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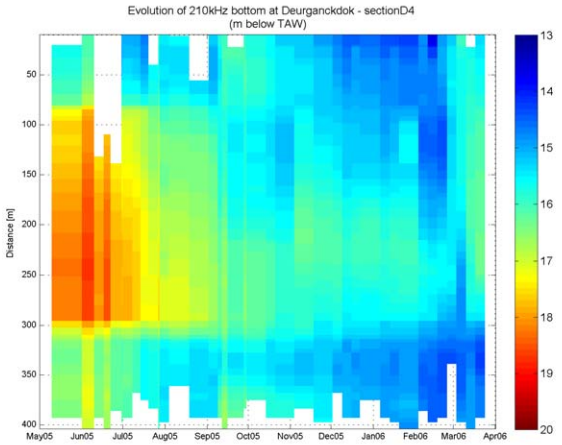
DEPARTEMENT MOBILITEIT EN OPENBARE WERKEN
WATERBOUWKUNDIG LABORATORIUM

Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing

Bestek 16EB/05/04

Deurganckdok– Evolution of water-bed interface in a cross-section of Deurganckdok



Deelrapport 1.1: Sediment balans 01/04/2006 – 30/06/2006

Report 1.1: Sediment balance 01/04/2006 – 30/06/2006

26 April 2007
I/RA/11283/06.113/MSA

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GLOSSARY

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

1. INTRODUCTION

1.1. The assignment

This report is part of the set of reports describing the results of the long-term measurements conducted in Deurganckdok aiming at the monitoring and analysis of silt accretion. This measurement campaign is an extension of the study "Extension of the study about density currents in the Beneden Zeeschelde" as part of the Long Term Vision for the Scheldt estuary. It is complementary to the study 'Field measurements high-concentration benthic suspensions (HCBS 2)'[1].

The terms of reference for this study were prepared by the 'Departement Mobiliteit en Openbare Werken van de Vlaamse Overheid, Afdeling Waterbouwkundig Laboratorium' (16EB/05/04). The repetition of this study was awarded to International Marine and Dredging Consultants NV in association with WL|Delft Hydraulics and Gems International on 10/01/2006.

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

The execution of the study involves a twofold assignment:

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

1.2. Purpose of the study

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

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

The first part of the study focuses on obtaining a sediment balance of Deurganckdok. Aside from natural sedimentation, the sediment balance is influenced by the maintenance and capital dredging works. This involves sediment influx from capital dredging works in the Deurganckdok, and internal relocation and removal of sediment by maintenance dredging works. To compute a sediment

[1] Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies

balance an inventory of bathymetric data (depth soundings), density measurements of the deposited material and detailed information of capital and maintenance dredging works will be made up.

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

1.3. Overview of the reports

1.3.1. Reports

Reports of the project 'Opvolging aanslibbing Deurganckdok' are summarized in Table 1-1.

Reports of the measurement campaign HCBS2 for which the winter campaign has been carried out simultaneously with the trough tide measurements in this project are listed in APPENDIX E.

Table 1-1: Overview of Deurganckdok Reports

Report	Description
Sediment Balance: Bathymetry surveys, Density measurements, Maintenance and construction dredging activities	
1.1	Sediment Balance: Three monthly report 1/4/2006 – 30/06/2006 (I/RA/11283/06.113/MSA)
1.2	Sediment Balance: Three monthly report 1/7/2006 – 30/09/2006 (I/RA/11283/06.114/MSA)
1.3	Sediment Balance: Three monthly report 1/10/2006 – 31/12/2006 (I/RA/11283/06.115/MSA)
1.4	Sediment Balance: Three monthly report 1/1/2007 – 31/03/2007 (I/RA/11283/06.116/MSA)
1.5	Annual Sediment Balance (I/RA/11283/06.117/MSA)
1.6	Sediment balance Bathymetry: 2005 – 3/2006 (I/RA/11283/06.118/MSA)
Factors contributing to salt and sediment distribution in Deurganckdok: Salt-Silt (OBS3A) & Frame measurements, Through tide measurements (SiltProfiling & ADCP)	
2.1	Through tide measurement Siltprofiler 21/03/2006 Laure Marie (I/RA/11283/06.087/WGO)
2.2	Through tide measurement Siltprofiler 26/09/2006 Stream (I/RA/11283/06.068/MSA)
2.3	Through tide measurement Sediview spring tide 22/03/2006 Veremans (I/RA/11283/06.110/BDC)
2.4	Through tide measurement Sediview spring tide 27/09/2006 Parel 2 (I/RA/11283/06.119/MSA)
2.5	Through tide measurement Sediview neap tide (to be scheduled) (I/RA/11283/06.120/MSA)
2.6	Salt-Silt distribution & Frame Measurements Deurganckdok 13/3/2006 – 31/05/2006

Report	Description
	(I/RA/11283/06.121/MSA)
2.7	Salt-Silt distribution & Frame Measurements Deurganckdok 15/07/2006 – 31/10/2006 (I/RA/11283/06.122/MSA)
2.8	Salt-Silt distribution & Frame Measurements Deurganckdok 15/01/2007 – 15/03/2007 (I/RA/11283/06.123/MSA)
Boundary Conditions: Upriver Discharge, Salt concentration Scheldt, Bathymetric evolution in access channels, dredging activities in Lower Sea Scheldt and access channels	
3.1	Boundary conditions: Three monthly report 1/1/2007 – 31/03/2007 (I/RA/11283/06.127/MSA)
3.2	Boundary condtions: Annual report (I/RA/11283/06.128/MSA)
Analysis	
4	Analysis of Siltation Processes and Factors (I/RA/11283/06.129/MSA)
Calibration	
6.1	Winter Calibration (I/RA/11291/06.092/MSA)
6.2	Summer Calibration and Final Report (I/RA/11291/06.093/MSA)

1.3.2. Measurement actions

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

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

In situ calibrations were conducted on several dates (15 March 2006; 14/04/2006; 23/06/2006; 18/09/2006) to calibrate all turbidity and conductivity sensors (IMDC, 2006f & IMDC, 2007l).

1.4. Structure of the report

This report is the sediment balance of the Deurganckdok for the period of 01/04/2006 to 30/06/2006. The first chapter comprises an introduction. The second chapter describes the project. Chapter 3 describes the methodology. The measurement results and processed data are presented in Chapter 4, whereas chapter 5 gives a preliminary analysis of the data.

2. SEDIMENTATION IN DEURGANCKDOK

2.1. Project Area: Deurganckdok

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

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

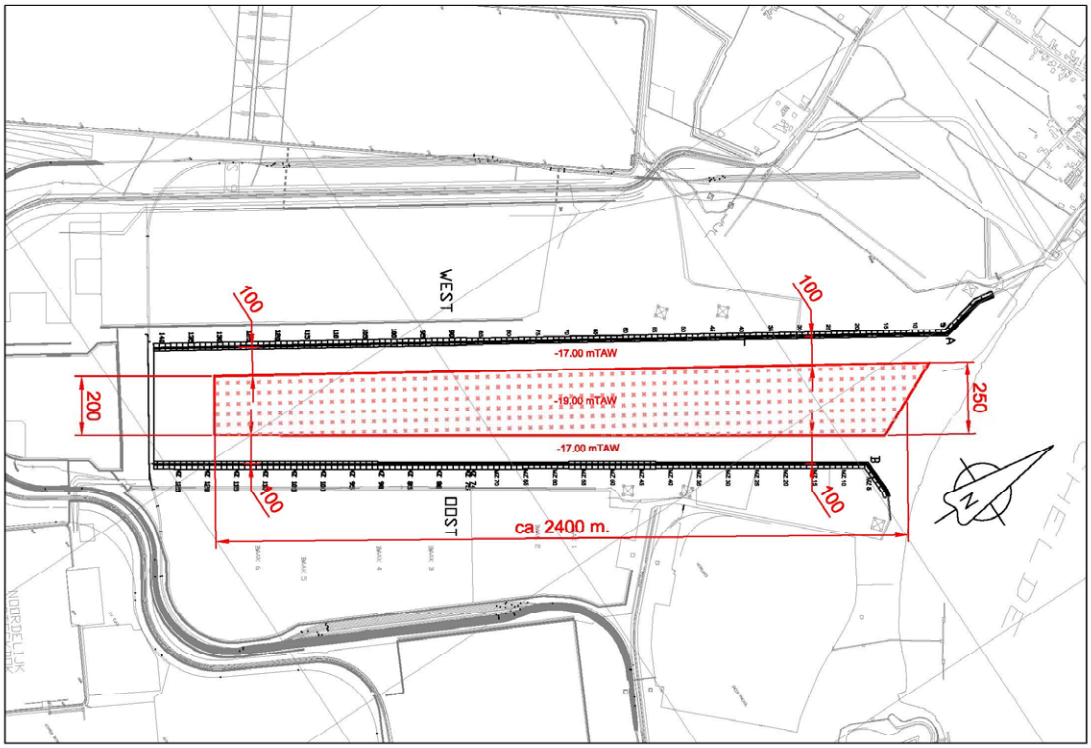


Figure 2-1: Overview of Deurganckdok

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

2.2. Overview of the studied parameters

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

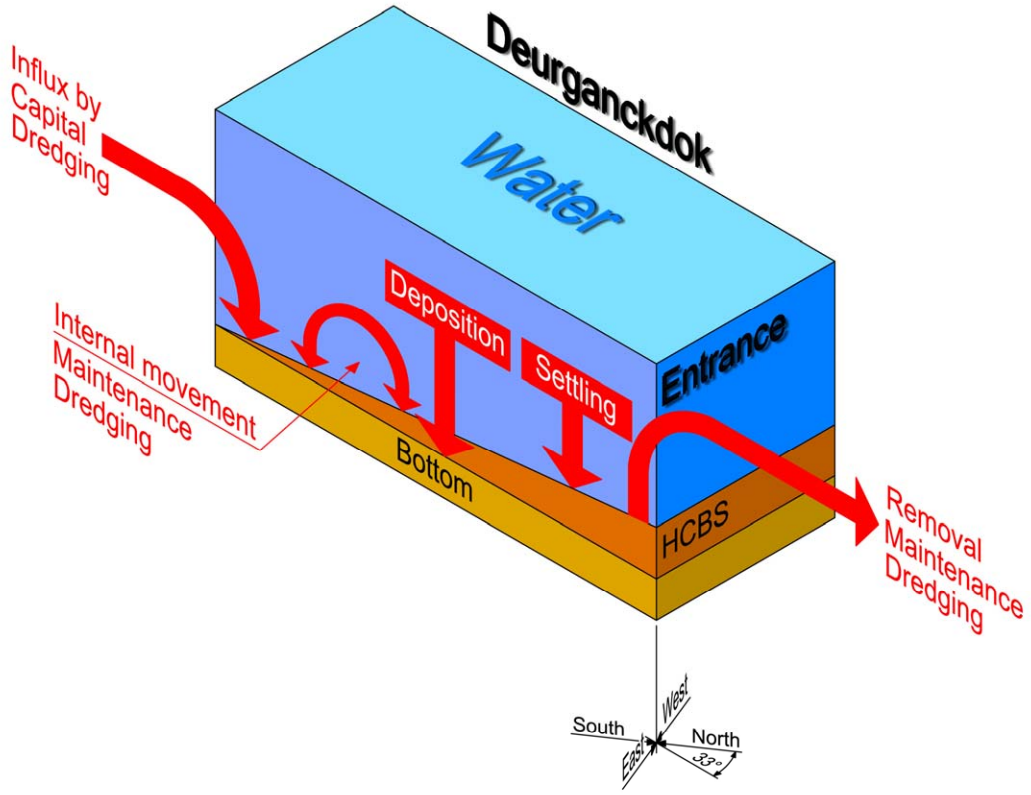


Figure 2-2: Elements of the sediment balance

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

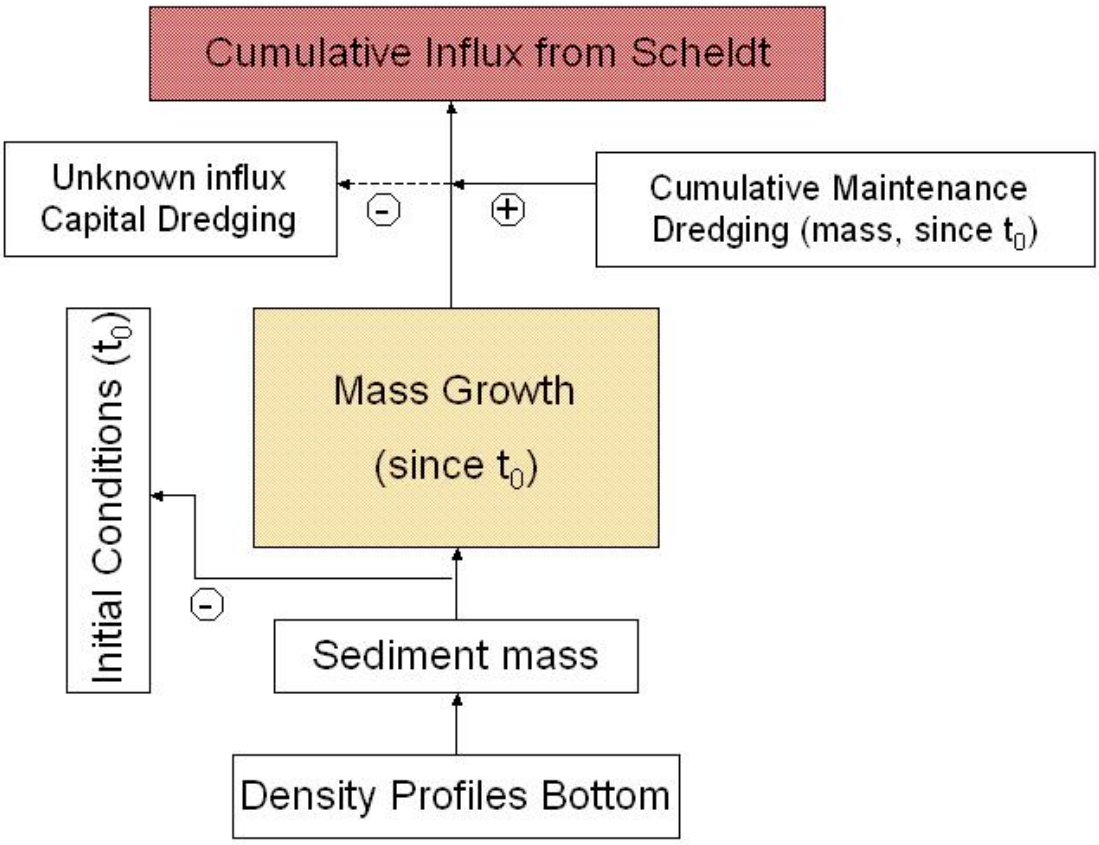


Figure 2-3: Determining a sediment balance

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

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

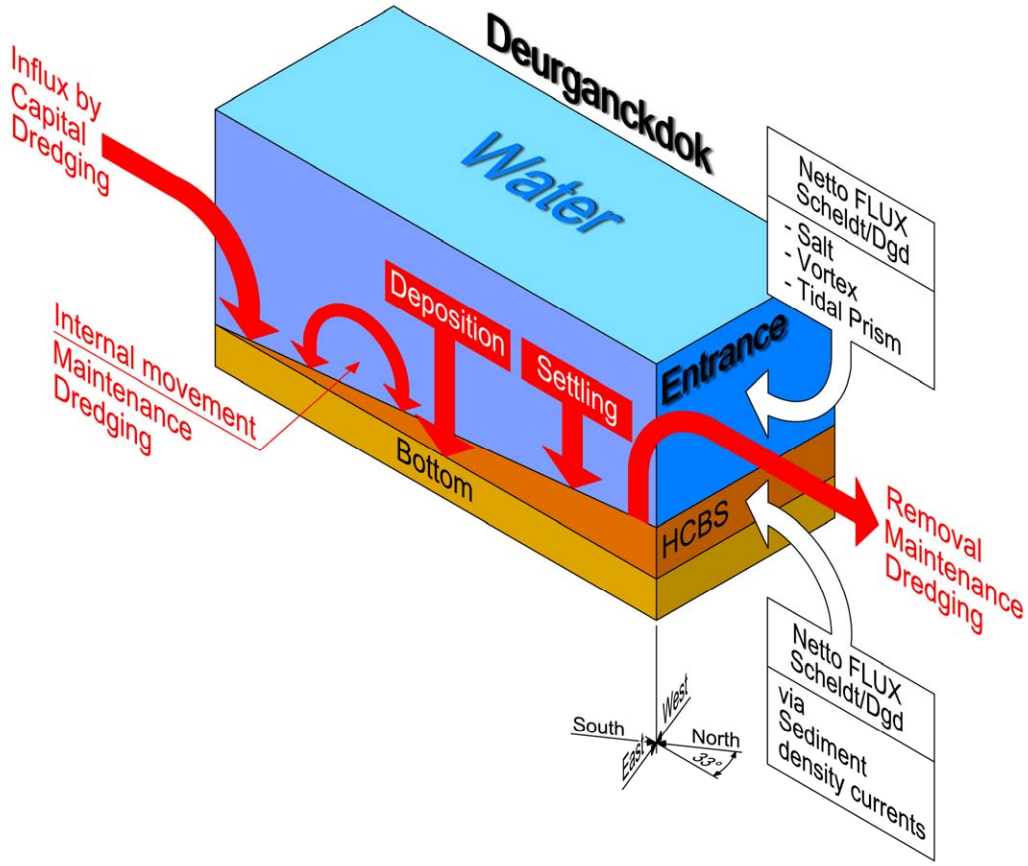


Figure 2-4: Transport mechanisms

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

Following data are being collected to understand these mechanisms:

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

3. MEASUREMENTS

3.1. Depth soundings

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

Table 3-1: Overview of the available depth soundings suitable for analysis 01/04/2006 – 30/06/2006

date	***type of measurement***	***signal***	***Source***
24/03/2006*	dual frequency 210-33 kHz	210	Afdeling Kust
14/04/2006	dual frequency 210-33 kHz	210	Afdeling Kust
21/04/2006	dual frequency 210-33 kHz	210	Afdeling Kust
28/04/2006	dual frequency 210-33 kHz	210	Afdeling Kust
12/05/2006	dual frequency 210-33 kHz	210	Afdeling Kust
26/05/2006	dual frequency 210-33 kHz	210	Afdeling Kust
9/06/2006	dual frequency 210-33 kHz	210	Afdeling Kust
30/06/2006	dual frequency 210-33 kHz	210	Afdeling Kust

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

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

A number of analyses were done using the depth soundings in Table 3-1. The raw depth sounding data was processed in ESRI ArcGIS. Only 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, effectively the earliest most complete measurement. This turned out to be the measurement on 24 March 2006. This will be considered as a reference situation, initial condition t_{0e}.

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

3.2. Density measurements

Navitracker was used to perform density measurements Density measurements are necessary to calculate a sediment balance of dry weight of sediment per surface unit.

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.

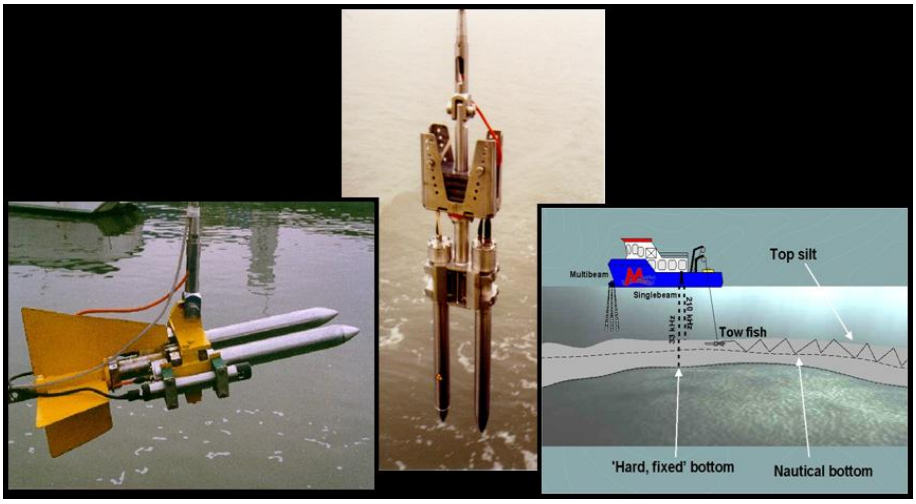


Figure 3-1: Navitracker

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.

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

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

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

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

There were no density measurements performed during this 3-month period.

3.3. Maintenance Dredging Data

All maintenance dredging (except sweep beam) activities in Deurganckdok were collected in the BIS-system. This system gives a standardised output per week, that states the weight, volume and V'[2] 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.

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

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

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

Table 3-3: Sweep beam Maintenance dredging activities in Deurganckdok and on the sill of Deurganckdok between April and June 2006 (source: Afdeling Maritieme Toegang)

From	***Till***	***Duration (days)***	***Location***
3/4/2006	3/4/2006	1	Sill DGD
10/4/2006	10/4/2006	1	Sill DGD
18/4/2006	22/4/2006	5	DGD+ Zandvliet Container Dock
24/4/2006	24/4/2006	1	Sill DGD
2/5/2006	6/5/2006	5	DGD
8/5/2006	8/5/2006	1	Sill DGD
15/5/2006	15/5/2006	1	Sill DGD
22/5/2006	22/5/2006	1	Sill DGD
29/5/2006	29/5/2006	1	Sill DGD
30/05/2006	3/6/2006	5	DGD commercial quays
6/6/2006	6/6/2006	1	Sill DGD
7/6/2006	8/6/2006	1	DGD commercial quays
12/6/2006	12/6/2006	1	Sill DGD
13/6/2006	17/6/2006	5	DGD
19/6/2006	19/06/2006	1	Sill DGD
26/6/2006	26/6/2006	1	Sill DGD

An overview of the total dredged mass in all zones (BIS data) is provided APPENDIX D.

[2] V' = Reduced Volume

4. SEDIMENT BALANCE ANALYSES

4.1. Project Area: (Sub)Zones and Sections

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

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

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

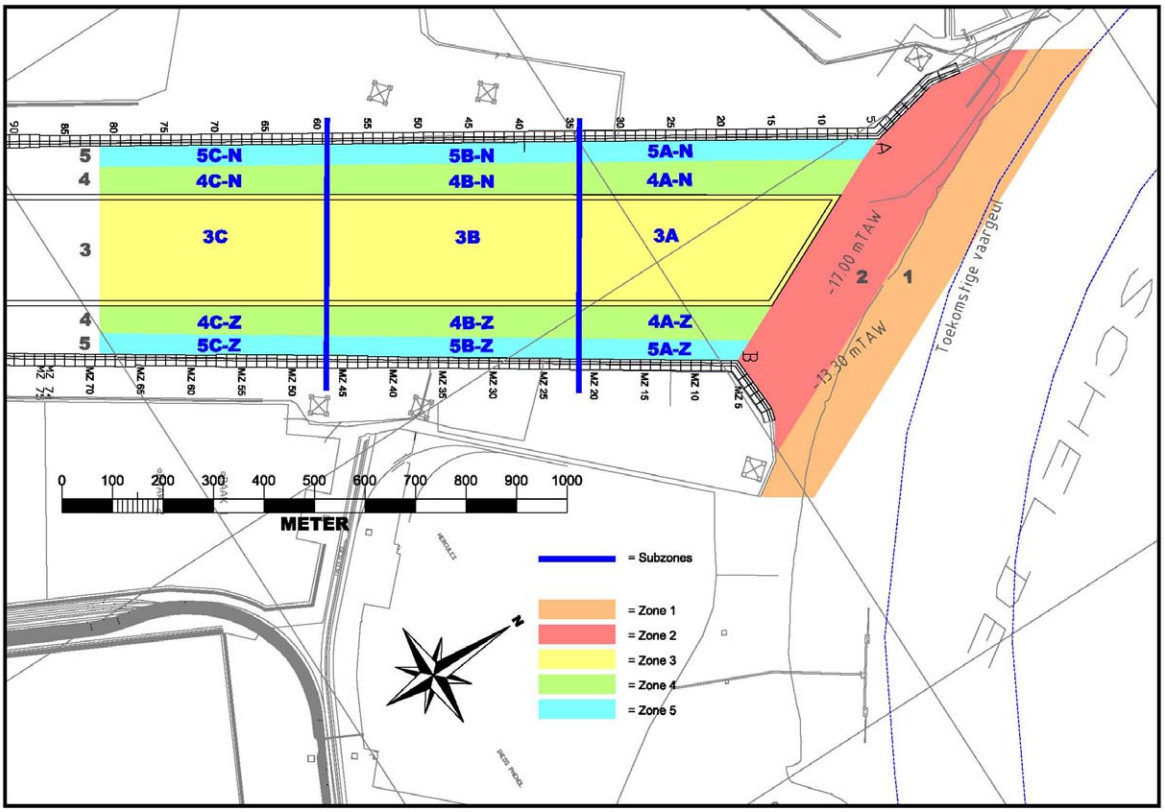


Figure 4-1: Deurganckdok: Zones and Subzones

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

- D sections are oriented perpendicular to the quay walls inside the dock and parallel to the navigation channel outside the dock (sill and Scheldt). The origin of the sections is taken on the quay wall at the left bank (West side) looking outwards.

