
II.1 Salinity Siltation Distribution at the entrance of Deurganckdok	
2.14	Salinity-Siltation distribution Deurganckdok in survey year 7: 01/04/2012 - 31/03/2013
2.15	Salinity-Siltation distribution Deurganckdok in survey year 8: 01/04/2013 – 31/03/2014
II.5 Quality Control instruments	
2.16	Calibration stationary equipment 2012
2.17	Calibration stationary equipment 2013

This report is a continuation of a set of mass balance reports that gains insight in sediment and water transport between Deurganckdok and the river Scheldt and establishes the mass balance of the dock between April 2012 and March 2013.

1.4 STRUCTURE OF THE REPORT

A general description of sedimentation and the measurements are presented in Chapter 2 and 3. The description of the steps followed to analyze the data are discussed in Chapter 4. A preliminary analyses is given in Chapter 5.

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 and of -19m TAW in the central trench.
3. the quay walls reach up to $+9\text{m TAW}$

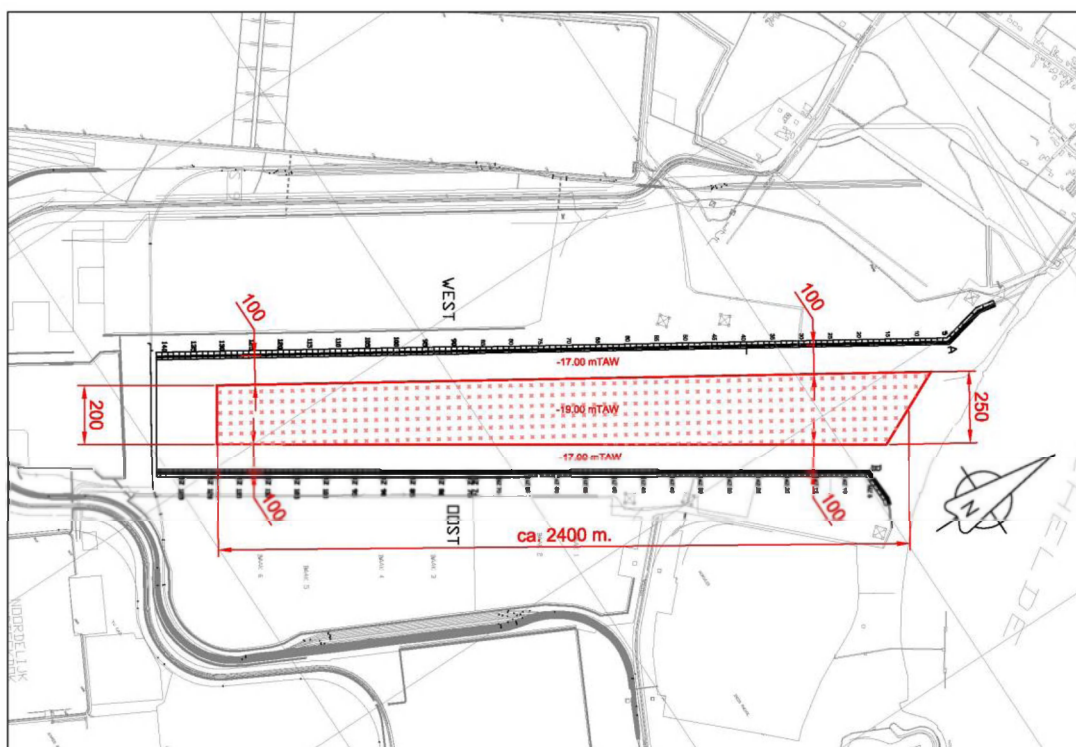


Figure 2-1: Overview of Deurganckdok

The dredging of the dock is performed in 3 phases between the start on February 2005 and finalization on February 2008. A Current Deflecting Wall (CDW) has been constructed at the entrance of Deurganckdok between 2010-2011 with the objective to reduce the yearly sedimentation in the dock. The CDW was completed in August 2011.

Other main construction works which occurred since the opening of Deurganckdok near the dock are summarized in Table 2-1.

Table 2-1 : Overview of construction works since the opening of Deurganckdok

Date	Description
18 th February 2005	Deurganckdok dike between the Scheldt and the dock was opened
18 th Feb 2005 – 1 st Aug 2005	Dredging Phase 2 (end)
Feb 2007 – Feb 2008	Dredging Phase 3, dock extended from 1500 to 2500m
Jul 2008 – Aug 2010	Deepening and widening of the Scheldt navigation channel in Belgium (spread over a long period, exact timing not known)
Nov 2009 – Jun 2010	Dredging of the entrance sill
Apr 2010 – Aug 2011	Construction of the Current Deflecting Wall (CDW)
> Mar 2011	Change of maintenance depth -15.9m / -17.5m / -15.2m in quays / trench / entrance (included in maintenance dredging)
> Nov 2011	Construction of the 2 nd Waaslandlock at the landward end of DGD

2.2 OVERVIEW OF THE STUDIED PARAMETERS

The purpose of this study entails evaluating the external effects on the siltation in the Deurganckdok (DGD) and is based on analysis and reporting of measurement data. The analysis of the measurement data contains two main components: the derivation of a yearly mass balance of the dock, and the analysis of sediment exchange mechanisms including a conceptual sedimentation model, which uses results from the mass balance, boundary conditions and measurement data at the entrance of Deurganckdock. Analysis and reporting of the natural and human conditions in the Lower Sea Scheldt would gain more insight in the mechanisms causing the siltation in Deurganckdok.

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).

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 river Scheldt since t_0 .

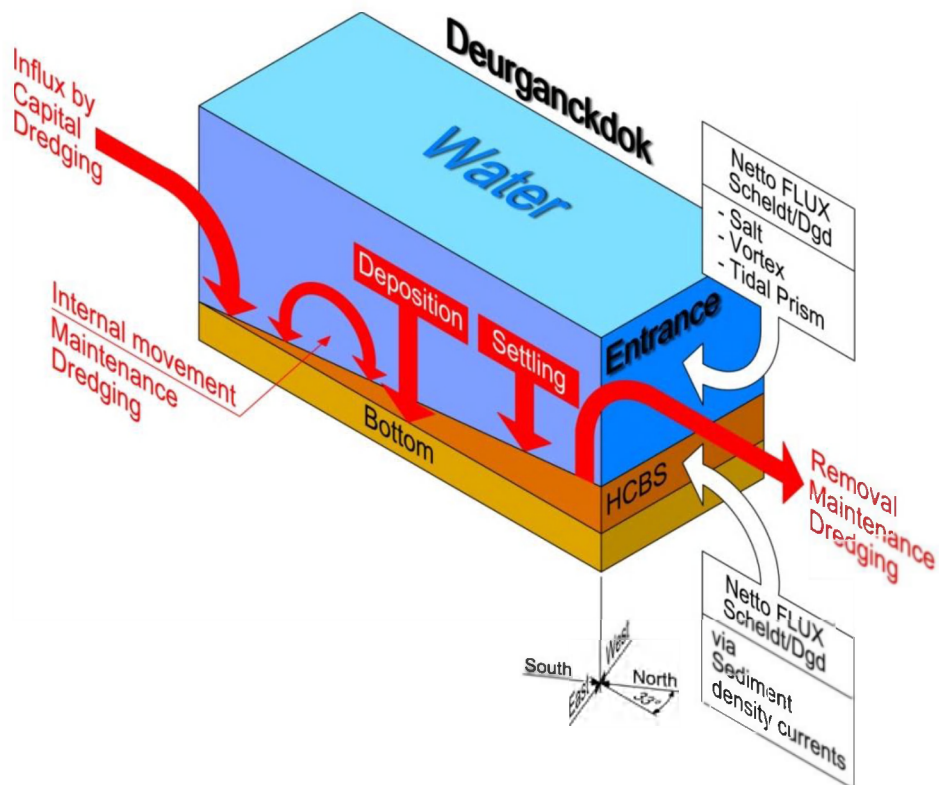


Figure 2-2: Elements of the sediment balance and transport mechanisms

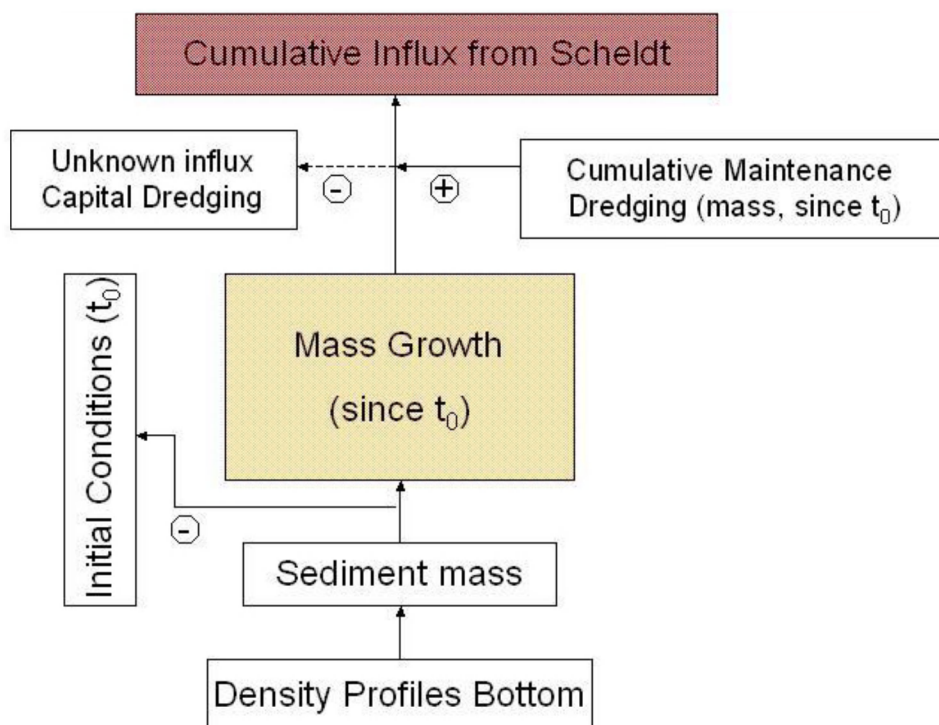


Figure 2-3: Determining a sediment balance

Concerning the sediment exchange, the following mechanisms will be aimed in this 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 salinity gradient between the Scheldt river and the dock
- Density currents due to highly concentrated benthic suspensions

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

Following data have been collected to understand these mechanisms:

- Monitoring upstream discharge in the river Scheldt.
- Monitoring Salinity and sediment concentration in the Lower Sea Scheldt at permanent measurement locations at Oosterweel, up- and downstream of the Deurganckdok.
- Long term measurements of salinity and suspended sediment distribution at the entrance of Deurganckdok.
- 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 CONVENTIONS

All measurements are reported in ED50 UTM31N coordinates with the depth in TAW. A time convention is not needed in this report, which does not contain time series.

3.2 DEPTH SOUNDINGS

Agentschap voor Maritieme Dienstverlening en Kust – Afdeling Kust executes monthly dual-frequency echo-sounder measurements 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.

During this measurement period all soundings covered most of the dock.

Table 3-1: Overview of the available depth soundings suitable for analysis 28/03/2012 – 15/03/2013

Date	Type of Measurement	Signal	Source
28/03/2012*	dual frequency 210	210	Afdeling Kust
25/04/2012	dual frequency 210	210	Afdeling Kust
07/06/2012	dual frequency 210	210	Afdeling Kust
03/07/2012	dual frequency 210	210	Afdeling Kust
27/07/2012	dual frequency 210	210	Afdeling Kust
31/08/2012	dual frequency 210	210	Afdeling Kust
03/10/2012	dual frequency 210	210	Afdeling Kust
30/10/2012	dual frequency 210	210	Afdeling Kust
30/11/2012	dual frequency 210	210	Afdeling Kust
16/01/2013	dual frequency 210	210	Afdeling Kust
14/02/2013	dual frequency 210	210	Afdeling Kust
15/03/2013	dual frequency 210	210	Afdeling Kust

*= reference situation depth soundings (for the difference maps): 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. The first sounding of the measurement year is chosen as reference situation. However, when dealing with different measurement years (2009-2011), a single reference situation needs to be selected; it was decided to use the design depth of the dock.

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 §4.5).

3.3 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, four devices were used, i.e. the Navitracker, the Densitune and the GraviProbe. The former device was applied until the end of August 2008, after which the Densitune was used. From May 3rd 2010 onward, the Navitracker has been used. During the measurement years 2010-2012 the Navitracker has been used all the time except for the measurement of March 20th 2010 which has still been done with the Densitune. During the measurement year 2012-2013 all three instruments have been used. An overview is presented in Table 3-2.

The application of different devices is related to a contract change for density measurements in the harbour of Zeebrugge. Some information about the devices is given below.

Table 3-2: Overview of the available density measurements suitable for analysis 28/03/2012 – 15/03/2013

Date	Type of instrument	Contractor	Source
28/03/2011	Navitracker	GEMS	Afdeling Kust
08/05/2012	Navitracker	GEMS	Afdeling Kust
27/06/2012	Navitracker	GEMS	Afdeling Kust
26/07/2012	Navitracker	GEMS	Afdeling Kust
18/09/2012	Navitracker	GEMS	Afdeling Kust
11/10/2012	Navitracker	GEMS	Afdeling Kust
06/12/2012	Navitracker	GEMS	Afdeling Kust
27/12/2012	GraviProbe	Eurosense	Afdeling Kust
23/01/2013	DensiTune	GeoXYZ	Afdeling Kust
07/03/2013	DensiTune	GeoXYZ	Afdeling Kust

3.3.1 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.

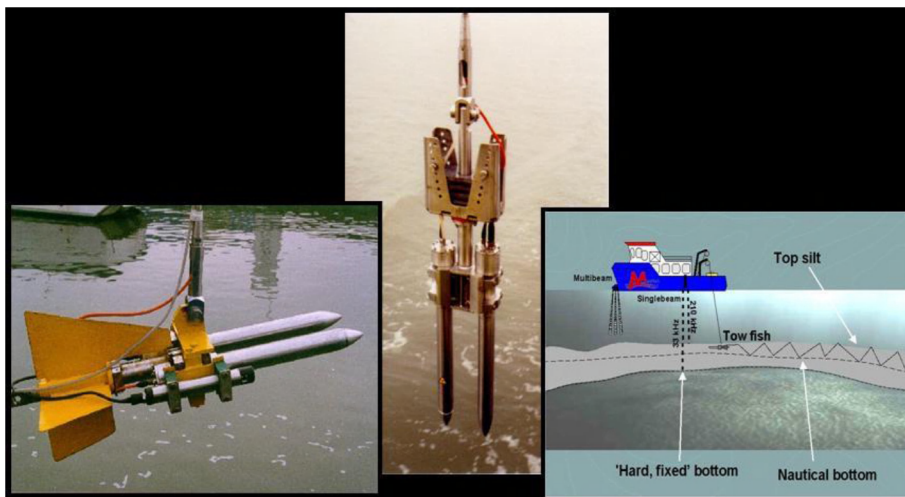


Figure 3-1: Navitracker

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.

3.3.2 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 with an accuracy of approximately 1% between 1.00 and 1.50 kg/dm³. More information is given in Annex A.

From previous research (IMDC, 2005; 2009r), it could be observed that the DensiTune measured higher densities at a specific depth in comparison to the Navitracker. DensiTune therefore identifies densities less deep than Navitracker, i.e. around 25 cm.

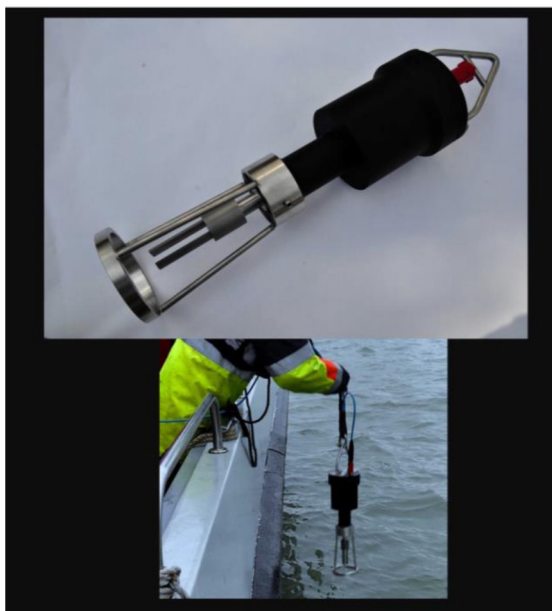


Figure 3-2: DensiTune

3.3.3 GraviProbe

The GraviProbe is developed by DotOcean and measures a density profile during free fall intrusion. The density conditions of the soil layers are determined from a dynamical model feeding by on-board accelerometers, inclinometers and pressure sensors. The system measures vertical density profiles in liquid silt layers at acquisition rates above 2kHz and with an accuracy of approximately 2%. The density range that instrument could capture reliable measurements is between 0.90 and 1.30 kg/dm³. More information is given in Annex A.

Due to its light weight the probe can be operated manually from a small vessel, platform or quay and is limiting the operational costs (DotOcean, 2013).

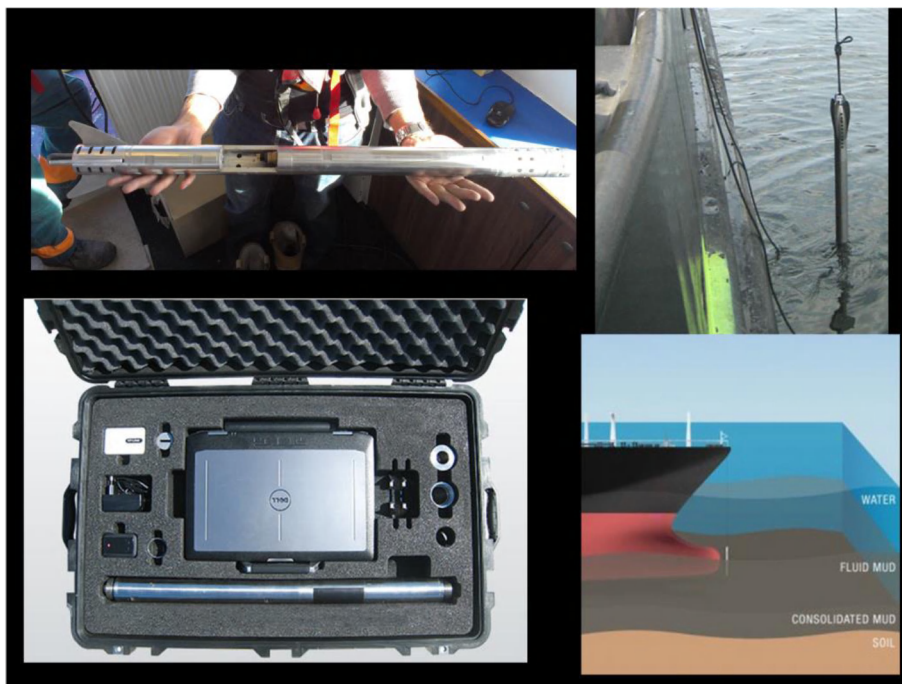


Figure 3-3: GraviProbe

3.3.4 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/dm^3 . The water-bed interface is defined as the layer with a density of 1.03 kg/dm^3 .

To calculate the local sediment mass in the dock, or zones of it, each measured density profile was integrated over its depth. The unmeasured part of the water column, covering the distance between the deepest sampling point and the design depth, needed to be estimated (if not measured). This sediment concentration was estimated as being constant for the unmeasured depth range and being proportional to the deepest measured concentration. As proportionality, a value of 1.02 was applied which was determined from a preliminary analyses of the density profiles near the bottom. A horizontal distribution of the sediment mass was subsequently obtained by cubic interpolation between the profiling locations onto a grid with a resolution of 5 m.

In this measurement campaign, density measurements were performed as presented in Table 3-2:

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

Table 3-3: Reference Situation Density Measurements (t0d)

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

3.4 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' 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 between 28 March 2012 and 10 March 2013.

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 in Table 3-4 of where and when a sweep beam dredger was working in Deurganckdok (DGD) or on the sill of Deurganckdok (sill DGD) for the period April 2011 - March 2012.

Table 3-4: Sweep beam maintenance dredging activities in Deurganckdok and on the sill of Deurganckdok between April 2012 and March 2013 (source: Afdeling Maritieme Toegang)

From	Till	Week	Location
03/04/2012	07/04/2012	13	Quays (details unknown)
07/11/2012	11/05/2012	19	Quays (details unknown)
14/05/2012	18/05/2012	20	Quays (details unknown)
21/05/2012	25/05/2012	21	Quays (details unknown)
28/05/2012	02/06/2012	22	Quays (details unknown)
11/06/2012	15/06/2012	24	Quays (details unknown)
18/06/2012	24/06/2012	25	Quays (details unknown)
16/07/2012	22/07/2012	29	Quays (details unknown)
20/08/2012	24/08/2012	34	Quays (details unknown)
27/08/2012	31/08/2012	35	Quays (details unknown)
03/09/2012	07/09/2012	36	Quays (details unknown)
10/09/2012	14/09/2012	37	Quays (details unknown)
01/10/2012	05/10/2012	40	Quays (details unknown)
22/10/2012	26/10/2012	43	Quays (details unknown)
12/11/2012	16/11/2012	46	Quays (details unknown)
26/11/2012	01/12/2012	48	Quays (details unknown)
10/12/2012	14/12/2012	50	Quays (details unknown)
17/12/2012	21/12/2012	51	Quays (details unknown)
07/01/2013	11/01/2013	2	Quays (details unknown)
14/01/2013	18/01/2013	3	Quays (details unknown)
21/01/2013	25/01/2013	4	Quays (details unknown)
11/02/2013	15/02/2013	7	Quays (details unknown)
25/02/2013	01/03/2013	9	Quays (details unknown)
18/03/2013	22/03/2013	12	Quays (details unknown)
25/03/2013	29/03/2013	13	Quays (details unknown)

An overview of the total dredged mass in all zones (BIS data) is provided in Annex J. The sweep beam tracks are not shown this time, because the added values of such figures is deemed to be low in comparison with the time needed to process the data.

Remark: Since March 2011 the dredging depths in the Deurganckdock are defined by the levels presented in Annex J (zero LAT is 0.72 m below zero TAW) and Table 3-5.

Table 3-5: Maintenance dredging depths for each dredging zone since March 2011

<i>Zone</i>	<i>Zone identification</i>	<i>Dredging Depth [m]</i>	<i>Dredging Depth [m LAT]</i>
1 & 3	Commercial quays	-16.62	-15.90
2	Central trench	-18.22	-17.50
4	Entrance area	-15.92	-15.20

3.5 OVERVIEW OF ACTIVITIES AND PROCESSES

To facilitate the data analysis in Chapter 5, Table 3-6 gives an overview of all conducted measurements and human interferences on the natural siltation in the dock. This makes it possible to identify periods of undisturbed siltation of specific zones in the dock, i.e. without any dredging operations. In this way, it is possible to distinguish between the “natural” siltation and “gross” siltation; the latter indicates that human interferences are included in the measurement results too. This is especially important for the determination of the natural volumetric siltation rate, as discussed in §5.2.

Table 3-6: Overview of measurements and dredging activities in Deurganckdok.

activity	April 12		May 12		June 12		July 12		August 12		September 12	
	1 - 15	16 - 30	1 - 15	16 - 31	1 - 15	16 - 30	1 - 15	16 - 31	1 - 15	16 - 31	1 - 15	16 - 30
depth sounding												
density measurements												
maintenance dredging												
sweep beam dredging - sill												
sweep beam dredging - commercial quays												
capital dredging												

activity	October 12		November 12		December 12		January 13		February 13		March 13	
	1 - 15	16 - 31	1 - 15	16 - 30	1 - 15	16 - 31	1 - 15	16 - 31	1 - 15	16 - 29	1 - 15	16 - 31
depth sounding												
density measurements												
maintenance dredging												
sweep beam dredging - sill												
sweep beam dredging - commercial quays												
capital dredging												

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 and removed in June 2010.
- 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. In addition, results are given for the whole zones 4 North, 4 South, 5 North and 5 South. Each of these takes the northern or southern zone of 4 or 5 across the A, B, C, D and E subzones resulting in the 4 newly defined zones.

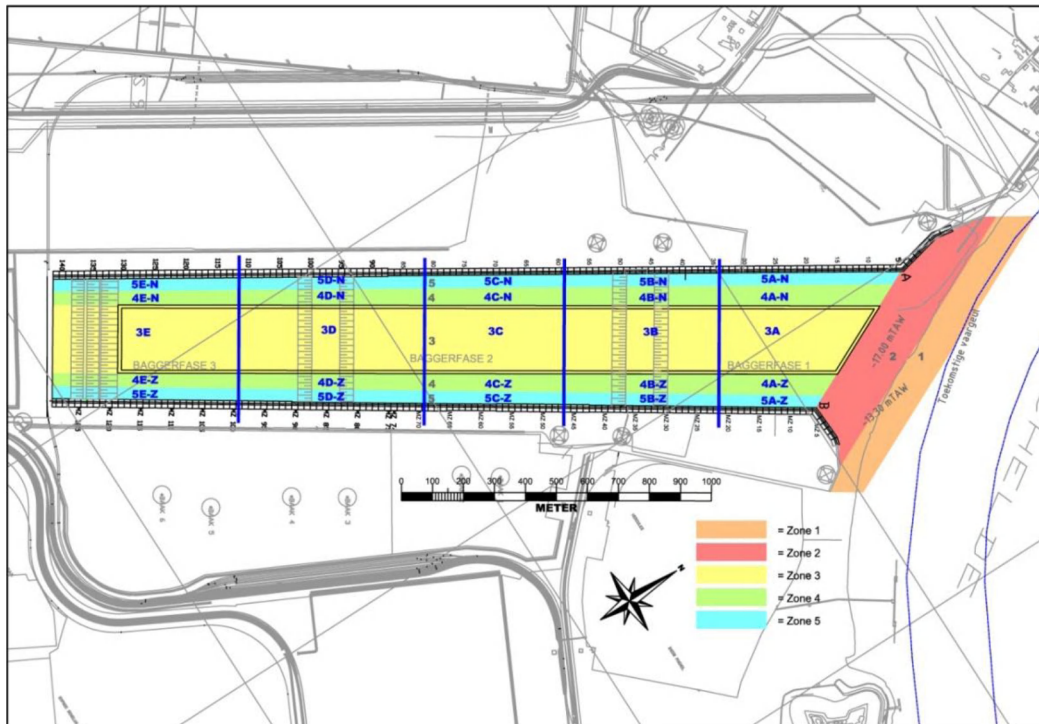


Figure 4-1 : Deurganckdok: Zones and Subzones

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 centreline of the dock and run from the navigation channel towards the inland end of the dock. 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-section				
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-Section				
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. The initial and final bathymetries are shown in Figure 4-3, and the enlarged format can be found in Annex B. Additionally the intermediate depth soundings are present.

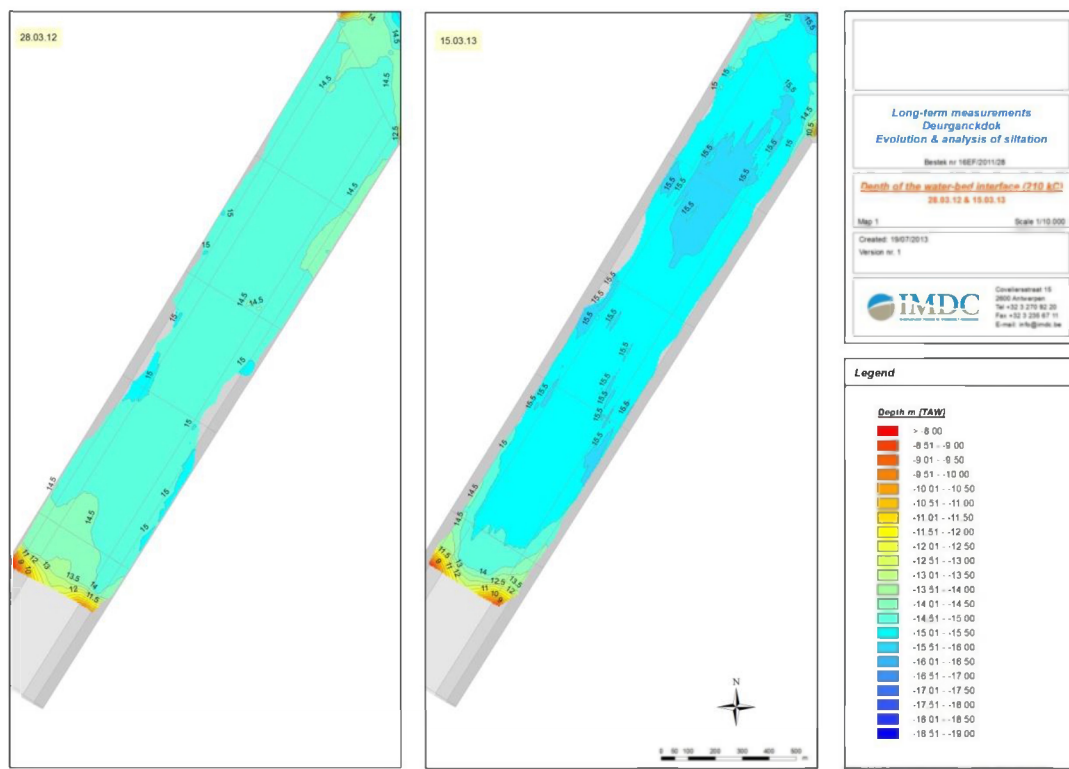


Figure 4-3: Map showing the depth of the water-bed interface (210 KC) for 28/03/2012 (first measurement) and 15/03/12 (last measurement).

4.3 EVOLUTION OF WATER-BED INTERFACE (210 KC)

GIS grid maps show the difference charts for every depth sounding in relation to a reference situation and to the previous sounding. Figure 4-4 shows such a difference chart covering the period of one year.

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 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 Annex C.



Figure 4-4: Difference charts of the depth sounding on 15/03/2013 in reference to 28/03/2013

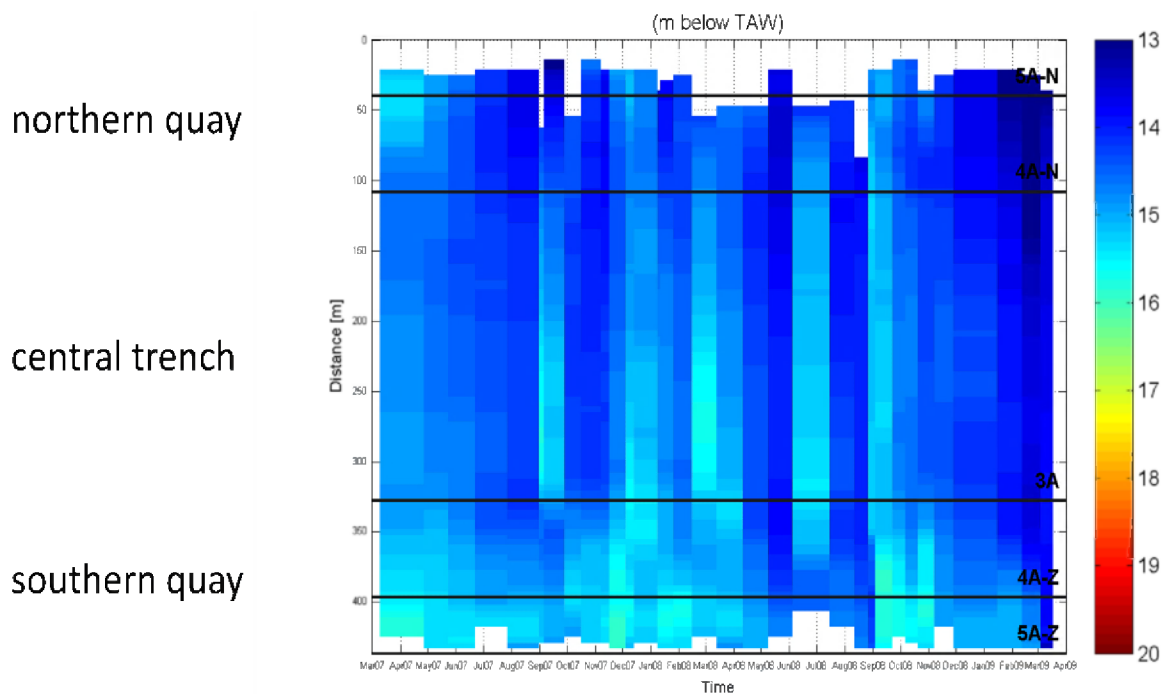


Figure 4-5: Example of a graph of evolution of the water-bed interface (210 kC).

4.4 VOLUMETRIC SILTATION RATES [CM/DAY] IN DIFFERENT ZONES AND SECTIONS

From the depth soundings, for the different zones and sections the volumetric siltation rates [cm/day] have been determined. A table with monthly average siltation rates for all (sub)zones is given in Annex D.1. Graphs in Annex D 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 : design depth) 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 the siltation rate and cumulative bed level change for the whole dock in Figure 4-6.

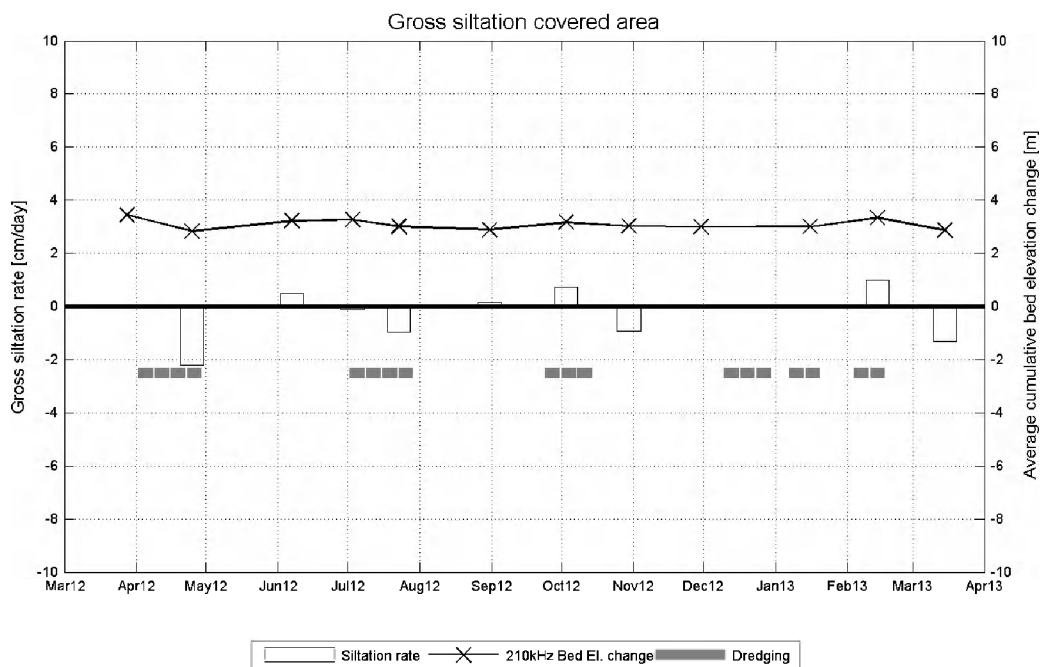


Figure 4-6: Volumetric siltation rate for the whole dock from March 2012 to March 2013.

4.5 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 4-7). 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/m^2 or $\text{Ton Dry Solids/m}^2$). 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 two years of data series are plotted in order to have a good view on the net mass evolution.

The averaged net mass growth rate [$\text{kg/m}^2/\text{day}$] is computed for each zone and subzone and is shown in Annex I. An example is shown in Figure 4-8 for the whole central trench (zones 3A to 3D, excluding 3E which is hardly dredged). In addition a similar graph is given in terms of total mass variation of the central trench rather than a growth rate per unit area.

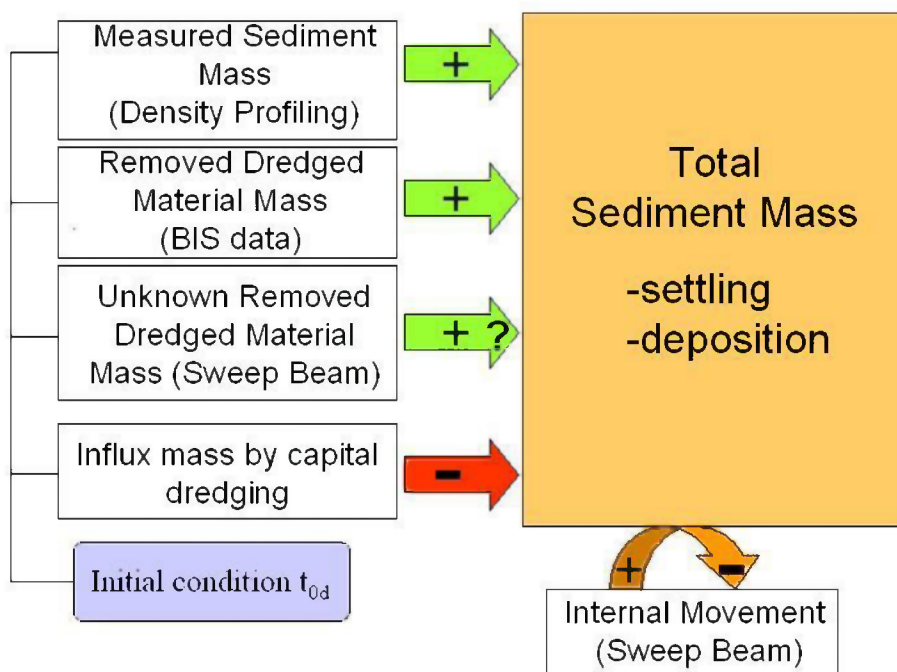


Figure 4-7: Flow chart with different elements contributing to total sediment mass for (sub)zones and total area

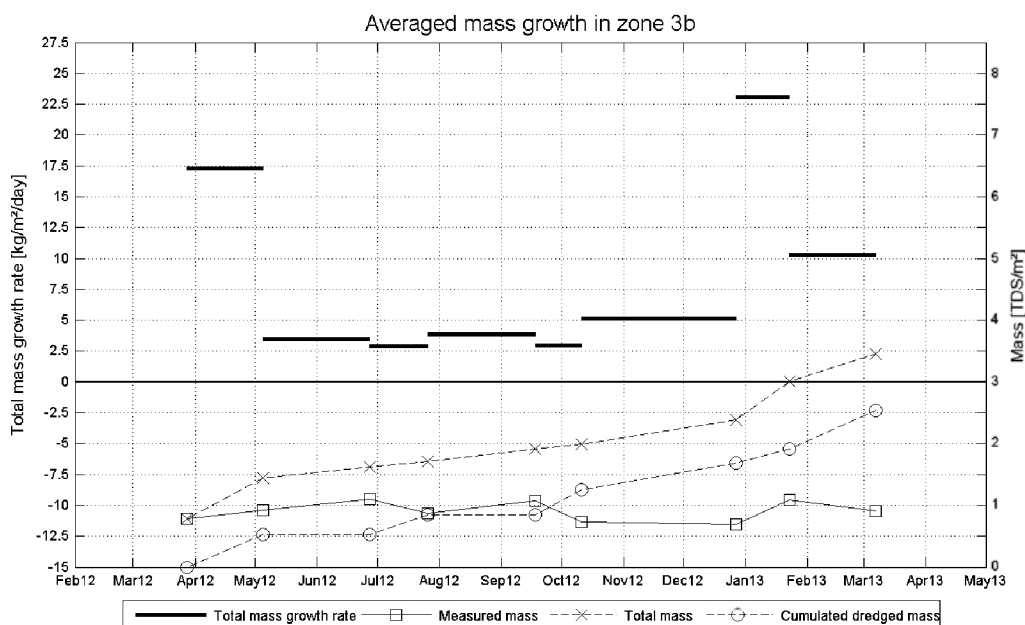


Figure 4-8: Example of averaged mass growth and mass evolution from April 2012 to March 2013 for the central trench (subzone 3B).

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 Annex I.1 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 [%]

Additionally, difference maps are presented in Annex H to visualize spatial variations of the total settled mass between two density profile measurements. The measured mass is calculated and interpolated in the whole dock from the density profiles, the mass dredged between the two measurements is not included.

5. PRELIMINARY ANALYSIS OF THE DATA

5.1 INTRODUCTION

This chapter discusses the measurements on a yearly basis.

With respect to the data analysis and its interpretation, it is important to keep in mind the different contributing terms in the sediment mass balance of each defined zone in the Deurganckdok:

$$\frac{dM_s}{dt} = R_{siltation} - R_{erosion} \pm R_{sweepbeam} - R_{maintenance} \pm R_{capitaldredging}$$

with:

- M_s = local amount of sediment mass [TDS]
- $R_{siltation}$ = sediment mass flux from siltation [TDS/day]
- $R_{erosion}$ = sediment erosive flux [TDS/day]
- $R_{sweepbeam}$ = mass flux from sweep beam dredging operations [TDS/day]
- $R_{maintenance}$ = mass flux from maintenance dredging [TDS/day]
- $R_{capitaldredging}$ = mass flux from capital dredging [TDS/day]

It is important to note that observations of bed level changes (from depth soundings and density measurements) refer to the gross effect of all contributing terms. Strictly seen, the siltation rate is only observed when no other process takes place at a specific location. With respect to the erosive flux, it is expected that flow velocities and shear forces are so low that erosion can be neglected from the mass balance.

The siltation in Deurganckdok can in fact be described in both a volumetric and a densimetric manner. The sediment volume is difficult to interpret because sediment volume is not conservative, i.e. sedimentation and consolidation increases the local sediment concentration. Sediment mass is therefore a better way of studying the siltation in the dock. However, due to the vast amount of depth soundings performed in this study and their additional information to density measurements, it is interesting to look at these data too.

Firstly, the 'volumetric siltation rate' is computed from the temporal bed level change as obtained from the depth soundings. Because different processes result in these observations, it is crucial to understand what is meant by the computed 'volumetric siltation rate'. For that reason, some definitions are considered important for the data interpretation:

- natural siltation rate: is computed from a time period in which only siltation occurs and no other external process;
- gross siltation rate: is computed from a time period in which other external processes occur besides the natural siltation;

The difference between these two definitions is schematised in Figure 5-1. Note that the gross siltation rate may also be larger than the natural one due to e.g. sweep beam activities, which may import sediment into the considered dock zone.

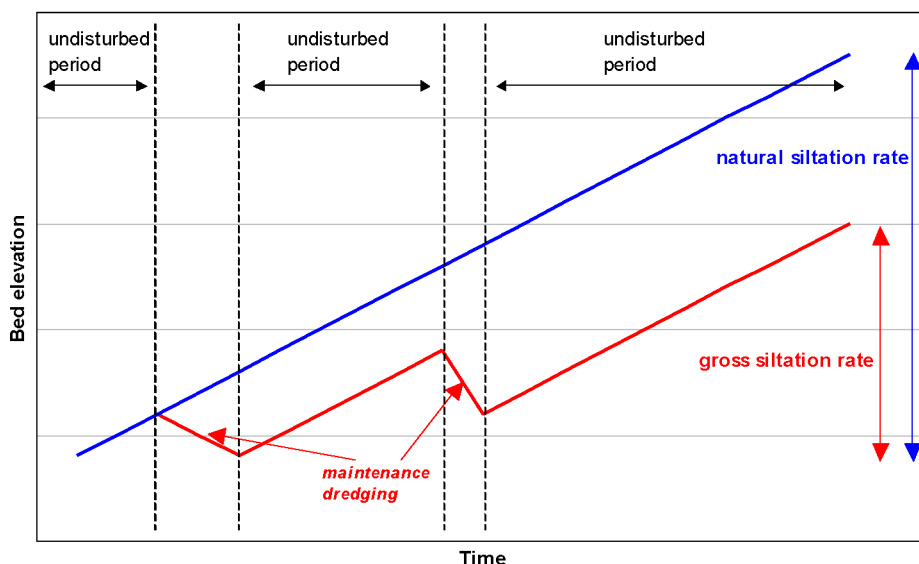


Figure 5-1: difference between natural and gross (volumetric) siltation rate

Secondly, the sediment mass distribution and its temporal evolution are studied. Here, densimetric growth rates can be calculated for the different dock zones. Because dredged mass is known, the sediment mass settled in a specific time frame can be computed, similar to the volumetric siltation rate as shown in Figure 5-1. Hence, according to Figure 5-2, the total sediment mass deposition rate (i.e. the densimetric growth rate) is to be computed as:

$$R_{siltation} = \frac{M_{meas,2} - M_{meas,1} + M_{dredge}}{t_2 - t_1}$$

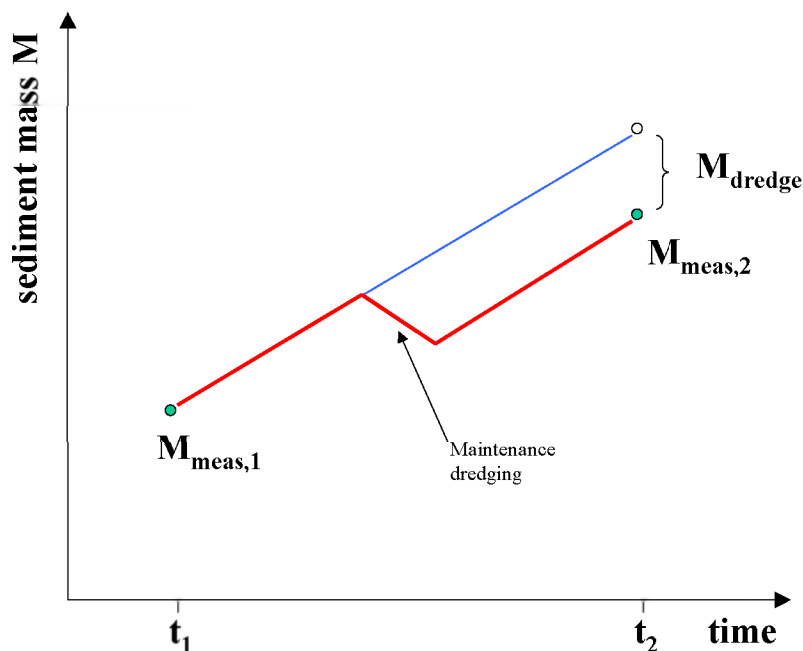


Figure 5-2: Principle of total deposited sediment mass calculated from the measured mass M_{meas} and dredged mass M_{dredge}

Seen the nature of collected data and their relation to the sediment balance, the chapter below will discuss the following topics:

- changes in elevation of the water-bed interface, i.e. the volumetric siltation rate;
- the accumulation of sediment mass in the dock, i.e. the densimetric siltation rate;
- and
- the dredged sediment mass.

5.2 VOLUMETRIC ANALYSIS

Depth sounding data was processed to show the evolution of the bed level as detected by the 210 kHz sounder. If more than 50% of the area of a (sub)zone was covered, an average bed level change was calculated.

Below, the natural and the gross yearly averaged siltation rates are discussed.

5.2.1 Gross yearly averaged siltation rate

To compute a gross yearly averaged siltation rate for every zone of the dock, the subsequent bed level measurements are used. As a consequence, effects from dredging activities are included in these results. The obtained siltation rates therefore refer to a gross yearly averaged siltation rate. This gross siltation rate is valid for the time period between March 28th 2012 and March 07th 2013.

The results are shown in Table 5-1, which indicate that, in general, gross siltation rates are very small and negative. This is in accordance with the comparable central trench bed level

(3a – 3d) and the lower bed level in zones 5Nd – 4Nd at the end of the year compared to the beginning (cf. Figure 4-3). This table shows a gross siltation rate of around -0.30 cm/day, with more variable estimates in zones 5Z and 5N due to their small size, lack of data and possible influence of sweep beam activities. No siltation rates are given for zone E because no depth soundings are available here. Observations are in agreement with the depth soundings: dredging activities maintained the bed level in several periods between the beginning of April 2012 and the end of March 2013.

Table 5-1: Gross yearly averaged siltation rates for every zone (cm/day).

Zone	5N	4N	3	4Z	5Z
A	-0.10	-0.26	-0.38	-0.31	-1.03
B	-0.29	-0.25	-0.37	-0.27	-1.67
C	-0.58	-0.19	-0.23	-0.21	-
D	-0.85	-0.12	-0.20	-0.12	-
E	-	-	-	-	-

5.2.2 Natural siltation rate

The observed siltation rates in §5.2.1 are the result of many processes of which natural siltation is only one. Human interferences such as maintenance and sweep beam dredging indeed largely influence the sediment balance of the dock. Whereas the maintenance dredging removes sediment from the dock, sweep beam dredging along the quays simply relocates the sediment towards the central trench (where it is removed by a subsequent maintenance dredging operation). Based on an IMDC turbidity experiment on a sweep beam plough in the harbour of Krankeloon could be observed that the bed material will re-suspended when the plough is moving (IMDC, 2009q) and will be also an influence on the natural siltation rate.

Quantifying the natural siltation is important as it determines the necessary dredging frequency. To do so, it is essential to identify undisturbed periods in which no human interferences took place. From the observed bed elevation trend during such a period, the natural siltation rate can be calculated. Note that siltation rates depend on local bathymetric and hydrodynamic conditions. Hence, it is important to acknowledge that calculated siltation rates cannot be generalised. The calculations however return an order of magnitude for the siltation rates and allow the investigation of any spatial distribution of this process variable.

When investigating the siltation in zones A - D (cf. Annex D.1), from Table 3-6 five periods can be identified being undisturbed by maintenance dredging, see Table 5-2. Of these, all periods experience sweepbeam dredging which may still influence the results.

Periods 1, 2 and 3 all contain subsequent depth soundings that can be used to assess natural siltation rates. The total mass dredged before each period is, respectively, 27.8%, 42.8% and 54% of the total mass of dredged sediment in the period from April 2nd 2012 until March 10th 2013

Table 5-2: Overview of periods investigated for natural siltation rates.

N°	Period	Time period (since last dredging) [days]	Total dredged amount ² [TDS]	% annual dredged amount ²
1	29/04/2012 – 02/07/2012	64	466 038	27.8 % of 2012-2013
2	29/07/2012 – 24/09/2012	57	251 675	15.0 %
3	14/10/2012 – 10/12/2012	57	186 734	11.1 %
4	24/12/2012 – 07/01/2013	14	258 205	15.4 %
5	16/01/2013 – 04/02/2013	19	80 379	4.8 %

² Dredged amount previous to undisturbed period

The natural siltation rates are determined based on two subsequent depth soundings which both lie within one of the periods of Table 5-2. The available natural siltation rates for the current investigated year are shown in Table 5-3. The following observations can be made:

- Natural siltation rates are higher than gross siltation rates: this is expected from the absence of dredging activities in these periods. In several zones negative siltation rates occur. This is most likely caused by sweep beam activities in the area.
- Siltation rates are approximately constant or decreasing towards the end of the dock: this corresponds to the observations of 2011-2012 and 2008-2009 (but not of 2009-2011). However, spatial trends are difficult to establish due to the spatial variation of dredging intensity over the years, which influences how fast the system locally returns to equilibrium. Siltation rates also do not account for mass.
- No data is available for the natural siltation in Zone 5
- In 2004, sediment transport simulations of Deurganckdok were performed in order to investigate natural siltation rates (IMDC, 2004). The applied mathematical model indicated that the first one third of the dock, near the Scheldt, was characterised with a siltation rate of 1.4 cm/day and decreased when going more inside the dock. The sediment transport simulations of Van Maren (2006a; 2006b) predicted a decrease of the natural siltation of approximately 15% – 18% due to the effect of the Current Deflecting Wall. The siltation rate of 1.4 cm/day then decreases to 1.19 – 1.15 cm/day. This spatial trend of siltation rates inside the dock is similar to what is found during the different periods. The siltation decreases inside the docks to increase again near the end of the dock. The value of 1.19 – 1.15 cm/day exceeds the values measured (max. 1.00 cm/day). The natural siltation rates and the observed sediment concentrations in river Scheldt (IMDC, 2013c) seem to be smaller compared to previous years. This indicates that the natural siltation rates within Deurganckdock are reduced by probably a combination of decrease of sediment concentration in the River Scheldt and the built of the current deflecting wall. Although more siltation measurements are required to make a definitive conclusion on this matter.
- In several cases negative natural siltation rates are observed, which seem to indicate erosion. However these values are most likely caused by sweep beam

activities (whose influence is neglected during the calculations of these values. Furthermore, for periods 1 and 2, dredging activities have occurred near the start/end of the considered period (dredging activities respectively 02/Jul – 08/Jul and 23/Jul-29/Jul). These activities also influence results regarding the natural siltation rate in the area.

Table 5-3: Natural siltation rates obtained from undisturbed (except for sweepbeam dredging) measurement periods (empty if no data during measurement period). Siltation rates calculated between two consecutive depth soundings (indicated in table header).

Zone	Natural siltation rates [cm/day]			
	Spring (period 1) 07/Jun – 03/Jul '12	Summer (period 2) 27/Jul – 31/Aug '12	Autumn (period 3) 30/Oct – 30/Nov '12	Winter (period 4 & 5)
3a	0.88	0.88	0.12	-
3b	0.44	0.31	-0.33	-
3c	0.36	0.09	0.00	-
3d	-0.05	0.26	0.34	-
4Na	0.97	0.26	0.40	-
4Nb	0.66	-0.54	-0.43	-
4Nc	-0.01	-0.04	-0.29	-
4Nd	-0.39	0.06	0.57	-
4Za	1.00	0.43	0.42	-
4Zb	0.50	-0.27	-0.24	-
4Zc	0.50	-0.65	-0.43	-
4Zd	-0.38	-0.71	-0.08	-
5Na		-0.25		-
5Nb				-
5Nc		-0.66		-
5Nd		-0.67		-
5Za		-0.29		-
5Zb				-

5.3 DENSIMETRIC SILTATION RATE

The volumetric siltation rate, computed from 210 kHz depth sounding profiles, does not reveal the amount of mass that settled. Information on the consolidation process remains unknown too. For that reason, a densimetric analysis is performed as well. In this chapter, both the dredging and the sediment mass accumulation in the dock are discussed.

5.3.1 Dredged sediment mass

From the BIS data (see Table 5-6), it can be concluded that almost 1.6 million TDS was dredged over the entire measurement period (April 1st 2012 to March 31st 2013, 364 days). This is 21% less than the previous measurement period of April 1st 2011 to March 31st 2012, when 2.0 million TDS were dredged and 4% less than during the 2011 – 2012 measurement period.

During the measurement period of 2011 – 2012 it was decided to maintain Deurganckdok at a level of 18.72 mTAW (18.0 mLAT) which is 0.5 m deeper than the maintenance level before. Therefore more material had to be dredged to accomplish this. Since April 2008 no capital dredging activities were performed, only maintenance dredging. Therefore it is to be expected that less sediment was to be dredged during the period 2012 -2013.

Table 5-4: Overview of the maintenance depth in Deurganckdok.

Period	Maintenance depth quays [mLAT]	Maintenance depth trench [mLAT]	Maintenance deptg sill [mLAT]
May 2008 – December 2010	14.8 – 15.7 m (variable)	15.0 – 17.0 m (variable)	No maintenance of sill except sweepbeam
December 2010	-	-	14.8 – 15.5 m (variable)
March 2011	15.9 m	17.5 m	15.2 m
October 2012	-	18.0 m	-

According to Table 5-6, more than half of the dredging occurred during two periods, firstly between beginning of April 2012 and end of May 2012 (28.0%), secondly in January and March 2013 (25.7%). 61.5 % from the central trench (zones 3a to 3d), 18.0% from the zones 5N and 5Z, 15.3 % from the sill (zones 1 and 2) and 5.1 % from the end of the dock (zone 3e). No sediment was dredged in zones 4N and 4Z, in which only sweepbeam dredging occurs.

Table 5-5: Overview of the total dredged mass per year in Deurganckdok.

Period	Dredged mass [TDS]
April 2007 – March 2008	14 587 900
April 2008 – March 2009	1 092 453
April 2009 – March 2010	1 310 519
April 2010 – March 2011	1 922 003
April 2011 – March 2012	1 987 293
April 2012 – March 2013	1 511 104

Table 5-6 : Dredged mass (TDS) per zone and dredging period between density measurement campaigns.

Date of campaigns / Zone	28-Mar-12 08-May-12	08-May-12 27-Jun-12	27-Jun-12 26-Jul-12	26-Jul-12 18-Sep-12	18-Sep-12 11-Oct-12	11-Oct-12 27-Dec-12	27-Dec-12 23-Jan-13	23-Jan-13 07-Mar-13	Total	Percentage [%]
1	26 717	0	18 936	0	5 483	11 812	352	5 364	68 664	4.5%
2	56 470	0	36 258	0	20 764	38 185	1 394	10 794	163 866	10.8%
3a	53 759	0	47 650	0	39 160	58 413	10 655	48 381	258 018	17.1%
3b	52 337	0	31 156	0	40 604	42 994	22 631	61 684	251 406	16.6%
3c	44 745	0	17 795	0	24 939	17 107	16 520	69 698	190 806	12.6%
3d	67 024	0	23 108	0	17 570	8 768	13 712	99 458	229 640	15.2%
3e	37 272	0	5 218	0	1 772	683	1 781	29 677	76 402	5.1%
4Na	0	0	6	0	0	0	0	0	6	0.0%
4Nb	0	0	0	0	0	0	0	0	0	0.0%
4Nc	17	0	0	0	0	0	0	0	17	0.0%
4Nd	0	0	0	0	0	0	0	45	45	0.0%
4Ne	0	0	0	0	0	0	0	0	0	0.0%
4Za	25	0	58	0	0	4	0	0	87	0.0%
4Zb	0	0	39	0	0	10	0	6	55	0.0%
4Zc	0	0	0	0	0	0	0	0	0	0.0%
4Zd	29	0	0	0	0	0	0	0	29	0.0%
4Ze	0	0	0	0	0	0	0	0	0	0.0%
5Na	17 844	0	10 510	0	4 021	18 182	476	9 638	60 670	4.0%
5Nb	10 701	0	5 779	0	2 864	10 157	1 184	8 925	39 610	2.6%

Date of campaigns / Zone	28-Mar-12 08-May-12	08-May-12 27-Jun-12	27-Jun-12 26-Jul-12	26-Jul-12 18-Sep-12	18-Sep-12 11-Oct-12	11-Oct-12 27-Dec-12	27-Dec-12 23-Jan-13	23-Jan-13 07-Mar-13	Total	Percentage [%]
5Nc	5 131	0	2 759	0	827	3,006	362	8 200	20 285	1.3%
5Nd	10 028	0	2 277	0	759	508	170	8 405	22 146	1.5%
5Ne	3 847	0	198	0	0	73	57	689	4,865	0.3%
5Za	11 143	0	10 000	0	4 409	12 026	530	4 201	42 309	2.8%
5Zb	9 834	0	5 655	0	2 684	10 228	912	8 465	37 778	2.5%
5Zc	5 531	0	2 891	0	978	2 770	842	6 541	19 553	1.3%
5Zd	8 142	0	3 345	0	831	835	1 067	7 908	22 128	1.5%
5Ze	2 013	0	271	0	9	41	201	183	2 718	0.2%
Total 3a-3d	255 137	0	124 927	0	124 045	127 965	65 299	308 899	1 006 272	66.6%
Total	422 610	0	223 908	0	167 673	235 804	72 846	388 264	1 511 104	100.0%
%	28.0%	0.0%	14.8%	0.0%	11.1%	15.6%	4.8%	25.7%	100.0%	

5.3.2 Densimetric growth rate

All observed growth rates are shown in Table 7-8 (cf. Annex I.1). For each zone the time evolution of the settled sediment mass is shown as quasi linearly increasing in time for the central trench area. The growth rates for the separate zones in the central trench are shown in Table 5-7. They are generally smaller than the growth rates during previous years.

Table 5-7: Densimetric growth rates in the central trench area, estimated from the total mass.

ZONE	Range of growth rate 2012-2013 [kg/m ² /day]	Avg growth rate 2012-2013 [kg/m ² /day]
3A	-2 to 11	4.96
3B	-1 to 10	3.61
3C	0 to 7	2.24
3D	-4 to 7	1.51

Table 5-8 shows the influence of dredging on the densimetric growth rates in the central trench, from 2007 to 2013. The difference in growth rates in the presence and absence of dredging can be due to two factors: maintenance dredging results in a lower bed level and a higher siltation rate, while sweepbeam dredging results in an artificial influx of sediment in the central trench. The highest growth rates during dredging are created when dredging occurs deeper than the reference measurement, resulting in a dredged “excess” which also has a higher dredged mass (because of the higher density). This causes the high growth rates not only to include new sediment mass which entered the dock between the considered density measurements but to also include sediment mass which was already in the dock at the reference measurement. The highest total “growth” rates were measured during and after the dredging campaigns of May 2011 and December 2011 – January 2012, during which the bed level has been deepened by around 1.0 m (cf. difference maps in Report 1.3 Annex C.1 (09/06/2011 – 06/05/2011; 18/01/2012 – 28/11/2011)).

Densimetric growth rates were similar to slightly smaller near the quays in comparison to the values observed in the central trench, and generally were in the order of -1 to 5 kg/m²/day, with maximum values around 13 kg/m²/day. Growth rates are sometimes negative near the quay walls, where sweepbeam dredging took place (cf. Table 7-8 in Annex I.1). These observations are in accordance with previous measurements.

Table 5-8: Influence of dredging on densimetric growth rates in the central trench area (3A-D)

kg/m ² /day	2007 – 2008	2008 – 2009	2009 – 2010	2010 – 2011	2011 – 2012	2012 - 2013
no dredging	2 – 8	1 – 15	2 – 8	-1 – 6	2 – 6	2 – 7
dredging	11 – 20	8 – 25	10 – 30	9 – 19	4 – 26	-4 – 19
difference	~10	~5 – 10	~10 – 20	~10	~5 – 20	-6 – 12

5.3.3 Total (cumulative) mass

Annex I.1 shows the total cumulative mass for the currently considered year in Table 7-6 and Table 7-7. This is visualised in Annex 7.1.2 for each separate zone and in Annex I.3 for the central trench area. In Figure 4-8 this is shown for the previous and current years (March 2011 – March 2013). These tables present the total cumulative mass calculated in each zone during each density campaign. The total cumulative mass is the sum of the measured mass with reference to the design level (cf. Table 7-3 and Table 7-4 in Annex I.2) and the cumulative dredged mass since March 20th 2010 (cf. Table 5-6).

Zones 3A-D and 4A-D (Z and N) have 100 % coverage, zones 5 and E (landside end) have a varying degree of coverage, sometimes under 50 % (cf. Table 7-11 in Annex I.1).

The data shows a higher cumulative sediment mass near the entrance of the dock (zone 3a) and increasing again at the end of the dock (zone 3d compared to zone 3c). This is also shown in Table 5-9.

Table 5-9: Mass settled per subzone in zones 3 and 4 (measured + dredged, in 10³ TDS) from March 2012 to March 2013.

	28/Mar 05/May	05/May 27/Jun	27/Jun 26/Jul	26/Jul 18/sep	18/Sep 11/Oct	11/Oct 23/Jan	23/Jan 07/Mar	Total
zone A	92	0	77	0	53	110	18	349
zone B	80	0	48	0	52	97	16	293
zone C	61	0	26	0	30	45	20	183
zone D	94	0	32	0	22	28	31	207
Total	327	0	184	0	156	280	85	1032

6. CONCLUSIONS AND LIMITATIONS

The present report aims at quantifying the different processes that contribute to the sediment balance in order to compute the sediment influx from the Scheldt. The different contributions are schematically shown in Figure 2-2 and the sediment balance equation is to be found in §5.1. During this reporting period, different density profilers are used. Each instrument has his own technical qualities (e.g. accuracies or ranges) to measure the density and must be taken into account during the interpretation. From previous research (IMDC, 2005; 2009r), it could be observed that the DensiTune measured higher densities at a specific depth in comparison to the Navitracker.

As in previous years, the 2012 – 2013 campaign covered an entire year of densimetric measurements enabling the setup of a mass balance. Different processes of the sediment transport have been considered densimetrically, such as:

- maintenance dredging;
- capital dredging;
- settling and consolidation (measured indirectly by the local sediment densities).

Only one process has been inadequately described, i.e. the sweep beam actions. Although the depth of the rake or plough and its location is known. Based on an IMDC turbidity experiment on a sweep beam plough in the harbour of Krakenloop could be observed that the bed material will re-suspended when the plough is moving (IMDC, 2009q). It is difficult to estimate the transport capacity of the re-suspension in the environment of the dock. The sweep beam data has therefore only been used for data interpretation.

The bed level measured by the depth soundings was approximately the same at the start (28/03/2011) and end (15/03/2012) of the considered year. The natural siltation rate (estimated to be 1 – 3 cm/day) is smaller compared to previous years. Lack of data on natural siltation rates might influence these results. On the other hand 21% less sediment mass was dredged compared to the previous year.

Important dredging activities took place from end of March 2012 to the end of May 2012, and accounted for 28.0% of the total dredged mass. Also the period January-March was important (25.7% of the total dredged mass).

The construction of the current deflecting wall (CDW) near the northern entrance of the dock was finished in August 2011. The present considered year is therefore the second complete year where the influence of the CDW can be investigated. Several factors have made it very difficult to make an investigation and a conclusion of the effect of the Current Deflecting Wall:

- The considered year was marked by a lot of dredging activity: Sweep beam dredging almost all year round and long periods of maintenance dredging have caused limited data with regard to the natural siltation rate;
- The evolution of sediment concentrations in the Scheldt river in relation to the deeper dredging of the dock should be investigated.

More analyses are required to better evaluate the effect of the Current Deflecting Wall on the natural siltation. This was executed in the general analysis report for the period 2009 - 2012 (IMDC, 2013a) and will be repeated for the measurement period 2012 - 2014.

7. REFERENCES

AWZ (2000): Baggerwerken 2000, Westerschelde en Zeeschelde

DotOcean (2013), Consulting the website about information on the GraviProbe, http://www.dotocean.eu/en/products/graviprobe_free_fall_penetrometer

IMDC (2002). Studie Densiteitsstroming in het kader van LTV Schelde, Stroom- en saliniteitsmeting t.h.v. Deurganckdok uitgevoerd op 12/06/202, I/RA/11216/02.042/CMA.

IMDC (2005). Kritische kwaliteitsanalyse peilplannen Havenbedrijf Antwerpen, gegenereerd met multibeam (I/RA/11272/05.038/MSA)

IMDC (2005a). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 1: Test survey 17/02/2005, I/RA/11265/05.008/MSA.

IMDC (2005b). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 2.1: Deurganckdok 17/02/2005, I/RA/11265/05.009/MSA.

IMDC (2005c). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 2.2: Zandvliet 17/02/2005, I/RA/11265/05.010/MSA.

IMDC (2005d). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 2.3: Liefkenshoek 17/02/2005, I/RA/11265/05.0011/MSA.

IMDC (2005e). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 2.4: Schelle 17/02/2005, I/RA/11265/05.0012/MSA.

IMDC (2005f). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 2.5: Deurganckdok 16/02/2005, I/RA/11265/05.013/MSA.

IMDC (2005g). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 2.6: Kallosluis 18/02/2005, I/RA/11265/05.014/MSA.

IMDC (2005h). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 2.7: Near bed continious monitoring: february 2005, I/RA/11265/05.015/MSA.

IMDC (2005i). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 3: Settling velocity INSSEV february 2005, I/RA/11265/05.016/MSA.

IMDC (2005j). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 4: Cohesive sediment properties february 2005, I/RA/11265/05.017/MSA

IMDC (2005k). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 5.1:

Overview of ambient conditions in the river Scheldt January-June 2005, I/RA/11265/05.018/MSA.

IMDC (2005l). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 5.2: Overview of ambient conditions in the river Scheldt July-December 2005, I/RA/11265/05.019/MSA.

IMDC (2006a) Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 6.1 Calibration Winter 15 March & 14 April 2006? I/RA/11291/06.092/MSA.

IMDC (2006b) Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 7.1 21 March 2006 Scheldewacht – Deurganckdok, I/RA/11291/06.094/MSA.

IMDC (2006c) Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 7.2 22 March 2006 Parel 2 – Deurganckdok (downstream), I/RA/11291/06.095/MSA.

IMDC (2006d) Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 7.3 22 March 2006 Laure Marie – Liefkenshoek, I/RA/11291/06.096/MSA.

IMDC (2006e) Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 7.4 23 March 2006 Parel 2 – Schelle, I/RA/11291/06.097/MSA.

IMDC (2006f) Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 7.5 23 March 2006 Laure Marie – Deurganckdok (downstream), I/RA/11291/06.098/MSA.

IMDC (2006g) Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 7.6 23 March 2006 Veremans – Waarde, I/RA/11291/06.099/MSA.

IMDC (2006h) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.1 Opmeting stroming en zout- en sedimentbeweging aan de ingang van het Deurganckdok (SiltProfiler), I/RA/11283/06.087/WGO.

IMDC (2006i) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.3. Opmeting stroming en zout-en sedimentbeweging aan de ingang van het Deurganckdok (ADCP), I/RA/11283/06.110/BDC

IMDC (2006j). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 8.1: Vaste meetopstelling in zake bodemgedrag, I/RA/11291/06.100/MSA.

IMDC (2006k) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.6 Zout en slibverdeling Deurganckdok 17/03/2006 – 23/05/2006, I/RA/11283/06.121/MSA.

IMDC (2006l) Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 5.3 Overview

of ambient conditions in the river Scheldt – January-June 2006 (I/RA/11291/06.089/MSA), in opdracht van AWZ.

IMDC (2006m): Studie van de stromingsvelden en sedimentuitwisseling aan de ingang van Deurganckdok. Current and Sediment flux measurements November 17th 2005 (I/RA/15030/06.021/BDC).

IMDC(2006n): Studie van de stromingsvelden en sedimentuitwisseling aan de ingang van Deurganckdok. Additional processing of ADCP and salinity data 17/11/2005 and 28/11/2005 (I/RA/15030/06.040/BDC).

IMDC (2006o). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 9: Valsnelheid slib – INSSEV, I/RA/11291/06.102/MSA, in opdracht van AWZ.

IMDC (2006p). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 2.7: Silt distribution and frame measurements 15/07/2006 – 31/10/2006. (I/RA/11291/06.122/MSA).

IMDC (2006q) Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 5.3 Overview of ambient conditions in the river Scheldt – Januari-June 2006 (I/RA/11291/06.089/MSA), in opdracht van AWZ.

IMDC (2006r) Mer verruiming Westerschelde, Nota Bovenafvoer Scheldebekken, I/NO/11282/06.104/FPE.

IMDC (2006s). Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.07 Zout en slibverdeling Deurganckdok 15/07/2006 – 31/10/2006, I/RA/11283/06.122/MSA.

IMDC (2007a) Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 6.2 Summer calibration and Final report, I/RA/11291/06.093/MSA.

IMDC (2007b). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 5.4 Overview of ambient conditions in the river Scheldt – July-December 2006 (I/RA/11291/06.089/MSA), in opdracht van AWZ.

IMDC (2007c). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 11.1 Through tide Measurement Sediview & Siltprofiler 27/9 Stream - Liefkenshoek (I/RA/11291/06.104/MSA), in opdracht van AWZ.

IMDC (2007d). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 11.2 Through tide Measurement Sediview 27/9 Veremans - Raai K (I/RA/11291/06.105/MSA), in opdracht van AWZ.

IMDC (2007e). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 11.3 Through tide Measurement Sediview & Siltprofiler 28/9 Stream - Raai K (I/RA/11291/06.106/MSA), in opdracht van AWZ.

IMDC (2007f). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 11.4 Through tide Measurement Sediview 28/9 Veremans - Waarde(I/RA/11291/06.107/MSA), in opdracht van AWZ.

IMDC (2007g). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 11.5 Through tide Measurement Sediview 28/9 Parel 2 - Schelle (I/RA/11291/06.108/MSA), in opdracht van AWZ.

IMDC (2007h). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 11.6 Through tide Measurement Salinity Distribution 26/9 Scheldewacht – Deurganckdok in opdracht van AWZ.

IMDC (2007i) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 1.1 Sediment Balance: Three monthly report 1/4/2006 – 30/06/2006 (I/RA/11283/06.113/MSA)

IMDC (2007j) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 1.2 Sediment Balance: Three monthly report 1/7/2006 – 30/09/2006 (I/RA/11283/06.114/MSA)

IMDC (2007k) 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)

IMDC (2007l) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 1.4 Sediment Balance: Three monthly report 1/1/2007 – 31/03/2007 (I/RA/11283/06.116/MSA)

IMDC (2007m) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 1.5 Annual Sediment Balance (I/RA/11283/06.117/MSA)

IMDC (2007n) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.2 Through tide measurement SiltProfiler 26/09/2006 Stream (I/RA/11283/06.068/MSA)

IMDC (2007o) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.4 Through tide measurement Sediview spring tide 27/09/2006 Parel 2 (I/RA/11283/06.119/MSA)

IMDC (2007p) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.7 Salt-Silt distribution & Frame Measurements Deurganckdok 15/07/2006 – 31/10/2006 (I/RA/11283/06.122/MSA)

IMDC (2007q) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.8 Salt-Silt distribution & Frame Measurements Deurganckdok 15/01/2007 – 15/03/2007 (I/RA/11283/06.123/MSA)

IMDC (2007r) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 3.1 Boundary conditions: Three monthly report 1/1/2007 – 31/03/2007 (I/RA/11283/06.127/MSA)

IMDC (2007s) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing
Deelrapport 1.10: Sediment Balance: Three monthly report 1/4/2007 – 30/06/2007
(I/RA/11283/07.081/MSA)

IMDC (2007t) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 1.11: Sediment Balance: Three monthly report 1/7/2007 – 30/09/2007
(I/RA/11283/07.082/MSA)

IMDC (2007v) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 2.16: Salt-Silt distribution Deurganckdok summer (21/6/2007 – 30/07/2007)
(I/RA/11283/07.092/MSA)

IMDC (2007w) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 3.10: Boundary conditions: Three monthly report 1/04/2007 – 30/06/2007
(I/RA/11283/07.097/MSA)

IMDC (2007u) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 3.11: Boundary conditions: Two monthly report 1/07/2007 – 30/09/2007
(I/RA/11283/07.098/MSA)

IMDC (2008a) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 2.5: Through tide measurement Sediview average tide 24/10/2007
(I/RA/11283/06.120/MSA)

IMDC (2008b) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 4.1: Analysis of siltation Processes and Factors (I/RA/11283/06.129/MSA)

IMDC (2008c) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 1.12: Sediment Balance: Four monthly report 1/9/2007 – 31/12/2007
(I/RA/11283/07.083/MSA)

IMDC (2008d) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 1.13: Sediment Balance: Four monthly report 1/01/2007 – 31/03/2007
(I/RA/11283/07.084/MSA)

IMDC (2008e) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 1.14: Annual Sediment Balance. (I/RA/11283/07.085/MSA)

IMDC (2008f) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 2.09: Calibration stationary equipment autumn (I/RA/11283/07.095/MSA)

IMDC (2008g) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 2.10: Through tide measurement SiltProfiler 23 October 2007
(I/RA/11283/07.086/MSA)

IMDC (2008h) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 2.11: Through tide measurement Salinity Profiling winter 12 March 2008
(I/RA/11283/07.087/MSA)

IMDC (2008i) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 2.12: Through tide measurement Sediview winter 11 March 2008 – Transect I
(I/RA/11283/07.088/MSA)

IMDC (2008j) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 2.13: Through tide measurement Sediview winter 11 March 2008 – Transect K
(I/RA/11283/07.089/MSA)

IMDC (2008k) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 2.14: Through tide measurement Sediview winter 11 March 2008 – Transect DGD
(I/RA/11283/07.090/MSA)

IMDC (2008l) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 2.15: Through tide measurement SiltProfiler winter 12 March 2008
(I/RA/11283/07.091/MSA)

IMDC (2008m) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 2.17: Salt-Silt distribution & Frame Measurements Deurganckdok autumn
(17/9/2007-10/12/2007) (I/RA/11283/07.093/MSA)

IMDC (2008n) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 2.18: Salt-Silt distribution & Frame Measurements Deurganckdok winter
(18/02/2007-31/03/2008) (I/RA/11283/07.094/MSA)

IMDC (2008o) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 2.19: Calibration stationary & mobile equipment winter (I/RA/11283/07.096/MSA)

IMDC (2008p) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 3.12: Boundary conditions: Three monthly report 1/9/2007 – 31/12/2007
(I/RA/11283/07.099/MSA)

IMDC (2008q) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 3.13: Boundary conditions: Three monthly report 1/1/2008 – 31/3/2007
(I/RA/11283/07.100/MSA)

IMDC (2008r) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 3.14: Boundary conditions: Annual report (I/RA/11283/07.101/MSA)

IMDC (2008s) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 4.10: Analysis of siltation Processes and Factors (I/RA/11283/07.102/MSA)

IMDC (2008t) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing
Deelrapport 1.20: Sediment Balance: Three monthly report 1/4/2008 – 30/06/2008
(I/RA/11283/08.076/MSA)

IMDC (2008u) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 2.20: Through tide measurement Sediview during average tide Spring 2008 – 19
June 2008 (I/RA/11283/08.081/MSA)

IMDC (2008v) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 2.21: Through tide measurement Sediview during average tide Spring 2008 – 26
June 2008 (I/RA/11283/08.082/MSA)

IMDC (2008w) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing
Deelrapport 1.21: Sediment Balance: Three monthly report 1/7/2008 – 30/09/2008
(I/RA/11283/08.077/MSA)

IMDC (2008x) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 2.22: Through tide measurement Sediview during neap tide Summer 2008 – 24
September 2008 (I/RA/11283/08.083/MSA)

IMDC (2008y) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 2.28: Through tide measurement ADCP eddy Summer 2008 – 1 October 2008
(I/RA/11283/08.089/MSA)

IMDC (2008z) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 2.32: Salt-Silt distribution Deurganckdok: six monthly report 1/4/2008 – 30/9/2008
(I/RA/11283/08.093/MSA)

IMDC (2008aa) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 3.20: Boundary conditions: Six monthly report 1/4/2008 – 30/09/2008
(I/RA/11283/08.096/MSA)

IMDC (2009a) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 2.23: Through tide measurement Sediview during spring tide Summer 2008 – 30
September 2008 (I/RA/11283/08.084/MSA)

IMDC (2009b) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 2.29: Through tide measurement SiltProfiler summer 2008 – 29 September 2008
(I/RA/11283/07.090/MSA)

IMDC (2009c) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 2.34: Calibration stationary & mobile equipment autumn 2008
(I/RA/11283/08.095/MSA)

IMDC (2009d) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing
Deelrapport 1.22: Sediment Balance: Three monthly report 1/10/2008 – 31/12/2008
(I/RA/11283/08.078/MSA)

IMDC (2009e) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 2.24: Through tide measurement Sediview during neap tide Autumn 2008
(I/RA/11283/08.085/MSA)

IMDC (2009f) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 2.25: Through tide measurement Sediview during spring tide Autumn 2008
(I/RA/11283/08.086/MSA)

IMDC (2009g) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing
Deelrapport 1.23: Sediment Balance: Three monthly report 1/01/2009 – 31/03/2009
(I/RA/11283/08.079/MSA)

IMDC (2009h) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing
Deelrapport 1.24: Annual Sediment Balance (I/RA/11283/08.080/MSA)

IMDC (2009i) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 2.26: Through tide measurement Sediview during neap tide Winter 2009
(I/RA/11283/08.087/MSA)

IMDC (2009j) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 2.30: Through tide measurement SiltProfiler winter 2009
(I/RA/11283/08.091/MSA)

IMDC (2009k) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 2.31: Through tide measurement Salinity Profiling winter 2009
(I/RA/11283/08.092/MSA)

IMDC (2009l) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing.
Deelrapport 2.33: Salt-Silt distribution Deurganckdok: six monthly report 1/10/2008 –
31/3/2009 (I/RA/11283/08.094/MSA)

IMDC (2009m) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 3.21: Boundary conditions: Six monthly report 1/10/2008 – 31/03/2009 (I/RA/11283/08.097/MSA)

IMDC (2009n) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.27: Through tide measurement Sediview during spring tide Winter 2009 (I/RA/11283/08.088/MSA)

IMDC (2009o) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 4.20: Analysis of siltation Processes and Factors (I/RA/11283/08.098/MSA)

IMDC (2009p) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.35: Salt-Silt distribution Deurganckdok: nine monthly report 1/04/2009 – 31/12/2009 (I/RA/11283/09.085/MSA)

IMDC (2009q) Turbidity experiment Dredging Plough. Factual data report turbidity measurements around the Alligator at krankeloon harbour, Antwerp commissioned by DEME - Dredging International (I/RA/17117/08.111/JME).

IMDC (2009r) Zoet Zout zeebrugge. Memo: Comparison RheoTune versus NaviTracker, commissioned by afdeling Martieme Toegang.

IMDC (2010a) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 2.5 Through Tide measurement: eddy currents DGD 02/03/2010 (I/RA/11283/10.051/MSA)

IMDC (2010b) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 2.8 Sal-Silt distribution Deurganckdok 01/04/2009 – 31/03/2010 (I/RA/11354/10.068/NZI)

IMDC (2011a) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 1.1 Annual Sediment Balance year 1: 1/04/2009 – 31/03/2010 (I/RA/11354/10.067/NZI)

IMDC (2011b) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 1.2 Annual Sediment Balance year 2: 1/04/2009 – 31/03/2010 (I/RA/11354/10.100/MBO/ANF)

IMDC (2011c) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 1.4 Boundary Conditions year 1: 01/04/2009 – 31/03/2010 (I/RA/11354/10.102/MBO/ANF)

IMDC (2011d) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 1.7 Synthesis report of research on Current Deflecting Wall (I/RA/11354/10.063/MBO)

IMDC (2012a) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 2.1 Through Tide Sediview measurement: entrance DGD during spring tide in Autumn 2011 (I/RA/11354/10.106/MBO/ANF)

IMDC (2012b) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 2.1 Through Tide Sediview measurement: entrance DGD during neap tide in Autumn 2011 (I/RA/11354/10.107/MBO/ANF)

IMDC (2012c) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 2.5 Through Tide measurement: eddy currents DGD Autumn 2011 (I/RA/11354/10.110/MBO/ANF)

IMDC (2012d) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 2.10 Salt-Silt & Current Distribution entrance Deurganckdok: Frame measurements and through tide measurements: Autumn 2011 (I/RA/11354/11.131/BQU)

IMDC (2012e) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 2.12 Calibration stationary & mobile equipment 16/03/2011 (I/RA/11354/11.113/MBO/ANF)

IMDC (2012f) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 1.5 Boundary conditions year 2: 01/04/2010 – 31/03/2011 (I/RA/11354/11.103/MBO/ANF)

IMDC (2012g) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 2.3 Through Tide Sediview measurement: entrance DGD during spring tide in Winter 2012 (I/RA/11354/10.108/MBO/ANF)

IMDC (2012h) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 2.4 Through Tide Sediview measurement: entrance DGD during neap tide in Winter 2012 (I/RA/11354/10.109/MBO/ANF)

IMDC (2012k) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 2.7 Through Tide measurement: eddy currents DGD Winter 2012 (I/RA/11354/10.111/MBO/ANF)

IMDC (2012l) Evaluatie externe effecten aanslibbing Deurganckdok Deelrapport 2.11 Salt-Silt & Current Distribution entrance Deurganckdok: Frame measurements and through tide measurements: Winter 2012 (I/RA/11354/11.114/MBO/ANF)

IMDC (2012m) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 1.3 Annual Sediment Balance year 3: 1/04/2011 – 31/03/2012 (I/RA/11354/10.101/MBO/ANF)

IMDC (2012n) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 2.9 Salt-Silt distribution Deurganckdok 01/04/2009 – 31/05/2010 (I/RA/11354/10.112/MBO/ANF)

IMDC (2012o) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 2.13 Calibration stationary & mobile equipment 01/06/2012 (I/RA/11354/12.011/JCA)

IMDC (2012p) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 1.6 Boundary conditions year 3: 01/04/2011 – 31/03/2012 (I/RA/11354/11.104/MBO/ANF)

IMDC (2013a) Evaluatie externe effecten aanslibbing Deurganckdok. Deelrapport 1.8 Analysis of external effects on siltation processes and factors (I/RA/11354/10.105/MBO/ANF)

IMDC (2013b) Evaluatie externe effecten aanslibbing Deurganckdok (2012-2014). Deelrapport 1.13 Analysis of boundary conditions of survey years 3 and 4: 01/04/2008 – 31/03/2010 (I/RA/11406/13.054/MGO).

IMDC (2013b) Evaluatie externe effecten aanslibbing Deurganckdok (2012-2014). Deelrapport 1.14 Analysis of boundary conditions of survey years 5 and 6: 01/04/2010– 31/03/2012 (I/RA/11406/13.062/MGO).

Unesco (1983). Algorithms for computation of fundamental properties of seawater, UNESCO Technical Papers in Marine Science, 44. UNESCO, France.

Van Maren (2006a). 3D slibtransport model Zeeschelde, scenario 5: Effect CDW op sedimentatie Deurganckdok, bestaand instrumentarium. Z3824.70, rapport IVe, 36 p.

Van Maren (2006b). 3D slibtransport model Zeeschelde, scenario 4: Effect CDW op sedimentatie Deurganckdok, nieuw instrumentarium. Z3824.70, rapport IVd, 80 p.

Annex A Technical information of the density profilers

A.1 DensiTune



DensiTune Portable The fluid mud density probe

Stema Systems is proud to announce the new DensiTune Portable. A light weight system, complete in case appr 15 kg, that can easily travel hand carried and is optimized to operate from any vessel of opportunity. This will enable the assessment of the nautical depth or pinpoint problems with fluid mud presence on short notice on any location.

SOME HISTORY

The DensiTune, developed in the mid-nineties, was the first practical and worldwide deployable in-situ density meter. In the 2005 followed up by the RheoTune probe. This probe had increased functionality and facilitated the calibration method. The RheoTune inherited the housing of the DensiTune. This body was primarily design for winch operation. Manual operation is possible but not very practical.

PORTABILITY AND FAST MOBILIZATION

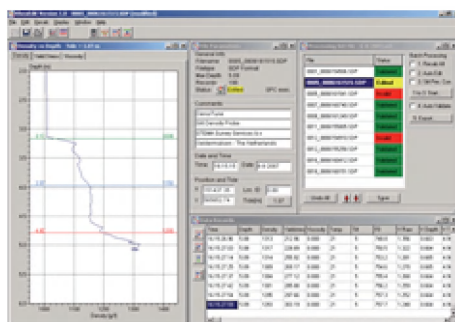
The integration of the Tune vertical profiles with acoustic surveys for nautical depth assessment, was found to require a unit that can quickly mobilised and easily deployed. For the acoustic calibration the main parameter of interest is mud density and this is still the adopted parameter for nautical depth definition. To comply with this demand, we redesigned the DensiTune probe into a unit that can be operated from any vessel in any place in the world by any operator.



- Calibration free (semi-) fluid mud density
- Light weight probe for easy manual operation
- Option to add weight for stability and penetration
- Field top unit with Wi-Fi data transmission to laptop/Windows-tablet
- 24V DC powered works on battery (battery pack with AC adapter optional)
- Optional: calibration free output of yield strength

THE DENSITY PORTABLE WILL BE YOUR PARTNER IN:

- Assurance of nautical accessibility of your harbor
- Calibration of Silas acoustic density mapping system
- Water bottom stability assessment in coastal studies
- Managing filling quantities in disposal areas
- Monitoring of siltation quantities and fluid loads in hopper bins





DensiTune Portable

The fluid mud density probe

Specifications

Output parameters	Density Temperature Depth (pressure) Optional: yield strength Optional: Dry Solids (calculated from density, requires input on specific mass of grains)	
Density	Accuracy Resolution Range	<1% of density (Newtonian fluid) 1 gr/l 1000 – 1500 gr/l (semi fluid materials with Bingham yield strength < 1 kPa)
Temperature	Accuracy Resolution Range	1% FS 1 deg C 0 – 60 deg C
Depth	Accuracy Resolution Range	0.15 % of measured depth 0.01 m 0 – 25 m
Housing	Probe Control box	Fibra reinforced polyamide / stainless steel (IP68, 40m) Plastic case with external connectors (IP65)
Dimensions	Probe: Control box: Transport case:	450 mm x 150mm (diameter) 0,22 x 0,20 x 0,150 (m) 0.65 x 0.50 x 0.35 (m)
Weight	Probe: Control box: Transport total:	5 kg (+ max 5 kg extra weight optional) 2 kg 22 kg (excluding extra weight)
Power Supply	Input Consumption	24 V DC 35 W
Output	Type Update rate	Ethernet UDP over Wi-Fi (internal antenna in control box) 20 Hz

A.2 GraviProbe



The background of the advertisement features a blue gradient with a stylized illustration of the GraviProbe instrument being lowered into the water. The instrument is a long, slender, silver-colored probe with a blue top section and a pointed tip. It is shown in two positions: one partially submerged and one fully submerged, illustrating its use in water.