- L Sections are oriented along the centerline of the dock and run from the navigation channel towards the inland end of the dock, in anticipation of the realisation of the third phase of Deurganckdok. The origin is situated on the intersection between each L section and section D10.

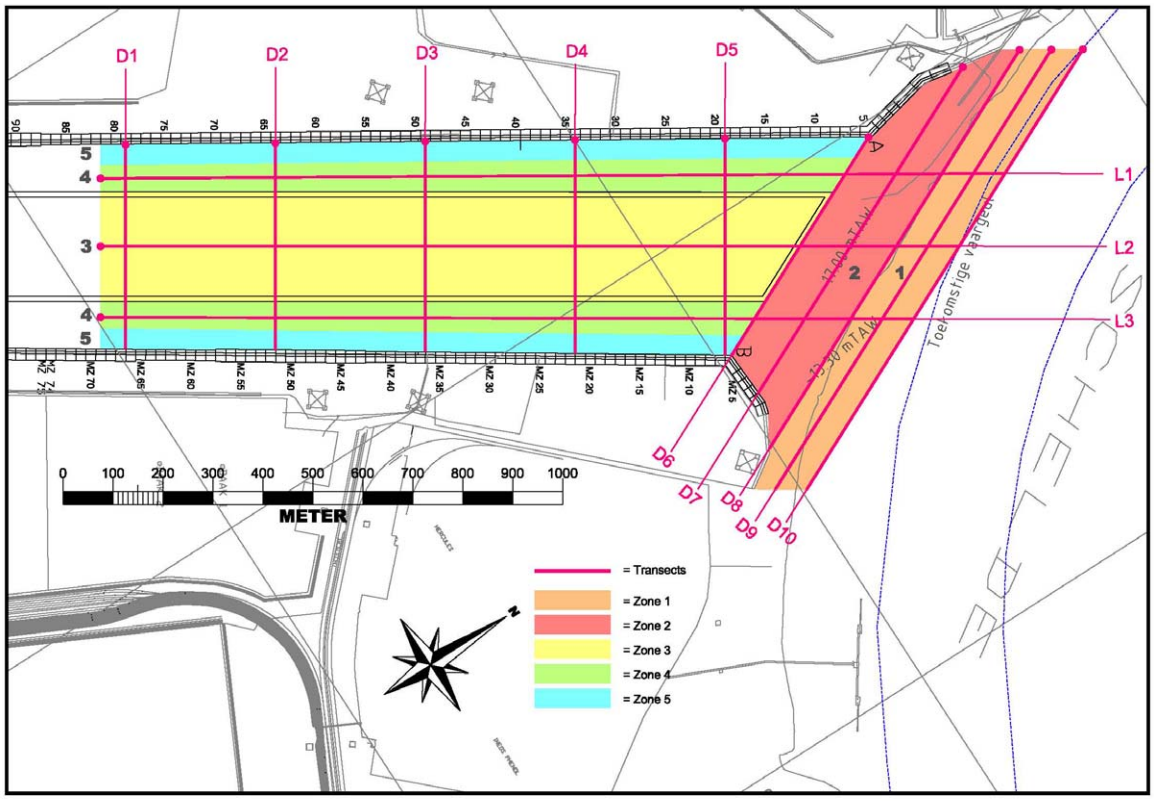


Figure 4-2: Deurganckdok: D and L Sections

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

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

Name	***Origin***		***End***	
	Easting	***Northing***	***Easting***	***Northing***
D Sections				
D1	587773	5683253	588123	5683037
D2	587929	5683510	588283	5683290
D3	588084	5683767	588444	5683544
D4	588239	5684023	588604	5683797
D5	588394	5684280	588765	5684051
D6	588542	5684526	588772	5684062
D7	588521	5684761	588864	5684068
D8	588552	5684875	588972	5684027
D9	588585	5684930	589047	5683994
D10	588617	5684984	589081	5684047
L Sections				
L1	588748	5684720	587805	5683175
L2	588825	5684565	587921	5683103
L3	588901	5684410	588043	5683028

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

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

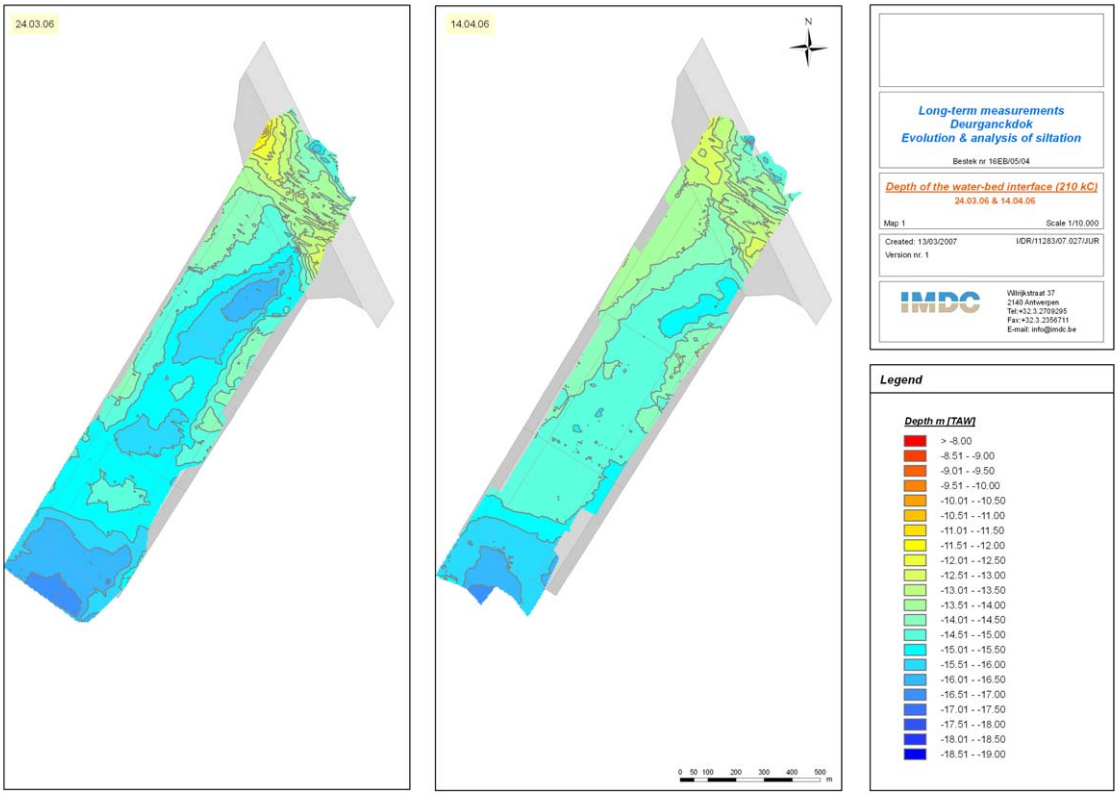


Figure 4-3: Example of a map showing depth of water-bed interface (210 kC) for 24/03/06 and 14/04/06

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

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

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

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

Maps and graphs are shown in APPENDIX B.

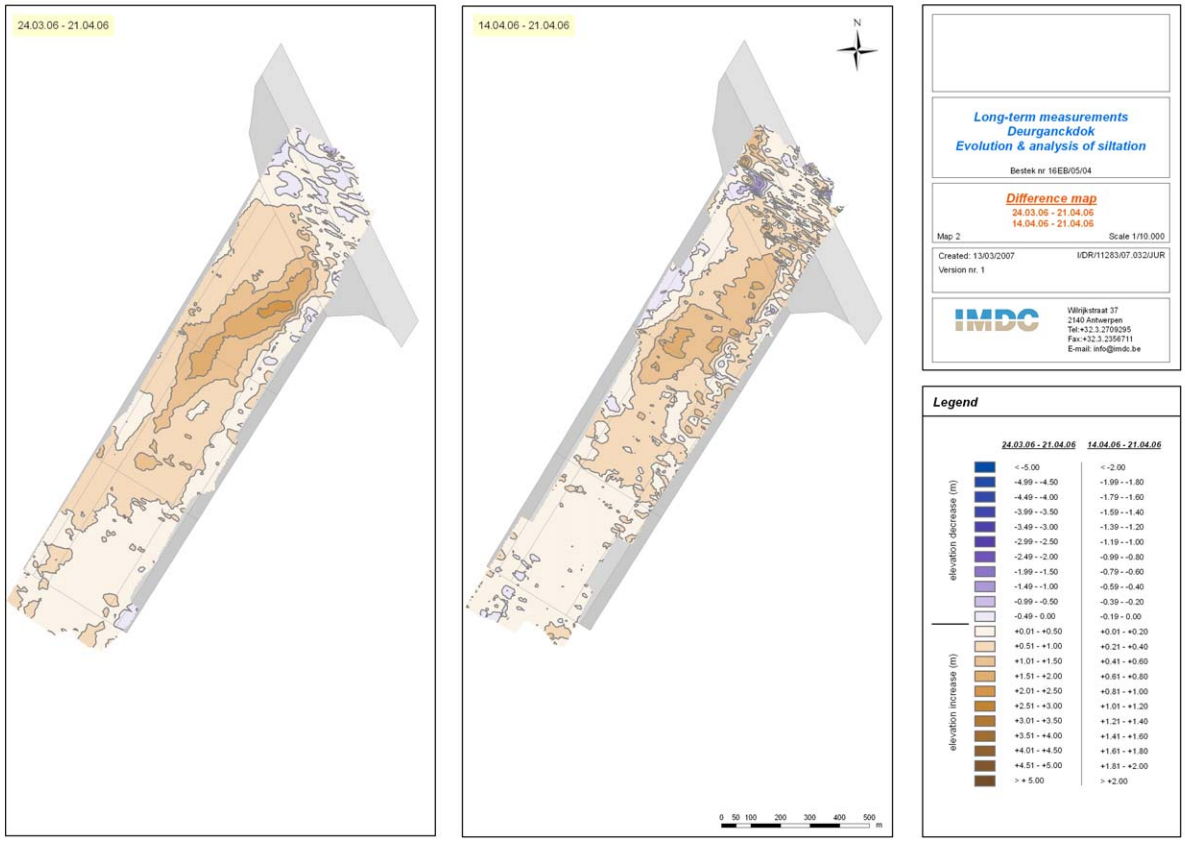


Figure 4-4: Difference charts of the depth sounding on 21/0406: in reference to t_{0e} (left), and to the previous measurement (right) on 14/04/06

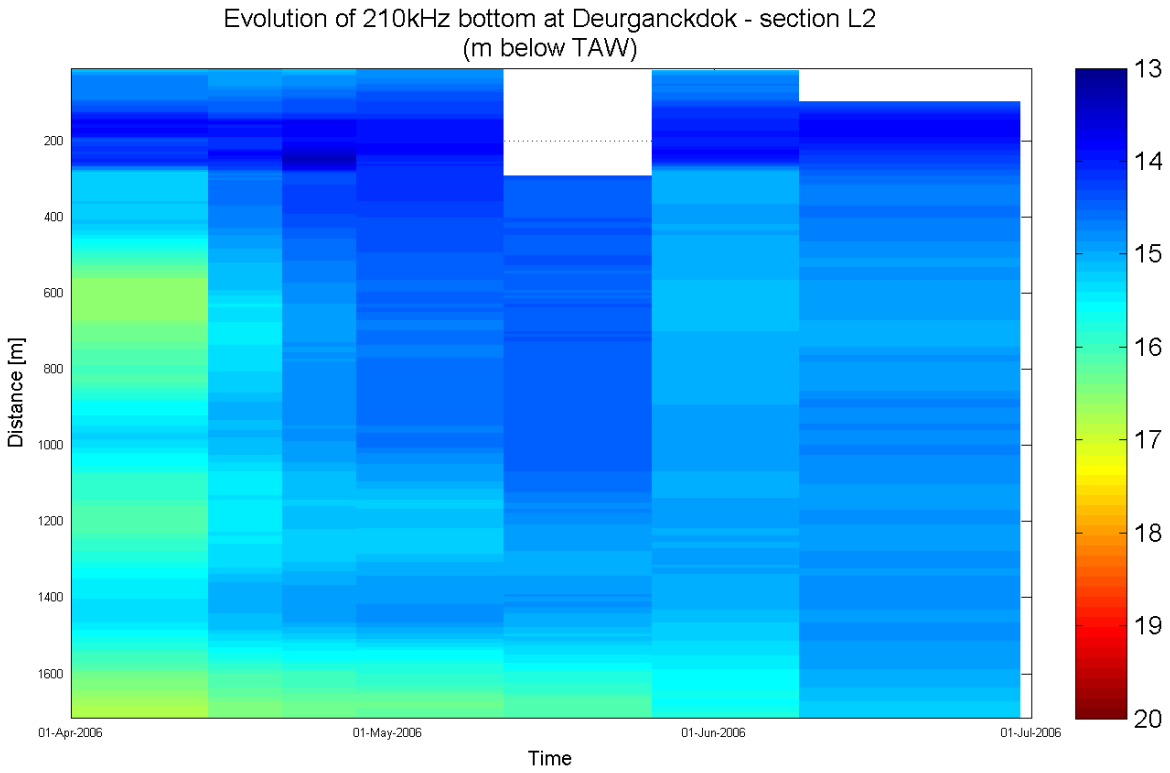


Figure 4-5: Graph of Evolution of the water-bed interface (210 kC) for section L2

4.4. Volumetric siltation rates in different zones and sections

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

Graphs in APPENDIX C show two parameters:

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

Dredging events from the BIS system are marked on each of these graphs. This is computed for all zones, subzones, sections and Deurganckdok as a whole. As an example we show siltation rate and cumulative bed level change for section D4 in Figure 4-6.

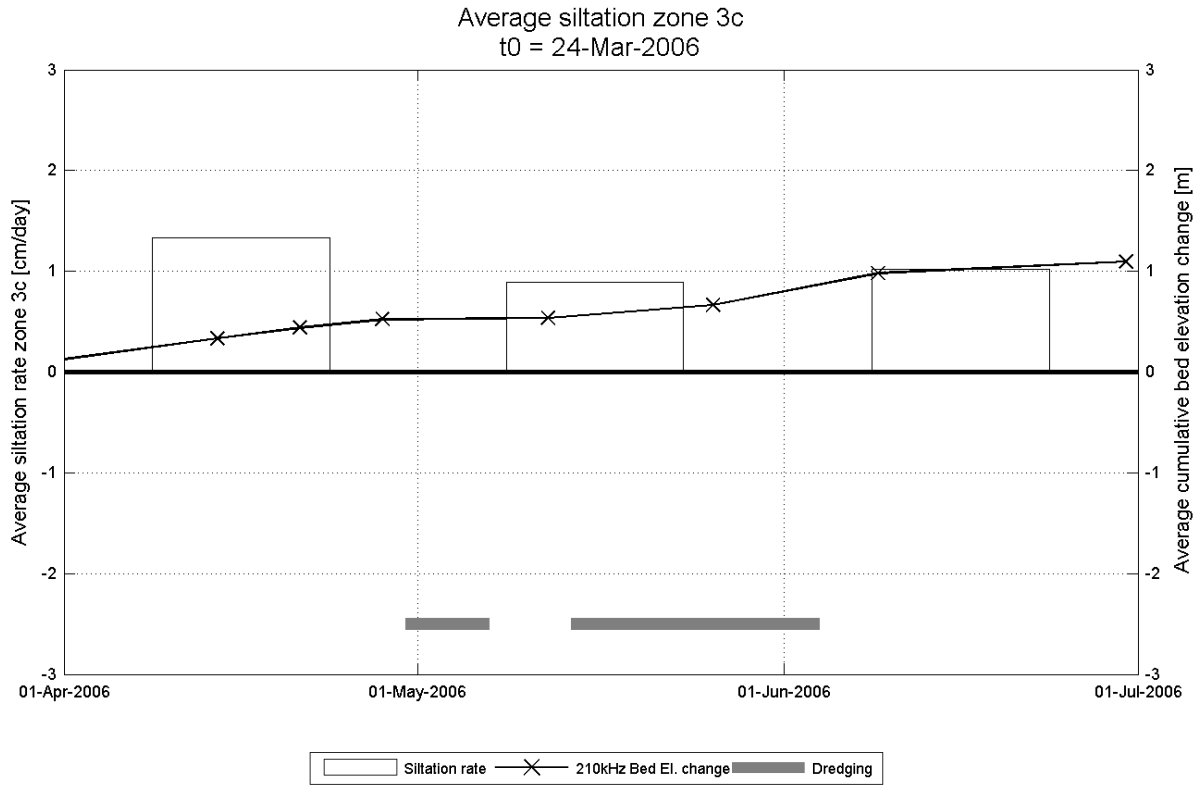


Figure 4-6: Volumetric siltation rate for zone 3c

5. PRELIMINARY ANALYSIS OF THE DATA

Depth sounding and dredging data are available for the period from April 2006 until June 2006. Therefore only a volumetric analysis can be performed.

Depth sounding data is processed to show the evolution of average volume per unit of surface, i.e. the average evolution of bed evolution as detected by a 210kHz sounder. If more than 50% of the area of a (sub)zone is covered an average siltation rate can be calculated. During this period a adequate coverage was attained during depth soundings, except for zone 1 and zones 5A-Z, 5B-Z and 5C-Z.

BIS data reveals that between the reference depth sounding on 24 March 2006 and the end of April no maintenance dredging was done in Deurganckdok excluding sweepbeam dredging on the sill and next to the quay walls. Between the end of April and the beginning of June a fair amount of hopper maintenance dredging was performed in Deurganckdok. The largest amount of dredged mass was removed in the week of 30 April till 7 May 2006 (156 672 TDS).

Keeping this in mind when looking at the bed elevation maps and difference maps, it can be seen that between 24 March 2006 and 28 April 2006 an increase in elevation occurs across Deurganckdok. After this date a status quo or elevation decrease is visible until the depth sounding of 9 June 2006. Between 9 June and 30 June 2006 bed elevation increase is clearly visible especially inside Deurganckdok near the entrance (zone 3A).

The difference charts in April show the highest increase in zone 3A for the Deurganckdok. During the month of May decreases on the difference charts are due to dredging activities . The decrease in elevation in zones 5 between 26 May and 9 June is due to sweepbeam activity between 30 May and 5 June and on 7-8 June 2006 next to the quay wall.

Siltation rates during the month of April (no dredging) amount up to 2.8 cm/day (Zone 3B) and 3.6 cm/day (Zone 3A). Intensive dredging during the month of May causes negative siltation rates, except in zones 3C, 4C-N, 4C-Z and 5N-C near the deep end of Deurganckdok. Zone 2 shows small siltation rates, due to its location closer to the navigation channel and thus more under influence of tidal currents. Frequent sweep beam activities must be taken into account in evaluating this zone.

The siltation rate for the whole Deurganckdok (zone 1 and 2) reflects the findings. A large siltation rate in April (2.5 cm/day) reflects the undisturbed state of the Deurganckdok. The negative siltation rate (-0.78 cm/day) in May is an indication of the intense maintenance dredging during this period. Between 30 April and 4 June a total of almost 484 000 TDS were dredged in Deurganckdok (all zones).

A table with siltation rates per month and for all cross sections, longitudinal sections and subzones is given in a table in APPENDIX C.

When comparing the siltation rates for this period (April 2006-June 2006) and the previous period (August 2005 – March 2006), it can be seen that for Deurganckdok comparable siltation rates are found in undisturbed periods. During the dredging activities in 19 February –24 March 2006 almost 850 000 TDS were removed from Deurganckdok (all zones). The siltation rate is very high (2.5 cm/day) in April 2006 following these dredging activities

The average siltation rate for the zones A and B (see Figure 5-1), shows that in an undisturbed period a siltation rate of about 1 cm/day is normal.

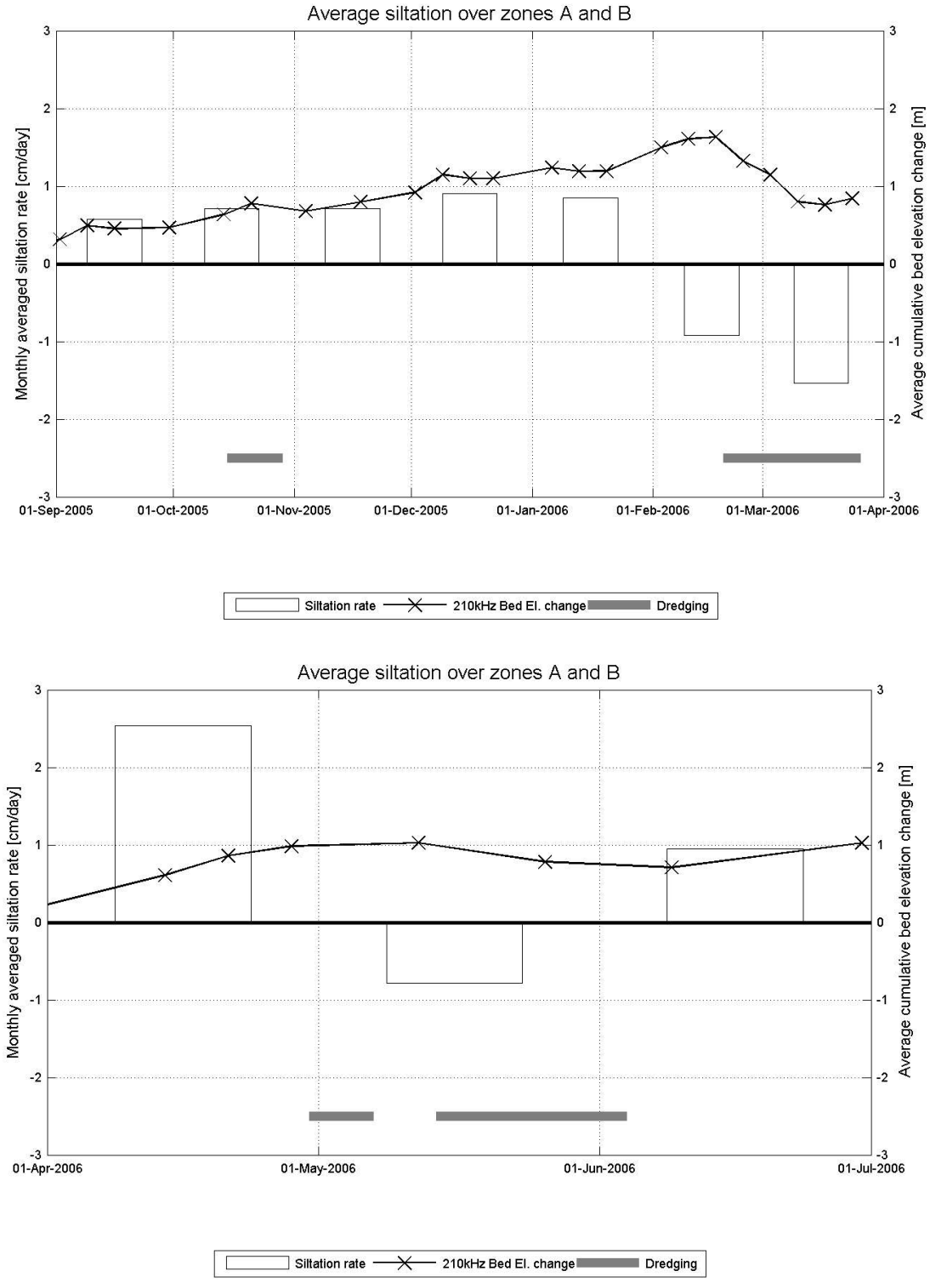


Figure 5-1: Monthly averaged siltation rate [cm/day] for first period (reference 4 August 2005) and second period (reference 24 March 2006)

In Table 5-1 different zones of Deurganckdok are compared in relation to different periods, (preferably undisturbed). June 2006 is chosen because of low dredging activity, though it must be

mentioned that sweepbeam dredging activity was done next to the commercial quays in June 2006. This was the least disturbed month of this period.