GraviProbe

mud version

World's fastest and lightest rheological and density profiling system

Developed to capture high quality rheological and density profiles of fluid and consolidated mud layers

The **GraviProbe** is a free fall impact instrument, analyzing the underwater sediment layers during intrusion. Under its own weight it accelerates and penetrates fluid and consolidated mud layers.

The rheological and density conditions of the soil layers are determining the probe's dynamical behavior. The data acquired from on-board accelerometers, inclinometers and pressure sensors is feeding a dynamical model which determines the rheological and density parameters.

As a result the **GraviProbe** is able to very accurately distinguish the depth of the fluid mud and consolidated mud layers, even in gassy environments.

Operational simplicity

The high sensor data acquisition rates of up to 2kHz in combination with a low drag housing results in the highest quality profiles at drop rates over 7 m/s. Due to its light weight the probe can be operated manually from a small vessel, platform or quay and is limiting the operational costs.

Applications	Benefits	Features
- Determination of the nautical depth in ports, harbors, seaways and estuaries - High accurate depth measurement, improving echo-sounder data - Complementary soil analysis during CPT and core sampling - Calculation of dredging sediment volumes - Mass balance calculation of dump areas - Classification of mud and soil structures	- Multiple parameters in a single instrument - Lightweight, compact and robust (no external sensors) - Fast, continuous and autonomous measurement - Accurate - Slim instrument, deep intrusion and limited disturbance of the medium - Insensitive for gassy or disturbed medium	- Simultaneous measurement of depth, density, undrained shear and viscosity - Fast sampling rate (2048Hz) - Ethernet communication, wifi ready - Internal storage (microSD) - Long battery life (Li-Ion, 16h autonomy)

SPECIFICATIONS

Depth		
Range	200	(m)
Accuracy	0.01	(m)
Density		
Range	900 - 1300	(gr/l)
Accuracy	2%	(Newtonian)
Undrained Shear		
Range	0 - 10000	(Pa)
Accuracy	2%	

DATA

Acquisition		
Sample Rate	2048	(Hz)
Communication		
	Ethernet	
Memory		
Internal storage	microSDHC	(FAT32)

ELECTRICAL

Battery	2x Li-Ion 3.75V, 2.2Ah
Battery Life	16h autonomy
Charge Type	Power-over-Ethernet (power injector included)

PHYSICAL

Materials	Marine Grade 18/10 Stainless Steel (Inox type 316) housing, polycarbonate & composite sensor components
Size	Ø50mm x 700mm (variable length)
Weight	7 – 10kg

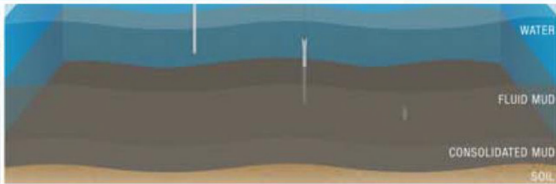
SOFTWARE

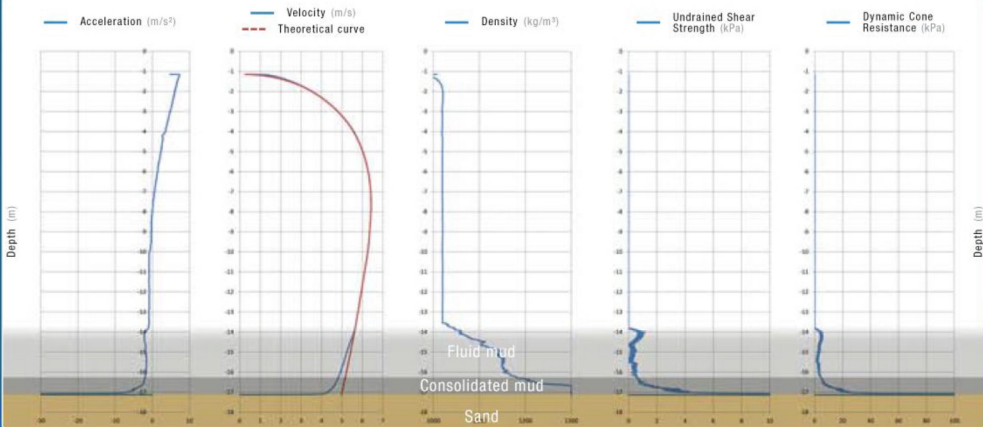
GraviProbe is supplied with Windows based software with following features:

- Instrument setup
- Data extraction
- Data transmission (to dotOcean servers)

- Import GPS-data
- Import/Generate Tidal Curve
- Visualise raw data (for data verification)

Processing is done by dotOcean and delivered to the customer in desired formats

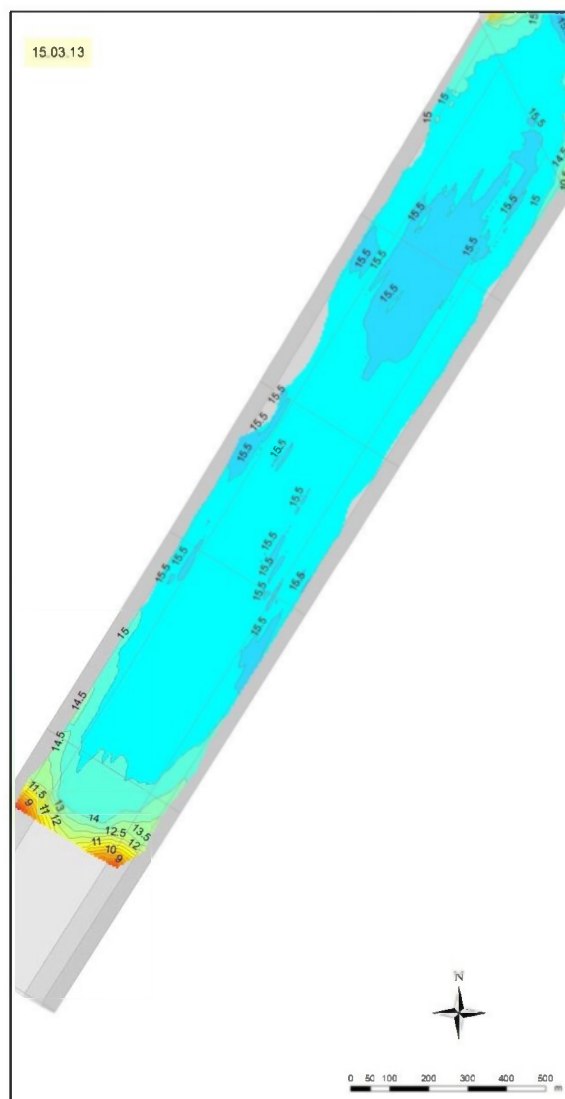
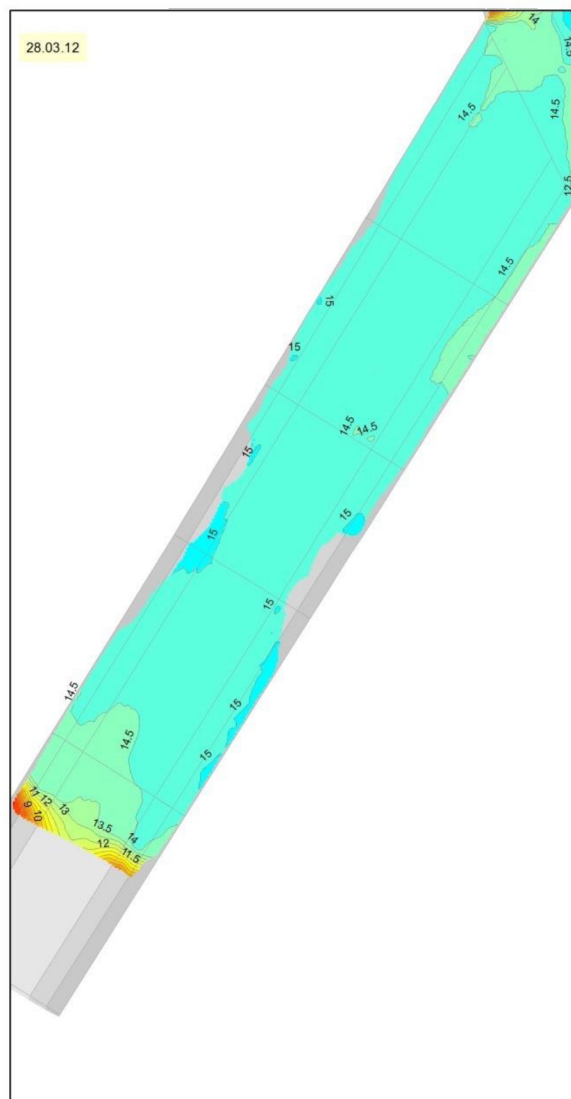



dotOcean NV | Lieven Bauwensstraat 20 | 8200 Brugge | Belgium
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Annex B Depth of the water-bed interface (210 kHz)



**Long-term measurements
Deurganckdok
Evolution & analysis of siltation**

Bestek nr 16EF/2011/28

**Depth of the water-bed interface (210 kC)
28.03.12 & 15.03.13**

Map 1 Scale 1/10.000

Created: 19/07/2013
Version nr. 1

IMDC
International Marine & Dredging Consultants

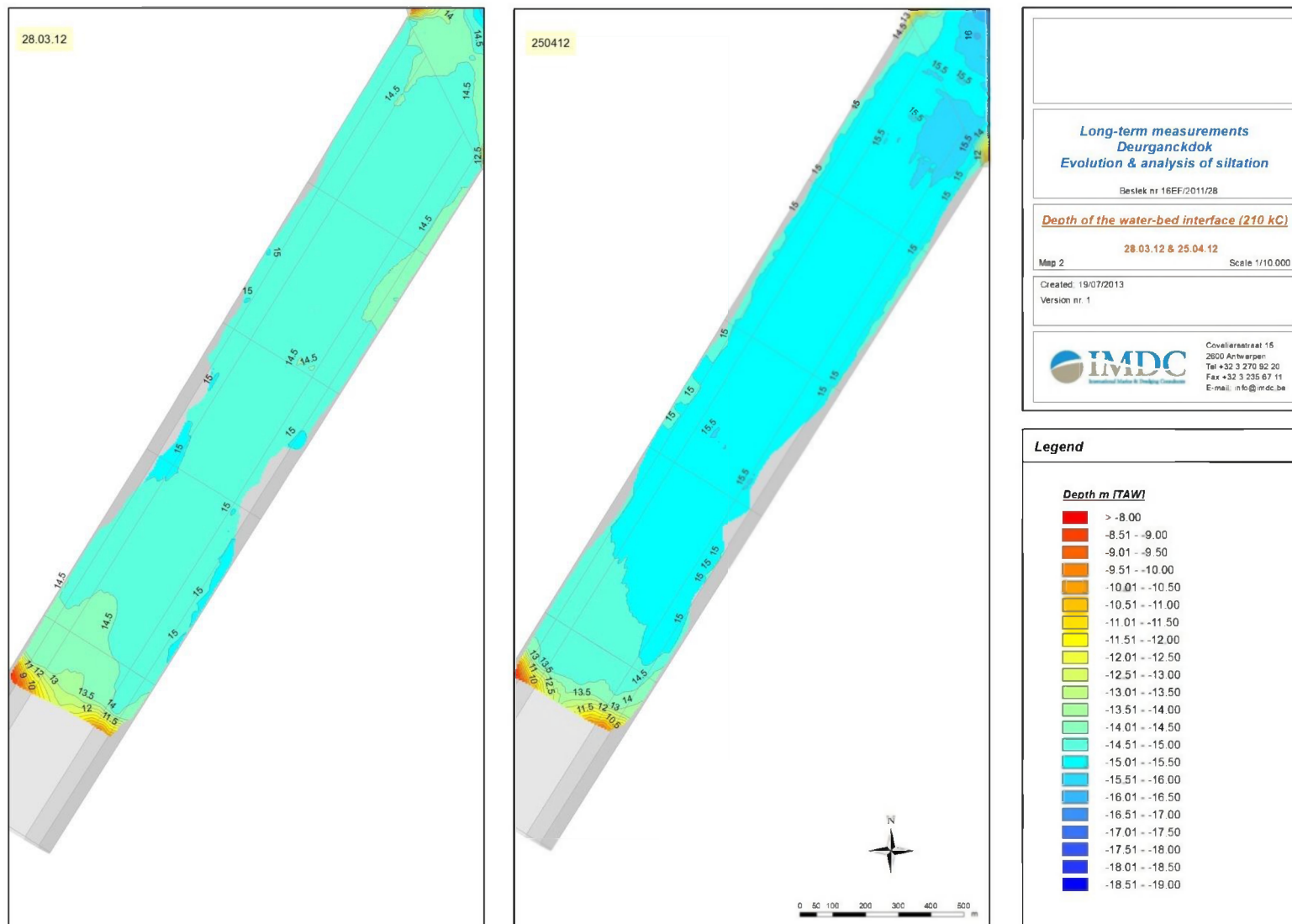
Covellersstraat 15
2000 Antwerpen
Tel +32 3 270 92 20
Fax +32 3 235 67 11
E-mail: info@imdc.be

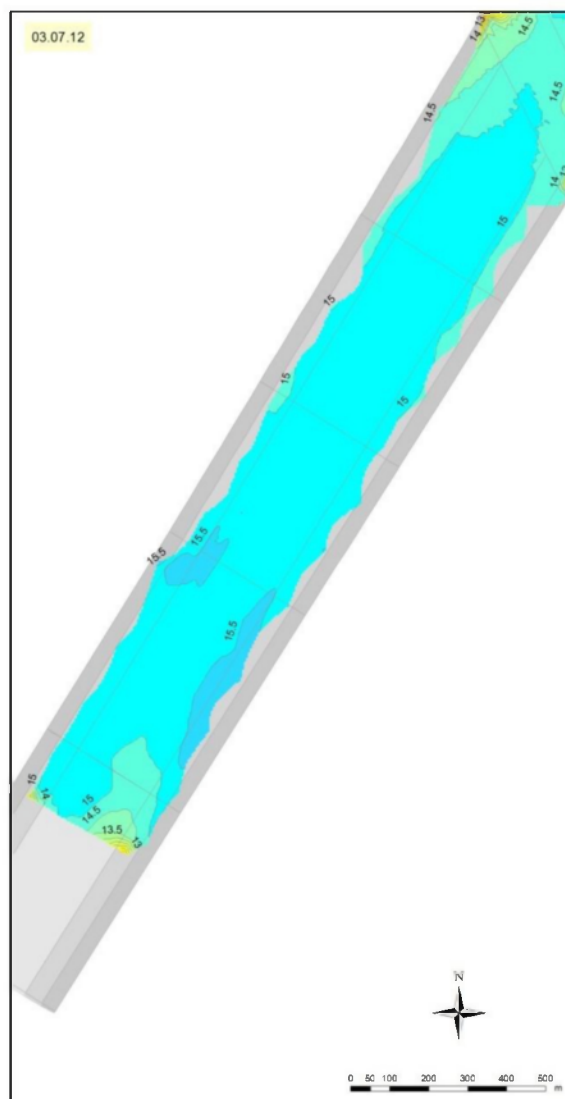
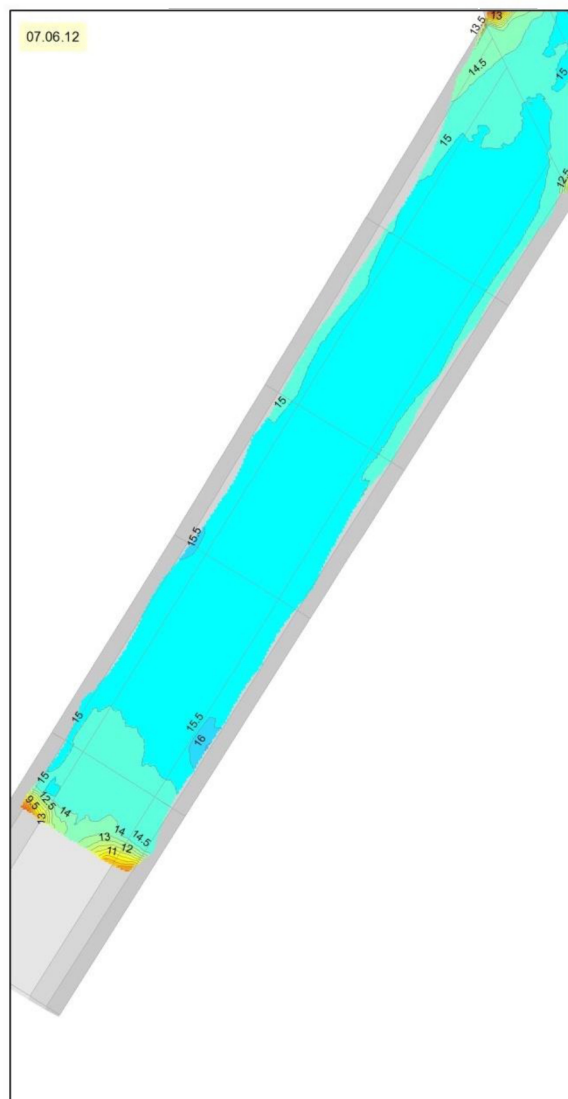
Legend

Depth m (TAW)

Red	> -8.00
Dark Red	-8.51 - -9.00
Red-Orange	-9.01 - -9.50
Orange	-9.51 - -10.00
Light Orange	-10.01 - -10.50
Yellow-Orange	-10.51 - -11.00
Yellow	-11.01 - -11.50
Light Yellow	-11.51 - -12.00
Yellow-Green	-12.01 - -12.50
Green	-12.51 - -13.00
Light Green	-13.01 - -13.50
Green	-13.51 - -14.00
Light Green	-14.01 - -14.50
Green	-14.51 - -15.00
Light Blue	-15.01 - -15.50
Blue	-15.51 - -16.00
Dark Blue	-16.01 - -16.50
Blue	-16.51 - -17.00
Dark Blue	-17.01 - -17.50
Blue	-17.51 - -18.00
Dark Blue	-18.01 - -18.50
Blue	-18.51 - -19.00

Path: W:\11406\GIS\Project\2012-2013\210 kC\W1_Bathy_280312-150313.mxd





**Long-term measurements
Deurganckdok
Evolution & analysis of siltation**

Bestek nr 16EF/2011/28

**Depth of the water-bed interface (210 kC)
07.06.12 & 03.07.12**

Map 3 Scale 1/10.000

Created: 23/07/2013
Version nr. 1

IMDC
International Marine & Dredging Consultants

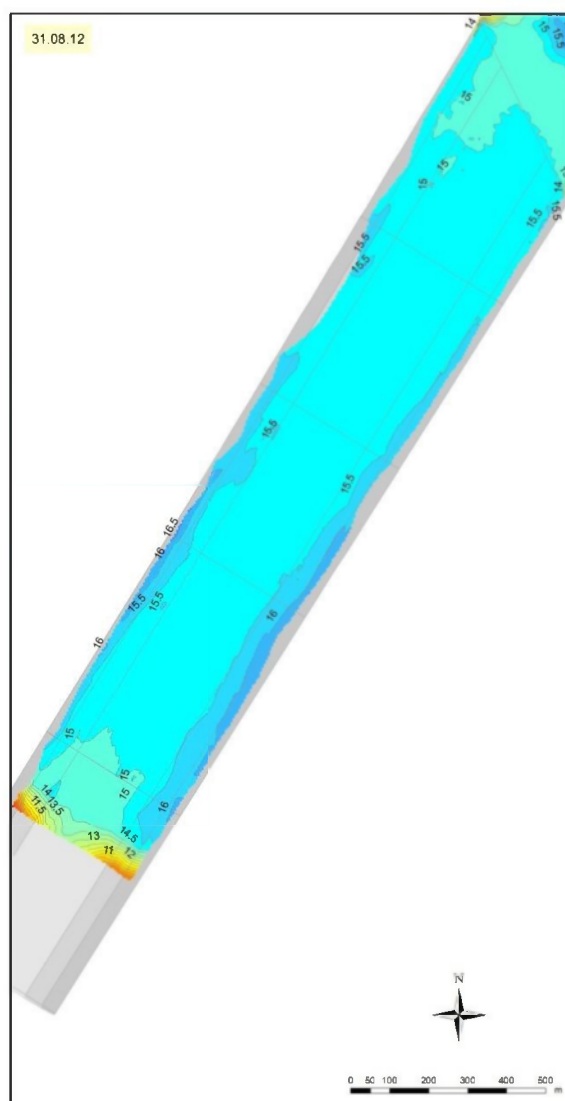
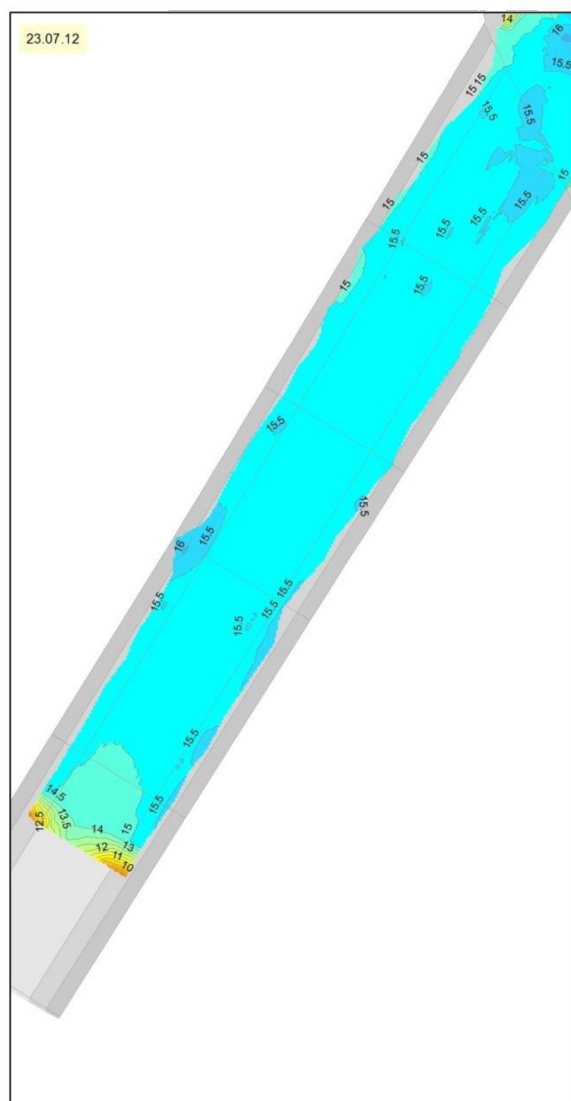
Covellersstraat 15
2000 Antwerpen
Tel +32 3 270 92 20
Fax +32 3 235 67 11
E-mail: info@imdc.be

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
	-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
	-17.51 - -18.00
	-18.01 - -18.50
	-18.51 - -19.00

Document Path: W:\11406\GIS\Project\2012-2013\210 kC\210 kC_070612-030712.mxd



Long-term measurements
Deurganckdok
Evolution & analysis of siltation

Bestek nr 16EF/2011/28

Depth of the water-bed interface (210 kC)
23.07.12 & 31.08.12

Map 4 Scale 1/10.000

Created: 23/07/2013
Version nr. 1

IMDC
International Marine & Docking Consultants

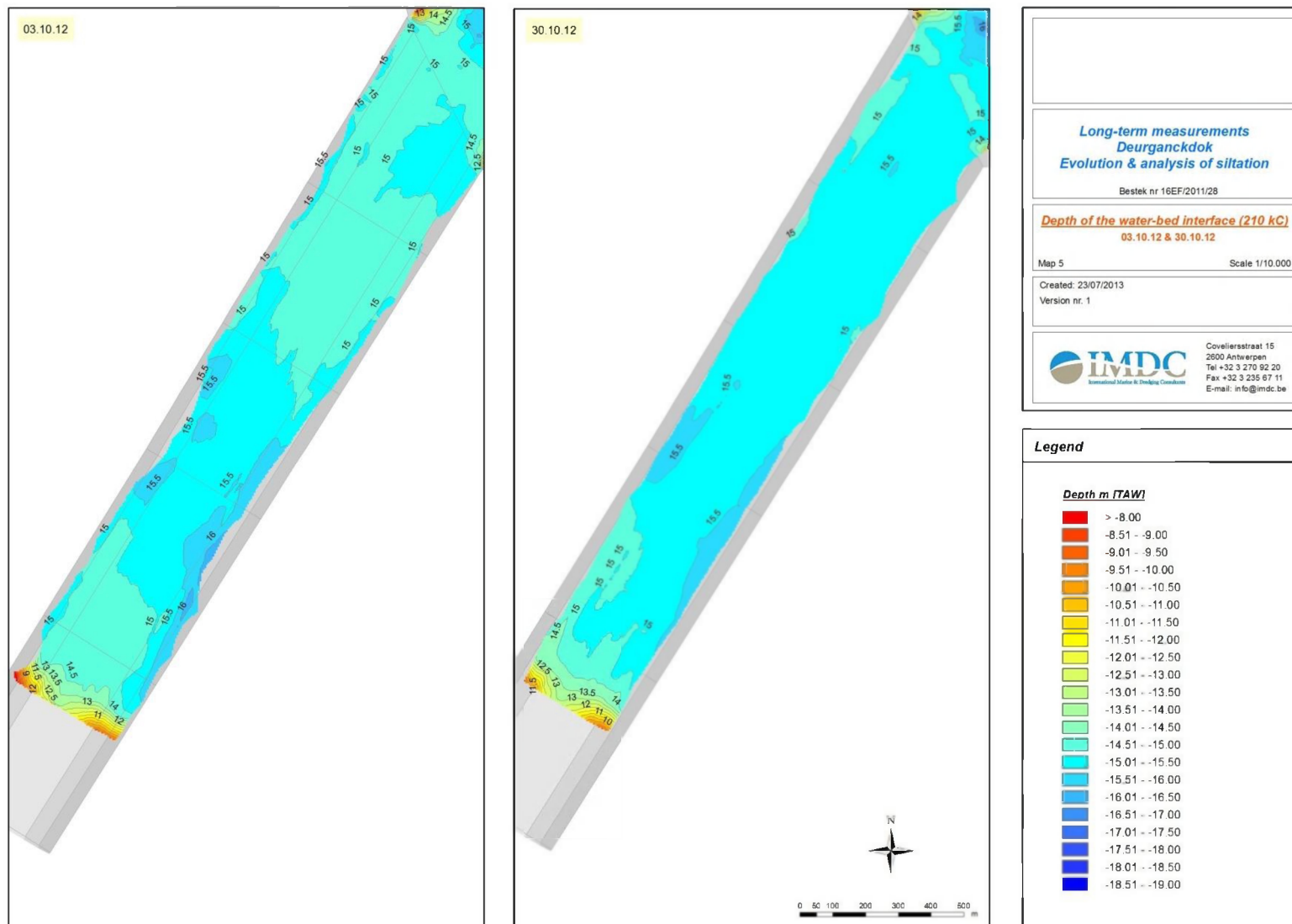
Coveliersstraat 15
2000 Antwerpen
Tel +32 3 270 92 20
Fax +32 3 235 67 11
E-mail: info@imdc.be

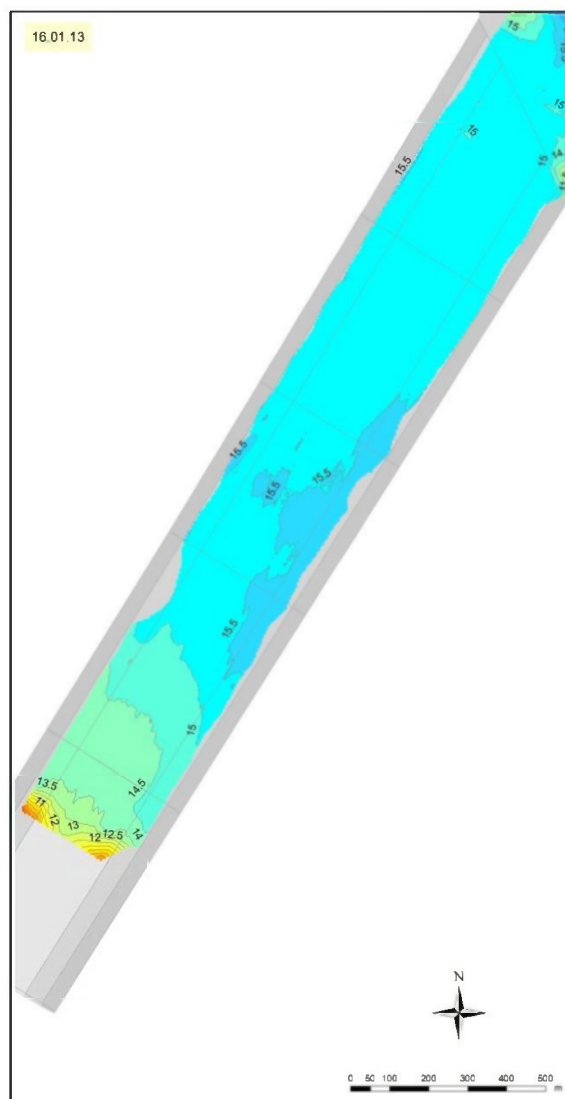
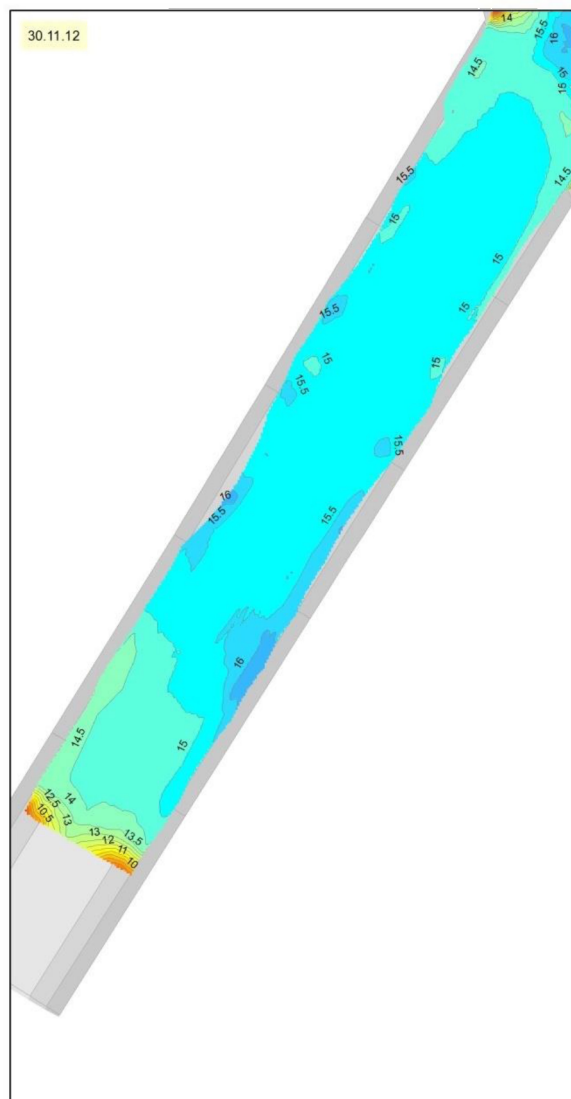
Legend

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
-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
-17.51 - -18.00
-18.01 - -18.50
-18.51 - -19.00

Document Path: W:\11406\GIS\Project\2012-2013\210 kC\K4_bathy_23072012-310812.mxd





**Long-term measurements
Deurganckdok
Evolution & analysis of siltation**

Bestek nr 16EF/2011/28

Depth of the water-bed interface (210 kC)
30.11.12 & 16.01.13

Map 6 Scale 1/10.000

Created: 23/07/2013
Version nr. 1

IMDC
International Marine & Docking Consultants

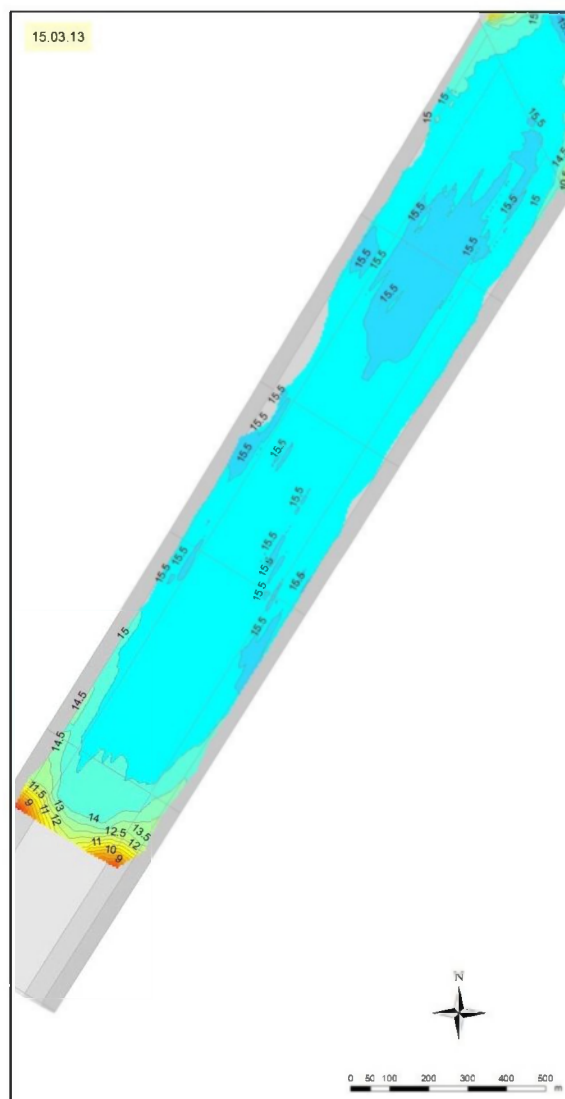
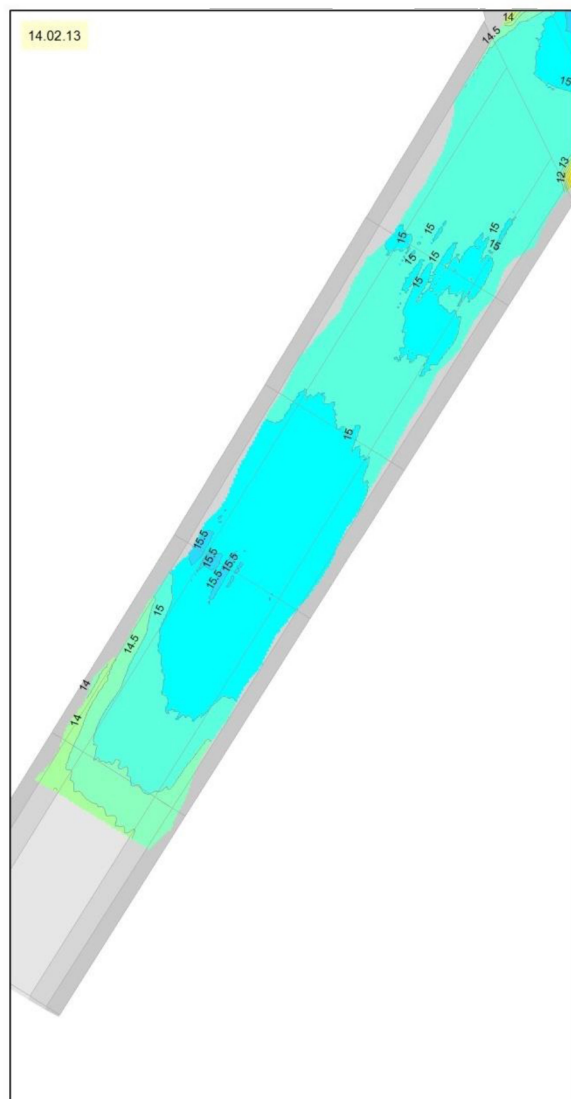
Coveliersstraat 15
2000 Antwerpen
Tel +32 3 270 92 20
Fax +32 3 235 67 11
E-mail: info@imdc.be

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
	-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
	-17.51 - -18.00
	-18.01 - -18.50
	-18.51 - -19.00

Document Path: W:\11406\GIS\Project\2012-2013\10_Kb\Kb03_bathy_301112_160113.mxd



**Long-term measurements
Deurganckdok
Evolution & analysis of siltation**

Bestek nr 16EF/2011/28

Depth of the water-bed interface (210 kC)
14.02.13 & 15.03.13

Map 7 Scale 1/10.000

Created: 23/07/2013
Version nr. 1

IMDC
Covertiersstraat 15
2000 Antwerpen
Tel +32 3 270 92 20
Fax +32 3 235 67 11
E-mail: info@imdc.be

Legend

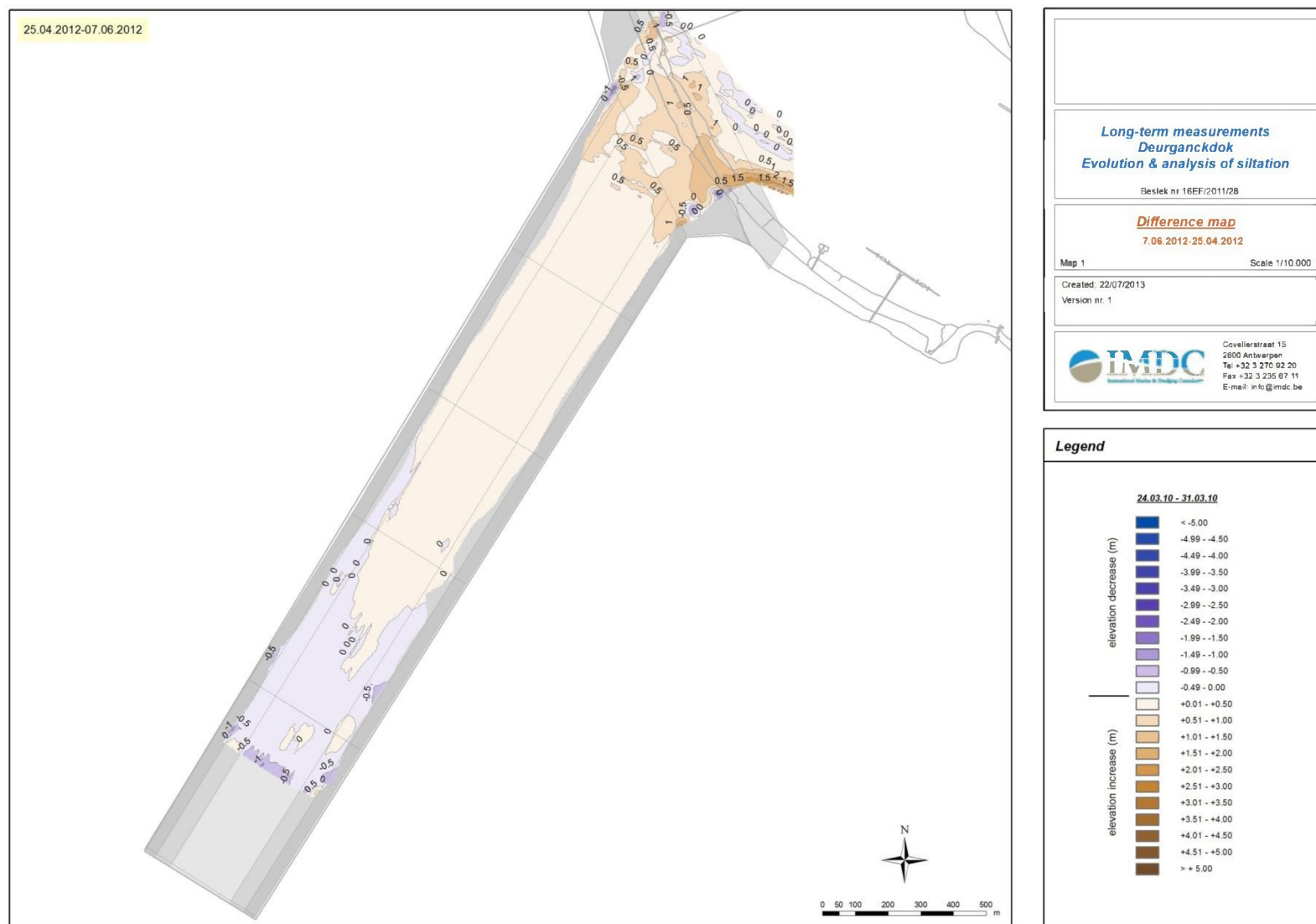
Depth m [TAW]

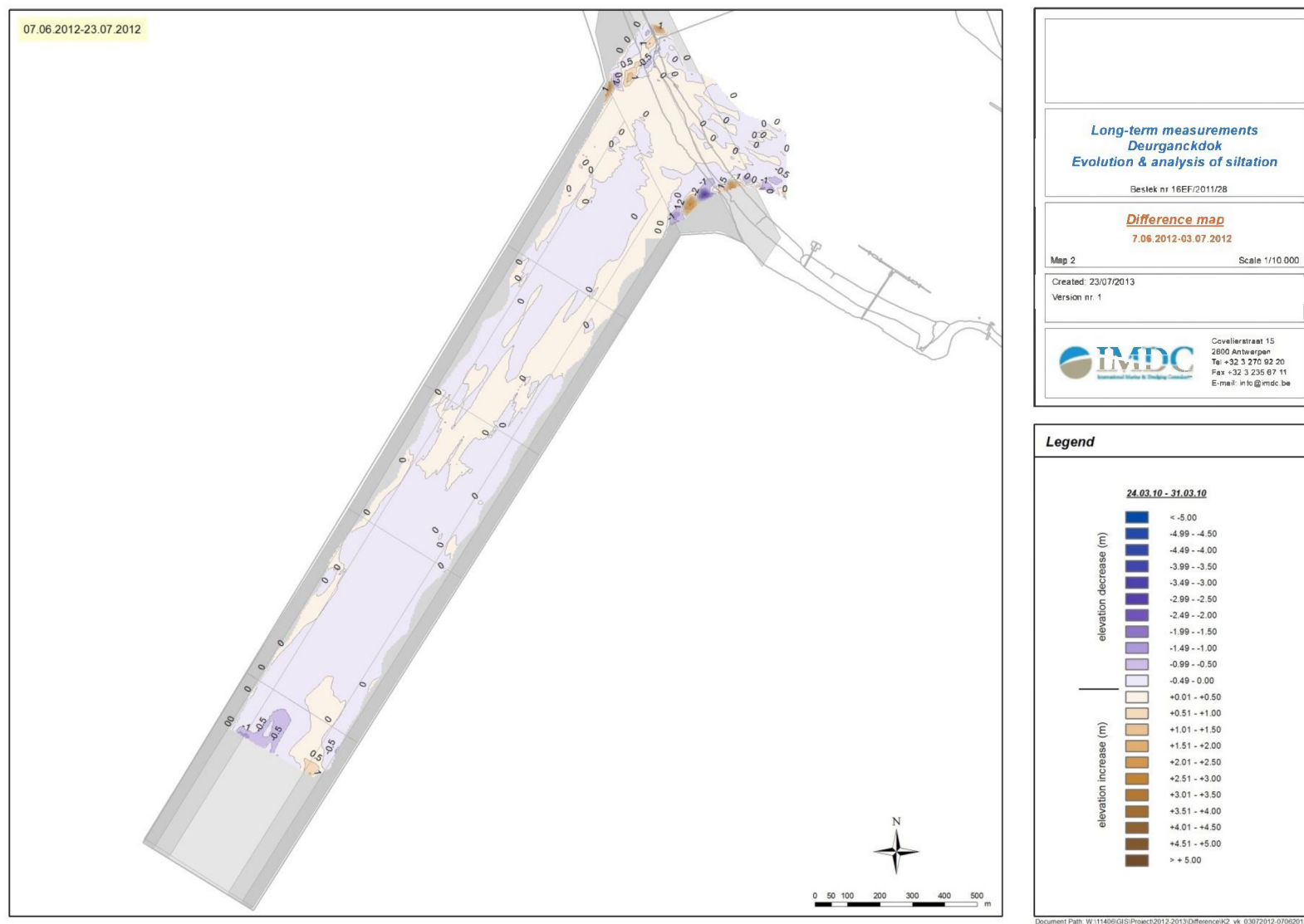
	> -8.00
	-8.51 -- -9.00
	-9.01 -- -9.50
	-9.51 -- -10.00
	-10.01 -- -10.50
	-10.51 -- -11.00
	-11.01 -- -11.50
	-11.51 -- -12.00
	-12.01 -- -12.50
	-12.51 -- -13.00
	-13.01 -- -13.50
	-13.51 -- -14.00
	-14.01 -- -14.50
	-14.51 -- -15.00
	-15.01 -- -15.50
	-15.51 -- -16.00
	-16.01 -- -16.50
	-16.51 -- -17.00
	-17.01 -- -17.50
	-17.51 -- -18.00
	-18.01 -- -18.50
	-18.51 -- -19.00

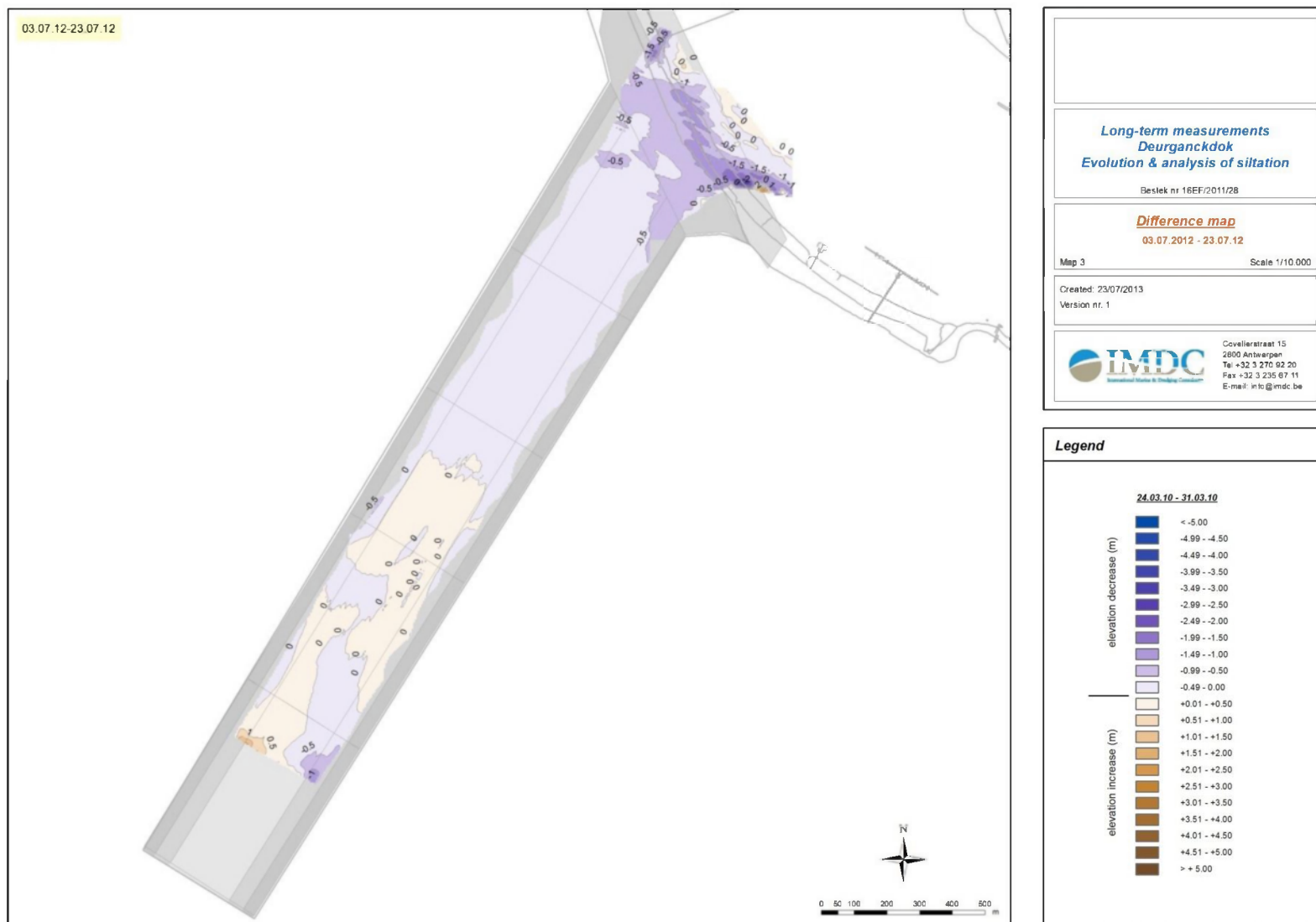
Document Path: W:\11406\GIS\Project\2012-2013\210 kHZ\7_bathy_140213_150313.mxd

Annex C Evolution of depth of water-bed interface (210 kHz)

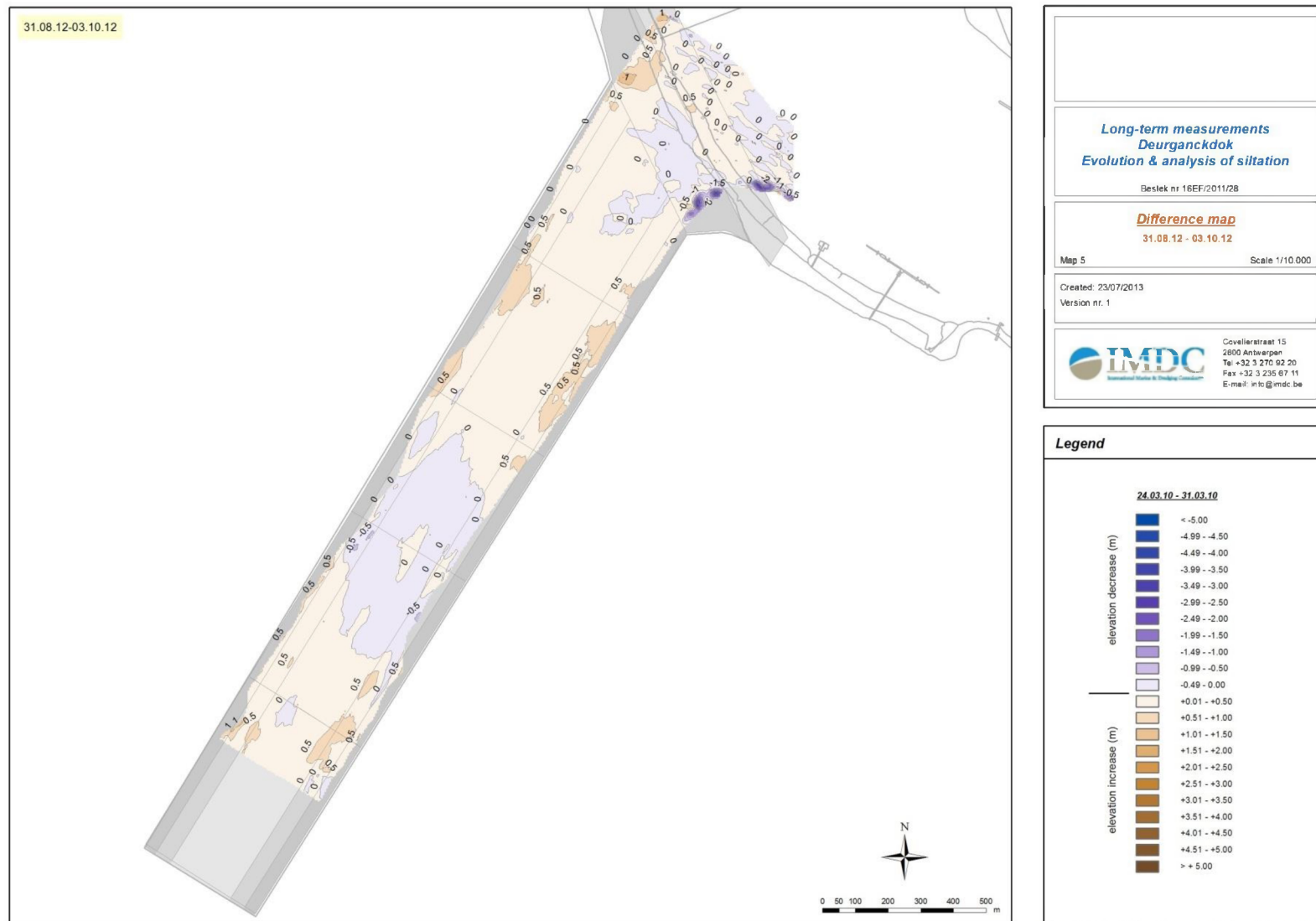
C.1 Difference maps

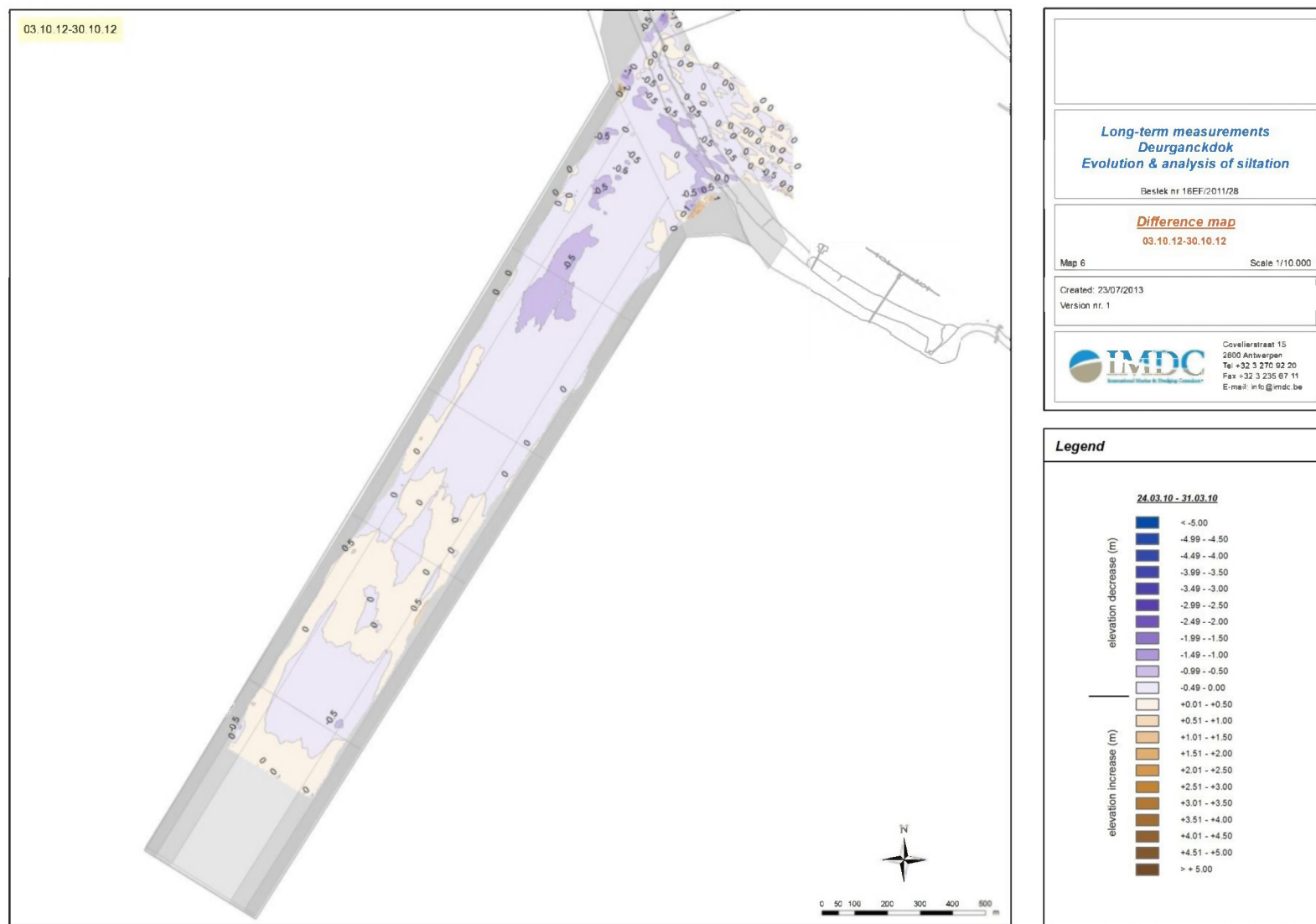


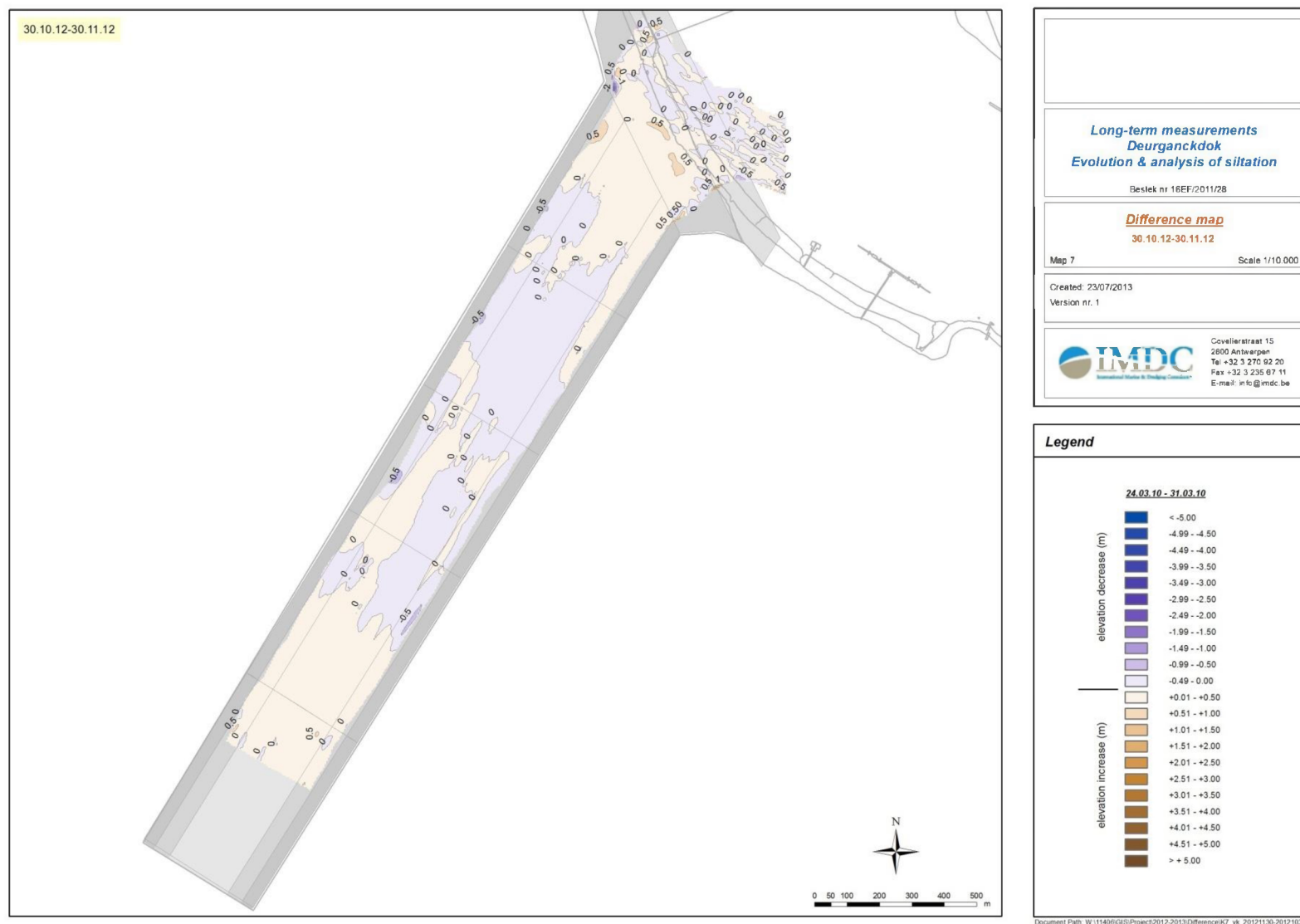


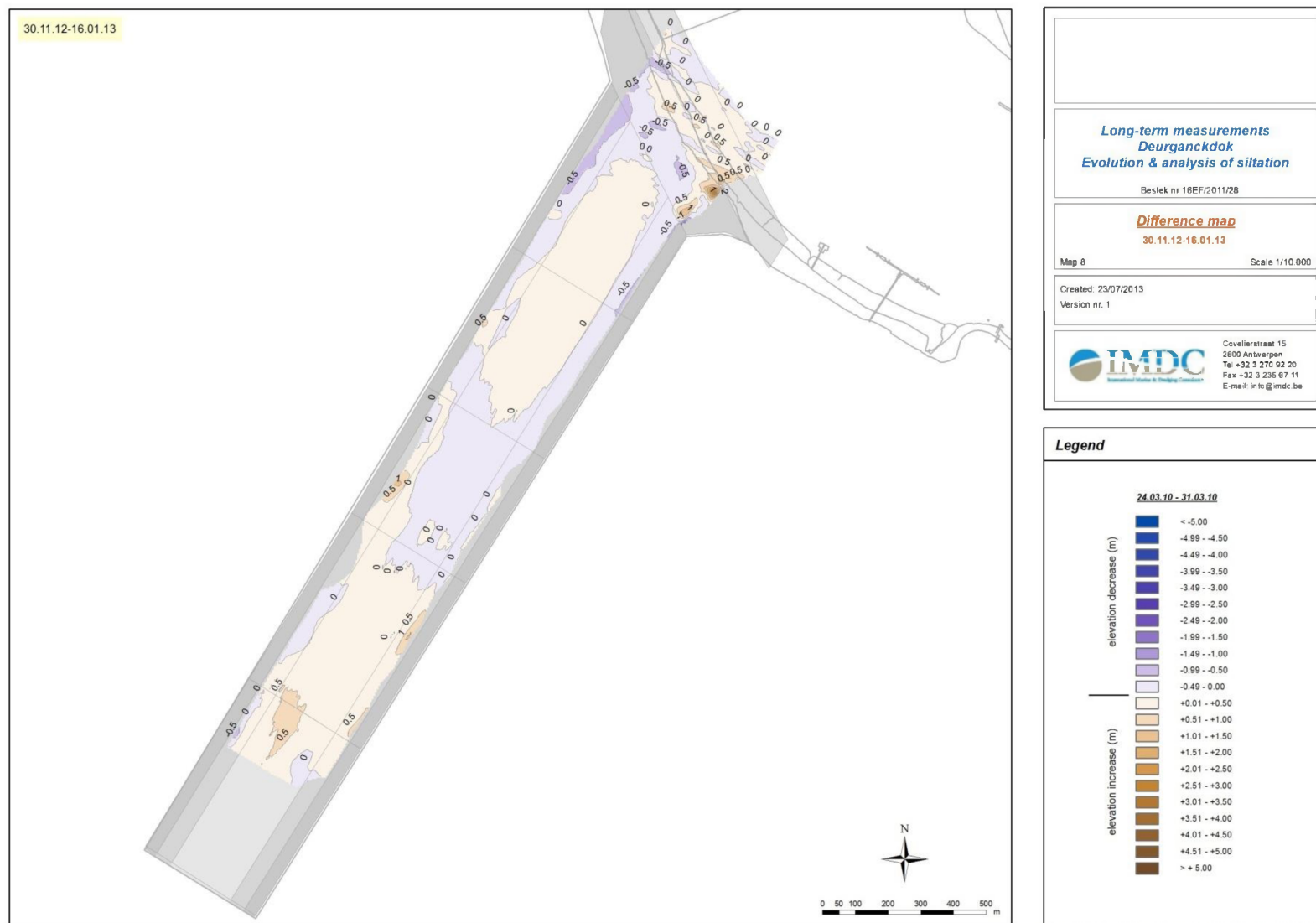
















**Long-term measurements
Deurganckdok
Evolution & analysis of siltation**

Bestek nr 16EF/2011/28

Difference map
14.02.13-15.03.13

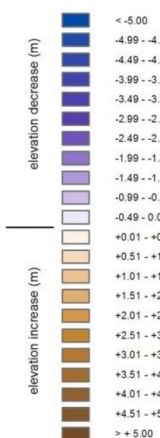
Map 10 Scale 1/10.000

Created: 23/07/2013
Version nr. 1

IMDC
Covellierestraat 15
2600 Antwerpen
Tel +32 3 270 92 20
Fax +32 3 235 07 11
E-mail: info@imdc.be

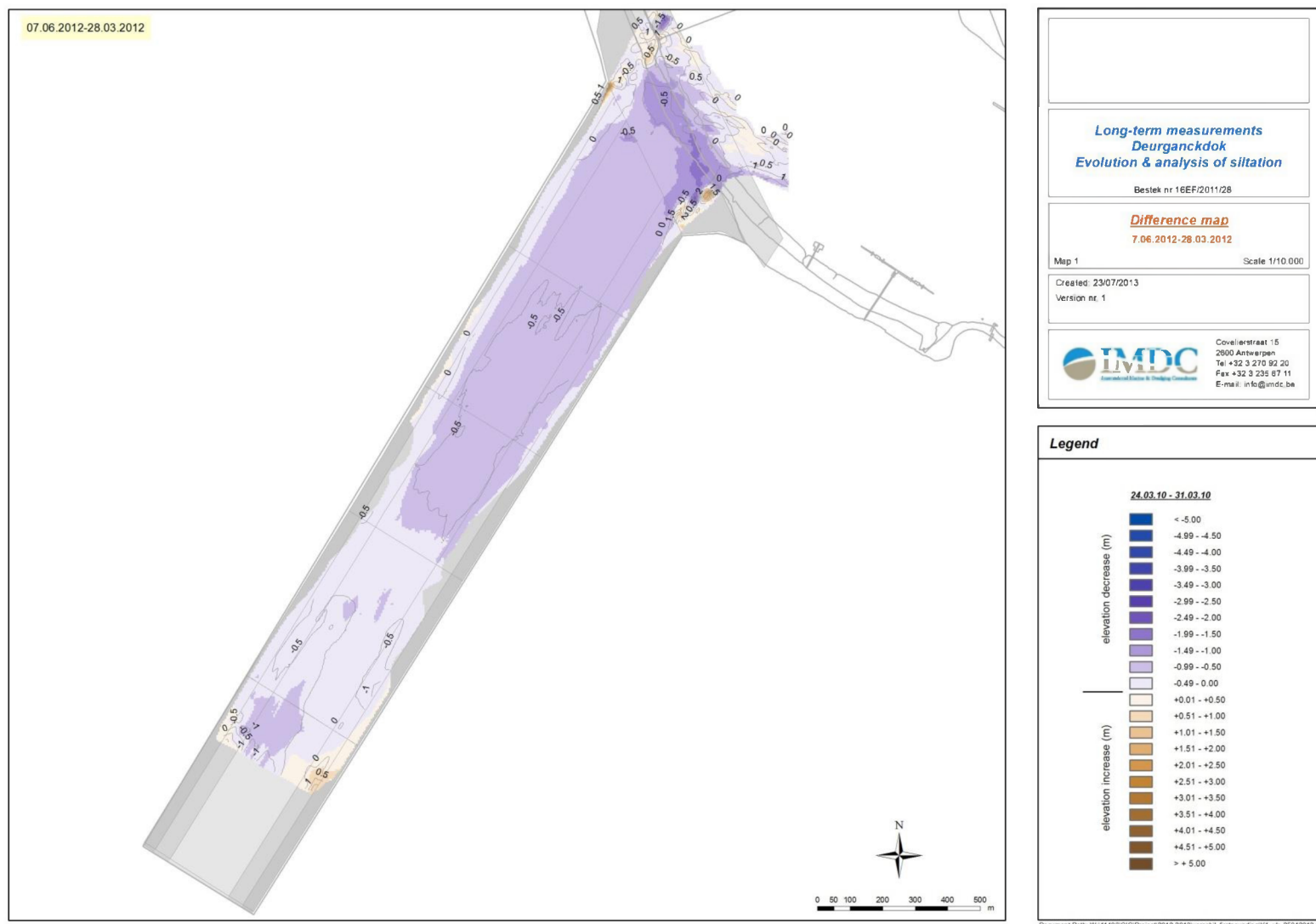
Legend

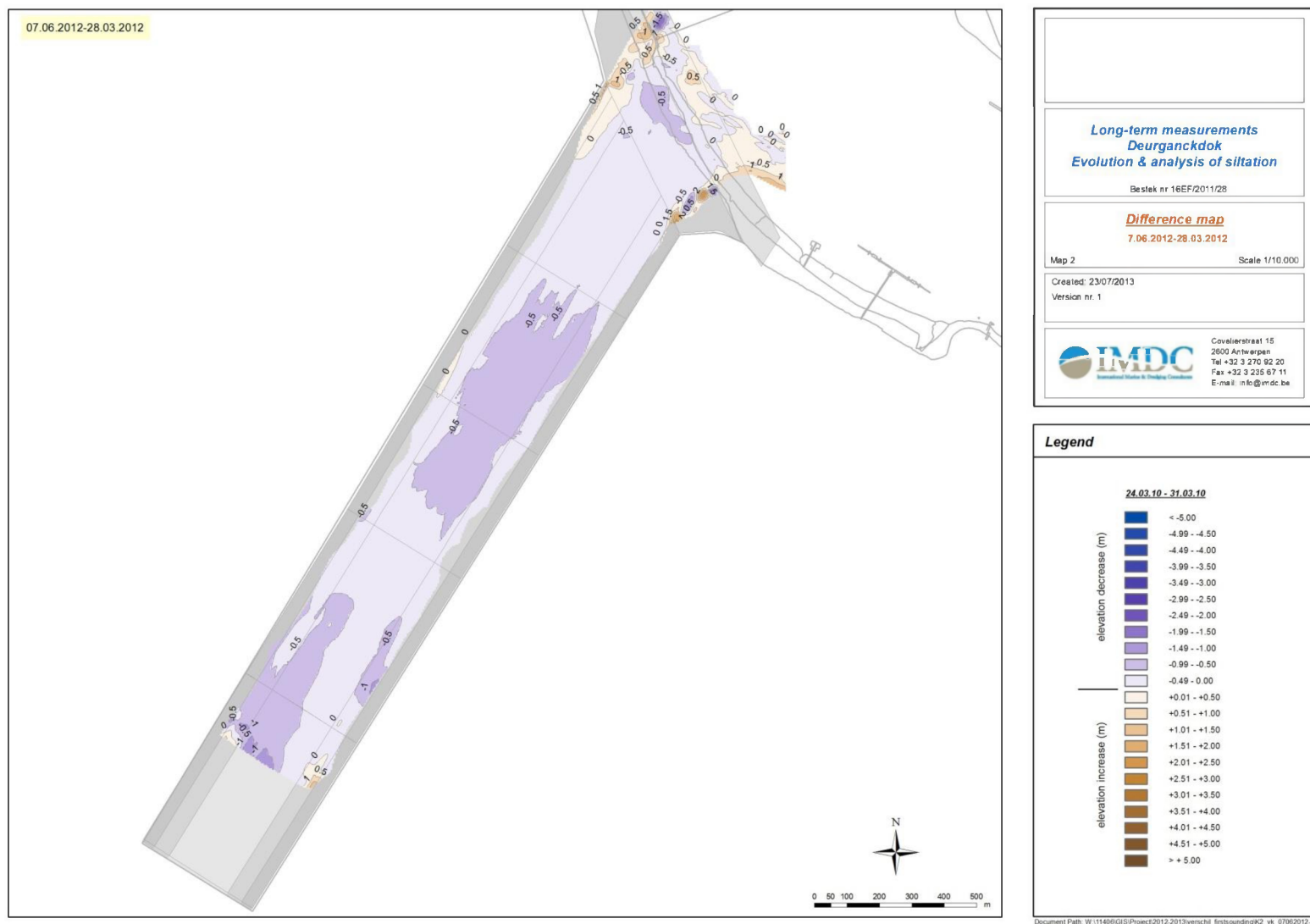
24.03.10 - 31.03.10

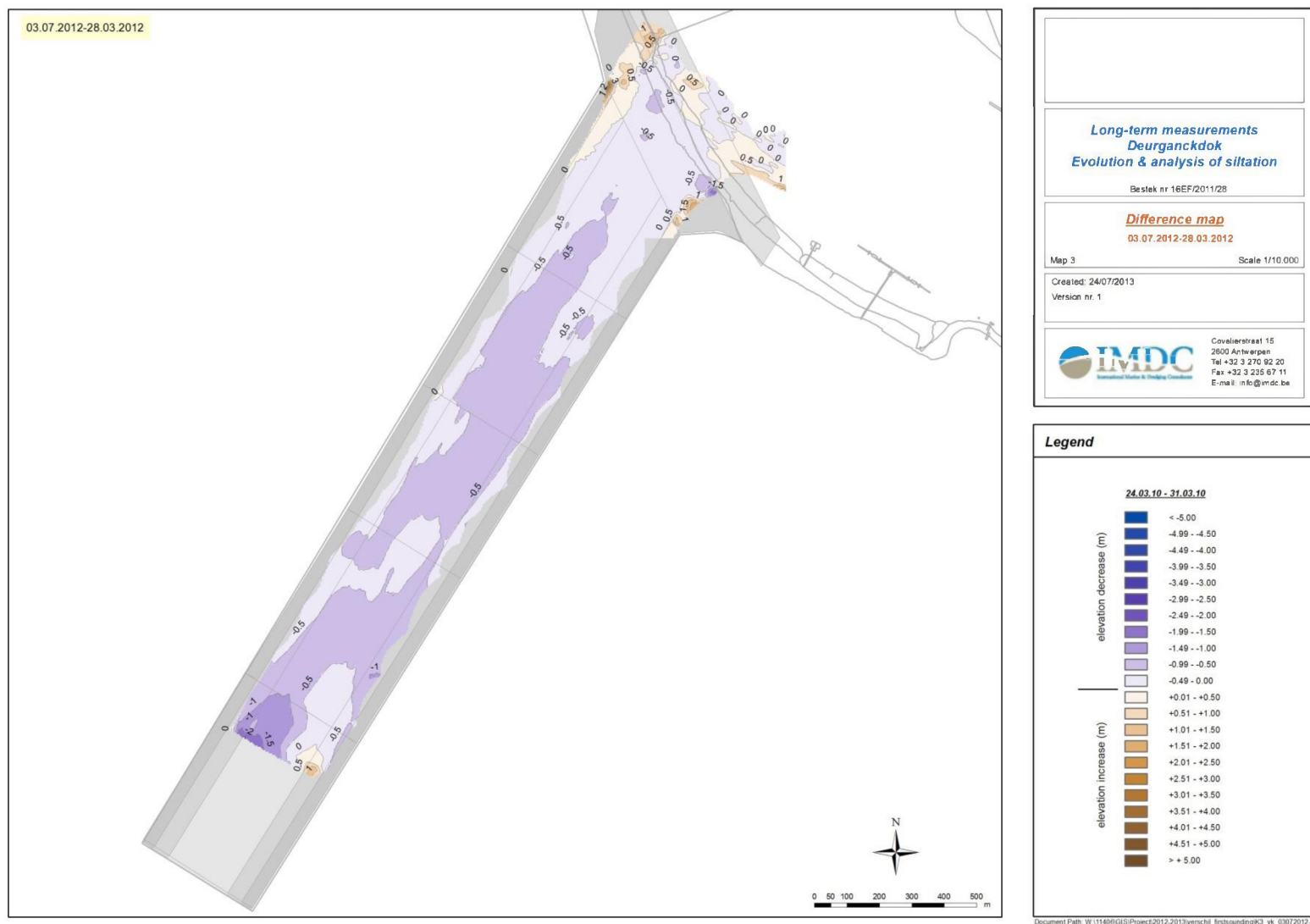


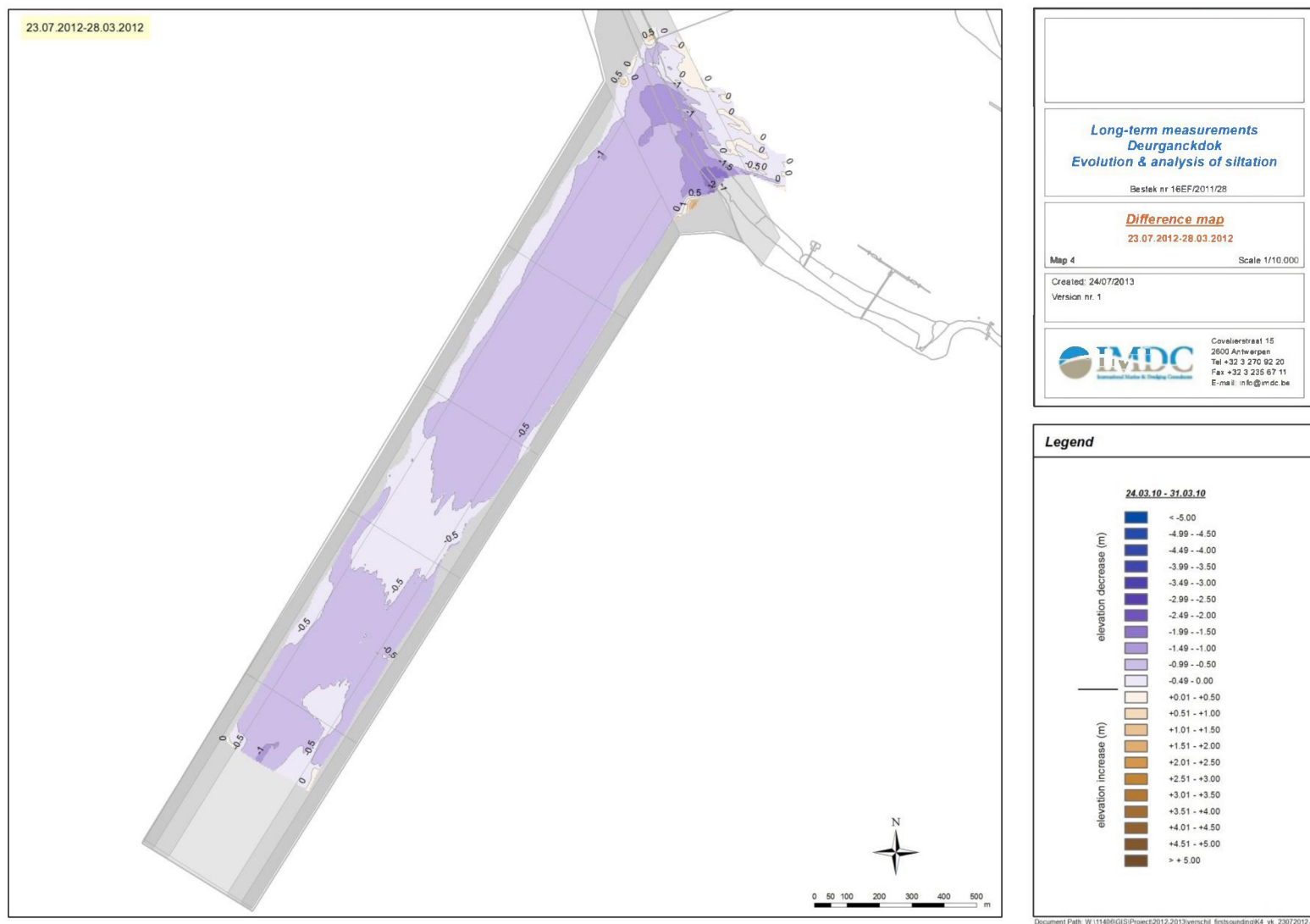
Document Path: W:\11406\GIS\Project\2012-2013\Difference\K10_vk_20130315-20130214.mxd

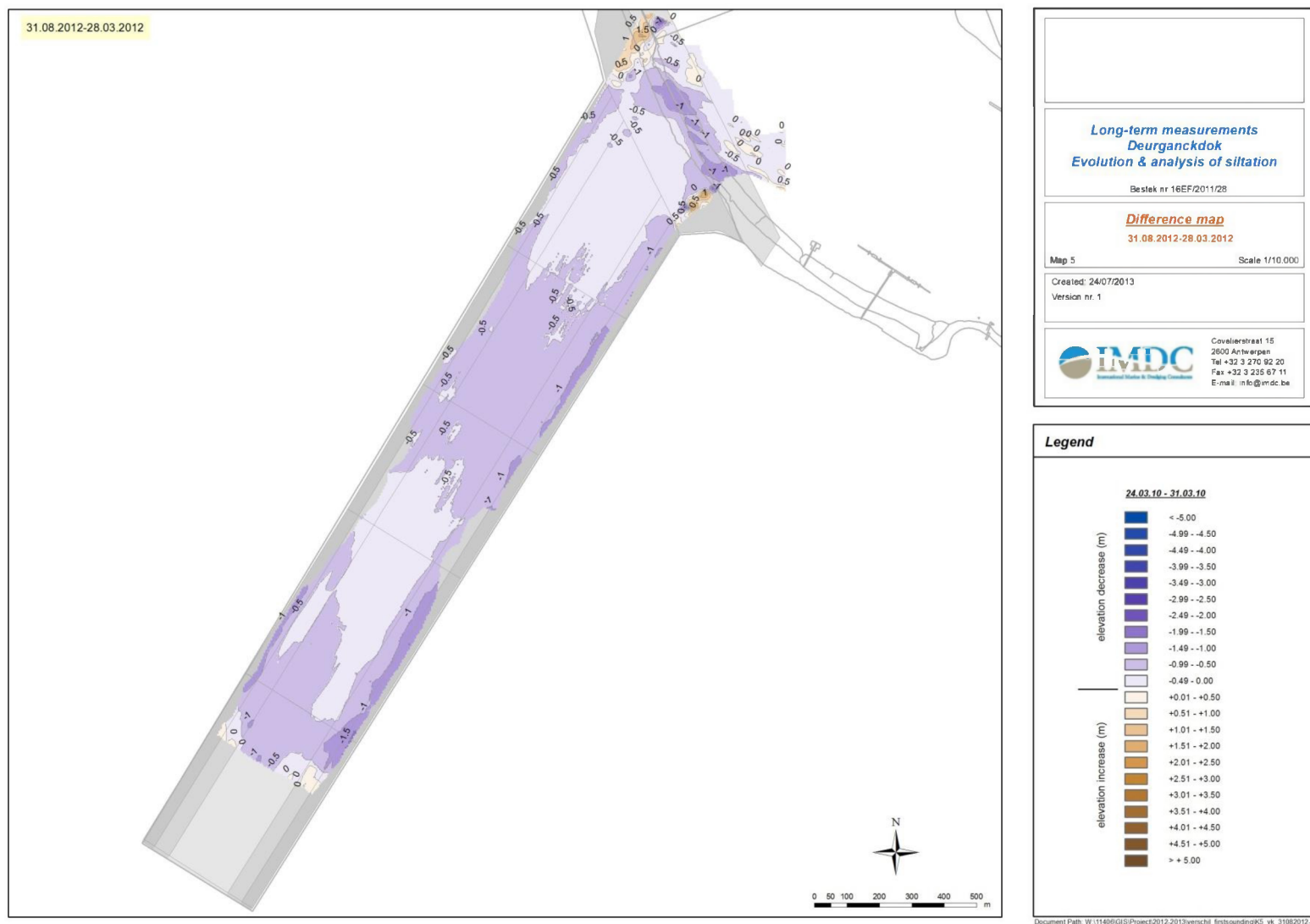
C.2 Difference maps relative to first sounding