*Table 5-1: Comparison of **undisturbed** monthly averaged siltation rates [cm/day] for both periods*

Locations	***8/2005- 3/2006 eg December 2005***	***4/2006 –6/2006 eg June 2006***
Sill: zone 2	1	0.7
Central Deurganckdok: zones 3A and 3B	0.6-0.9	1-1.2
Back Central Deurganckdok: zone 3C	No data	1.0
North front quay Deurganckdok: zones 4A-N 5A-N	1.6	1.3-2.2
South front quay Deurganckdok: zones 4A-Z, 5A-Z	0.8	0.6

In Table 5-1 it can be seen that during both periods for the sill, central DGD and back central DGD siltation rates are comparable. There is a difference in siltation rate for north and south front quays. During both periods siltation rates are higher at the north front quay.

6. REFERENCES

AWZ (2000): Baggerwerken 2000, Westerschelde en Zeeschelde

IMDC (2006a) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 1.6 Sediment balance Bathymetry: 2005 – 3/2006 (I/RA/11283/06.118/MSA)

IMDC (2006b) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.1 Through tide measurement SiltProfiler 21/03/2006 Laure Marie (I/RA/11283/06.087/WGO).

IMDC (2006c) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.3 Through tide measurement Sediview spring tide 22/03/2006 Veremans (I/RA/11283/06.110/BDC)

IMDC (2006d) 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 (2006e) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.6 Salt-Silt distribution & Frame Measurements Deurganckdok 13/3/2006 – 31/05/2006 (I/RA/11283/06.121/MSA).

IMDC (2006f). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 6.1 Winter Calibration (I/RA/11291/06.092/MSA), in opdracht van AWZ.

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

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

IMDC (2007f) 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 (2007g) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.5 Through tide measurement Sediview neap tide (to be scheduled) (I/RA/11283/06.120/MSA)

IMDC (2007h) 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 (2007i) 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 (2007j) 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 (2007k) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 3.2 Boundary condtions: Annual report (I/RA/11283/06.128/MSA)

IMDC (2007l) 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)

APPENDIX A. DEPTH OF THE WATER-BED INTERFACE (210 KC)

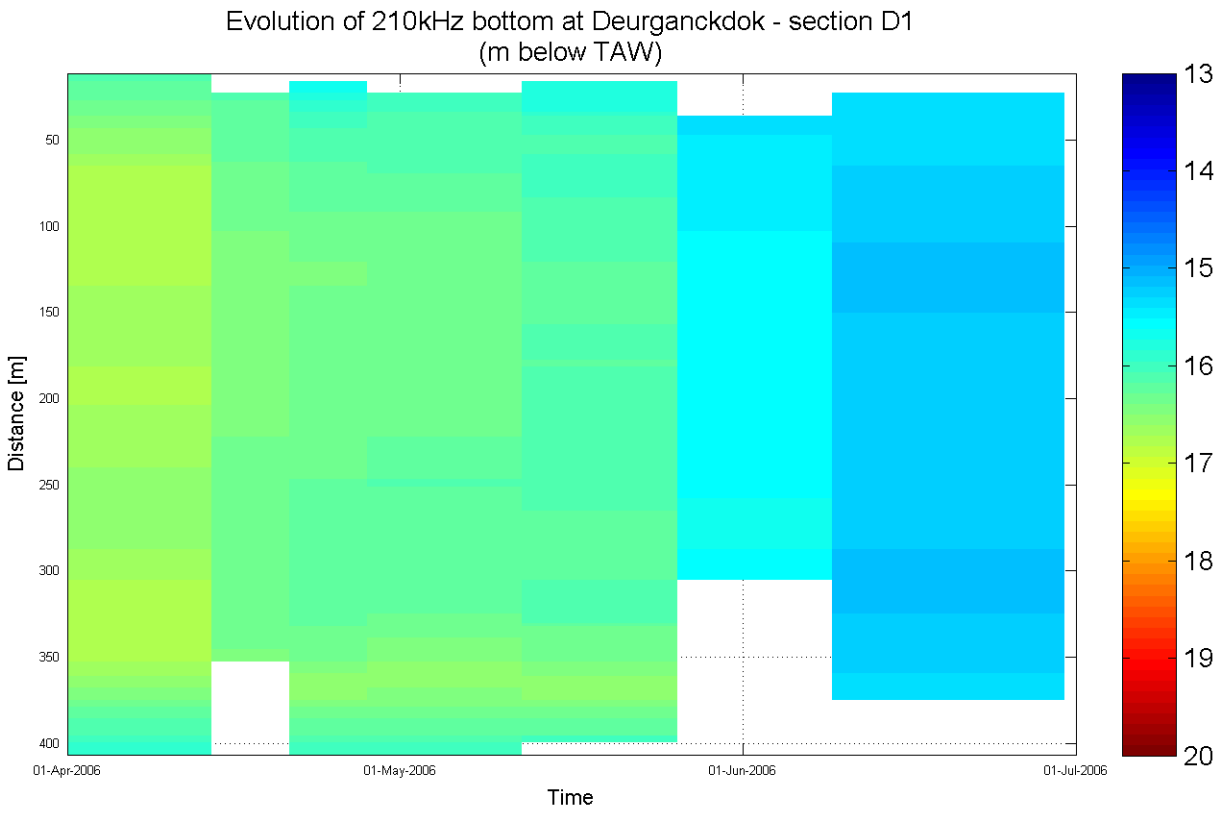
APPENDIX B. EVOLUTION OF DEPTH OF WATER-BED INTERFACE (210 KC)

B.1 Difference maps

B.2 Bed elevation evolution per section

Long-term monitoring siltation Deurganckdok

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



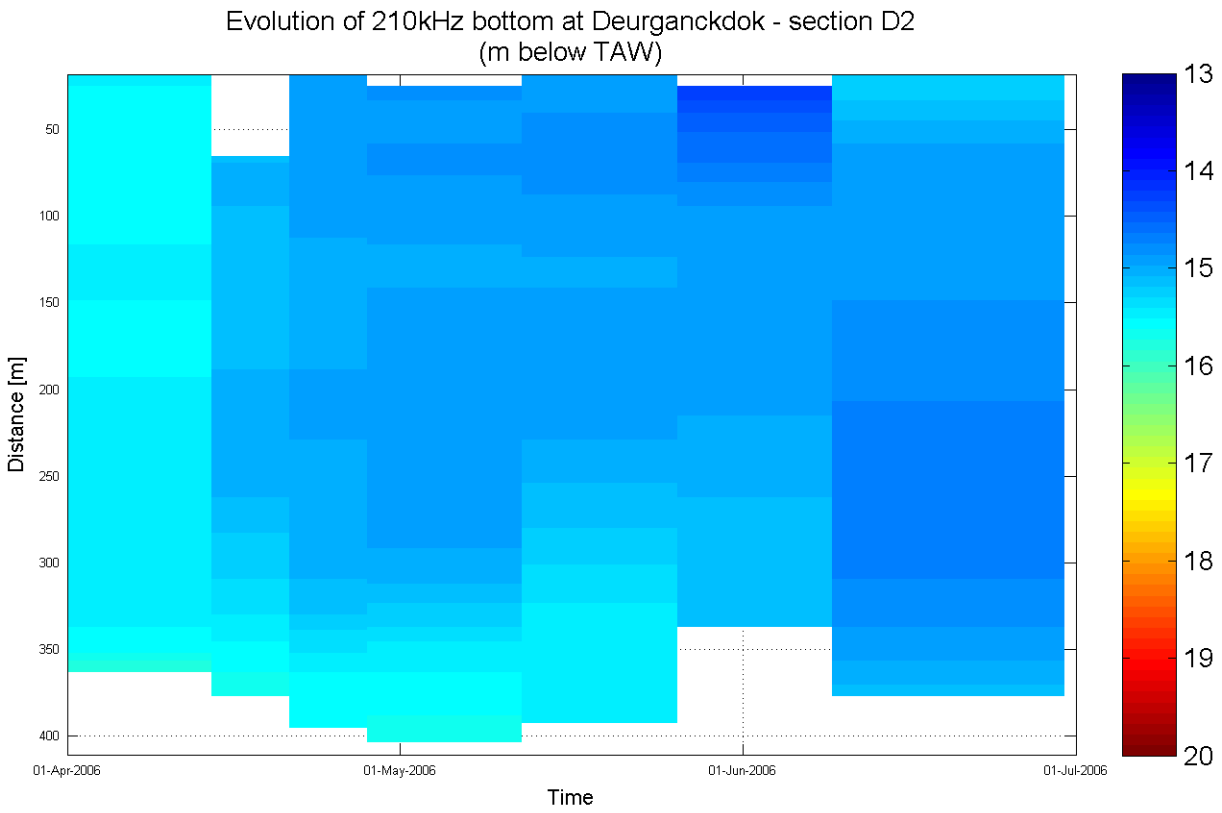
Data Processed by:

In association with :

I/RA/11283/06.113/MSA

Long-term monitoring siltation Deurganckdok

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



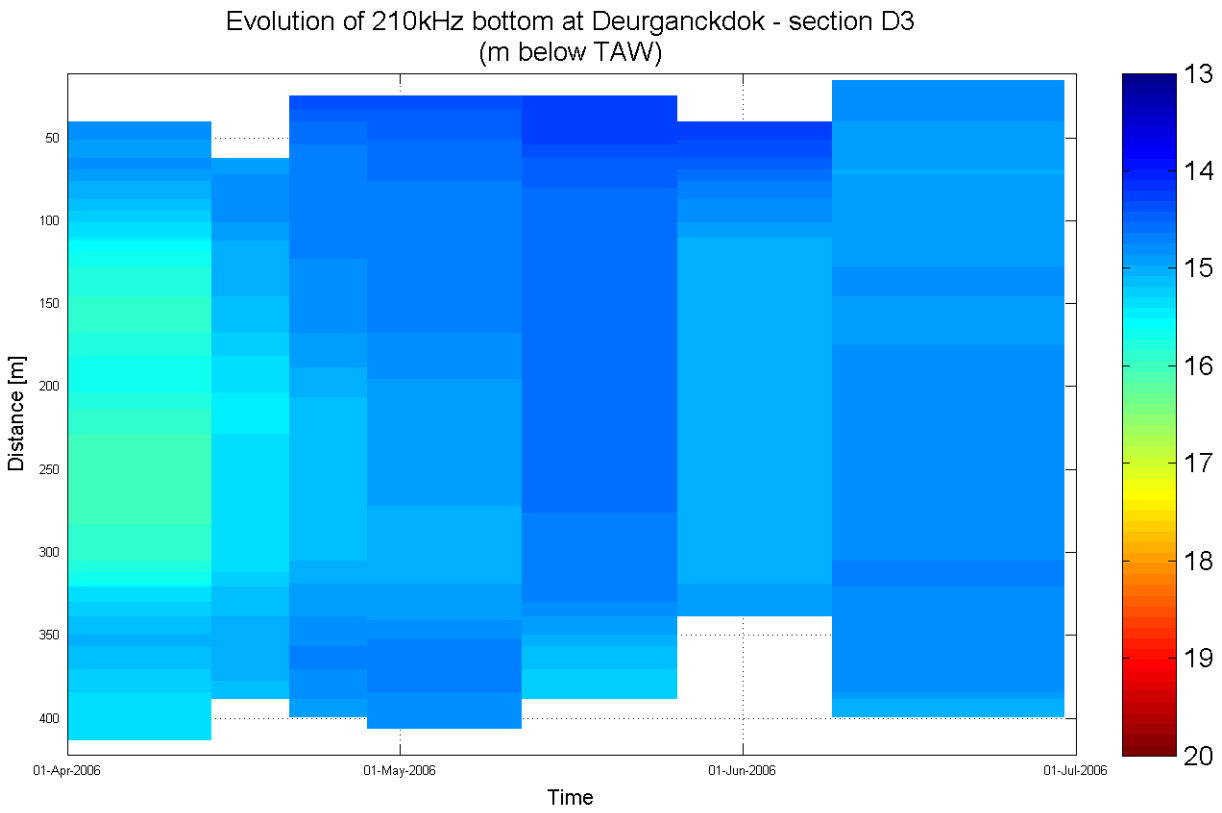
Data Processed by:

In association with :

I/RA/11283/06.113/MSA

Long-term monitoring siltation Deurganckdok

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



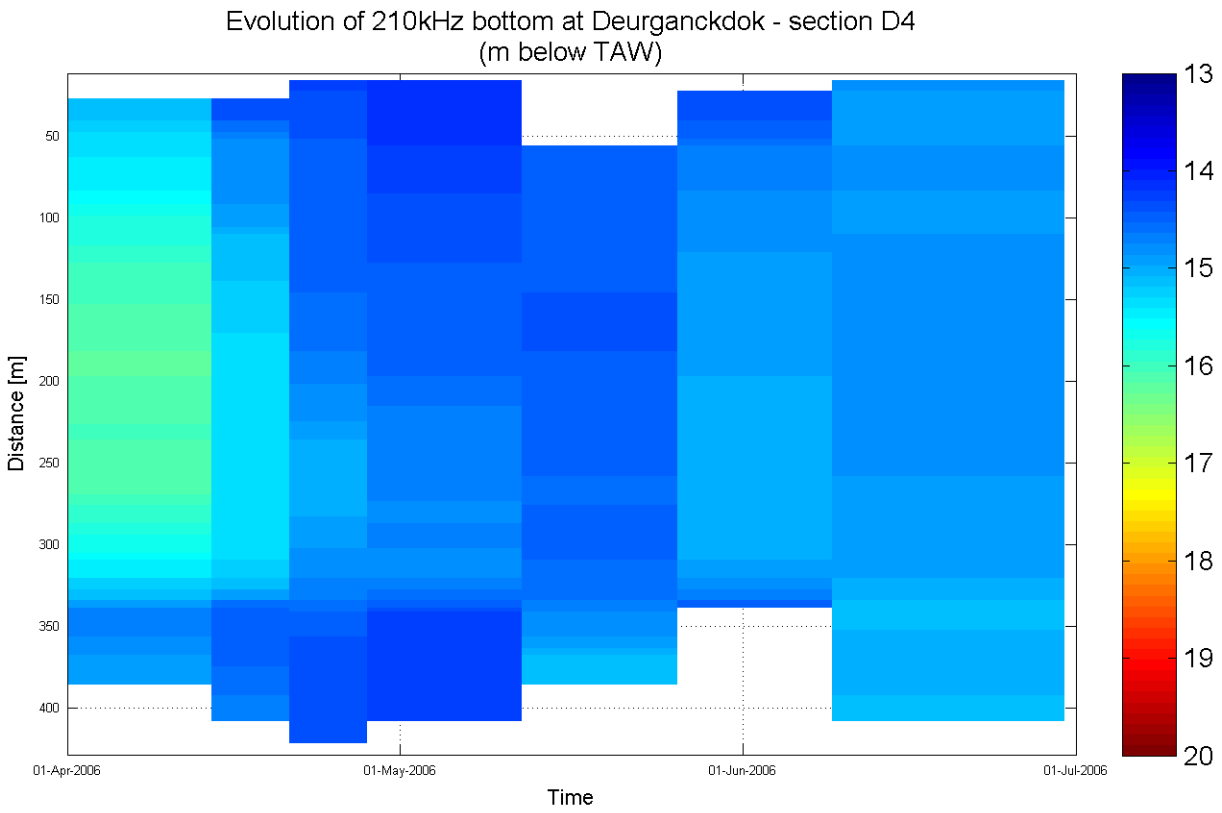
Data Processed by:

In association with :

I/RA/11283/06.113/MSA

Long-term monitoring siltation Deurganckdok

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



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In association with :

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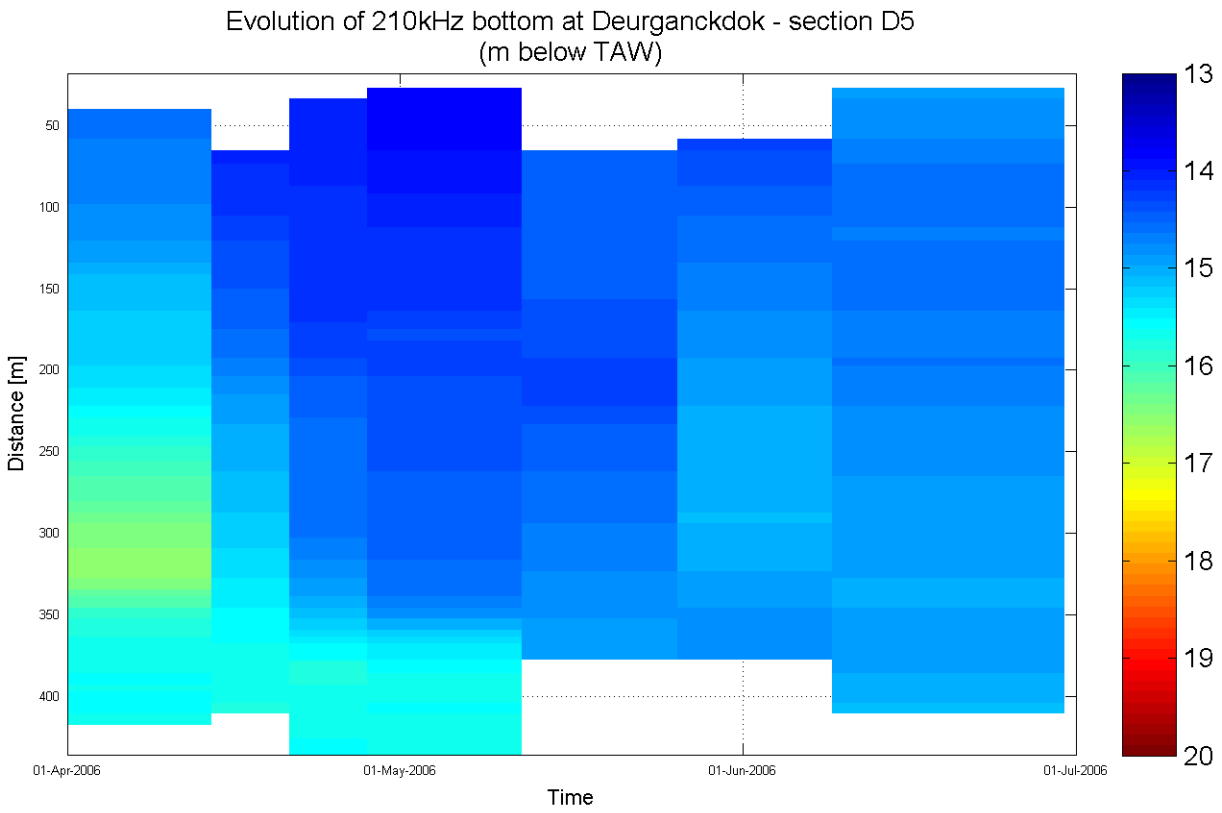
Long-term monitoring siltation Deurganckdok

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



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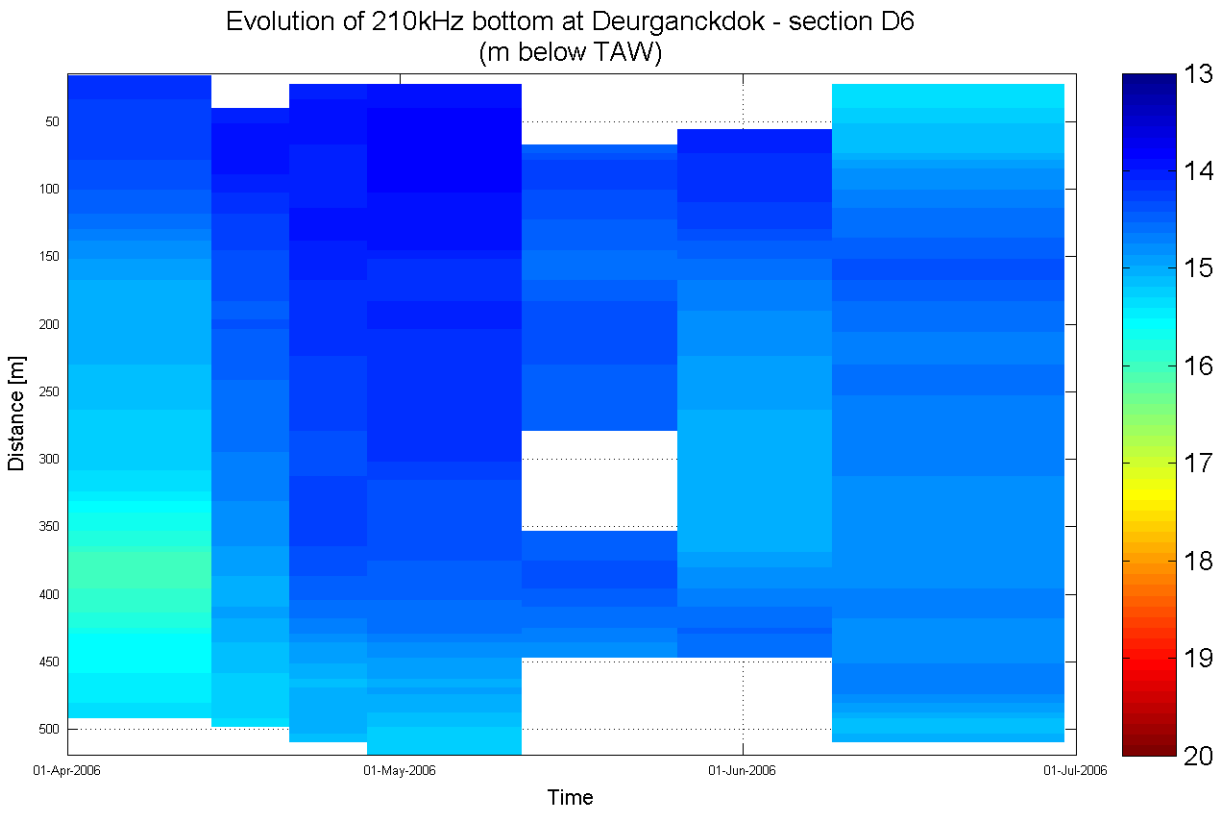
In association with :