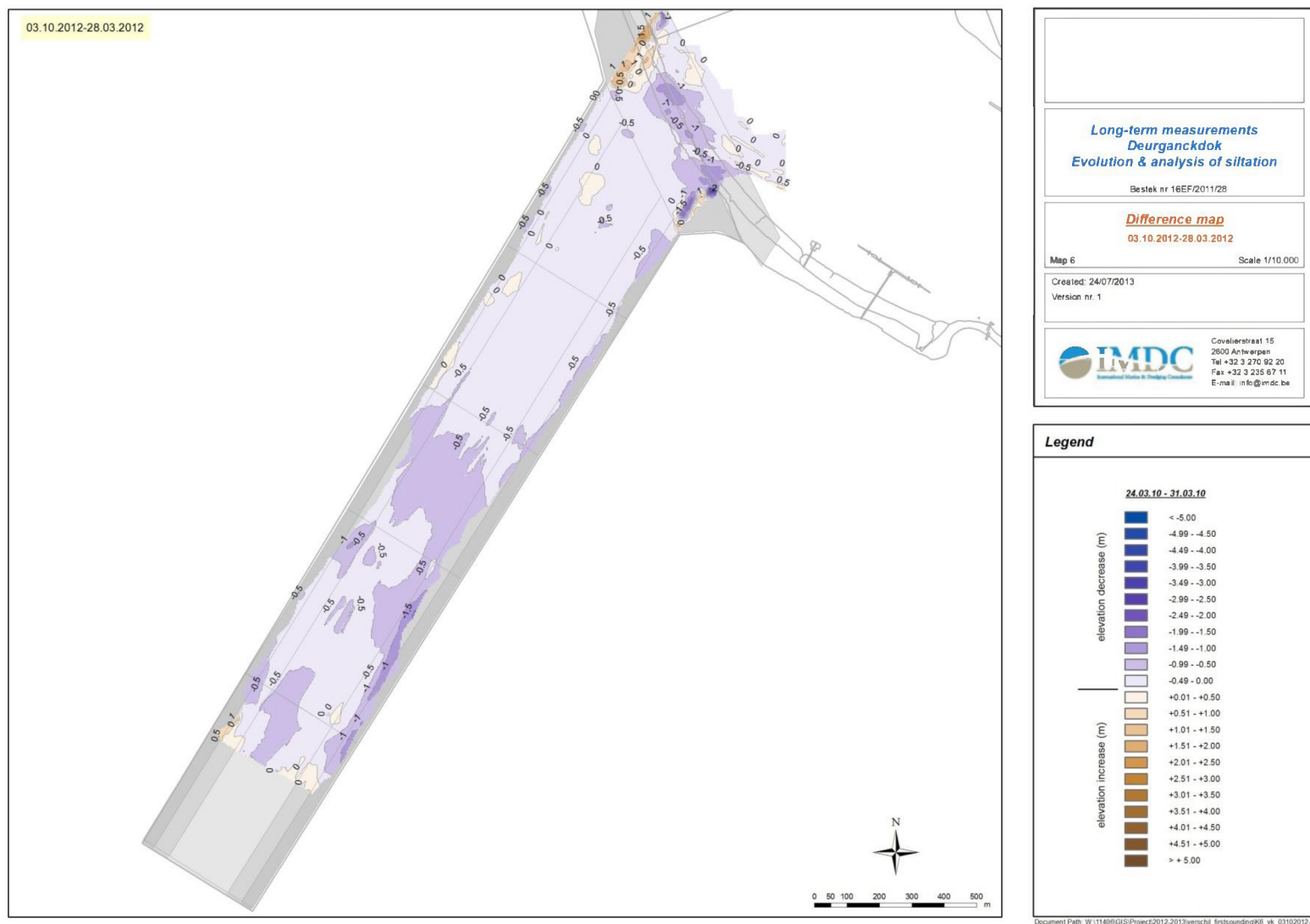


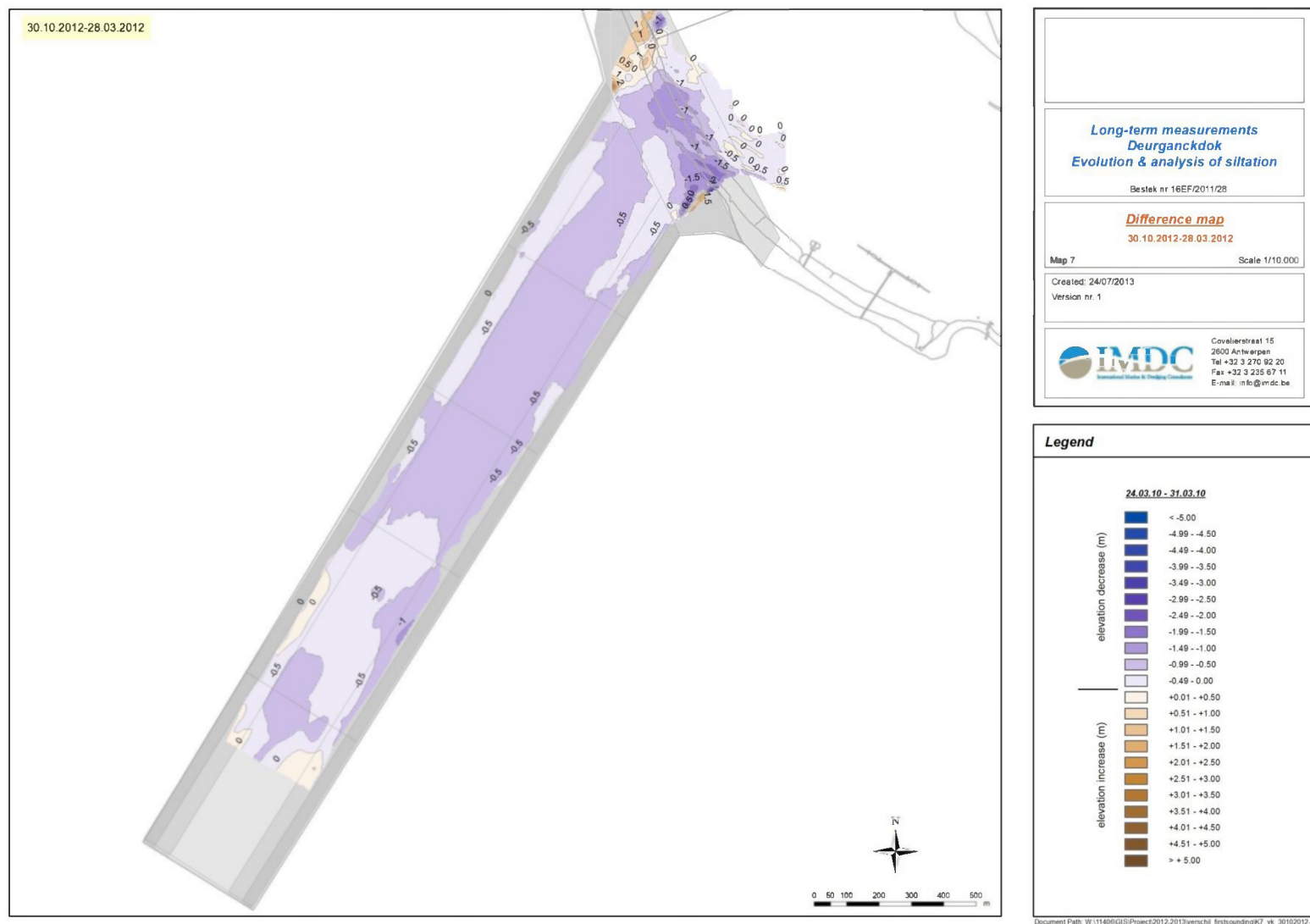


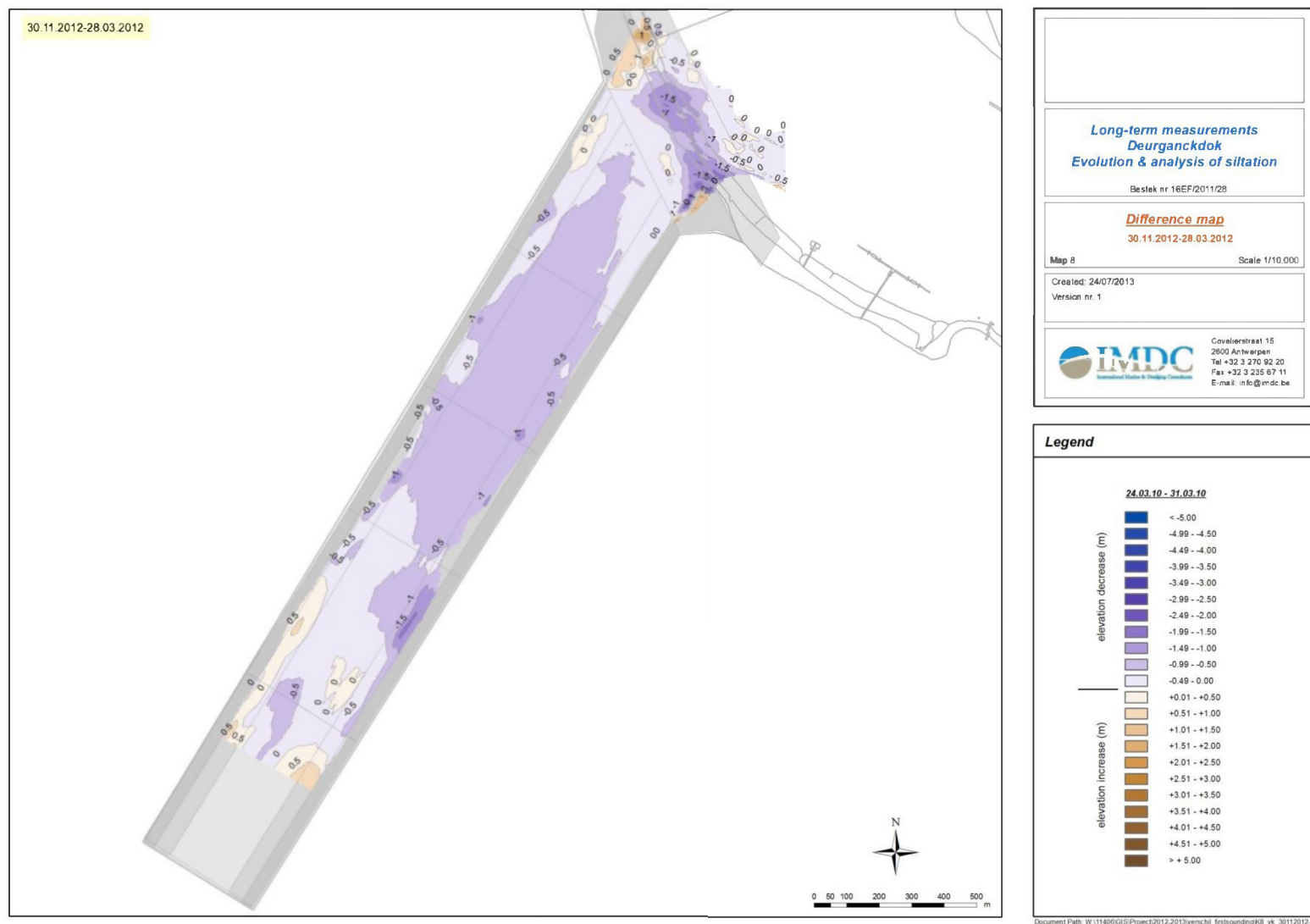


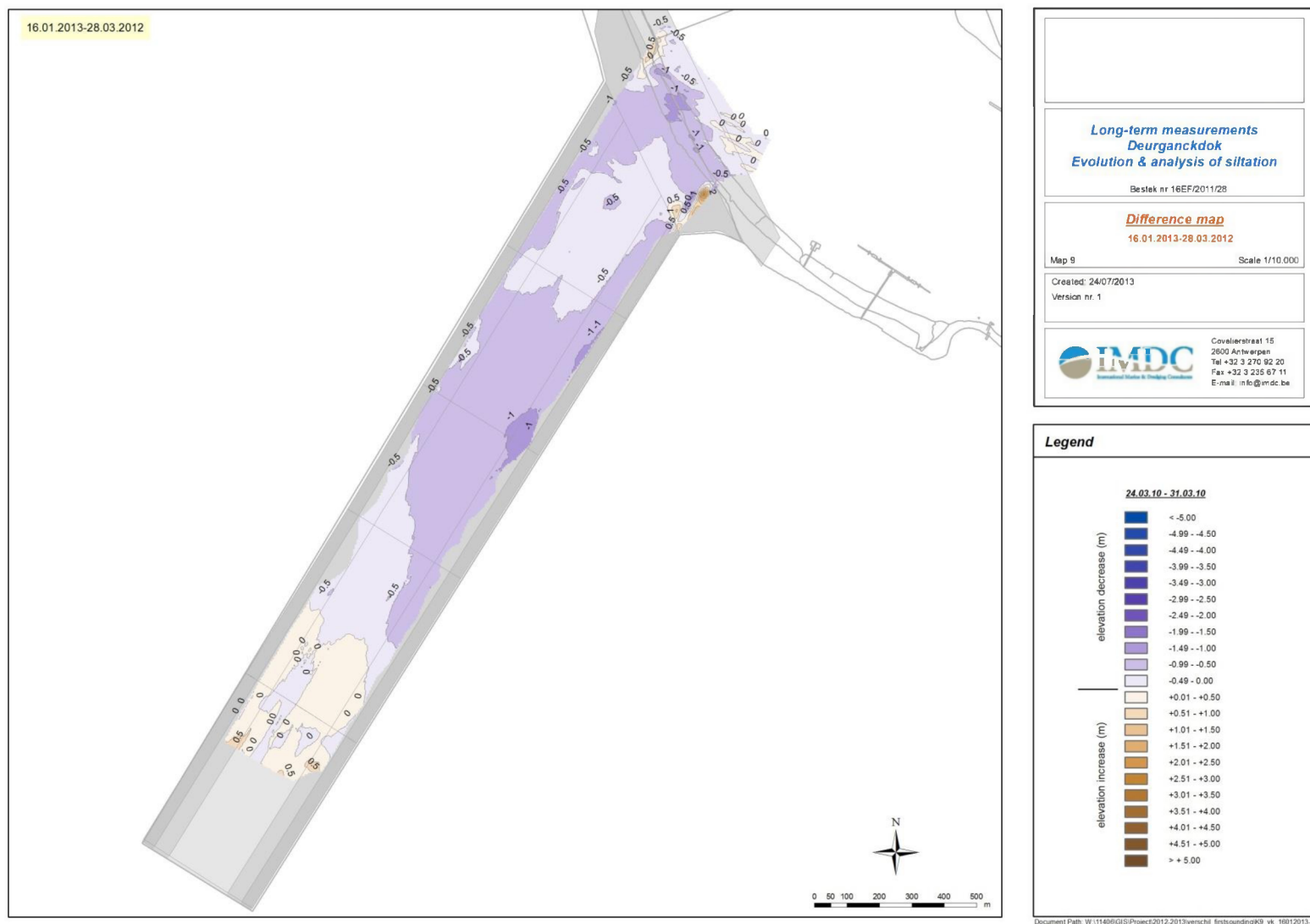




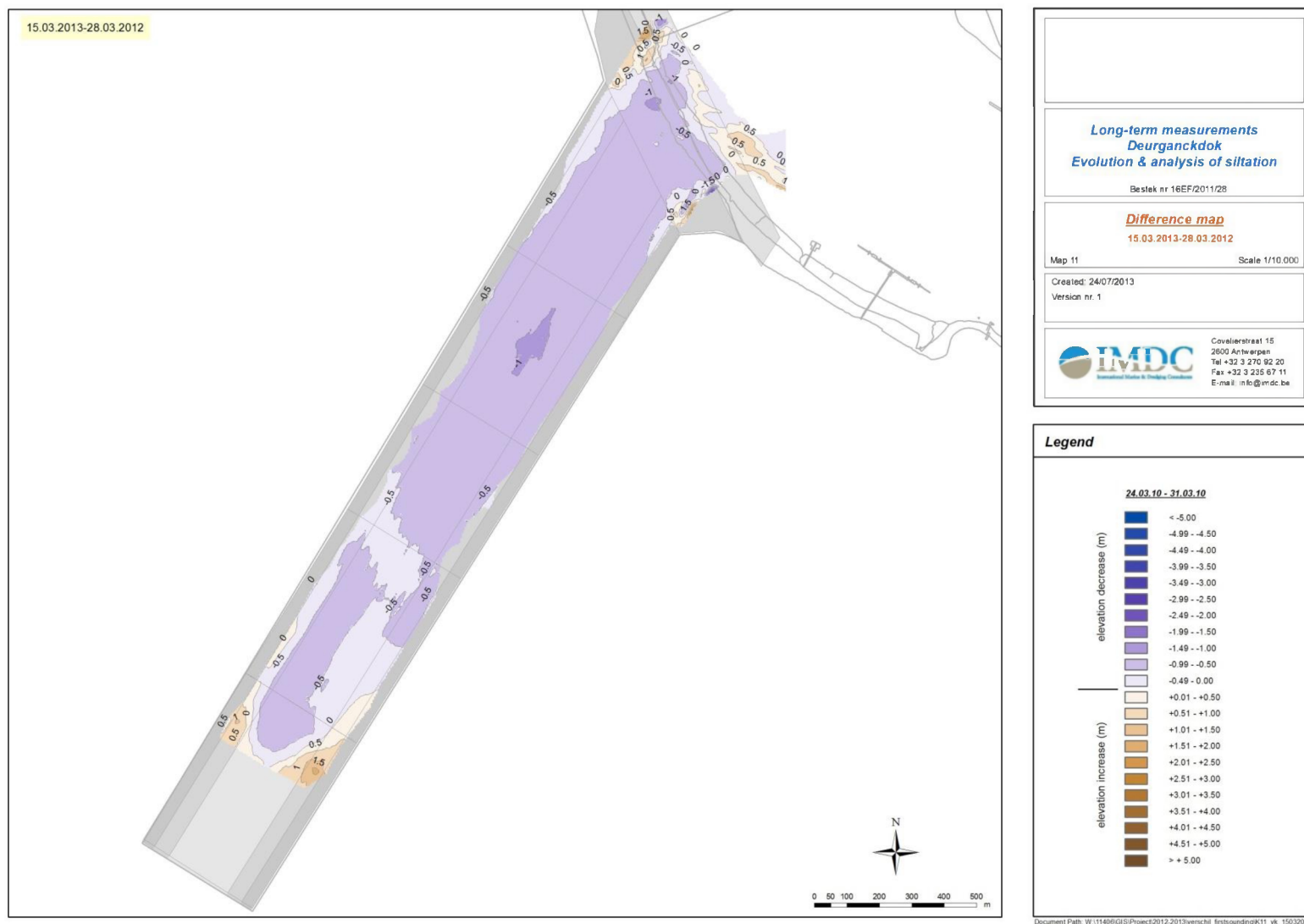












C.3 Bed elevation - evolution per section

Evaluation of external effects on the siltation of Deurganckdok

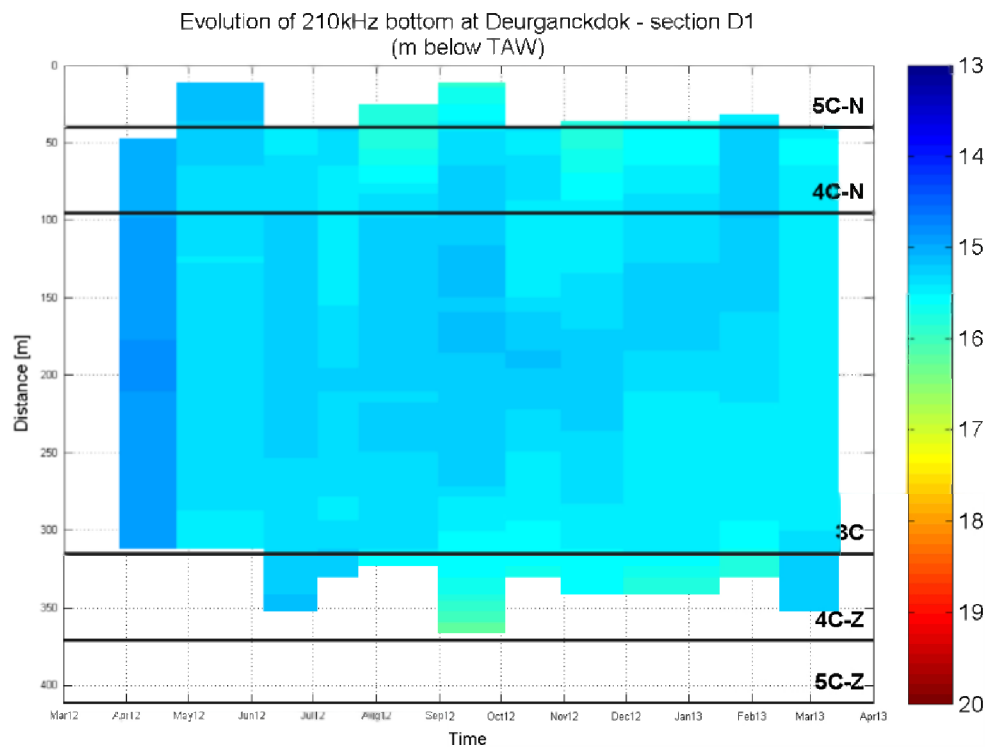
Evolution 210kHz bottom

Equipment(s):

210kHz depth sounder

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

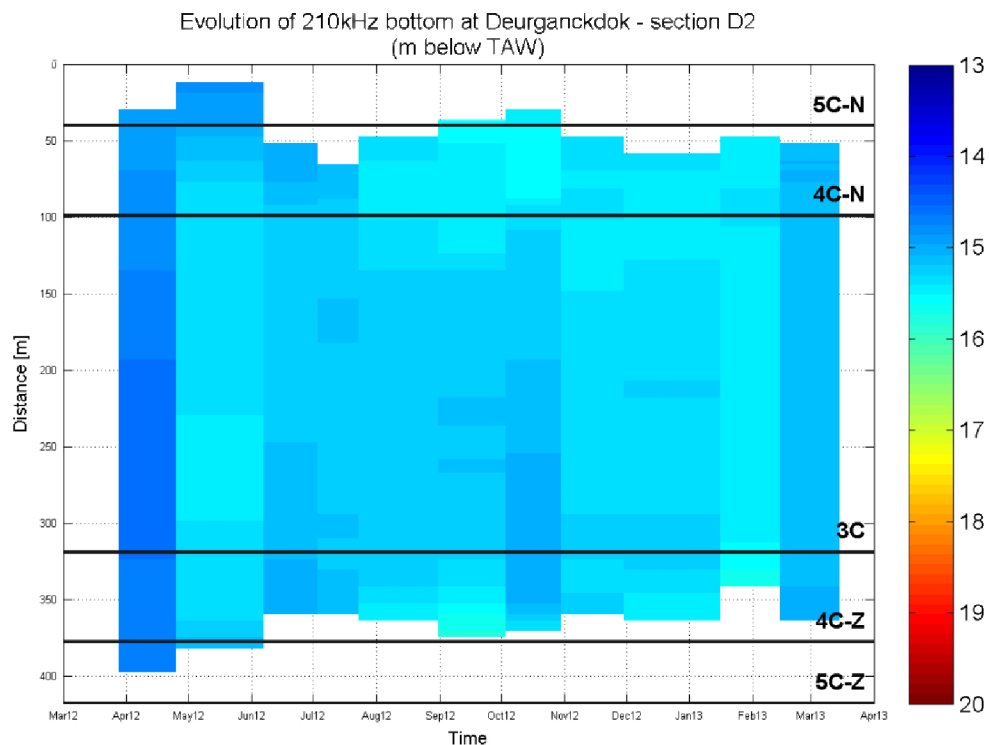
Evolution 210kHz bottom

Equipment(s):

210kHz depth sounder

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

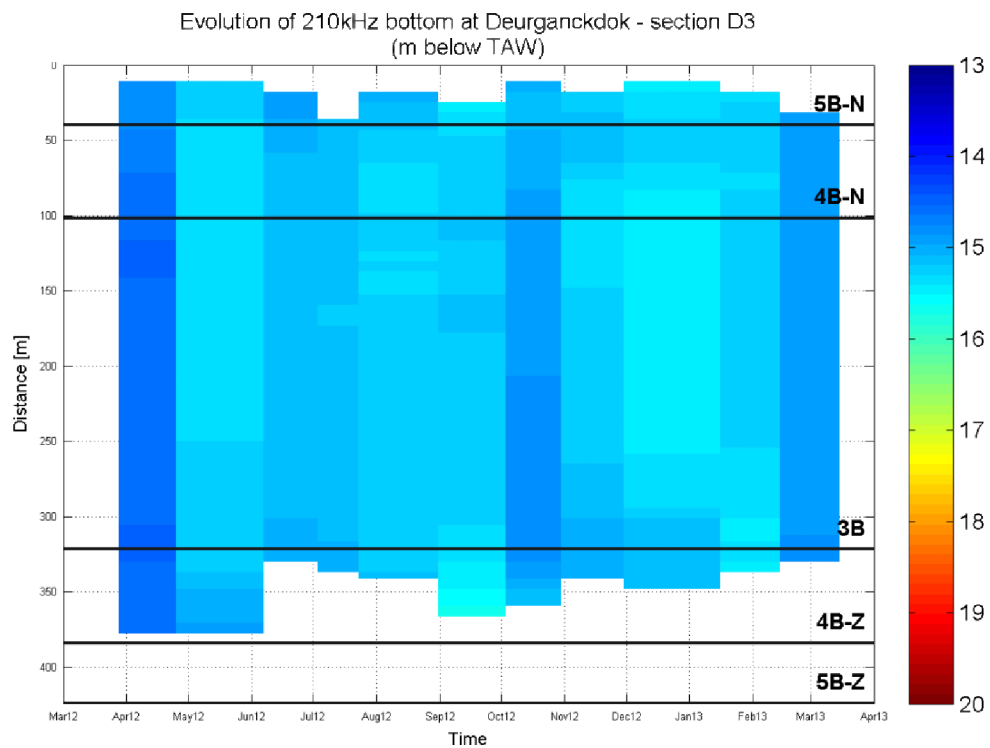
Evolution 210kHz bottom

Equipment(s):

210kHz depth sounder

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

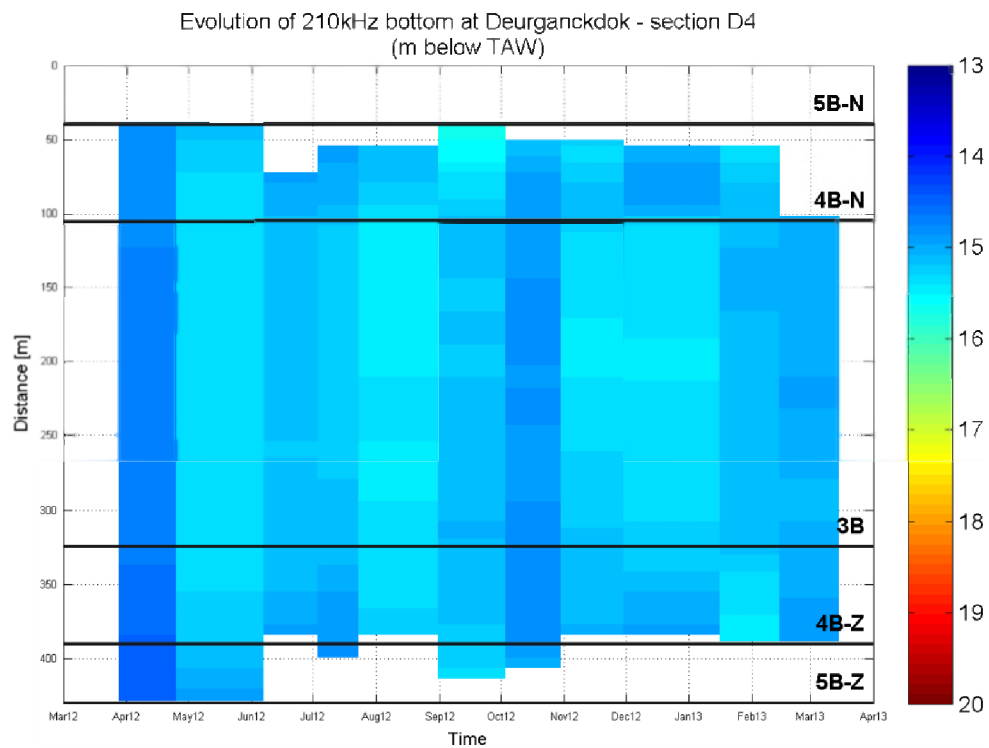
Evolution 210kHz bottom

Equipment(s):

210kHz depth sounder

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

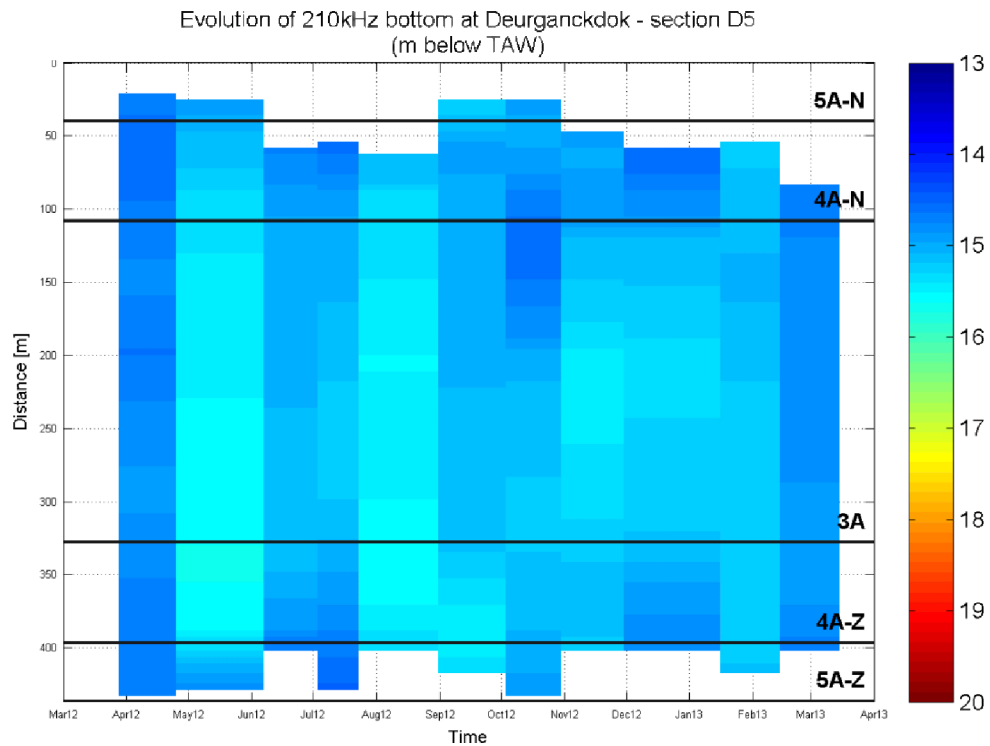
Evolution 210kHz bottom

Equipment(s):

210kHz depth sounder

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

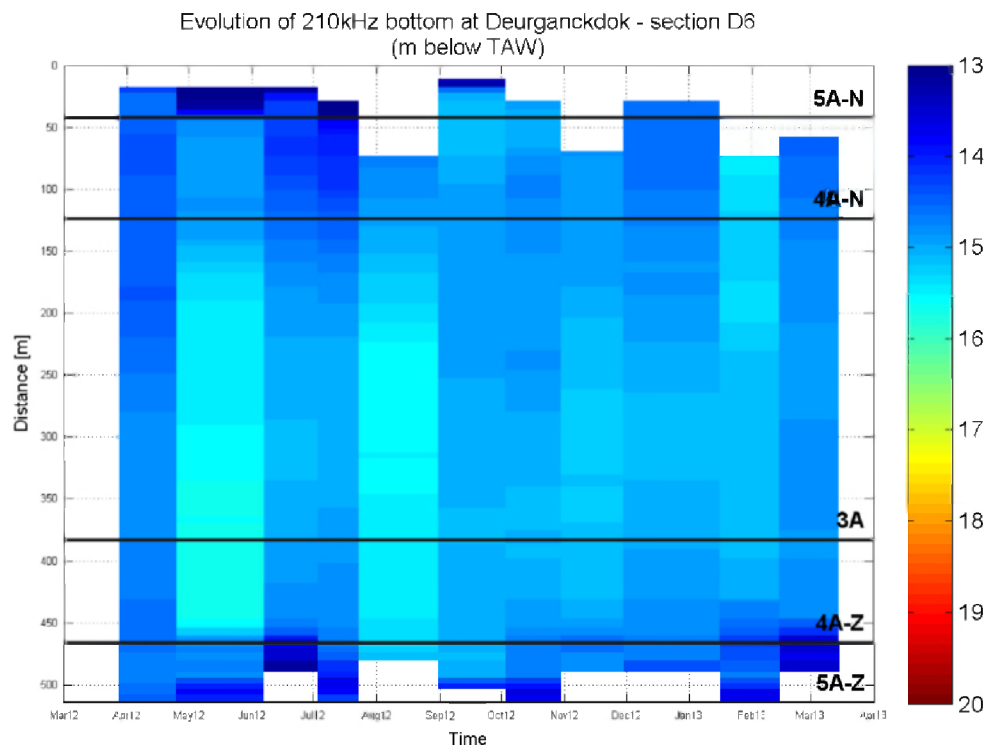
Evolution 210kHz bottom

Equipment(s):

210kHz depth sounder

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

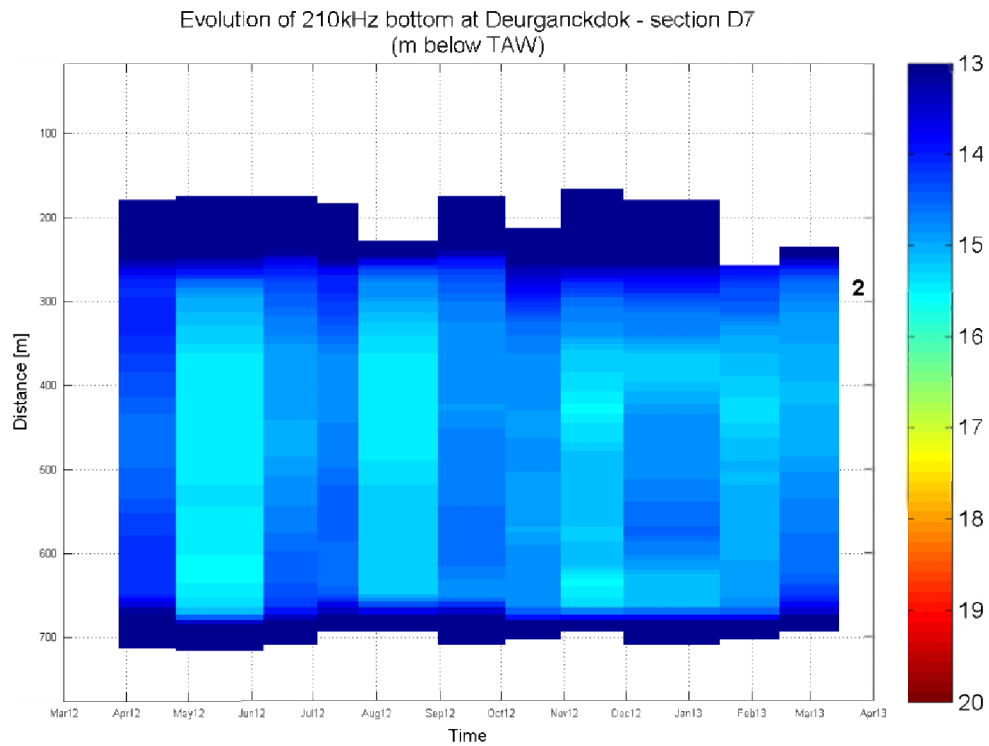
Evolution 210kHz bottom

Equipment(s):

210kHz depth sounder

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

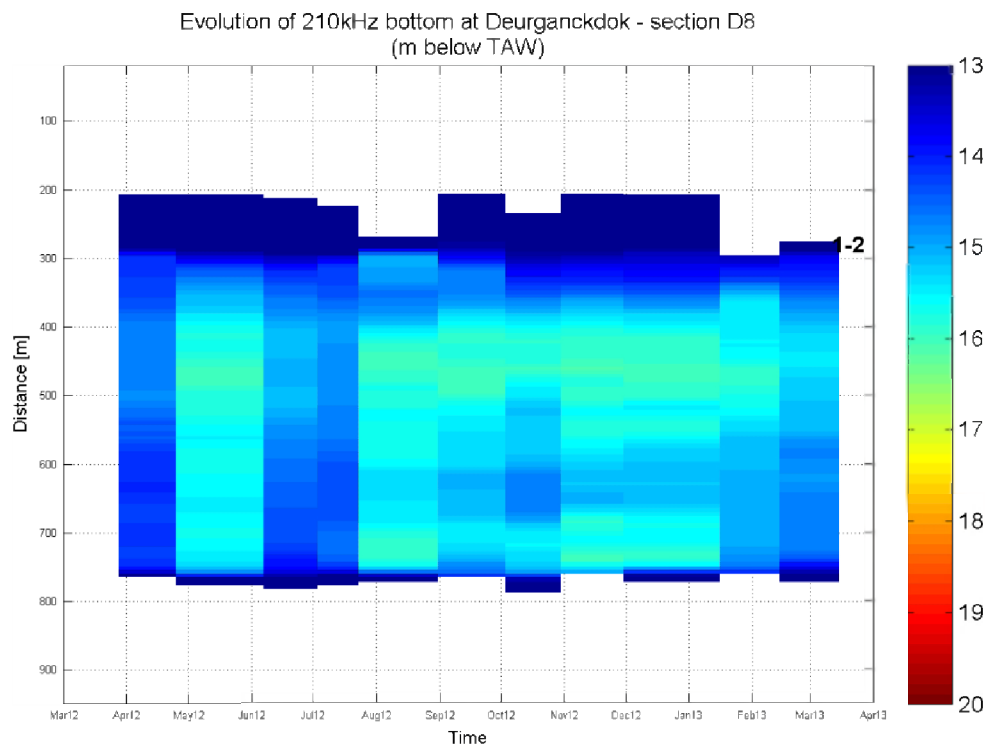
Evolution 210kHz bottom

Equipment(s):

210kHz depth sounder

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

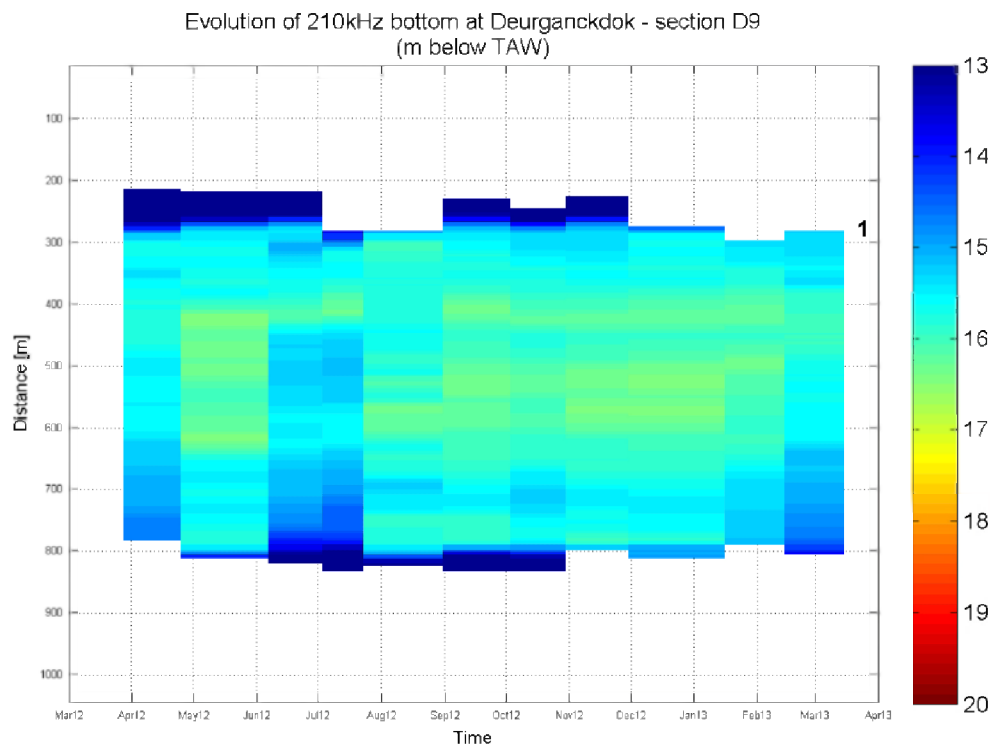
Evolution 210kHz bottom

Equipment(s):

210kHz depth sounder

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

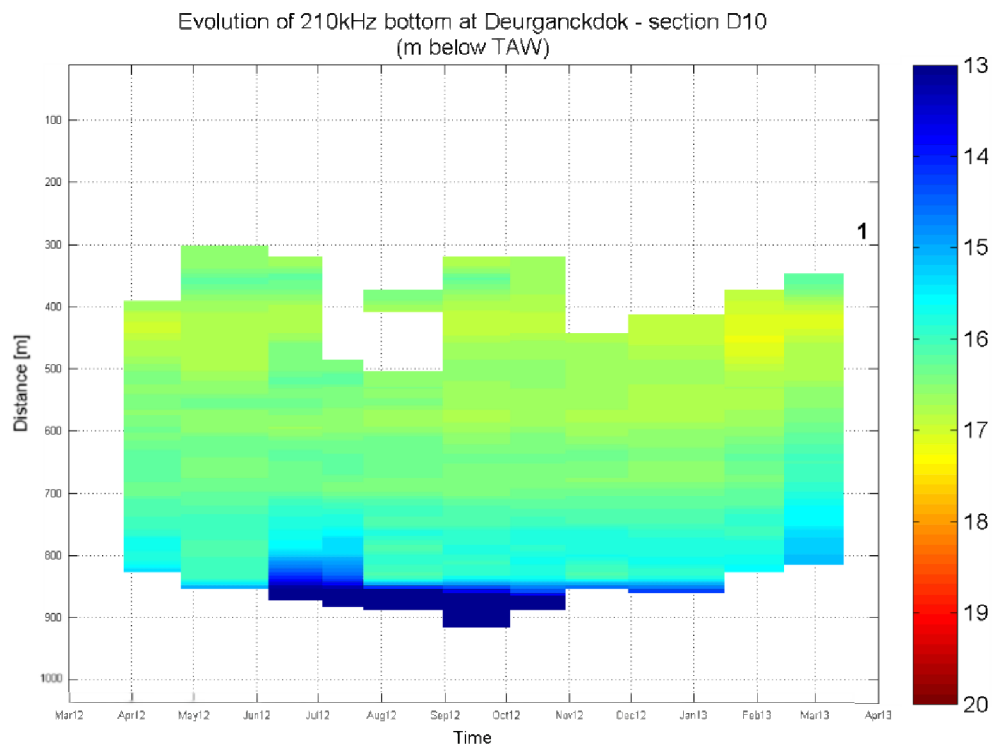
Evolution 210kHz bottom

Equipment(s):

210kHz depth sounder

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

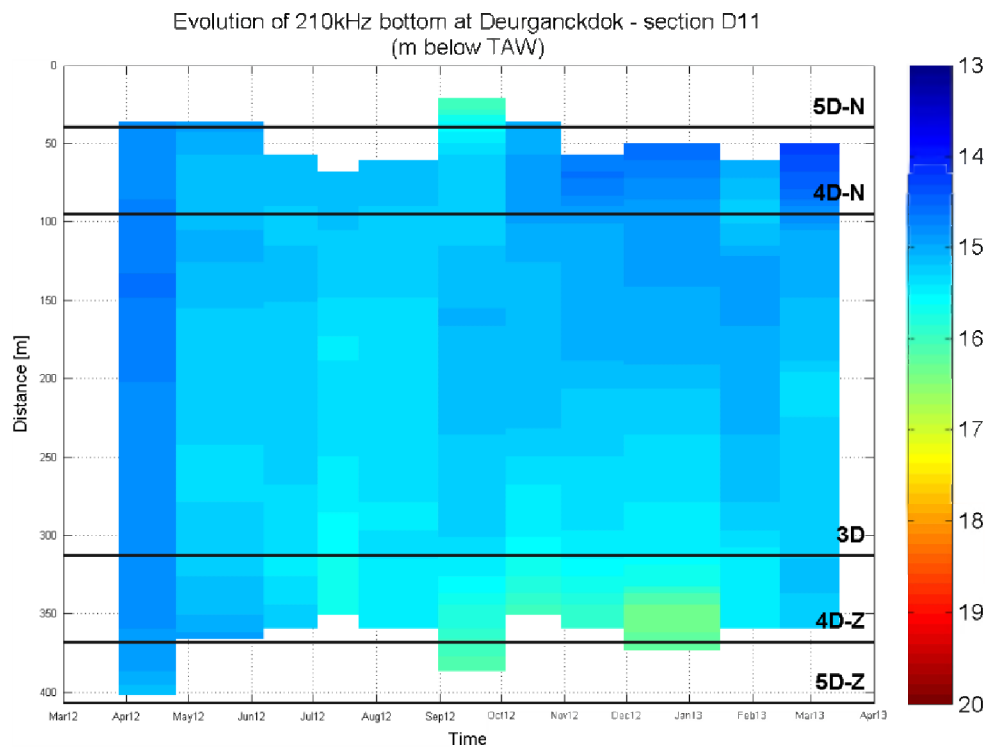
Evolution 210kHz bottom

Equipment(s):

210kHz depth sounder

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

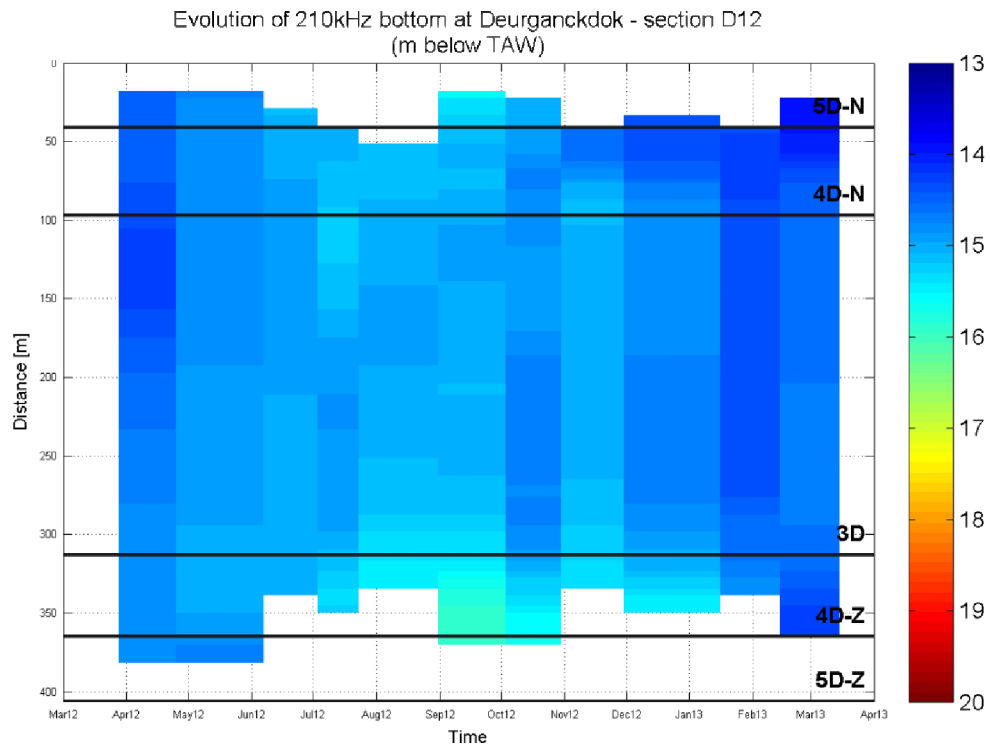
Evolution 210kHz bottom

Equipment(s):

210kHz depth sounder

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

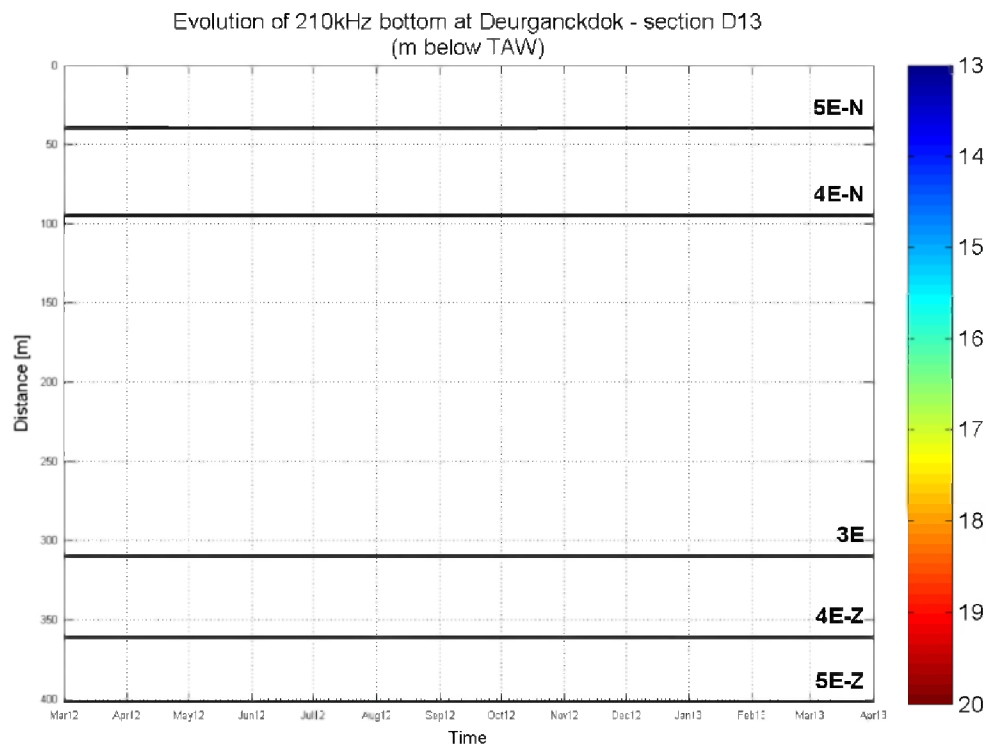
Evolution 210kHz bottom

Equipment(s):

210kHz depth sounder

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

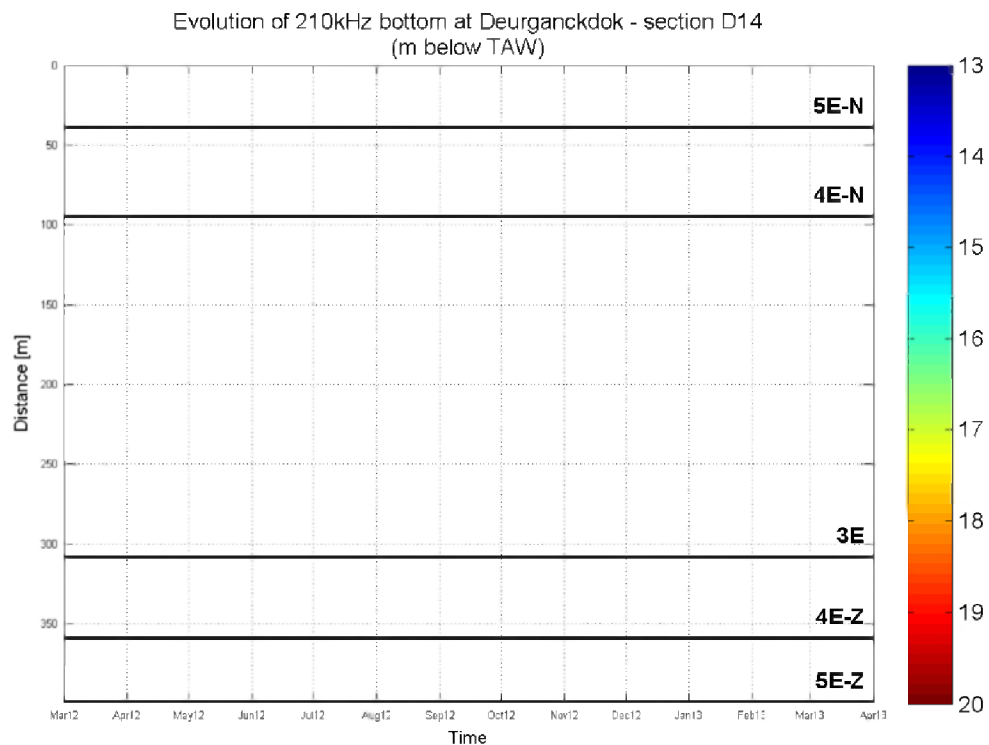
Evolution 210kHz bottom

Equipment(s):

210kHz depth sounder

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

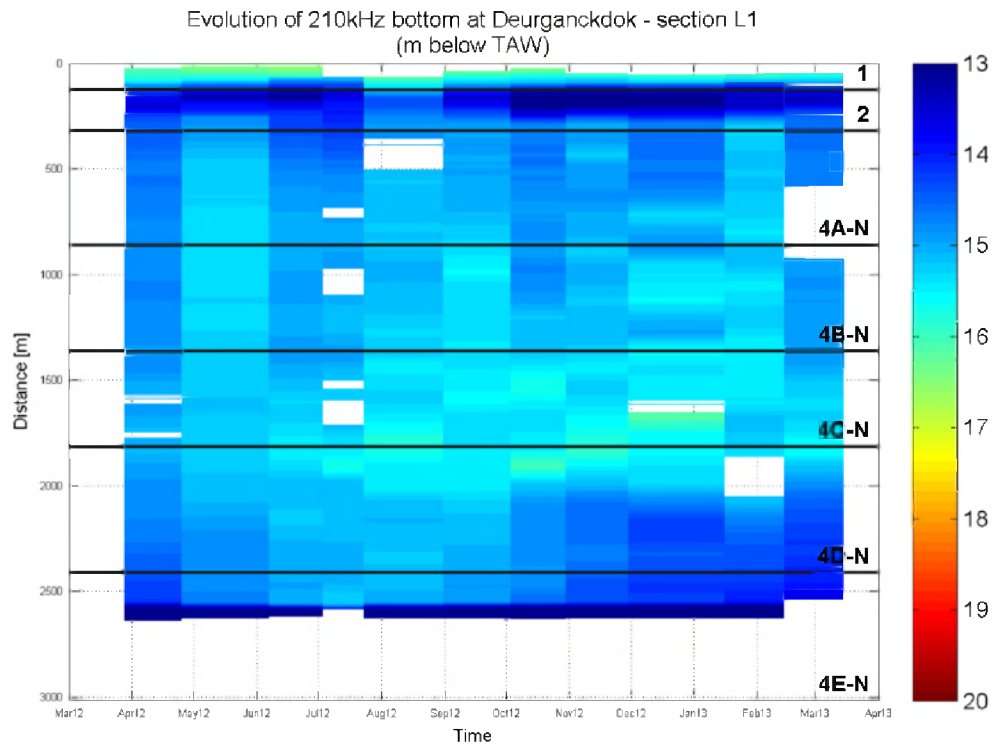
Evolution 210kHz bottom

Equipment(s):

210kHz depth sounder

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

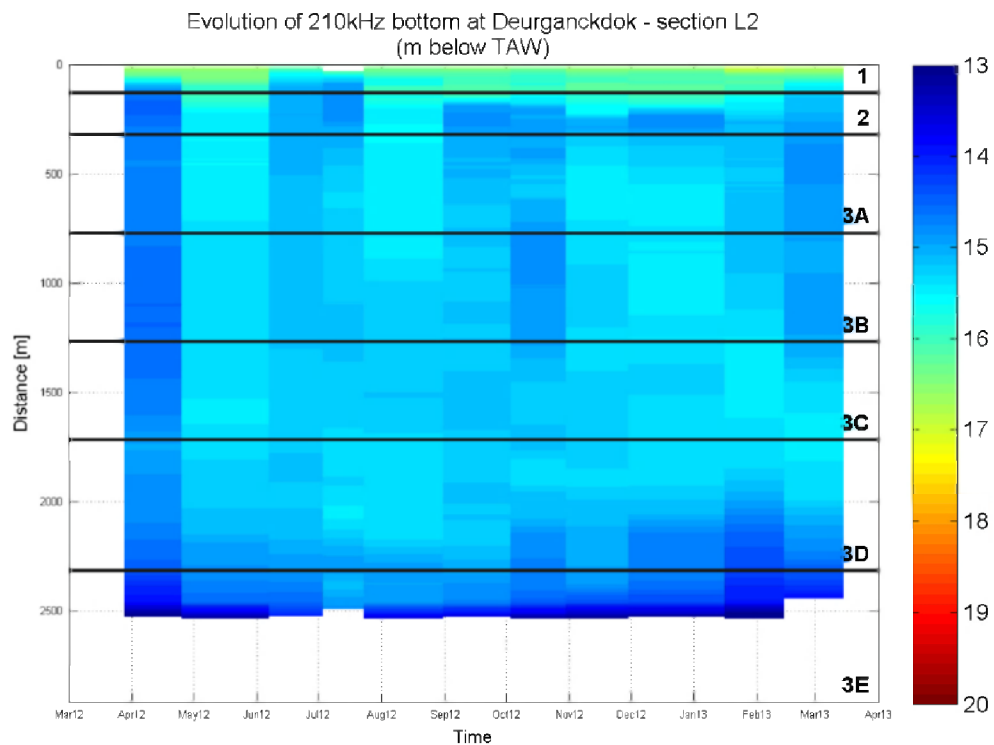
Evolution 210kHz bottom

Equipment(s):

210kHz depth sounder

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

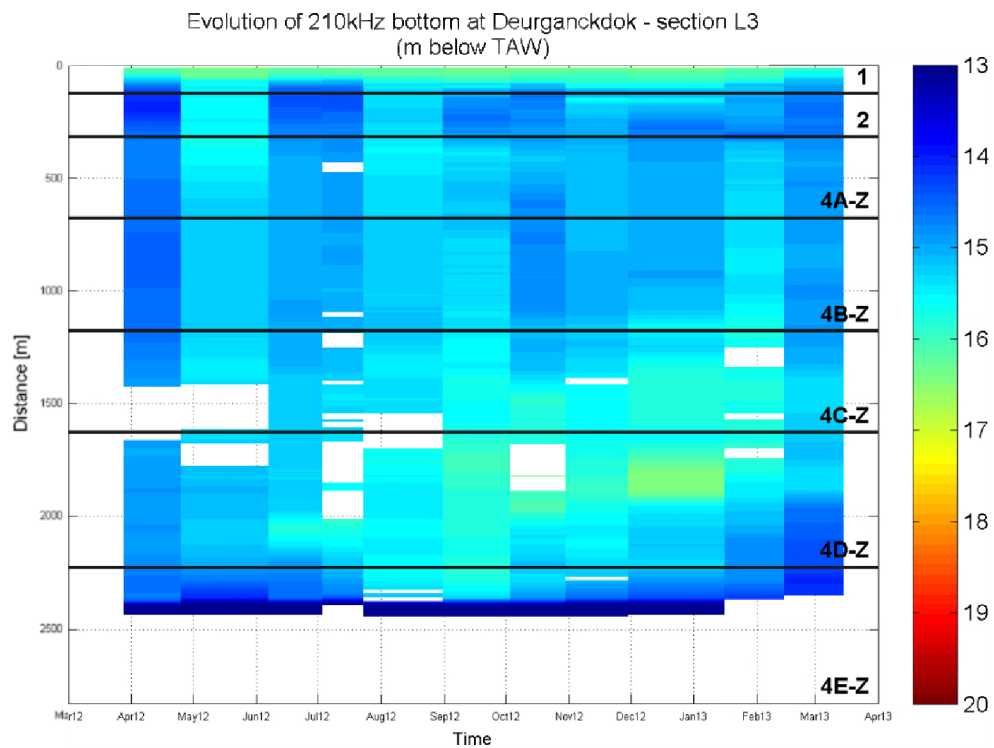
Evolution 210kHz bottom

Equipment(s):

210kHz depth sounder

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Annex D VOLUMETRIC SILTATION RATES IN DIFFERENT ZONES AND SECTIONS

D.1 SILTATION RATES (TABULAR)

Table 7-1: Siltation rates [cm/day] per zone at each depth sounding day, based on the water-bed interface level difference between two consecutive depth soundings. For period March 28th 2012 – March 15th 2013.

Per zone	24/Apr	07/Jun	03/Jul	27/Jul	31/Aug	03/Oct	30/Oct	30/Nov	16/Jan	14/Feb	15/Mar
1	-1.87	1.38	0.843	-4.234	0.767	0.077	-0.593	-0.537	NaN	0.234	0.077
2	-2.417	0.998	-0.208	-5.905	3.05	-0.953	0.81	-0.309	-1.422	0.84	0.029
3a	-2.651	0.884	-0.201	-1.569	0.881	0.493	-1.351	0.116	0.233	0.932	-1.971
3b	-2.622	0.438	-0.024	-0.824	0.307	1.004	-1.568	-0.329	0.256	1.015	-1.746
3c	-2.337	0.362	-0.188	0.156	0.09	-0.179	-0.288	0	-0.195	0.537	-0.51
3d	-1.367	-0.053	-0.597	0.064	0.257	0.161	-0.12	0.335	0.375	-0.595	-0.705
3e	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
4Na	-1.996	0.969	0.21	-2.076	0.255	0.833	-0.806	0.404	-0.79	1.844	-1.727
4Nb	-1.755	0.66	-0.283	-0.522	-0.536	1.239	-0.651	-0.434	-0.094	1.435	-1.852
4Nc	-1.029	-0.009	-0.019	-1.089	-0.039	0.031	-0.083	-0.289	0.397	0.439	-0.827
4Nd	-0.929	-0.389	-0.19	-0.366	0.058	0.489	0.53	0.568	0.201	0.494	-1.823
4Ne	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
4Za	-2.657	0.999	0.239	-2.416	0.431	0.73	-0.509	0.419	-0.568	1.378	-1.506
4Zb	-2.476	0.5	-0.033	-1	-0.274	1.419	-0.854	-0.241	-0.604	1.752	-1.179

Per zone	24/Apr	07/Jun	03/Jul	27/Jul	31/Aug	03/Oct	30/Oct	30/Nov	16/Jan	14/Feb	15/Mar
4Zc	-2.127	0.503	-0.349	-0.464	-0.651	0.664	-0.175	-0.431	-0.27	1.563	-0.574
4Zd	-0.986	-0.384	-0.645	0.054	-0.709	0.595	-0.005	-0.075	0.755	1.141	-1.093
4Ze	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
5Na	-0.642	NaN	NaN	NaN	-0.251	0.602	NaN	NaN	NaN	NaN	NaN
5Nb	-0.287	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
5Nc	-0.509	NaN	NaN	NaN	-0.659	NaN	NaN	NaN	NaN	NaN	NaN
5Nd	-1.022	NaN	NaN	NaN	-0.669	NaN	NaN	NaN	NaN	NaN	NaN
5Ne	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
5Za	-1.777	NaN	NaN	NaN	-0.287	NaN	NaN	NaN	NaN	NaN	NaN
5Zb	-1.671	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
5Zc	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
5Zd	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
5Ze	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
4Ztot	-1.75	0.263	-0.385	-0.72	-0.339	0.981	-0.37	-0.103	-0.252	1.288	-0.605
4Ntot	-1.534	0.232	-0.318	-0.753	0.005	0.819	-0.37	0.293	-0.243	1.02	-1.151
5Ztot	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
5Ntot	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN

Table 7-2: Siltation rates [cm/day] per section at each depth sounding day, based on the water-bed interface level difference between two consecutive depth soundings. For period March 28th 2012 – March 15th 2013.

Per section	24/Apr	07/Jun	03/Jul	27/Jul	31/Aug	03/Oct	30/Oct	30/Nov	16/Jan	14/Feb	15/Mar
D1	-1.455	0.094	-0.338	-0.11	-0.01	0.012	-0.192	0.022	0.155	-0.208	-0.047
D2	-2.172	0.373	-0.131	-0.554	-0.119	0.348	-0.426	-0.018	-0.251	1.21	-1.098
D3	-2.422	0.387	-0.125	-0.565	-0.06	1.065	-1.071	-0.466	0.123	1.34	-1.686
D4	-2.195	0.436	-0.047	-1.22	0.383	1.024	-1.442	0.046	0.134	0.629	-1.646
D5	-2.404	0.895	0.092	-2.289	0.797	0.506	-0.934	0.372	-0.159	1.233	-1.79
D6	-1.768	0.999	0.282	-3.817	1.096	0.216	-0.748	0.619	-0.358	1.172	-1.489
D7	-2.531	0.939	-0.4	-5.565	3.395	-1.737	0.976	0.541	-2.065	0.439	0.207
D8	-2.937	1.689	-0.342	-6.932	2.467	-0.142	0.05	0.124	-1.734	1.586	0.375
D9	-1.675	1.418	0.031	-3.743	0.602	0.19	-0.731	-0.975	NaN	0.615	-0.059
D10	-0.171	1.085	NaN	NaN	0.706	-2.009	NaN	NaN	NaN	NaN	NaN
D11	-1.307	-0.184	-0.558	0.272	-0.093	0.36	0.212	-0.223	0.23	0.381	-0.85
D12	-1.081	-0.288	-0.303	-0.202	-0.225	0.859	-0.482	0.813	0.794	-0.302	-1.575
D13	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
D14	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
L1	-1.359	0.301	-0.138	-1.02	0.096	0.719	-0.057	0.114	-0.154	0.616	-0.829
L2	-2.314	0.485	-0.313	-0.694	0.406	0.394	-0.835	0.075	0.257	0.192	-1
L3	-1.96	0.472	-0.221	-1.35	-0.211	0.87	-0.462	-0.095	-0.14	1.491	-0.677
Avg	-2.198	0.491	-0.12	-0.961	0.149	0.715	-0.914	-0.043	-0.07	0.997	-1.326

D.2 WATER-BED INTERFACE EVOLUTION FOR ALL ZONES

Evaluation of external effects on the siltation of Deurganckdok

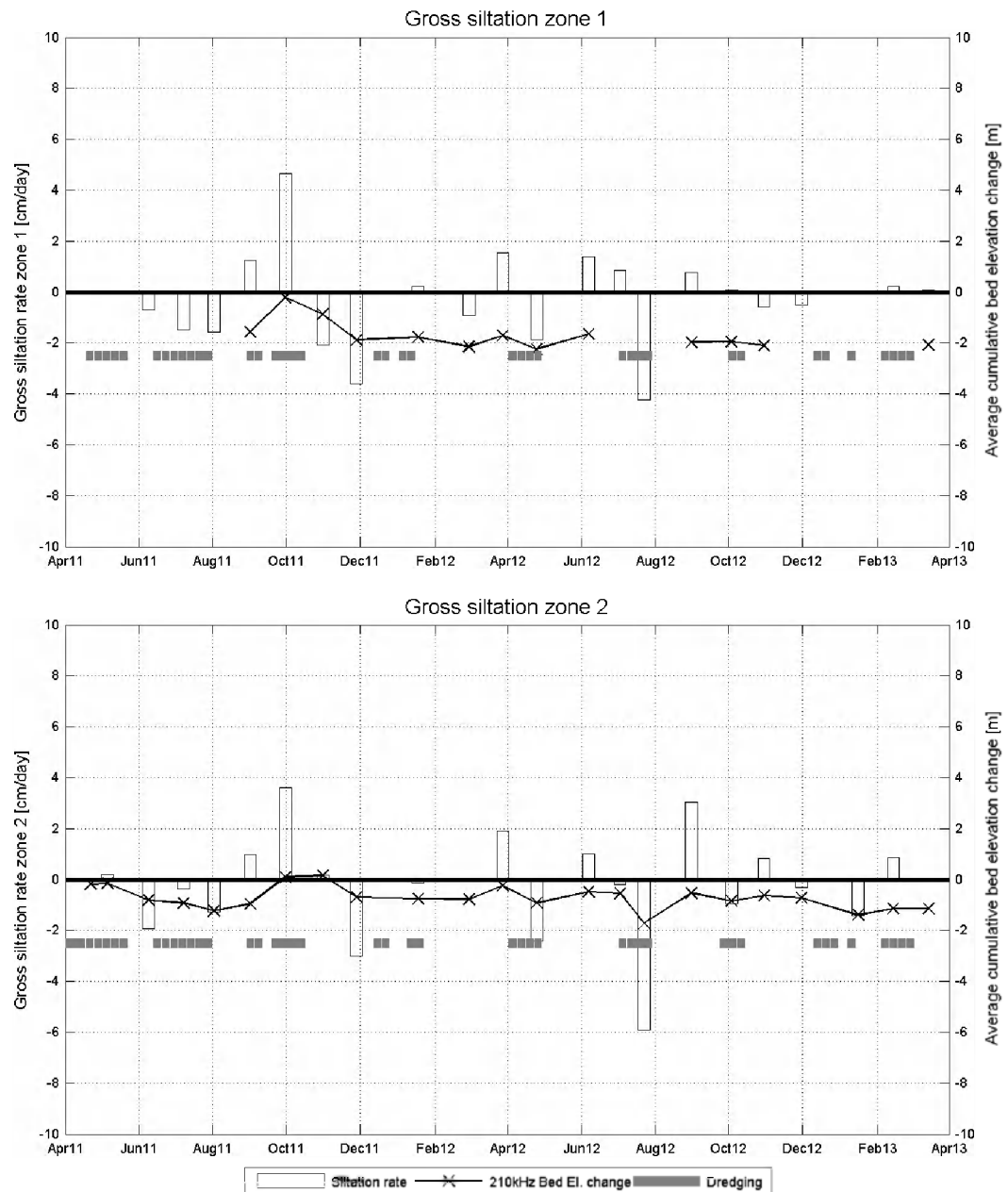
Siltation height / gross siltation rate

Equipment(s):

210kHz depth sounder

Location:

DGD



Reference level: design depth

Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

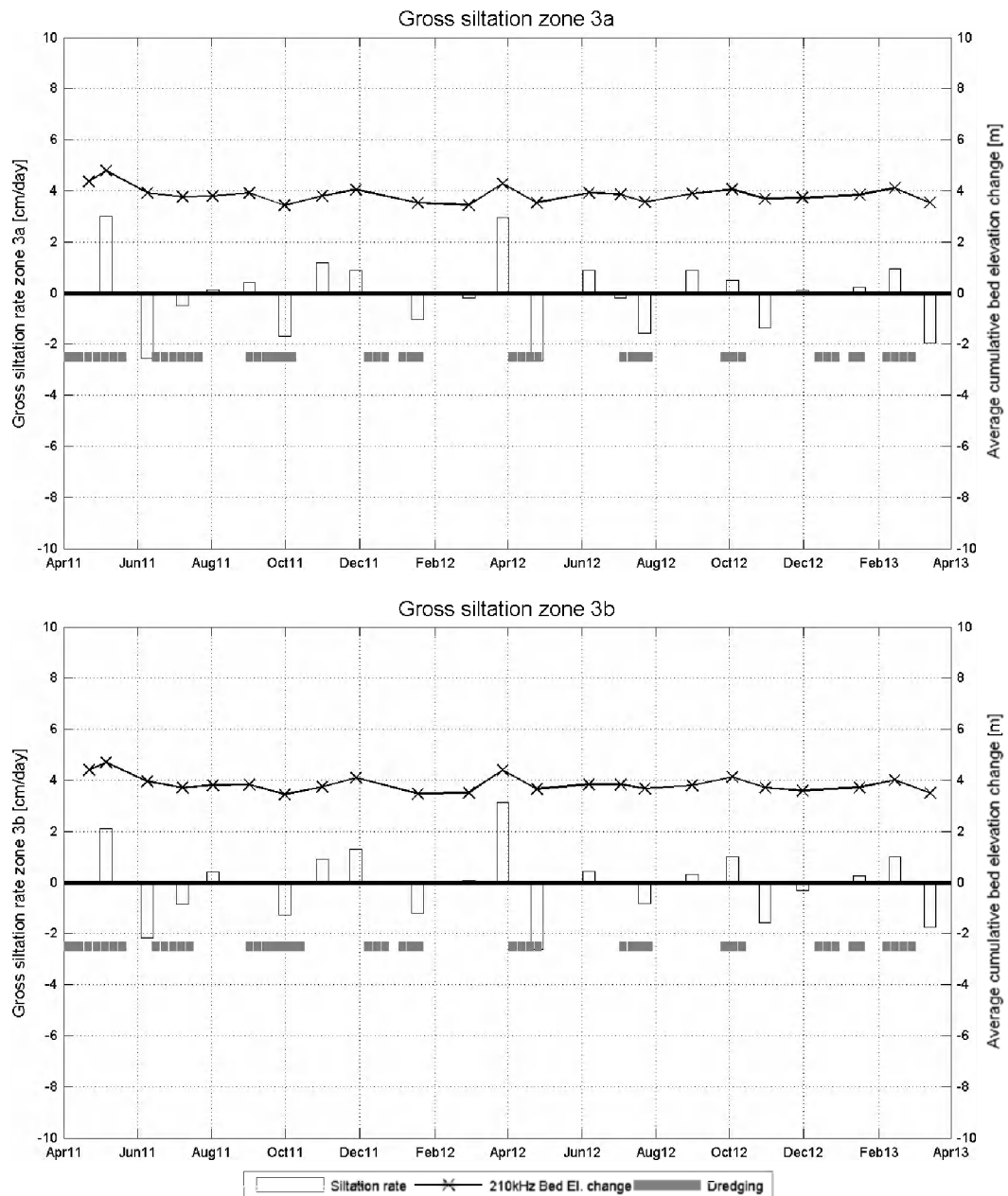
Siltation height / gross siltation rate

Equipment(s):

210kHz depth sounder

Location:

DGD



Reference level: design depth

Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

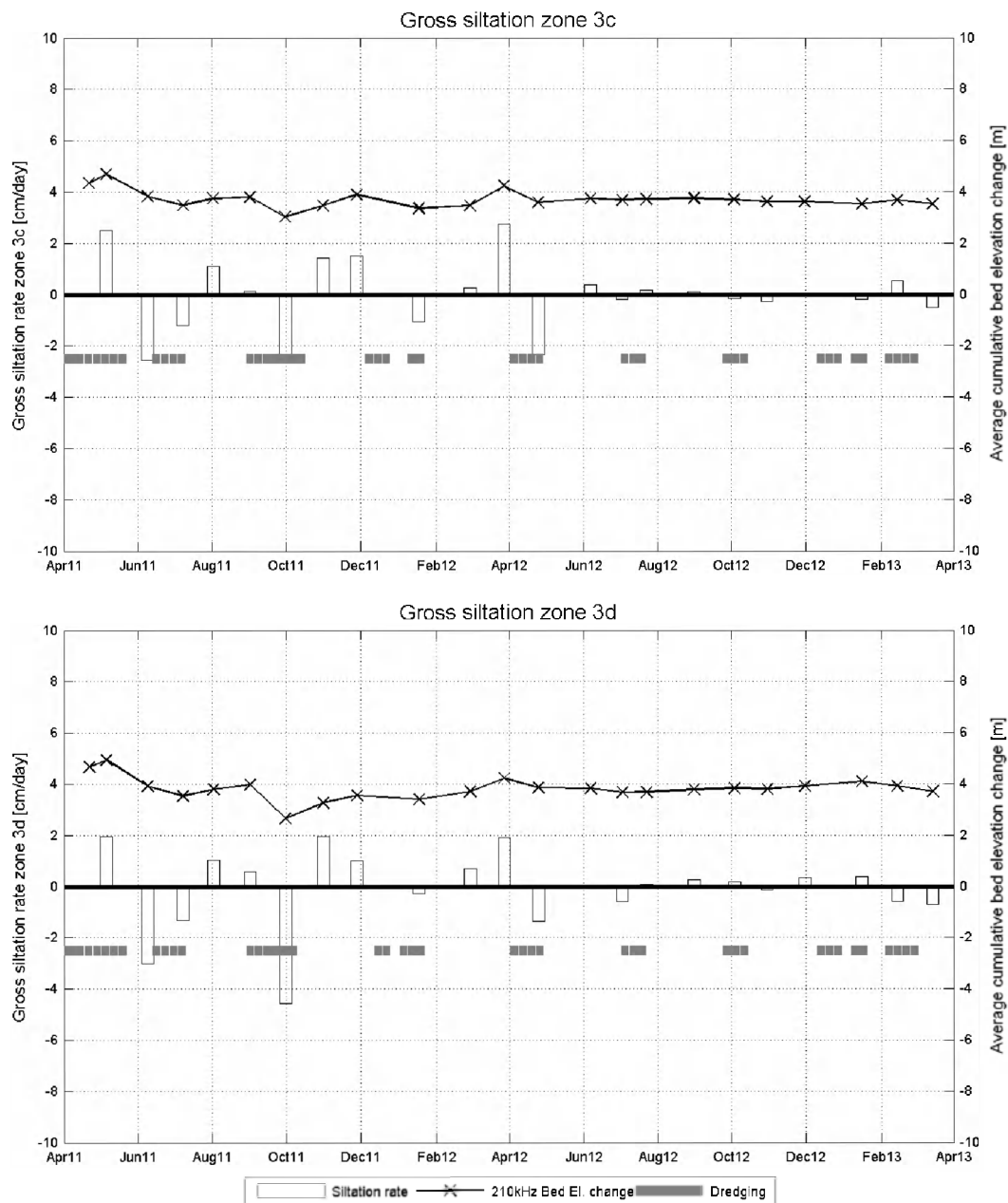
Siltation height / gross siltation rate

Equipment(s):

210kHz depth sounder

Location:

DGD



Reference level: design depth

Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

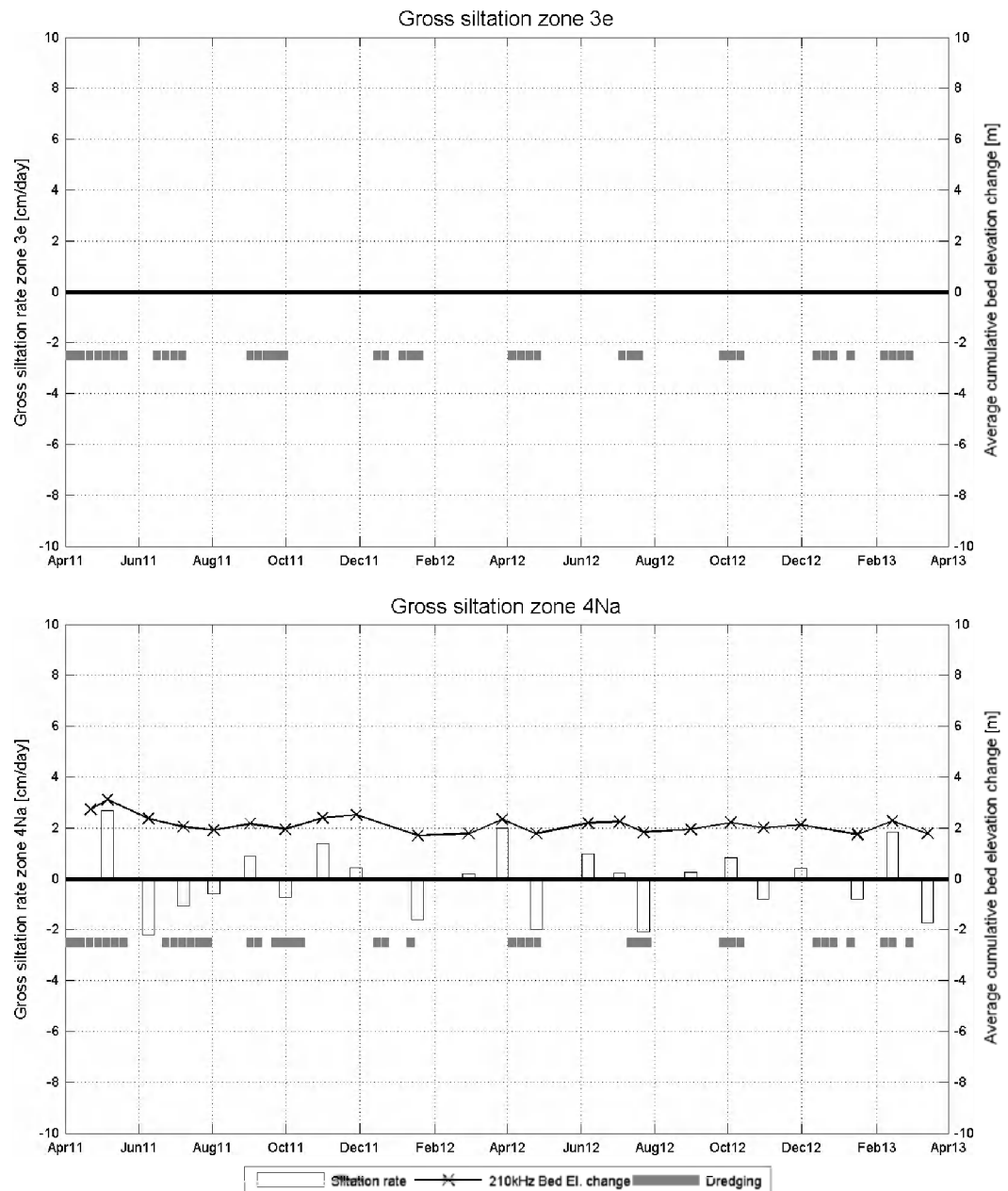
Siltation height / gross siltation rate

Equipment(s):

210kHz depth sounder

Location:

DGD



Reference level: design depth

Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

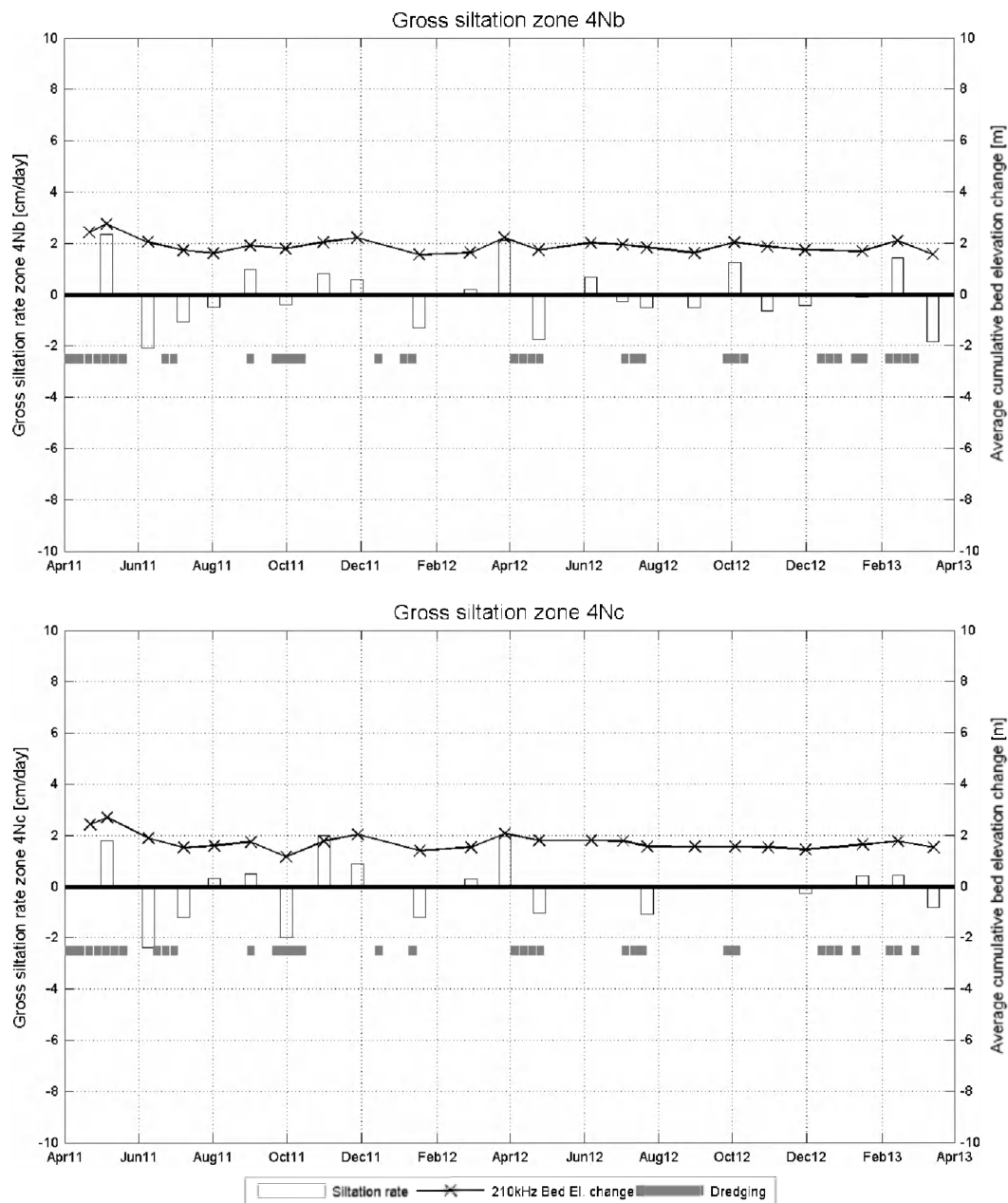
Siltation height / gross siltation rate

Equipment(s):

210kHz depth sounder

Location:

DGD



Reference level: design depth

Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

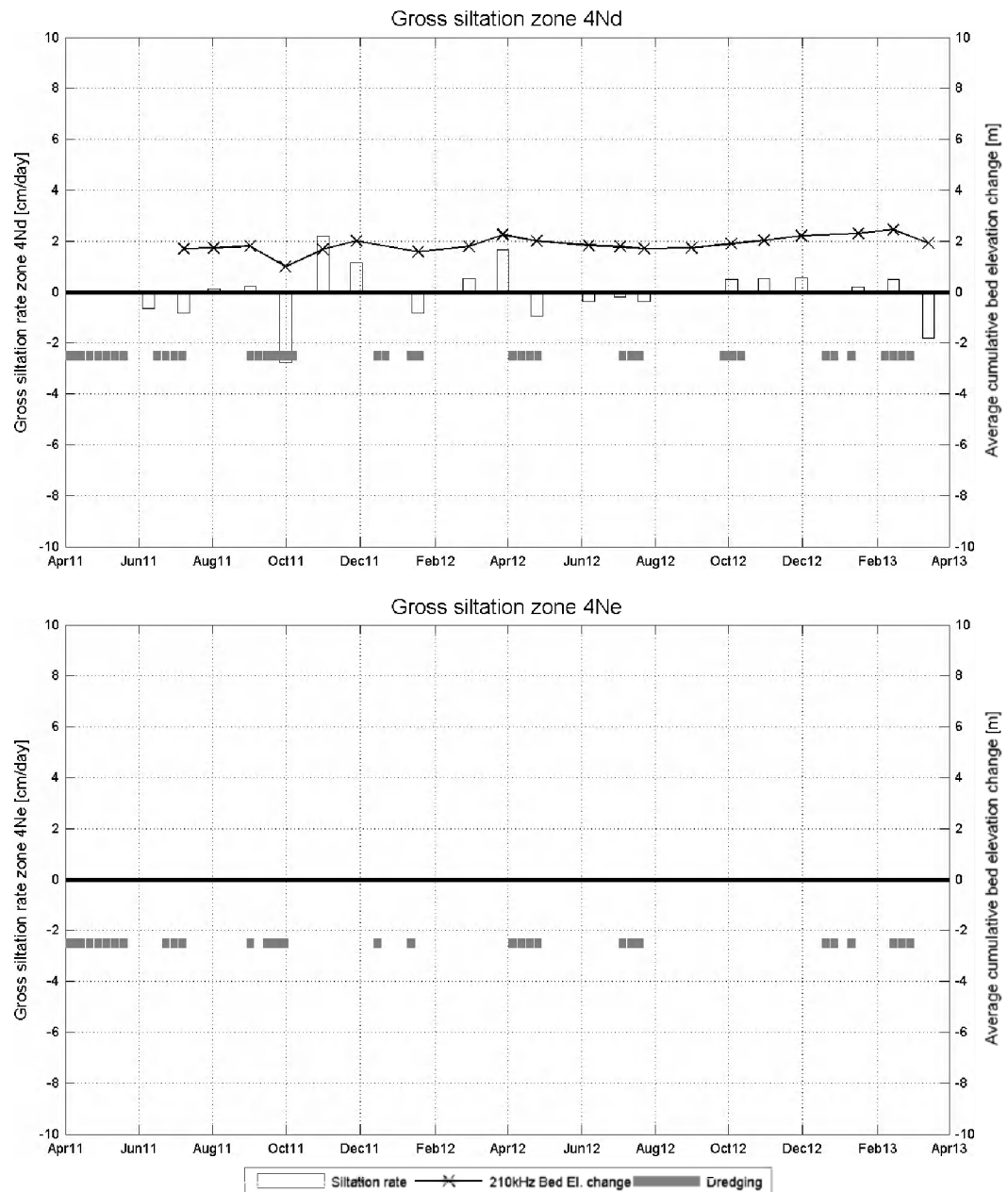
Siltation height / gross siltation rate

Equipment(s):

210kHz depth sounder

Location:

DGD



Reference level: design depth

Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

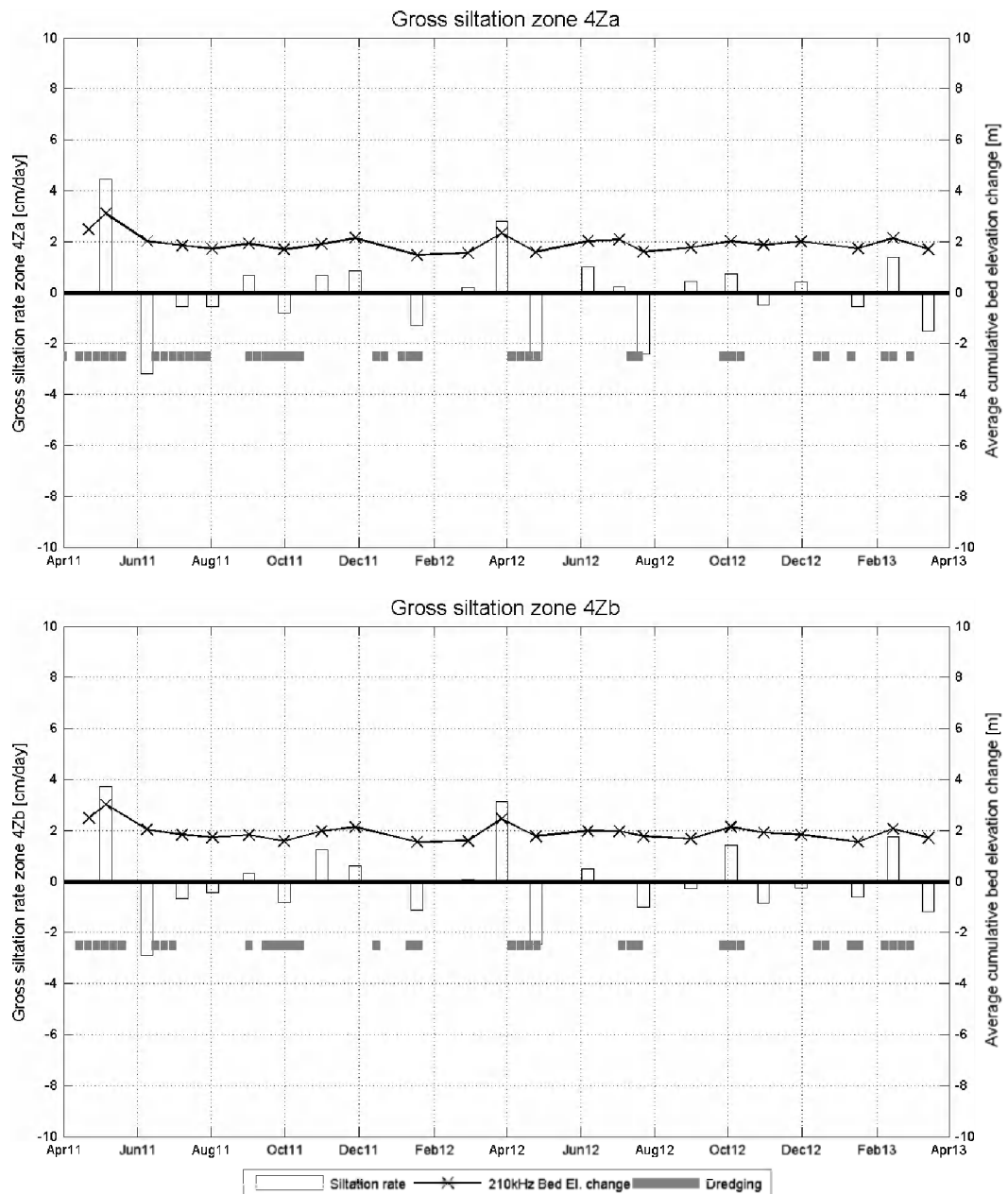
Siltation height / gross siltation rate

Equipment(s):