I/RA/11283/06.113/MSA

Long-term monitoring siltation Deurganckdok

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



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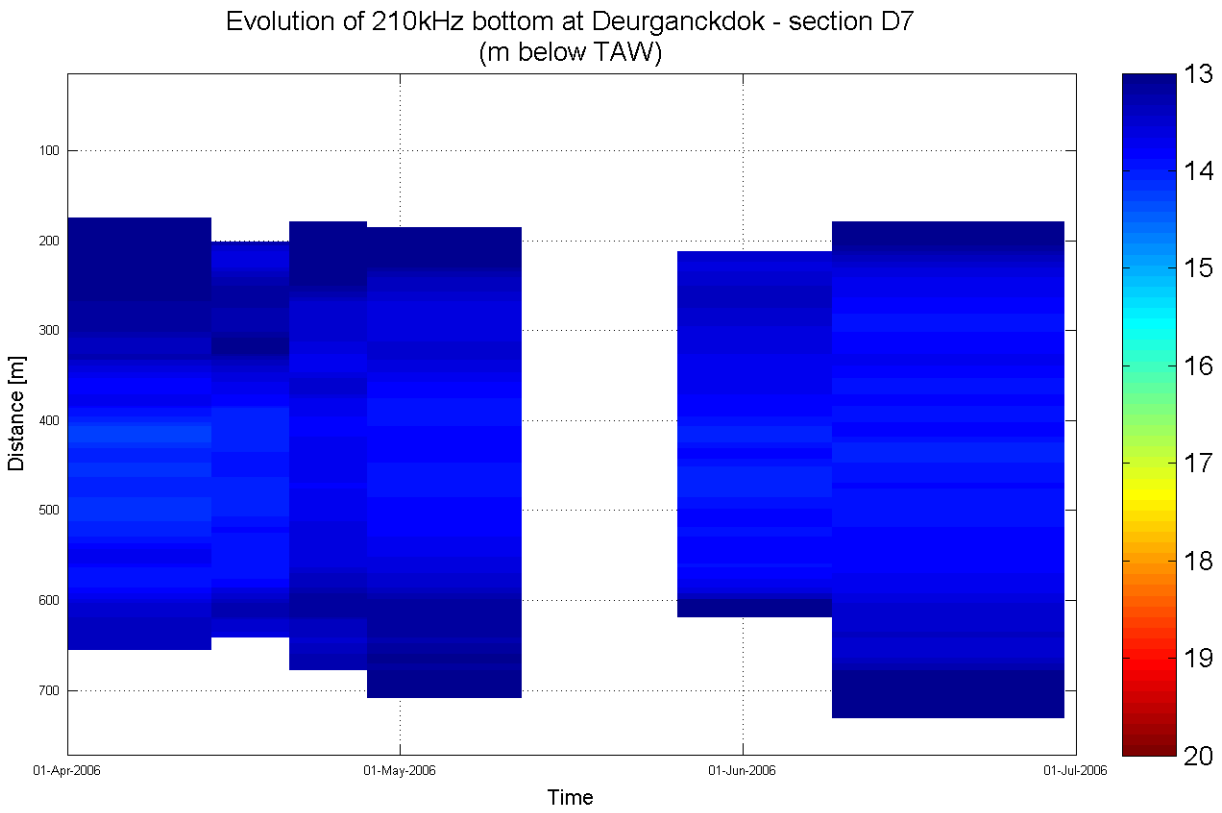
In association with :

I/RA/11283/06.113/MSA

Long-term monitoring siltation Deurganckdok

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



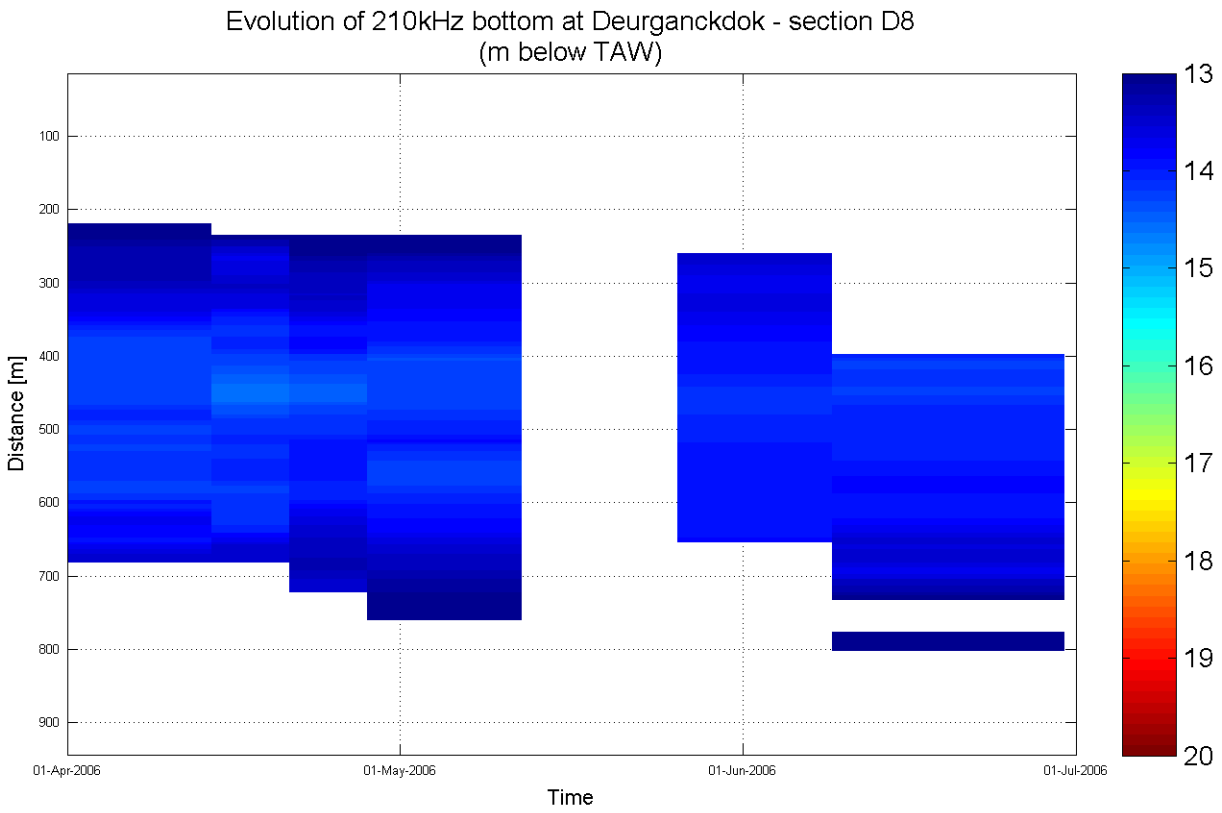
Data Processed by:

In association with :

I/RA/11283/06.113/MSA

Long-term monitoring siltation Deurganckdok

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



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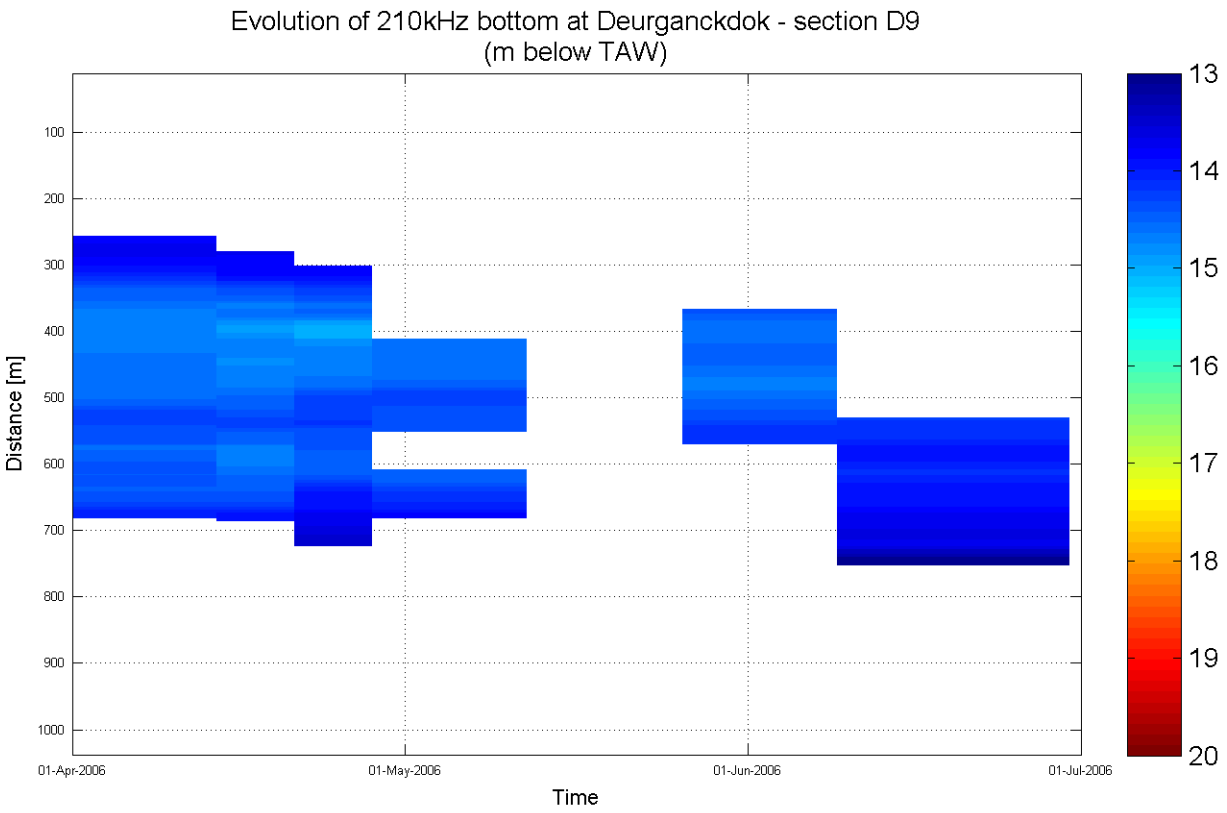
I/RA/11283/06.113/MSA

Long-term monitoring siltation Deurganckdok

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



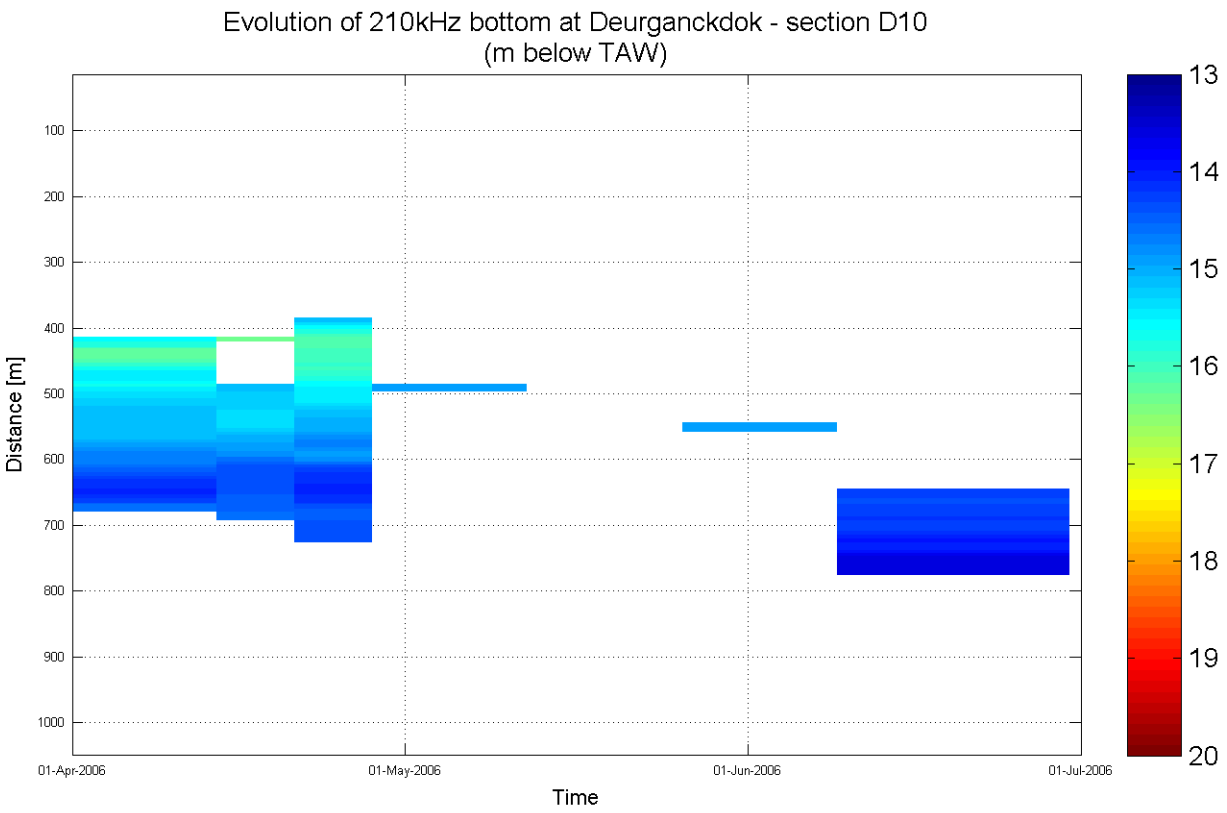
Data Processed by:

In association with :

I/RA/11283/06.113/MSA

Long-term monitoring siltation Deurganckdok

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



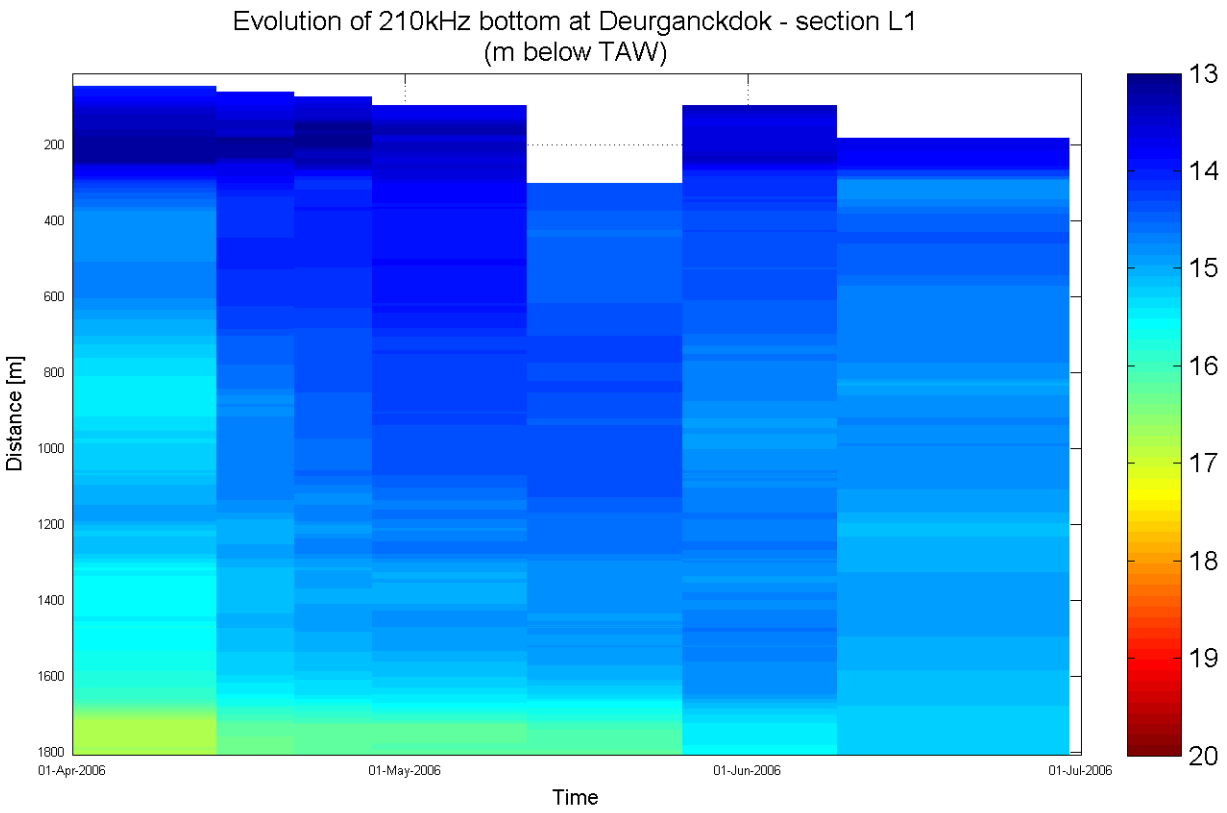
Data Processed by:

In association with :

I/RA/11283/06.113/MSA

Long-term monitoring siltation Deurganckdok

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



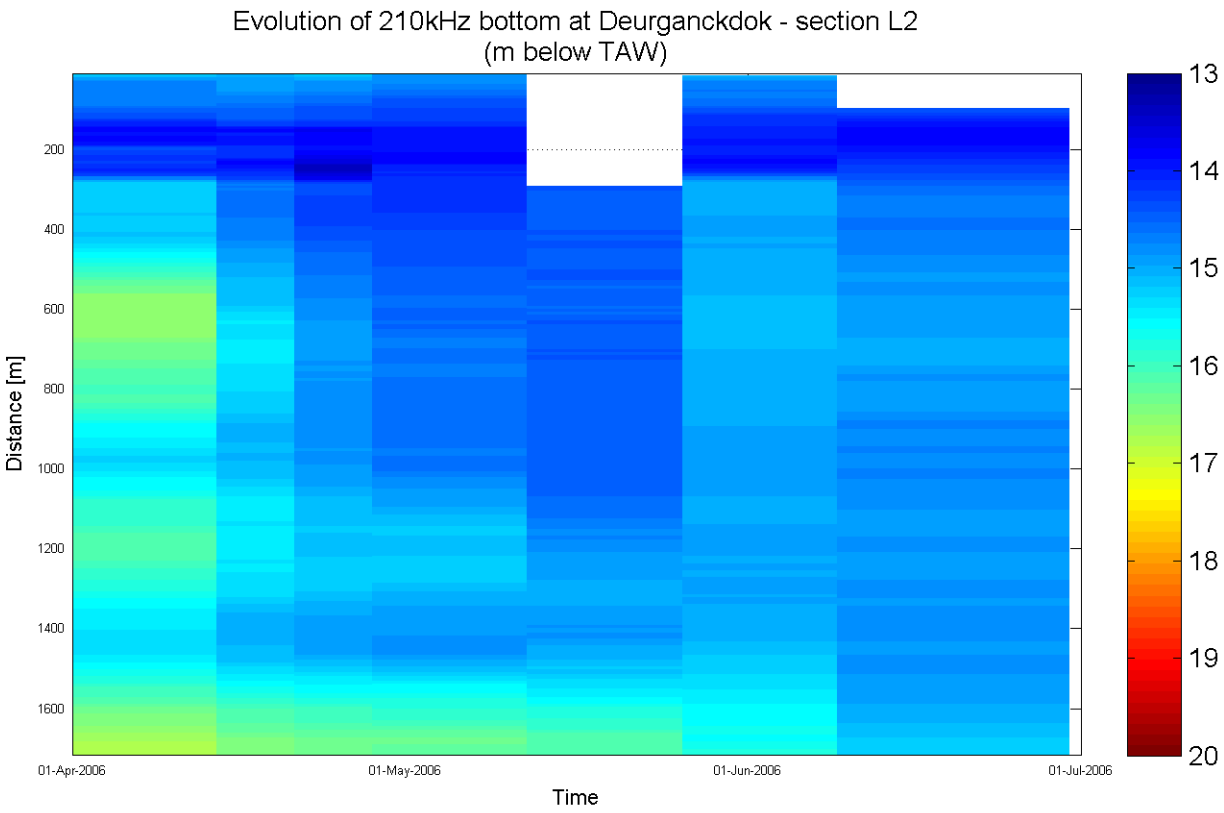
Data Processed by:

In association with :

I/RA/11283/06.113/MSA

Long-term monitoring siltation Deurganckdok

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



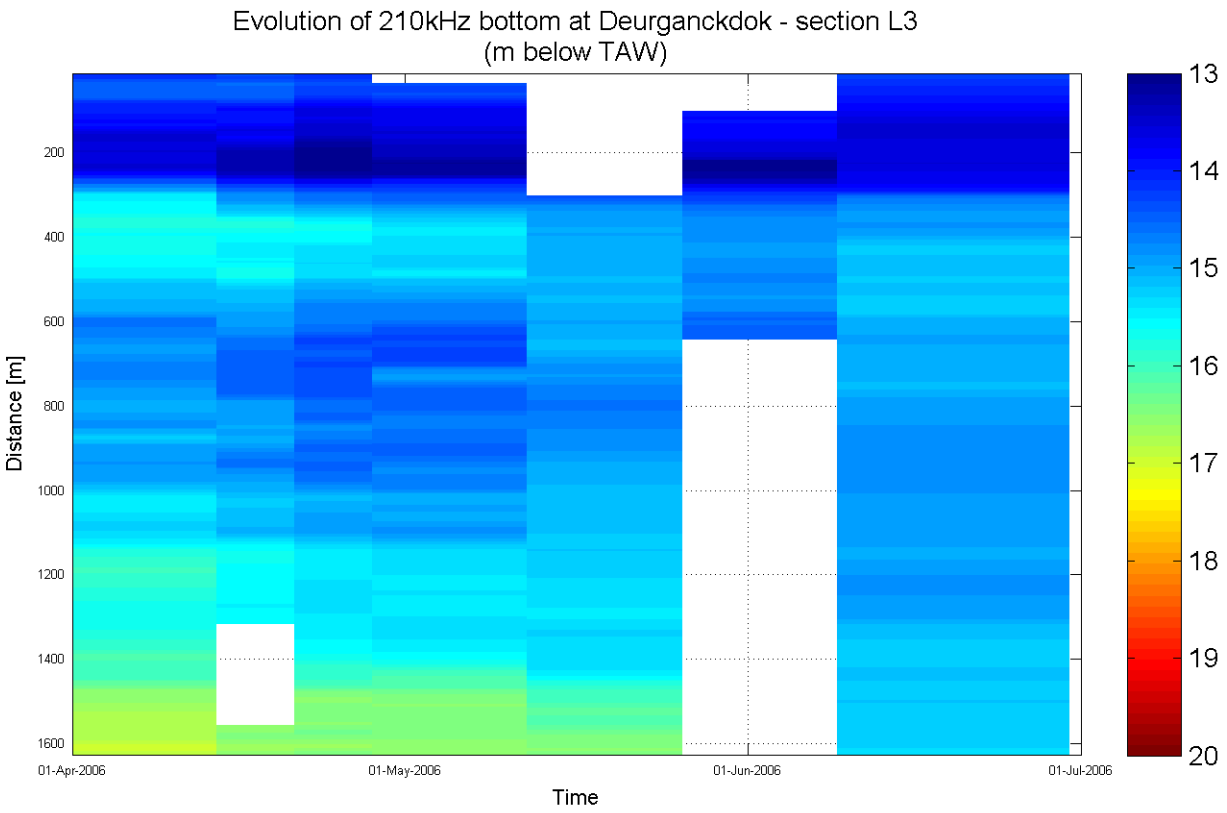
Data Processed by:

In association with :

I/RA/11283/06.113/MSA

Long-term monitoring siltation Deurganckdok

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



Data Processed by:

In association with :

I/RA/11283/06.113/MSA

APPENDIX C.