210kHz depth sounder

Location:

DGD



Reference level: design depth

Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

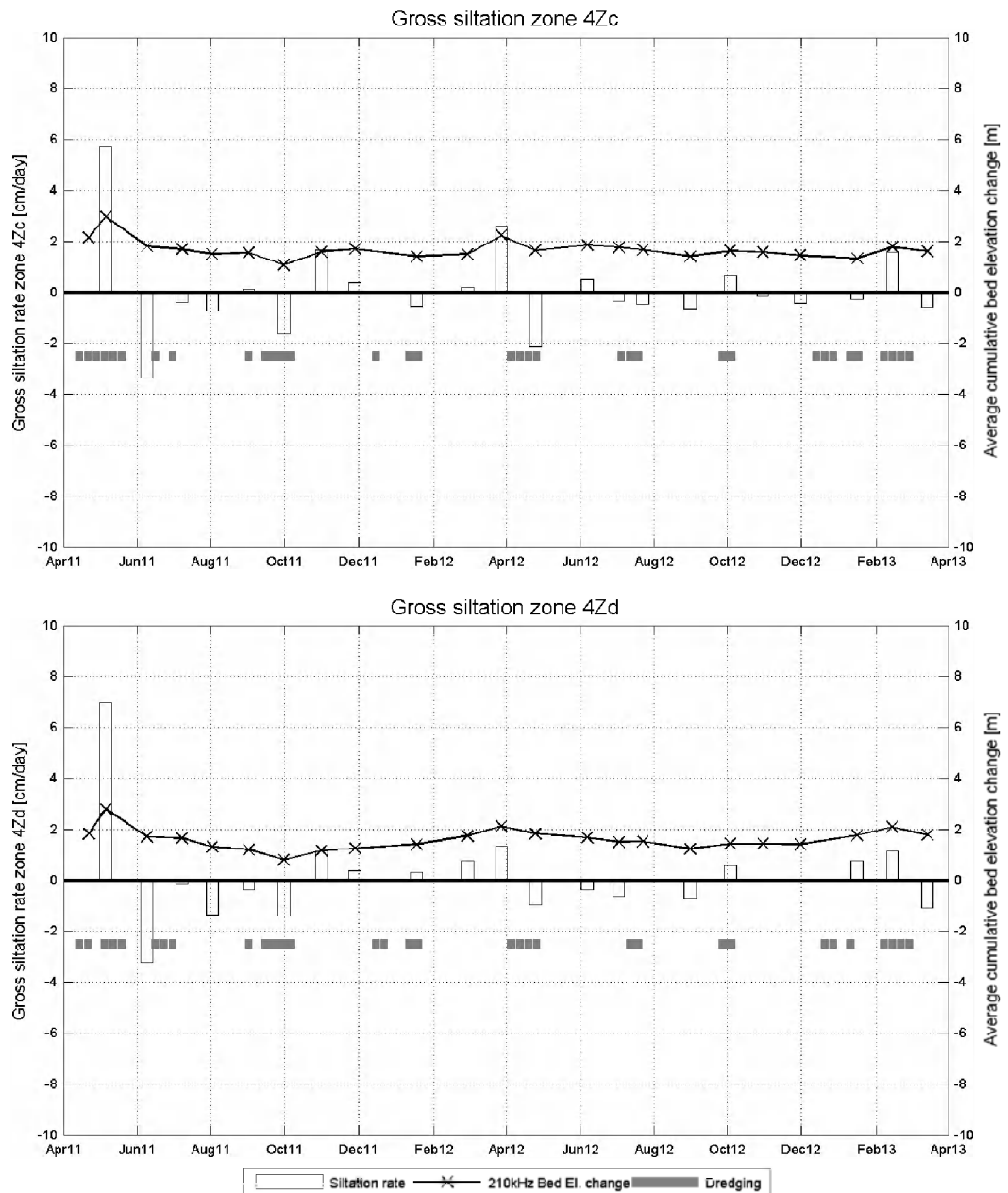
Siltation height / gross siltation rate

Equipment(s):

210kHz depth sounder

Location:

DGD



Reference level: design depth

Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

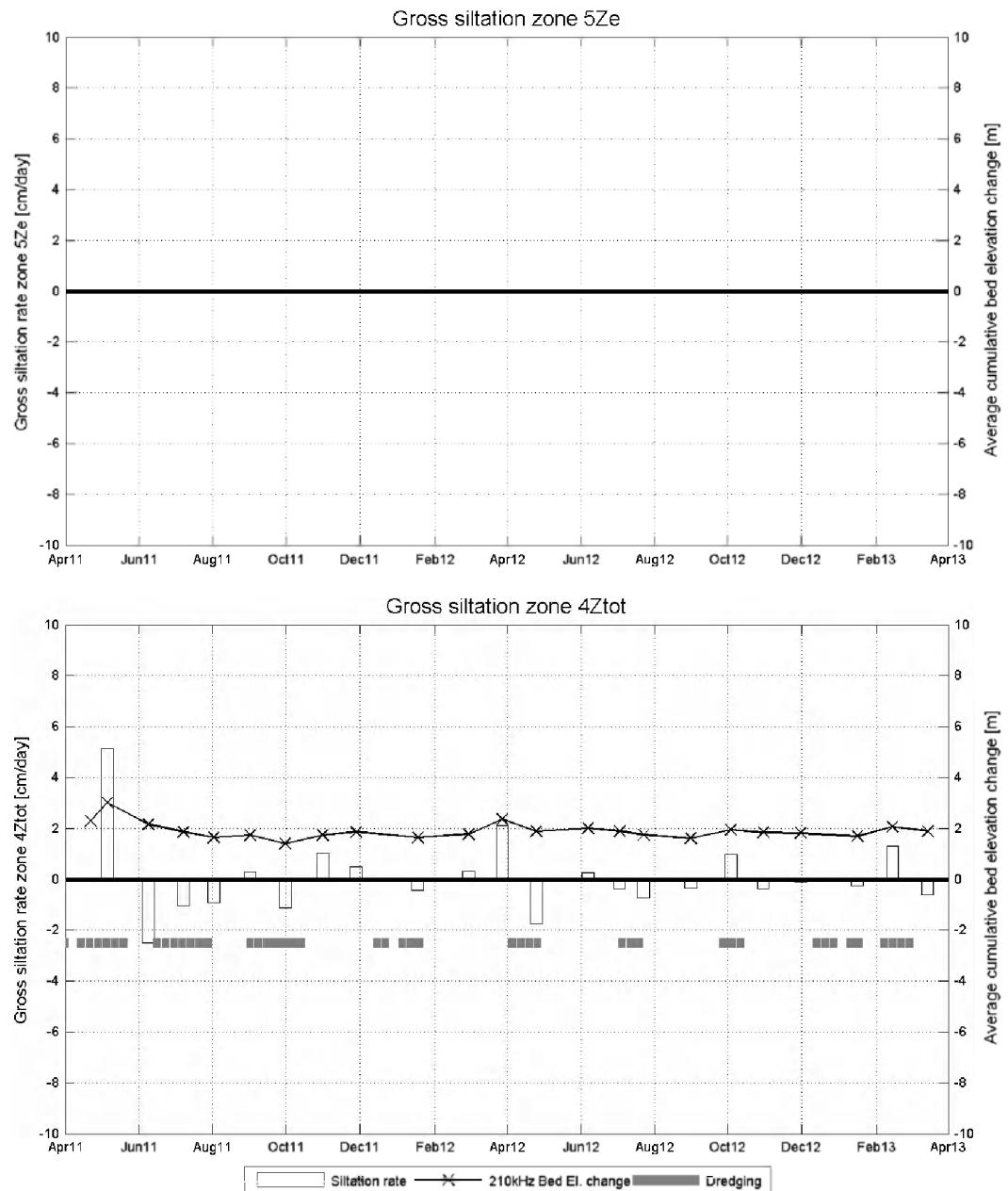
Siltation height / gross siltation rate

Equipment(s):

210kHz depth sounder

Location:

DGD



Reference level: design depth

Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

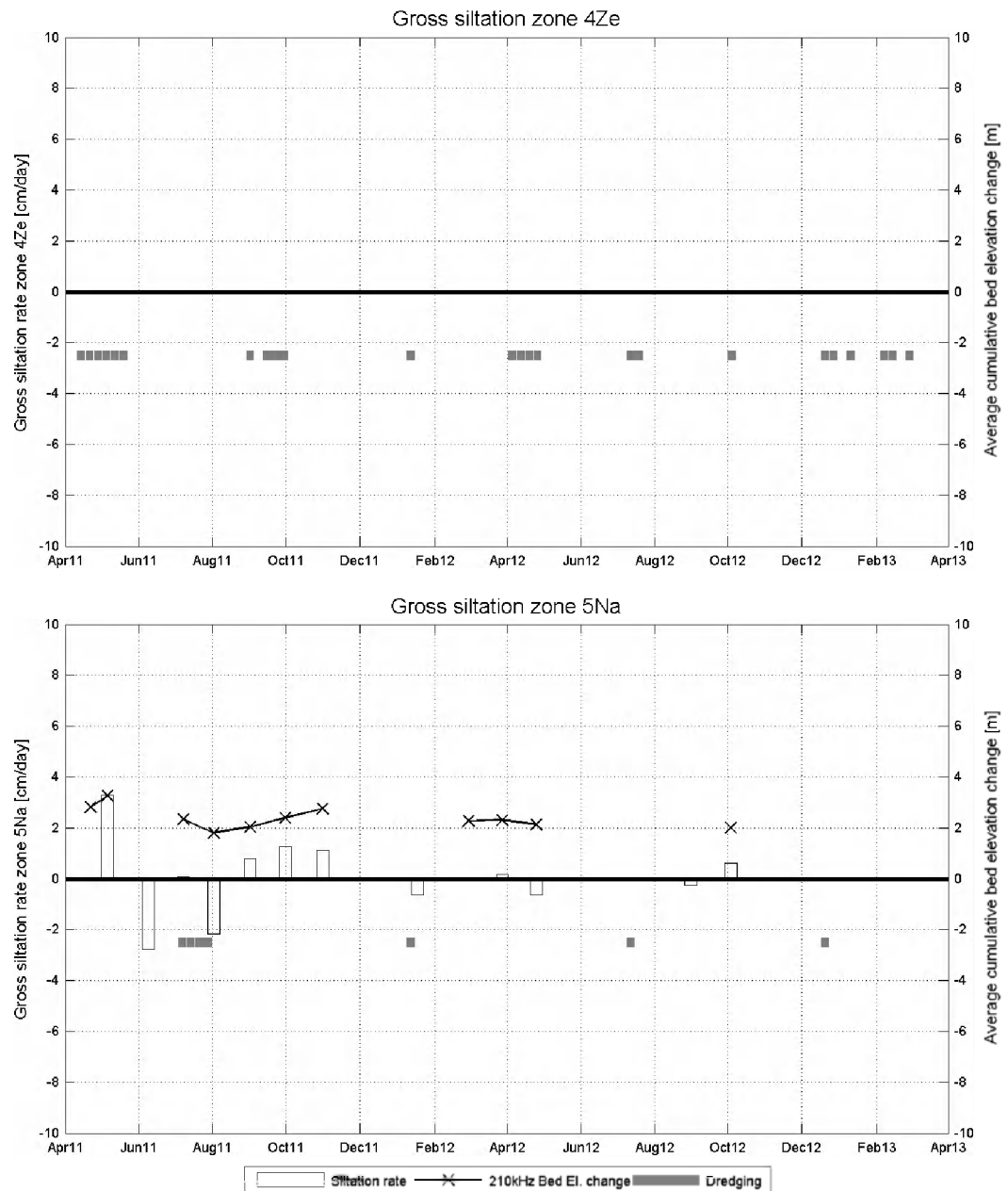
Siltation height / gross siltation rate

Equipment(s):

210kHz depth sounder

Location:

DGD



Reference level: design depth

Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

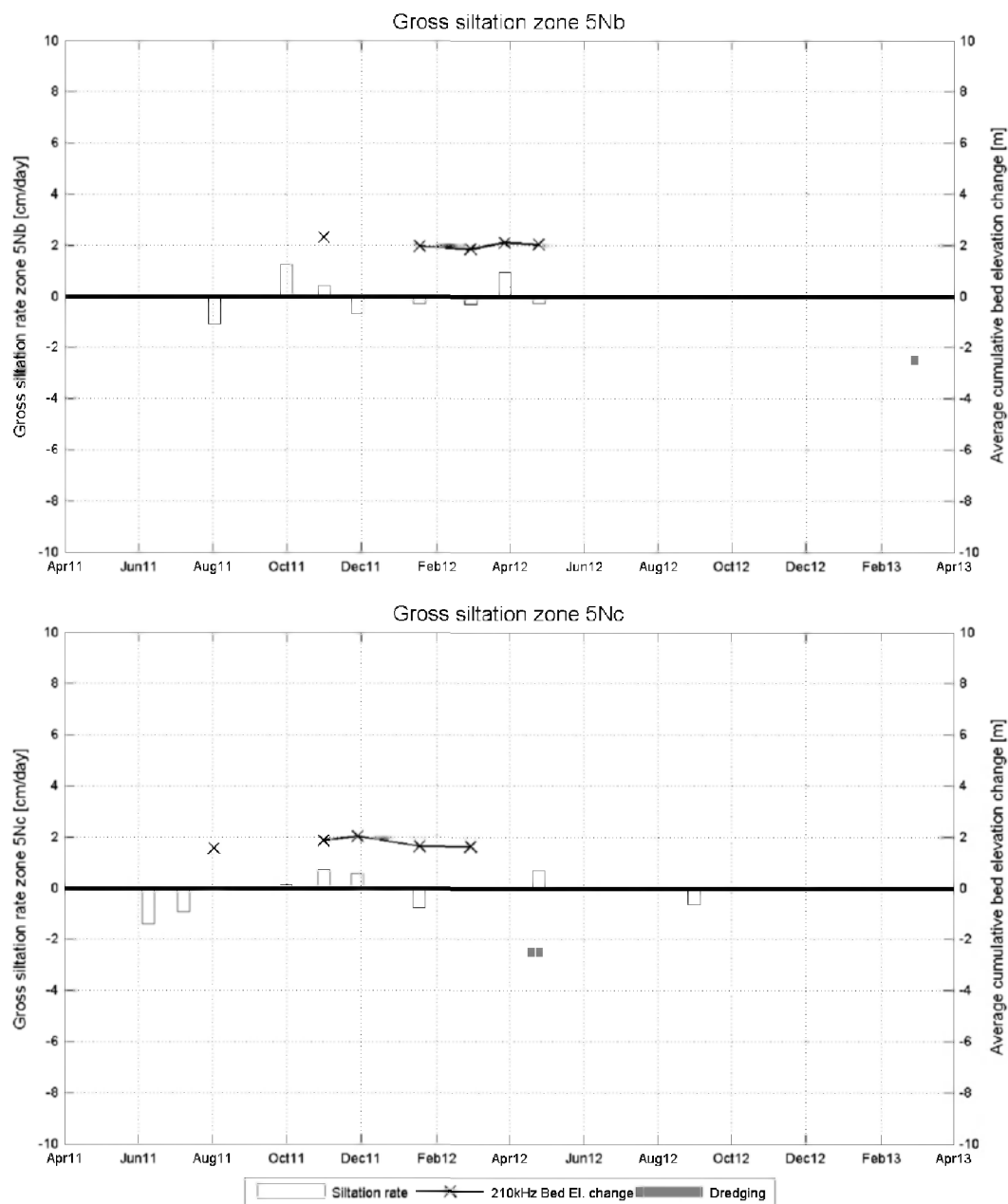
Siltation height / gross siltation rate

Equipment(s):

210kHz depth sounder

Location:

DGD



Reference level: design depth

Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

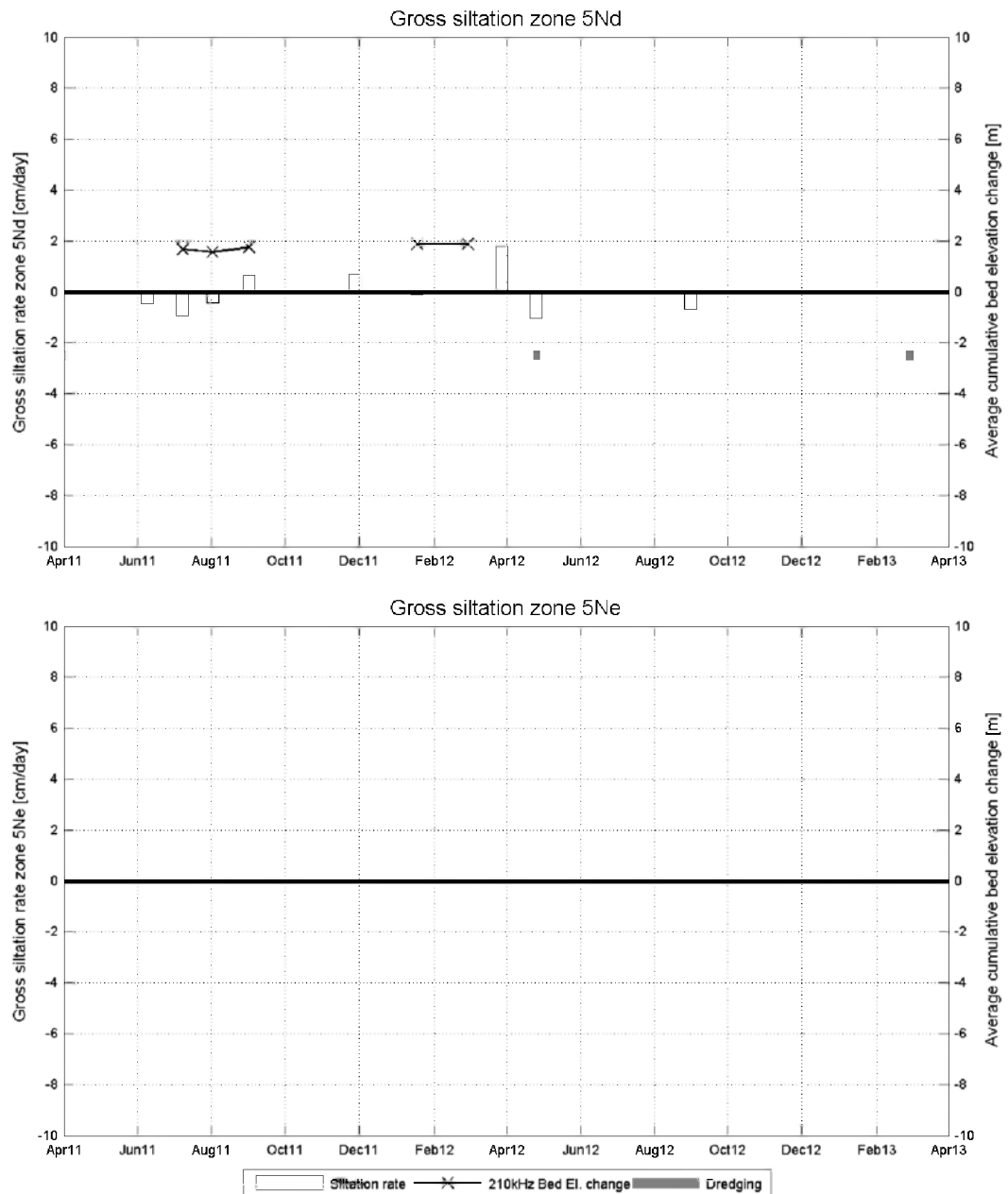
Siltation height / gross siltation rate

Equipment(s):

210kHz depth sounder

Location:

DGD



Reference level: design depth

Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

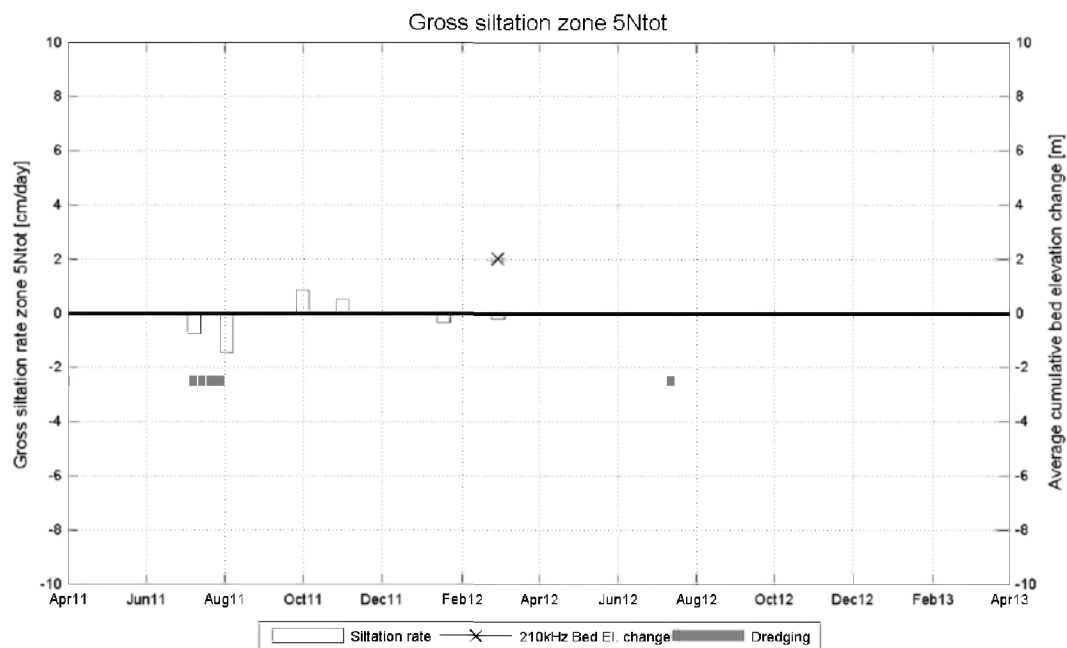
Siltation height / gross siltation rate

Equipment(s):

210kHz depth sounder

Location:

DGD



Reference level: design depth

Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

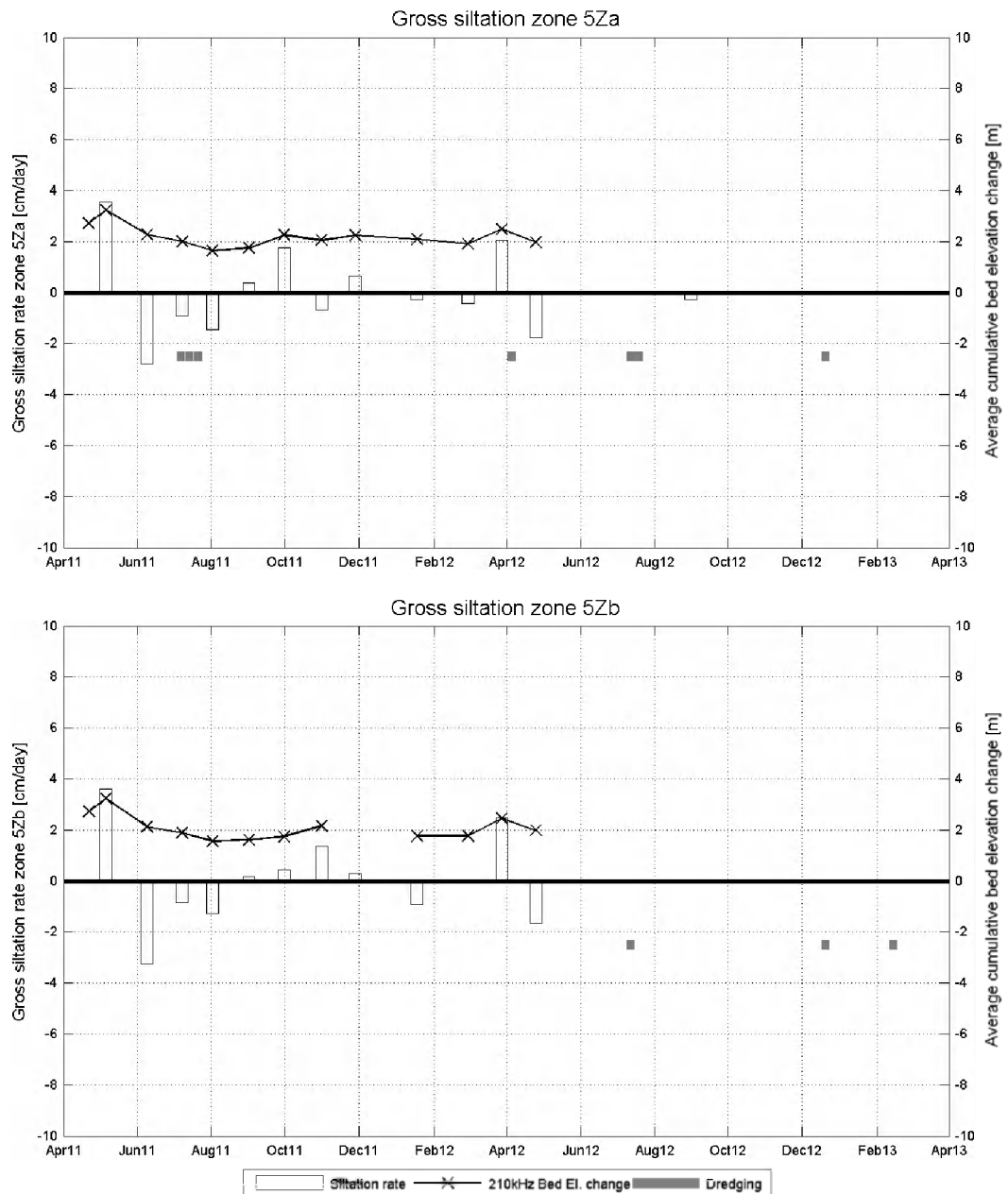
Siltation height / gross siltation rate

Equipment(s):

210kHz depth sounder

Location:

DGD



Reference level: design depth

Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

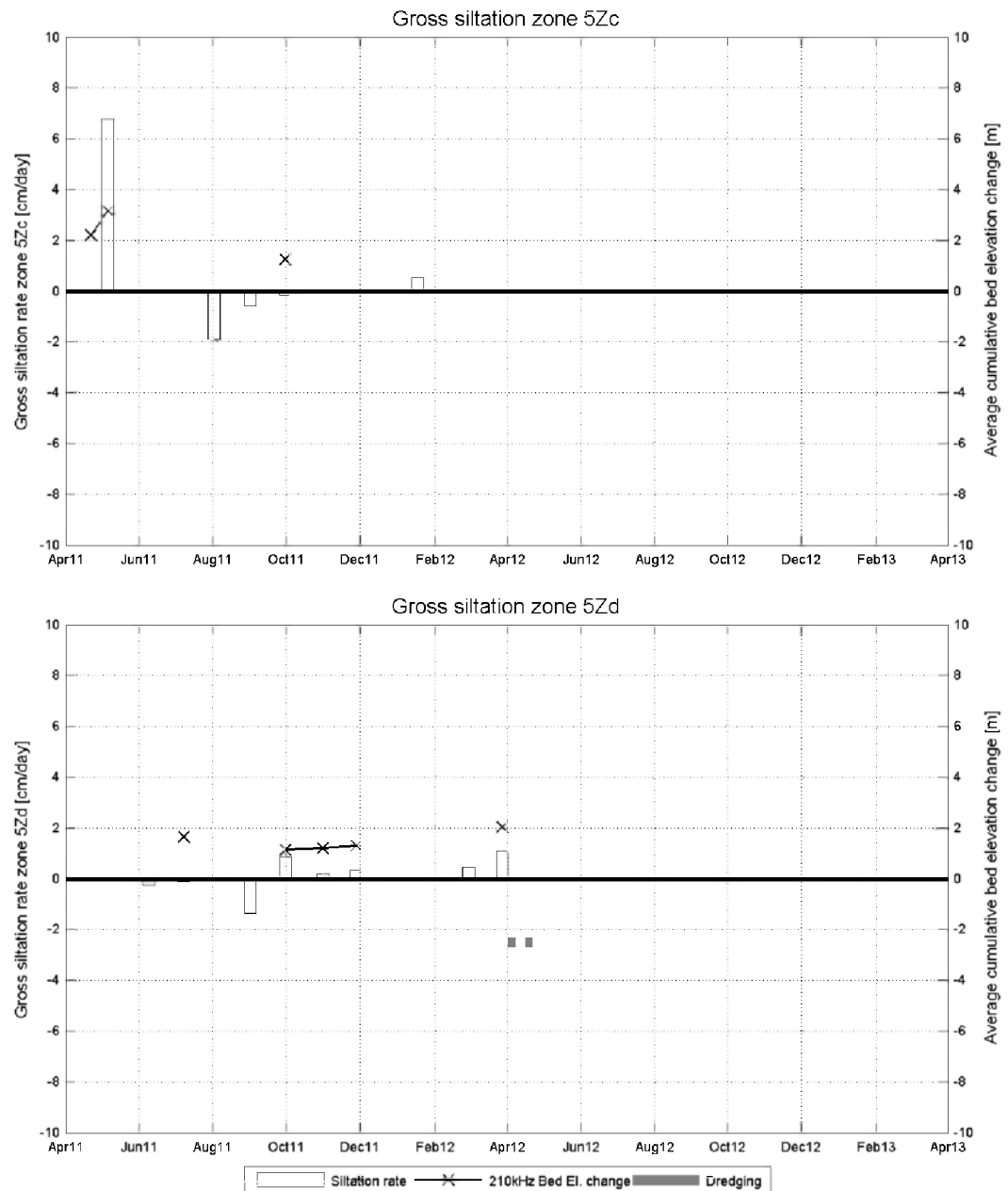
Siltation height / gross siltation rate

Equipment(s):

210kHz depth sounder

Location:

DGD



Reference level: design depth

Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

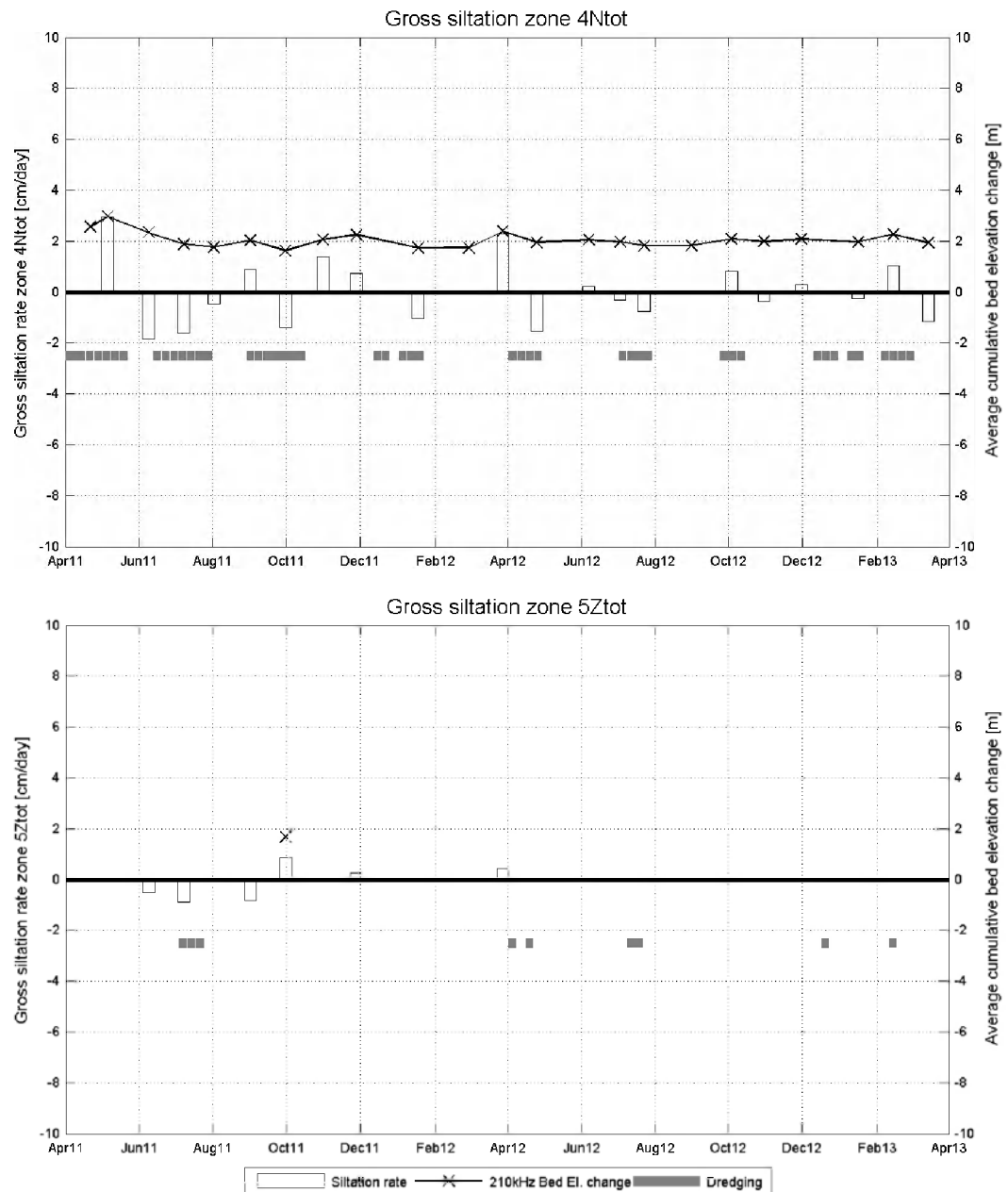
Siltation height / gross siltation rate

Equipment(s):

210kHz depth sounder

Location:

DGD



Reference level: design depth

Data Processed by:

In association with :



I/RA/11406/13.143/JCA



D.3 WATER-BED INTERFACE EVOLUTION FOR ALL SECTIONS

Evaluation of external effects on the siltation of Deurganckdok

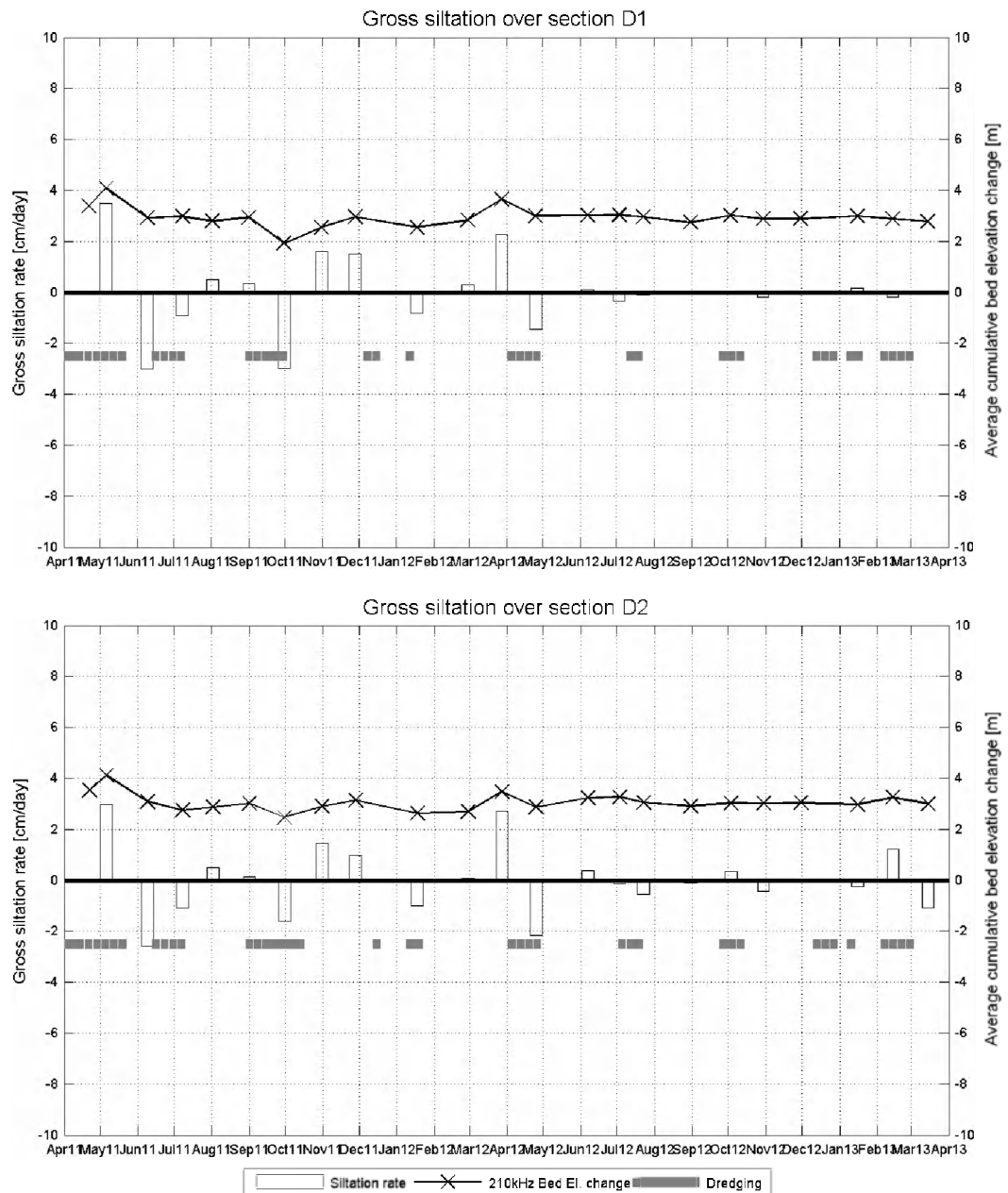
Siltation height / gross siltation rate

Equipment(s):

210kHz depth sounder

Location:

DGD



Reference level: design depth

Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

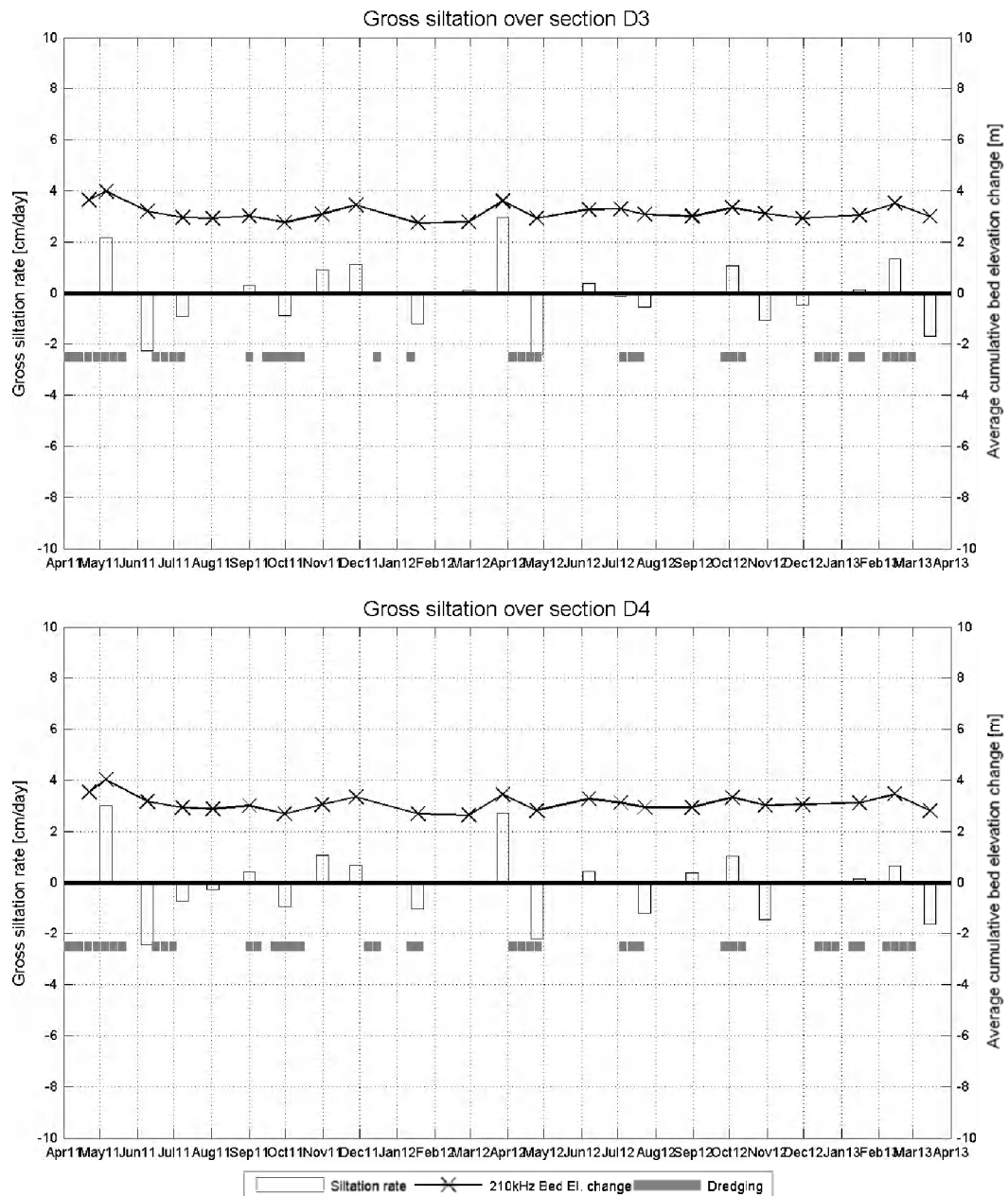
Siltation height / gross siltation rate

Equipment(s):

210kHz depth sounder

Location:

DGD



Reference level: design depth

Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

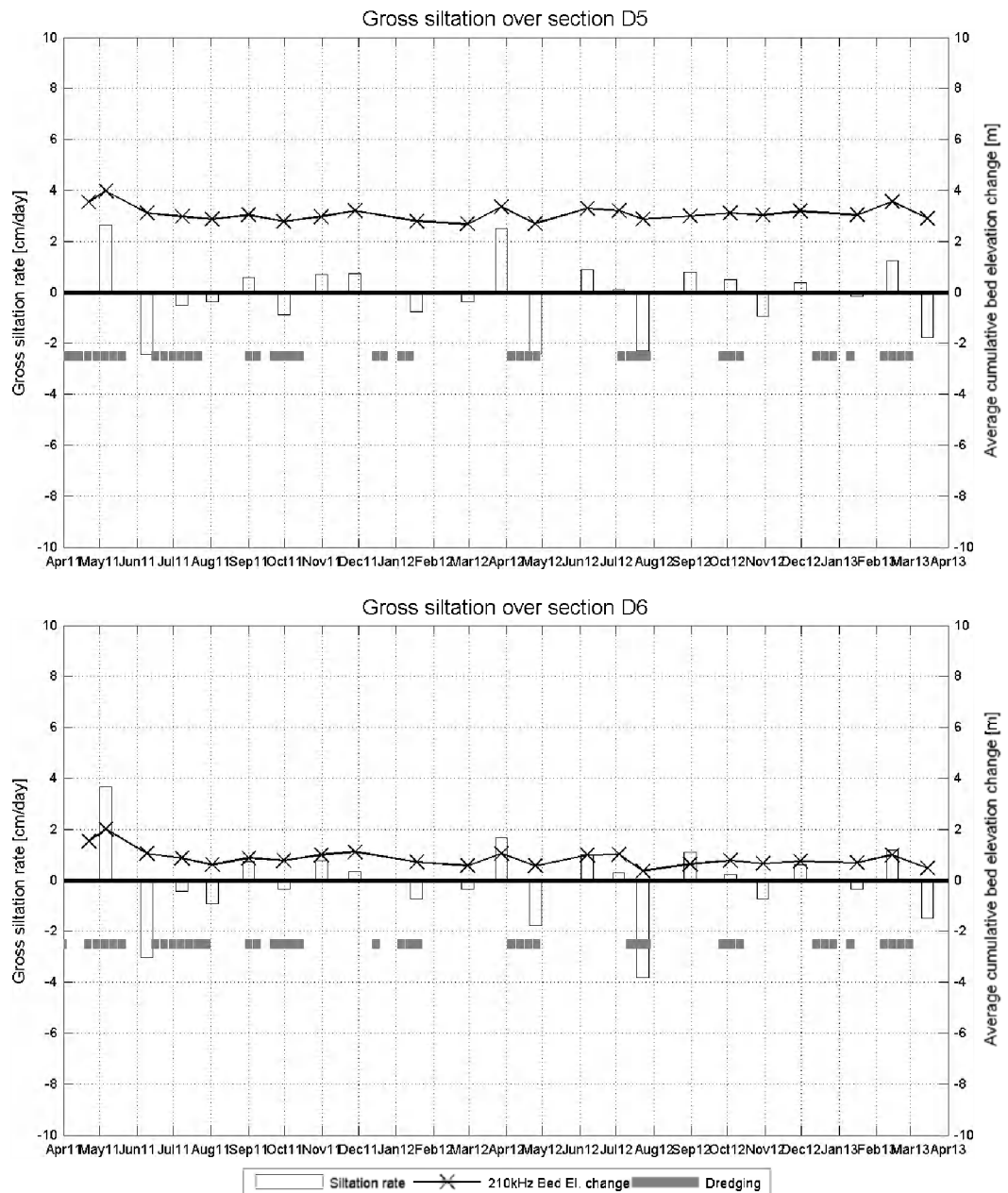
Siltation height / gross siltation rate

Equipment(s):

210kHz depth sounder

Location:

DGD



Reference level: design depth

Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

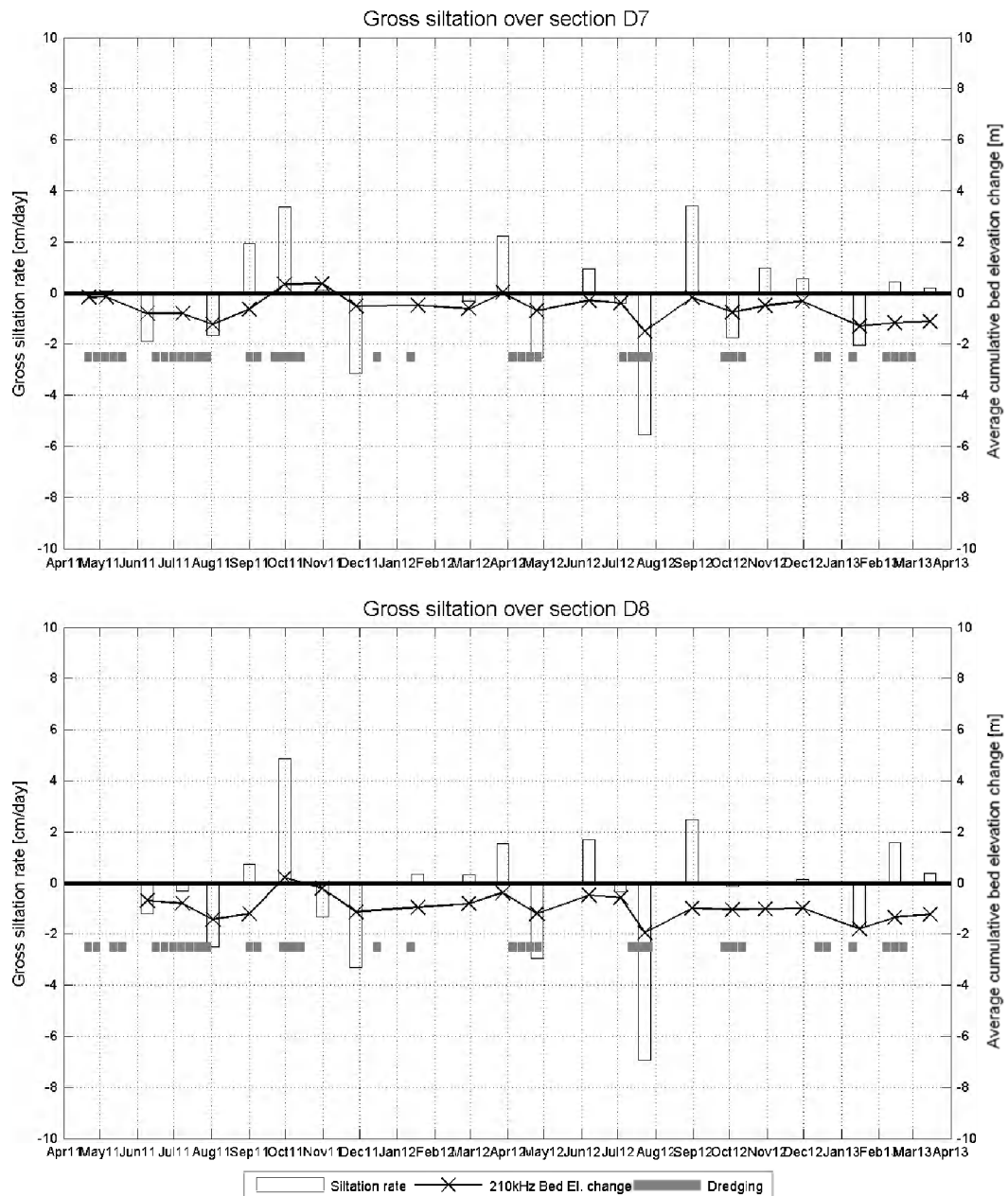
Siltation height / gross siltation rate

Equipment(s):

210kHz depth sounder

Location:

DGD



Reference level: design depth

Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

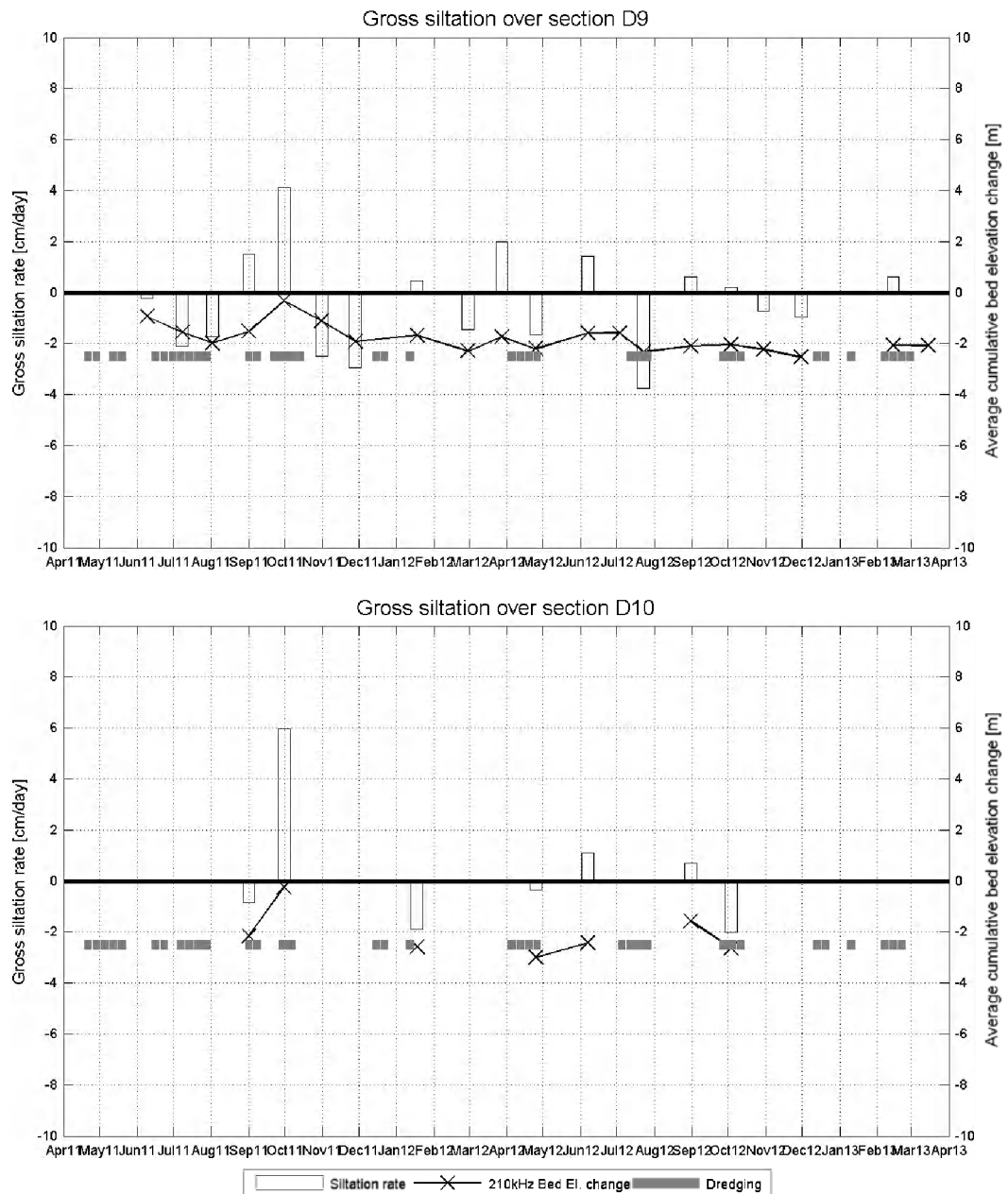
Siltation height / gross siltation rate

Equipment(s):

210kHz depth sounder

Location:

DGD



Reference level: design depth

Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

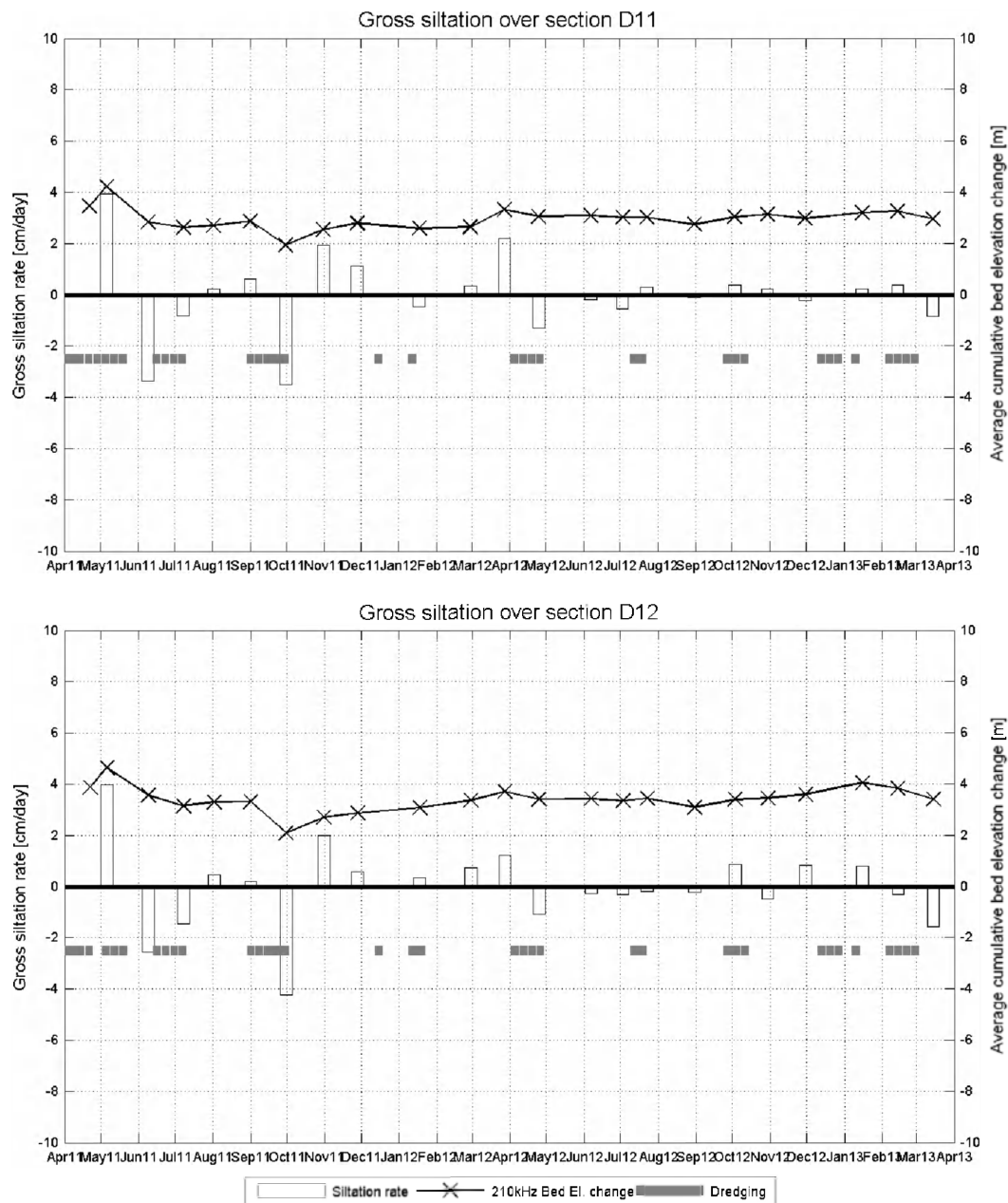
Siltation height / gross siltation rate

Equipment(s):

210kHz depth sounder

Location:

DGD



Reference level: design depth

Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

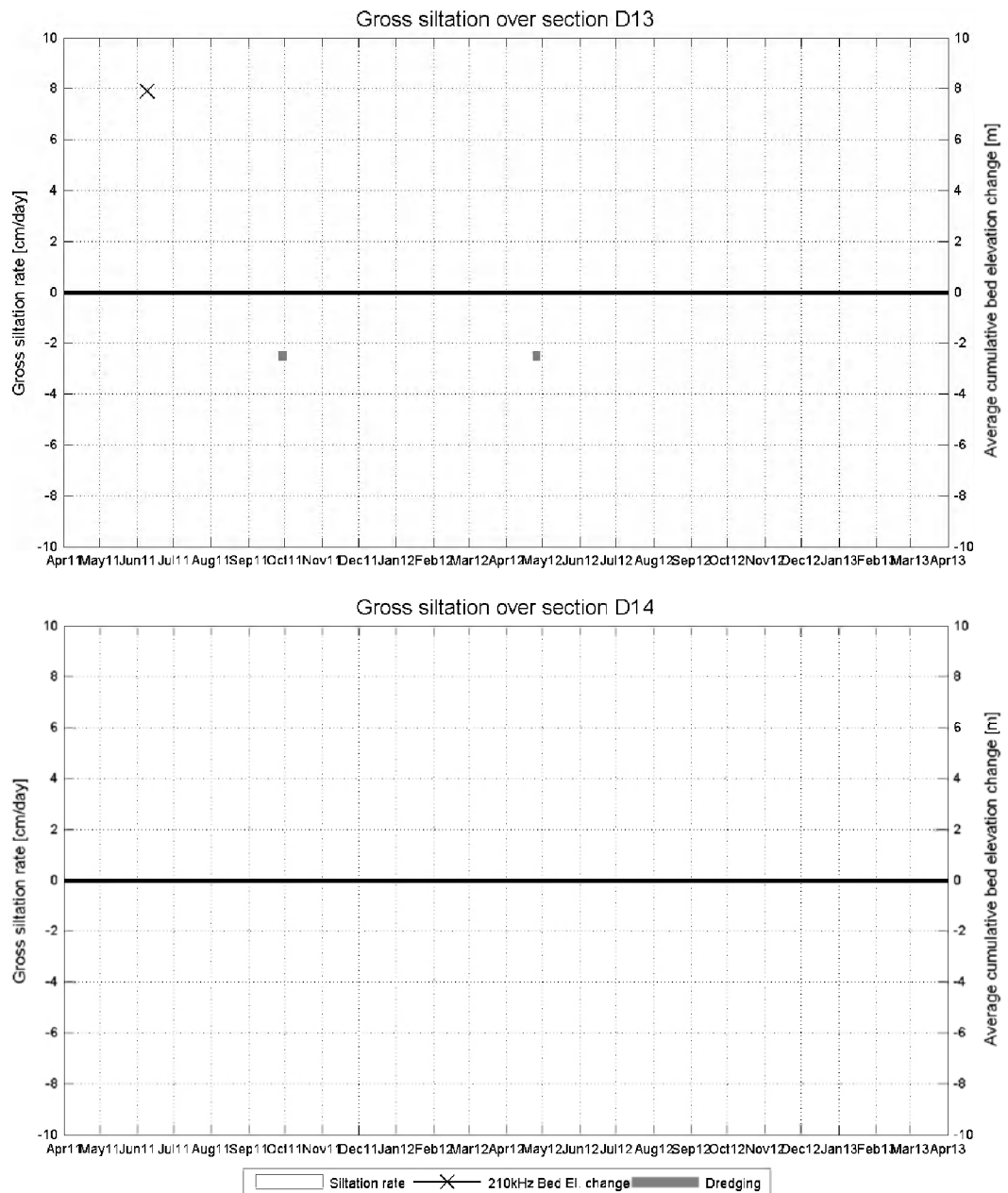
Siltation height / gross siltation rate

Equipment(s):

210kHz depth sounder

Location:

DGD



Reference level: design depth

Data Processed by:

In association with:



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

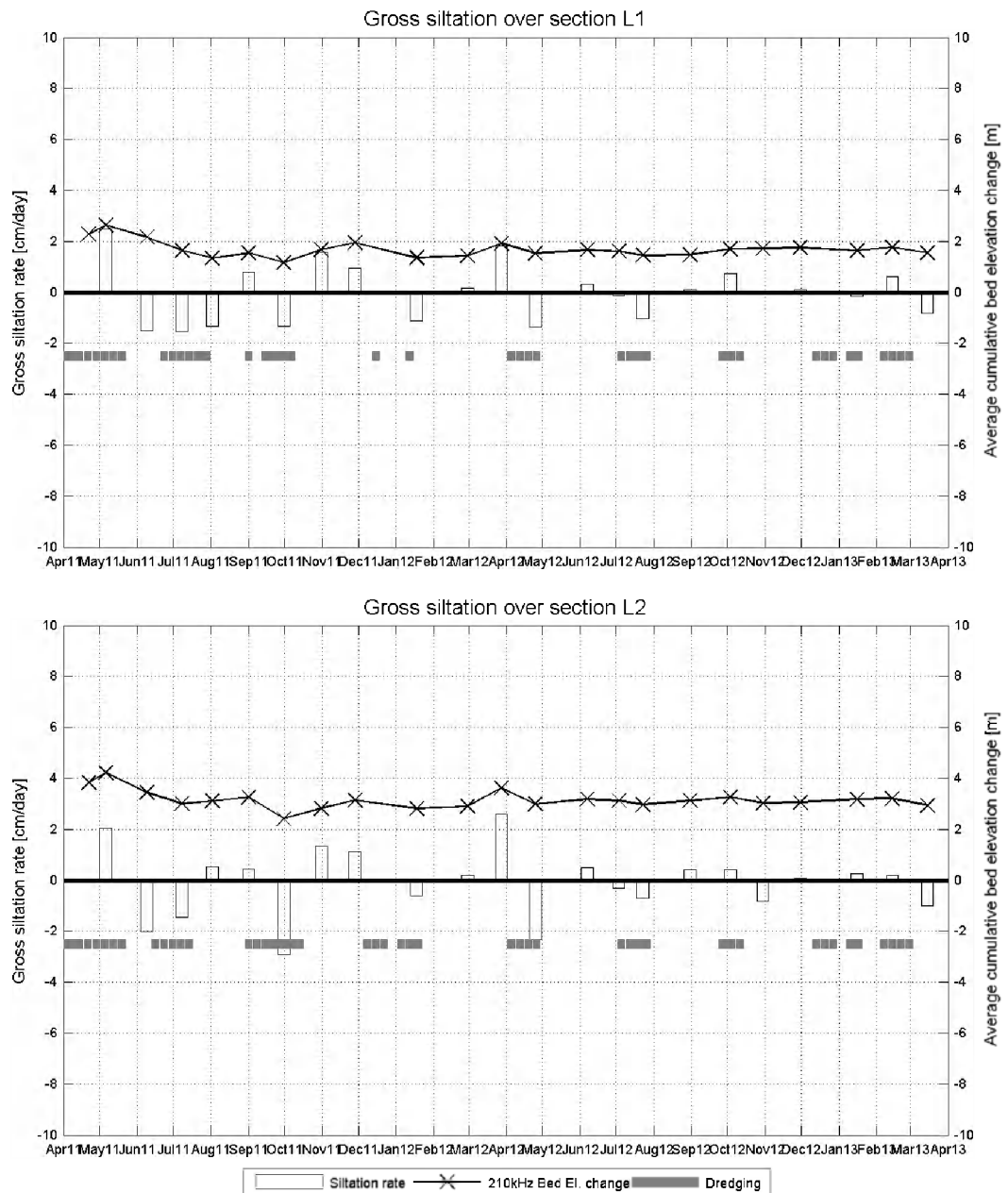
Siltation height / gross siltation rate

Equipment(s):

210kHz depth sounder

Location:

DGD



Reference level: design depth

Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

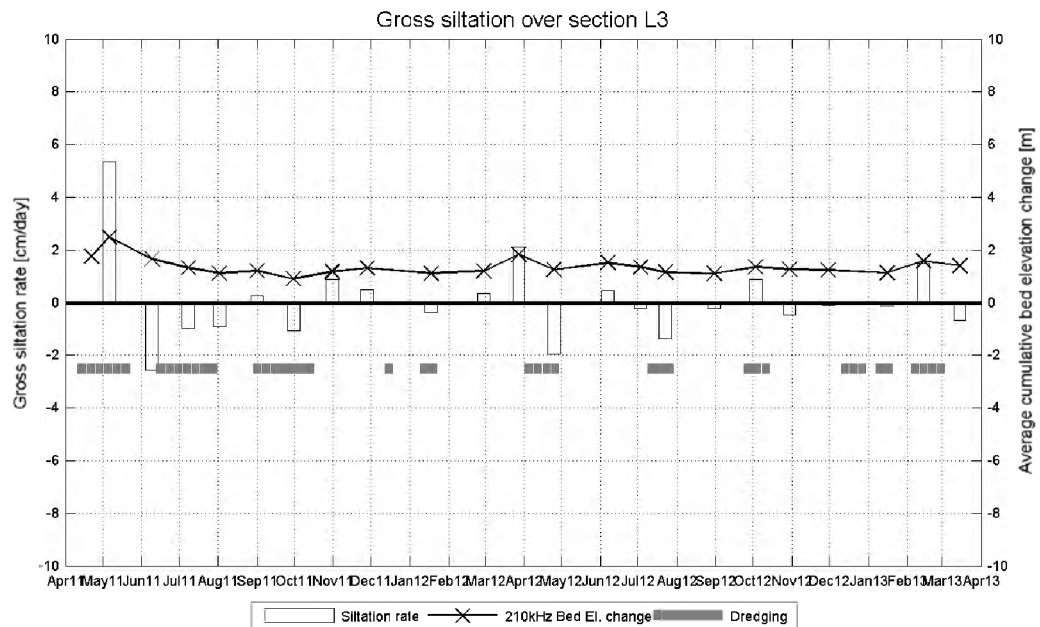
Siltation height / gross siltation rate

Equipment(s):

210kHz depth sounder

Location:

DGD



Reference level: design depth

Data Processed by:

In association with :



I/RA/11406/13.143/JCA



D.4 SILTATION RATE COMPLETE DEURGANCKDOK

Evaluation of external effects on the siltation of Deurganckdok

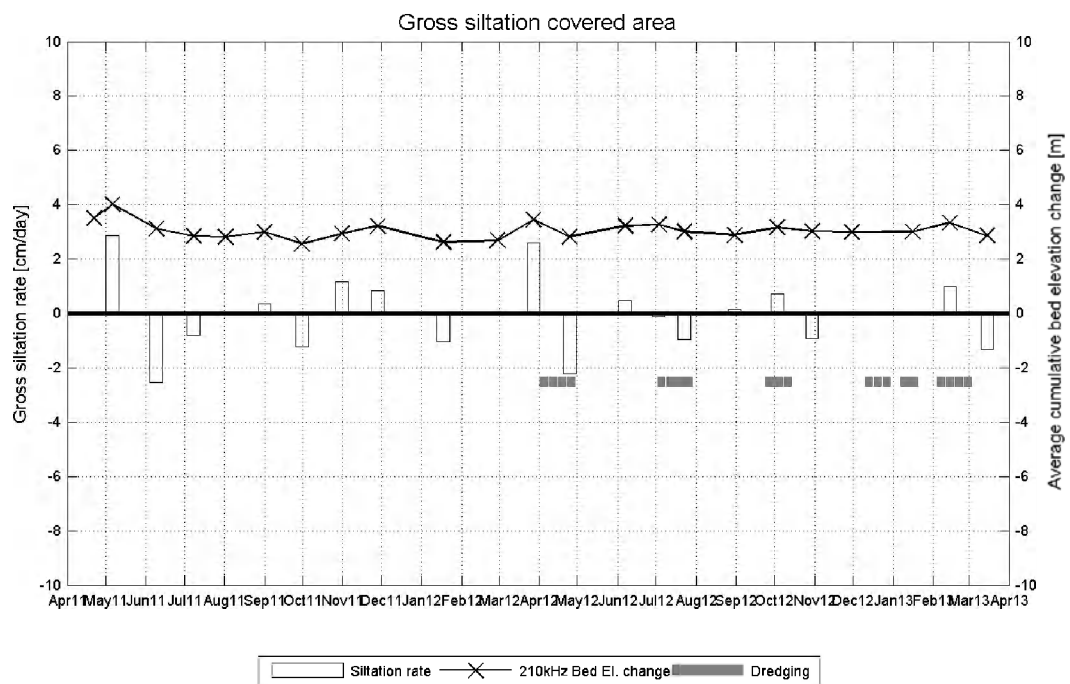
Siltation height / gross siltation rate

Equipment(s):

210kHz depth sounder

Location:

DGD



Reference level: design depth

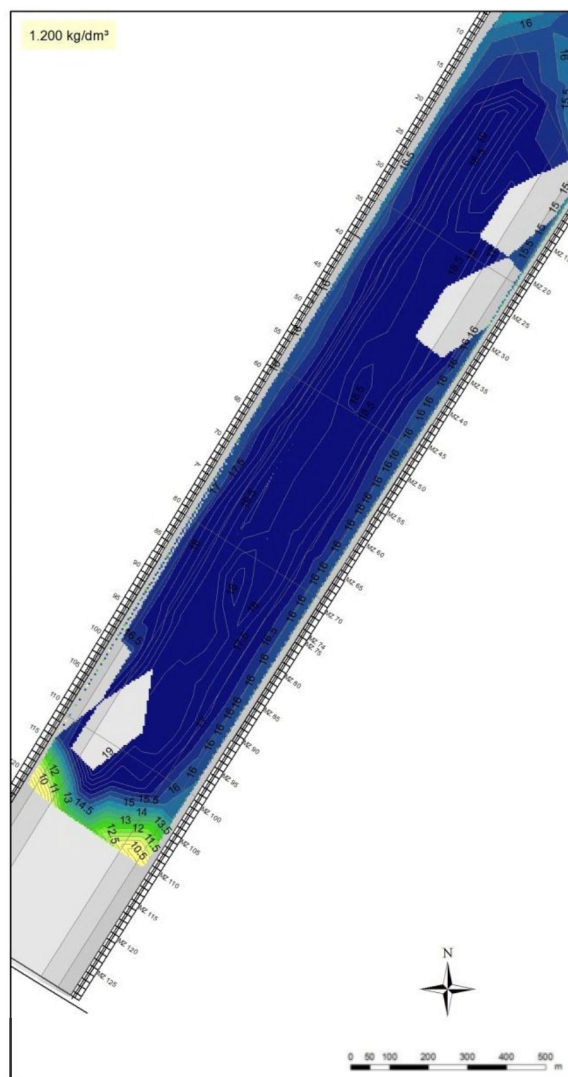
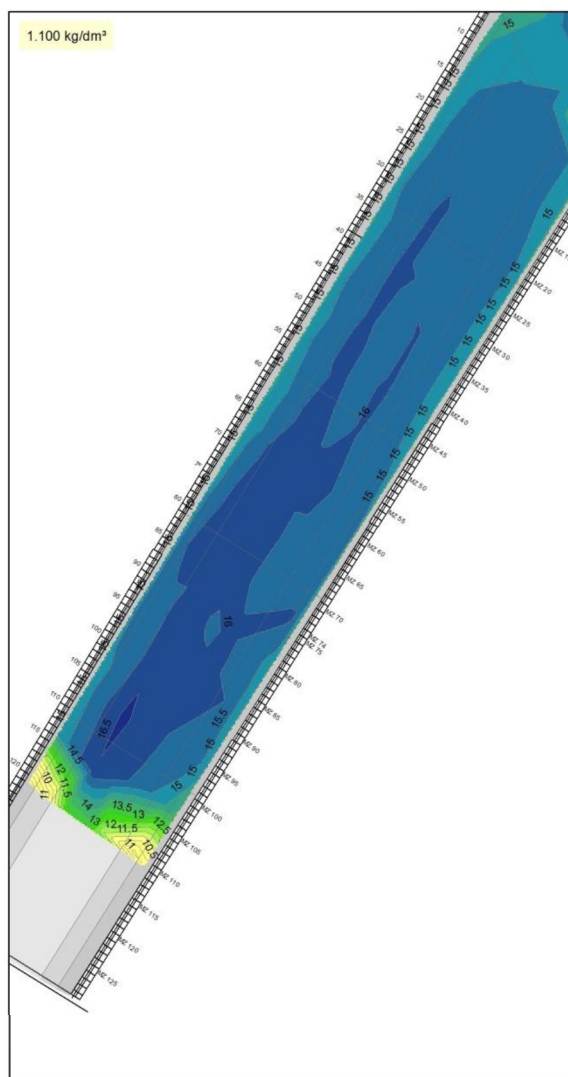
Data Processed by:

In association with :



I/RA/11406/13.143/JCA

Annex E DEPTH OF WATER-BED INTERFACE AND EQUAL DENSITY LAYERS



Long-term measurements
Deurganckdok
Evolution & analysis of siltation

Bestek nr 16EB/2011/28

Water-bed interface & equal density layer
8 May 2012

Map 1 Scale: 1/10.000

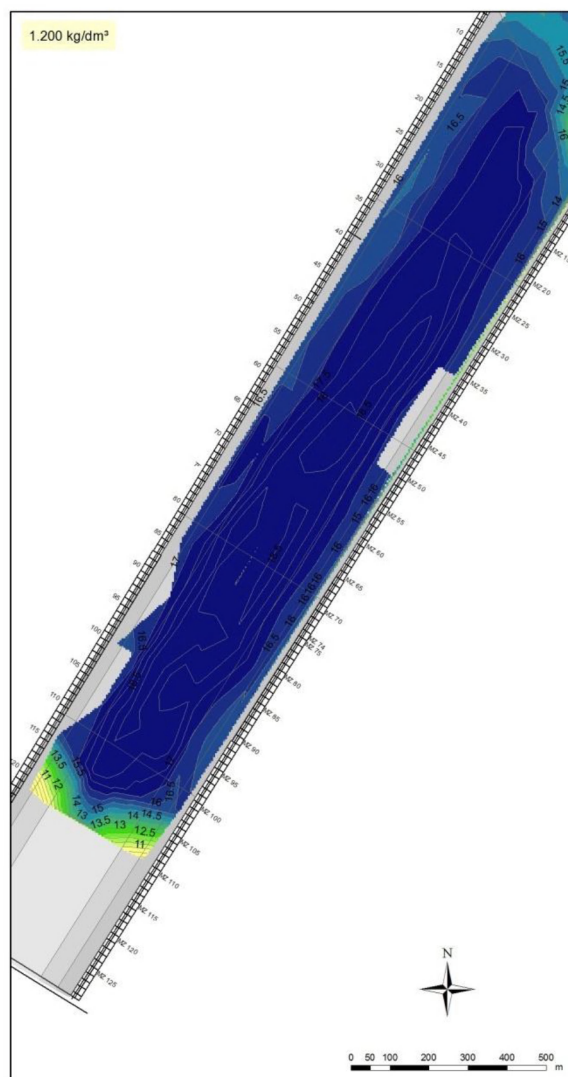
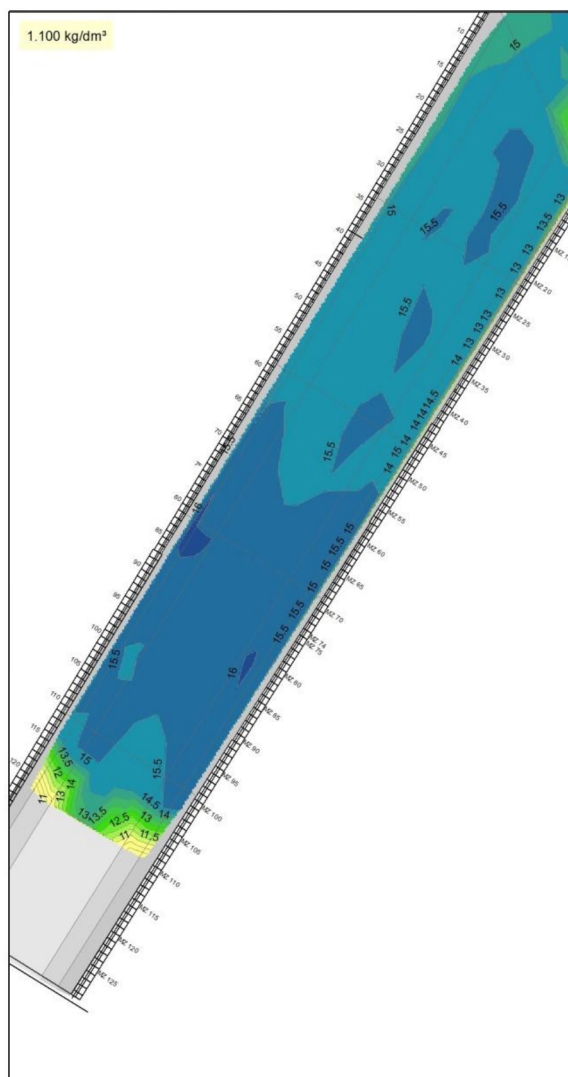
Created: 22/07/2013
Version nr. 1

IMDC
Covelerstraat 15
2600 Antwerpen
Tel +32 3 270 92 20
Fax +32 3 235 87 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



Long-term measurements
Deurganckdok
Evolution & analysis of siltation

Bestek nr 16EB/2011/28

Water-bed interface & equal density layer
27 June 2012

Map 2 Scale: 1/10.000

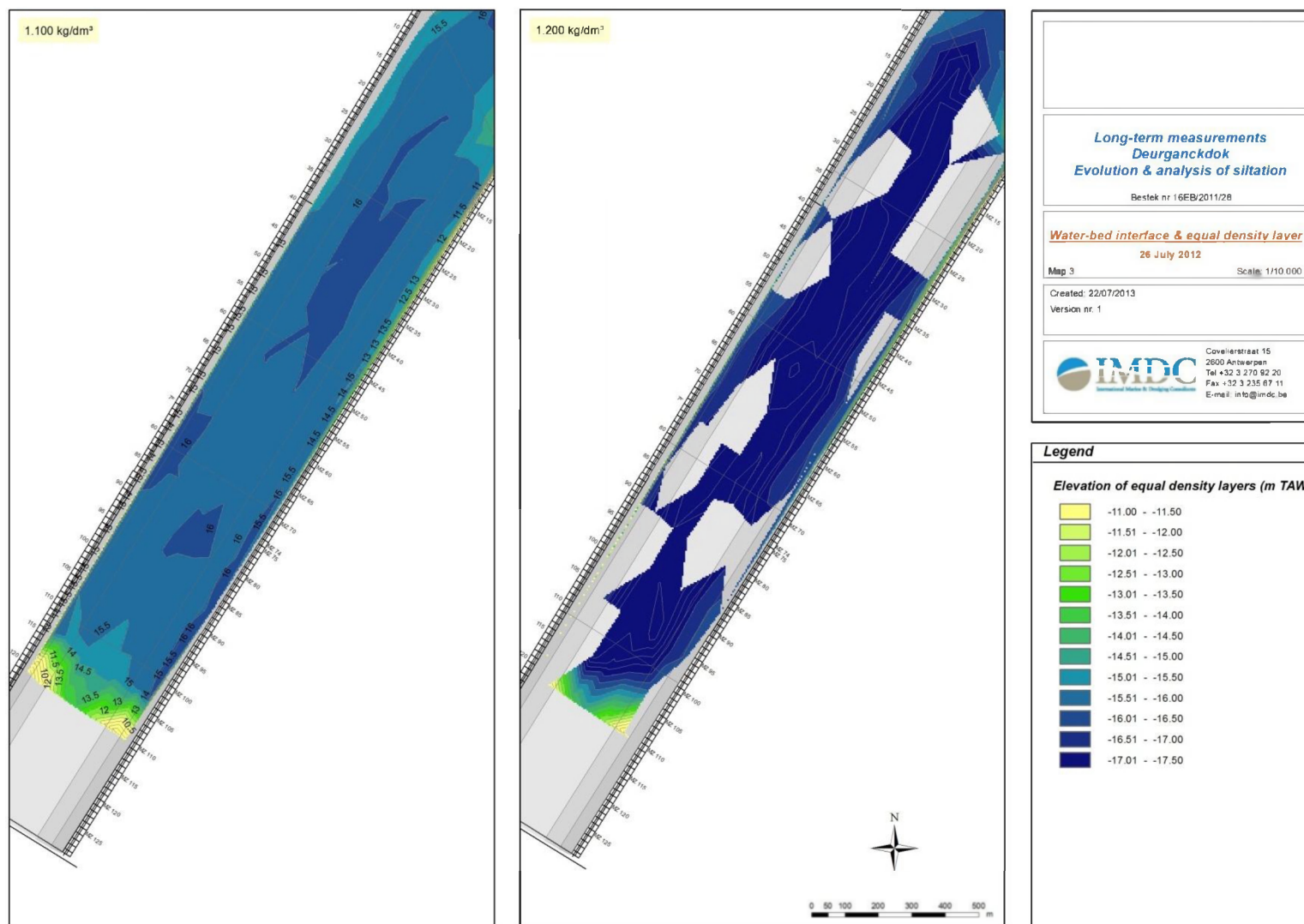
Created: 22/07/2013
Version nr. 1

IMDC
Coördinator: 15
2600 Antwerpen
Tel +32 3 270 92 20
Fax +32 3 235 87 11
E-mail: info@imdc.be

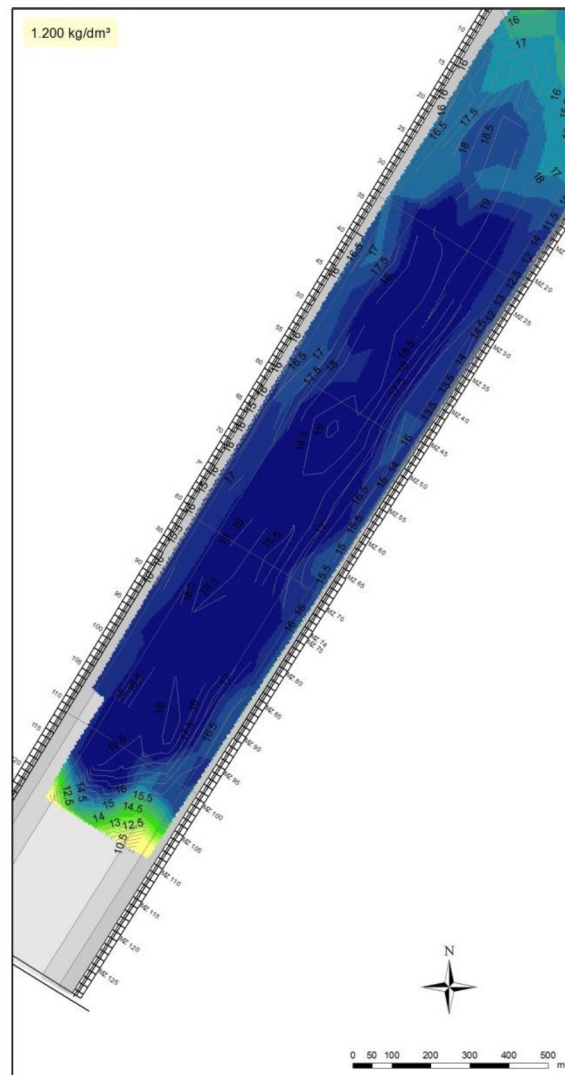
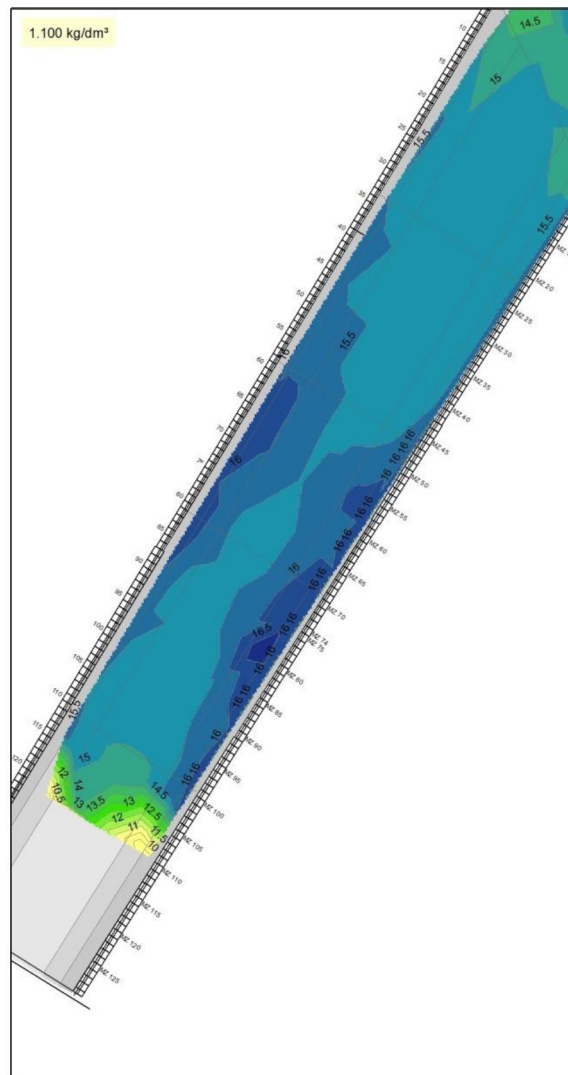
Legend

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:\11406\GIS\Project\2012-2013\denstetstapken\EDL_DGD_K3_1100-1200_July2012_130722.mxd



Long-term measurements
Deurganckdok
Evolution & analysis of siltation

Bestek nr 16EB/2011/28

Water-bed interface & equal density layer
18 September 2012

Map 4 Scale: 1/10.000

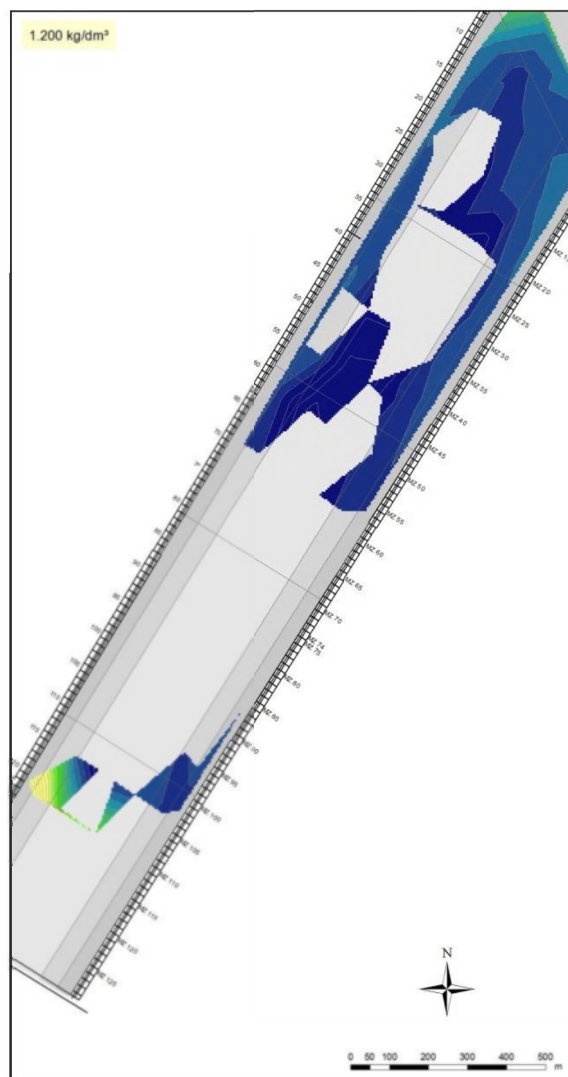
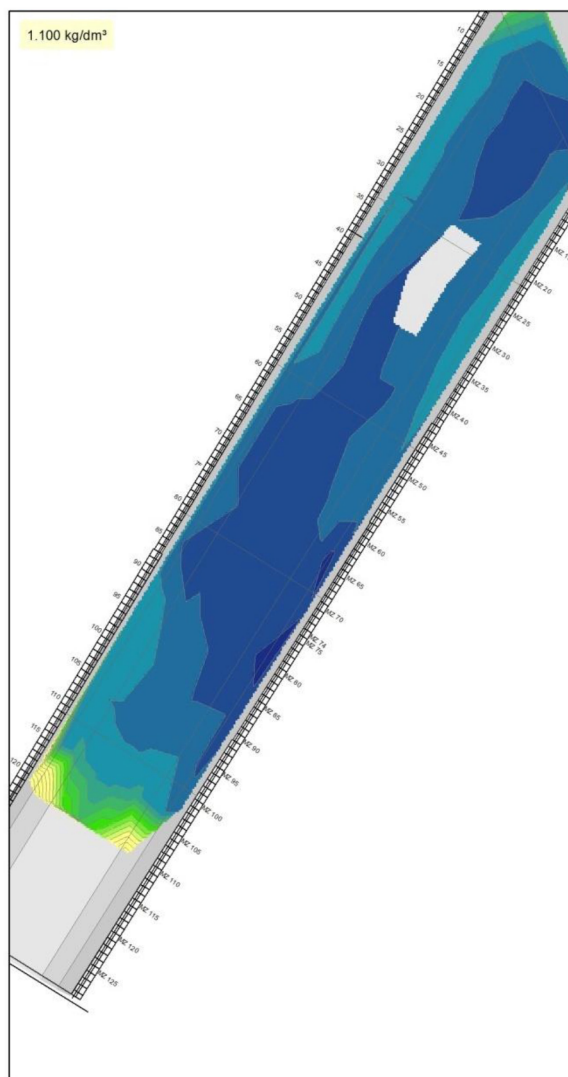
Created: 22/07/2012
Version nr. 1

IMDC
Coördinatorstraat 15
2600 Antwerpen
Tel +32 3 270 92 20
Fax +32 3 235 87 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



Long-term measurements
Deurganckdok
Evolution & analysis of siltation

Bestek nr 16EB/2011/28

Water-bed interface & equal density layer
11 October 2012

Map 5 Scale: 1/10.000

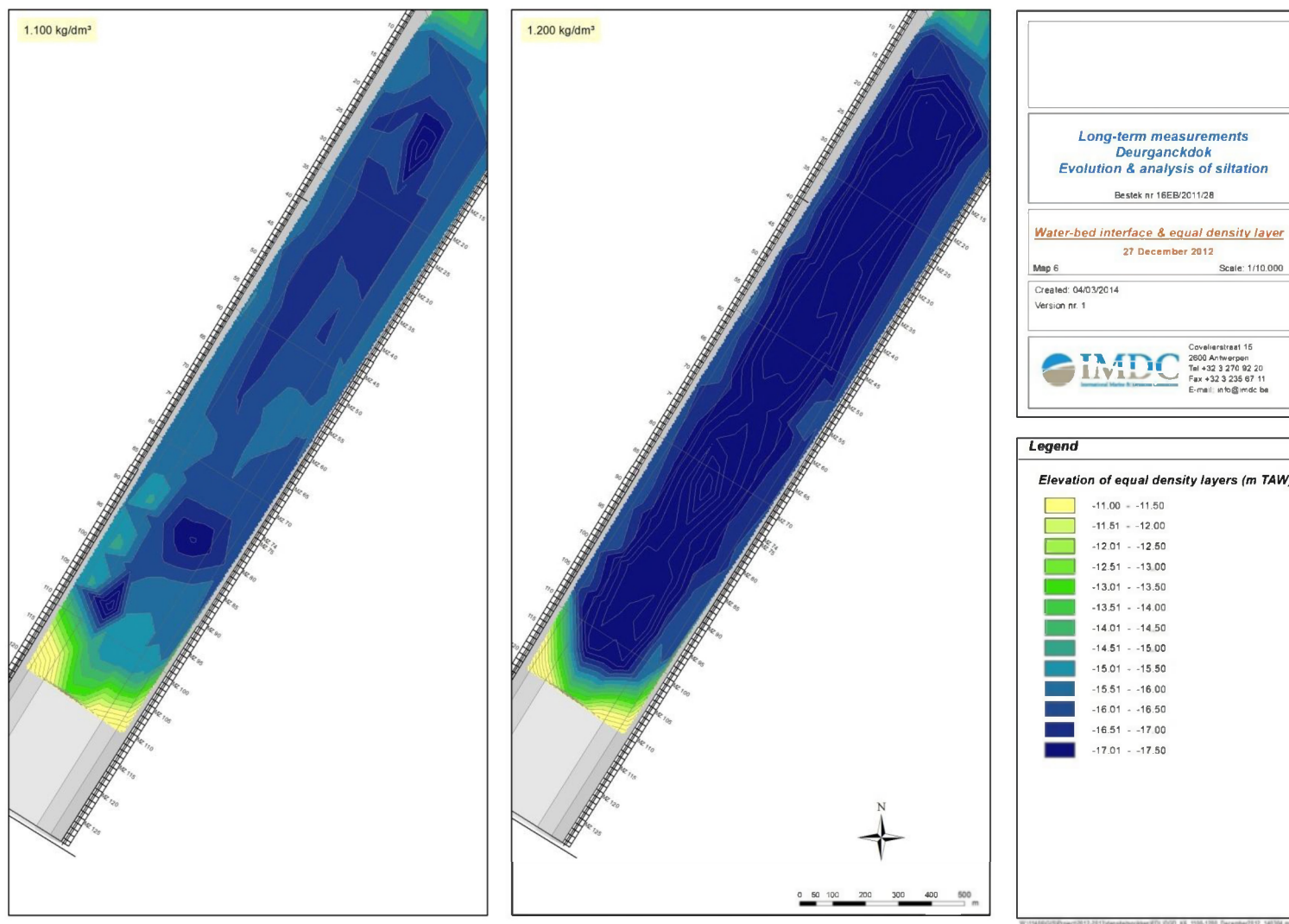
Created: 22/07/2012
Version nr. 1

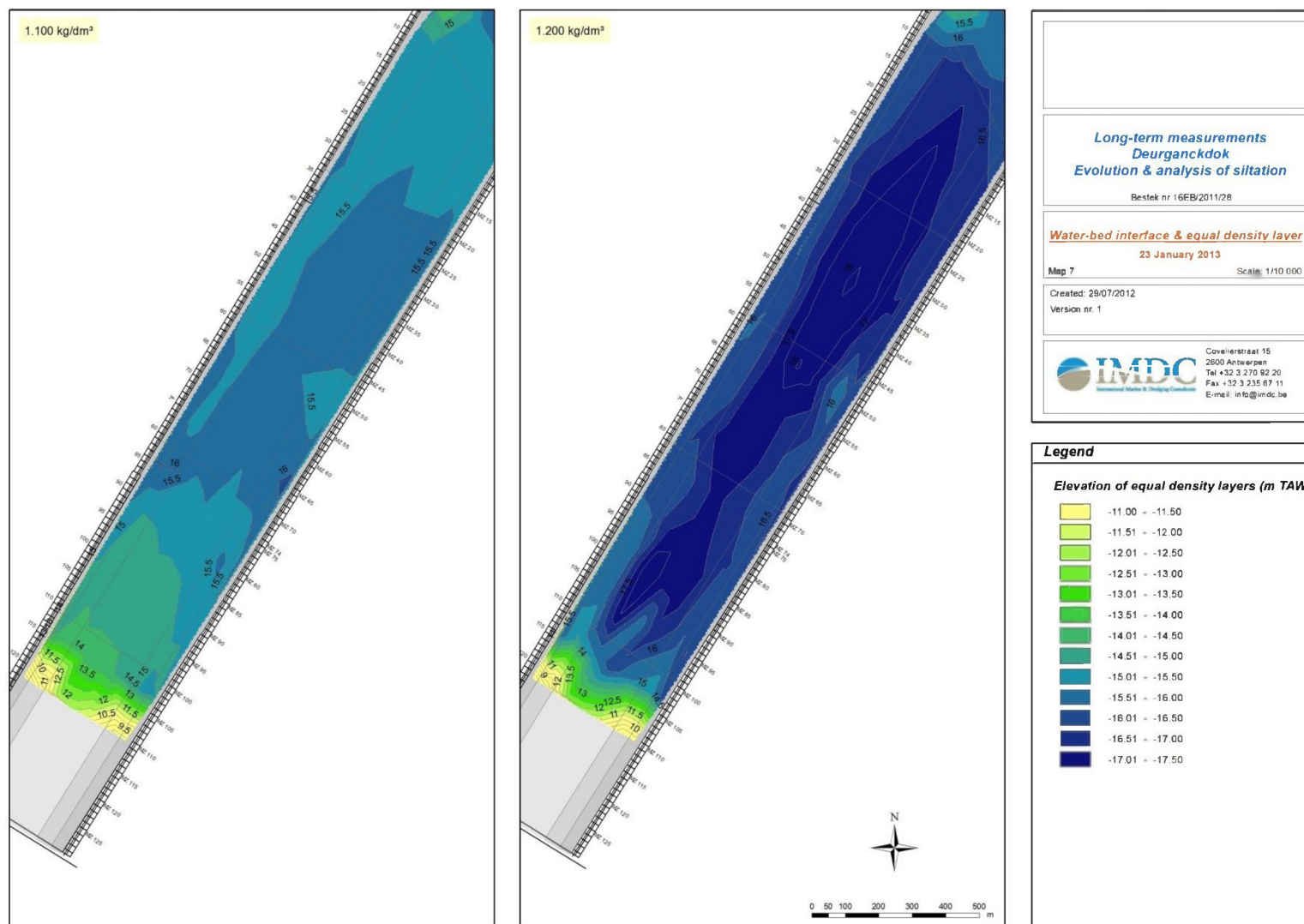
IMDC
Covelerstraat 15
2600 Antwerpen
Tel +32 3 270 92 20
Fax +32 3 235 87 11
E-mail: info@imdc.be

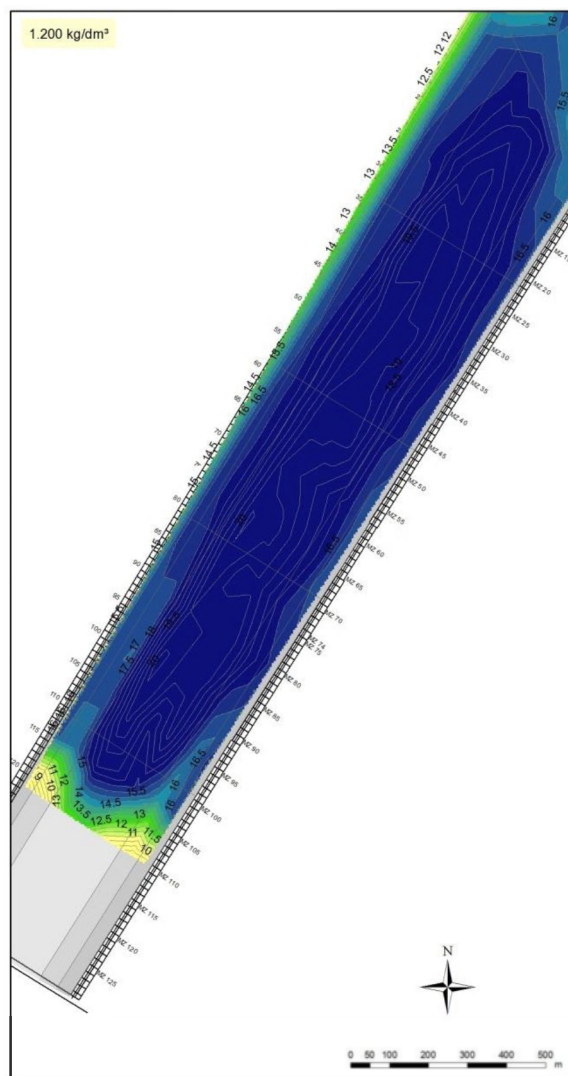
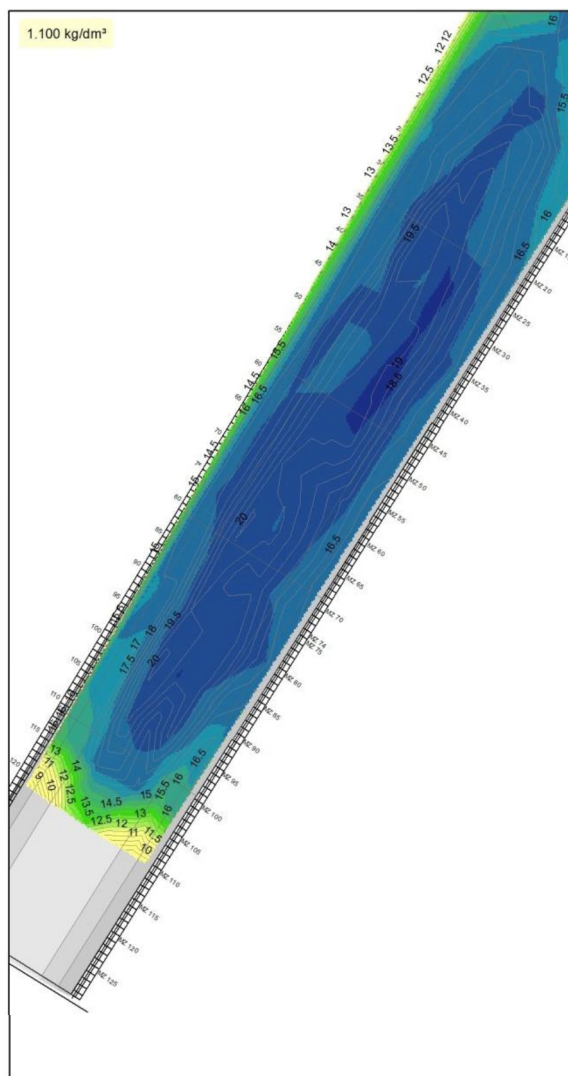
Legend

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







Long-term measurements
Deurganckdok
Evolution & analysis of siltation

Bestek nr 16EB/2011/28

Water-bed interface & equal density layer
7 March 2013

Map 8 Scale: 1/10.000

Created: 29/07/2012
Version nr. 1

IMDC
Covelerstraat 15
2600 Antwerpen
Tel +32 3 270 92 20
Fax +32 3 235 87 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

Annex F DEPTH OF PLANES OF CONSTANT DENSITY

F.1 MEASUREMENTS MAY 5th, 2012

Evaluation of external effects on the siltation of Deurganckdok

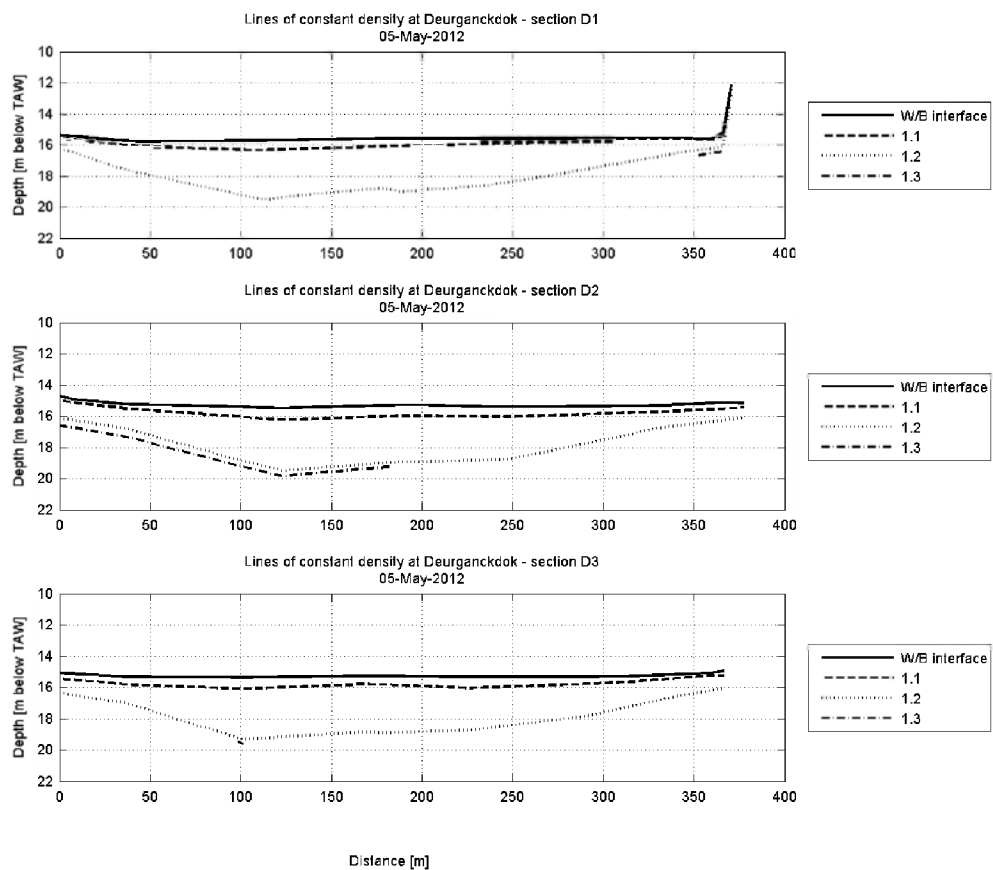
Cross sections planes constant density

Equipment(s):

Navitracker

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

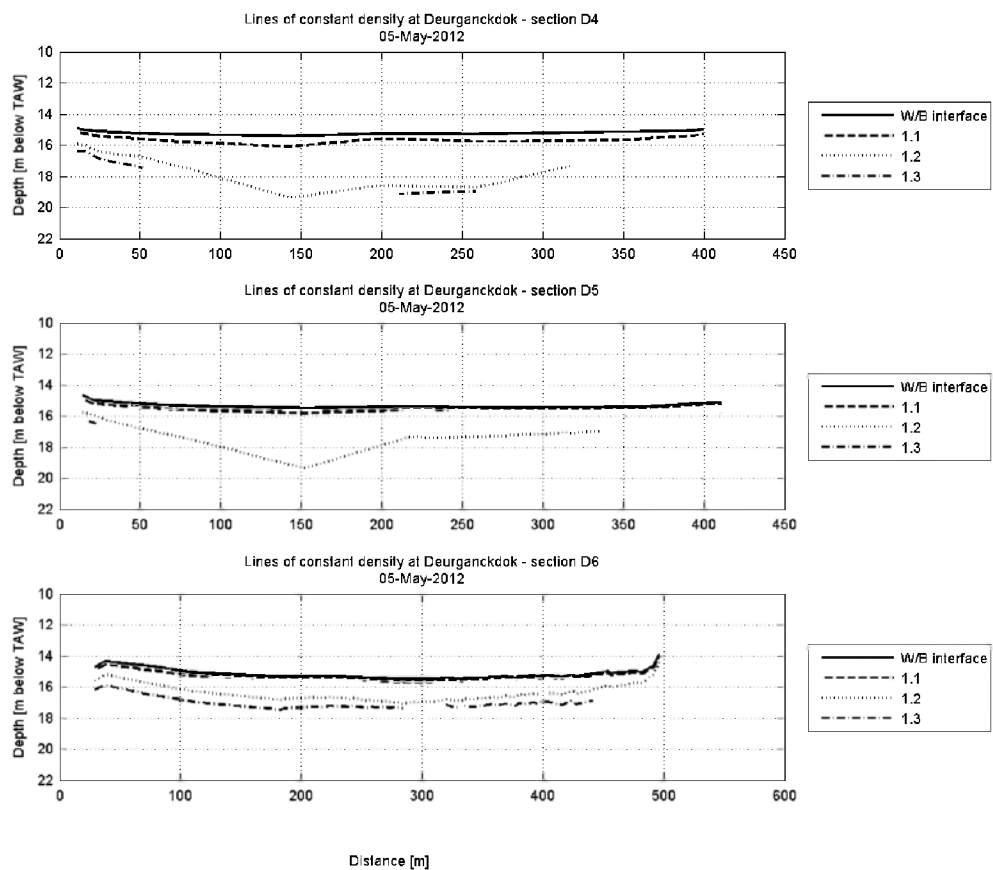
Cross sections planes constant density

Equipment(s):

Navitracker

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

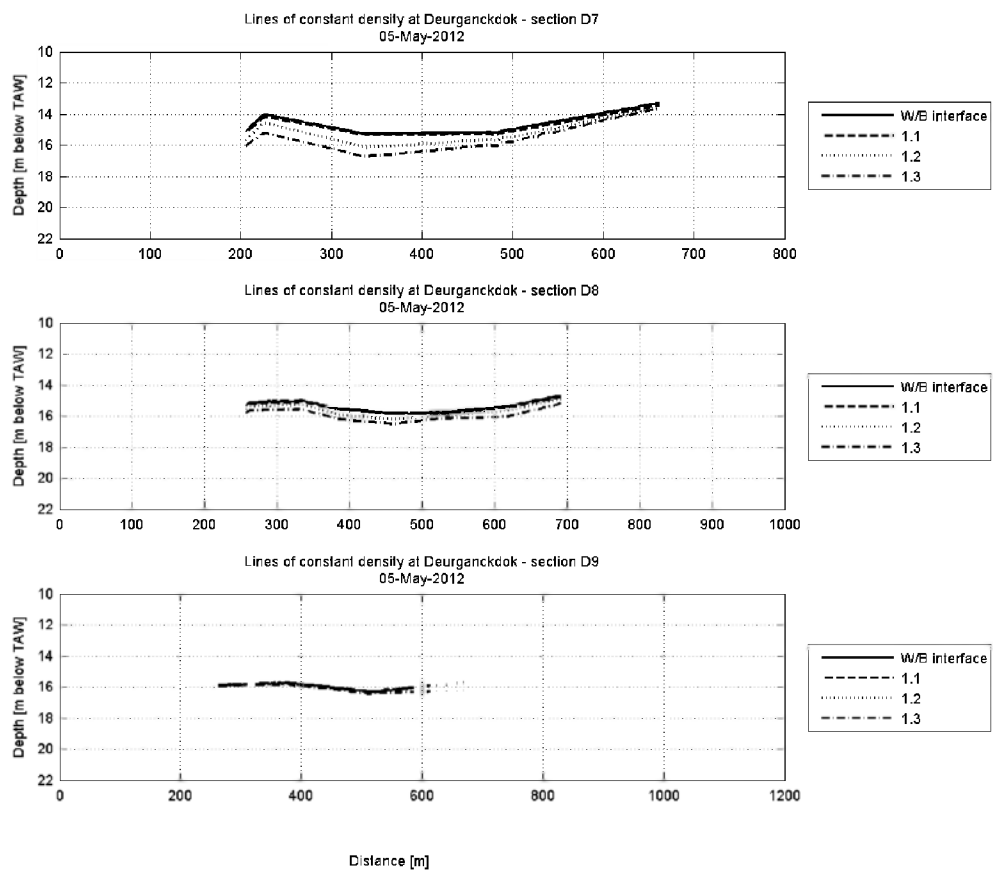
Cross sections planes constant density

Equipment(s):

Navitracker

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

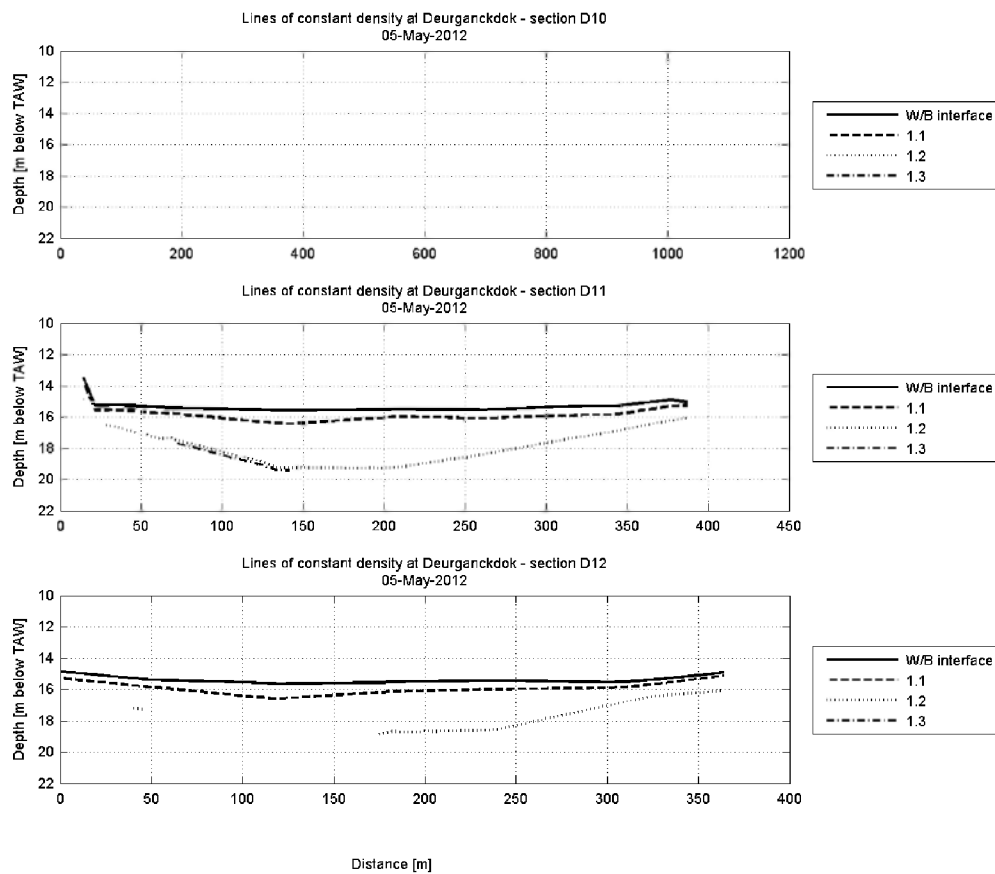
Cross sections planes constant density

Equipment(s):

Navitracker

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA

Evaluation of external effects on the siltation of Deurganckdok

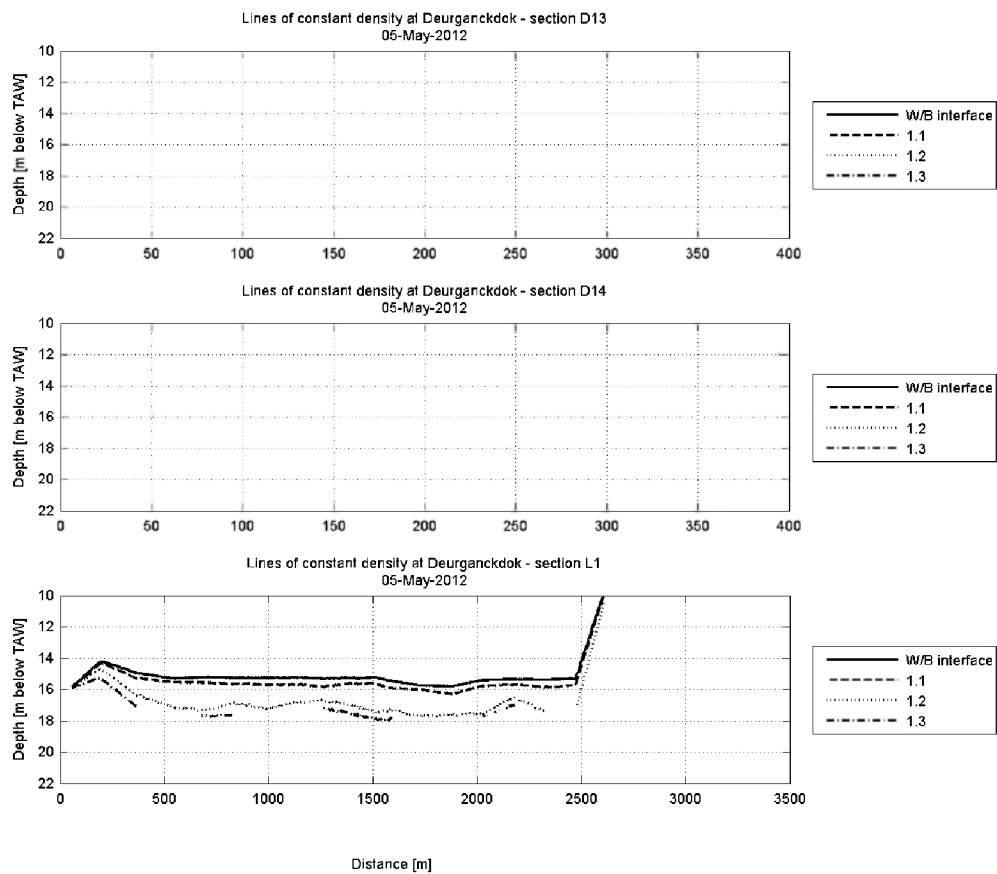
Cross sections planes constant density

Equipment(s):

Navitracker

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

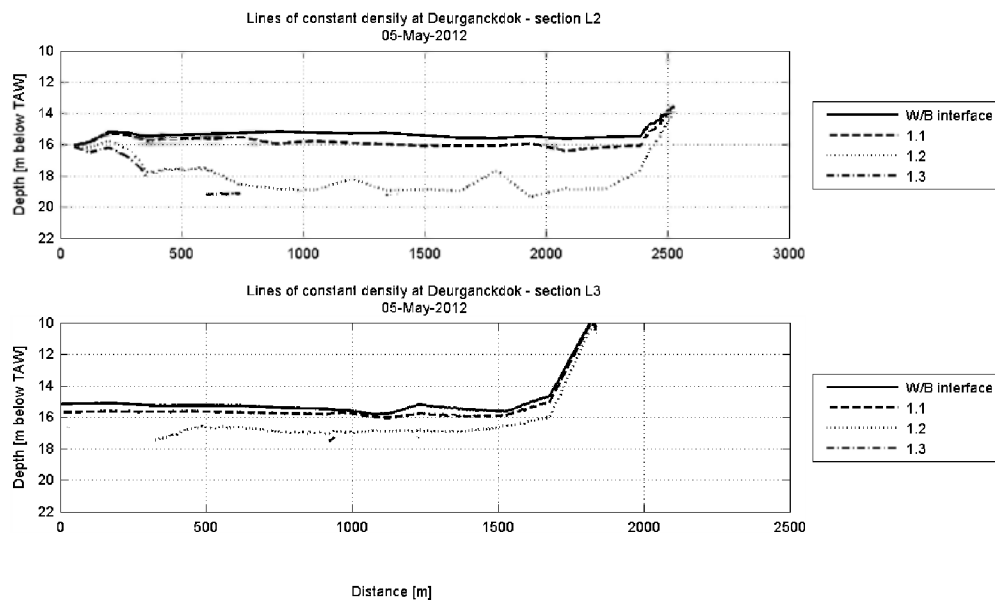
Cross sections planes constant density

Equipment(s):

Navitracker

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



F.2 MEASUREMENTS June 27th, 2012

Evaluation of external effects on the siltation of Deurganckdok

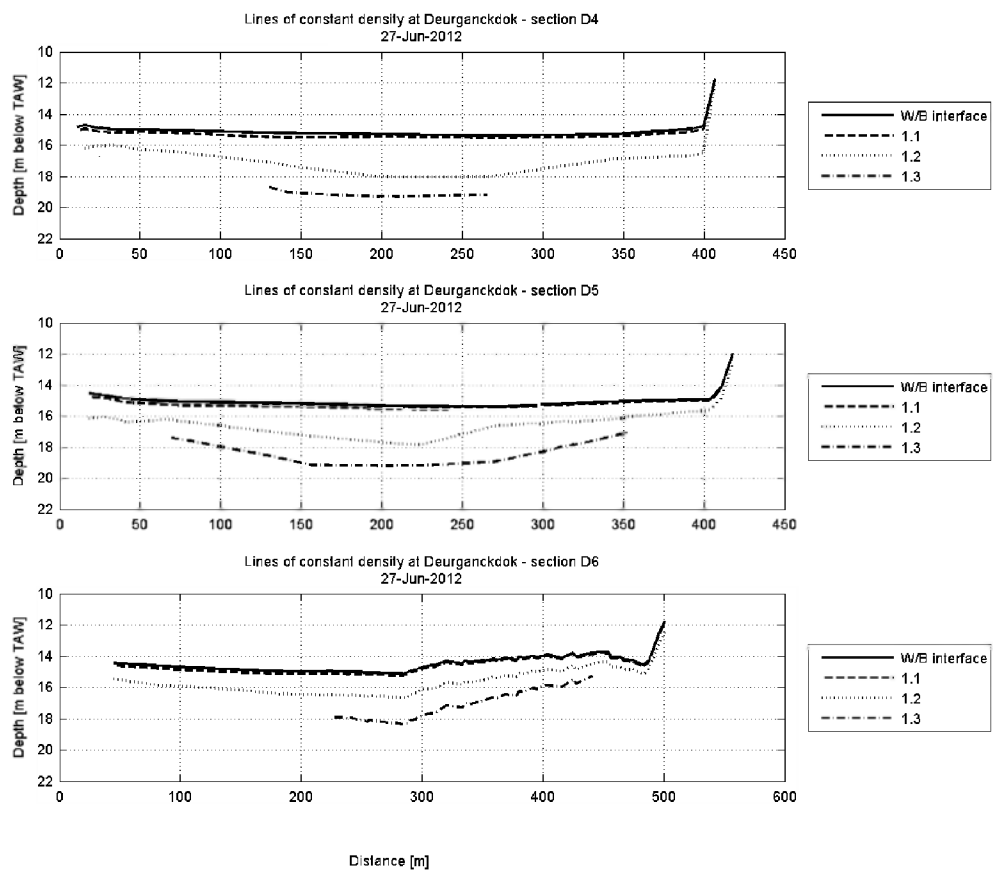
Cross sections planes constant density

Equipment(s):

Navitracker

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

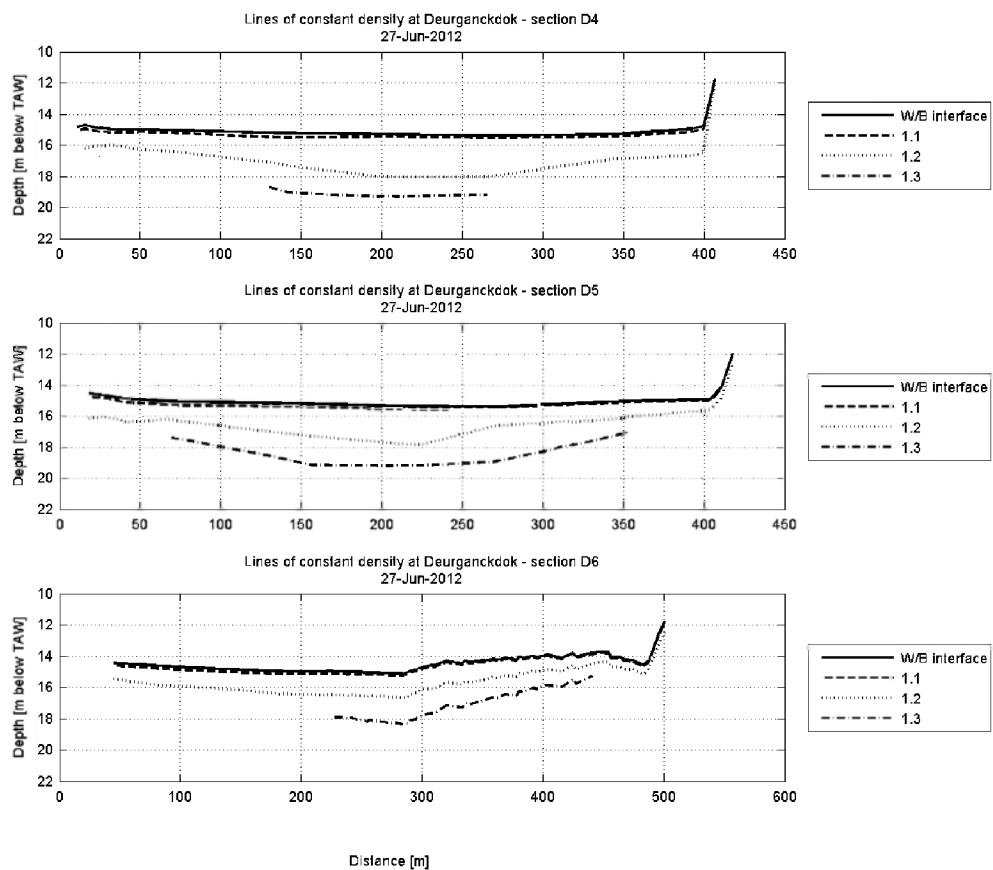
Cross sections planes constant density

Equipment(s):

Navitracker

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

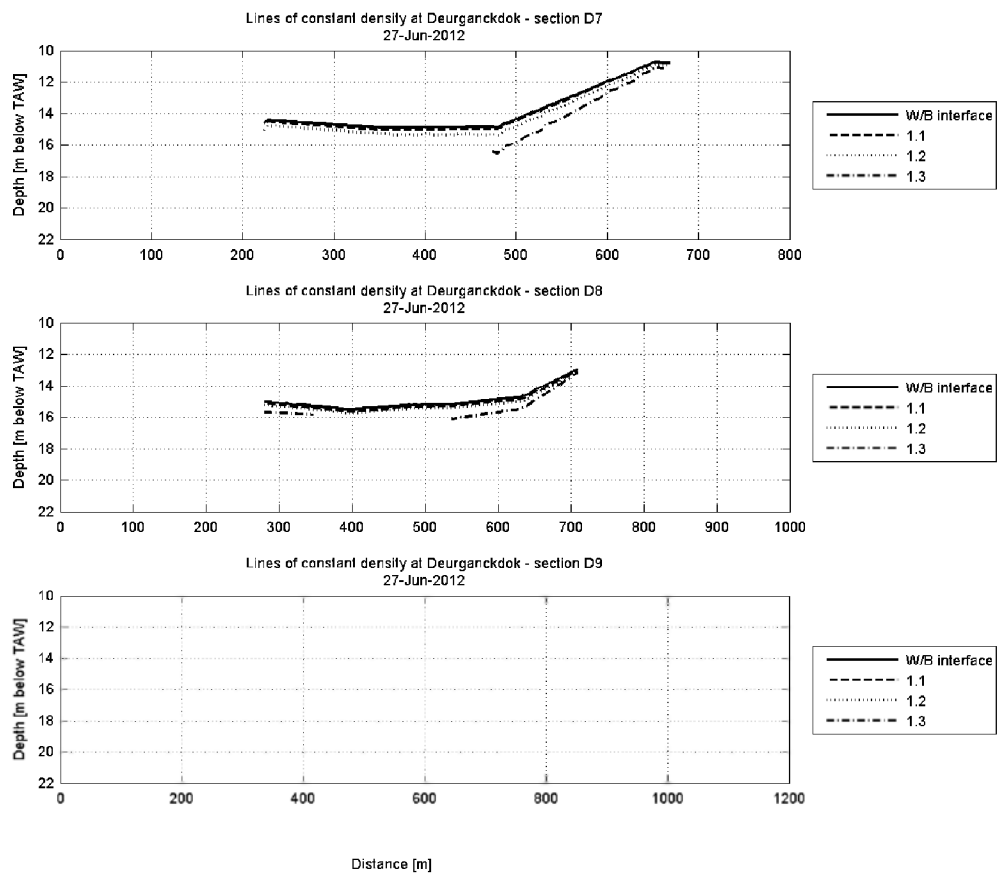
Cross sections planes constant density

Equipment(s):

Navitracker

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA

Evaluation of external effects on the siltation of Deurganckdok

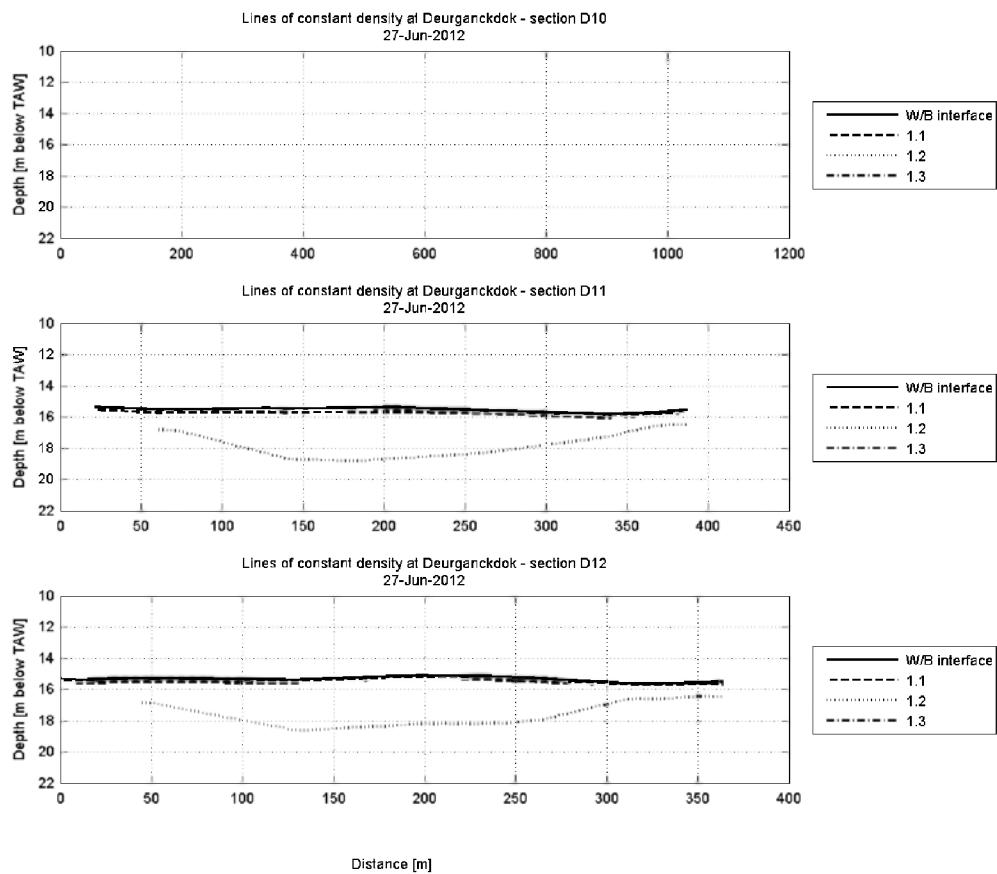
Cross sections planes constant density

Equipment(s):

Navitracker

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

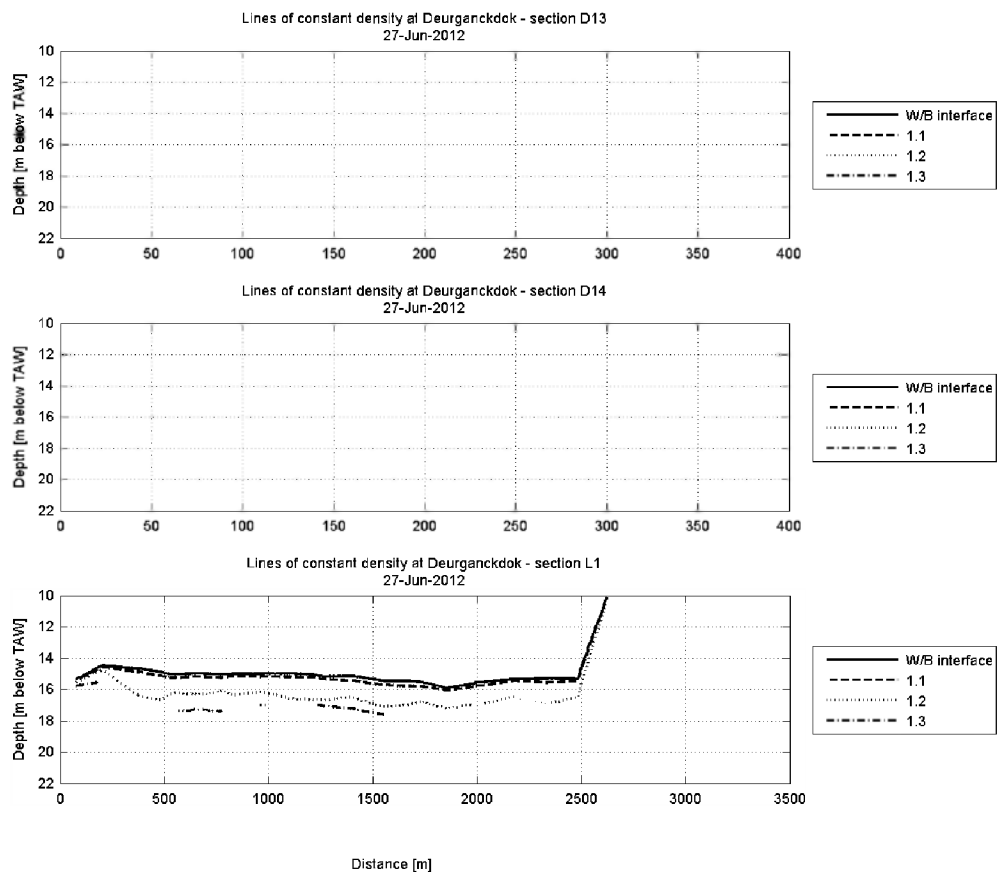
Cross sections planes constant density

Equipment(s):

Navitracker

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA

Evaluation of external effects on the siltation of Deurganckdok

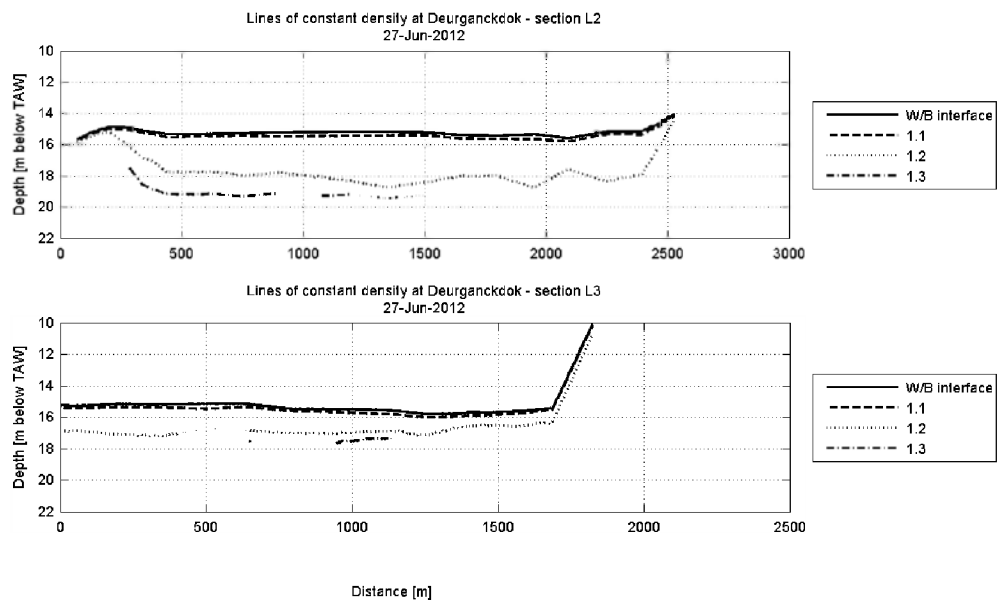
Cross sections planes constant density

Equipment(s):

Navitracker

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA

F.3 MEASUREMENTS July 26th, 2012

Evaluation of external effects on the siltation of Deurganckdok

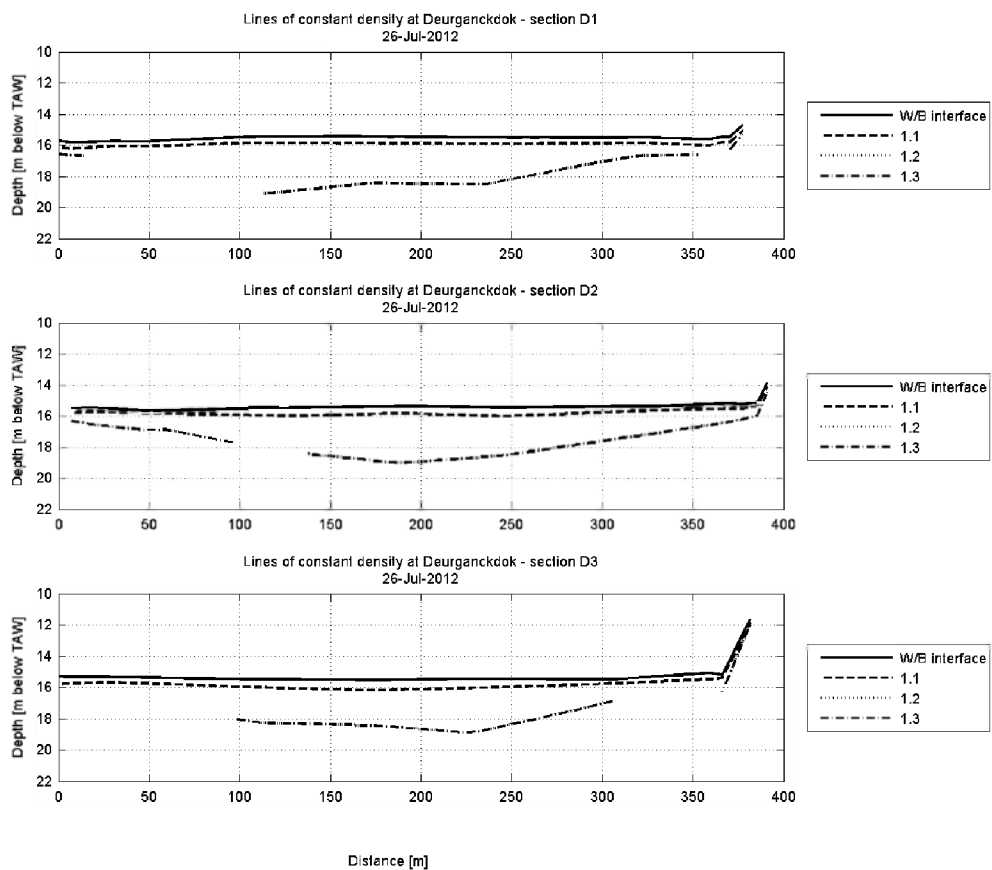
Cross sections planes constant density

Equipment(s):

Navitracker

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

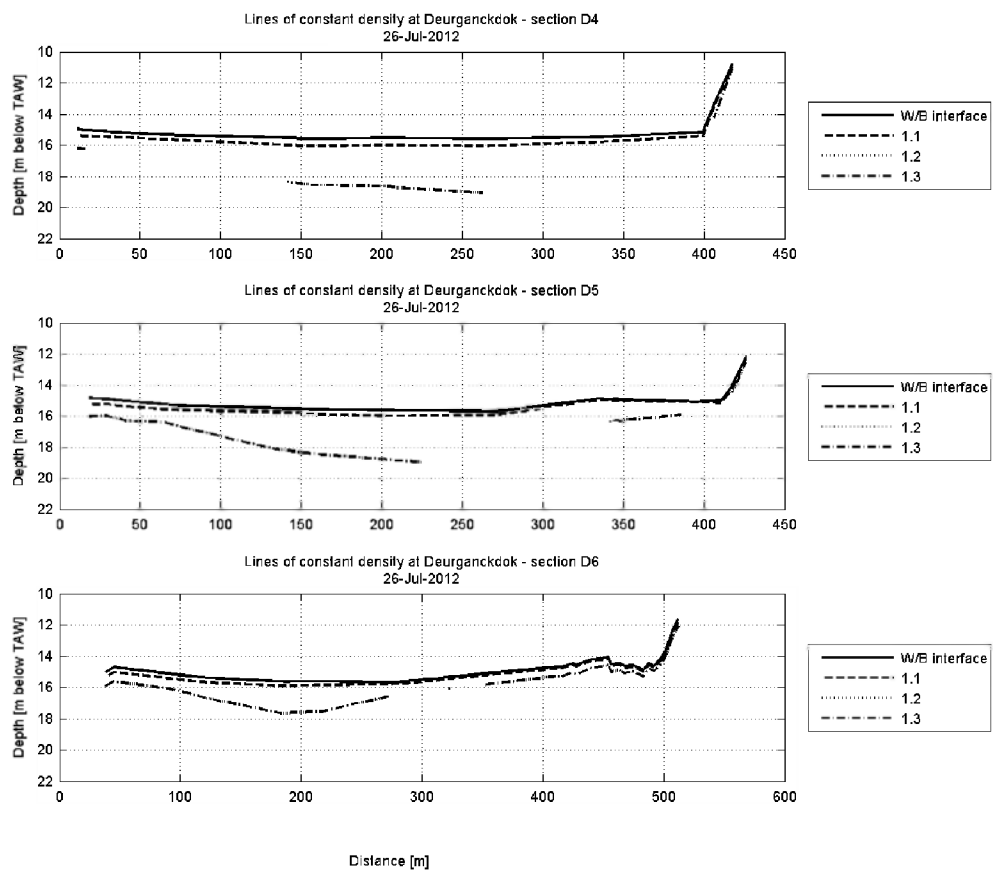
Cross sections planes constant density

Equipment(s):

Navitracker

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

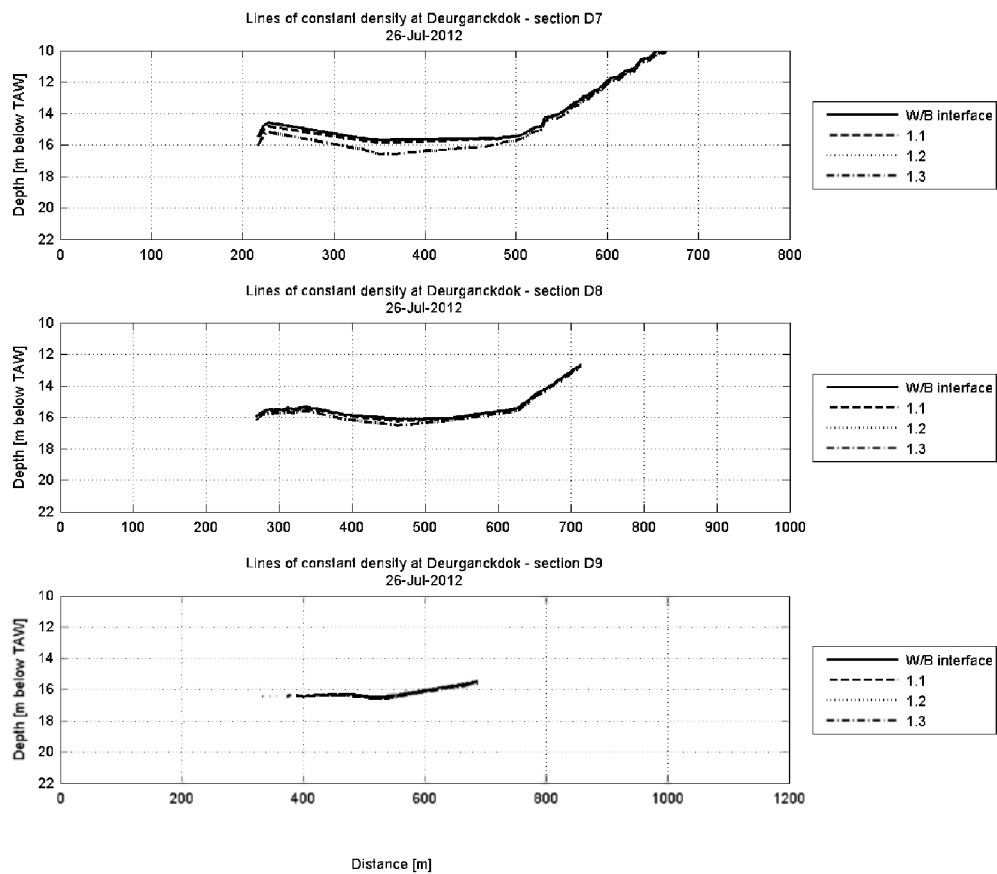
Cross sections planes constant density

Equipment(s):

Navitracker

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA

Evaluation of external effects on the siltation of Deurganckdok

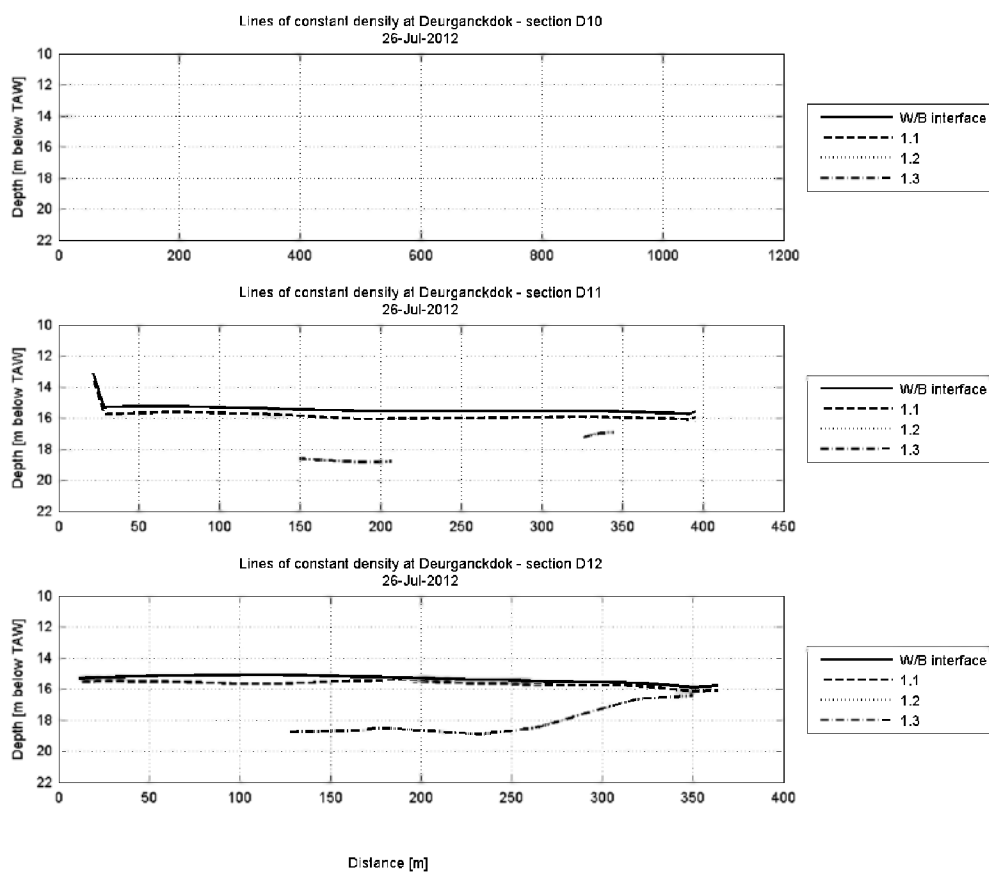
Cross sections planes constant density

Equipment(s):

Navitracker

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

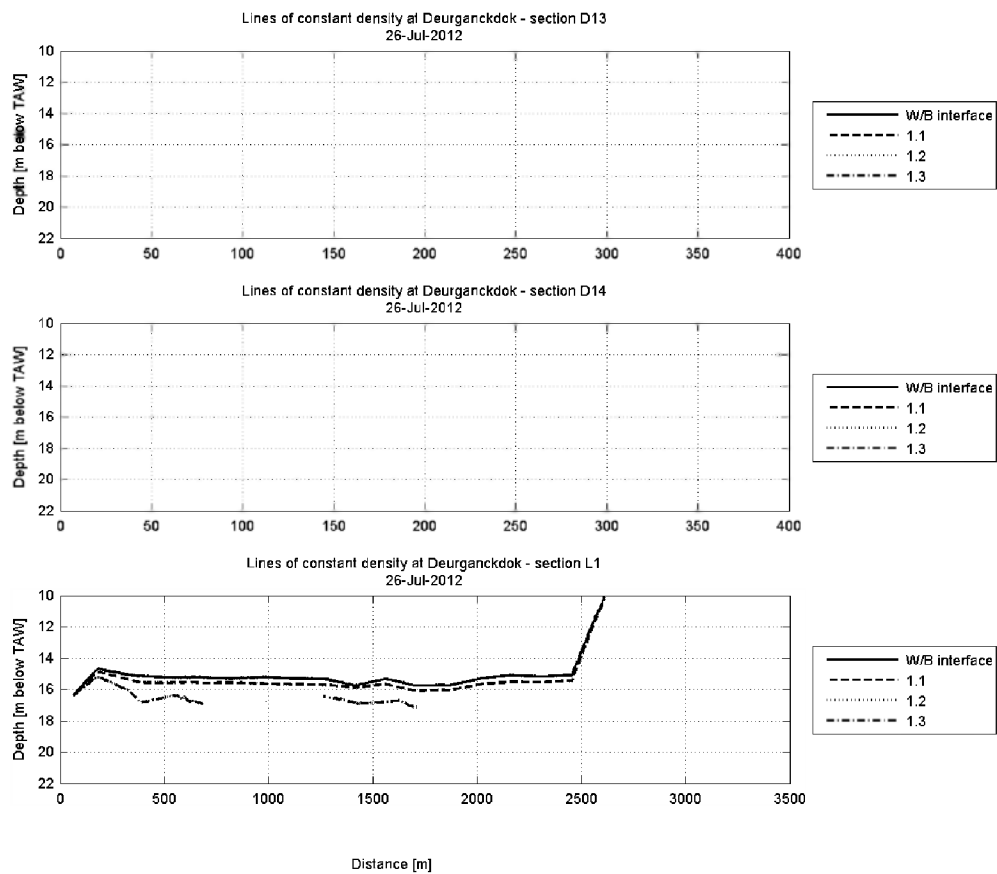
Cross sections planes constant density

Equipment(s):

Navitracker

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA

Evaluation of external effects on the siltation of Deurganckdok

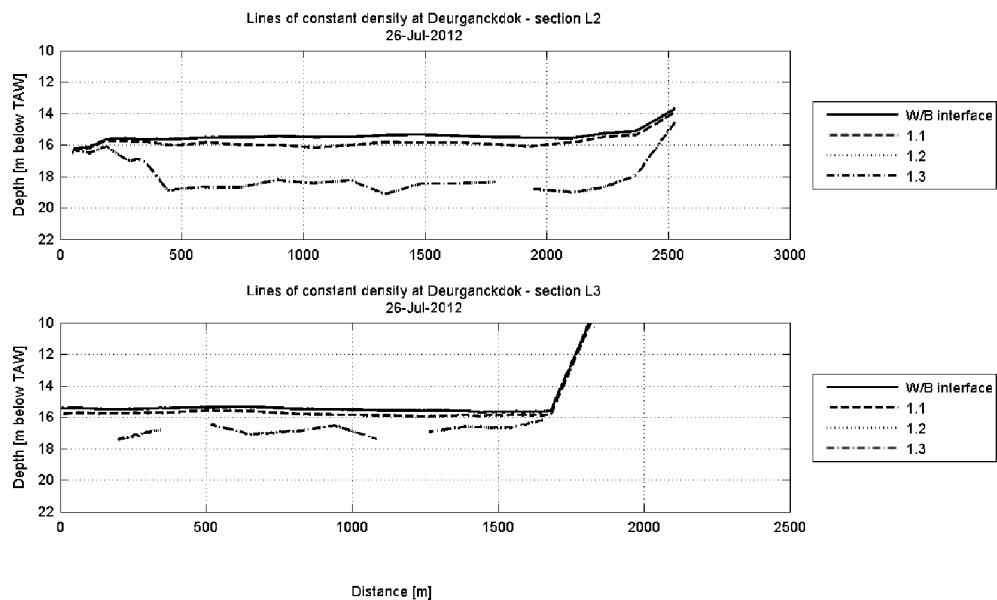
Cross sections planes constant density

Equipment(s):

Navitracker

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA

F.4 MEASUREMENTS SEPTEMBER 18th, 2012

Evaluation of external effects on the siltation of Deurganckdok

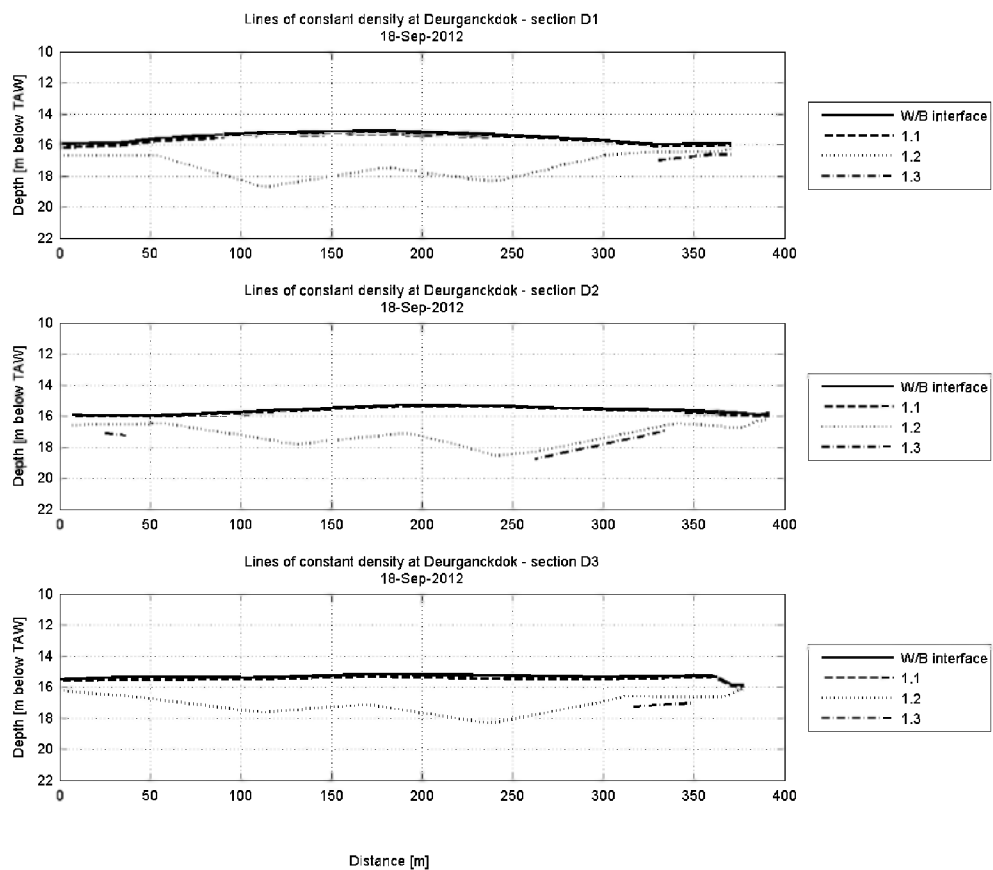
Cross sections planes constant density

Equipment(s):

Navitracker

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

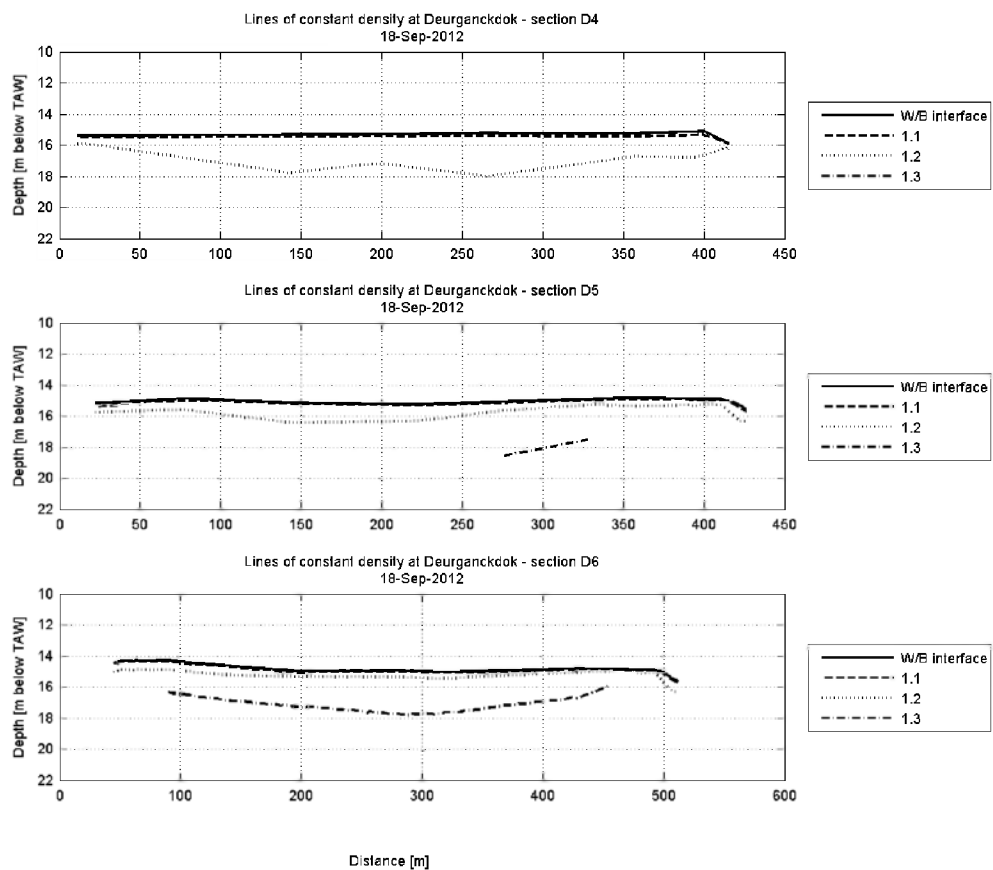
Cross sections planes constant density

Equipment(s):

Navitracker

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

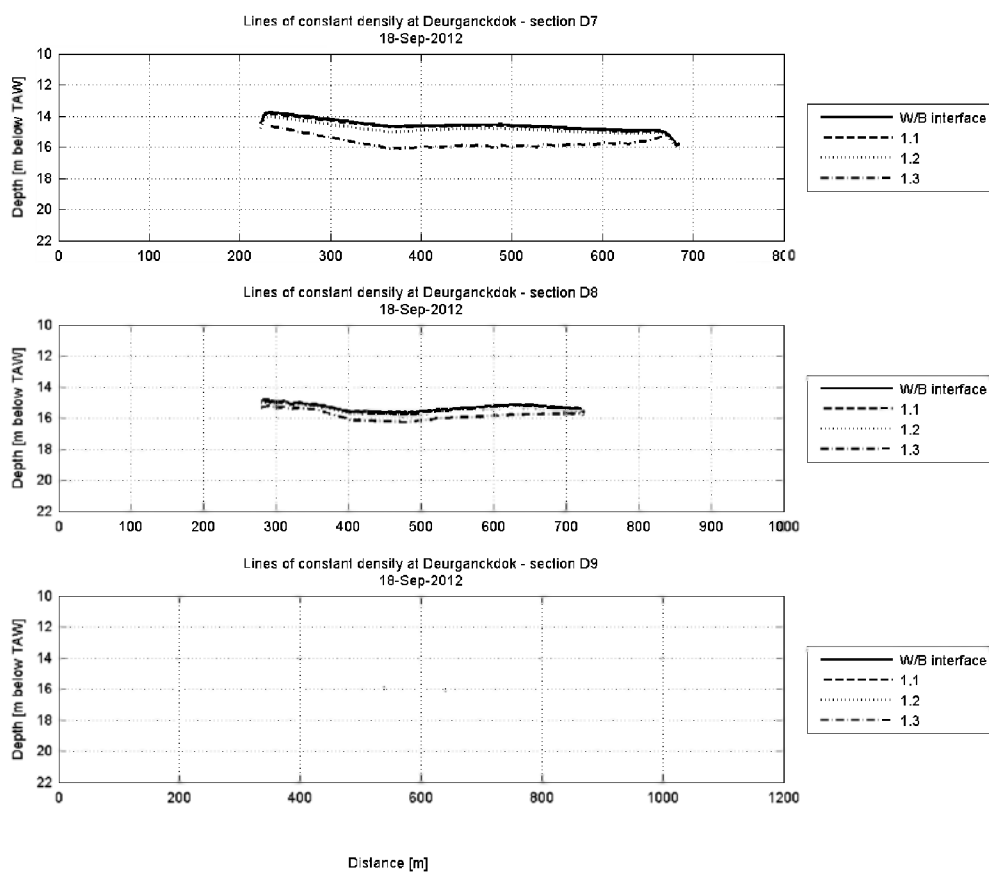
Cross sections planes constant density

Equipment(s):

Navitracker

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

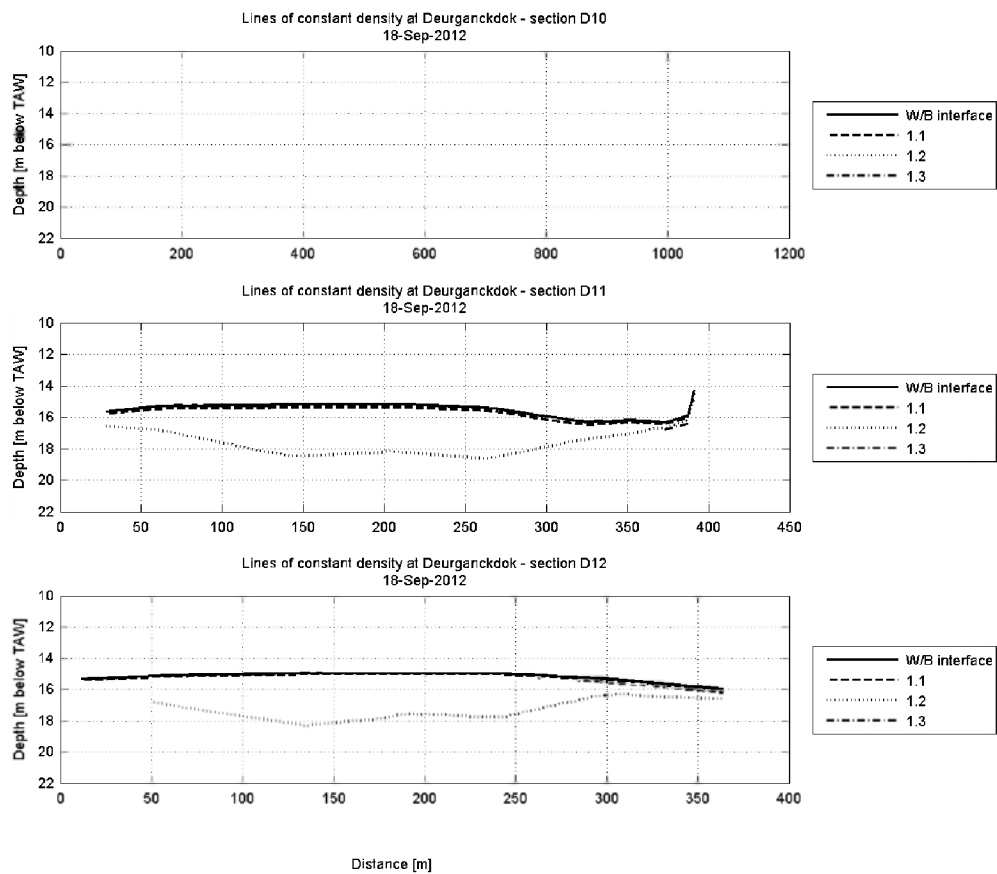
Cross sections planes constant density

Equipment(s):

Navitracker

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA

Evaluation of external effects on the siltation of Deurganckdok

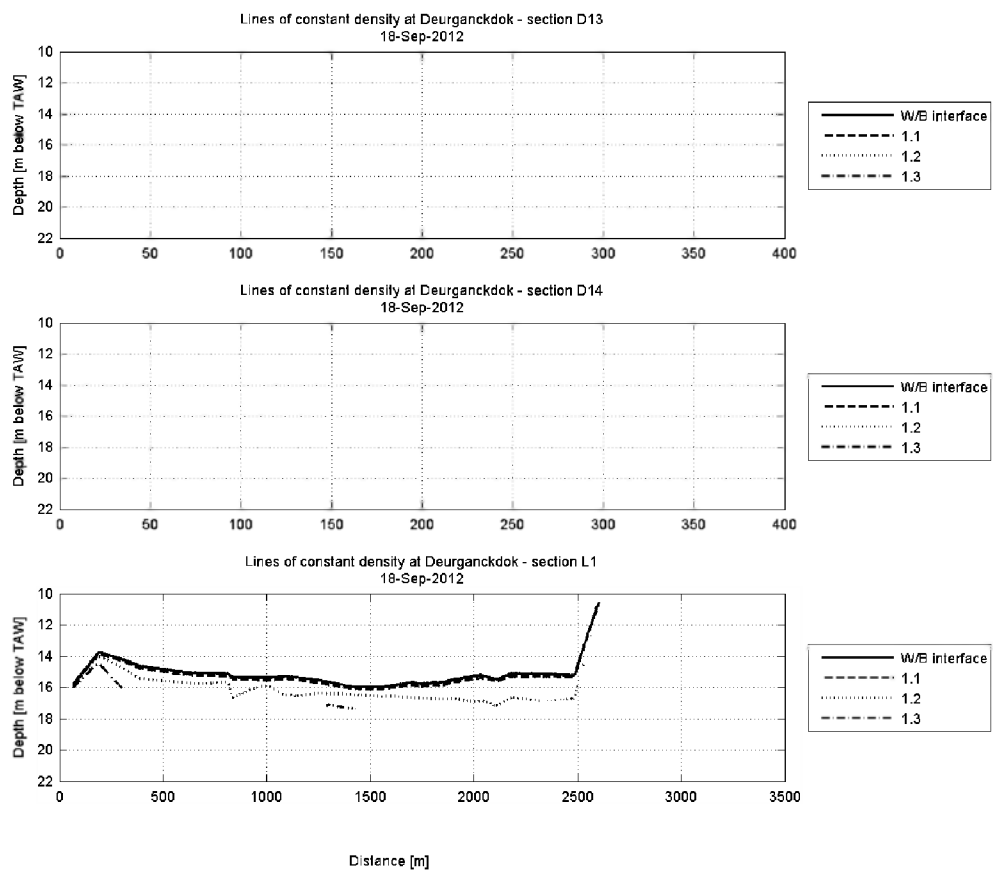
Cross sections planes constant density

Equipment(s):

Navitracker

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

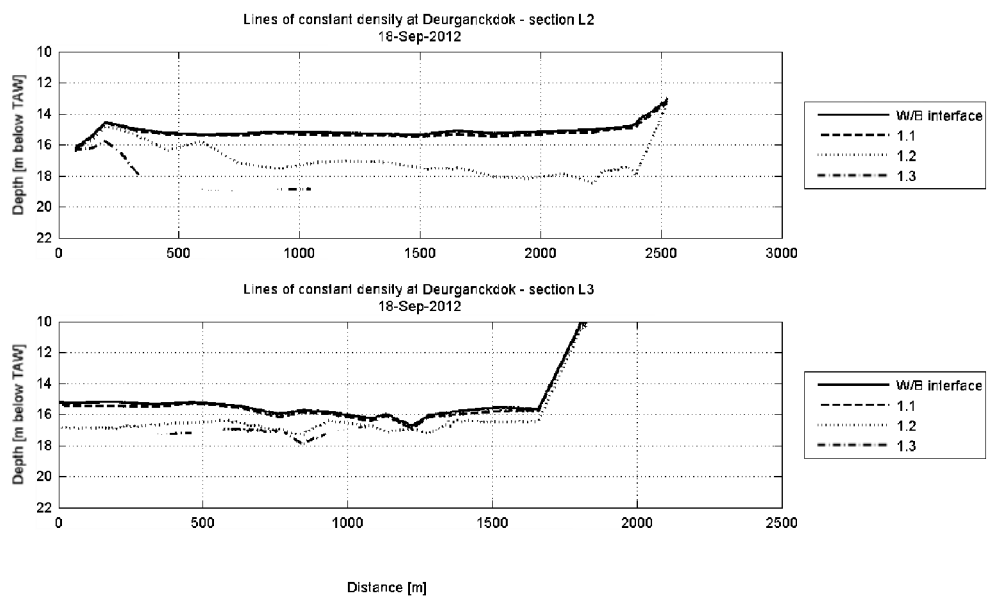
Cross sections planes constant density

Equipment(s):

Navitracker

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



F.5 MEASUREMENTS OCTOBER 11th, 2012

Evaluation of external effects on the siltation of Deurganckdok

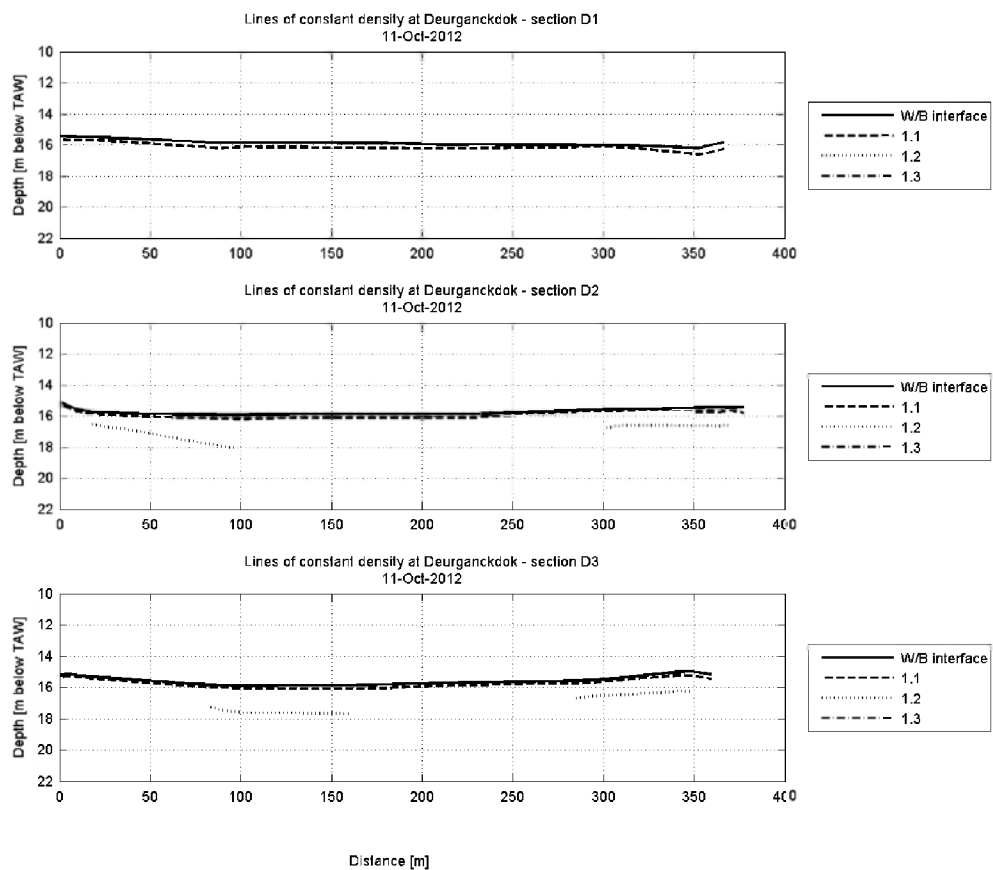
Cross sections planes constant density

Equipment(s):

Navitracker

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

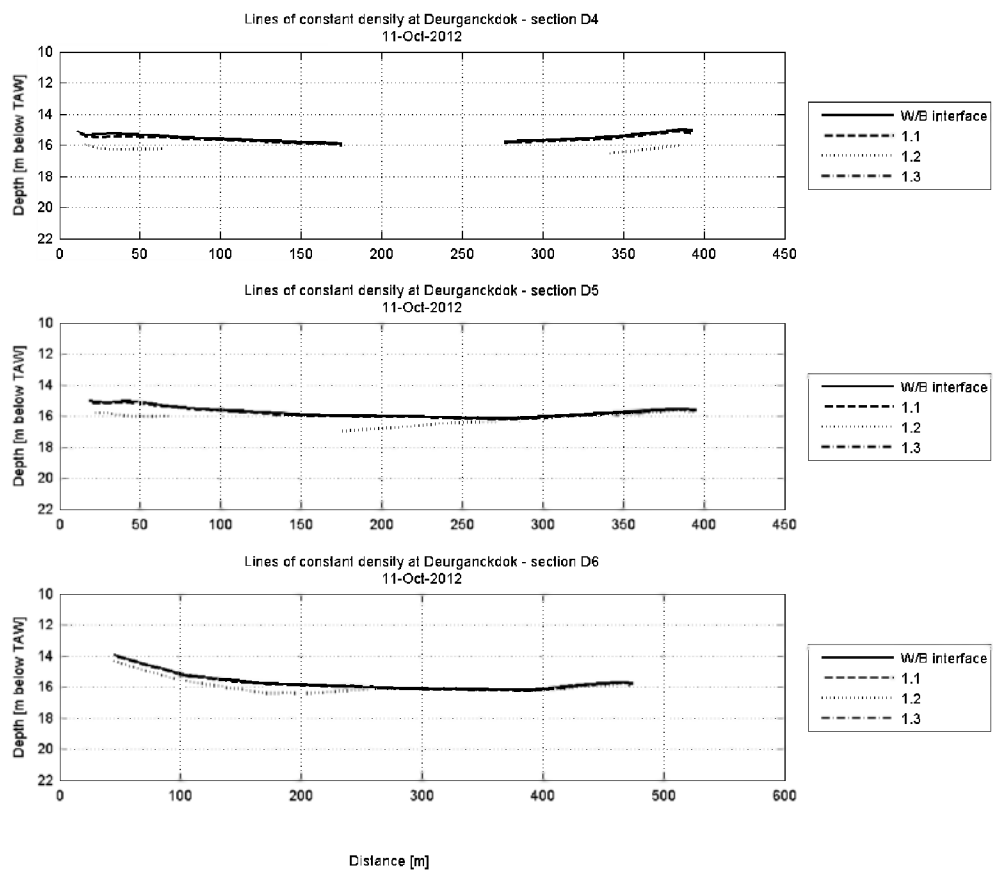
Cross sections planes constant density

Equipment(s):

Navitracker

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

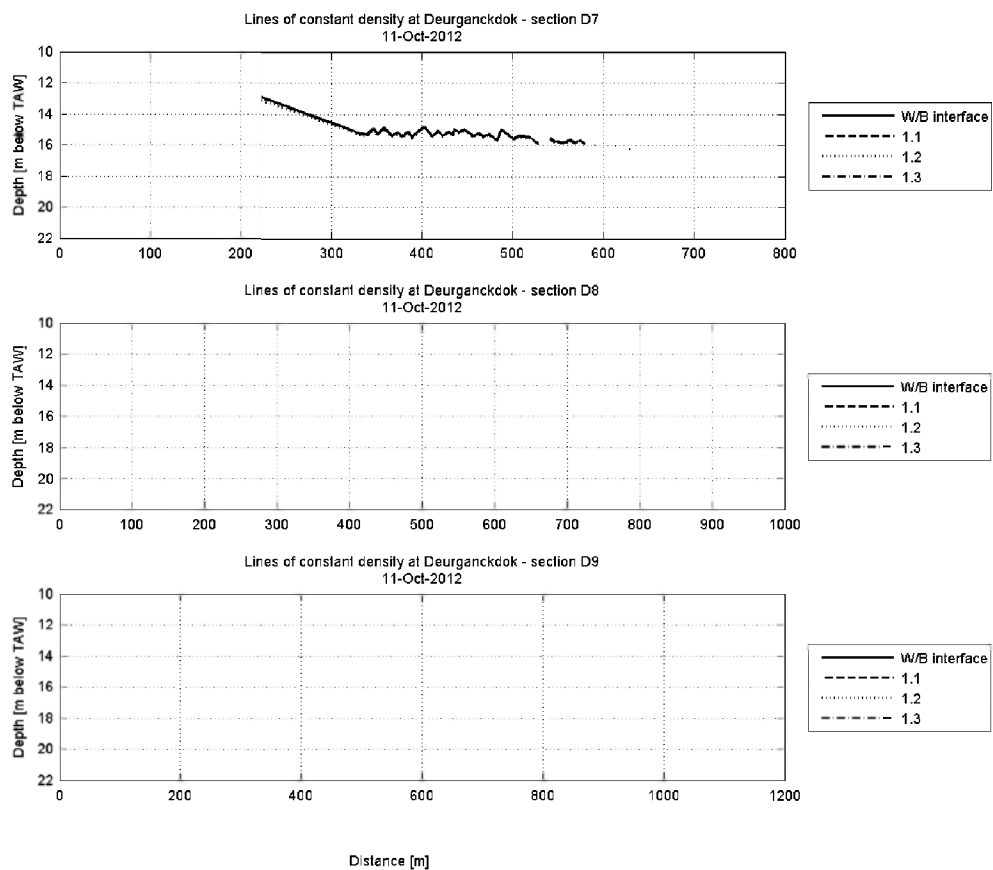
Cross sections planes constant density

Equipment(s):

Navitracker

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

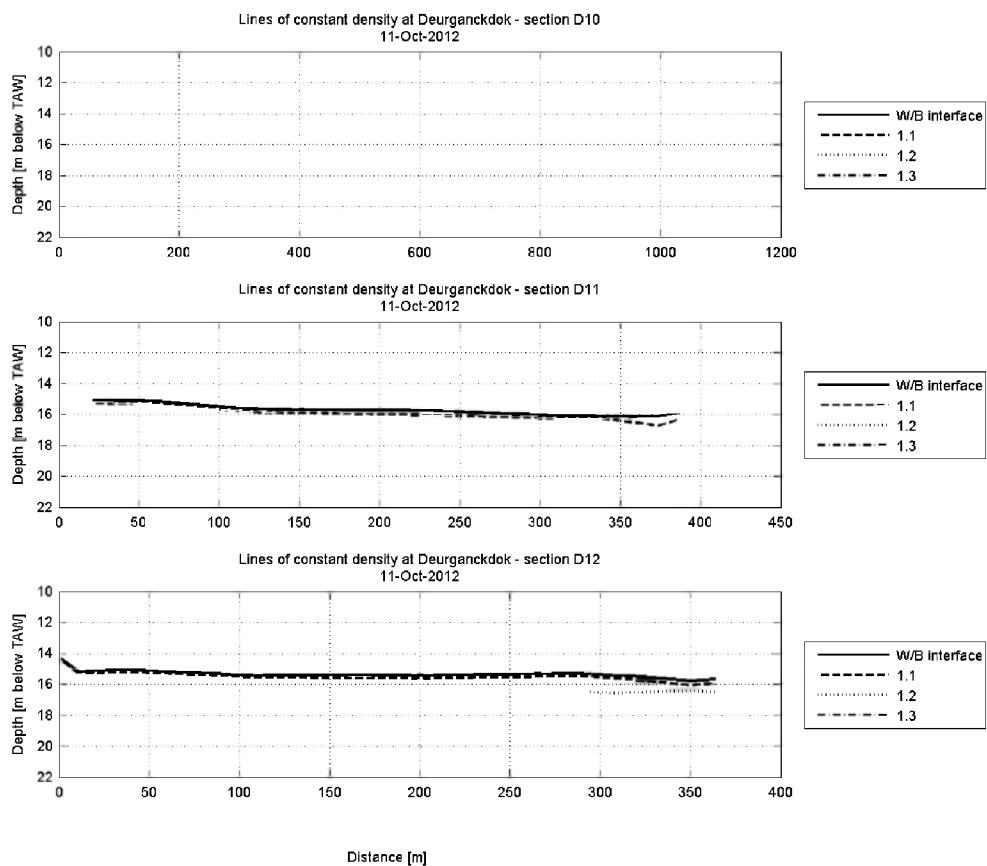
Cross sections planes constant density

Equipment(s):

Navitracker

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

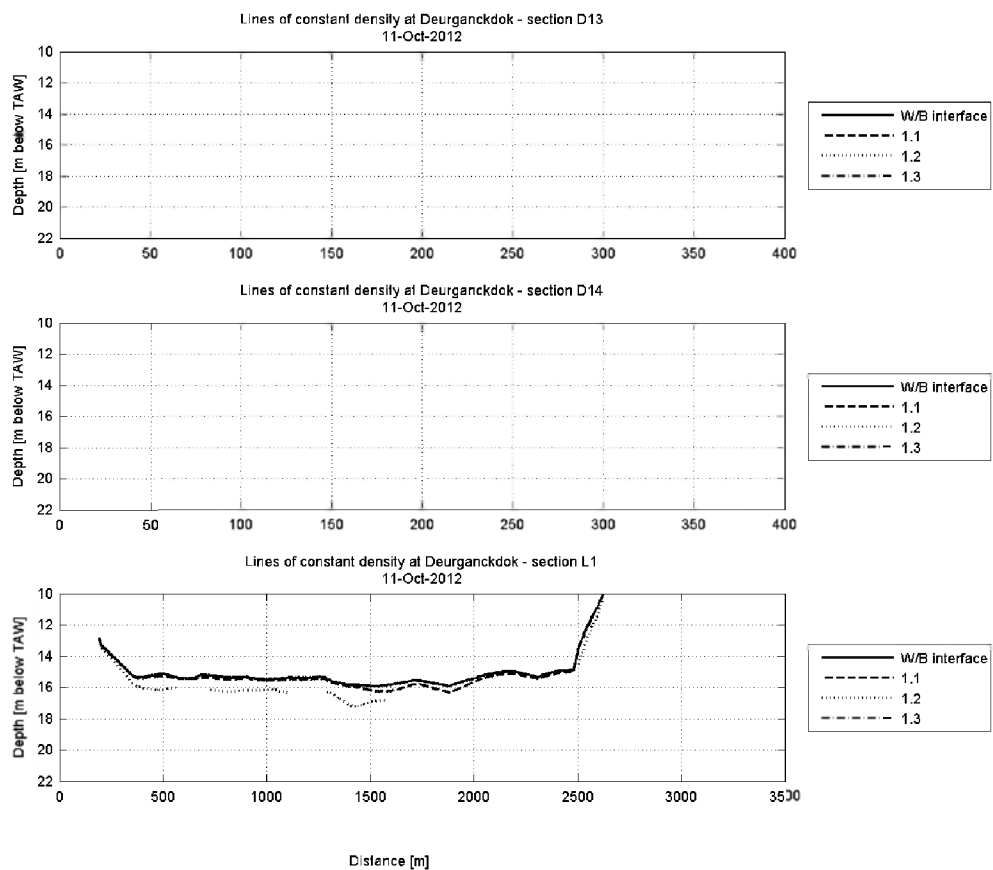
Cross sections planes constant density

Equipment(s):

Navitracker

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

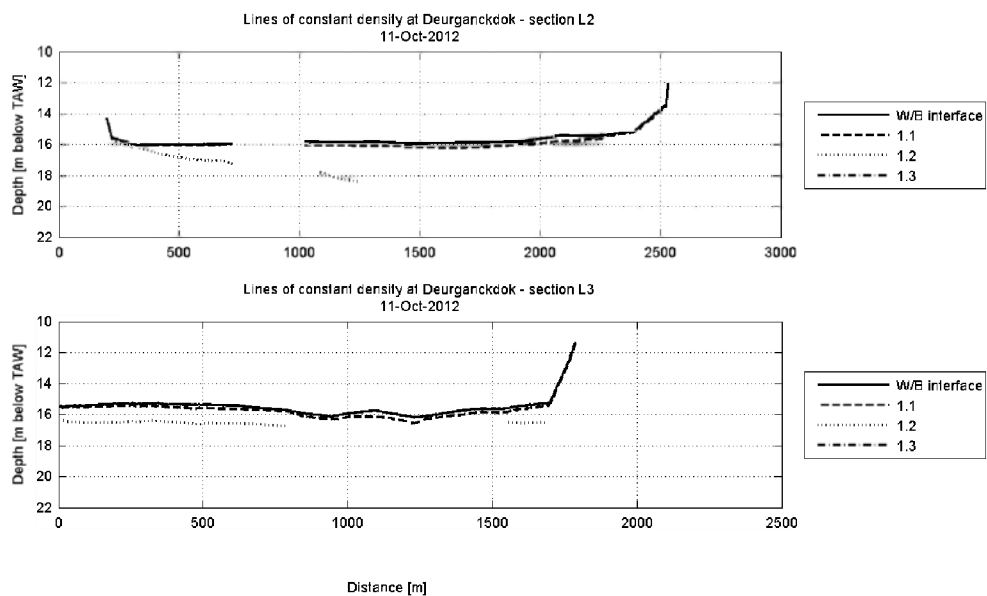
Cross sections planes constant density

Equipment(s):

Navitracker

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



F.6 MEASUREMENTS December 27th, 2012

Evaluation of external effects on the siltation of Deurganckdok

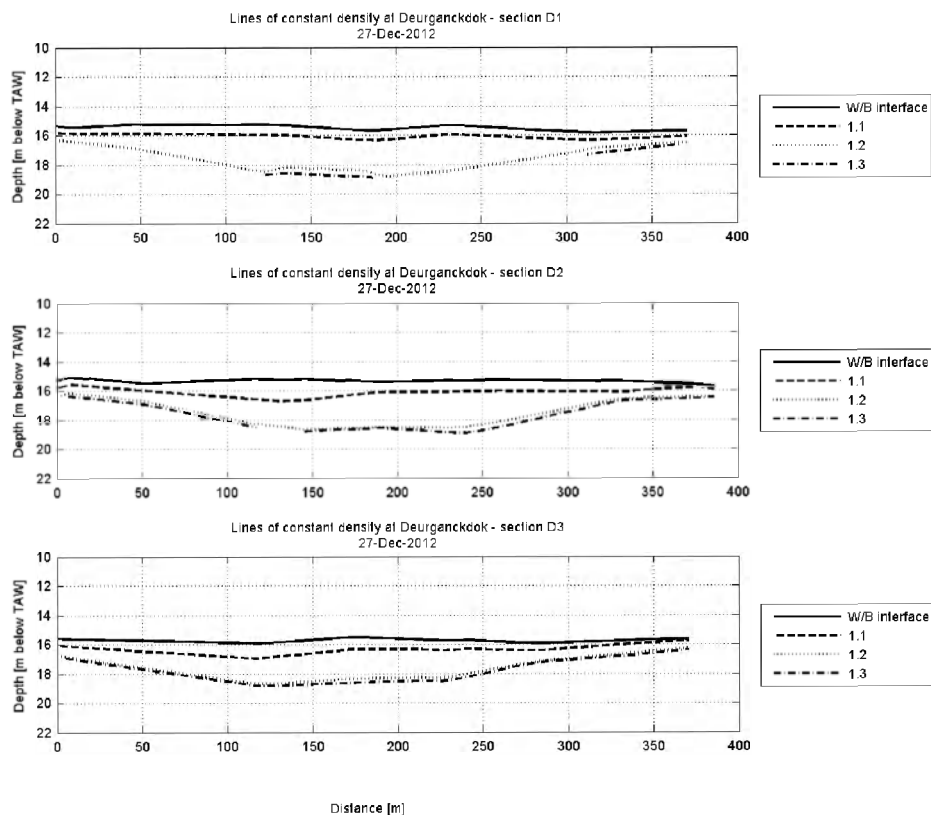
Cross sections planes constant density

Equipment(s):

Graviprobe

Location:

DGD

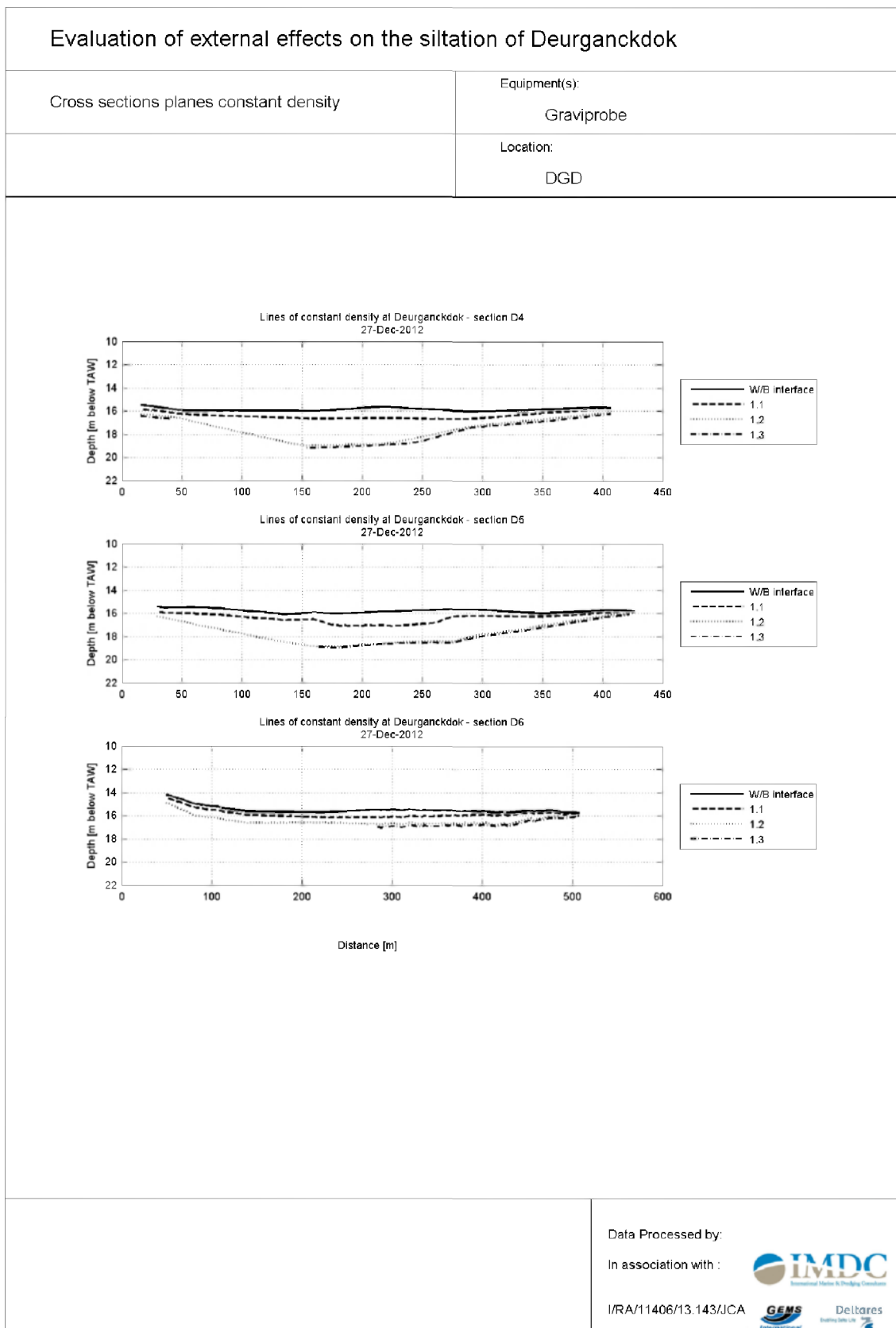


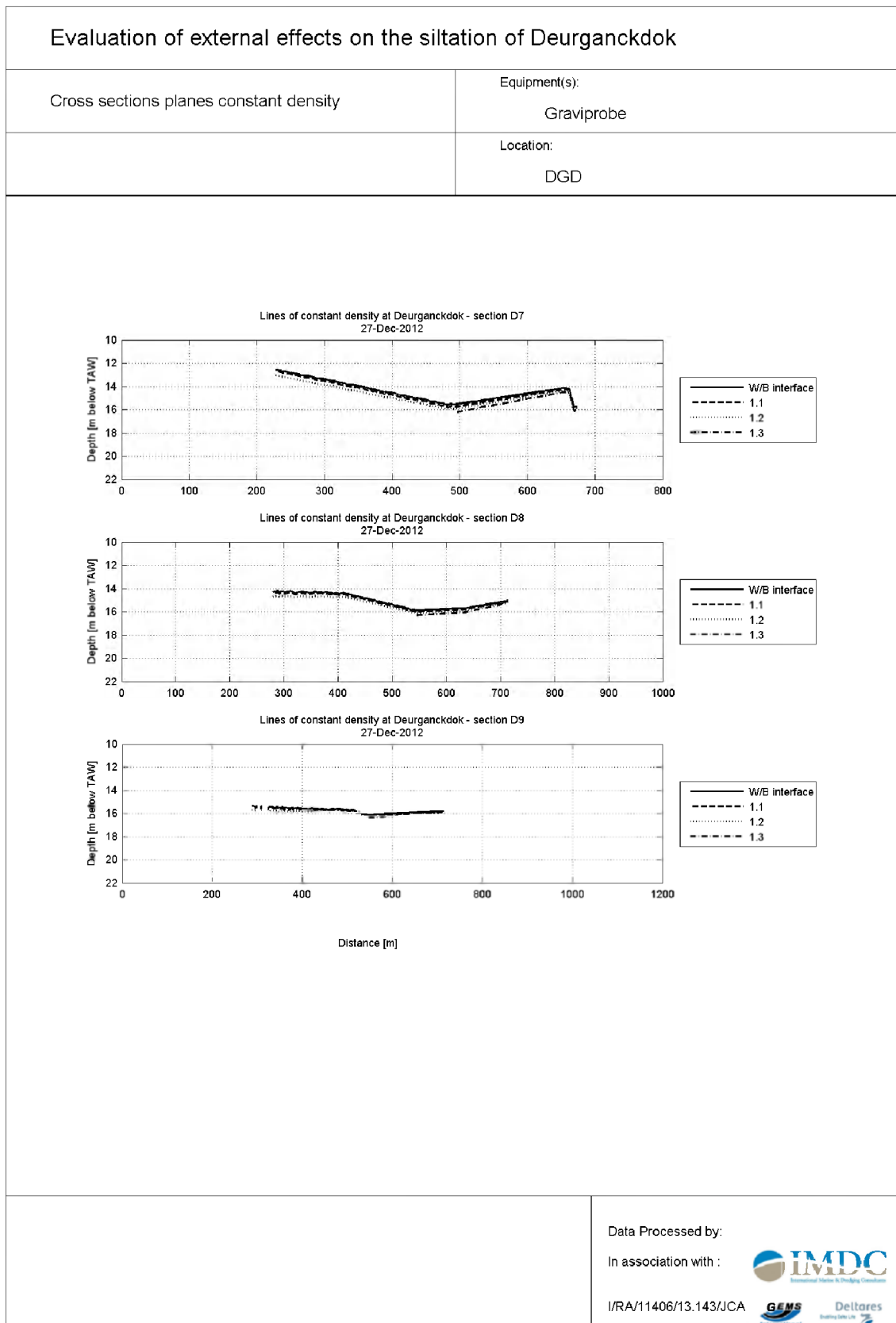
Data Processed by:

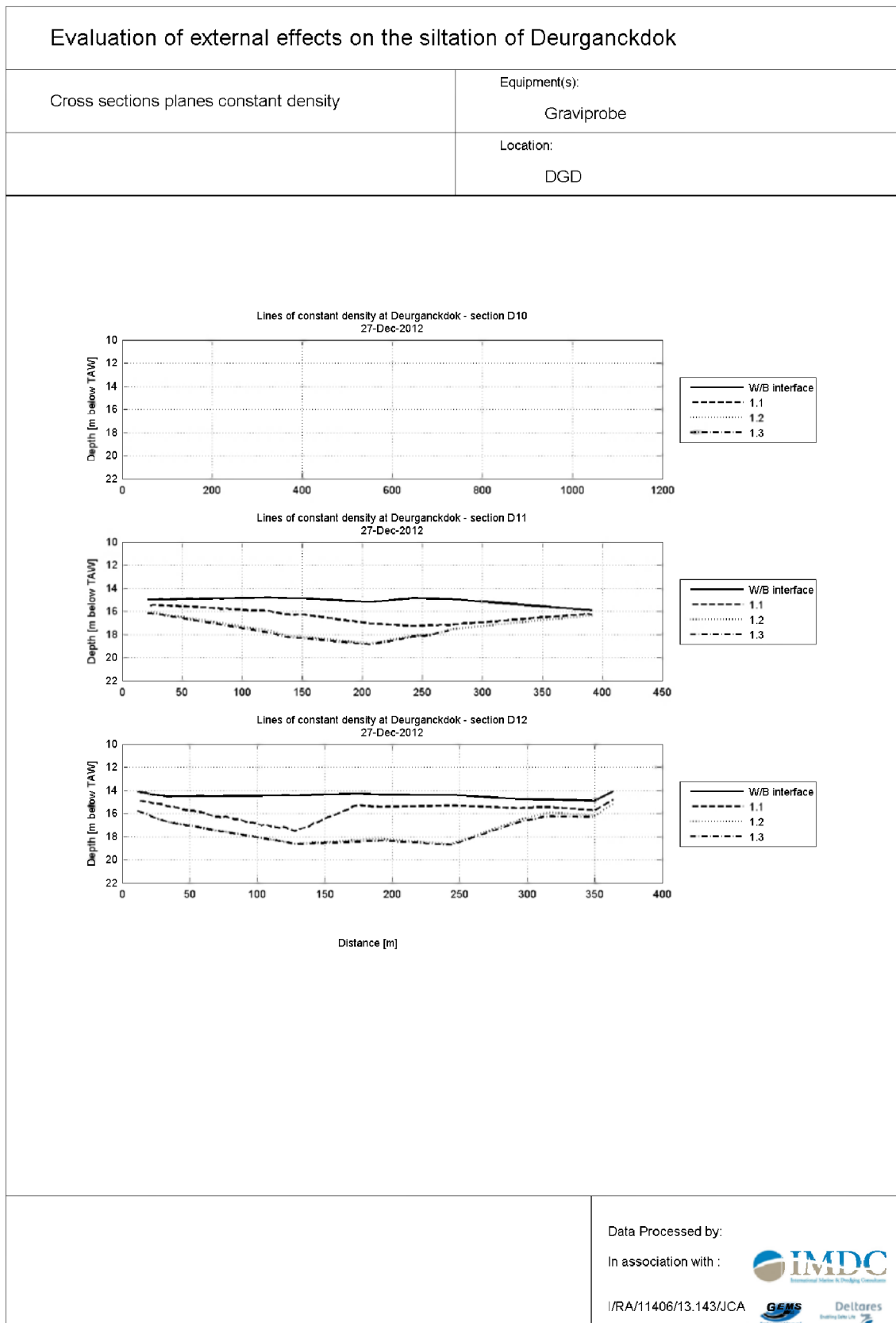
In association with :

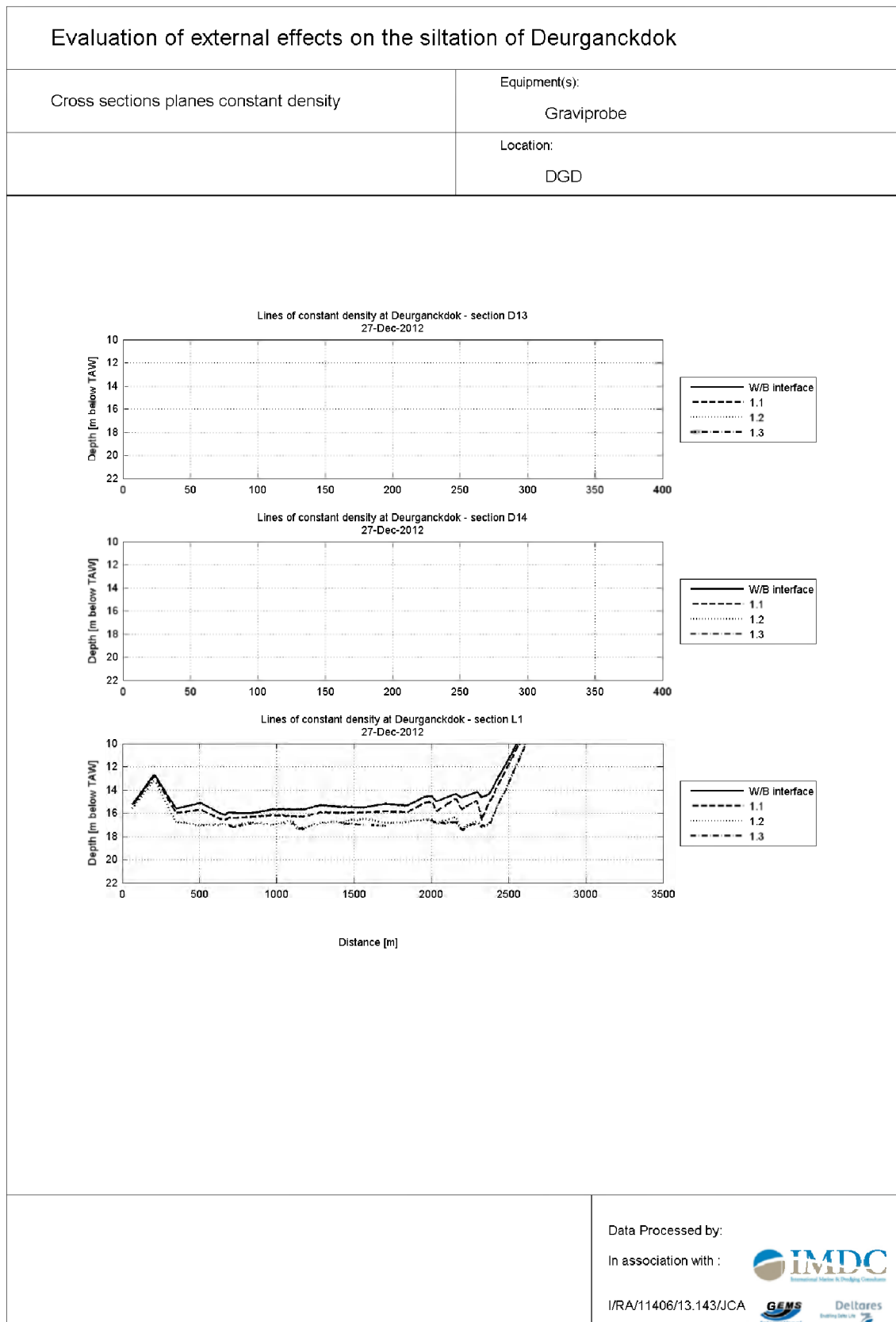
I/RA/11406/13.143/JCA

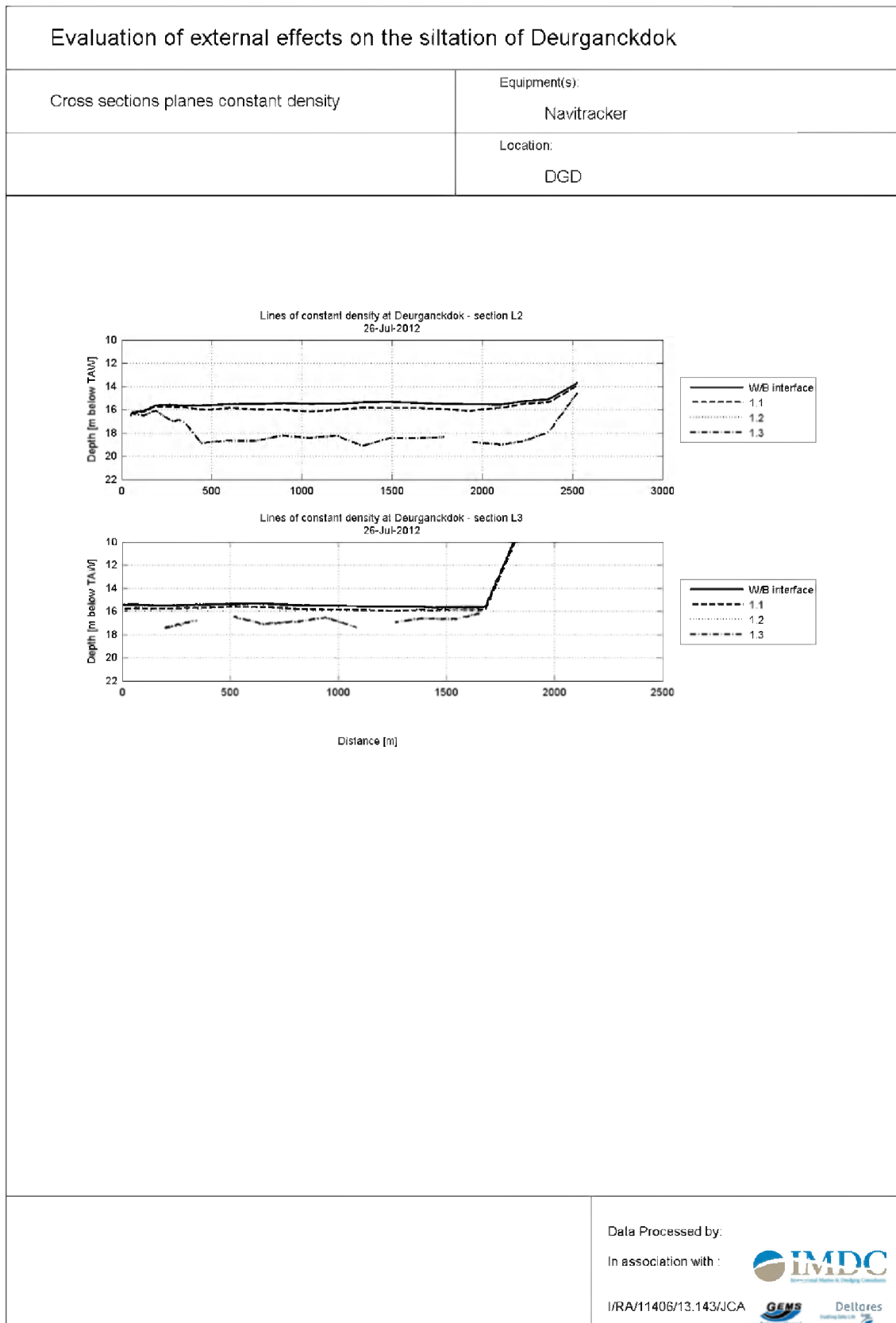












F.7 MEASUREMENTS JANUARY 23th, 2013

Evaluation of external effects on the siltation of Deurganckdok

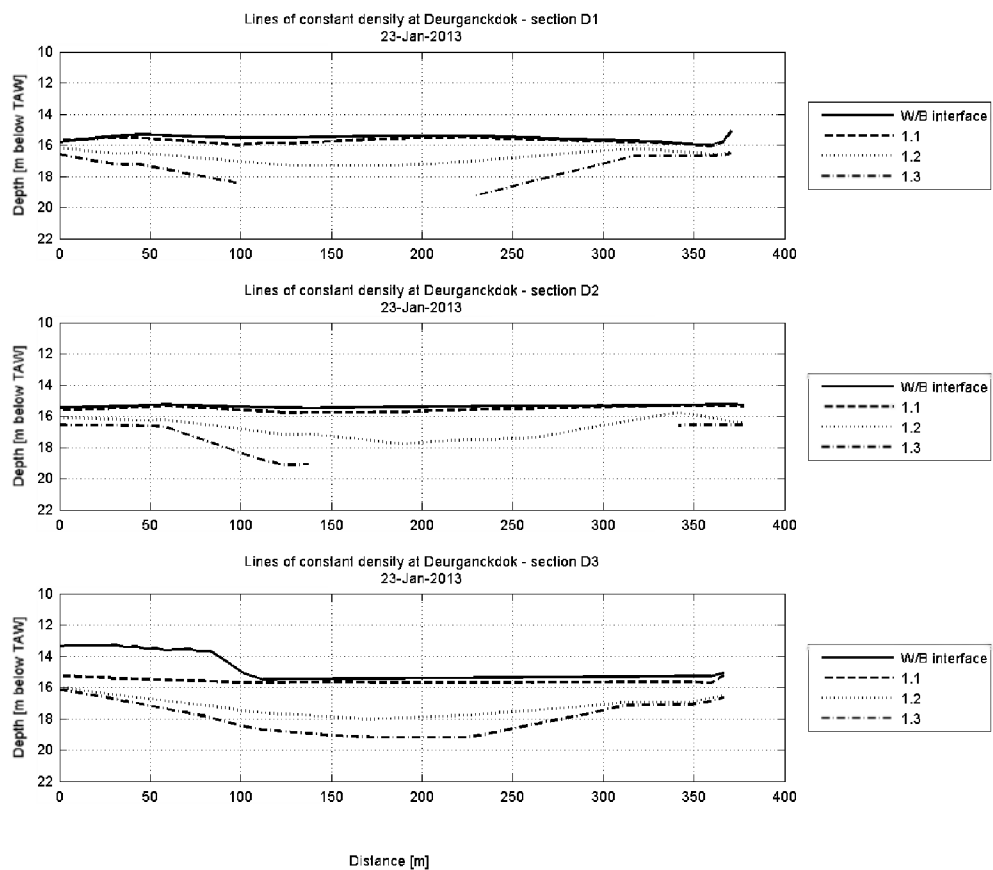
Cross sections planes constant density

Equipment(s):

Densitune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

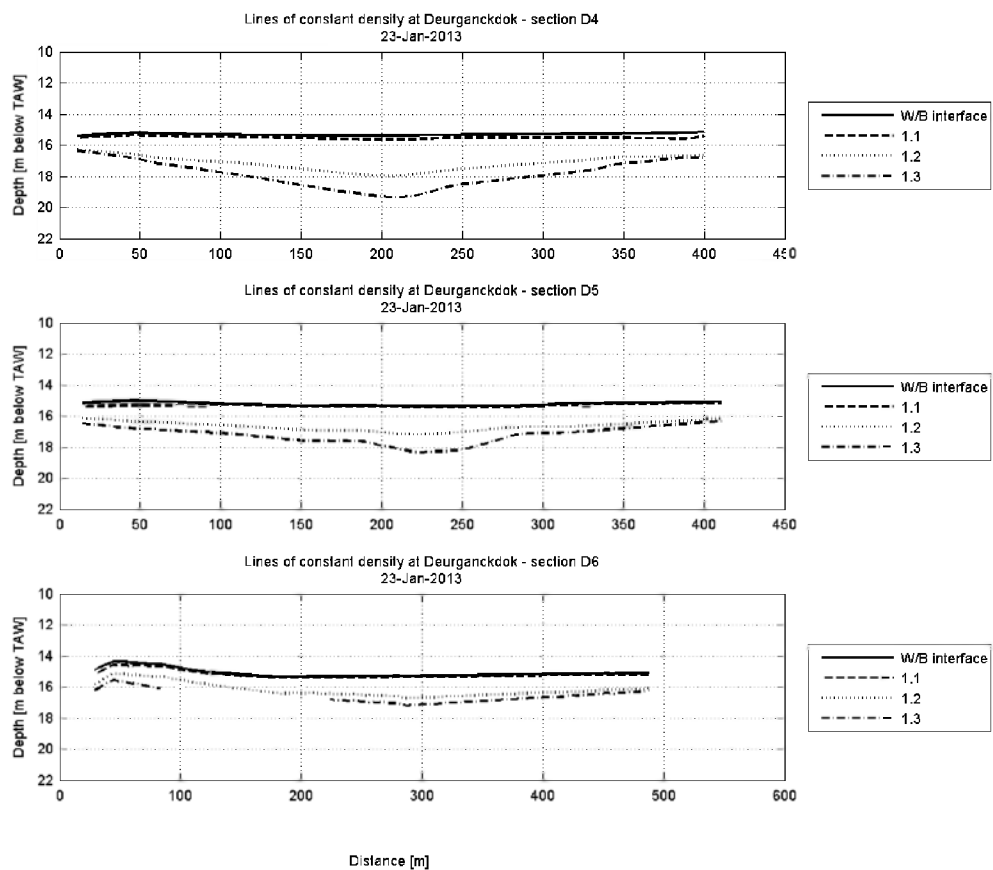
Cross sections planes constant density

Equipment(s):

Densitune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

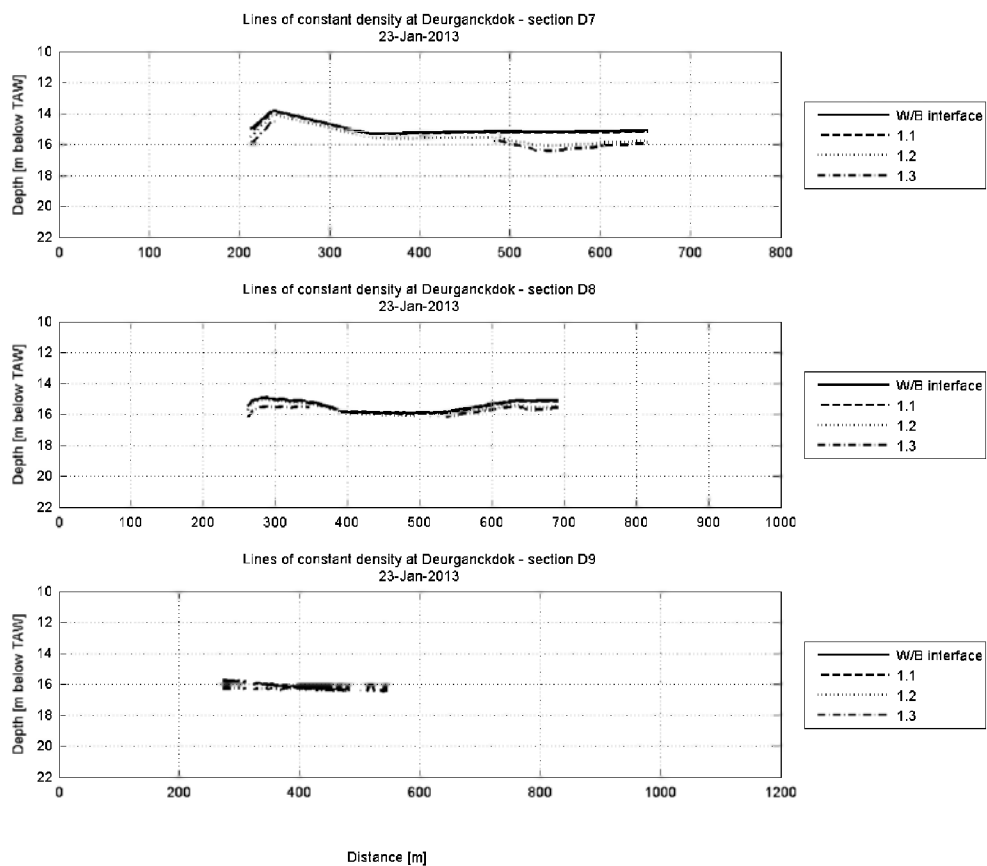
Cross sections planes constant density

Equipment(s):

Densitune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

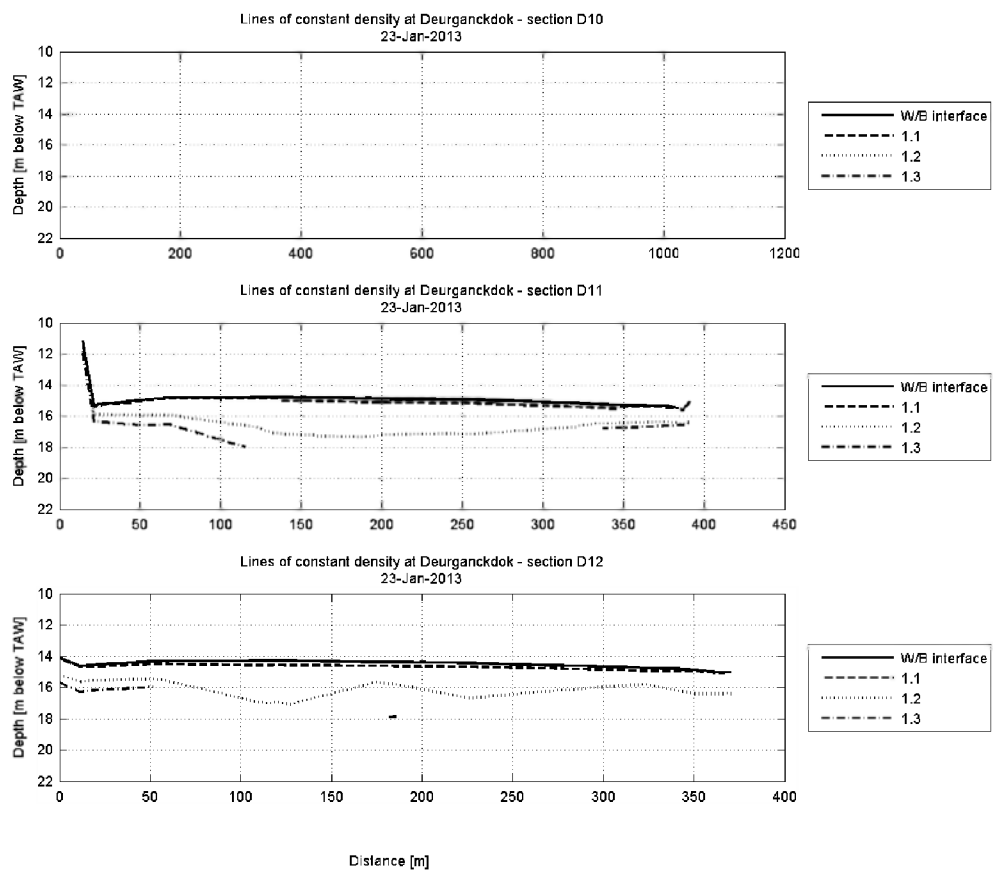
Cross sections planes constant density

Equipment(s):

Densitune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

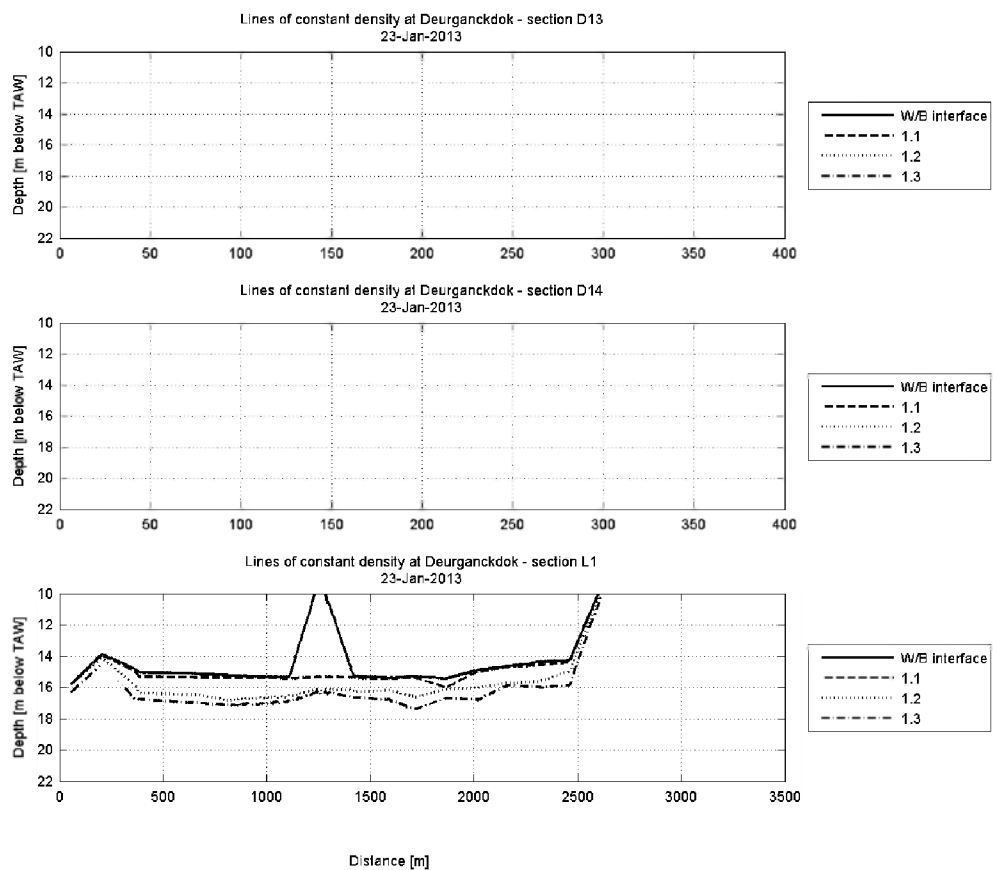
Cross sections planes constant density

Equipment(s):

Densitune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

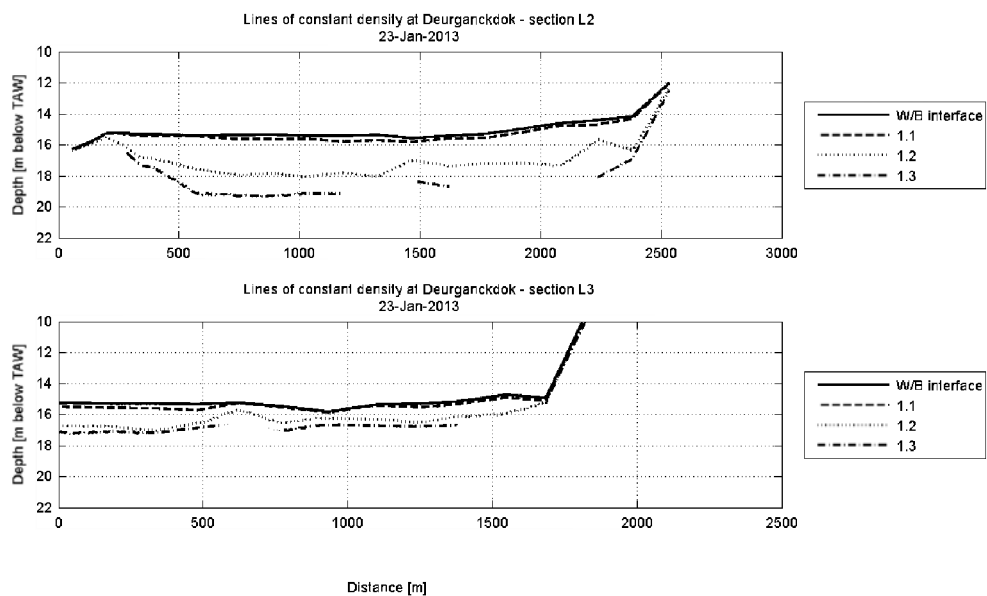
Cross sections planes constant density

Equipment(s):

Densitune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



F.8 MEASUREMENTS MARCH 7th, 2013

Evaluation of external effects on the siltation of Deurganckdok

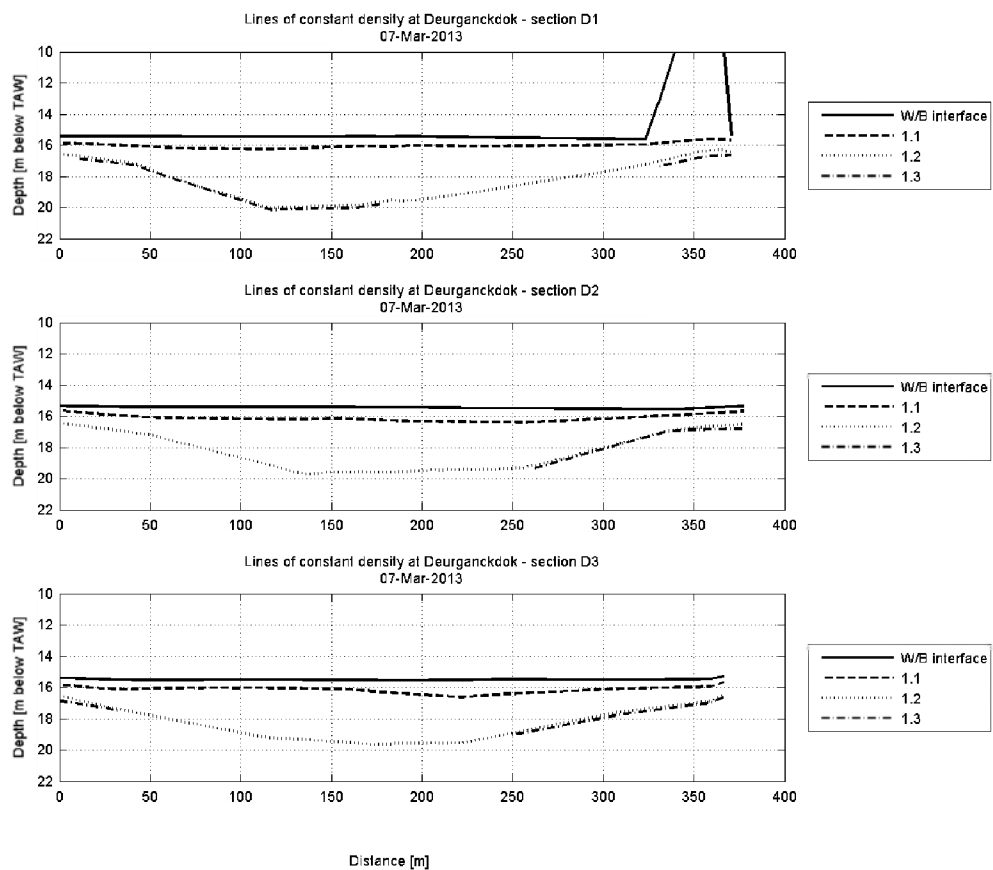
Cross sections planes constant density

Equipment(s):

Densitune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

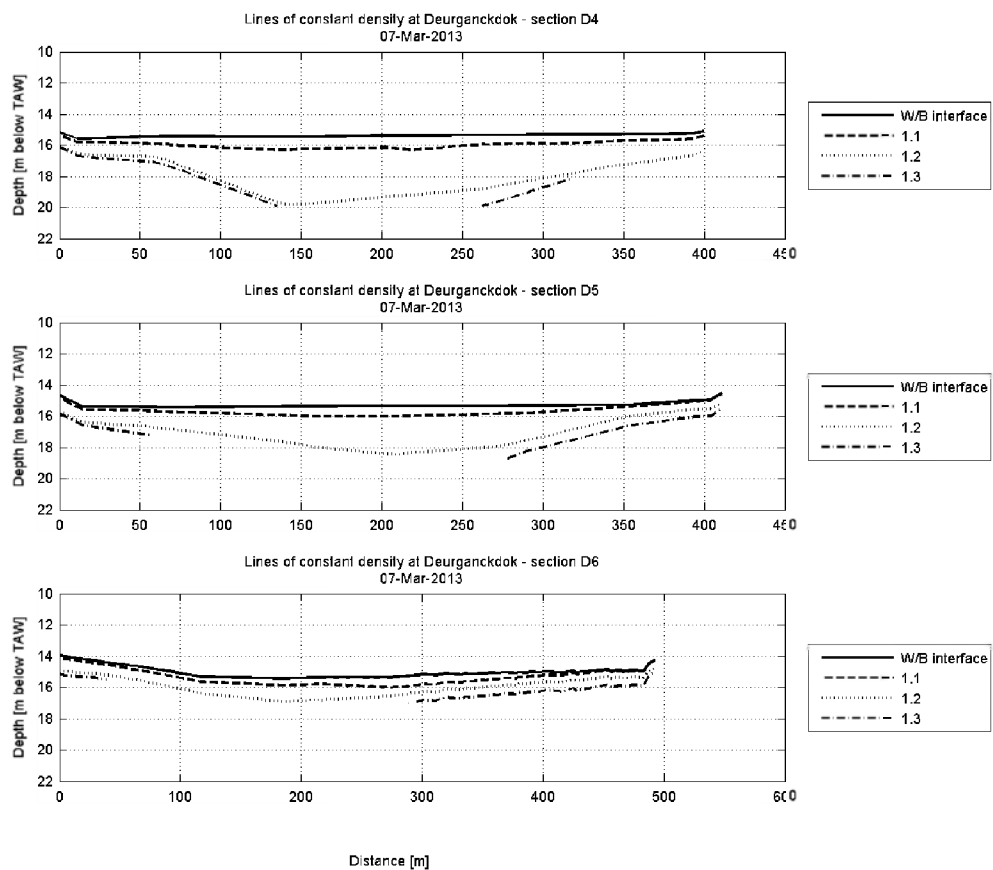
Cross sections planes constant density

Equipment(s):

Densitune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

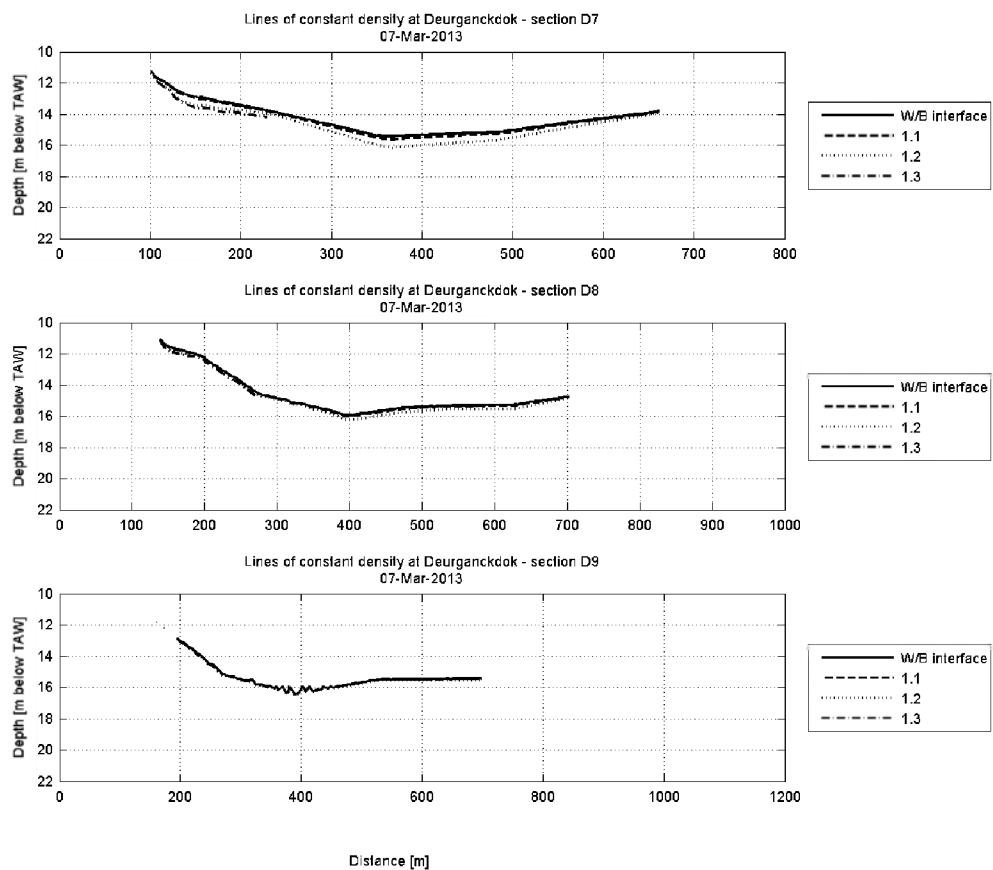
Cross sections planes constant density

Equipment(s):

Densitune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

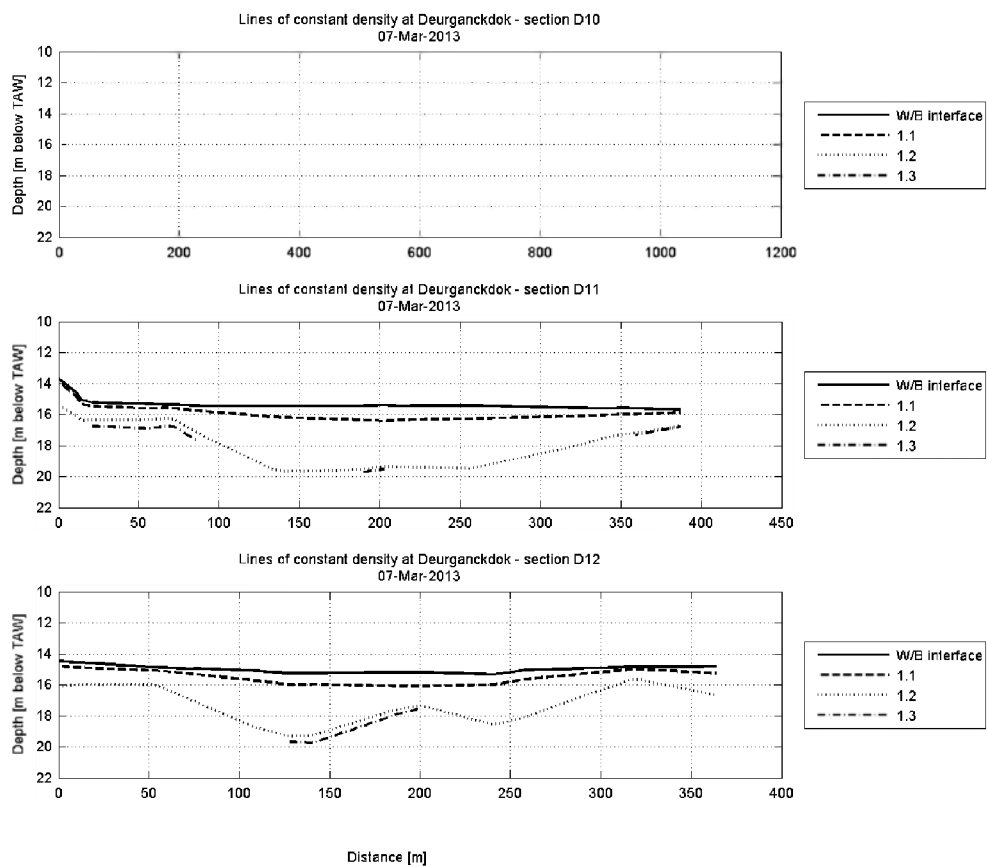
Cross sections planes constant density

Equipment(s):

Densitune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

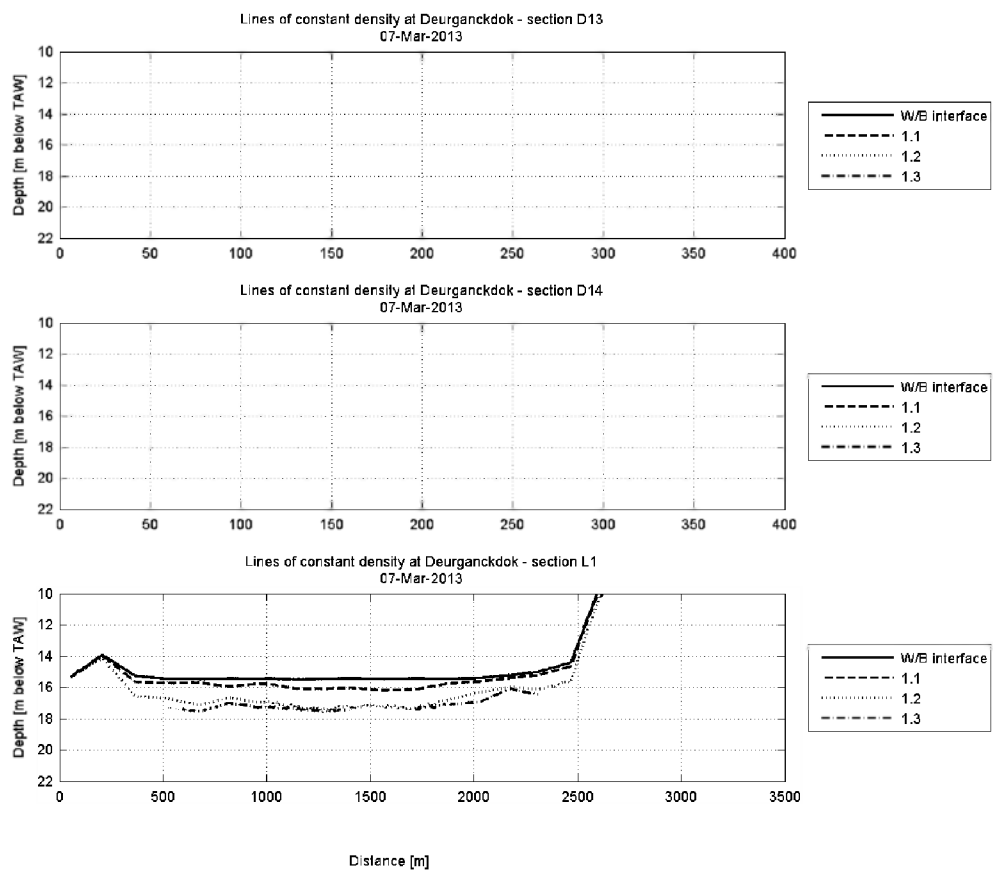
Cross sections planes constant density

Equipment(s):

Densitune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

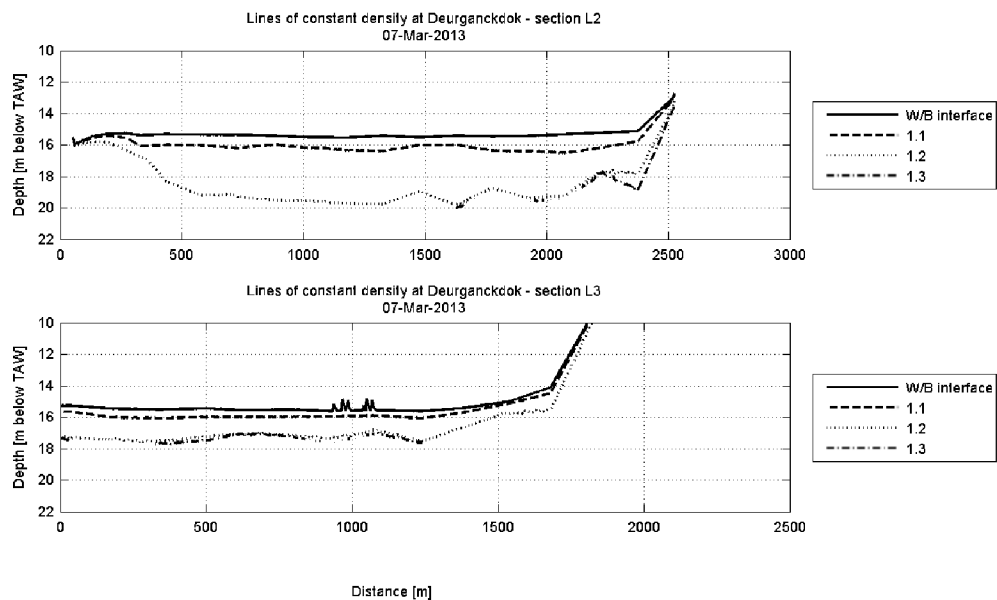
Cross sections planes constant density

Equipment(s):

Densitune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA

Annex G DEPTH EVOLUTION OF PLANES OF CONSTANT DENSITY

Evaluation of external effects on the siltation of Deurganckdok

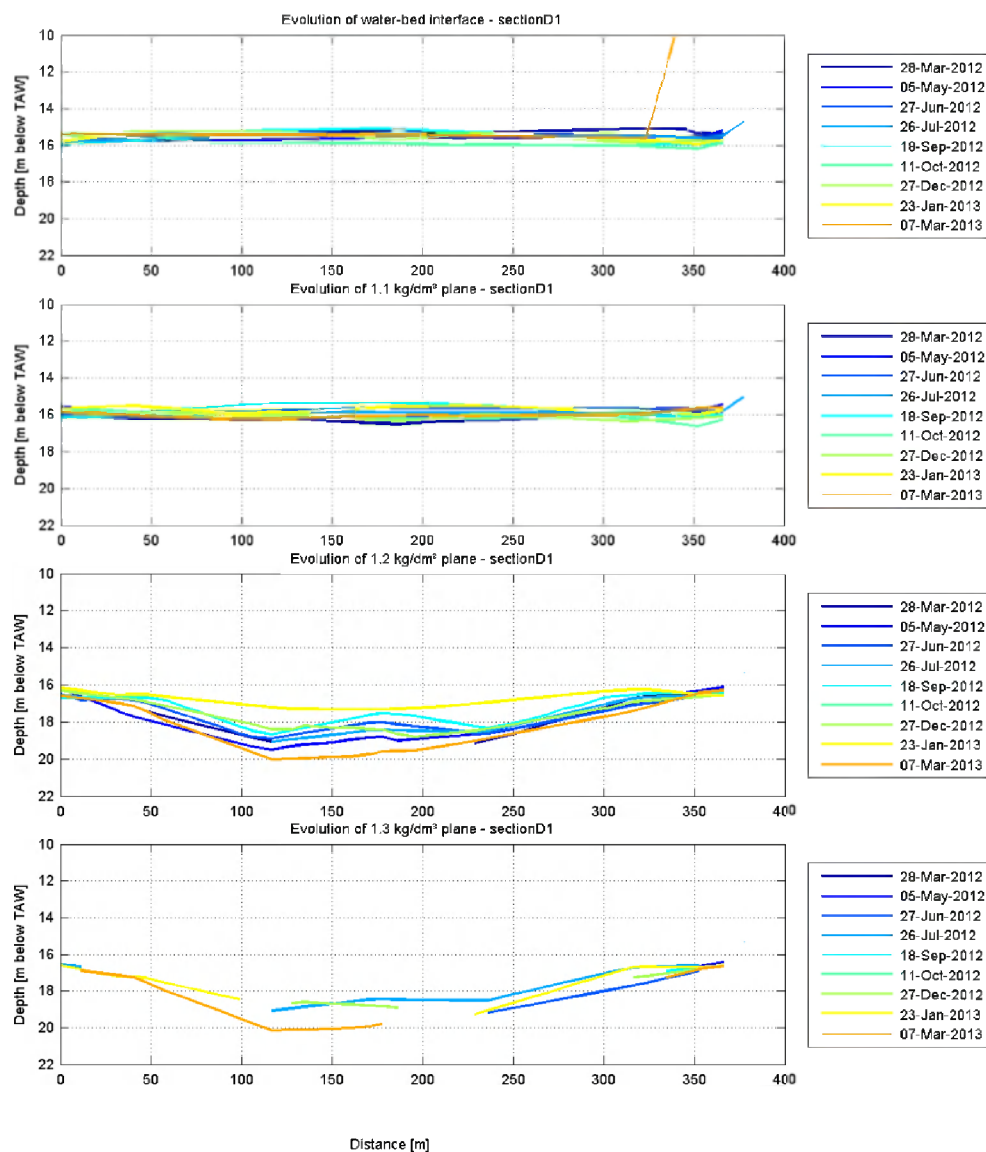
Evolution of planes of constant density

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

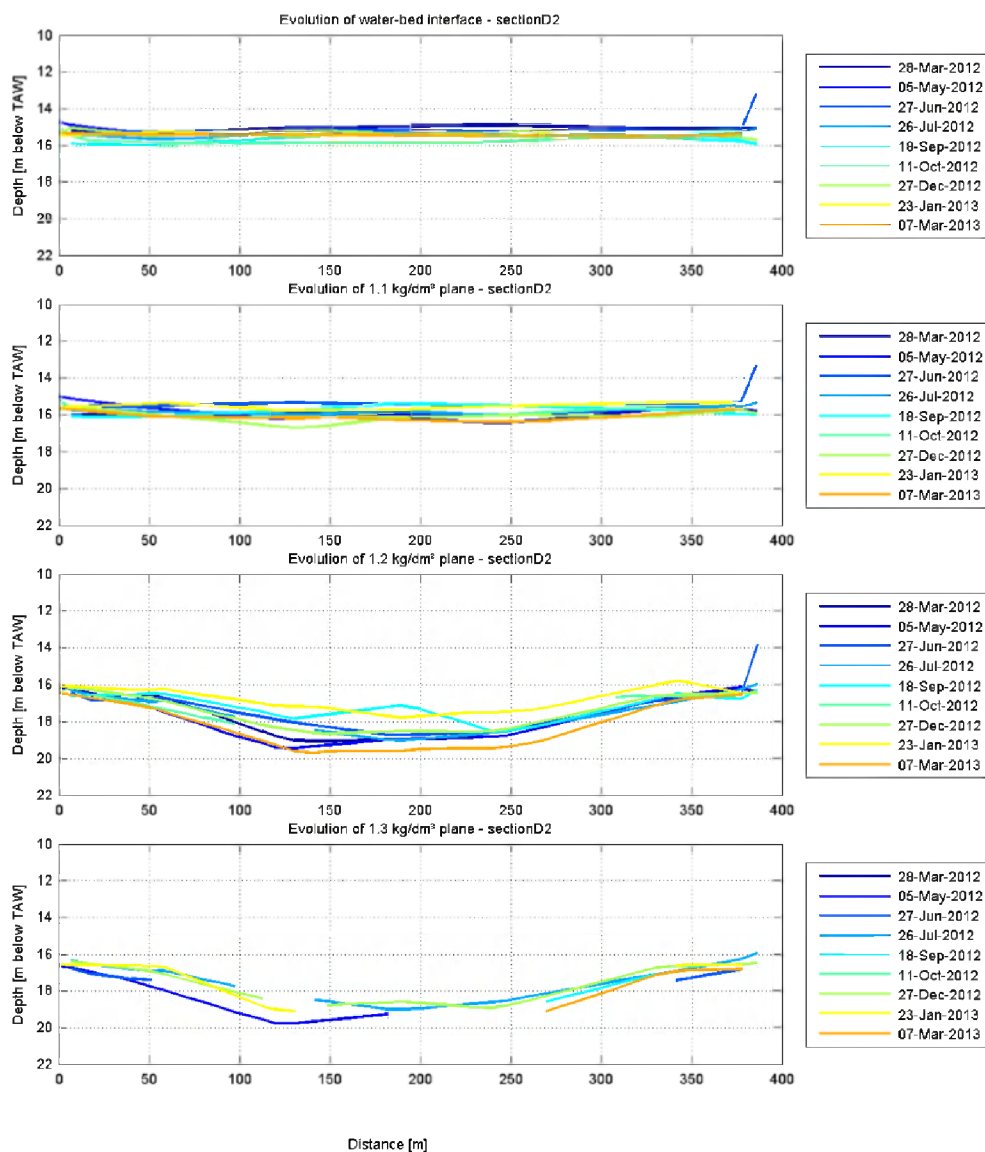
Evolution of planes of constant density

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

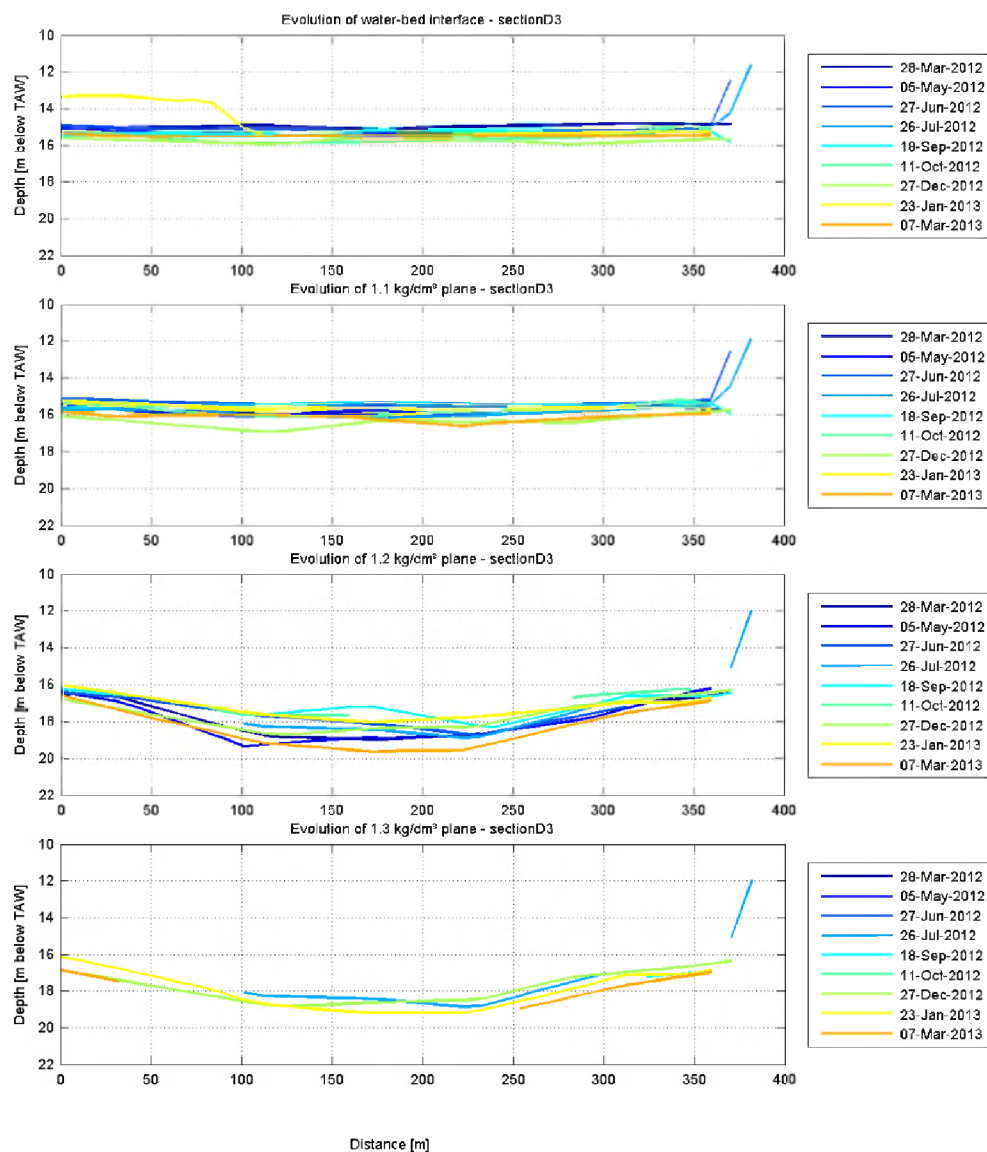
Evolution of planes of constant density

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

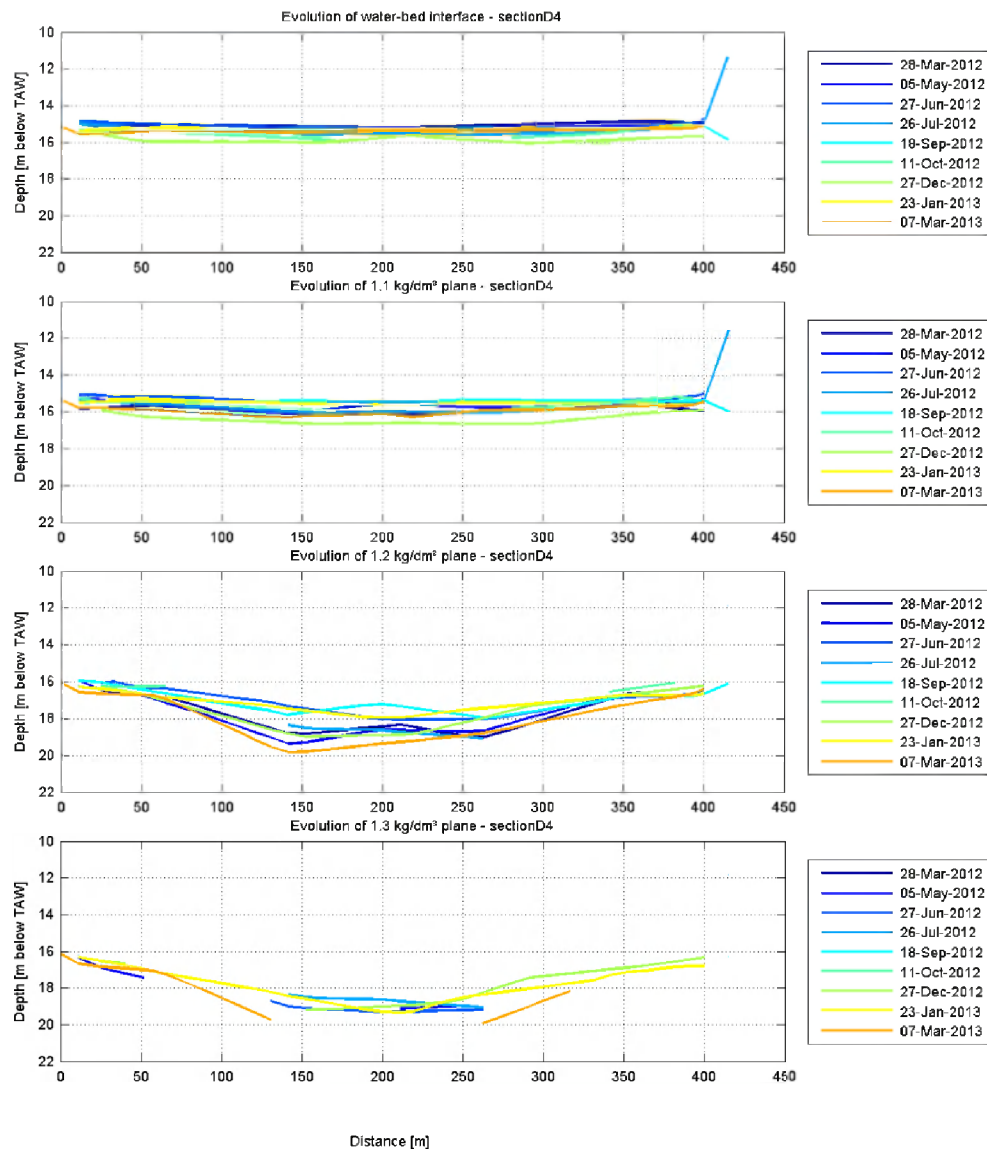
Evolution of planes of constant density

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

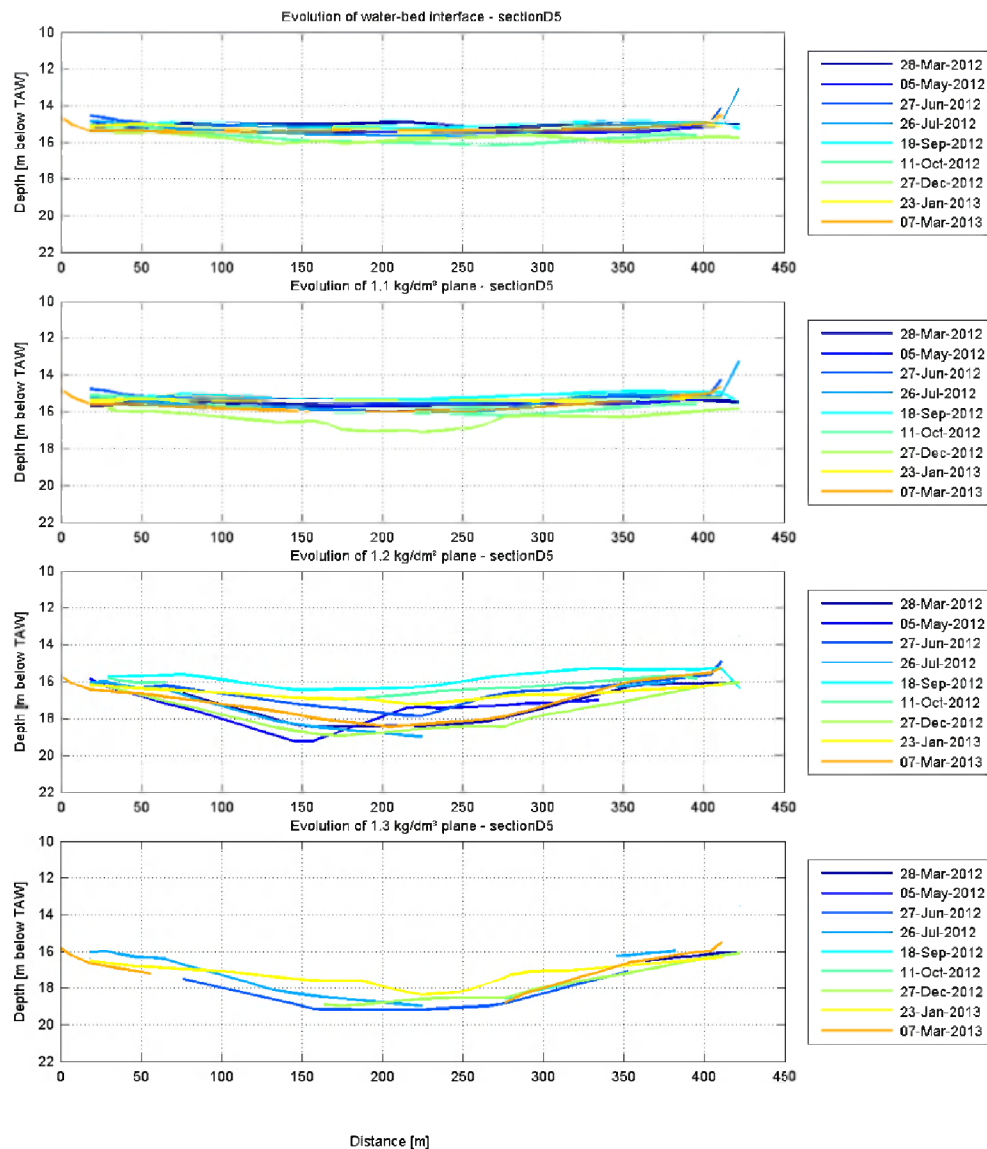
Evolution of planes of constant density

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

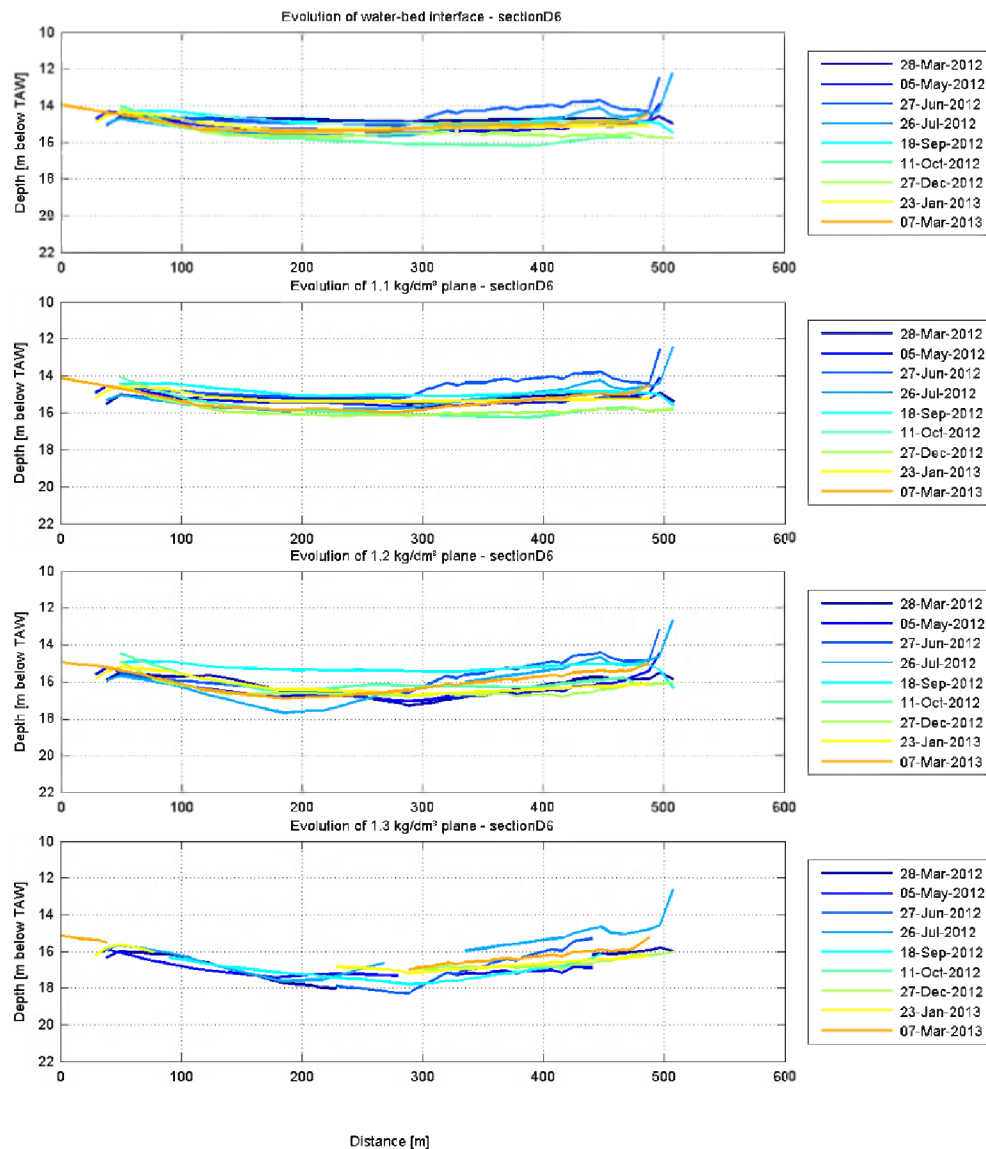
Evolution of planes of constant density

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

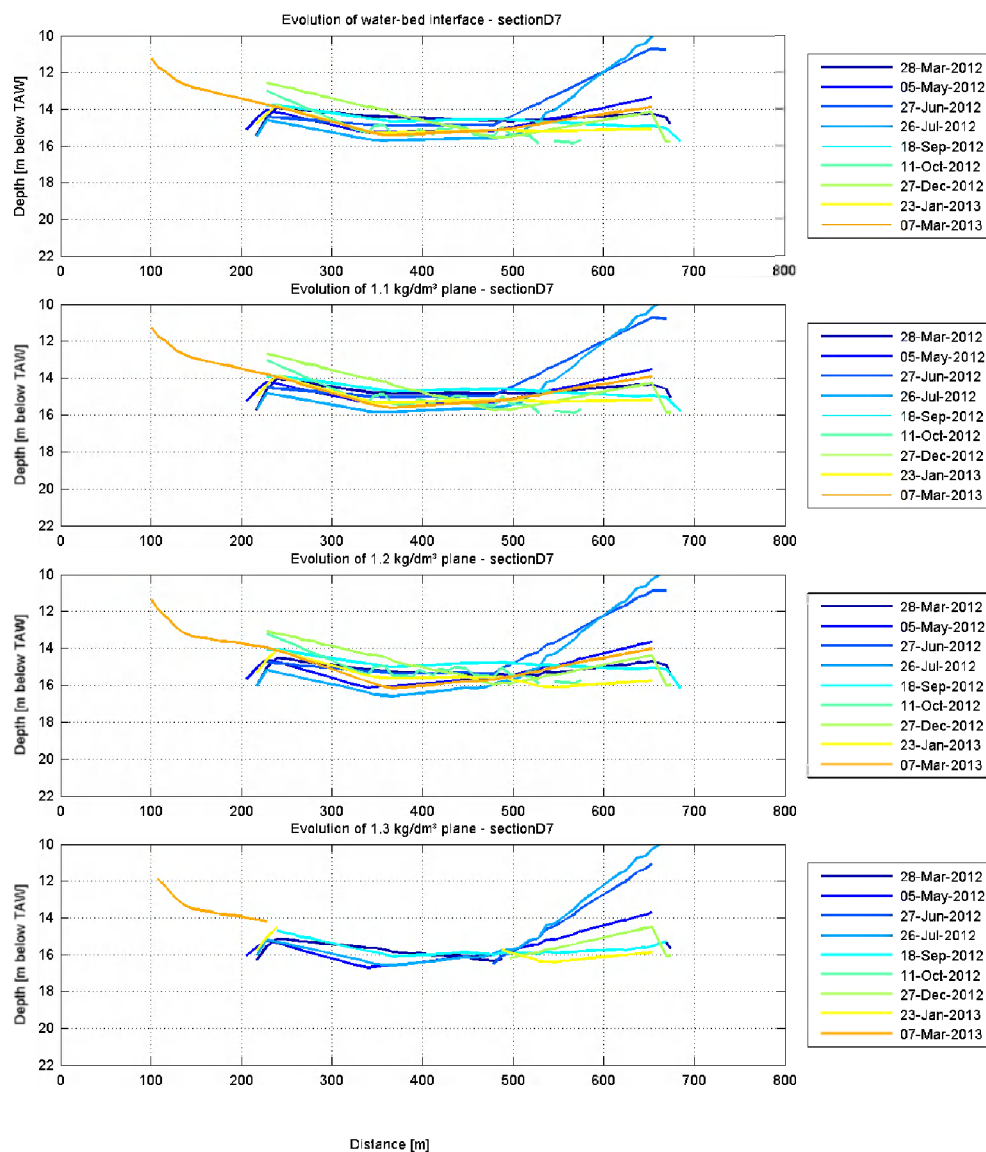
Evolution of planes of constant density

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

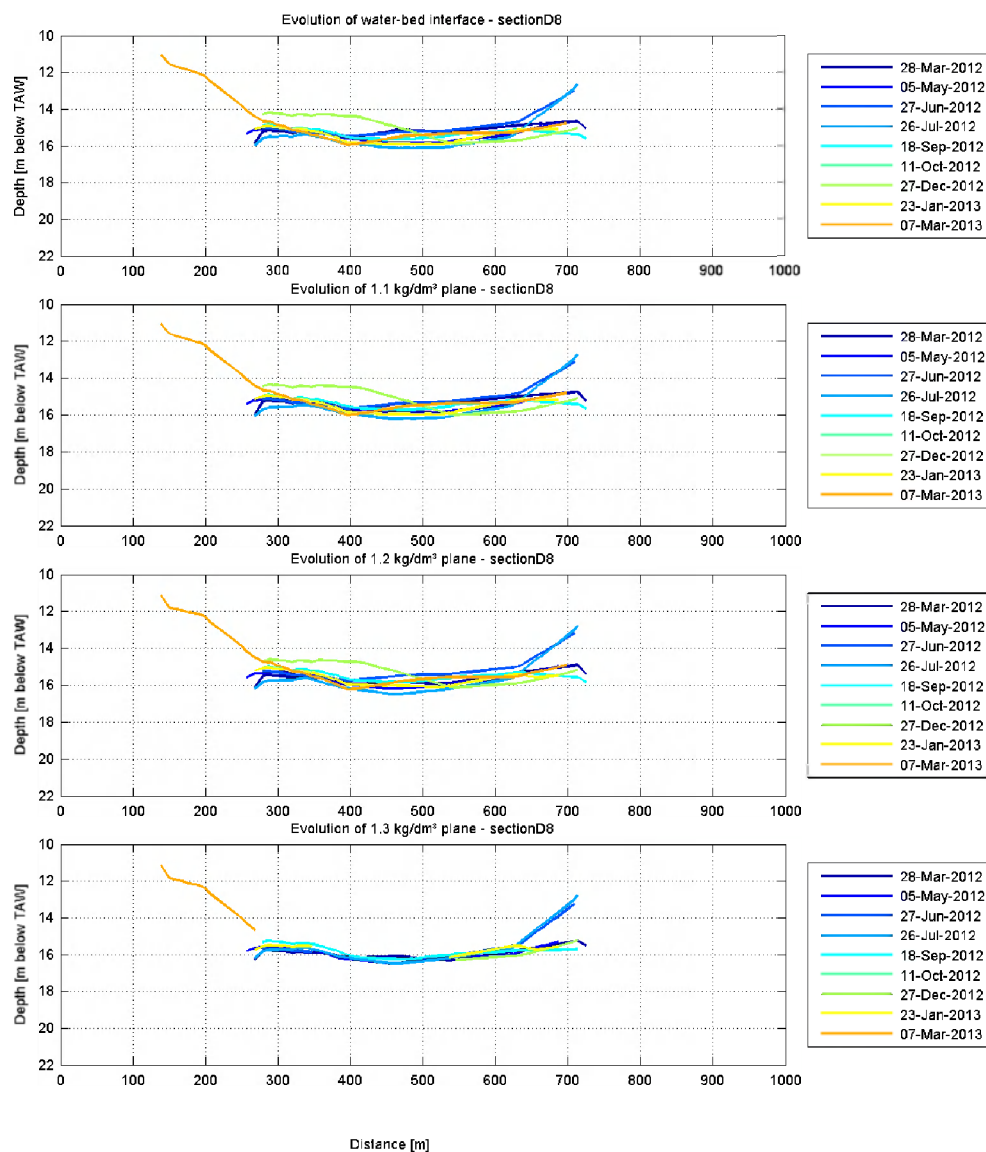
Evolution of planes of constant density

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

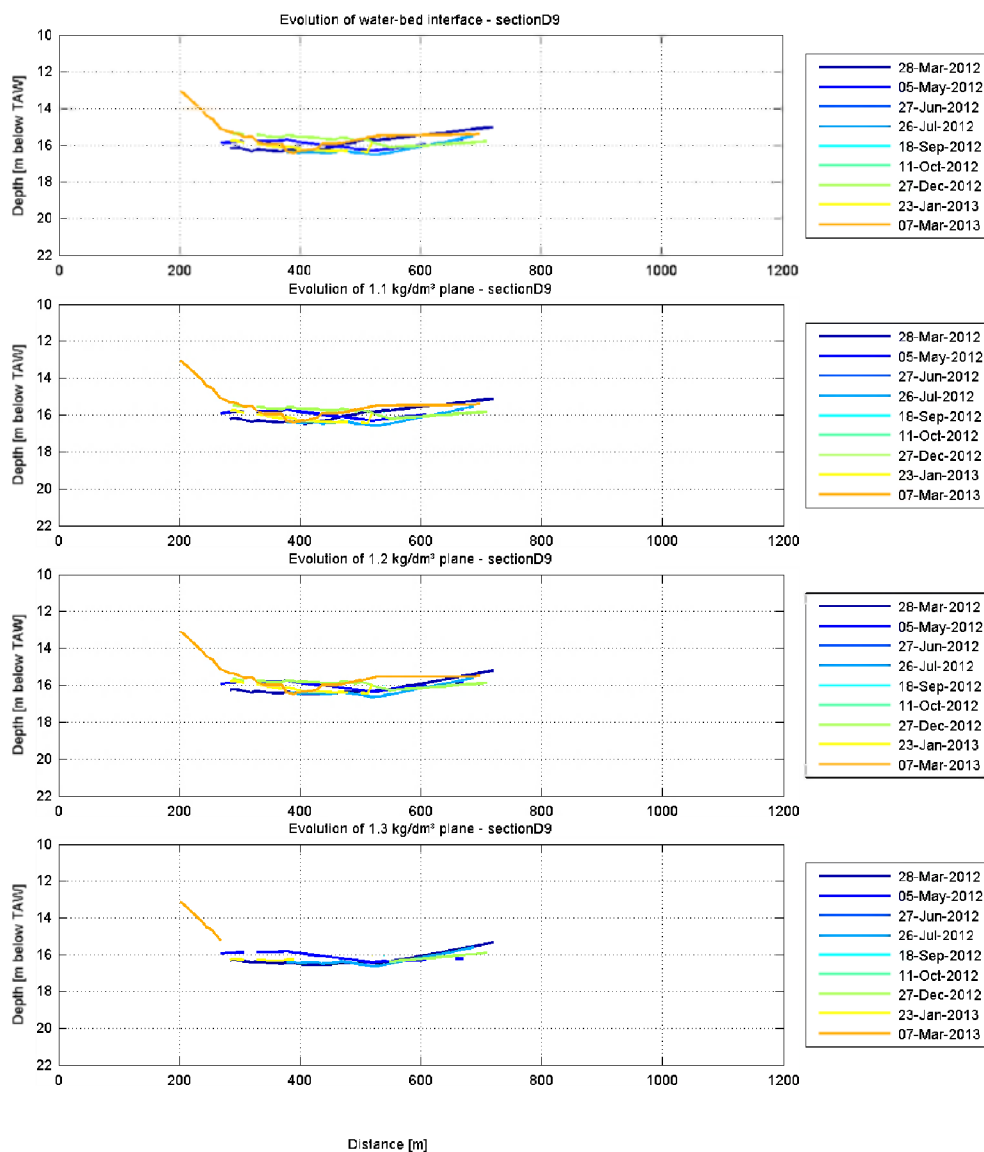
Evolution of planes of constant density

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

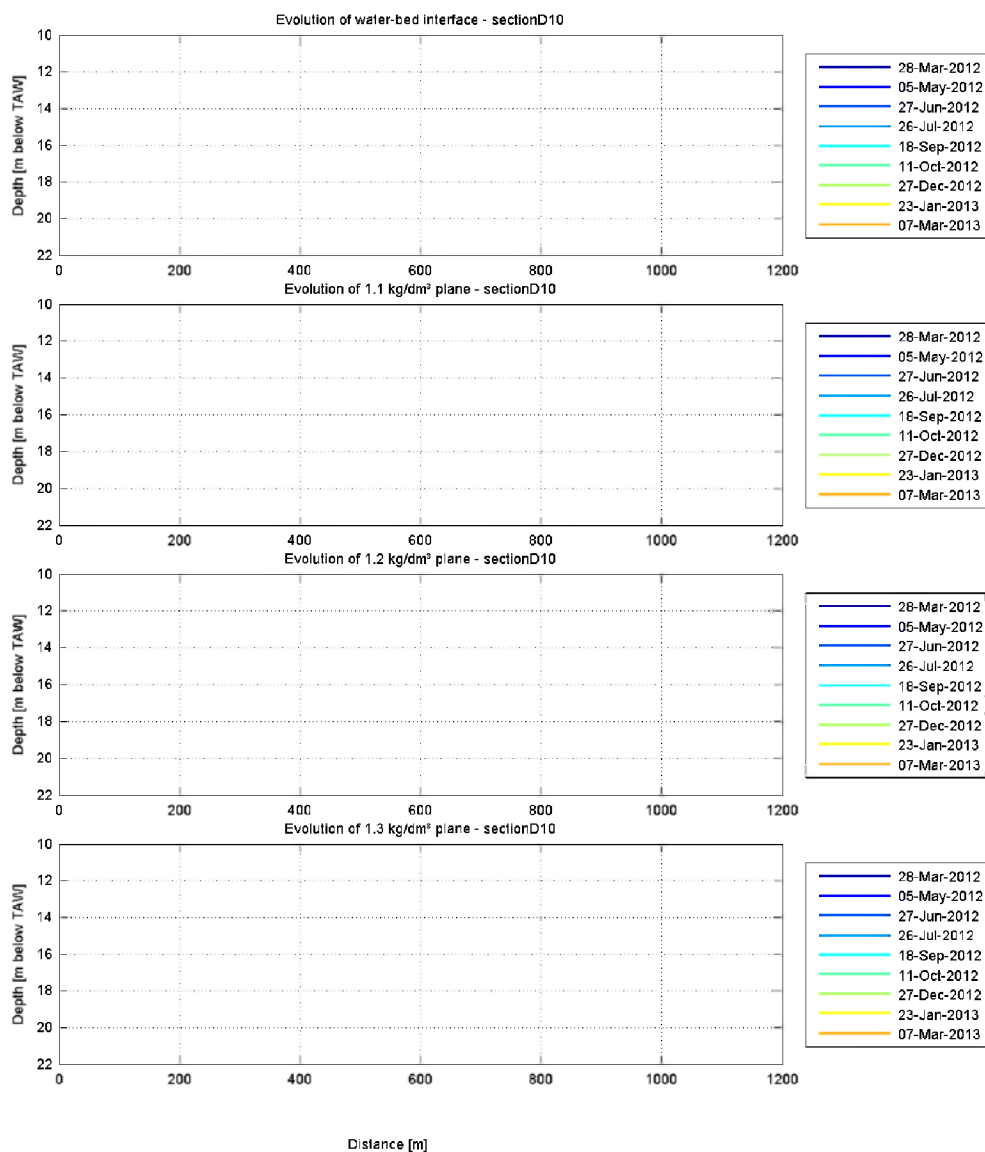
Evolution of planes of constant density

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

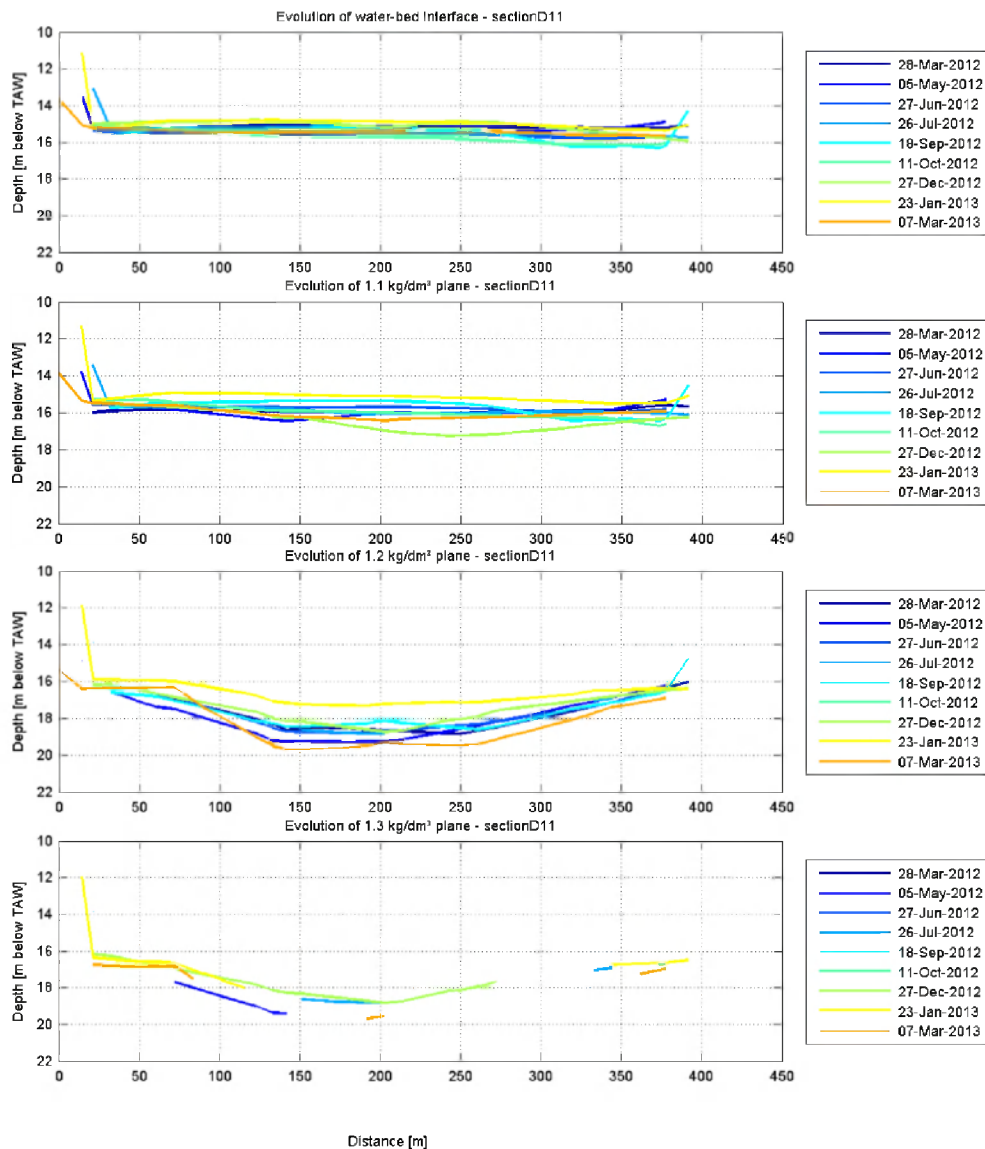
Evolution of planes of constant density

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

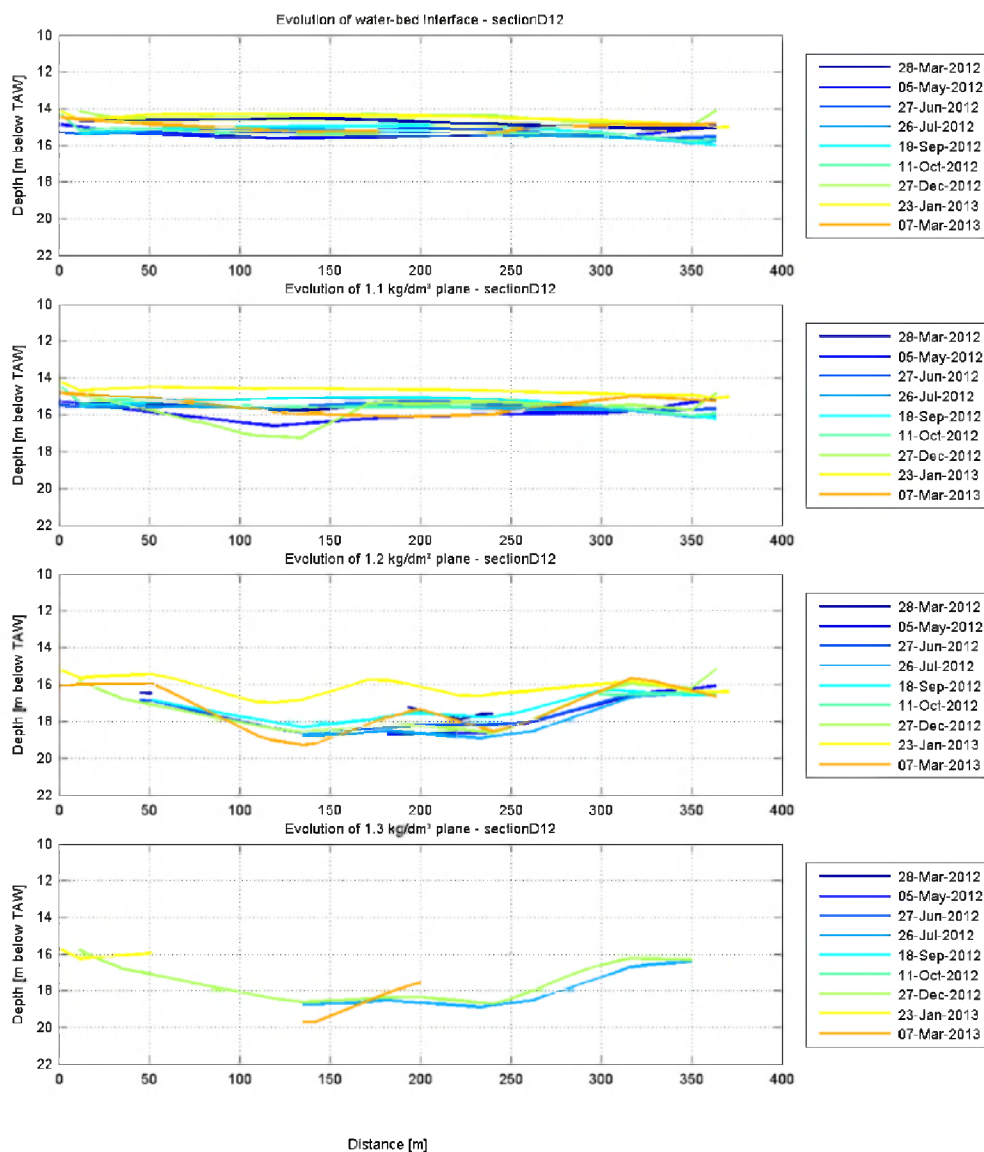
Evolution of planes of constant density

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

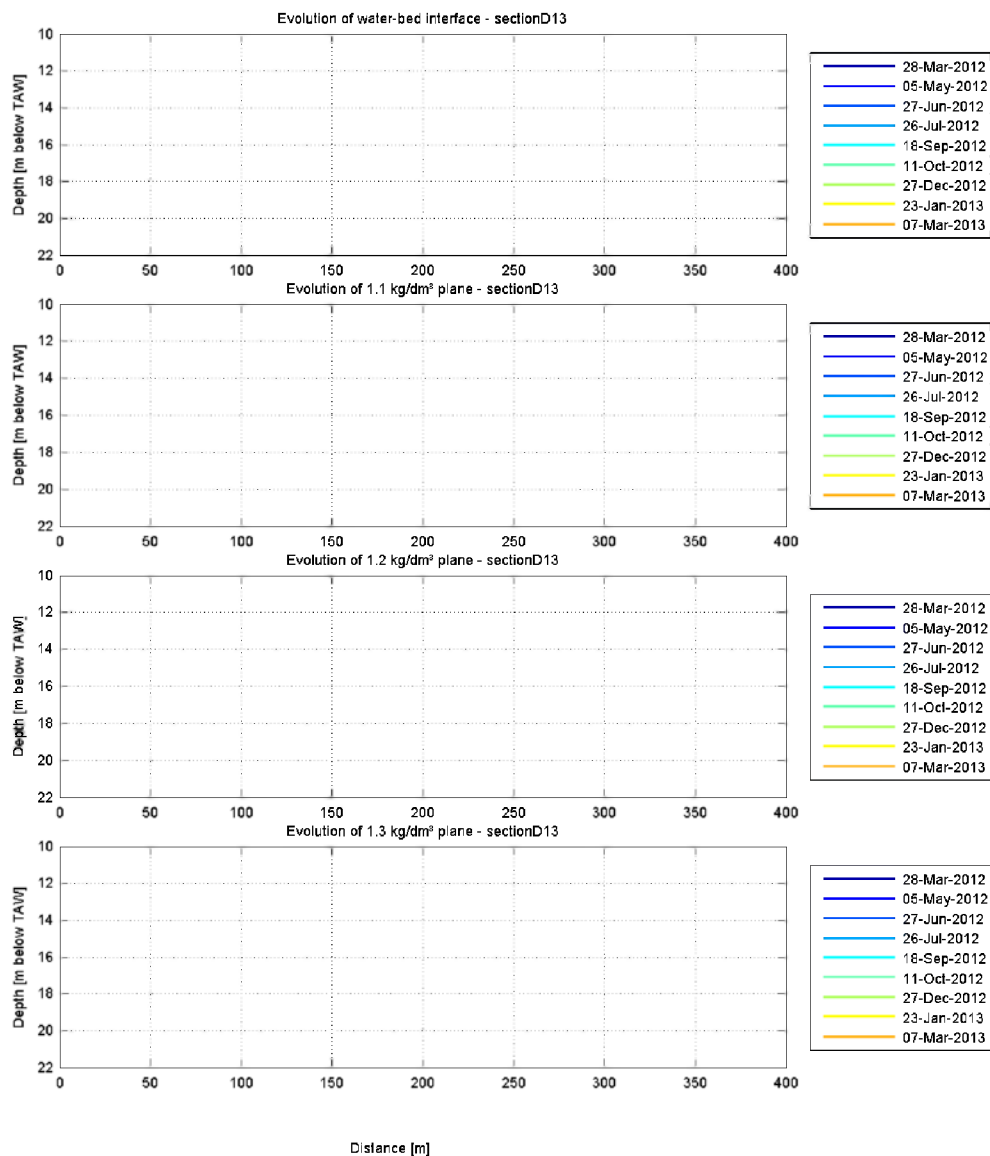
Evolution of planes of constant density

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

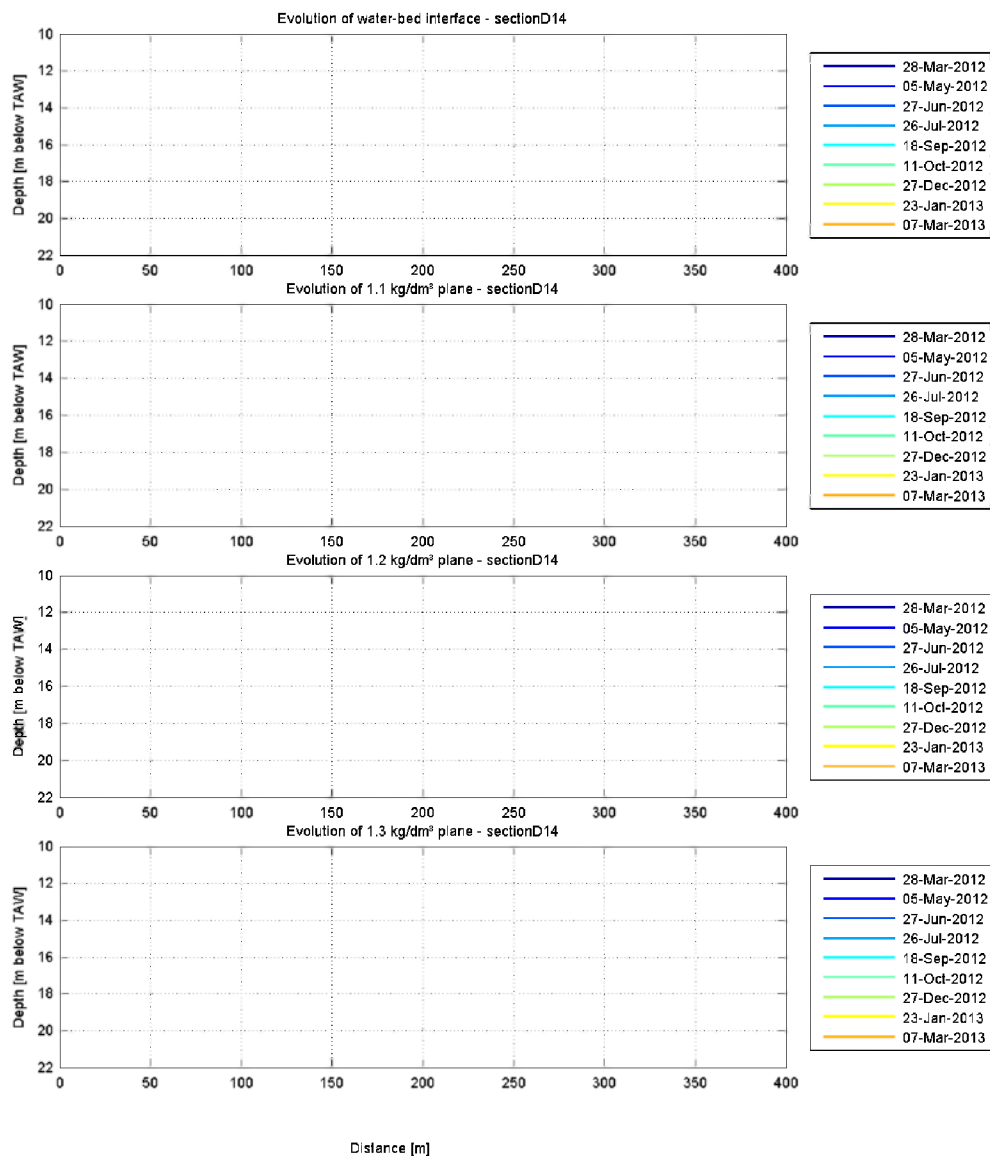
Evolution of planes of constant density

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

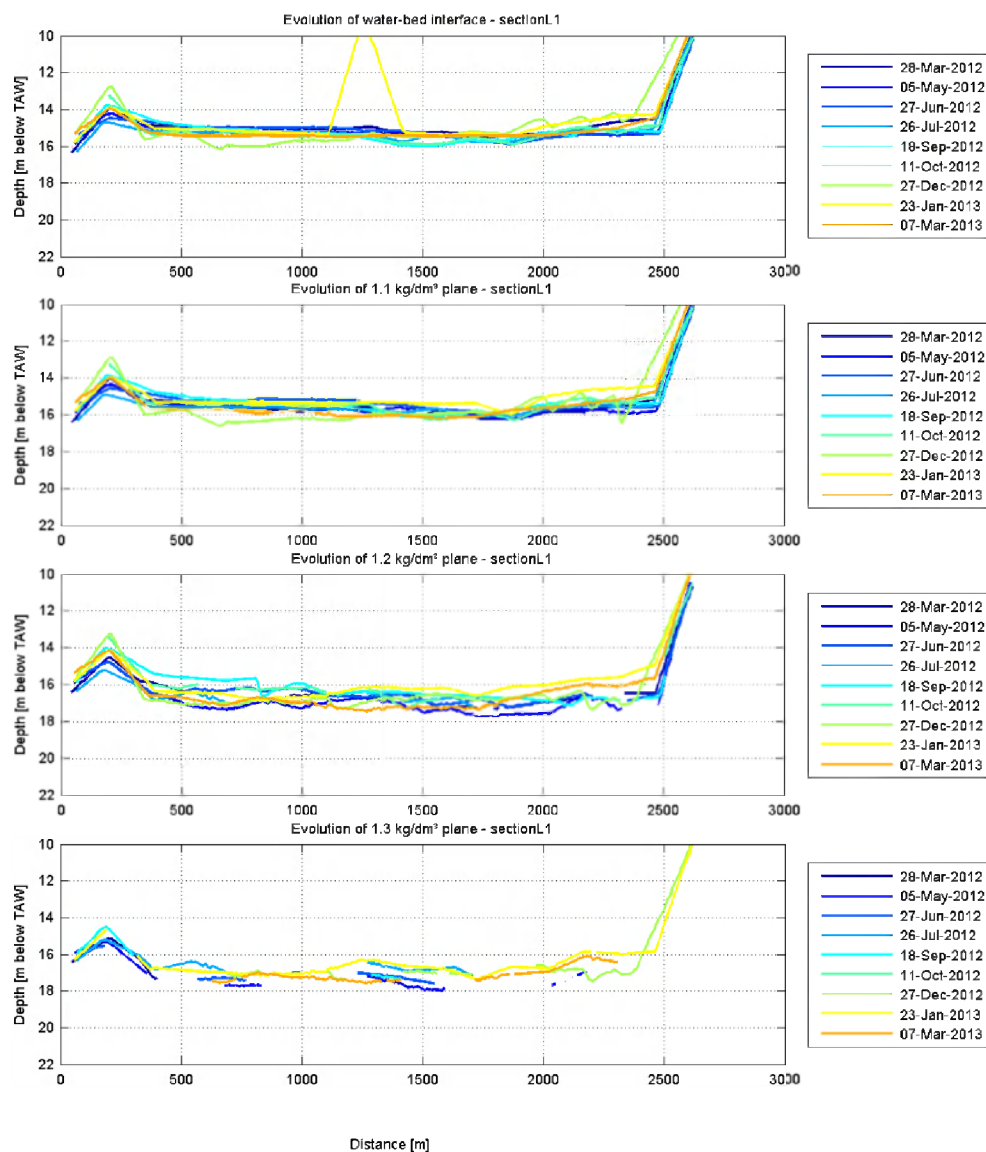
Evolution of planes of constant density

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

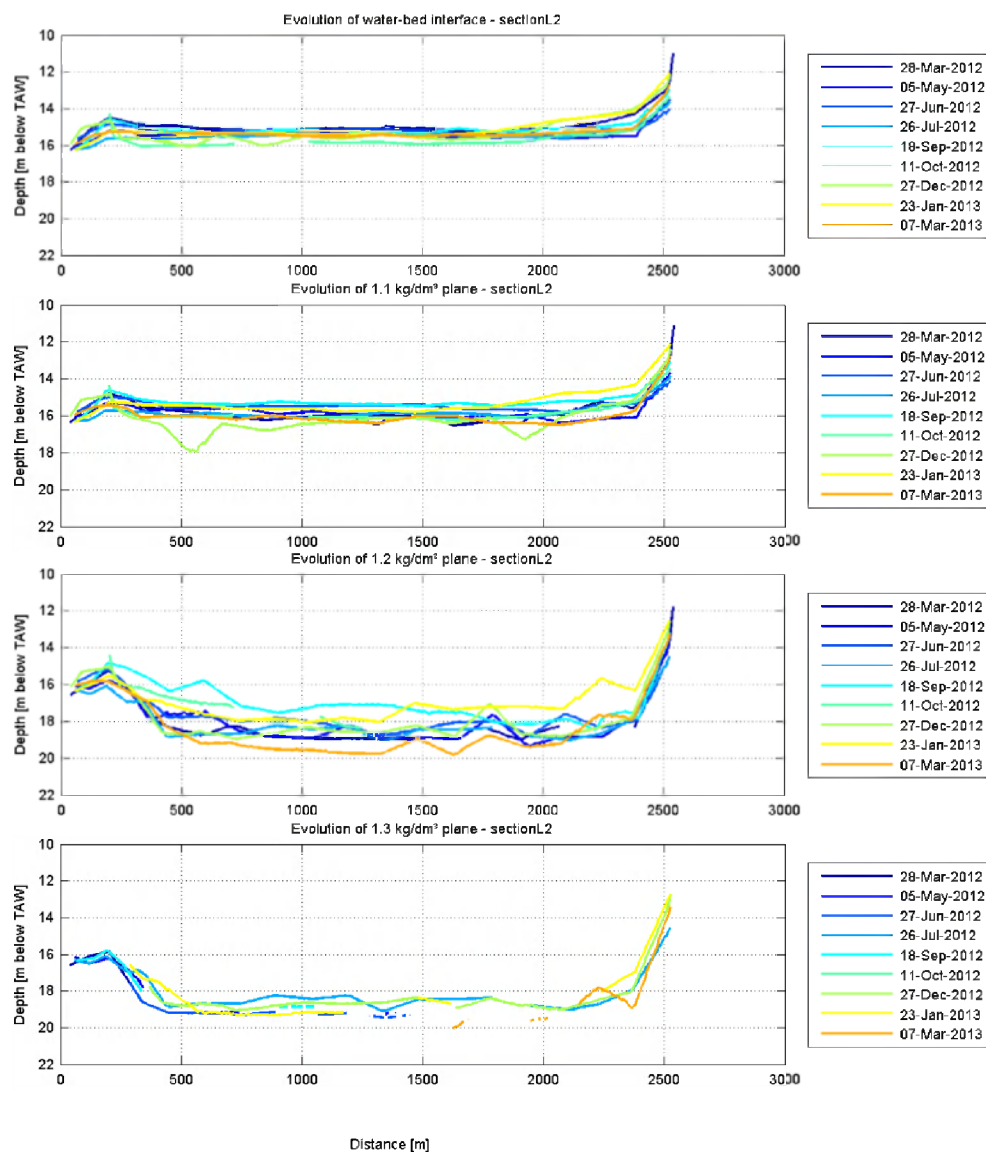
Evolution of planes of constant density

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

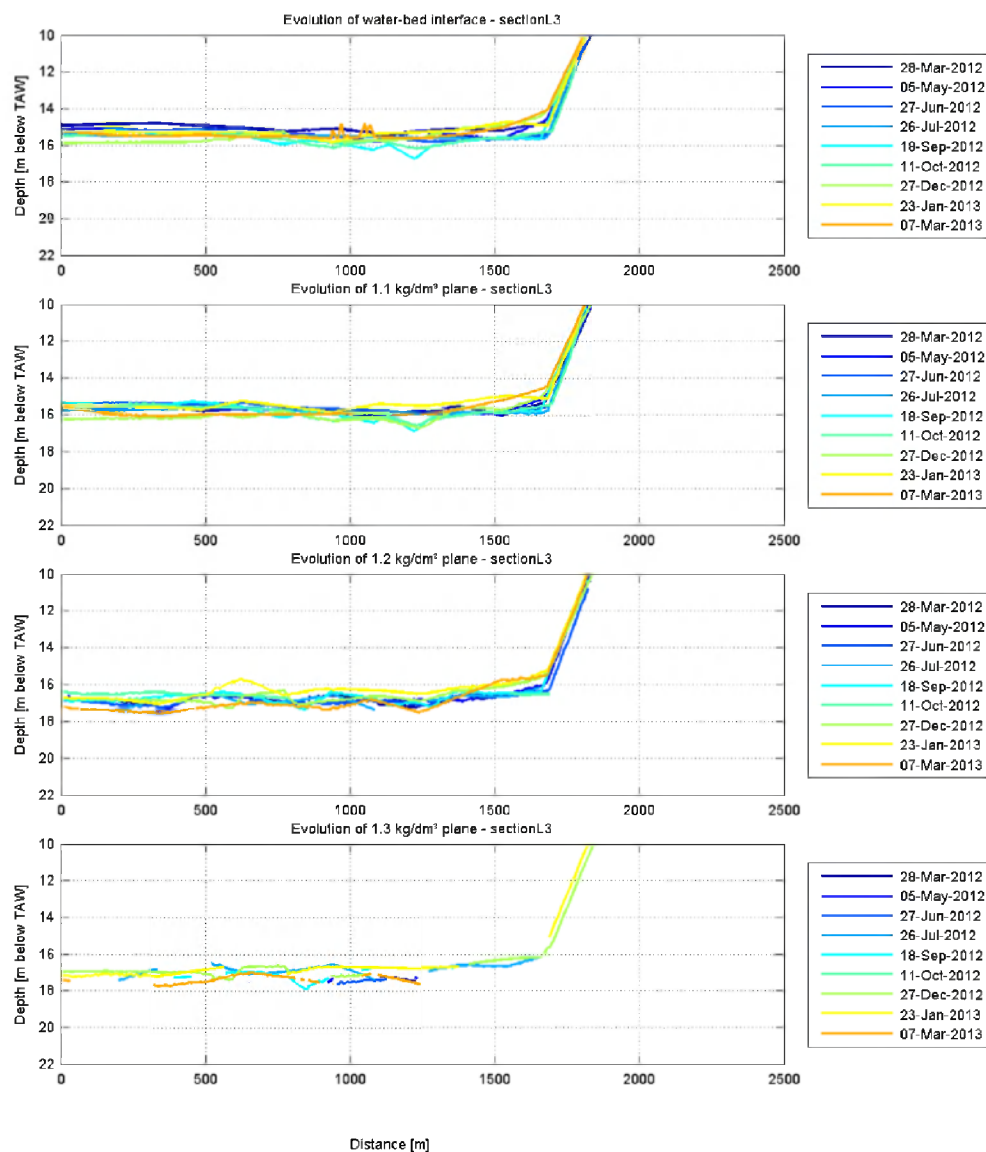
Evolution of planes of constant density

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :

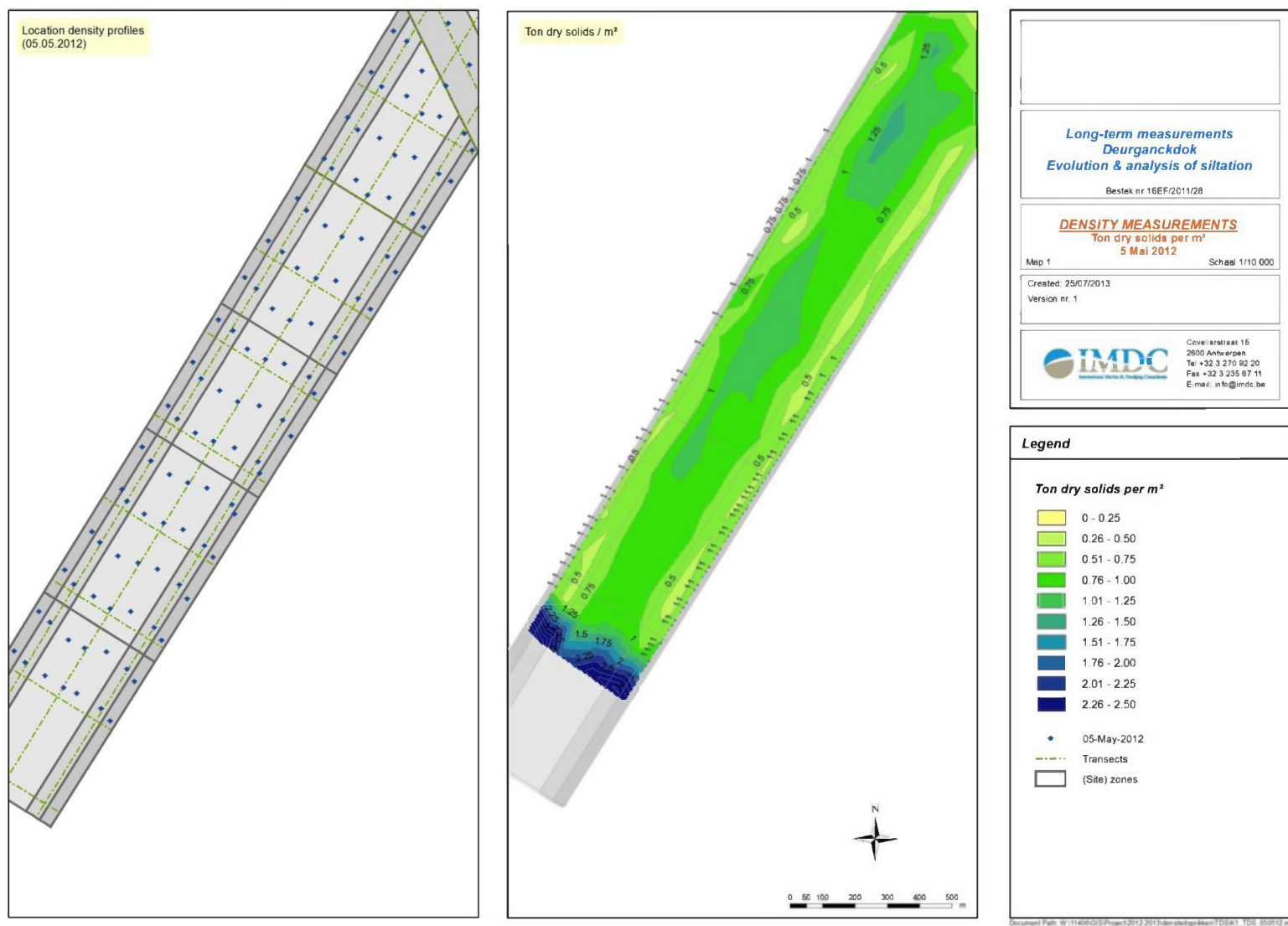


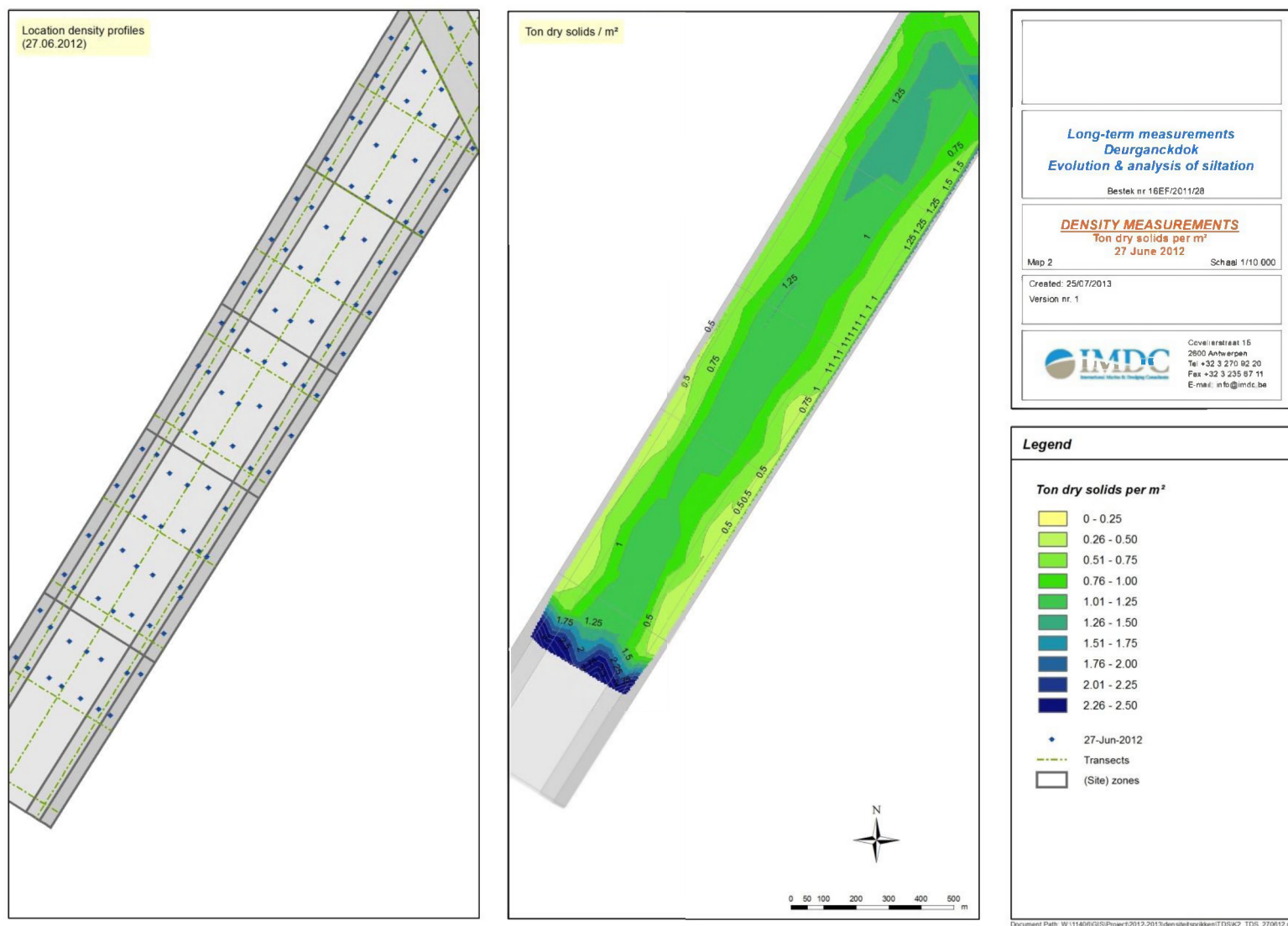
I/RA/11406/13.143/JCA

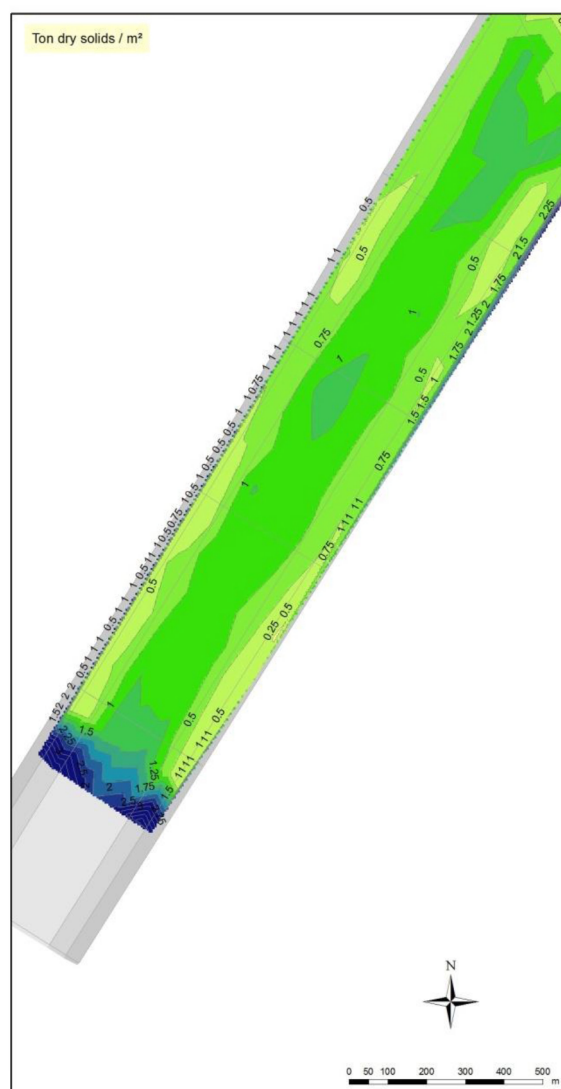
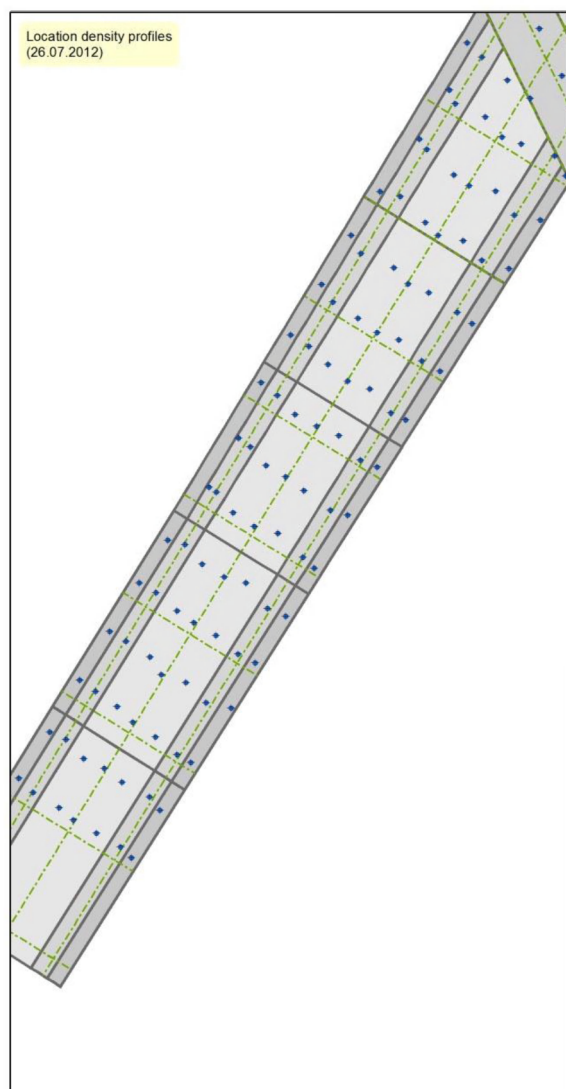


Annex H SEDIMENT MASS DISTRIBUTION IN DEURGANCKDOK

H.1 LOCATIONS OF DENSITY PROFILES AND MEASURED MASS







Long-term measurements
Deurganckdok
Evolution & analysis of siltation

Bestek nr 16EF/2011/28

DENSITY MEASUREMENTS
Ton dry solids per m²
26 July 2012

Map 3 Schaal 1/10 000

Created: 25/07/2013
Version nr. 1

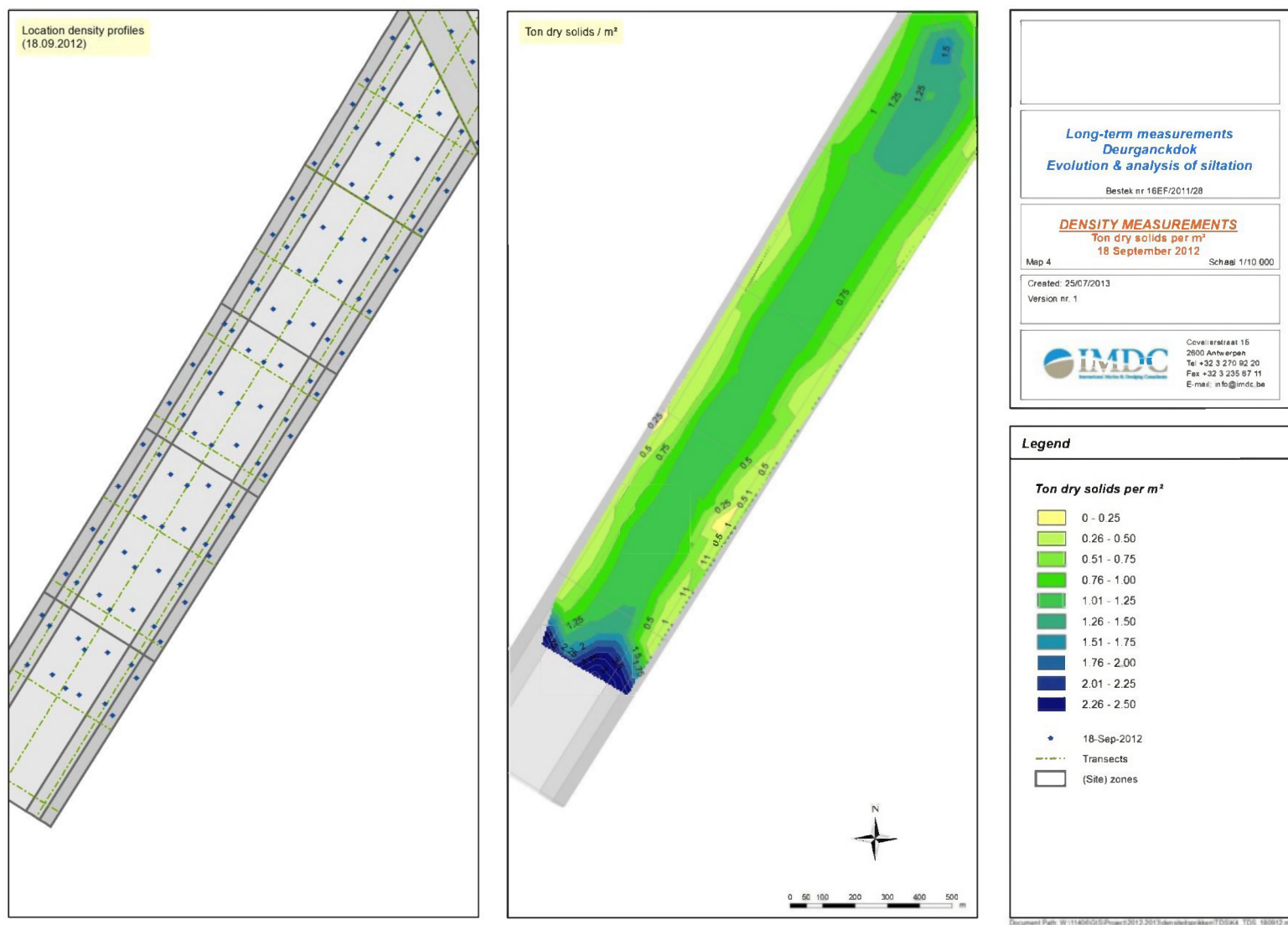
IMDC
Coördinatoraat 15
2800 Antwerpen
Tel: +32 3 270 92 20
Fax: +32 3 235 97 11
E-mail: info@imdc.be

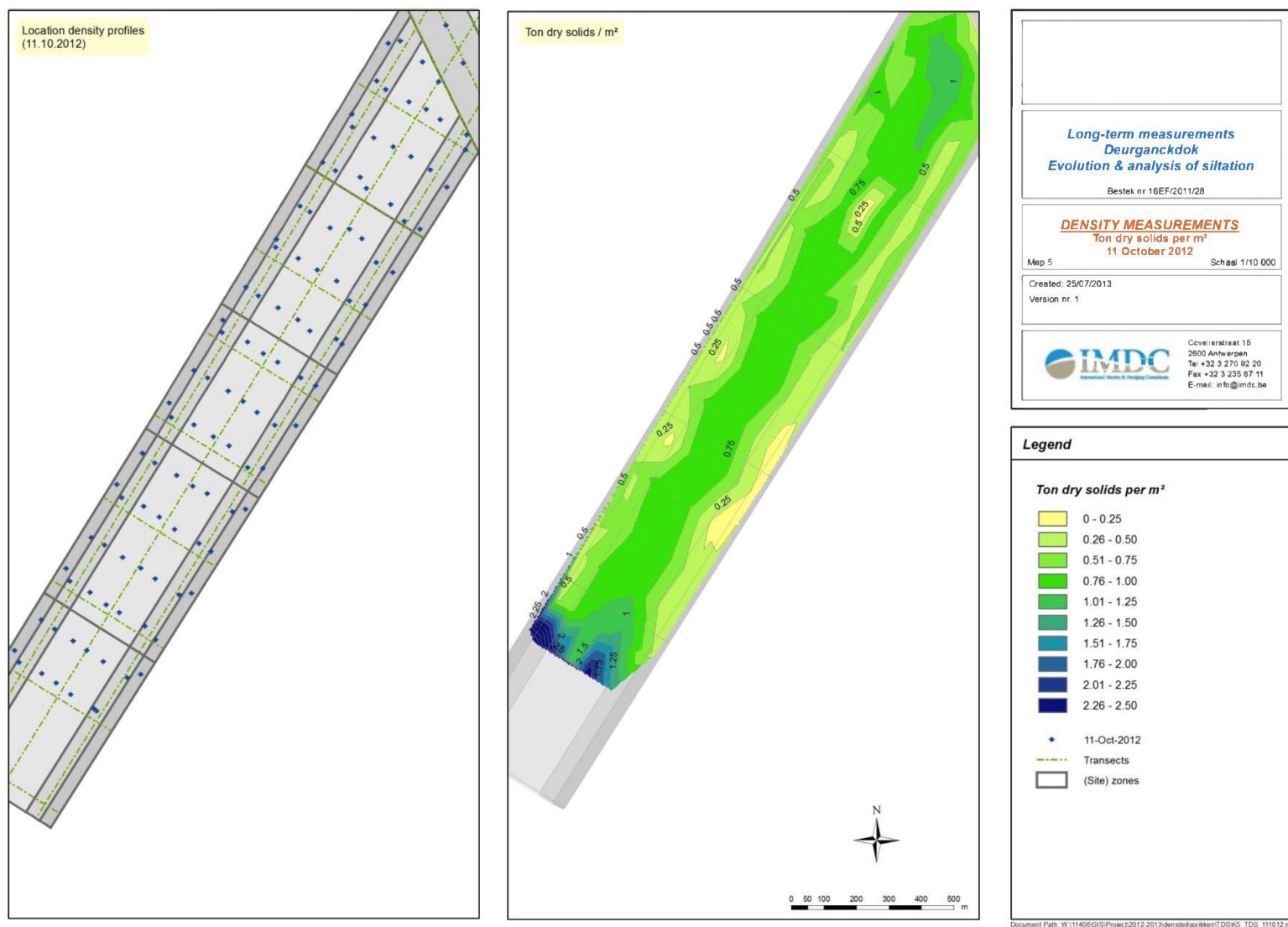
Legend

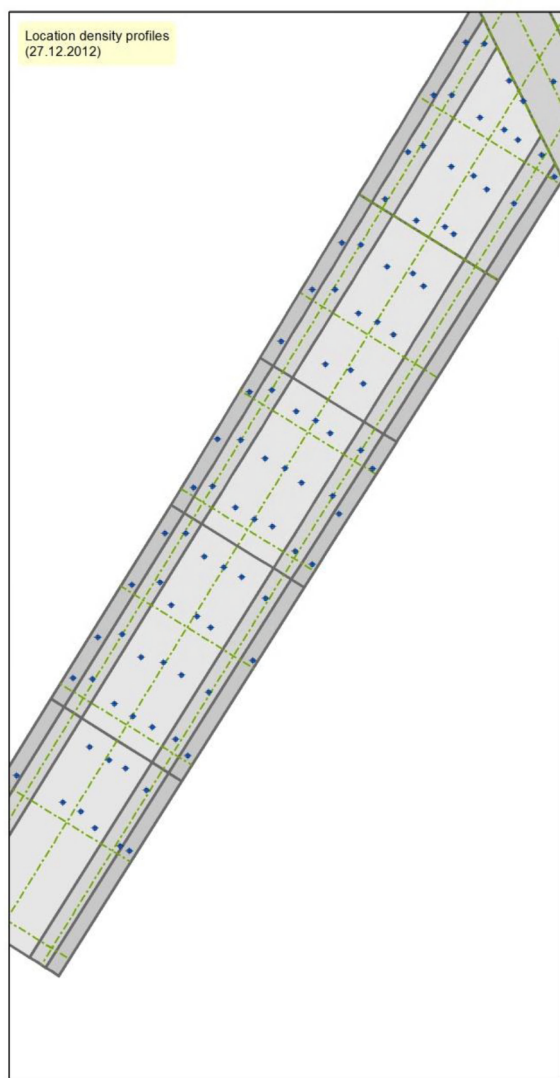
Ton dry solids per m²

- 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

- 26-Jul-2012
- Transects
- (Site) zones







Long-term measurements
Deurganckdok
Evolution & analysis of siltation

Bestek nr 16EF/2011/28

DENSITY MEASUREMENTS
Ton dry solids per m²
27 December 2012

Map 6 Schaal 1/10.000

Created: 04/03/2014
Version nr. 1

IMDC
Instituut voor de Middelen en de Dredging en de Dredging

Covellierstraat 15
2000 Antwerpen
Tel +32 3 270 92 20
Fax +32 3 235 07 11
E-mail: info@imdc.be

Legend

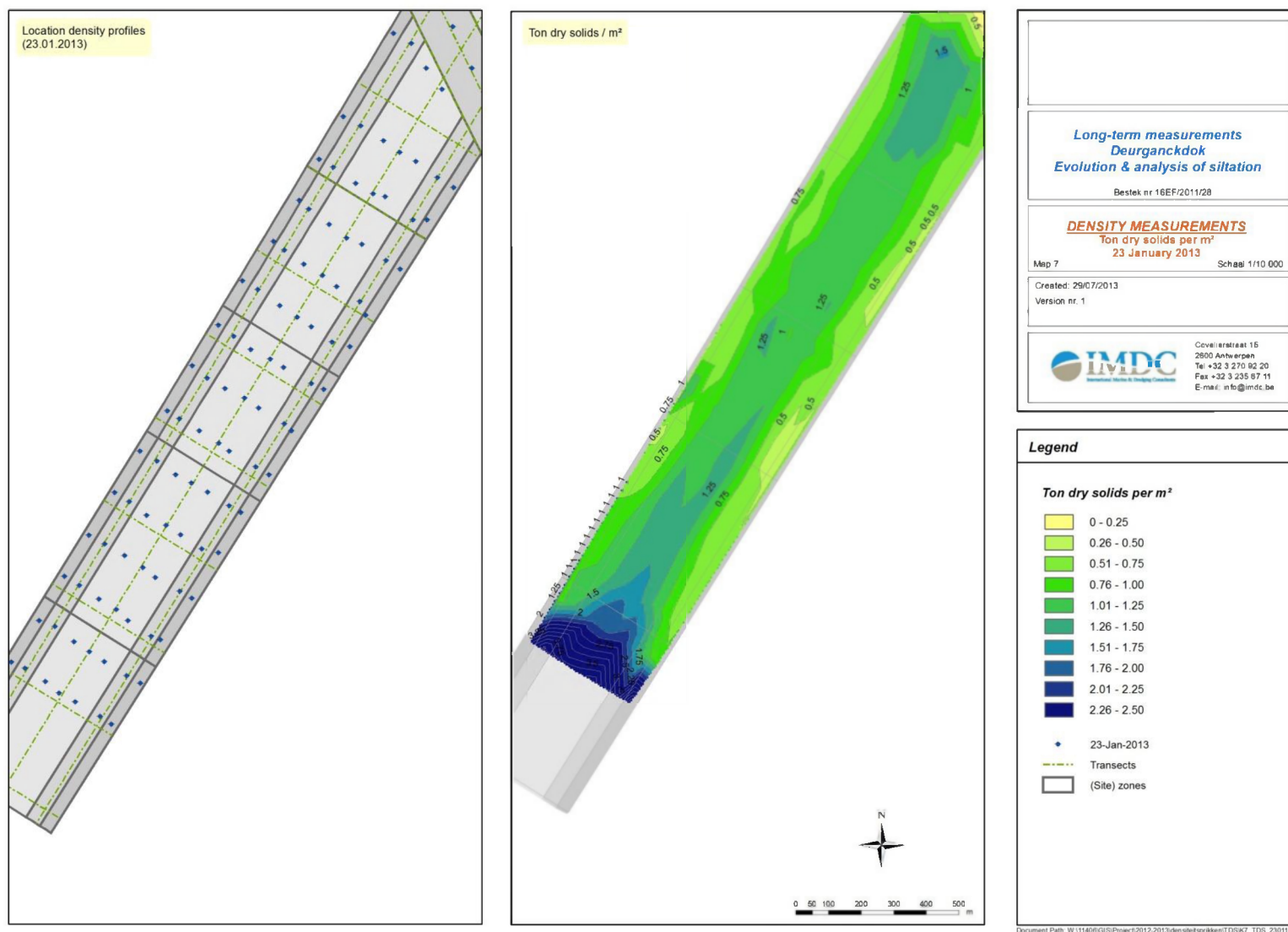
Ton dry solids per m²

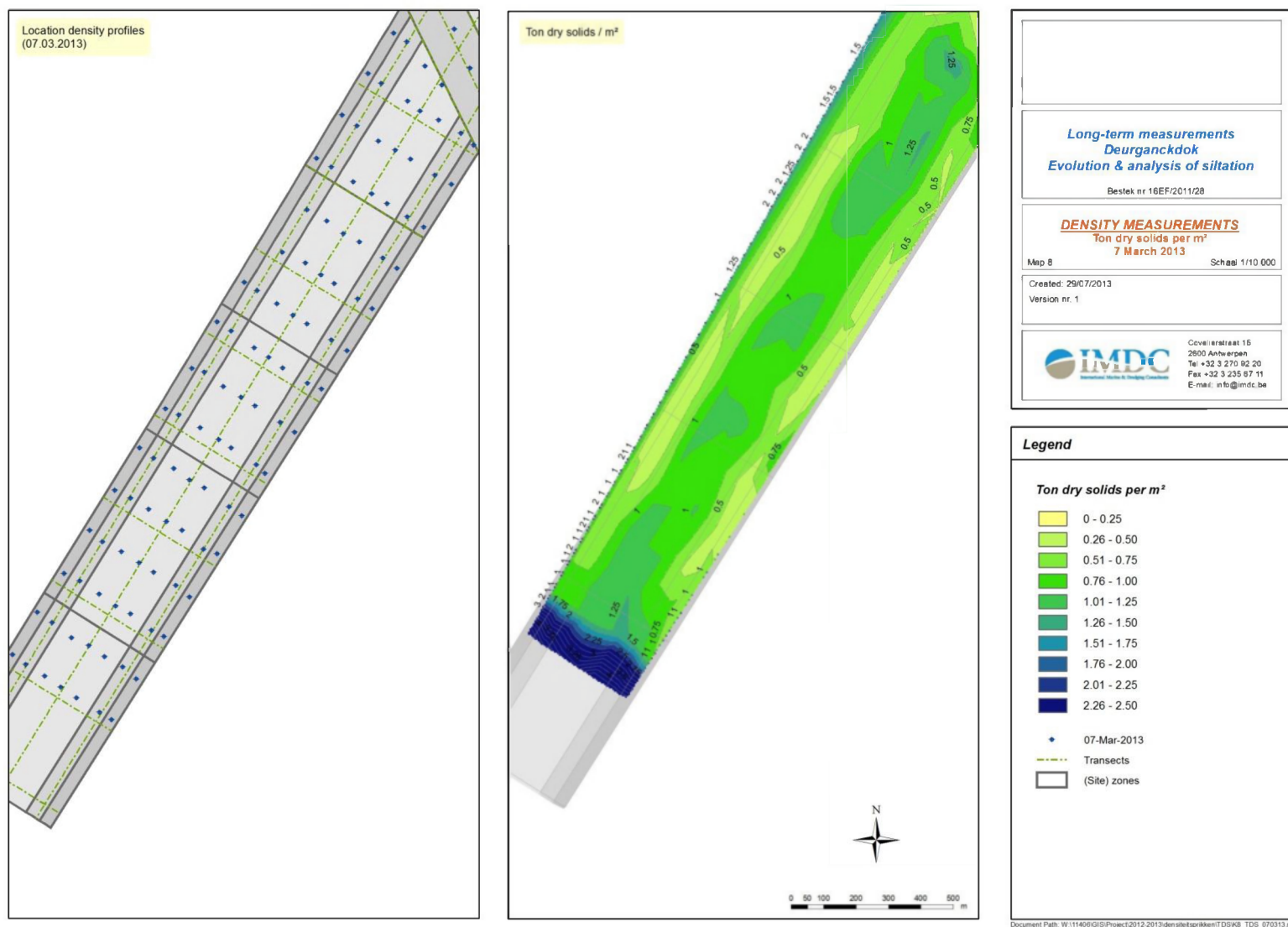
0 - 0.25
0.26 - 0.50
0.51 - 0.75
0.76 - 1.00
1.01 - 1.25
1.26 - 1.50
1.51 - 1.75
1.76 - 2.00
2.01 - 2.25
2.26 - 2.50

• 27-Dec-2012

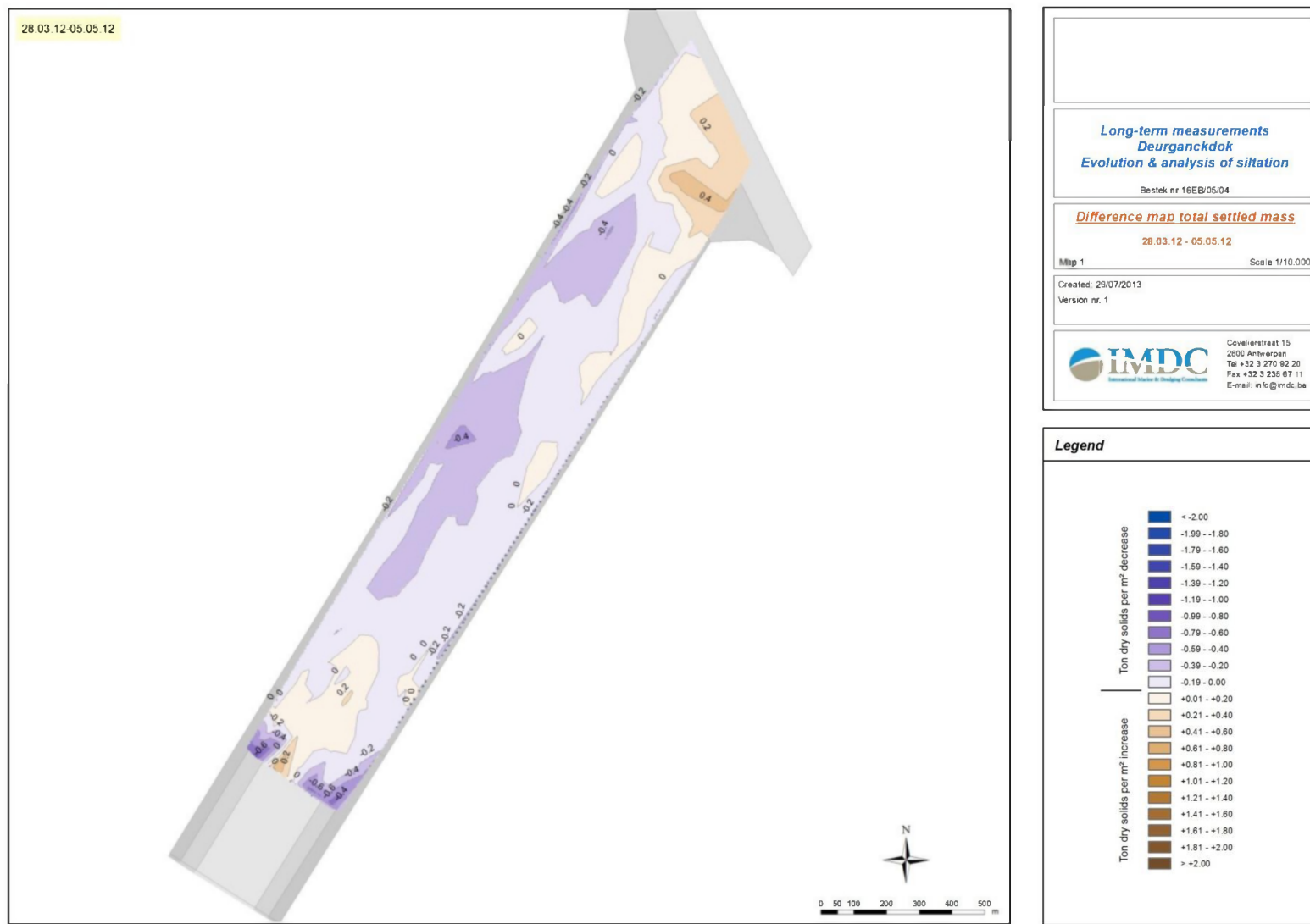
--- Transects

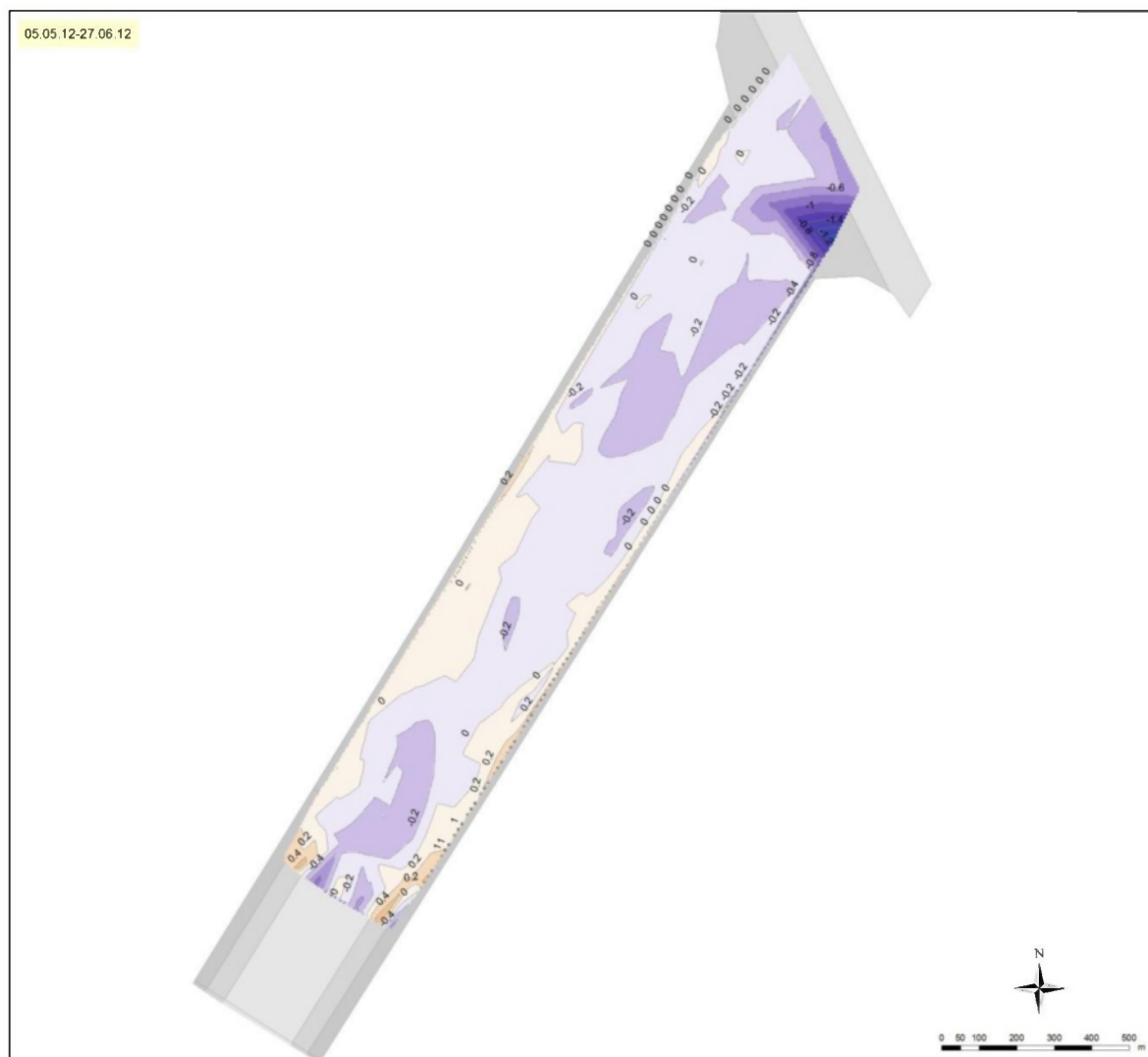
□ (Site) zones





H.2 DIFFERENCE MAPS





*Long-term measurements
Deurganckdok
Evolution & analysis of siltation*

Bestek nr 16EB/05/04

Difference map total settled mass

05.05.12 - 27.06.12

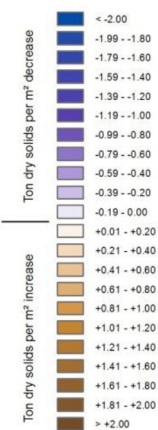
Map 2 Scale 1/10 000

Created: 29/07/2013
Version nr. 1

IMDC
International Marine Dredging Consultants

Covellierstraat 15
2600 Antwerpen
Tel +32 3 270 62 20
Fax +32 3 235 67 11
E-mail: info@imdc.be

Legend





Long-term measurements
Deurganckdok
Evolution & analysis of siltation

Bestek nr 16EB/05/04

Difference map total settled mass
27.06.12 - 26.07.12

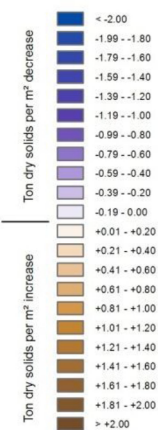
Map 3 Scale 1/10 000

Created: 29/07/2013
Version nr. 1

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Legend





Long-term measurements
Deurganckdok
Evolution & analysis of siltation

Bestek nr 16EB/05/04

Difference map total settled mass

26.07.12-18.09.12

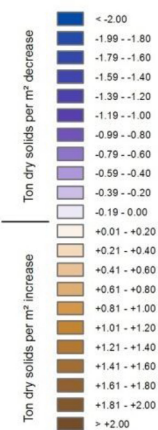
Map 4 Scale 1/10 000

Created: 29/07/2013
Version nr. 1

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Legend





*Long-term measurements
Deurganckdok
Evolution & analysis of siltation*

Bestek nr 16EB/05/04

Difference map total settled mass

18.09.12 - 11.10.12

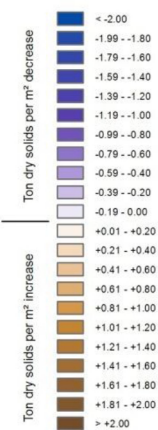
Map 5 Scale 1/10 000

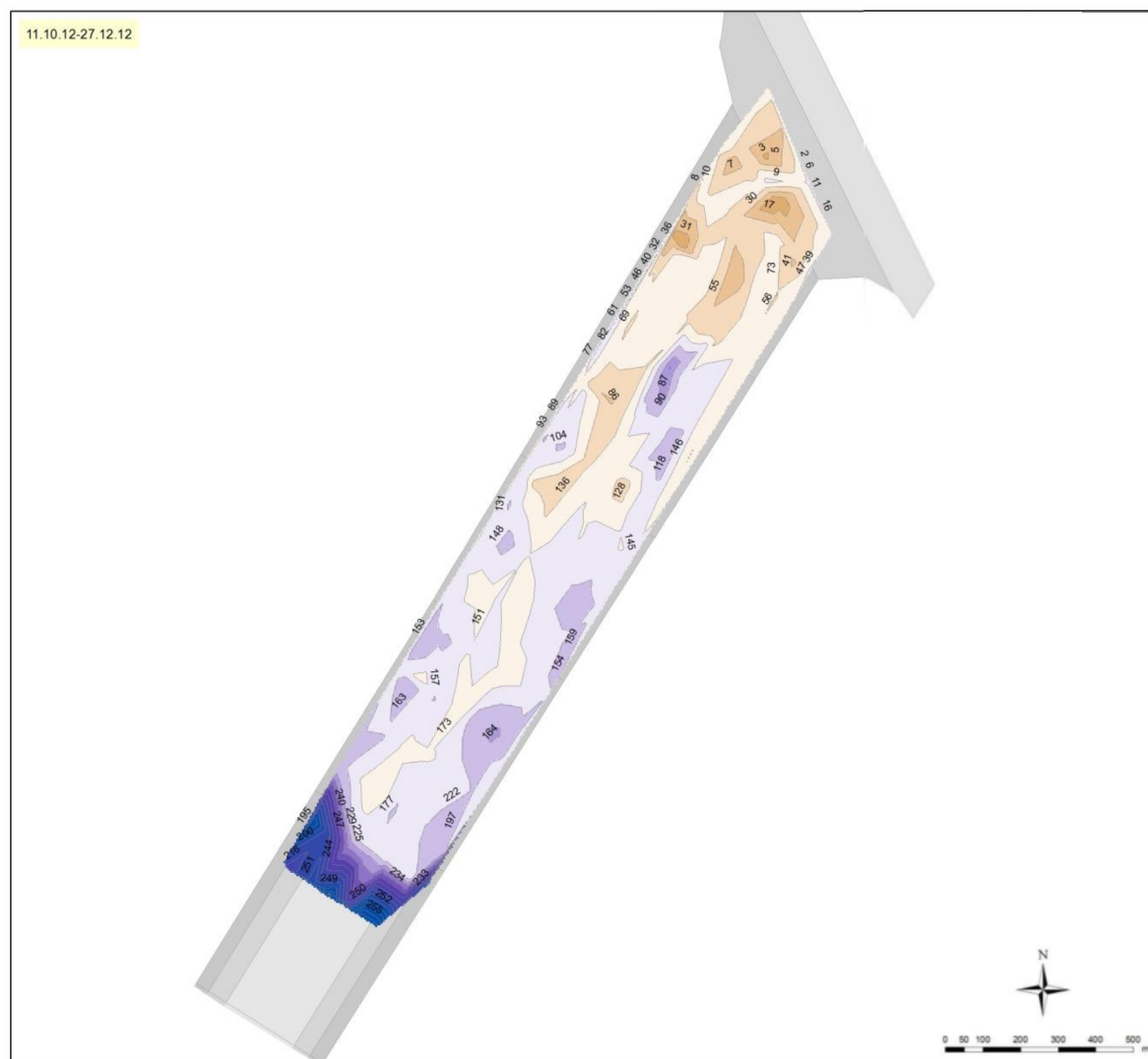
Created: 29/07/2013
Version nr. 1

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

Legend





Long-term measurements
Deurganckdok
Evolution & analysis of siltation

Bestek nr 16EB/05/04

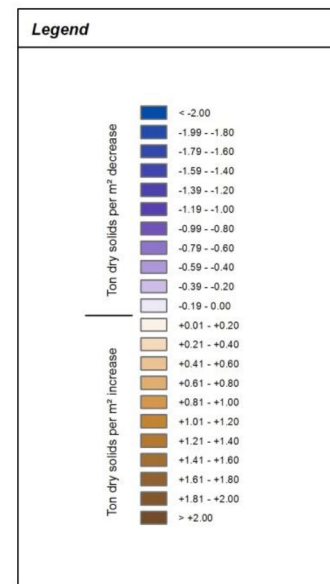
Difference map total settled mass
11.10.12 - 27.12.12

Map 6 Scale 1/10 000

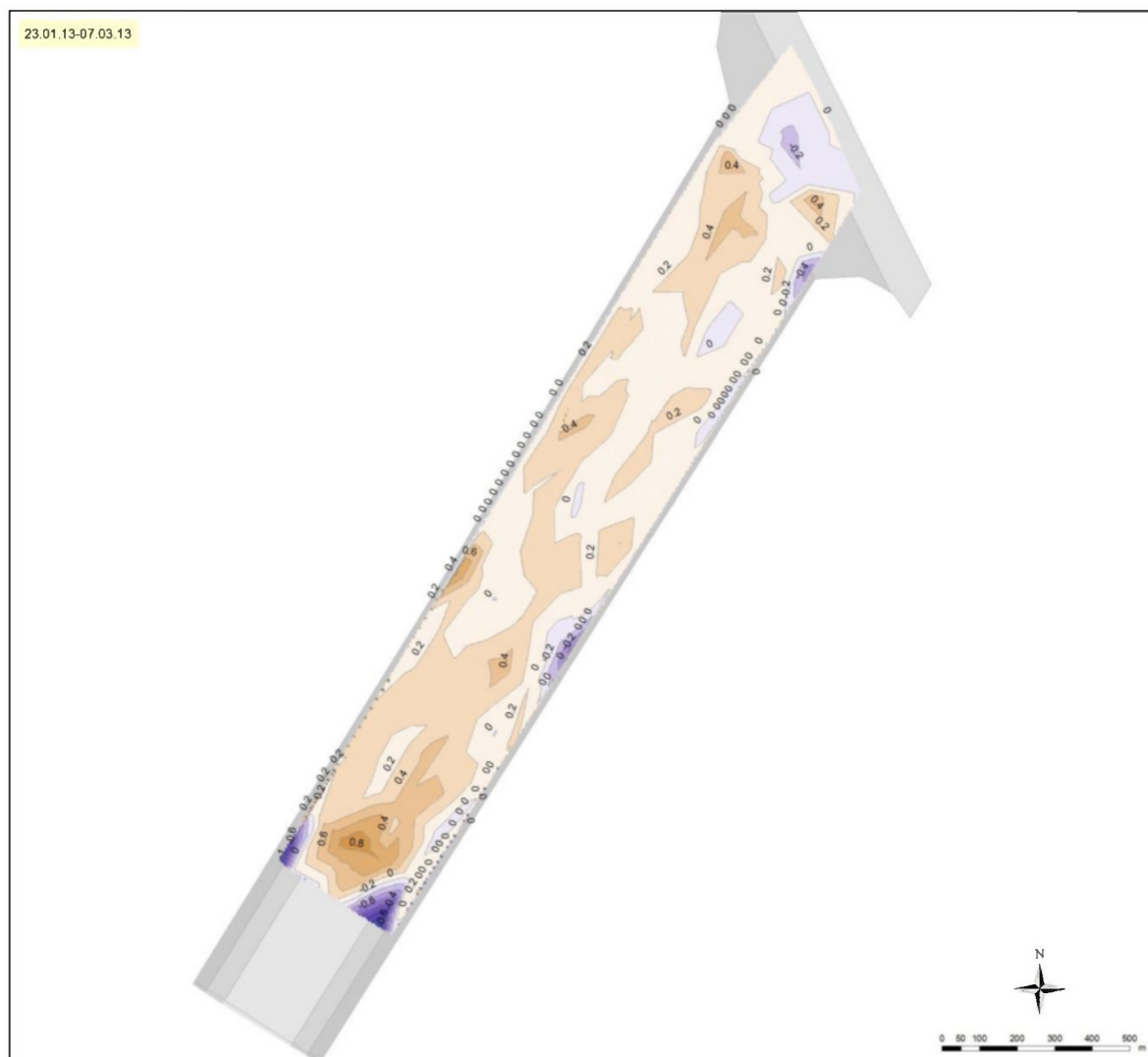
Created: 04/03/2014
Version nr. 1

IMDC
International Marine & Dredging Consultants

Coverstraat 15
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Tel +32 3 270 82 00
Fax +32 3 235 87 11
E-mail: info@imdc.be







Long-term measurements
Deurganckdok
Evolution & analysis of siltation

Bestek nr 16EB/05/04

Difference map total settled mass
23.01.13 - 07.03.13

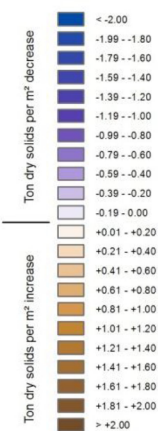
Map 7 Scale 1/10.000

Created: 29/07/2013
Version nr. 1

IMDC
International Marine & Dredging Consultants

Covellestraat 15
2600 Antwerpen
Tel +32 3 270 92 20
Fax +32 3 226 67 11
E-mail: info@imdc.be

Legend





Long-term measurements
Deurganckdok
Evolution & analysis of siltation

Bestek nr 16EB/05/04

Difference map total settled mass
28.03.12 - 07.03.13

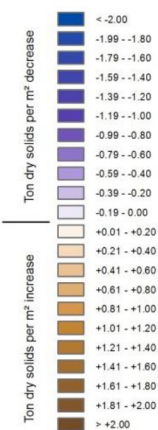
Map 8 Scale 1/10.000

Created: 29/07/2013
Version nr. 1

IMDC
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2600 Antwerpen
Tel +32 3 270 92 20
Fax +32 3 236 67 11
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Legend



Annex I AVERAGE MASS GROWTH AND GROWTH RATE

I.1 TABULAR RESULTS

Table 7-3: Measured dry sediment mass above design level [TDS/m²] per zone based on density profiles of the considered measurement day. For period March 28th 2012 to March 07th 2013.

	05/May	27/Jun	26/Jul	18/Sep	11/Oct	27/Dec	23/Jan	07/Mar
1	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
2	0.75	0.56	1.00	0.86	0.79	NaN	0.24	0.47
3a	0.94	1.05	1.23	0.94	1.26	0.90	0.66	1.21
3b	0.79	0.92	1.10	0.87	1.08	0.73	0.70	1.09
3c	0.73	0.95	1.04	0.89	1.03	0.76	0.77	1.08
3d	0.77	0.84	0.96	0.85	1.01	0.77	0.84	1.25
3e	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
4Na	0.61	0.69	0.81	0.59	0.82	0.68	0.41	0.78
4Nb	0.50	0.65	0.72	0.53	0.62	0.50	0.45	0.76
4Nc	0.46	0.71	0.65	0.57	0.49	0.42	0.47	0.73
4Nd	0.46	0.57	0.54	0.48	0.53	0.50	0.70	0.86
4Ne	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
4Za	0.71	0.63	0.85	0.70	0.76	0.55	0.38	0.72
4Zb	0.51	0.51	0.63	0.55	0.65	0.49	0.54	0.64
4Zc	0.50	0.54	0.61	0.61	0.56	0.35	0.51	0.61
4Zd	0.50	0.54	0.51	0.50	0.47	0.35	0.58	0.68
4Ze	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
5Na	NaN	NaN	NaN	NaN	NaN	NaN	NaN	0.71
5Nb	NaN	0.73	NaN	NaN	NaN	NaN	NaN	0.71
5Nc	NaN	0.72	0.56	0.69	NaN	0.53	0.66	0.75
5Nd	NaN	0.65	0.51	NaN	NaN	0.57	0.77	0.77
5Ne	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
5Za	0.56	0.61	0.82	0.90	0.46	NaN	0.42	0.60
5Zb	0.52	0.64	0.69	0.82	0.47	NaN	0.43	0.56
5Zc	0.48	0.65	0.59	0.66	0.43	0.34	0.46	0.58
5Zd	0.51	0.67	0.53	0.50	0.46	0.33	0.55	0.63

	05/May	27/Jun	26/Jul	18/Sep	11/Oct	27/Dec	23/Jan	07/Mar
5Ze	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
4Ztot	0.62	0.65	0.70	0.66	0.68	0.47	0.67	0.77
4Ntot	0.58	0.72	0.75	0.62	0.65	0.61	0.73	0.91
5Ztot	0.54	0.71	0.67	0.74	0.49	NaN	0.62	0.68
5Ntot	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
Trench area mean	0.80	0.93	1.07	0.88	1.09	0.79	0.74	1.16

Table 7-4: Measured dry sediment mass above design level [TDS] per zone based on density profiles of the considered measurement day. For period March 28th 2012 to March 07th 2013.

	05/May	27/Jun	26/Jul	18/Sep	11/Oct	27/Dec	23/Jan	07/Mar
1	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
2	92,914	69,624	124,707	106,325	98,497	NaN	29,245	58,513
3a	92,926	103,239	121,506	92,278	124,790	88,978	64,626	119,878
3b	86,366	100,828	121,221	95,278	118,251	80,330	76,415	120,064
3c	72,603	93,999	102,772	88,597	101,871	74,767	75,797	106,919
3d	100,386	109,606	124,826	110,411	131,546	100,625	109,239	163,266
3e	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
4Na	21,997	24,962	29,377	21,397	29,694	24,545	14,761	28,234
4Nb	15,475	20,192	22,459	16,408	19,164	15,691	14,042	23,637
4Nc	11,877	18,253	16,818	14,512	12,503	10,844	12,082	18,738
4Nd	15,017	18,566	17,705	15,776	17,413	16,418	22,850	28,086
4Ne	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
4Za	17,213	15,177	20,492	16,807	18,368	13,312	9,272	17,489
4Zb	15,768	16,000	19,713	17,176	20,129	15,422	16,792	20,103
4Zc	12,814	13,915	15,884	15,737	14,481	9,133	13,058	15,870
4Zd	15,995	17,440	16,454	16,062	15,147	11,166	18,543	21,898
4Ze	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
5Na	NaN	NaN	NaN	NaN	NaN	NaN	NaN	16,250

	05/May	27/Jun	26/Jul	18/Sep	11/Oct	27/Dec	23/Jan	07/Mar
5Nb	NaN	14,614	NaN	NaN	NaN	NaN	NaN	14,171
5Nc	NaN	13,076	10,055	12,512	NaN	9,609	11,934	13,459
5Nd	NaN	15,535	12,042	NaN	NaN	13,575	18,268	18,290
5Ne	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
5Za	7,298	7,948	10,739	11,785	6,028	NaN	5,520	7,855
5Zb	10,306	12,682	13,707	16,292	9,449	NaN	8,666	11,113
5Zc	8,692	11,711	10,566	11,888	7,721	6,134	8,326	10,439
5Zd	12,248	16,054	12,642	11,988	10,915	7,783	13,211	14,984
5Ze	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
4Ztot	91,960	97,207	104,754	99,247	102,055	70,336	100,312	115,186
4Ntot	97,730	121,581	125,547	104,558	108,609	103,255	123,057	152,577
5Ztot	53,643	69,844	66,074	72,806	48,961	NaN	61,822	66,878
5Ntot	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
Trench area	352,281	407,672	470,325	386,563	476,458	344,700	326,077	510,128

Table 7-5: Cumulative dredged mass in covered area [TDS] per zone based on measurements during the maintenance dredging (BIS). Cumulative values given on each density measurement day. For period March 28th 2012 to March 07th 2013.

	05/May	27/Jun	26/Jul	18/Sep	11/Oct	27/Dec	23/Jan	07/Mar
1	27,261	27,261	47,791	47,791	53,421	65,608	65,984	71,052
2	62,257	62,257	102,782	102,782	125,631	167,034	168,544	179,017
3a	59,716	59,716	113,393	113,393	156,840	220,840	232,314	243,374
3b	57,681	57,681	92,857	92,857	138,234	185,668	210,471	223,768
3c	49,627	49,627	69,738	69,738	97,708	116,577	135,040	152,696
3d	73,874	73,874	100,011	100,011	119,862	129,738	145,075	174,328
3e	42,268	42,268	48,386	48,386	50,452	51,228	53,325	58,477
4Na	19,718	19,718	31,627	31,627	36,116	56,141	56,670	62,258
4Nb	11,890	11,890	18,430	18,430	21,641	32,885	34,174	36,123
4Nc	5,646	5,646	8,795	8,795	9,732	13,087	13,476	14,960

	05/May	27/Jun	26/Jul	18/Sep	11/Oct	27/Dec	23/Jan	07/Mar
4Nd	11,117	11,117	13,691	13,691	14,547	15,130	15,314	16,158
4Ne	4,499	4,499	4,748	4,748	4,748	4,828	4,888	5,093
4Za	12,319	12,319	23,562	23,562	28,593	41,595	42,182	43,314
4Zb	10,751	10,751	17,076	17,076	20,059	31,292	32,243	33,391
4Zc	6,078	6,078	9,306	9,306	10,389	13,535	14,476	14,932
4Zd	8,943	8,943	12,672	12,672	13,613	14,511	15,670	16,485
4Ze	2,284	2,284	2,606	2,606	2,620	2,676	2,905	3,012
5Na	0	0	19	19	19	42	42	42
5Nb	0	0	0	0	0	0	0	0
5Nc	33	33	33	33	33	33	33	33
5Nd	14	14	14	14	14	14	14	14
5Ne	0	0	0	0	0	0	0	0
5Za	28	28	102	102	102	107	107	107
5Zb	0	0	40	40	40	51	51	58
5Zc	0	0	0	0	0	0	0	0
5Zd	33	33	33	33	33	33	33	33
5Ze	0	0	0	0	0	0	0	0
4Ztot	41,193	41,193	66,843	66,843	77,043	105,972	110,041	113,832
4Ntot	52,917	52,917	77,344	77,344	86,837	122,147	124,598	134,668
5Ztot	61	61	171	171	171	182	182	186
5Ntot	0	0	13	13	13	13	13	13
Total	466,038	466,038	717,713	717,713	904,447	1,162,652	1,243,030	1,676,280

Table 7-6: Total cumulative sediment mass [TDS/m²], which includes both the measured dry sediment mass above design level and the dredged sediment mass. Cumulative values given on each density measurement day. For period March 28th 2012 to March 07th 2013.

	05/May	27/Jun	26/Jul	18/Sep	11/Oct	27/Dec	23/Jan	07/Mar
1	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
2	1.06	1.50	1.68	1.62	NaN	1.579	1.83	2.00

	05/May	27/Jun	26/Jul	18/Sep	11/Oct	27/Dec	23/Jan	07/Mar
3a	1.65	1.84	2.08	2.41	2.49	2.892	3.57	3.48
3b	1.44	1.63	1.71	1.92	1.99	2.385	3.01	2.95
3c	1.45	1.54	1.60	1.73	1.74	1.942	2.44	2.45
3d	1.41	1.52	1.61	1.77	1.69	1.831	2.36	2.27
3e	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
4Na	1.23	1.35	1.46	1.69	1.67	1.951	2.34	2.30
4Nb	1.03	1.10	1.12	1.21	1.20	1.506	1.86	1.66
4Nc	0.93	0.87	0.91	0.83	0.80	0.979	1.25	1.11
4Nd	0.91	0.88	0.90	0.95	0.95	1.16	1.33	1.10
4Ne	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
4Za	1.14	1.36	1.67	1.73	1.73	2.102	2.47	2.42
4Zb	0.86	0.98	1.10	1.19	1.14	1.54	1.68	1.61
4Zc	0.77	0.85	0.97	0.92	0.75	1.028	1.17	1.08
4Zd	0.82	0.79	0.89	0.86	0.77	1.024	1.16	1.07
4Ze	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
5Na	NaN	NaN	NaN	NaN	NaN	NaN	0.71	0.66
5Nb	0.73	NaN	NaN	NaN	NaN	NaN	0.71	0.58
5Nc	0.73	0.56	0.69	NaN	0.53	0.662	0.75	0.53
5Nd	0.65	0.51	NaN	NaN	0.57	0.767	0.77	0.69
5Ne	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
5Za	0.61	0.83	0.91	0.47	NaN	0.431	0.61	0.64
5Zb	0.64	0.69	0.82	0.48	NaN	0.436	0.56	0.54
5Zc	0.65	0.59	0.66	0.43	0.34	0.462	0.58	0.62
5Zd	0.67	0.53	0.50	0.46	0.33	0.553	0.63	0.59
5Ze	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
4Ztot	0.93	0.98	1.11	1.13	0.99	1.38	1.51	1.46
4Ntot	1.04	1.06	1.08	1.10	1.13	1.456	1.65	1.48
5Ztot	0.71	0.67	0.74	0.50	NaN	0.626	0.68	0.67

	05/May	27/Jun	26/Jul	18/Sep	11/Oct	27/Dec	23/Jan	07/Mar
5Ntot	NaN	NaN	NaN	NaN	NaN	NaN	NaN	0.74
Trench area mean	1.48	1.62	1.74	1.95	1.96	2.23	2.81	2.75

Table 7-7: Total cumulative sediment mass [TDS], which includes both the measured dry sediment mass above design level and the dredged sediment mass. Cumulative values given on each density measurement day. For period March 28th 2012 to March 07th 2013.

	05/May	27/Jun	26/Jul	18/Sep	11/Oct	27/Dec	23/Jan	07/Mar
1	27,261	27,261	47,791	47,791	53,421	65,608	65,984	71,052
2	62,257	62,257	102,782	102,782	125,631	167,034	168,544	179,017
3a	59,716	59,716	113,393	113,393	156,840	220,840	232,314	243,374
3b	57,681	57,681	92,857	92,857	138,234	185,668	210,471	223,768
3c	49,627	49,627	69,738	69,738	97,708	116,577	135,040	152,696
3d	73,874	73,874	100,011	100,011	119,862	129,738	145,075	174,328
3e	42,268	42,268	48,386	48,386	50,452	51,228	53,325	58,477
4Na	19,718	19,718	31,627	31,627	36,116	56,141	56,670	62,258
4Nb	11,890	11,890	18,430	18,430	21,641	32,885	34,174	36,123
4Nc	5,646	5,646	8,795	8,795	9,732	13,087	13,476	14,960
4Nd	11,117	11,117	13,691	13,691	14,547	15,130	15,314	16,158
4Ne	4,499	4,499	4,748	4,748	4,748	4,828	4,888	5,093
4Za	12,319	12,319	23,562	23,562	28,593	41,595	42,182	43,314
4Zb	10,751	10,751	17,076	17,076	20,059	31,292	32,243	33,391
4Zc	6,078	6,078	9,306	9,306	10,389	13,535	14,476	14,932
4Zd	8,943	8,943	12,672	12,672	13,613	14,511	15,670	16,485
4Ze	2,284	2,284	2,606	2,606	2,620	2,676	2,905	3,012
5Na	0	0	19	19	19	42	42	42
5Nb	0	0	0	0	0	0	0	0
5Nc	33	33	33	33	33	33	33	33
5Nd	14	14	14	14	14	14	14	14
5Ne	0	0	0	0	0	0	0	0
5Za	28	28	102	102	102	107	107	107
5Zb	0	0	40	40	40	51	51	58
5Zc	0	0	0	0	0	0	0	0
5Zd	33	33	33	33	33	33	33	33

	05/May	27/Jun	26/Jul	18/Sep	11/Oct	27/Dec	23/Jan	07/Mar
5Ze	0	0	0	0	0	0	0	0
4Ztot	41,193	41,193	66,843	66,843	77,043	105,972	110,041	113,832
4Ntot	52,917	52,917	77,344	77,344	86,837	122,147	124,598	134,668
5Ztot	61	61	171	171	171	182	182	186
5Ntot	0	0	13	13	13	13	13	13
Trench area	466,038	466,038	717,713	717,713	904,447	1,162,652	1,243,030	1,348,727

Table 7-8: **Growth rate [kg/m²/day]**. For period March 28th 2012 to March 07th 2013.

	28/Mar	05/May	27/Jun	26/Jul	18/Sep	11/Oct	27/Dec	23/Jan
	05/May	27/Jun	26/Jul	18/Sep	11/Oct	27/Dec	23/Jan	07/Mar
1	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
2	8.25	8.36	6.14	-1.17	NaN	NaN	9.17	4.32
3a	18.67	3.49	8.54	6.10	3.36	5.22	25.03	7.80
3b	17.28	3.50	2.90	3.87	2.95	5.14	23.07	10.31
3c	18.87	1.67	2.07	2.48	0.38	2.61	18.54	14.24
3d	16.75	2.20	3.10	3.00	-3.69	1.84	19.68	12.58
3e	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
4Na	16.42	2.29	3.73	4.23	-0.79	3.66	14.27	2.54
4Nb	14.03	1.37	0.54	1.64	-0.36	4.00	12.94	1.35
4Nc	12.31	-1.05	1.13	-1.45	-1.22	2.32	10.15	3.53
4Nd	11.79	-0.50	0.68	0.93	-0.18	2.78	6.13	0.93
4Ne	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
4Za	11.18	4.14	10.77	1.19	-0.04	4.81	13.47	2.28
4Zb	9.26	2.24	4.18	1.75	-2.40	5.24	5.06	4.47
4Zc	7.30	1.44	4.11	-0.90	-7.17	3.55	5.37	3.98
4Zd	8.47	-0.58	3.57	-0.53	-4.10	3.33	5.18	3.54
4Ze	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
5Na	NaN	NaN	NaN	NaN	NaN	NaN	NaN	-1.14

	28/Mar	05/May	27/Jun	26/Jul	18/Sep	11/Oct	27/Dec	23/Jan
5Nb	NaN	NaN	NaN	NaN	NaN	NaN	NaN	-3.14
5Nc	NaN	-3.15	4.69	NaN	NaN	1.67	3.13	-5.12
5Nd	NaN	-2.77	NaN	NaN	NaN	2.56	0.03	-1.88
5Ne	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
5Za	1.37	4.04	2.96	-8.17	NaN	NaN	6.63	0.70
5Zb	3.13	0.97	4.53	-6.34	NaN	NaN	4.54	-0.37
5Zc	4.41	-1.20	2.53	-4.28	-3.83	1.58	4.34	0.88
5Zd	4.22	-2.69	-0.94	-0.83	-5.69	2.94	2.74	-0.87
5Ze	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
4Ztot	8.18	0.95	4.65	0.35	-6.26	5.12	4.69	3.23
4Ntot	11.99	0.44	0.70	0.45	1.07	4.25	7.03	0.39
5Ztot	4.32	-0.72	2.38	-4.46	NaN	NaN	1.89	-0.14
5Ntot	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
Trench area mean	17.79	2.70	4.04	3.80	0.49	3.60	21.48	11.31

Table 7-9: **Growth rate [TDS/day]**. For period March 28th 2012 to March 07th 2013.

	28/Mar	05/May	27/Jun	26/Jul	18/Sep	11/Oct	27/Dec	23/Jan
	05/May	27/Jun	26/Jul	18/Sep	11/Oct	27/Dec	23/Jan	07/Mar
1	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
2	1025	1039	764	-145	NaN	NaN	1140	538
3a	1843	345	843	602	332	515	2471	770
3b	1899	385	318	425	324	565	2535	1133
3c	1869	166	205	246	38	258	1836	1411
3d	2187	287	404	391	-481	240	2569	1642
3e	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
4Na	597	83	136	154	-29	133	519	92
4Nb	437	43	17	51	-11	125	403	42
4Nc	316	-27	29	-37	-31	60	261	91

	28/Mar	05/May	27/Jun	26/Jul	18/Sep	11/Oct	27/Dec	23/Jan
4Nd	386	-16	22	30	-6	91	201	31
4Ne	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
4Za	271	100	261	29	-1	116	326	55
4Zb	289	70	131	55	-75	164	158	140
4Zc	189	37	106	-23	-185	92	139	103
4Zd	273	-19	115	-17	-132	107	167	114
4Ze	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
5Na	NaN	NaN	NaN	NaN	NaN	NaN	NaN	-26
5Nb	NaN	NaN	NaN	NaN	NaN	NaN	NaN	-63
5Nc	NaN	-57	85	NaN	NaN	30	56	-93
5Nd	NaN	-66	NaN	NaN	NaN	61	1	-45
5Ne	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
5Za	18	53	39	-107	NaN	NaN	86	9
5Zb	63	19	90	-127	NaN	NaN	91	-7
5Zc	79	-22	46	-77	-69	28	78	16
5Zd	101	-64	-23	-20	-136	70	66	-21
5Ze	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
4Ztot	1222	142	695	52	-936	765	702	483
4Ntot	2020	75	119	75	180	716	1184	65
5Ztot	428	-71	236	-442	NaN	NaN	187	-14
5Ntot	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
Trench area	7,797	1,182	1,770	1,665	212	1579	9412	-620

Table 7-10: Covered area of each zone [ha] by density measurements. For period March 28th 2012 to March 07th 2013.

	05/May	27/Jun	26/Jul	18/Sep	11/Oct	27/Dec	23/Jan	07/Mar
1	2.46	1.98	2.56	2.25	0	2.89	2.35	3.33
2	7.56	7.41	7.7	7.63	4.04	7.41	7.39	9.16

	05/May	27/Jun	26/Jul	18/Sep	11/Oct	27/Dec	23/Jan	07/Mar
3a	9.87	9.87	9.87	9.87	9.87	9.87	9.87	9.87
3b	10.99	10.99	10.99	10.99	10.99	10.99	10.99	10.99
3c	9.91	9.91	9.91	9.91	9.91	9.91	9.91	9.91
3d	13.06	13.06	13.06	13.06	13.06	13.06	13.06	13.06
3e	4.79	4.76	4.74	4.68	4.83	4.86	4.89	4.77
4Na	3.64	3.64	3.64	3.64	3.64	3.63	3.64	3.64
4Nb	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12
4Nc	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57
4Nd	3.28	3.28	3.28	3.28	3.28	3.28	3.28	3.28
4Ne	1.17	1.21	1.17	0.97	1.22	1.2	1.23	1.19
4Za	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42
4Zb	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12
4Zc	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59
4Zd	3.23	3.23	3.23	3.23	3.23	3.23	3.23	3.23
4Ze	1.18	1.12	1.15	1.1	1	1.19	1.16	1.15
5Na	1.1	0.86	0.9	0.7	0.78	0.44	1.3	2.29
5Nb	1.12	0.96	0.93	0.97	0.96	0.82	1.3	1.99
5Nc	1.13	0.99	0.92	0.88	1.04	1.05	1.21	1.81
5Nd	1.46	1.31	1.14	0.86	1.42	1.25	1.41	2.22
5Ne	0.46	0.34	0.34	0.06	0.48	0.29	0.44	0.55
5Za	0.95	1.06	1.31	1.31	0.51	1.23	0.84	0.84
5Zb	1.37	1.51	1.99	1.9	0.95	1.75	1.31	1.28
5Zc	1.17	1.26	1.64	1.47	0.99	1.44	1.21	1.13
5Zd	1.43	1.5	1.82	1.55	1.4	1.67	1.61	1.4
5Ze	0.5	0.39	0.46	0.43	0.21	0.55	0.54	0.47
4Ztot	13.03	12.96	13	12.95	12.85	13.04	13.01	13
4Ntot	14.67	14.71	14.67	14.43	14.72	14.69	14.73	14.69
5Ztot	5.34	5.63	7.13	6.56	3.98	6.53	5.41	5.04

	05/May	27/Jun	26/Jul	18/Sep	11/Oct	27/Dec	23/Jan	07/Mar
5Ntot	4.37	3.55	3.31	2.59	3.78	2.95	4.75	8.62
Total	95.62	94.41	96.51	94.50	87.60	95.79	95.94	101.35

*Table 7-11: **Percent of zone covered [%]** by density measurements. For period March 28th 2011 to March 07th 2013.*

	05/May	27/Jun	26/Jul	18/Sep	11/Oct	27/Dec	23/Jan	07/Mar
1	22	18	23	20	0	26	21	30
2	61	60	62	61	32	60	59	74
3a	100	100	100	100	100	100	100	100
3b	100	100	100	100	100	100	100	100
3c	100	100	100	100	100	100	100	100
3d	100	100	100	100	100	100	100	100
3e	37	37	37	36	37	37	38	37
4Na	100	100	100	100	100	100	100	100
4Nb	100	100	100	100	100	100	100	100
4Nc	100	100	100	100	100	100	100	100
4Nd	100	100	100	100	100	100	100	100
4Ne	35	37	35	29	37	36	37	36
4Za	100	100	100	100	100	100	100	100
4Zb	100	100	100	100	100	100	100	100
4Zc	100	100	100	100	100	100	100	100
4Zd	100	100	100	100	100	100	100	100
4Ze	38	36	37	36	32	39	38	37
5Na	48	37	39	30	34	19	57	100
5Nb	56	48	46	49	48	41	65	100
5Nc	62	55	51	49	57	58	67	100
5Nd	61	55	48	36	60	53	59	93
5Ne	19	14	14	2	20	12	18	23

	05/May	27/Jun	26/Jul	18/Sep	11/Oct	27/Dec	23/Jan	07/Mar
5Za	73	81	100	100	39	94	64	65
5Zb	69	75	99	95	48	87	65	64
5Zc	65	70	91	81	55	80	67	63
5Zd	60	62	76	65	59	70	67	59
5Ze	21	16	19	18	9	23	22	19
4Ztot	87	87	87	87	86	87	87	87
4Ntot	87	87	87	86	87	87	87	87
5Ztot	54	57	72	66	40	66	55	51
5Ntot	40	33	30	24	35	27	44	79
Mean	71	70	73	70	65	72	72	78

I.2 FOR EACH ZONE

Evaluation of external effects on the siltation of Deurganckdok

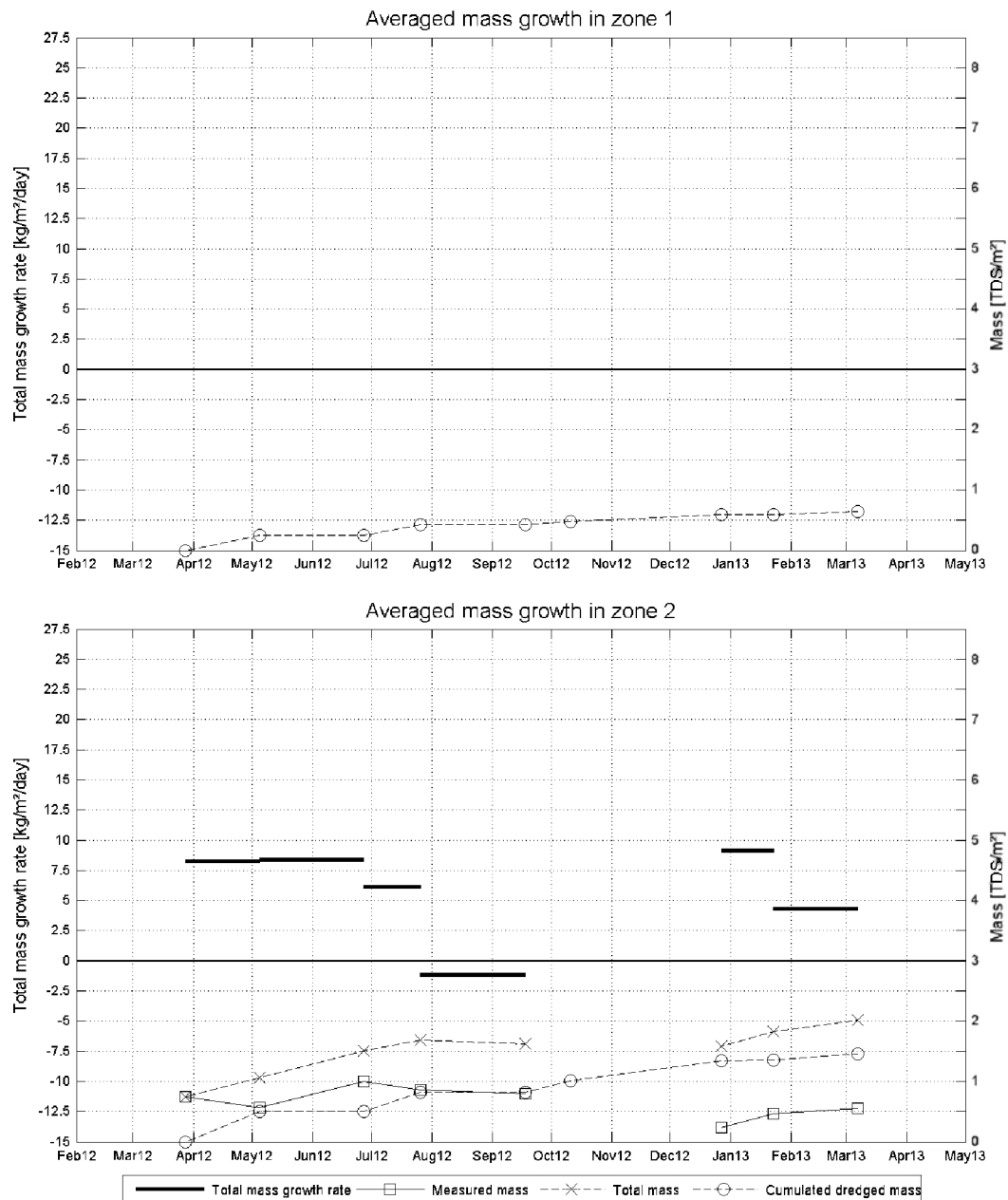
Measured/Dredged/Total Mass

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

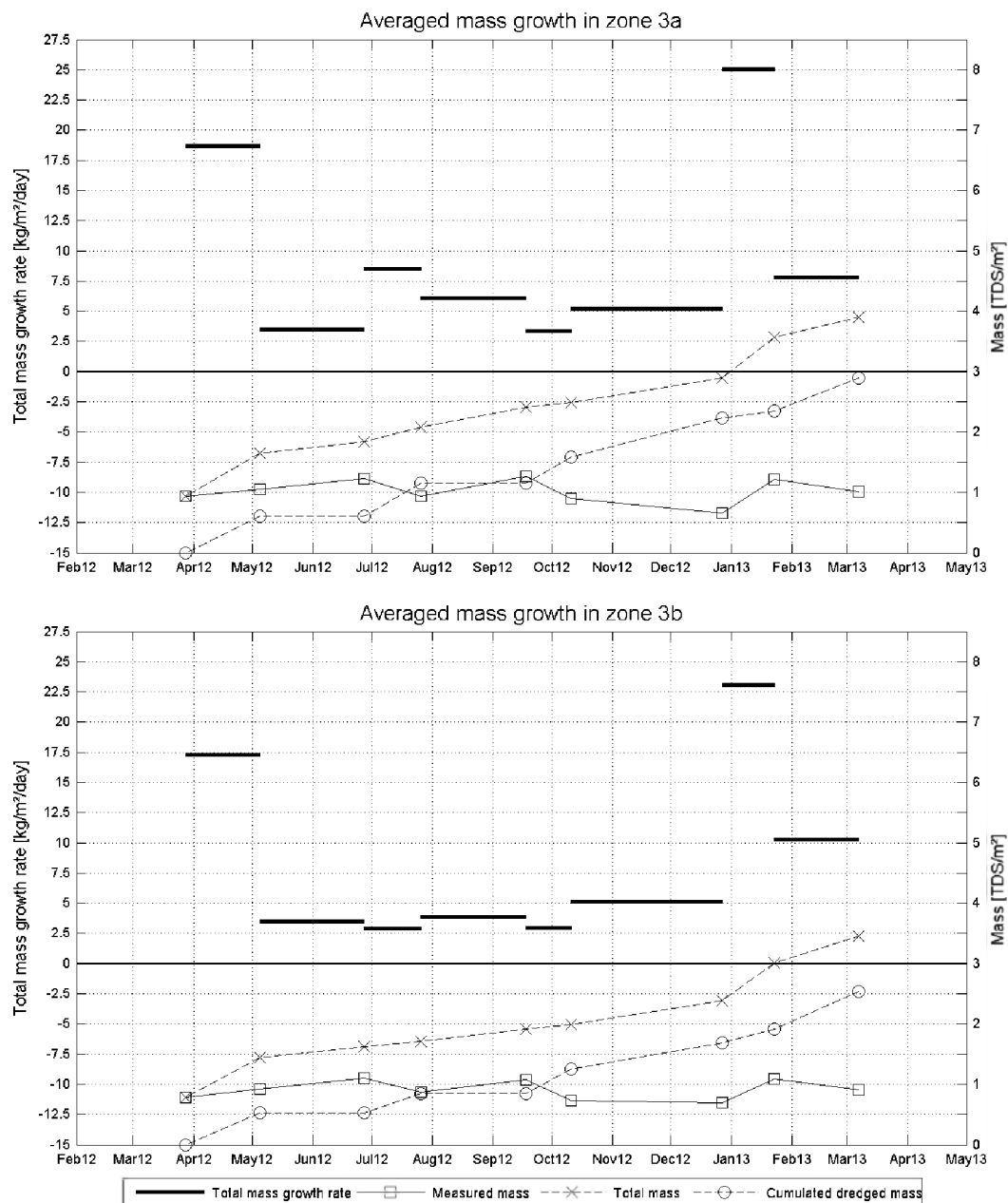
Measured/Dredged/Total Mass

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

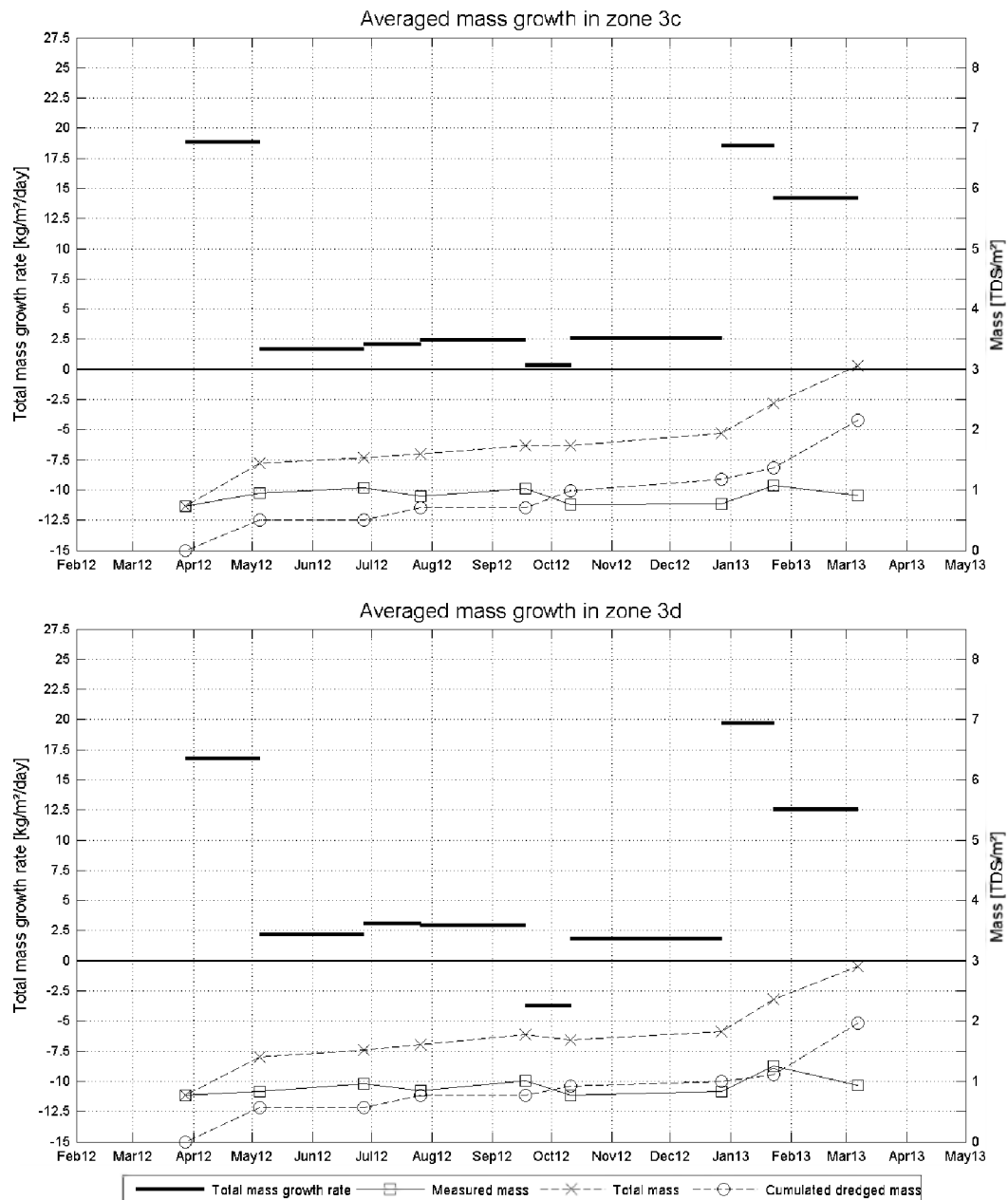
Measured/Dredged/Total Mass

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

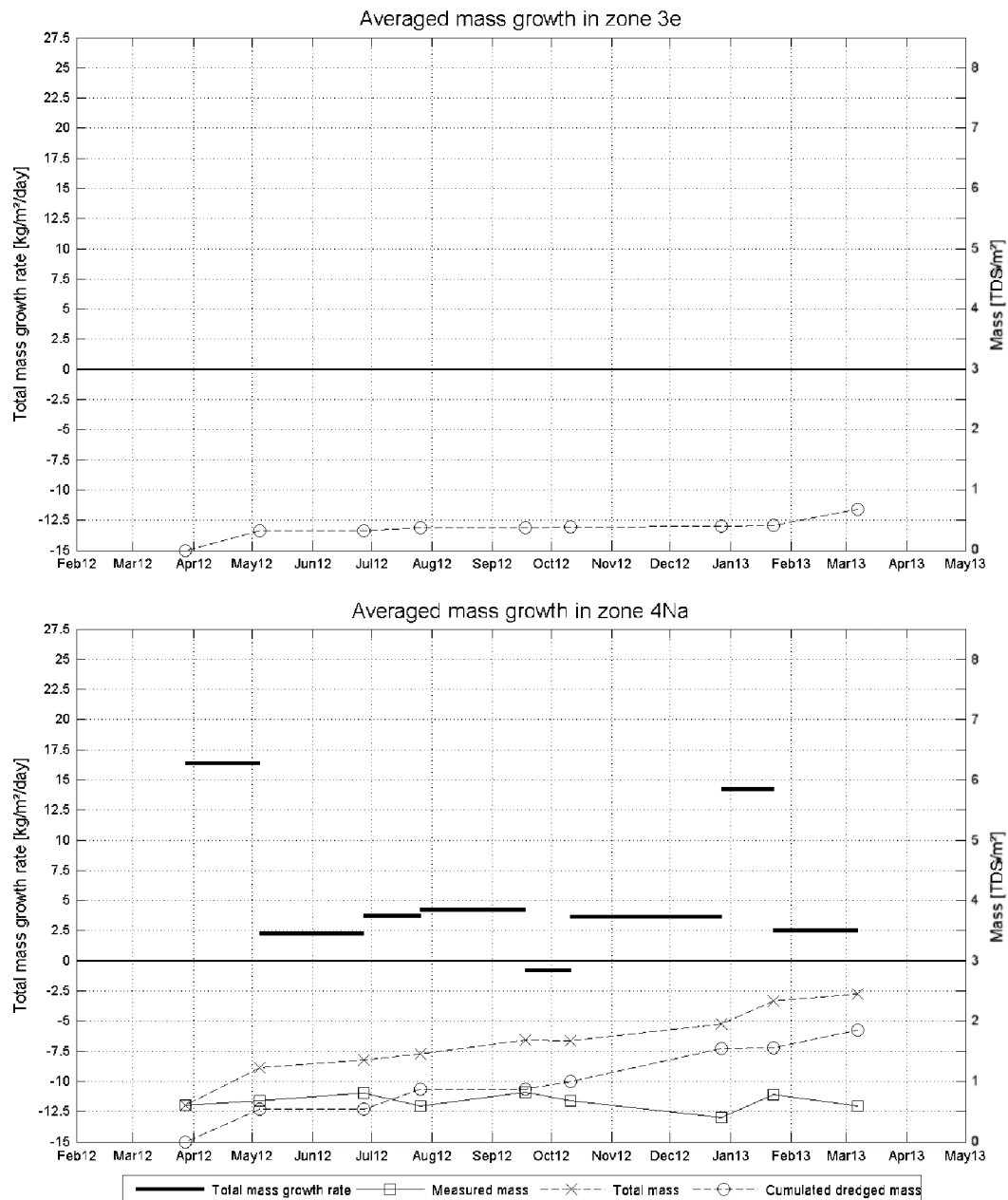
Measured/Dredged/Total Mass

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

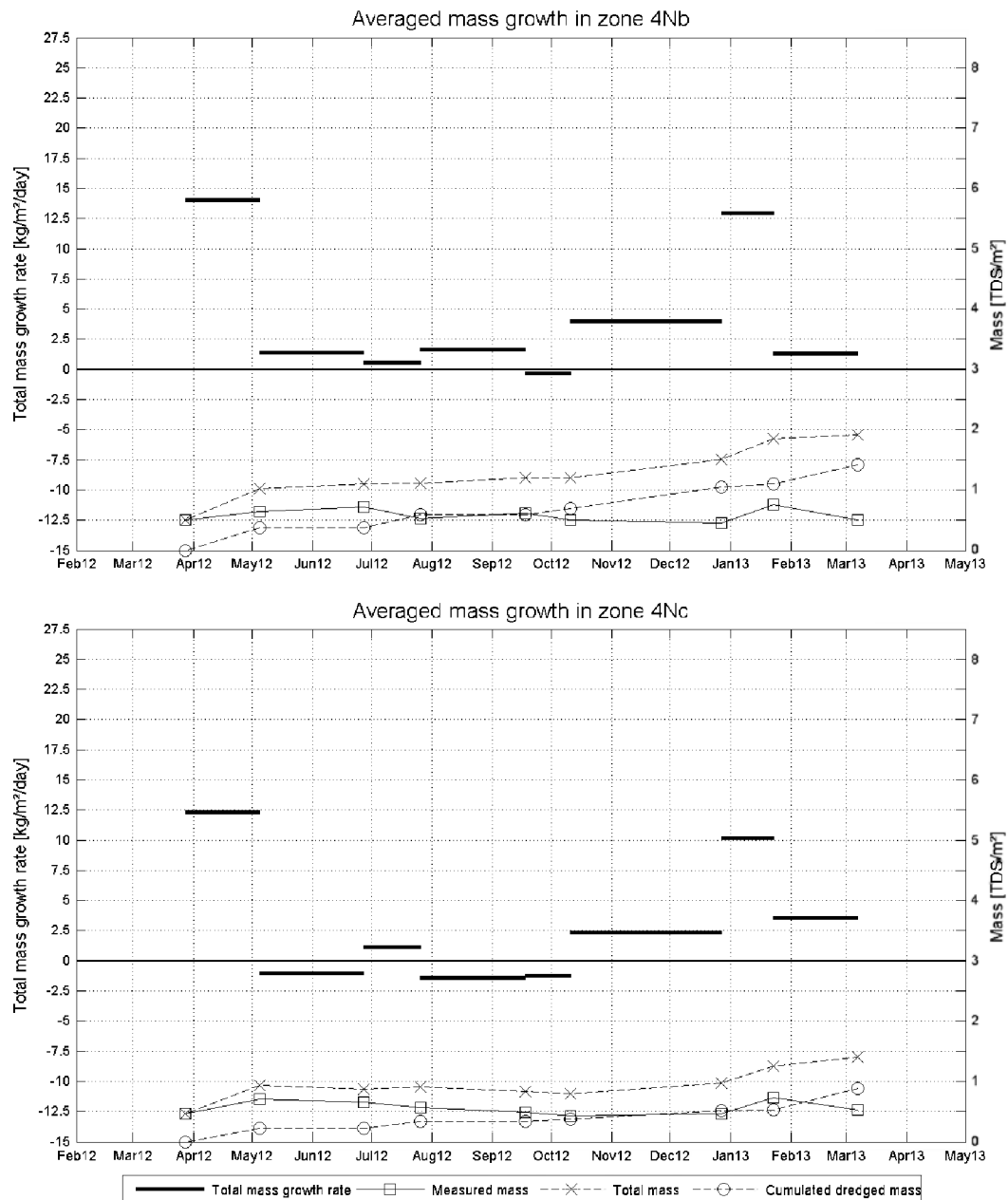
Measured/Dredged/Total Mass

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

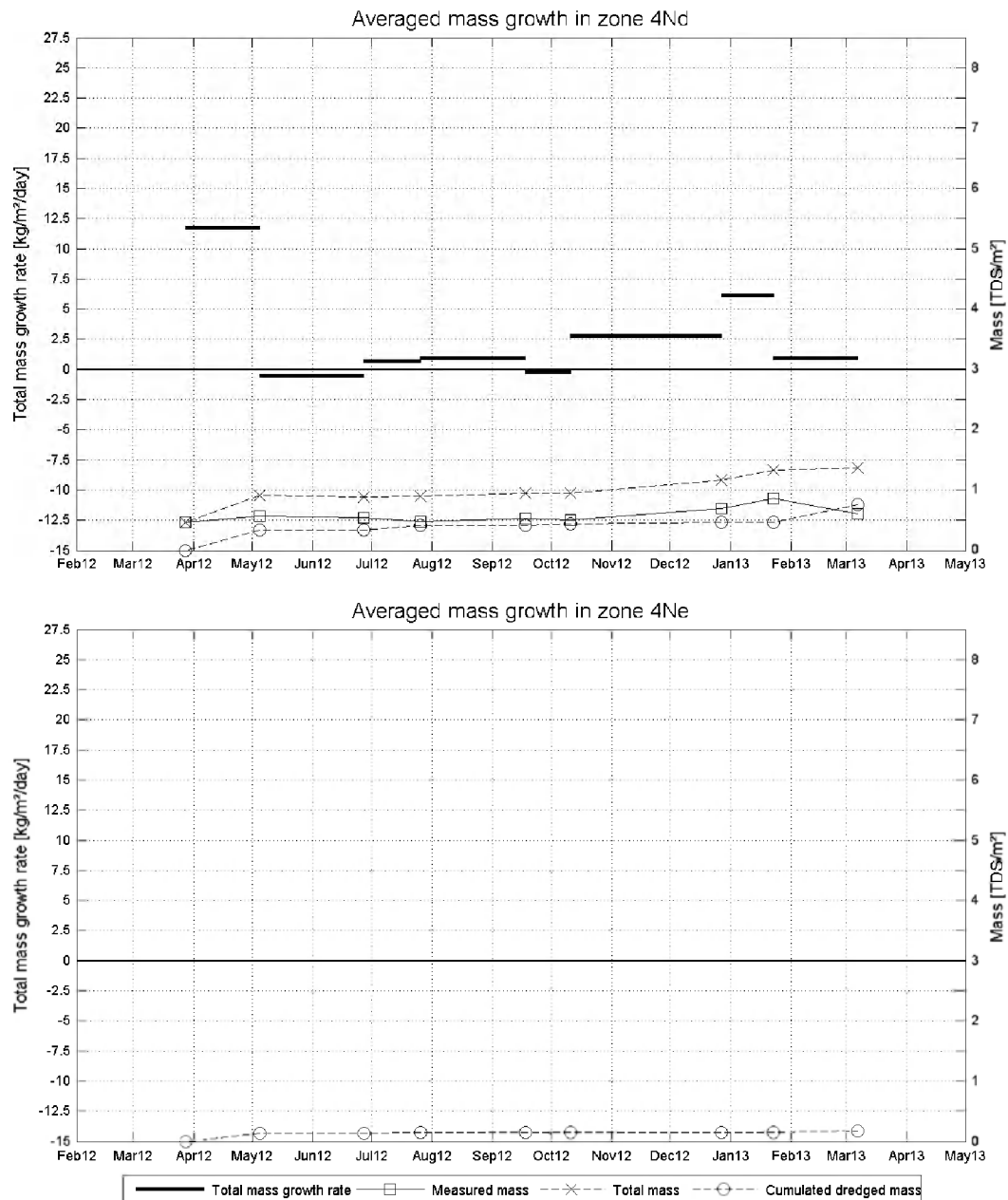
Measured/Dredged/Total Mass

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

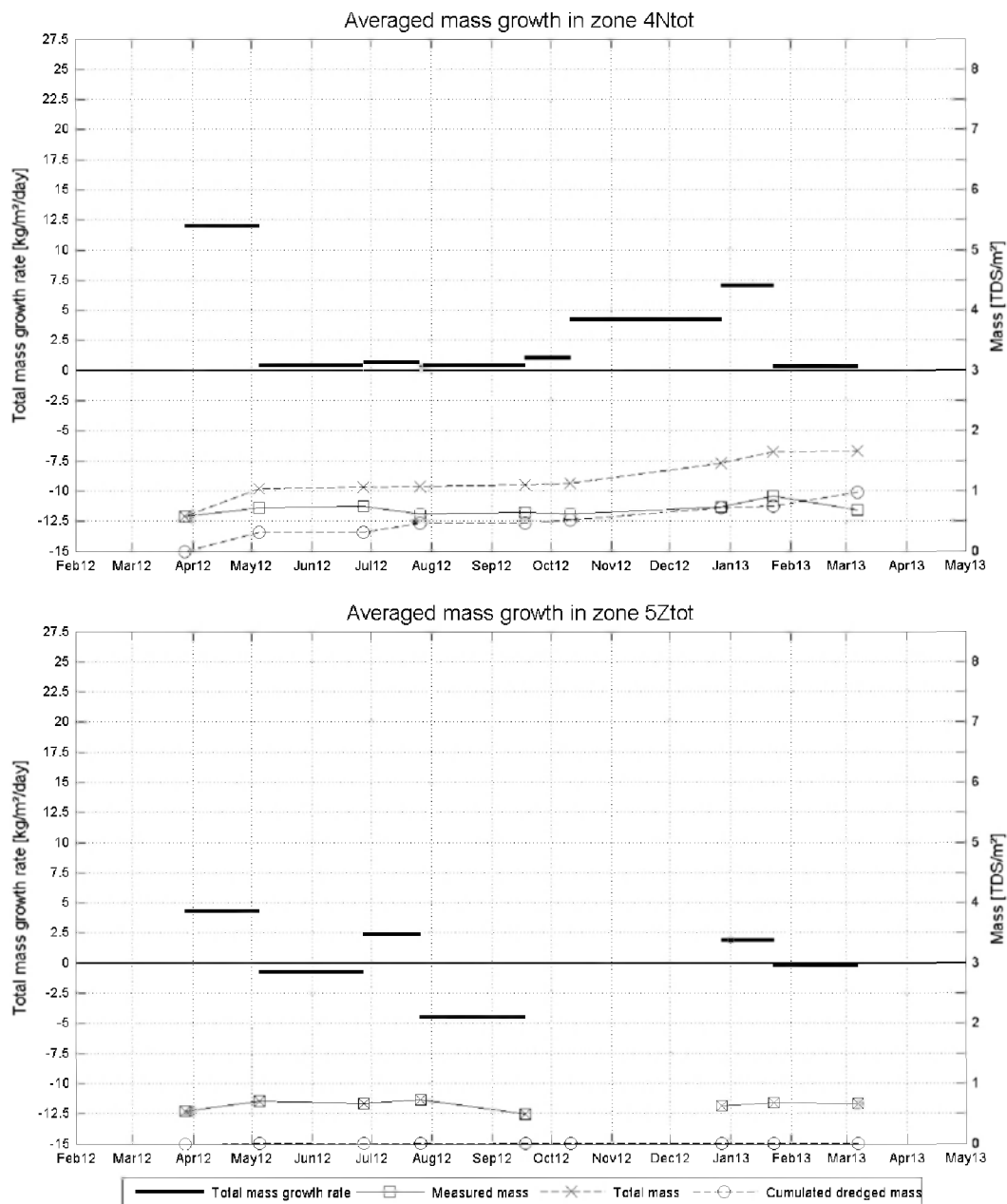
Measured/Dredged/Total Mass

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with:



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

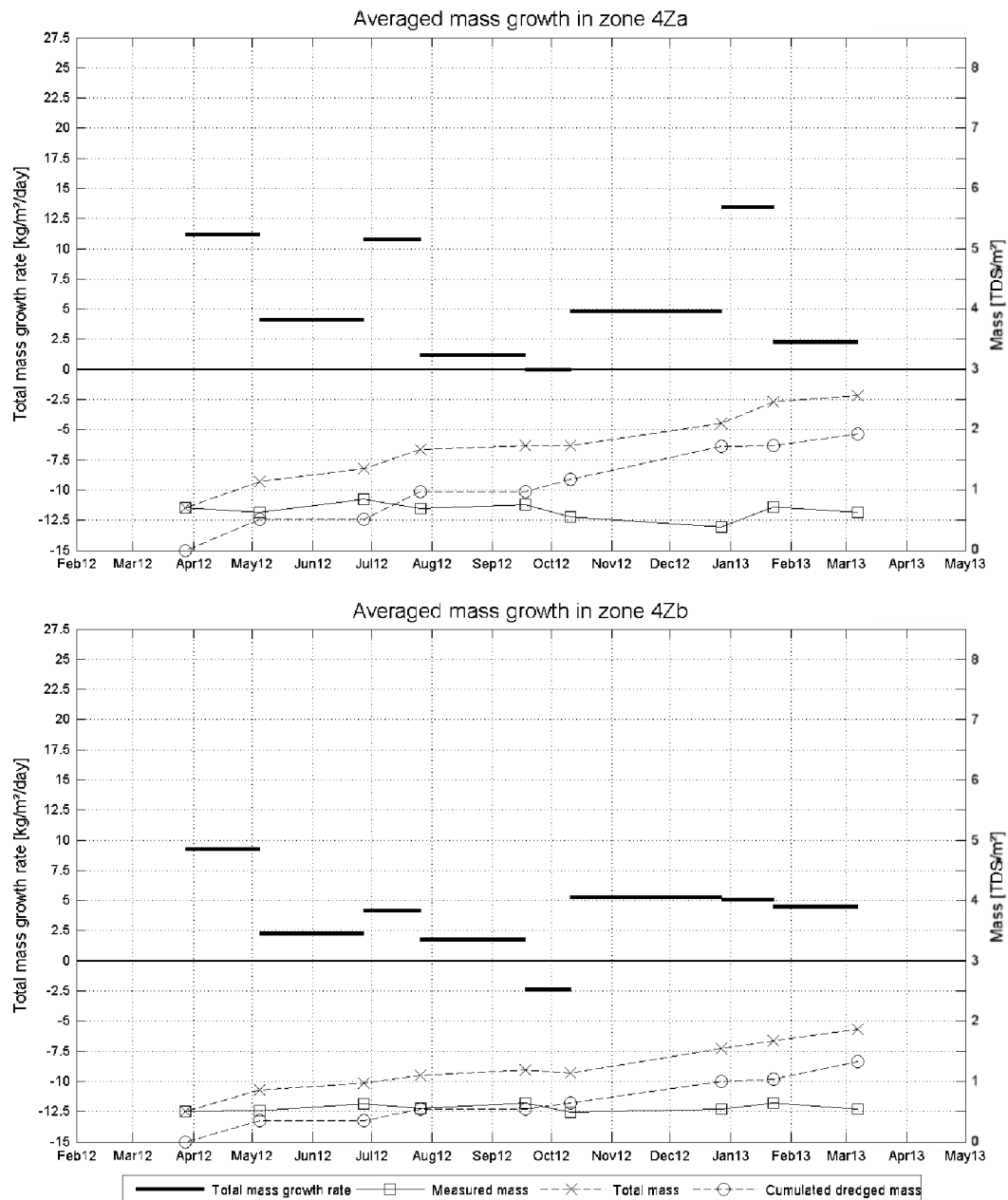
Measured/Dredged/Total Mass

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

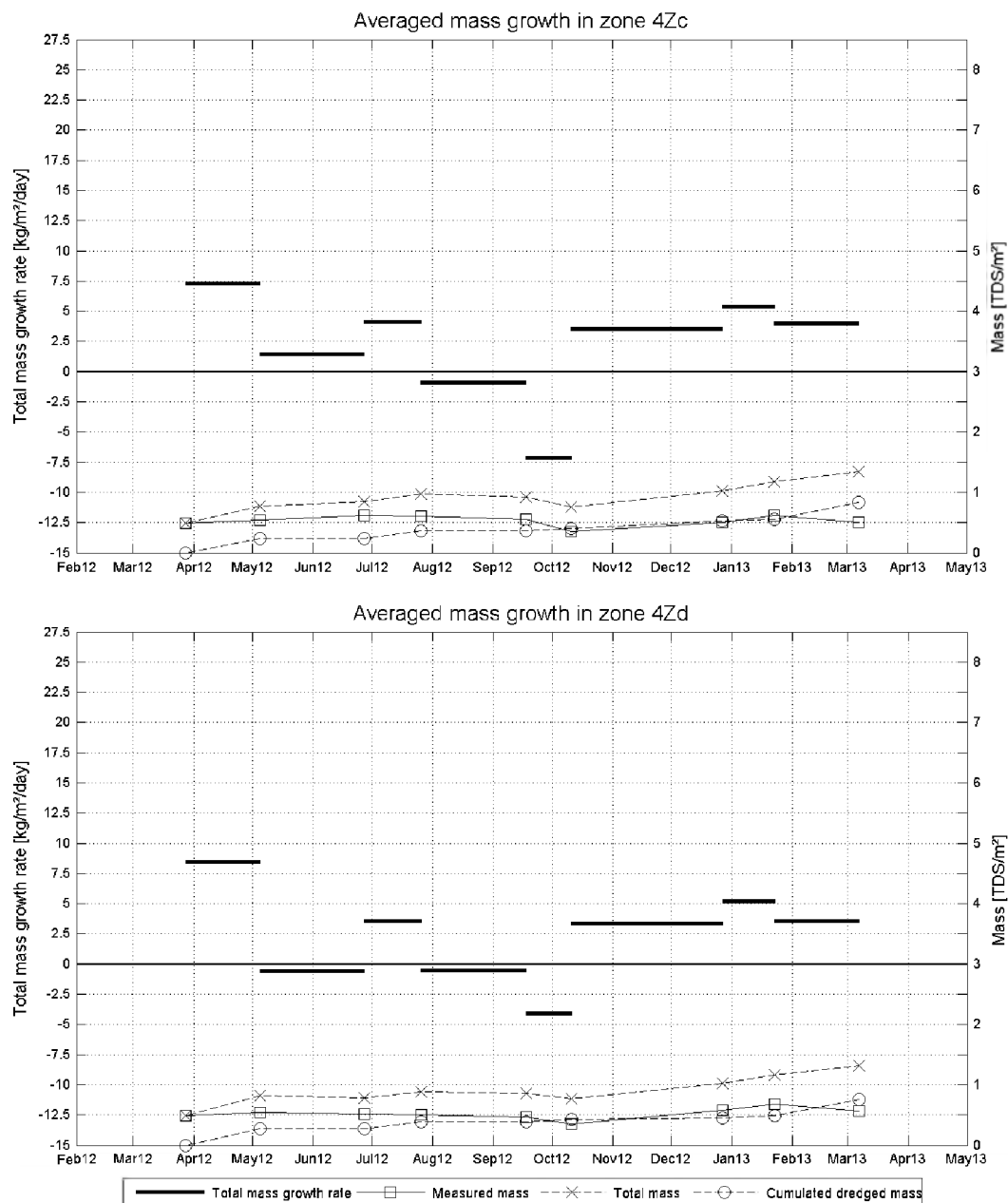
Measured/Dredged/Total Mass

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

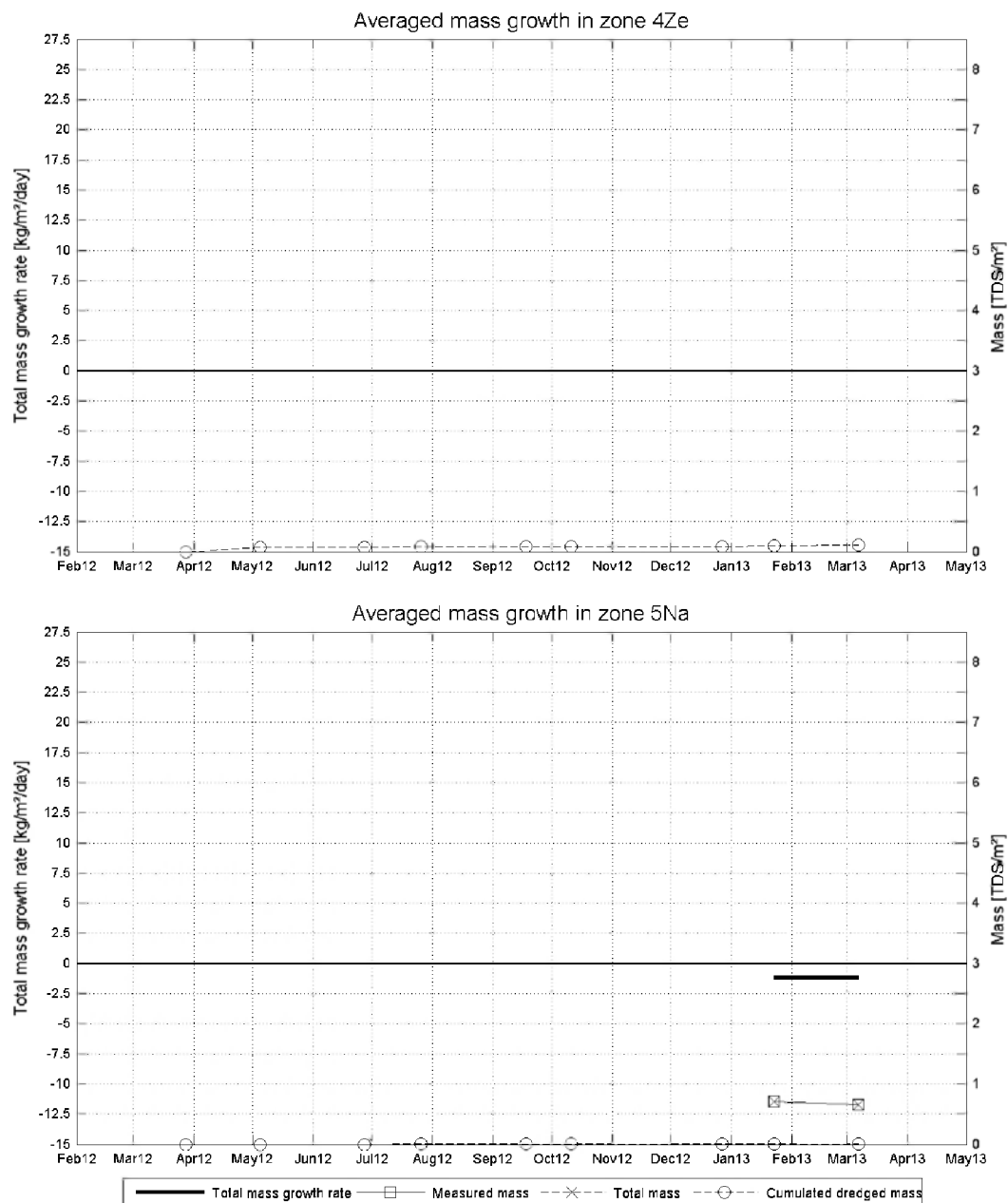
Measured/Dredged/Total Mass

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

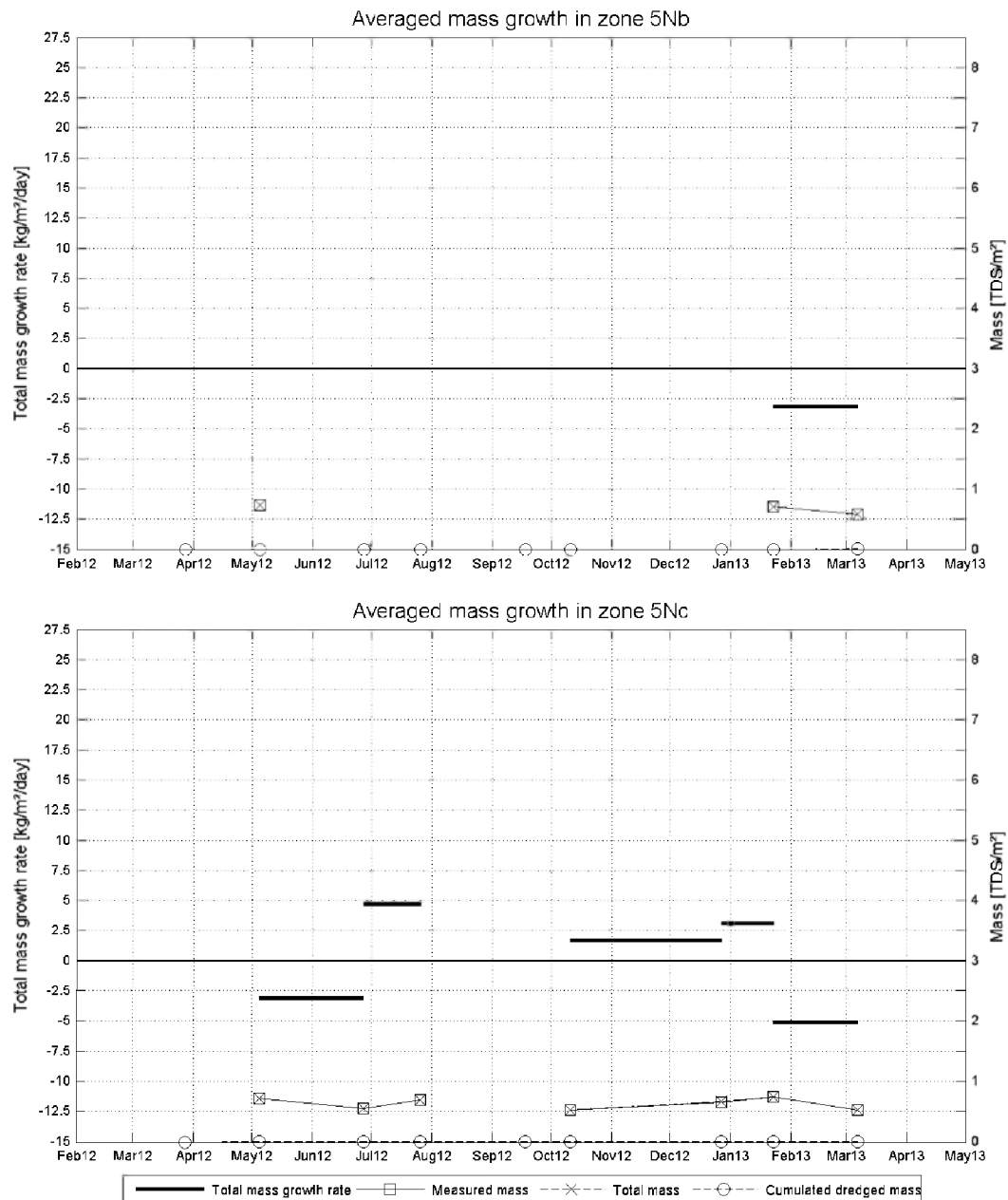
Measured/Dredged/Total Mass

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

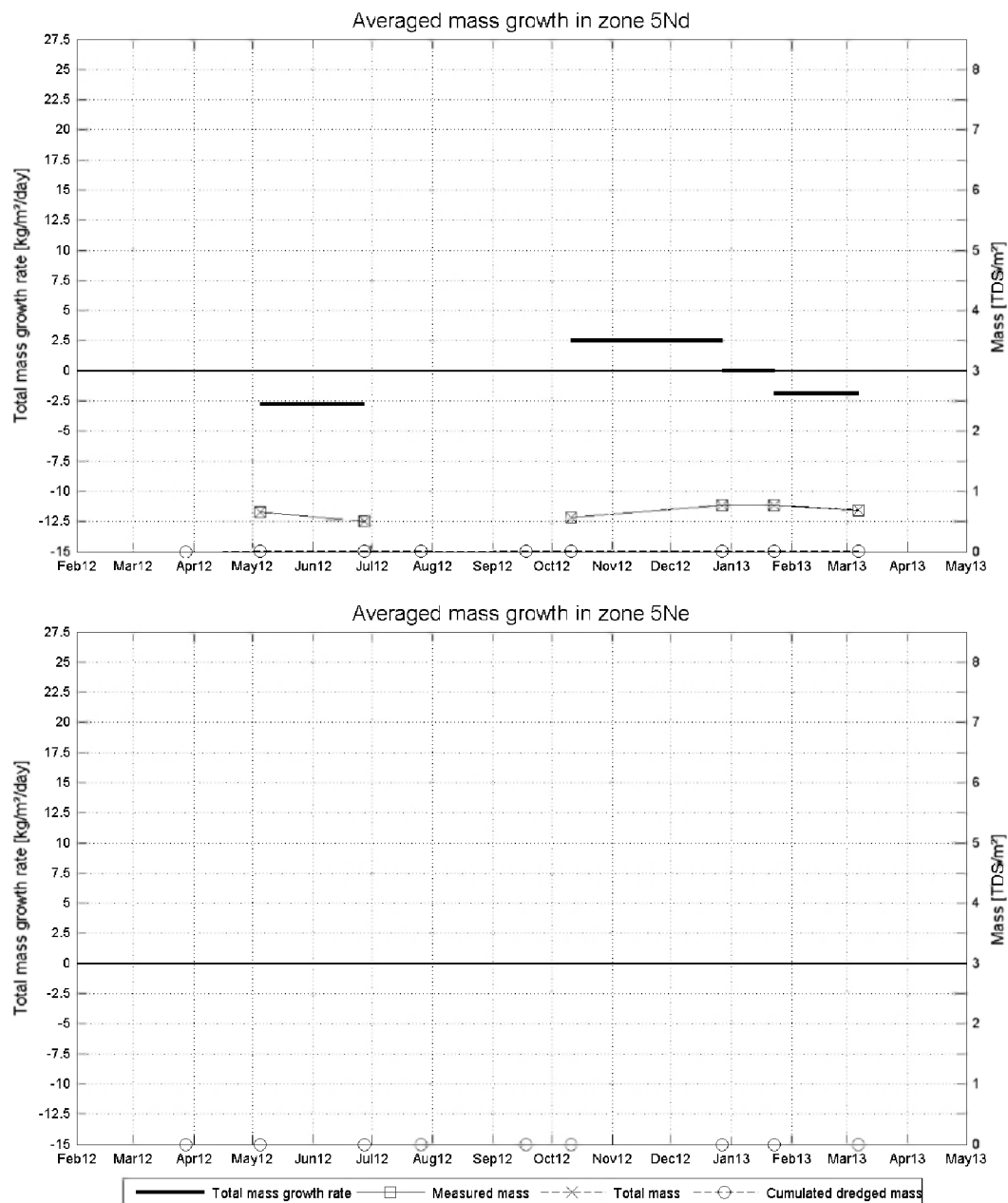
Measured/Dredged/Total Mass

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

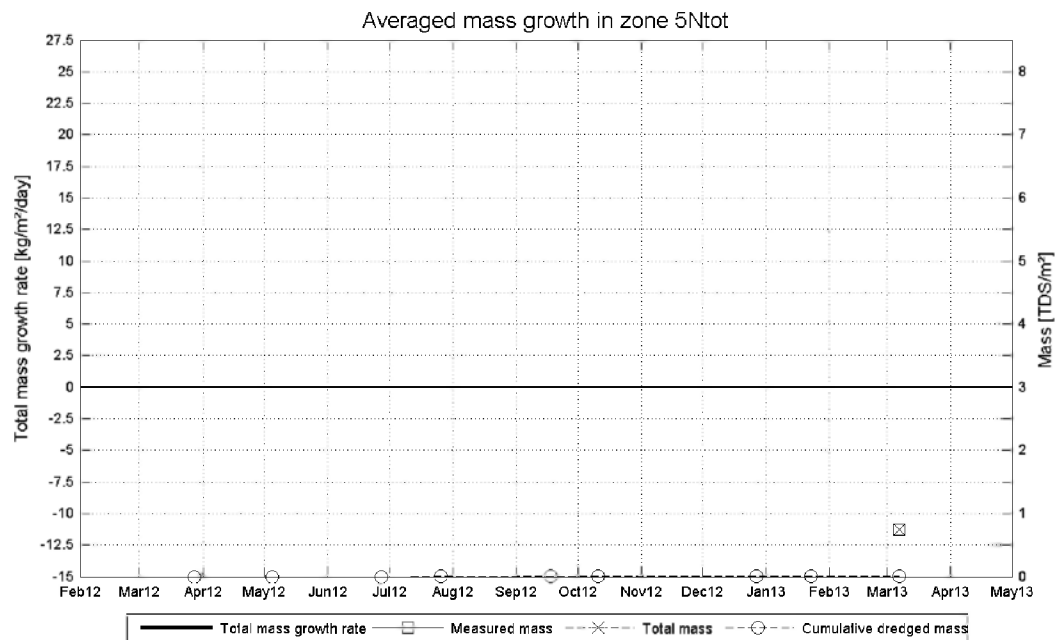
Measured/Dredged/Total Mass

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

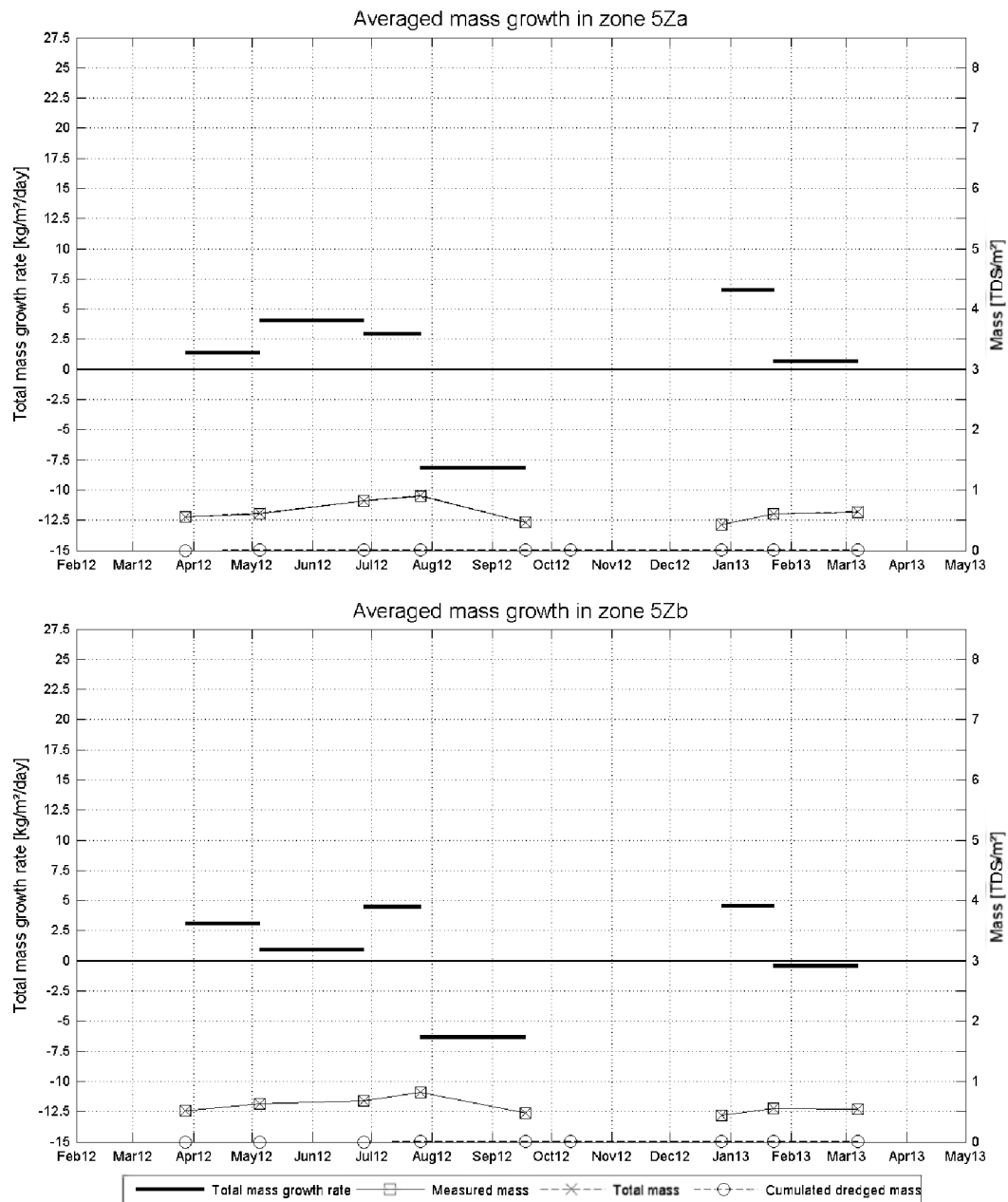
Measured/Dredged/Total Mass

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

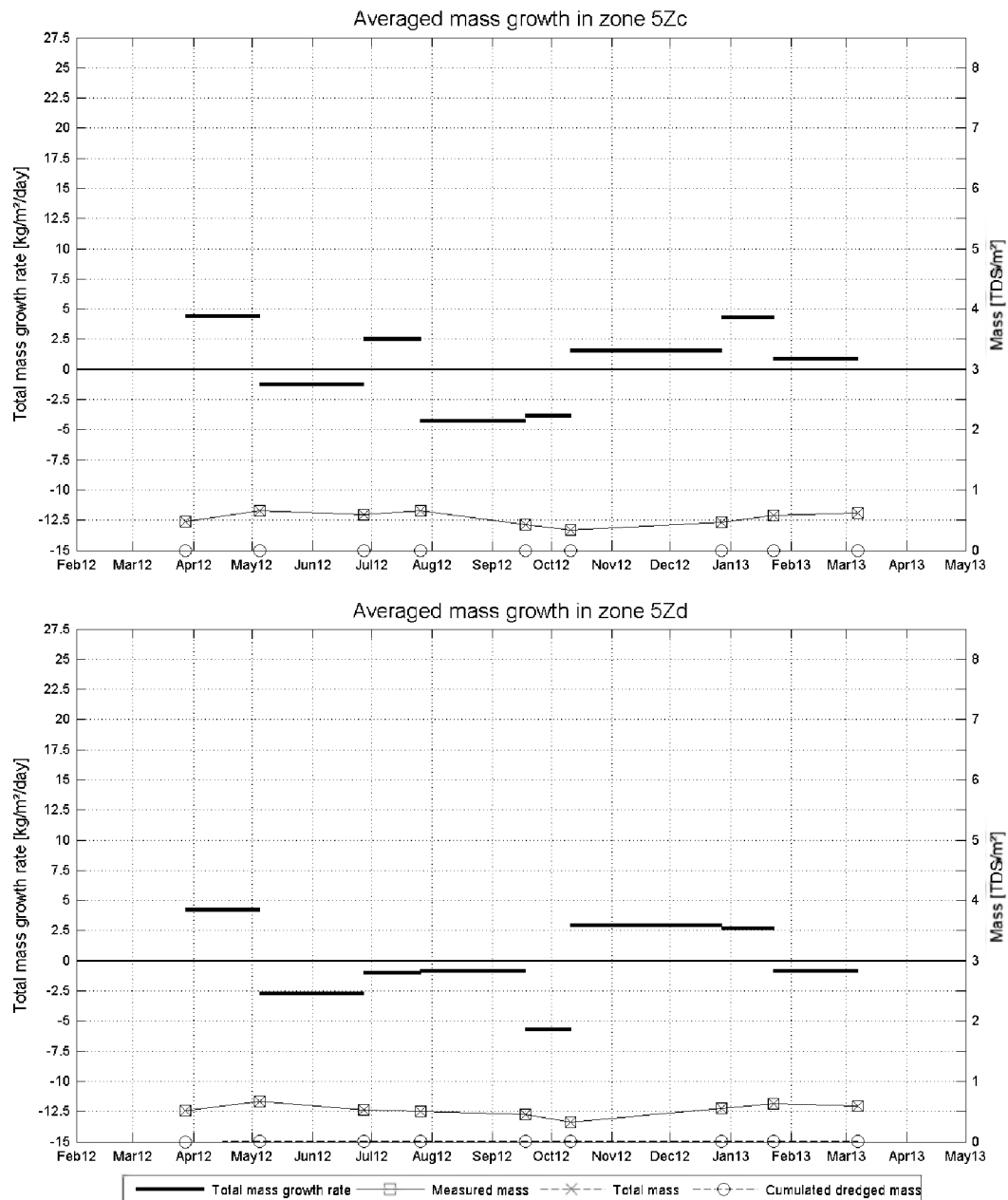
Measured/Dredged/Total Mass

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

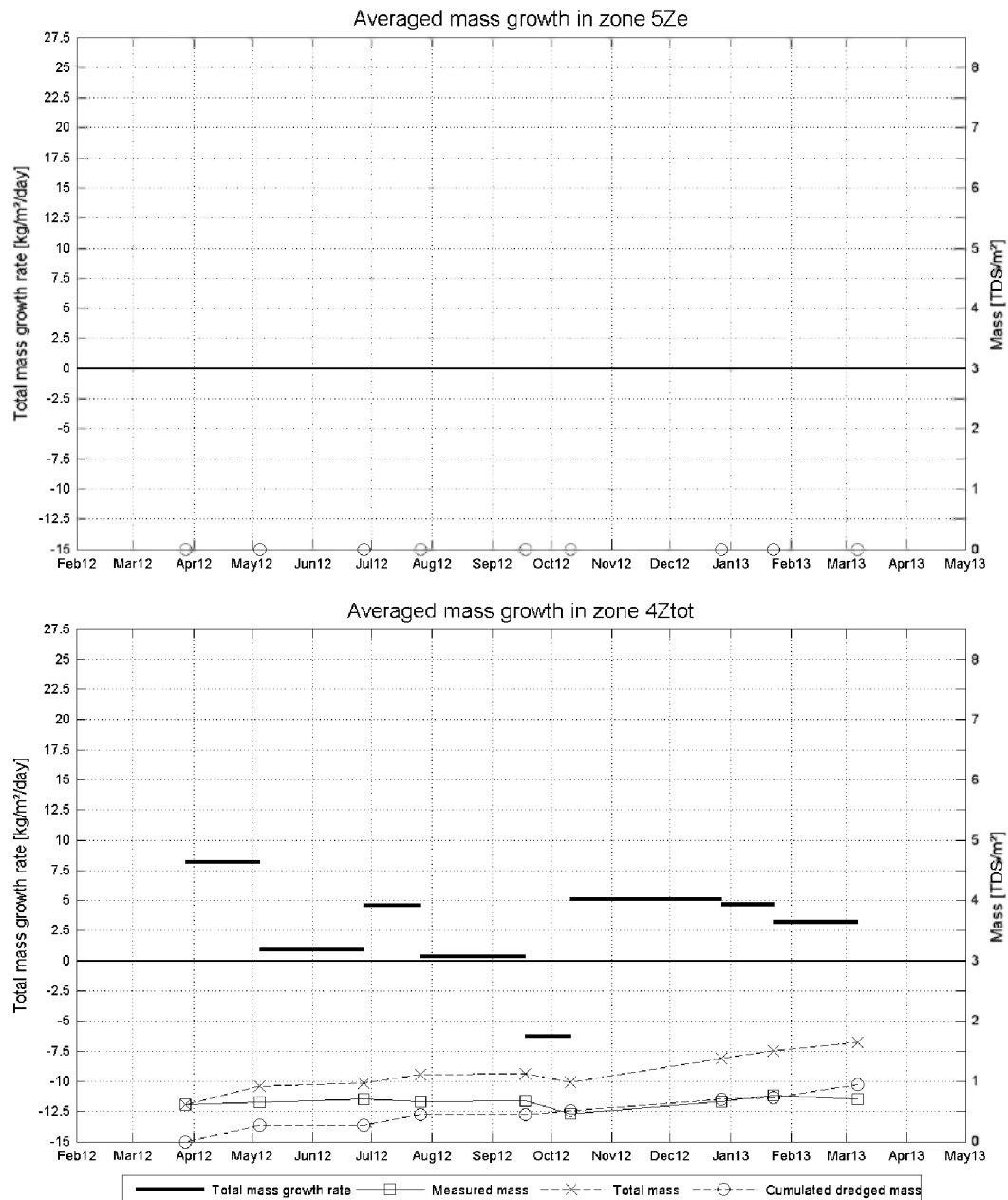
Measured/Dredged/Total Mass

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



I.3 FOR CENTRAL TRENCH AREA OF DEURGANCKDOK

Evaluation of external effects on the siltation of Deurganckdok

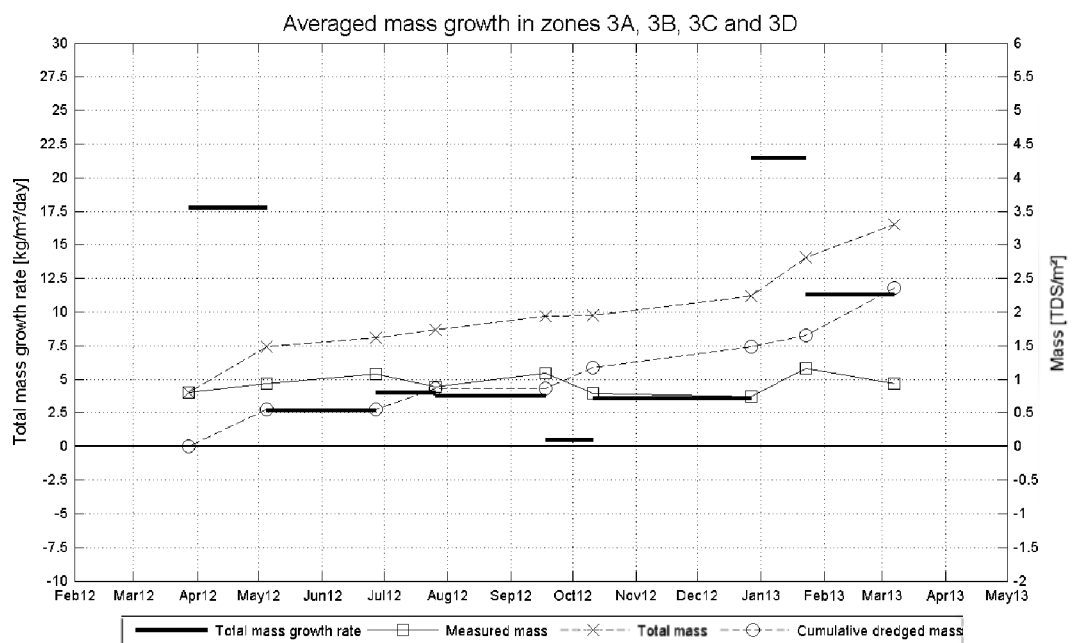
Measured/Dredged/Total Mass

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :



I/RA/11406/13.143/JCA



Evaluation of external effects on the siltation of Deurganckdok

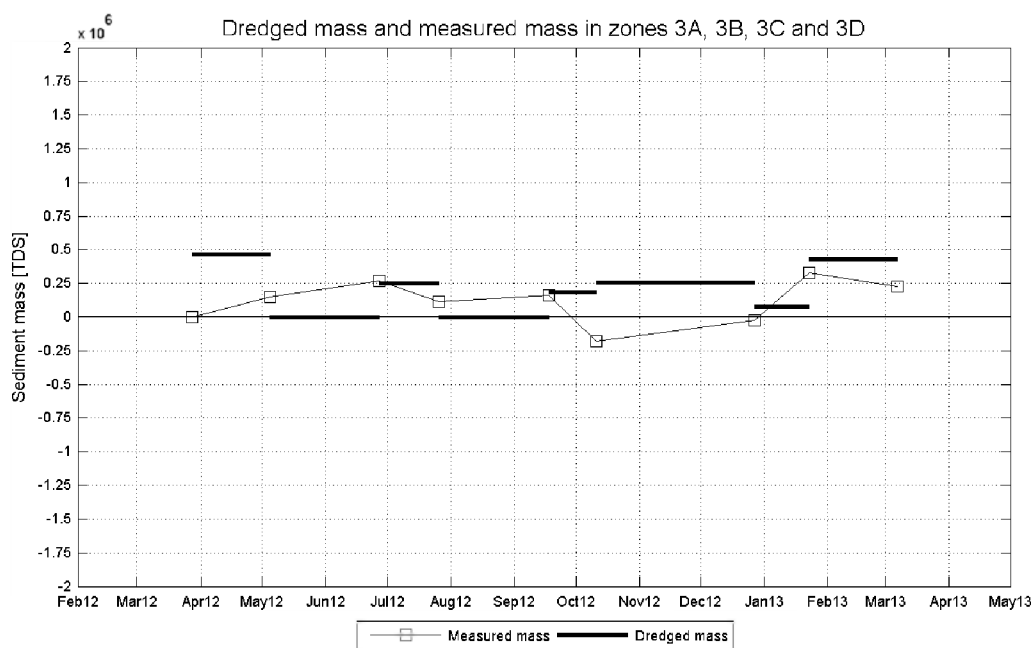
Measured/Dredged/Total Mass

Equipment(s):

Navitracker/GraviProbe/DensiTune

Location:

DGD



Data Processed by:

In association with :

I/RA/11406/13.143/JCA



Annex J DREDGING DATA

Table 7-12: Dredged mass in covered area [TDS] between consecutive density measurement campaigns. For March 28th 2012 to March 07th 2013.

	28/Mar	05/May	27/Jun	26/Jul	18/Sep	11/Oct	27/Dec	23/Jan		
	05/May	27/Jun	26/Jul	18/Sep	11/Oct	27/Dec	23/Jan	07/Mar	Total	%
1	27,261	0	20,530	0	5,630	12187	377	5685	71669	4.3%
2	62,257	0	40,525	0	22,849	41402	1511	12027	180572	10.8%
3a	59,716	0	53,677	0	43,447	64000	11475	53091	285405	17.0%
3b	57,681	0	35,176	0	45,376	47434	24802	68541	279011	16.6%
3c	49,627	0	20,111	0	27,970	18869	18463	78036	213075	12.7%
3d	73,874	0	26,137	0	19,851	9876	15337	111346	256421	15.3%
3e	42,268	0	6,117	0	2,066	776	2097	34208	87532	5.2%
4Na	19,718	0	11,910	0	4,489	20025	529	10756	67426	4.0%
4Nb	11,890	0	6,540	0	3,212	11244	1289	9967	44142	2.6%
4Nc	5,646	0	3,149	0	937	3355	389	9134	22610	1.3%
4Nd	11,117	0	2,573	0	856	583	184	9509	24824	1.5%
4Ne	4,499	0	249	0	0	80	60	836	5723	0.3%
4Za	12,319	0	11,243	0	5,031	13001	588	4570	46752	2.8%
4Zb	10,751	0	6,325	0	2,983	11233	951	9309	41552	2.5%
4Zc	6,078	0	3,228	0	1,082	3147	940	7178	21653	1.3%
4Zd	8,943	0	3,729	0	940	898	1159	8719	24389	1.5%

	28/Mar	05/May	27/Jun	26/Jul	18/Sep	11/Oct	27/Dec	23/Jan		
4Ze	2,284	0	323	0	13	56	229	269	3173	0.2%
5Na	0	0	19	0	0	23	0	0	42	0.0%
5Nb	0	0	0	0	0	0	0	11	11	0.0%
5Nc	33	0	0	0	0	0	0	0	33	0.0%
5Nd	14	0	0	0	0	0	0	51	65	0.0%
5Ne	0	0	0	0	0	0	0	0	0	0.0%
5Za	28	0	74	0	0	6	0	0	107	0.0%
5Zb	0	0	40	0	0	11	0	8	58	0.0%
5Zc	0	0	0	0	0	0	0	0	0	0.0%
5Zd	33	0	0	0	0	0	0	0	33	0.0%
5Ze	0	0	0	0	0	0	0	0	0	0.0%
4Ztot	41,193	0	25,650	0	10,200	28928	4069	30889	140929	8.4%
4Ntot	52,917	0	24,427	0	9,493	35310	2451	40265	164863	9.8%
5Ztot	61	0	110	0	0	11	0	3	186	0.0%
5Ntot	0	0	13	0	0	0	0	0	13	0.0%
Total 3a-3e	283,167	0	141,218	0	138,711	258205	80379	433250	1676280	4.3%
Total	560,209	0	301,874	0	206,427	12187	377	5685	71669	100.0%
%	27.8%	0.0%	15.0%	0.0%	11.1%	15.4%	4.8%	25.8%	100.0%	

Annex K MAINTENANCE DREDGING DEPTHS SINCE MARCH 2011