VOLUMETRIC SILTATION RATES IN DIFFERENT ZONES AND SECTIONS

C.1 Siltation rates (tabular)

Siltation rates in cm/day

1/ Per zone

	apr/06	***may/06***	***jun/06***
1	NaN	NaN	NaN
2	0.774	-0.548	0.731
3a	3.58	-1.408	1.27
3b	2.765	-0.417	0.938
3c	1.331	0.888	1.022
4Na	1.951	-1.384	1.34
4Nb	1.951	-0.866	0.87
4Nc	1.505	1.013	0.453
4Za	1.308	0.101	0.582
4Zb	0.96	-0.319	0.844
4Zc	NaN	1.705	0.654
5Na	NaN	-2.279	2.176
5Nb	NaN	-1.204	0.937
5Nc	NaN	0.049	0.629
5Za	NaN	NaN	NaN
5Zb	NaN	NaN	NaN
5Zc	NaN	NaN	NaN
AVG	**2.533**	**-0.78**	**0.945**

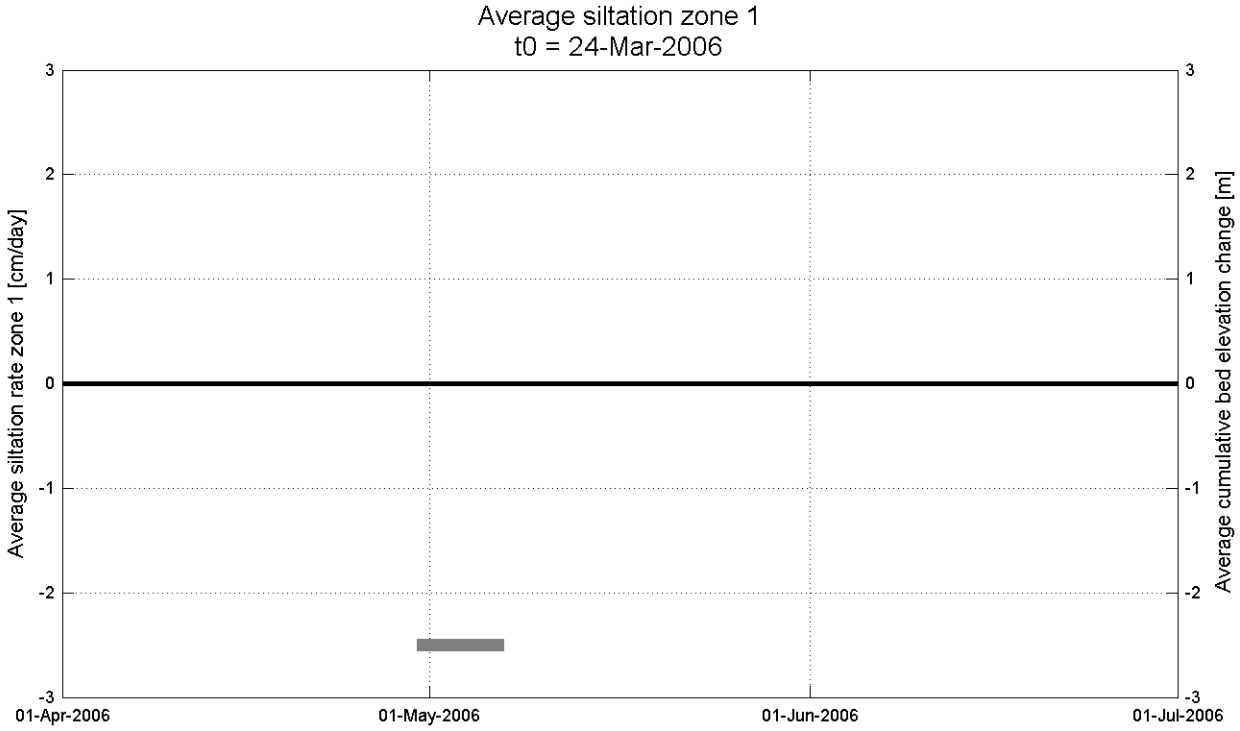
1/ Per section

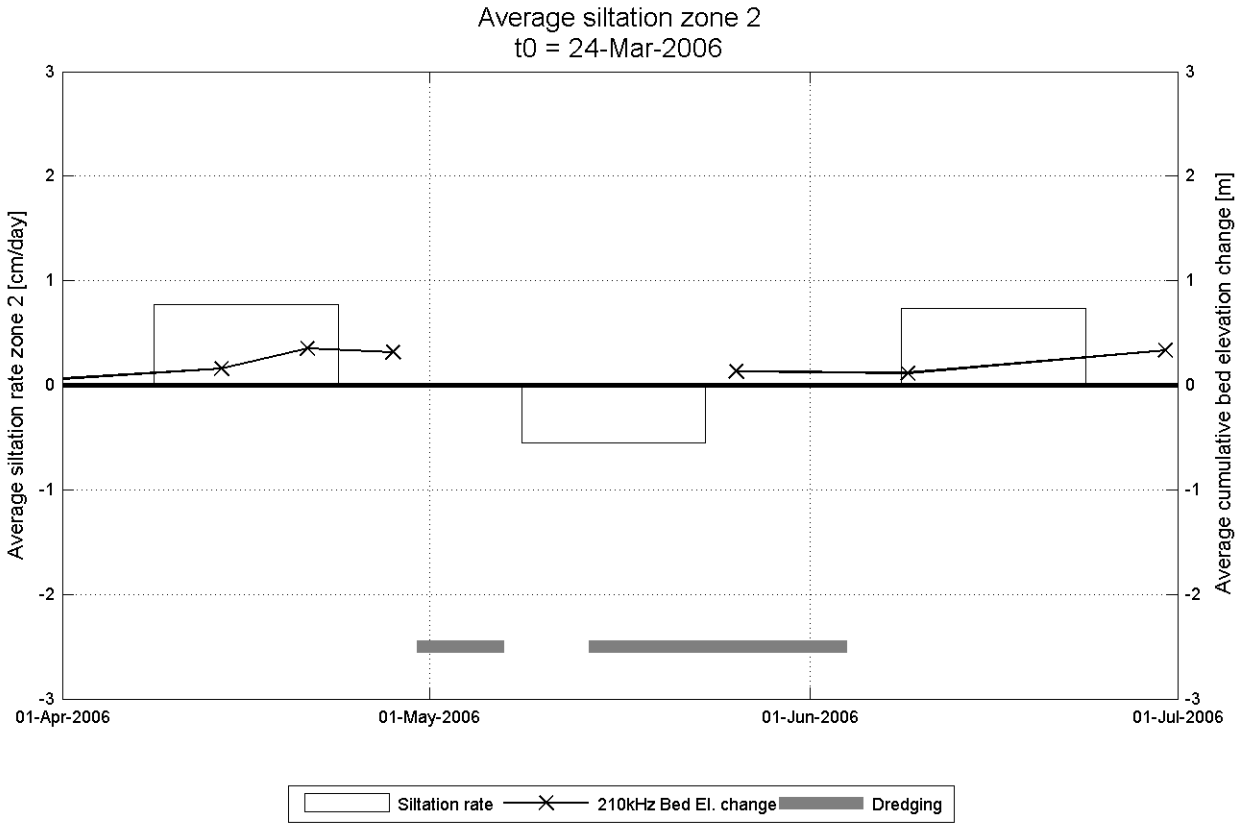
	apr/06	***may/06***	***jun/06***
D1	0.821	2.826	0.873
D2	1.301	0.337	0.366
D3	2.033	-0.223	0.7
D4	3.143	-1.042	0.997
D5	2.506	-0.868	1.036
D6	1.986	-1.26	1.33
D7	0.169	-0.357	0.292
D8	NaN	0.273	0.273
D9	NaN	NaN	NaN
D10	NaN	NaN	NaN
L1	1.587	-0.53	0.886
L2	2.371	-0.424	0.925
L3	0.924	0.367	0.738

C.2 Water-bed interface evolution for all zones

Long-term monitoring siltation Deurganckdok

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





Reference level: depth sounding 24-Mar-2006

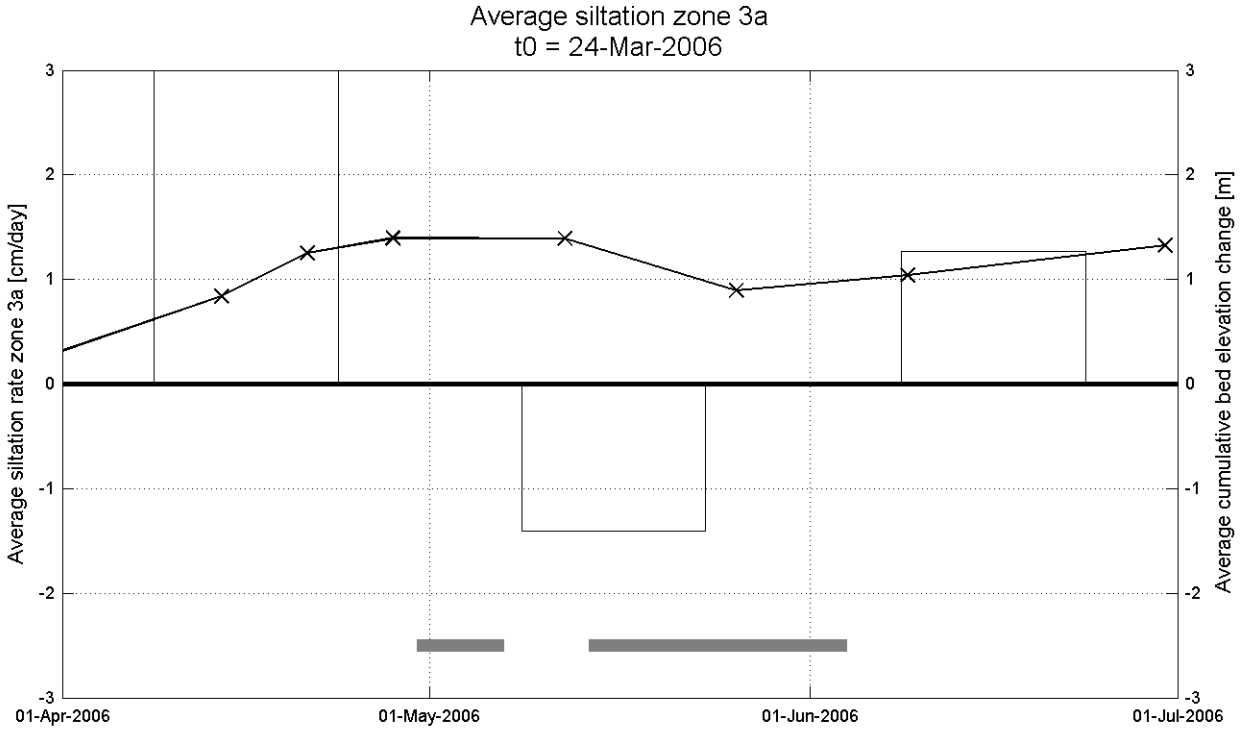
Data Processed by:

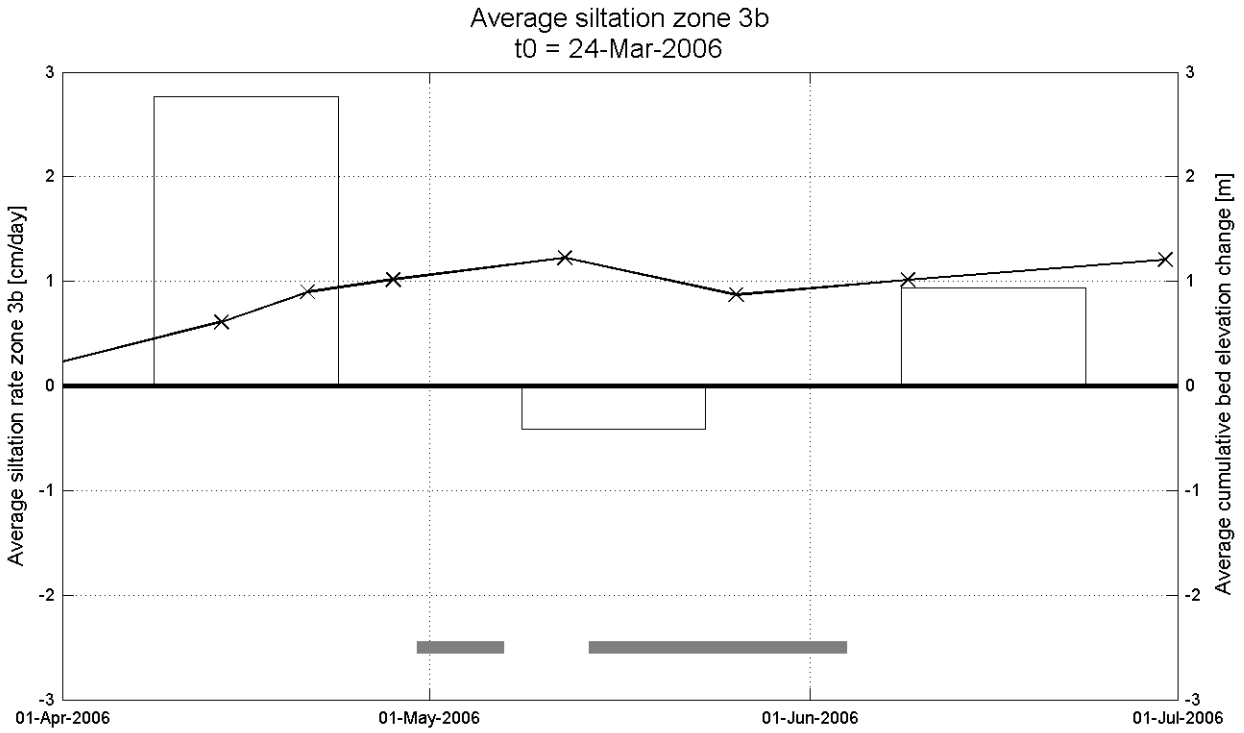
In association with :

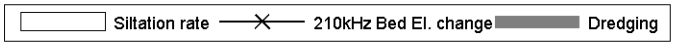
I/RA/11283/06.113/MSA

Long-term monitoring siltation Deurganckdok

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







Reference level: depth sounding 24-Mar-2006

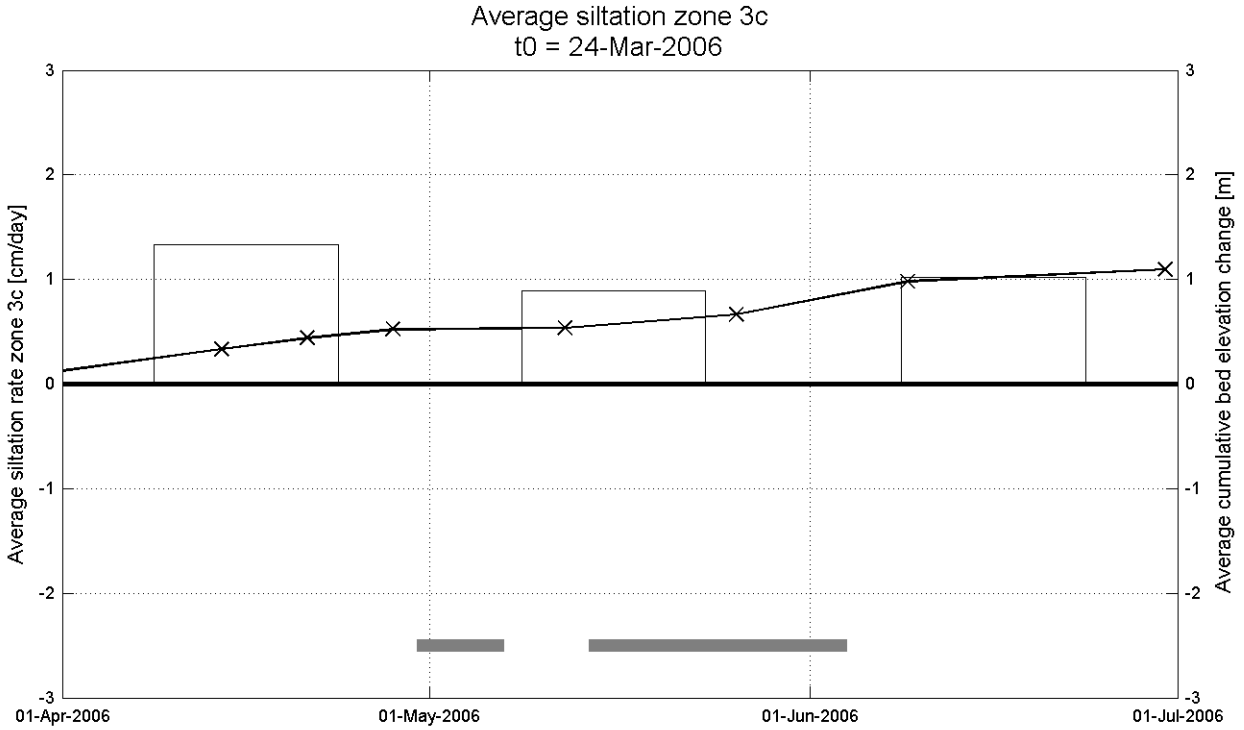
Data Processed by:

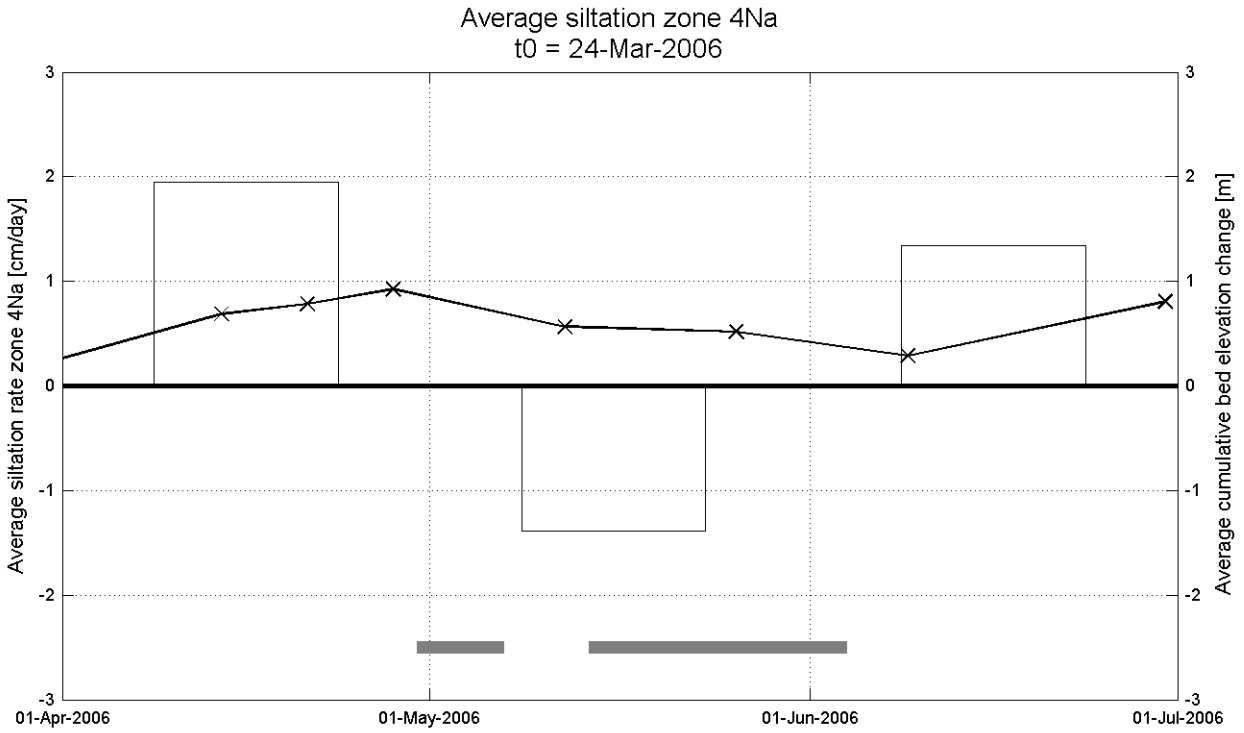
In association with :

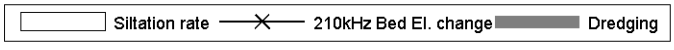
I/RA/11283/06.113/MSA

Long-term monitoring siltation Deurganckdok

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







Reference level: depth sounding 24-Mar-2006

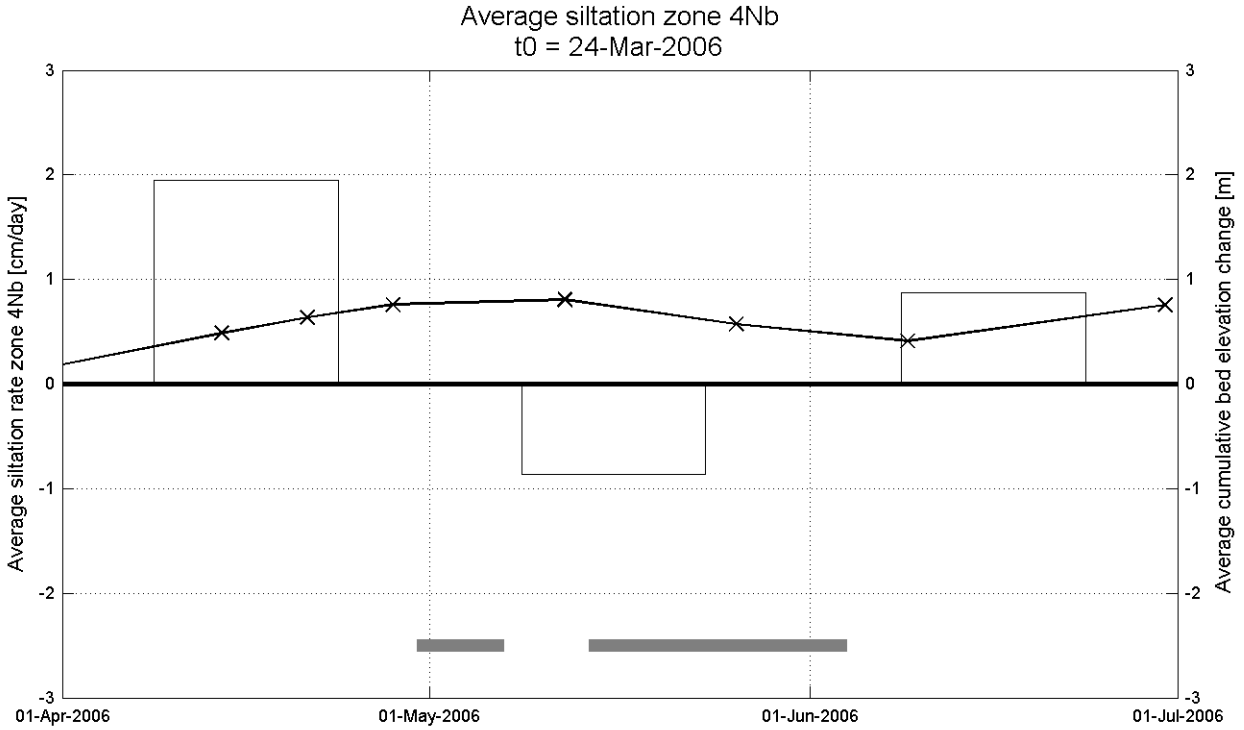
Data Processed by:

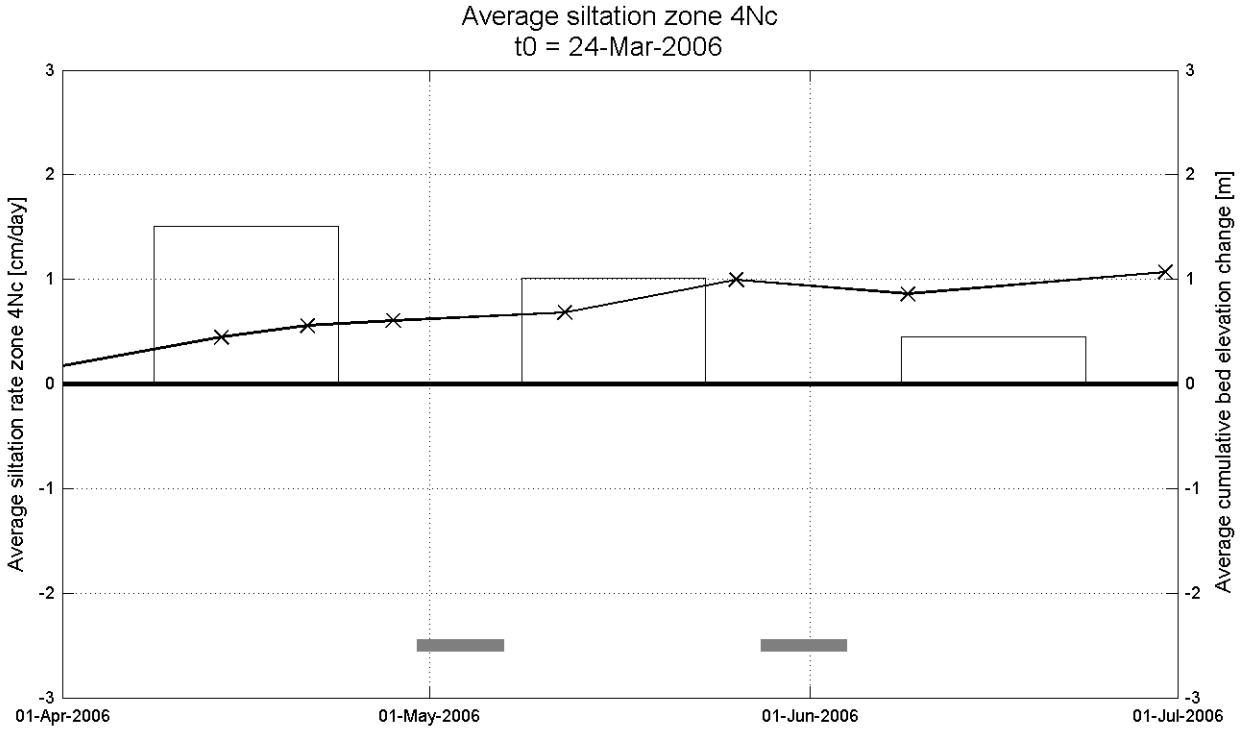
In association with :

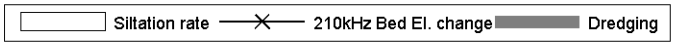
I/RA/11283/06.113/MSA

Long-term monitoring siltation Deurganckdok

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







Reference level: depth sounding 24-Mar-2006

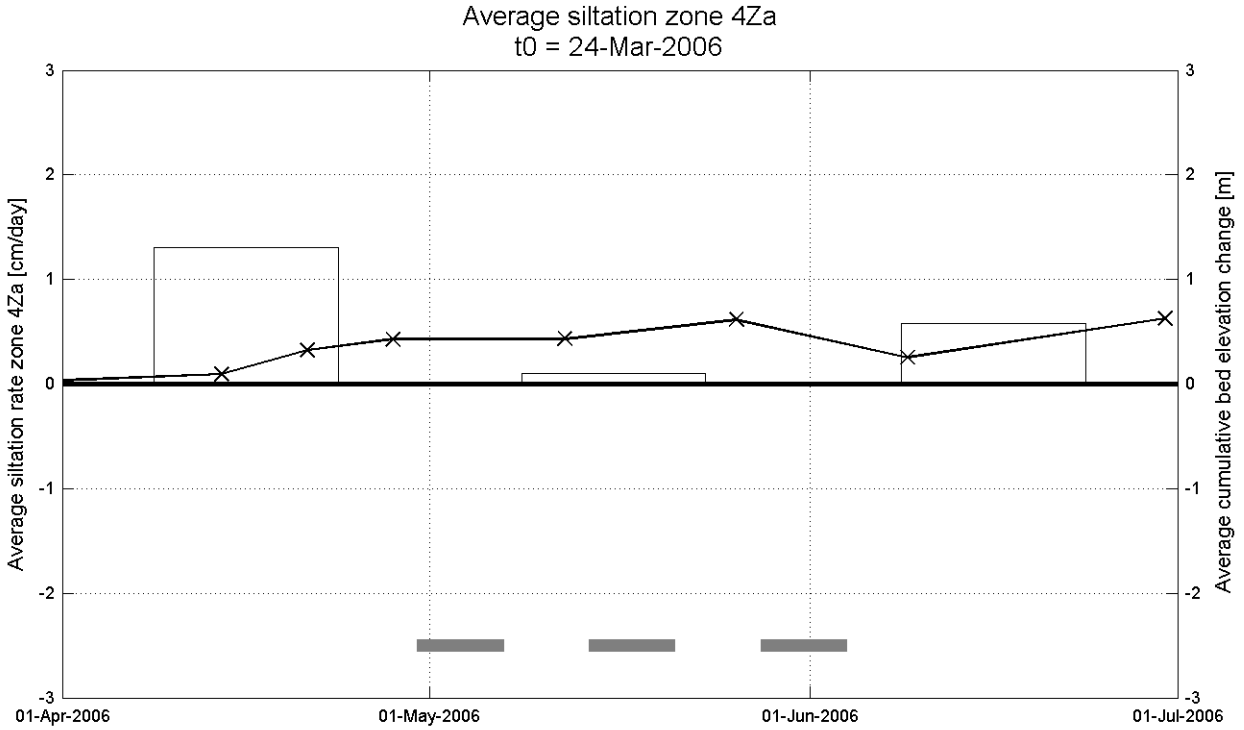
Data Processed by:

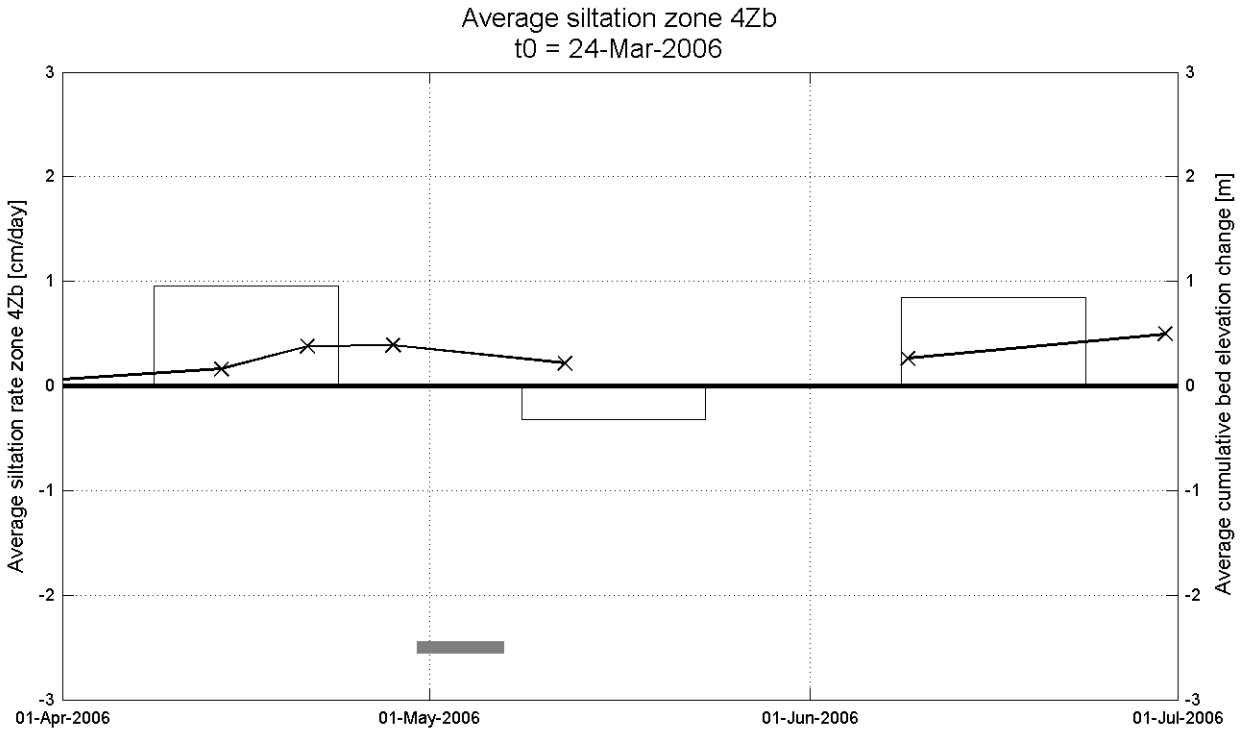
In association with :

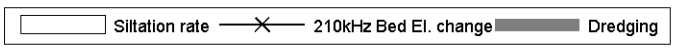
I/RA/11283/06.113/MSA

Long-term monitoring siltation Deurganckdok

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







Reference level: depth sounding 24-Mar-2006

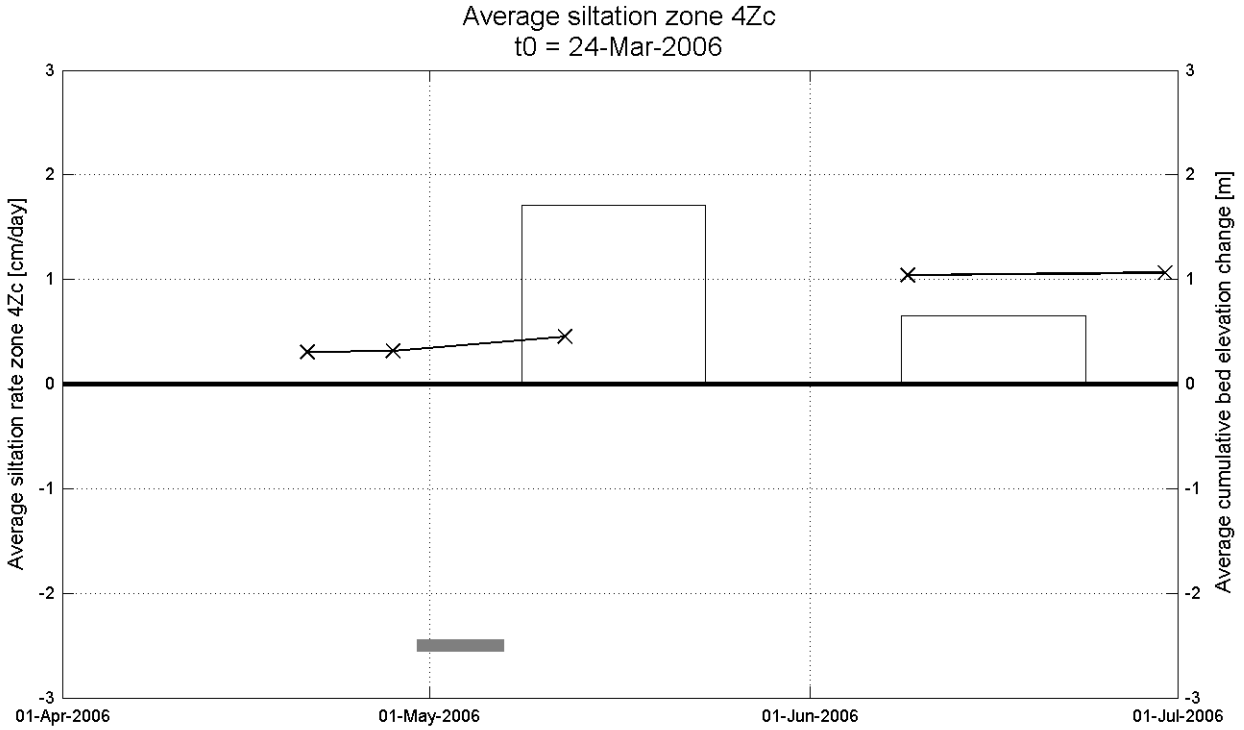
Data Processed by:

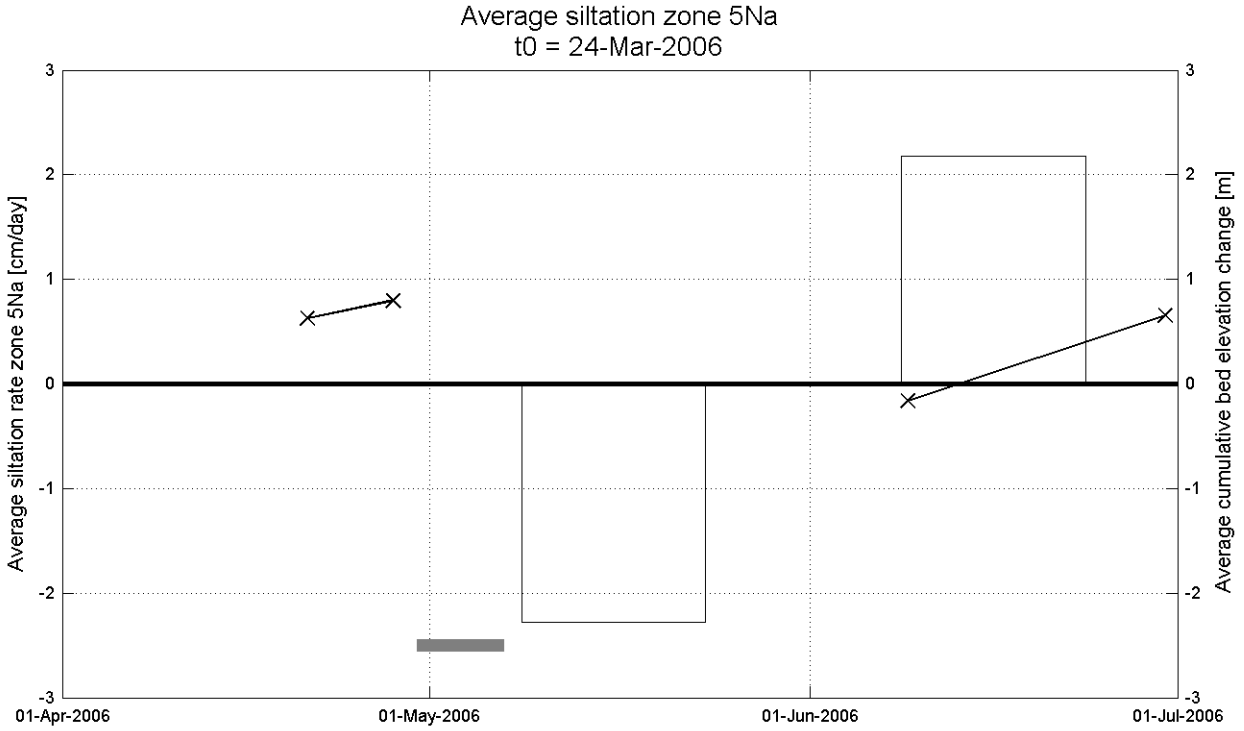
In association with :

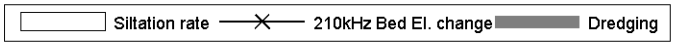
I/RA/11283/06.113/MSA

Long-term monitoring siltation Deurganckdok

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







Reference level: depth sounding 24-Mar-2006

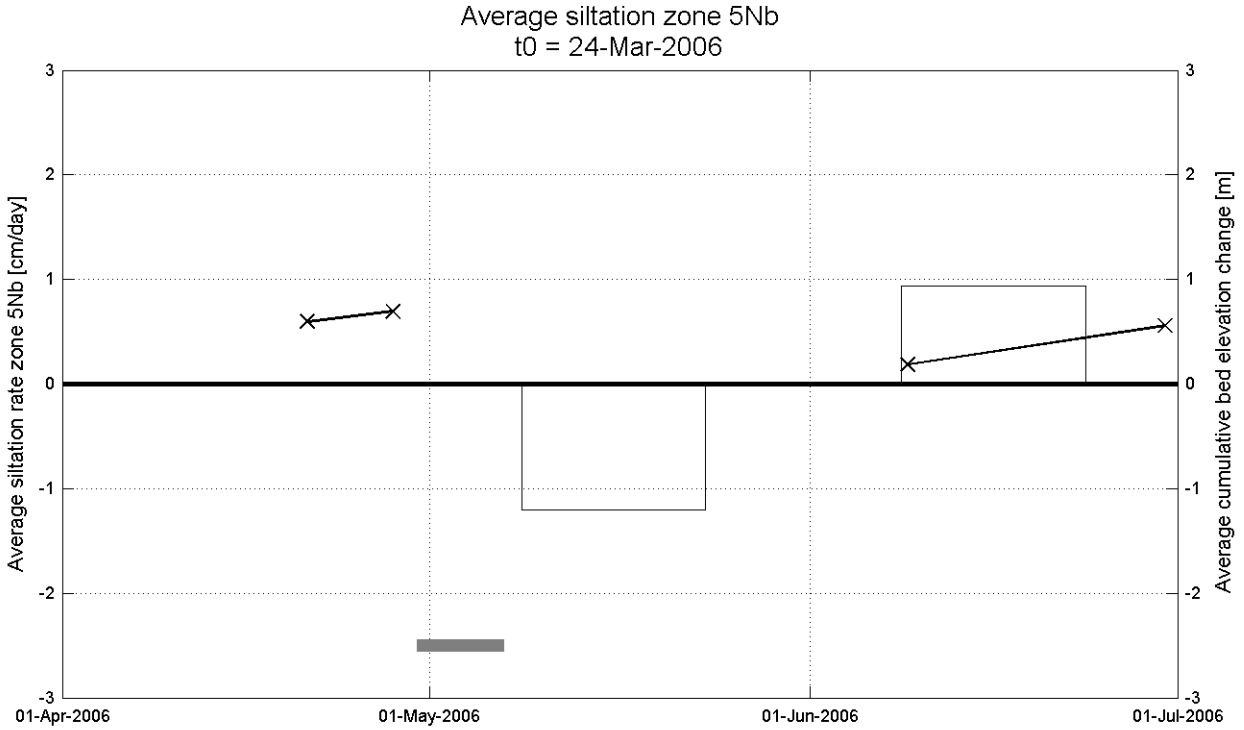
Data Processed by:

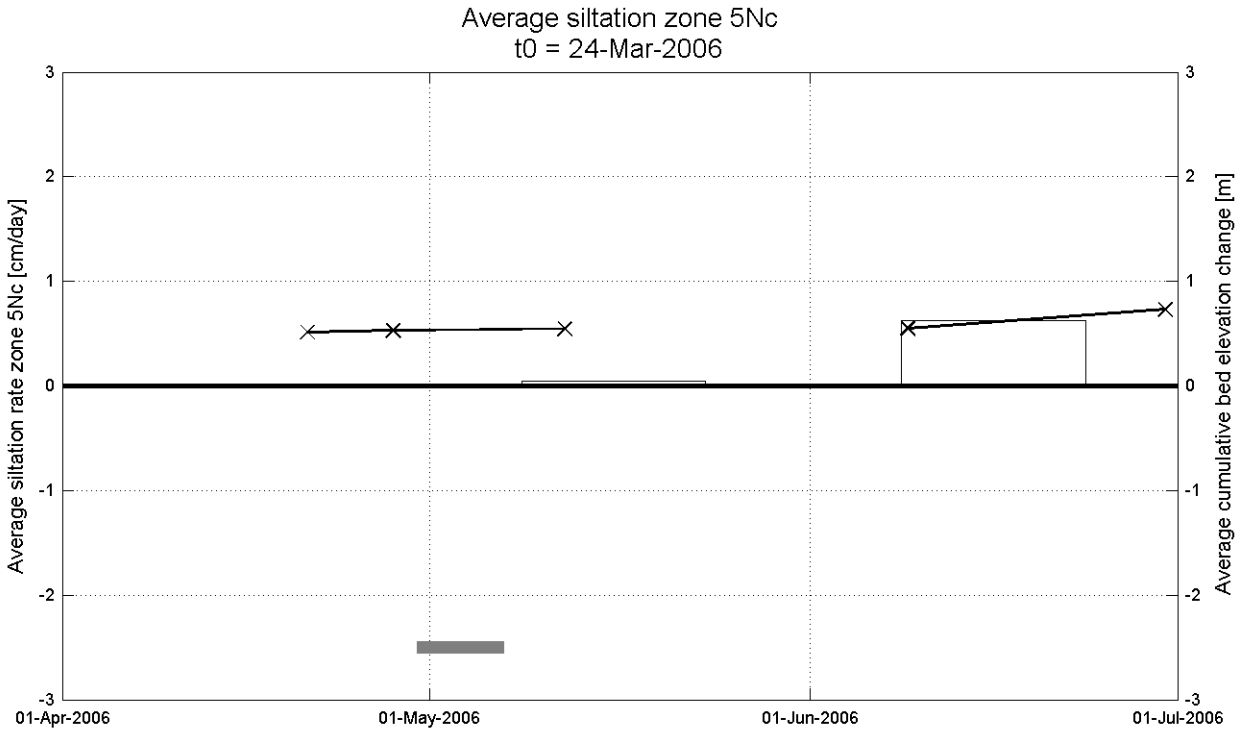
In association with :

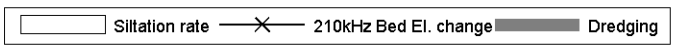
I/RA/11283/06.113/MSA

Long-term monitoring siltation Deurganckdok

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







Reference level: depth sounding 24-Mar-2006

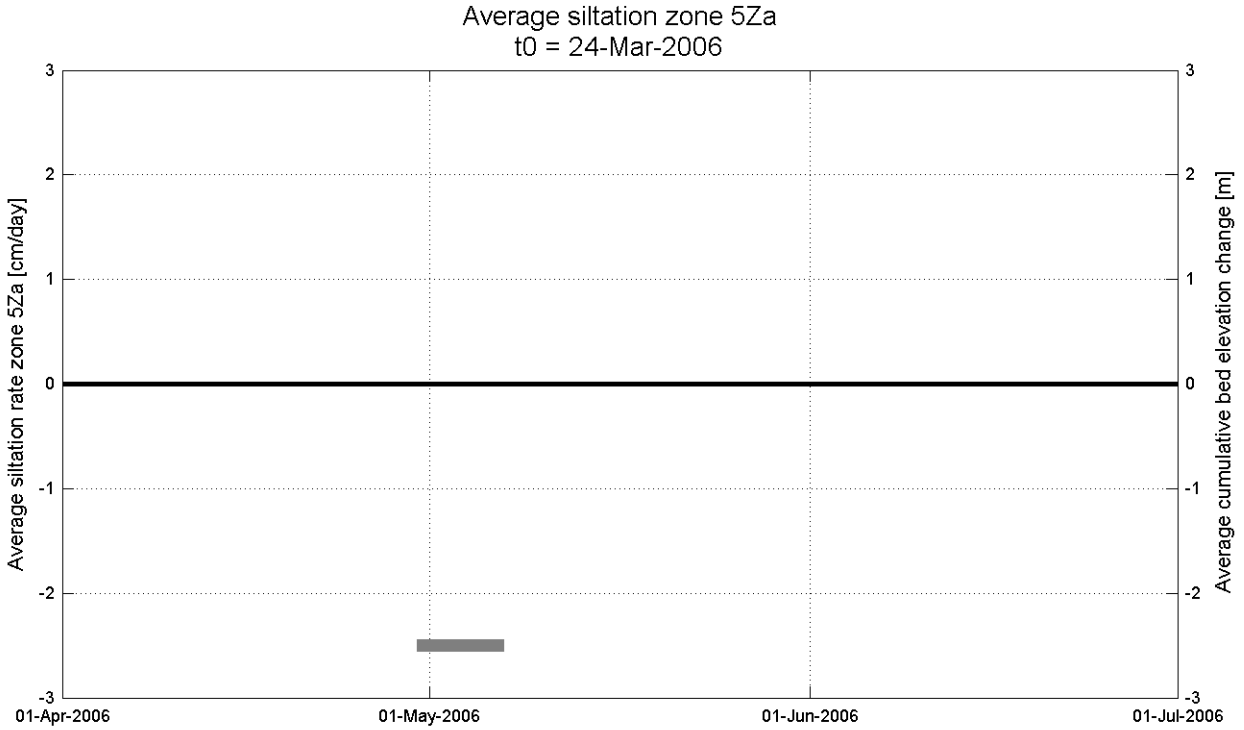
Data Processed by:

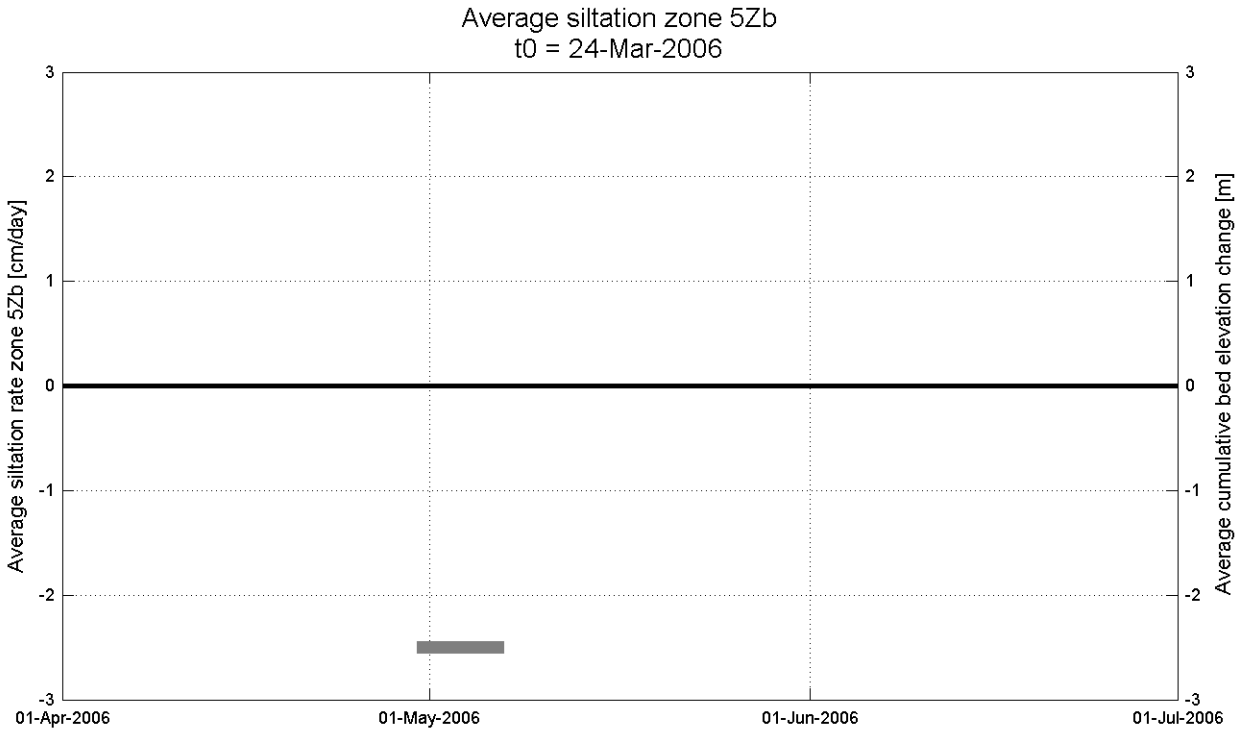
In association with :

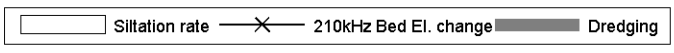
I/RA/11283/06.113/MSA

Long-term monitoring siltation Deurganckdok

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







Reference level: depth sounding 24-Mar-2006

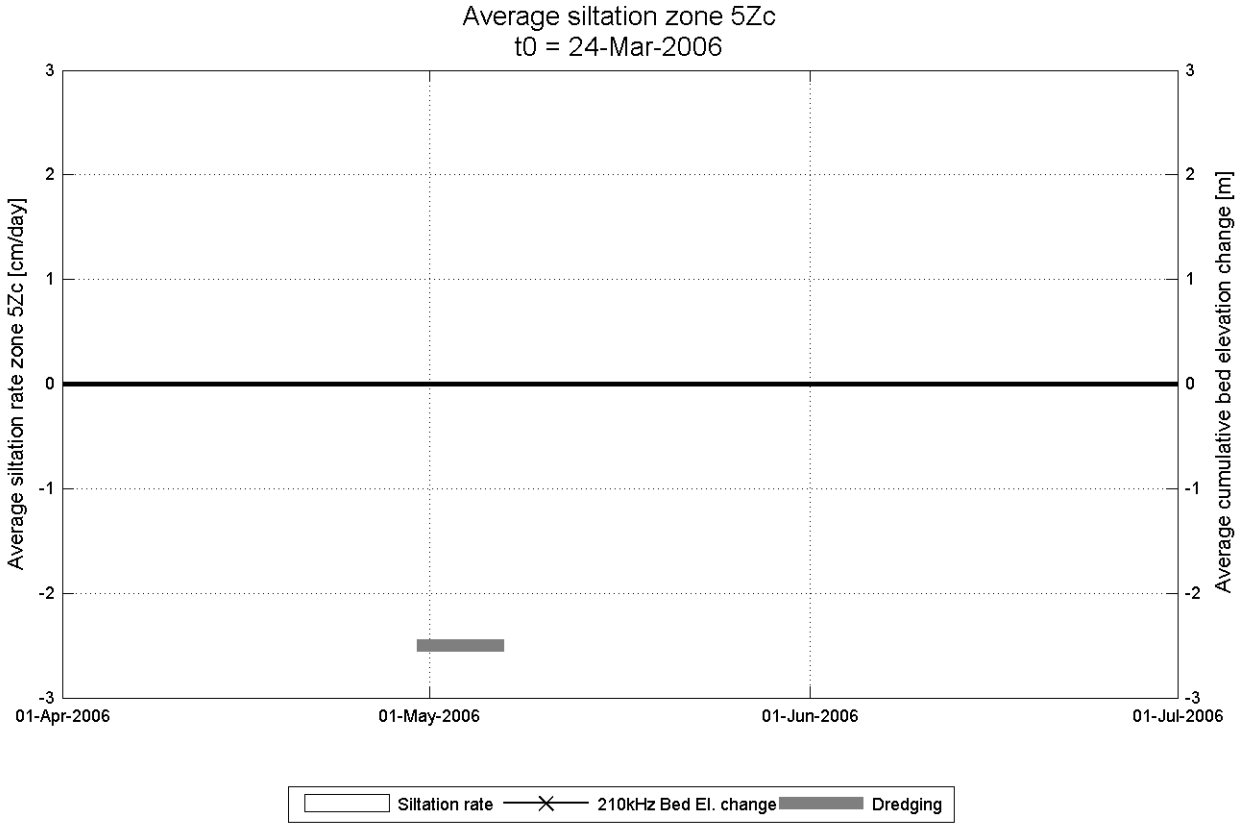
Data Processed by: IMDC

In association with : GEMS

I/RA/11283/06.113/MSA

Long-term monitoring siltation Deurganckdok

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



Reference level: depth sounding 24-Mar-2006

Data Processed by:

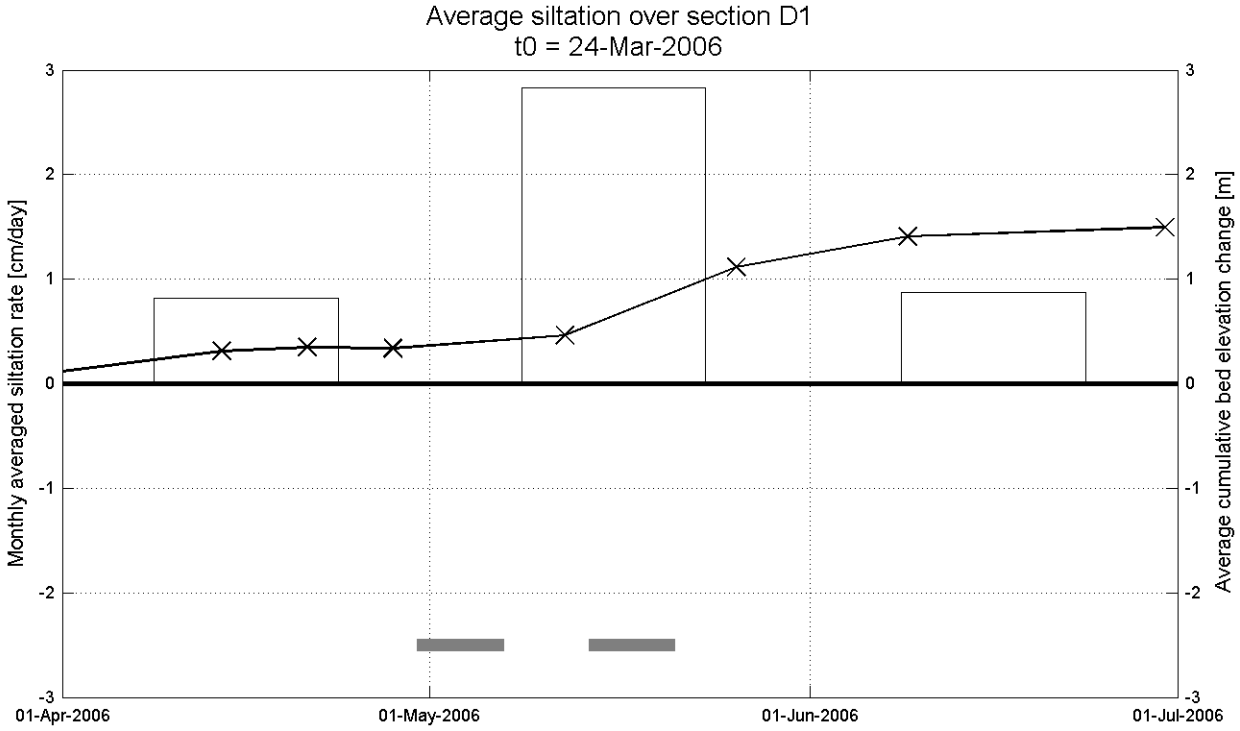
In association with :

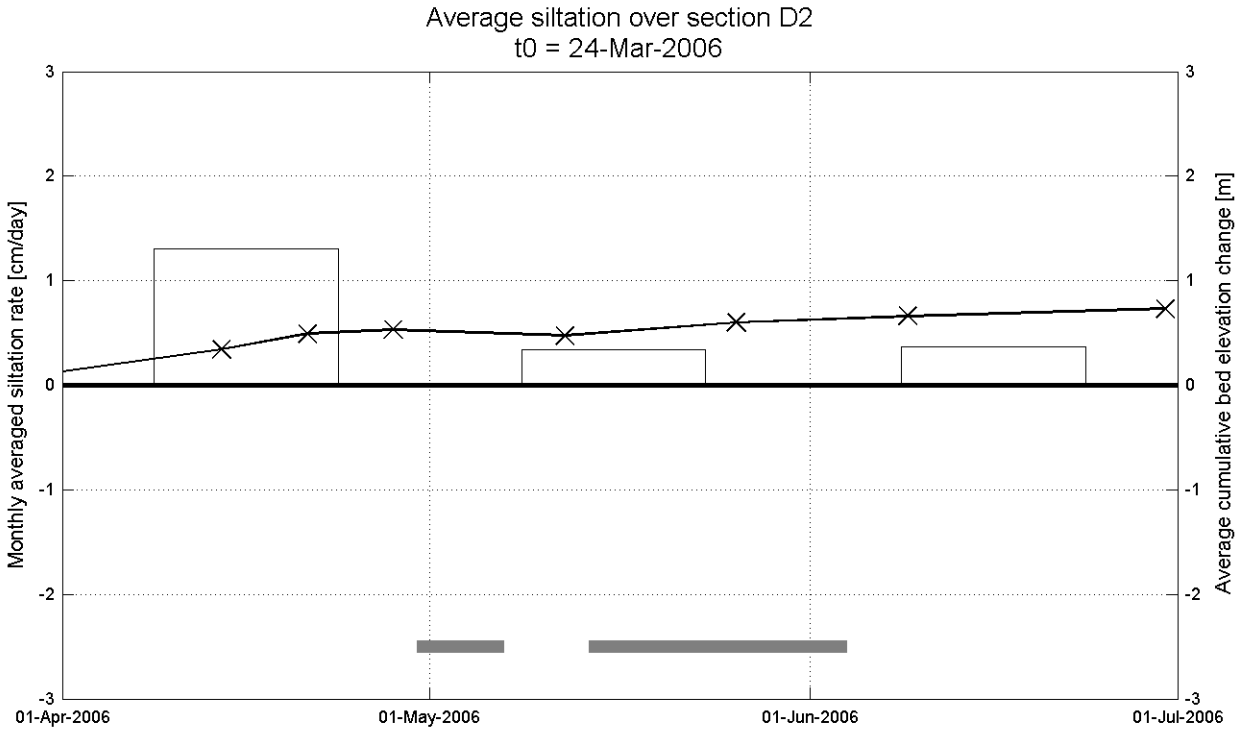
I/RA/11283/06.113/MSA

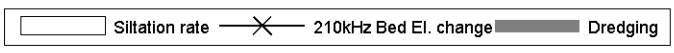
C.3 Water-bed interface evolution for all sections

Long-term monitoring siltation Deurganckdok

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







Reference level: depth sounding 24-Mar-2006

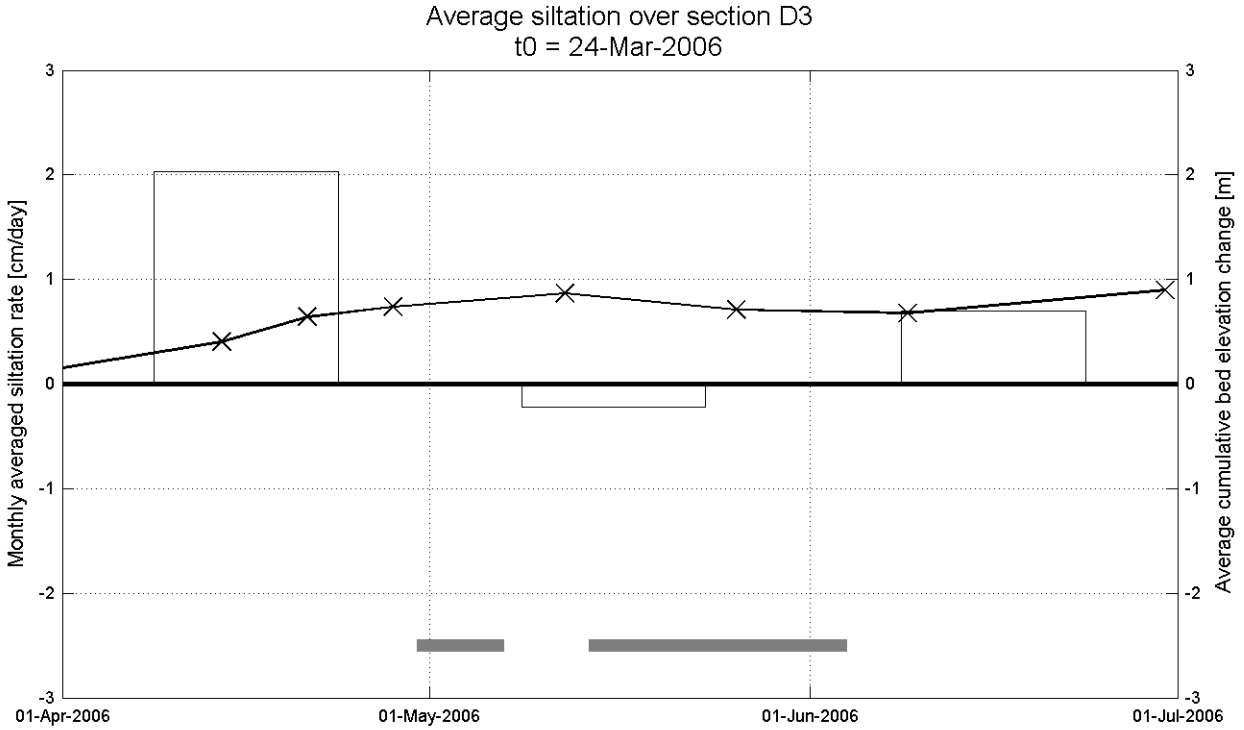
Data Processed by:

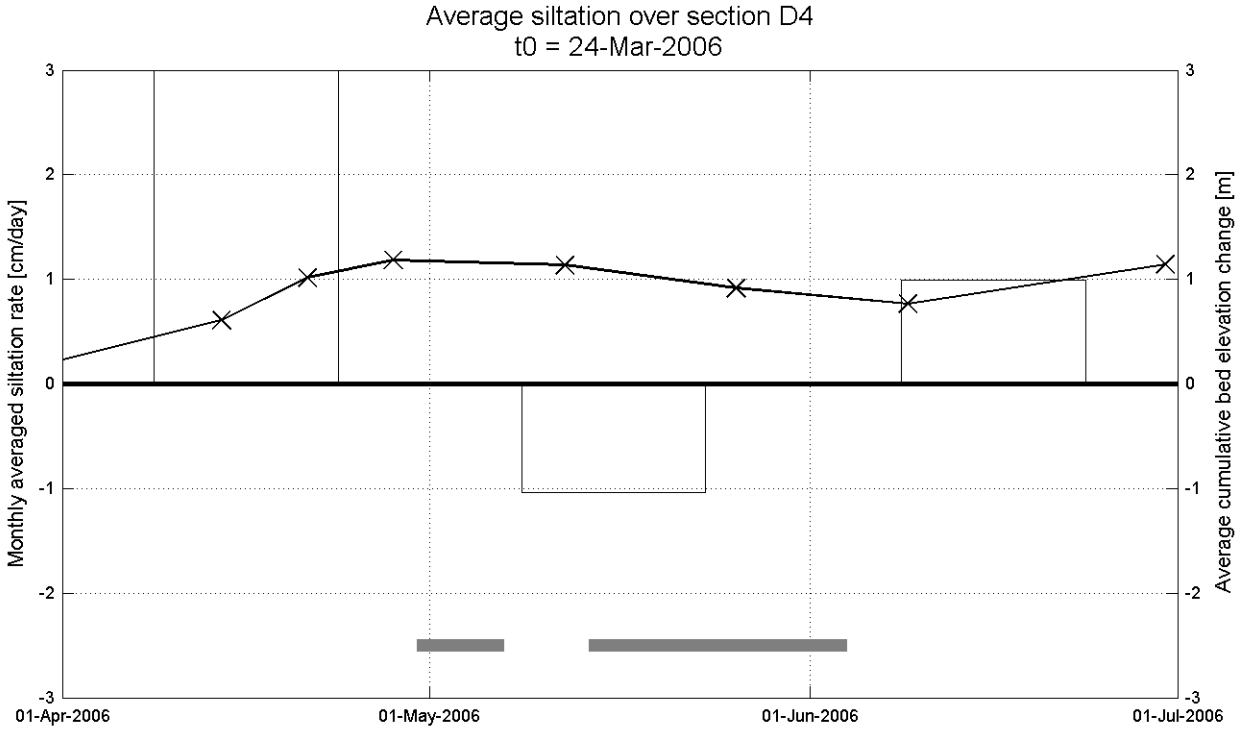
In association with :

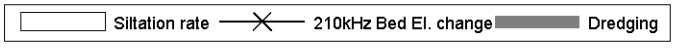
I/RA/11283/06.113/MSA

Long-term monitoring siltation Deurganckdok

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







Reference level: depth sounding 24-Mar-2006

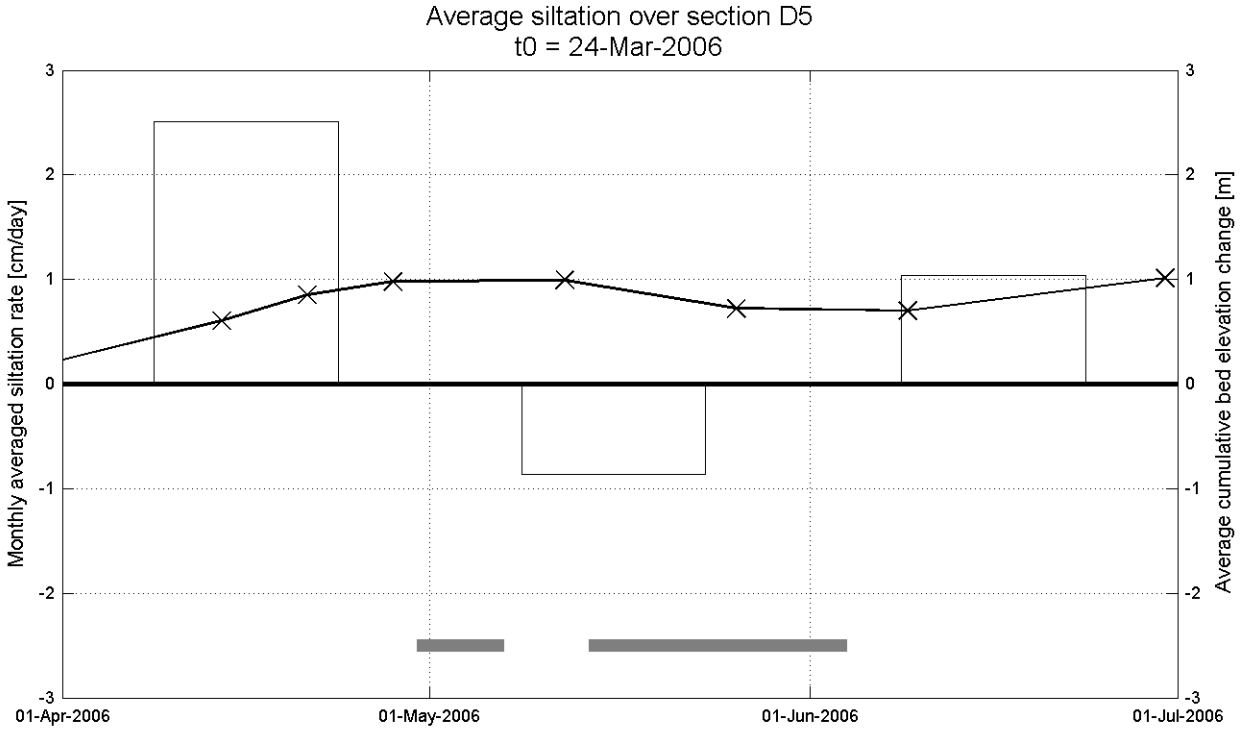
Data Processed by:

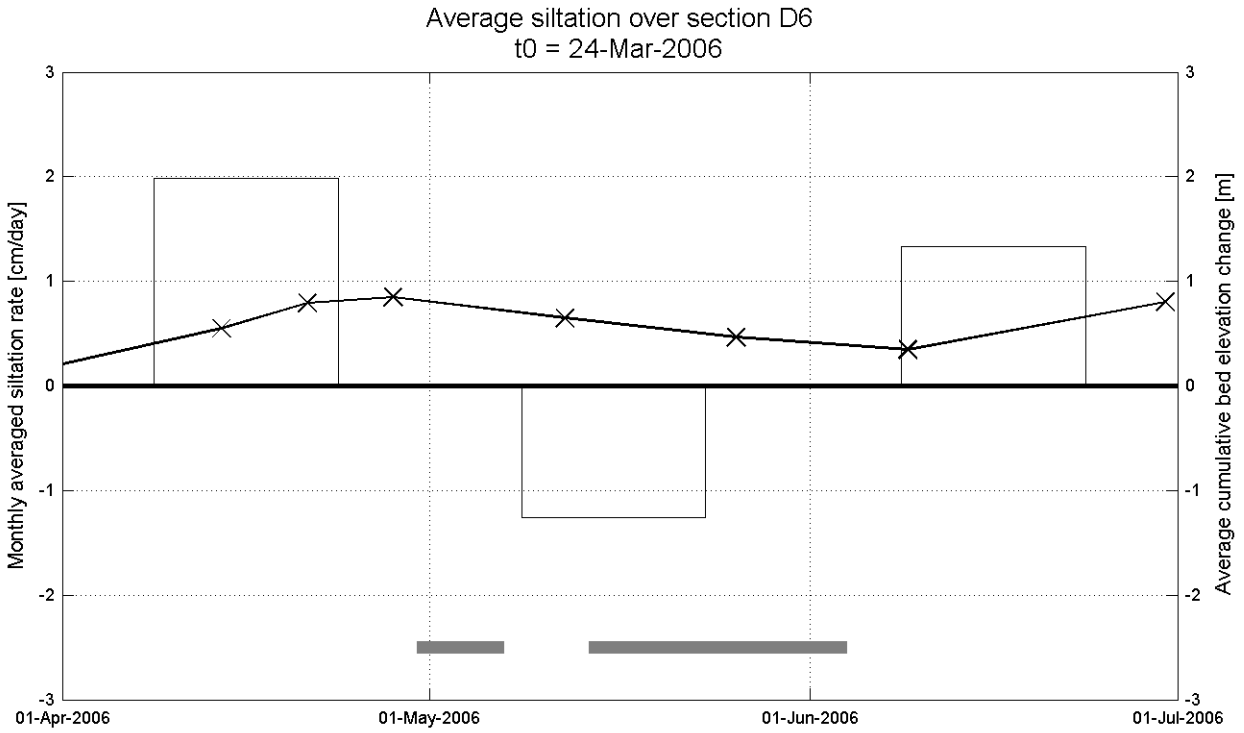
In association with :

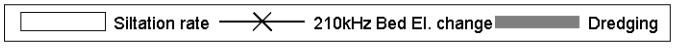
I/RA/11283/06.113/MSA

Long-term monitoring siltation Deurganckdok

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







Reference level: depth sounding 24-Mar-2006

Data Processed by:

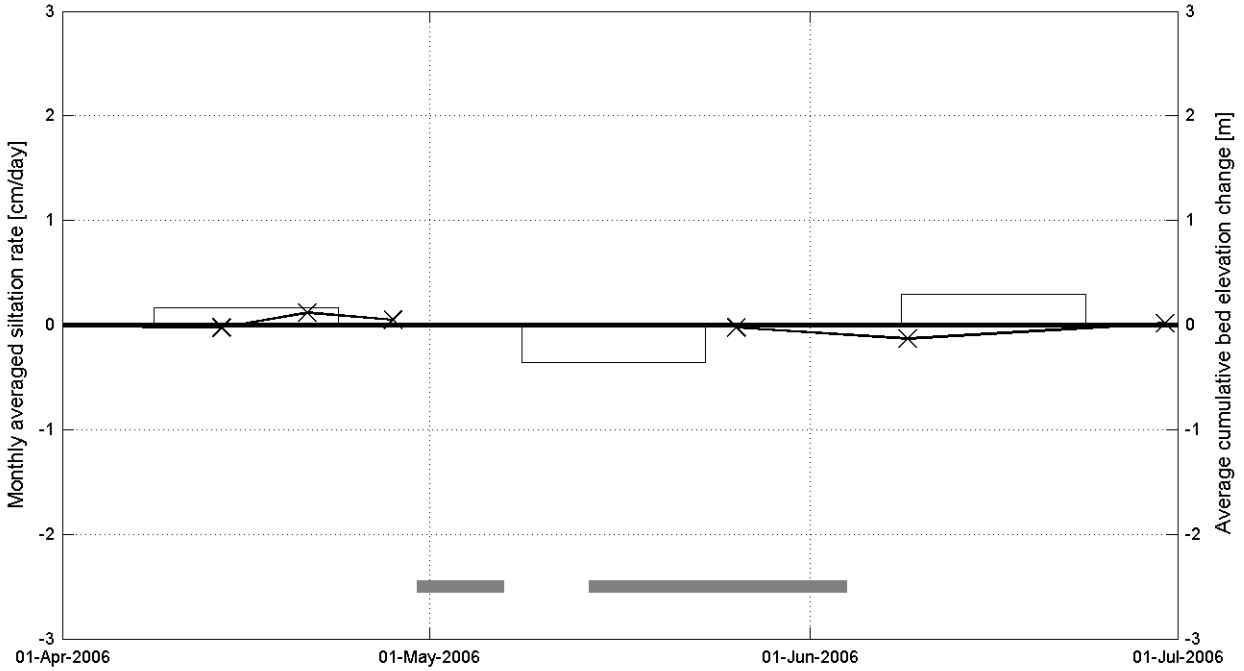
In association with :

I/RA/11283/06.113/MSA

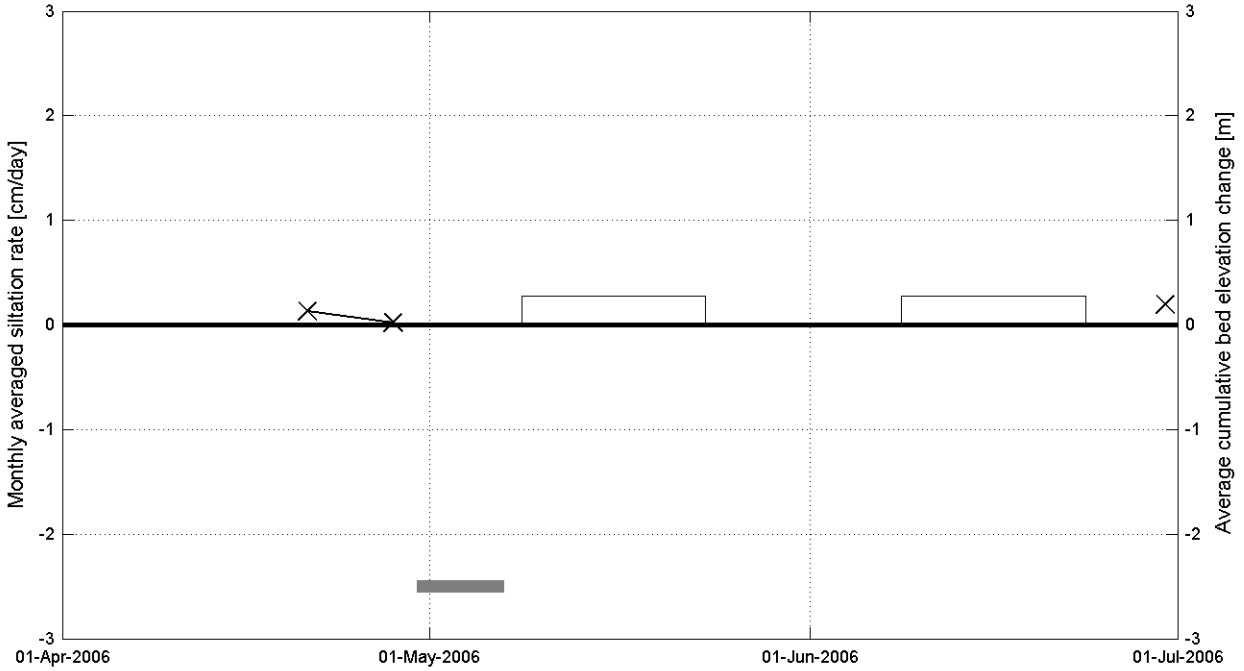
Long-term monitoring siltation Deurganckdok

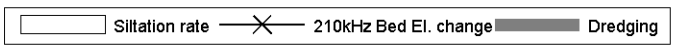
Siltation height / monthly siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD

Average siltation over section D7
t0 = 24-Mar-2006



Average siltation over section D8
t0 = 24-Mar-2006





Reference level: depth sounding 24-Mar-2006

Data Processed by:

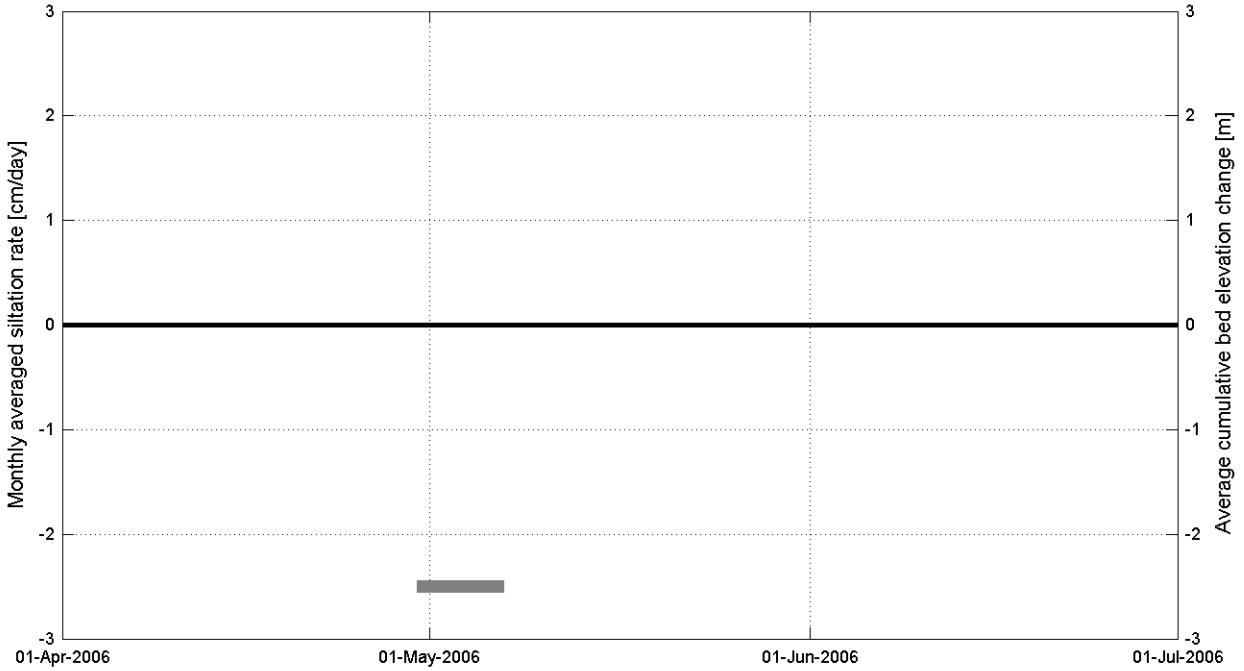
In association with :

I/RA/11283/06.113/MSA

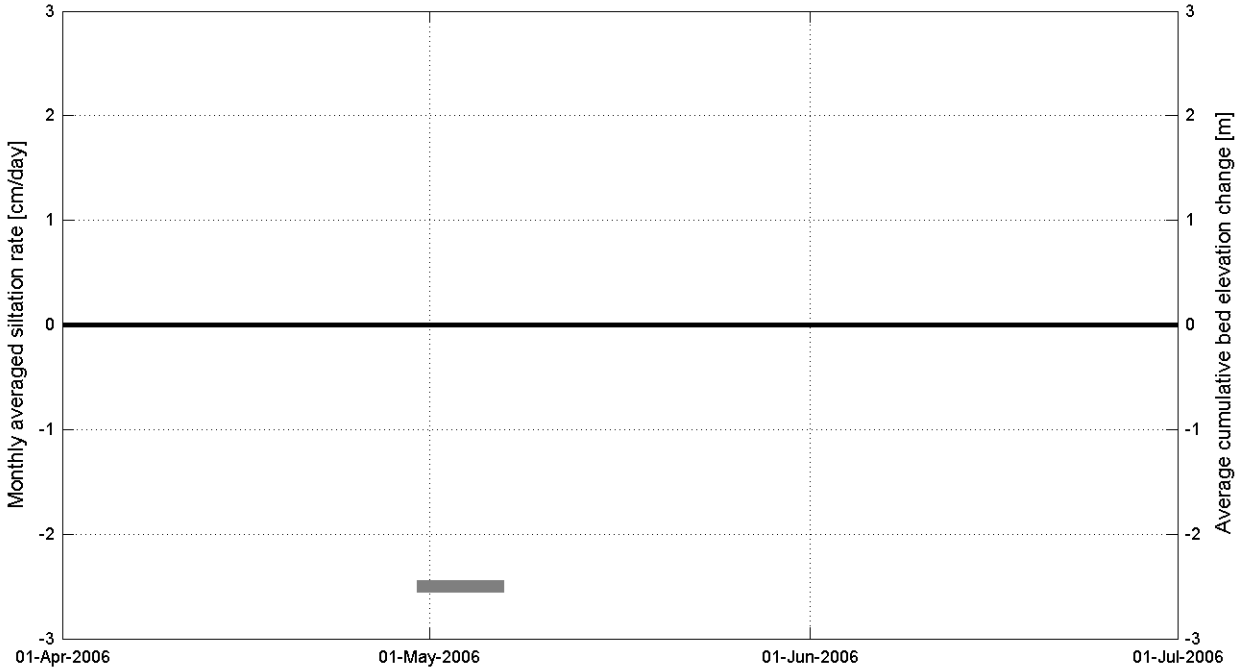
Long-term monitoring siltation Deurganckdok

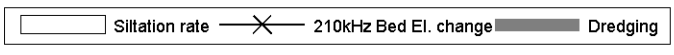
Siltation height / monthly siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD

Average siltation over section D9
t0 = 24-Mar-2006



Average siltation over section D10
t0 = 24-Mar-2006





Reference level: depth sounding 24-Mar-2006

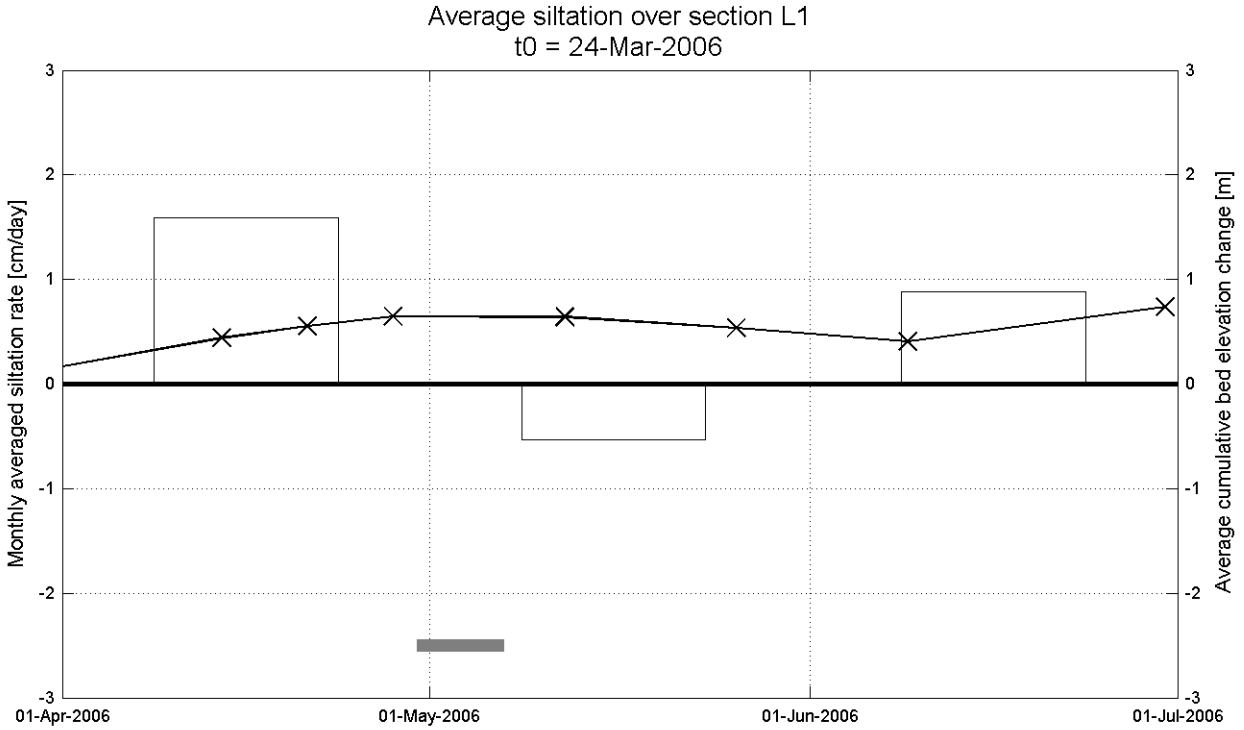
Data Processed by:

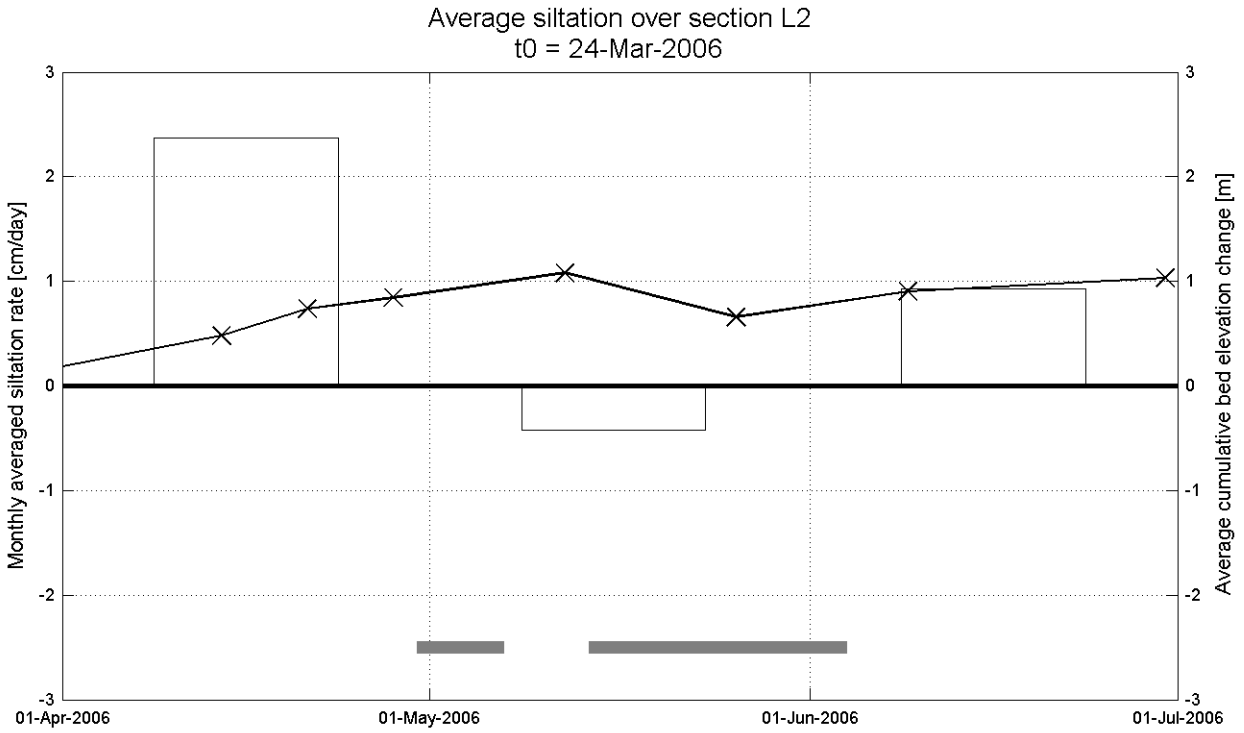
In association with :

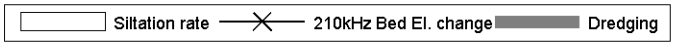
I/RA/11283/06.113/MSA

Long-term monitoring siltation Deurganckdok

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







Reference level: depth sounding 24-Mar-2006

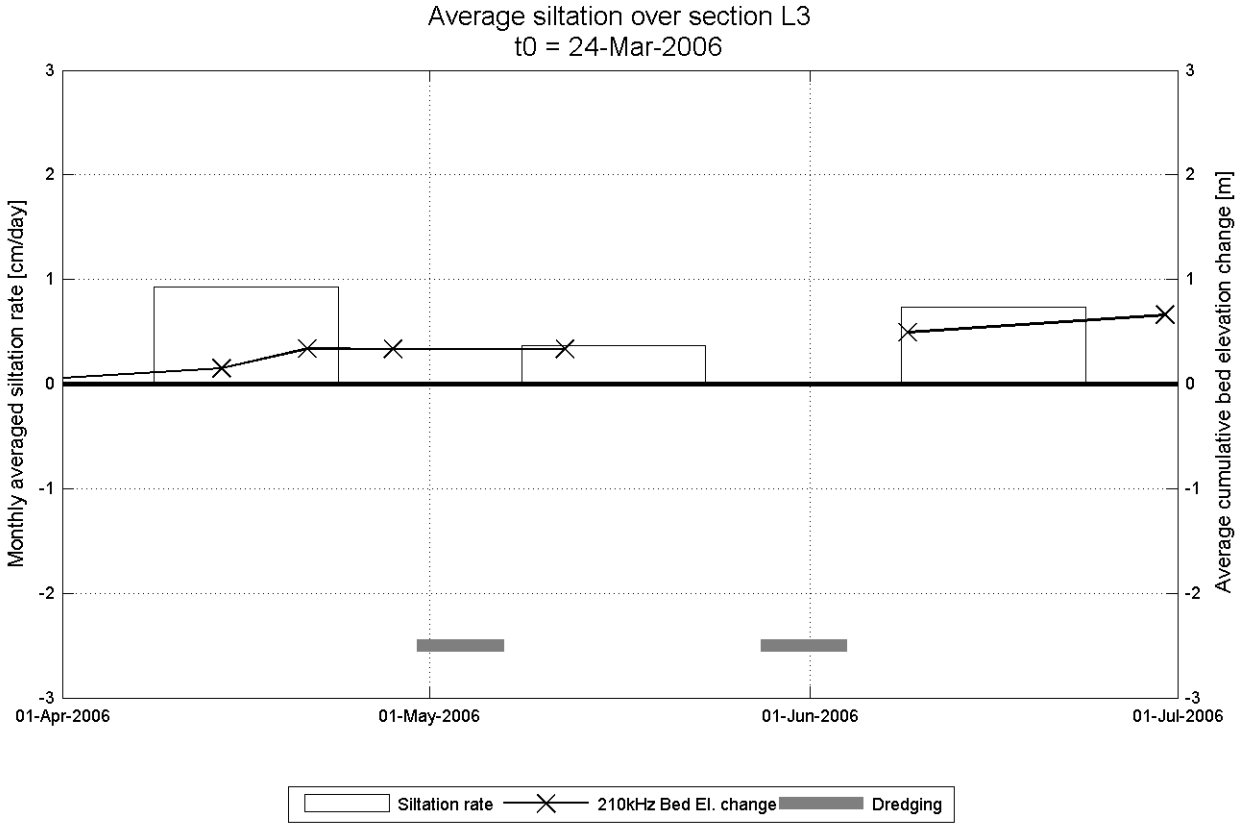
Data Processed by:

In association with :

I/RA/11283/06.113/MSA

Long-term monitoring siltation Deurganckdok

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



Reference level: depth sounding 24-Mar-2006

Data Processed by:

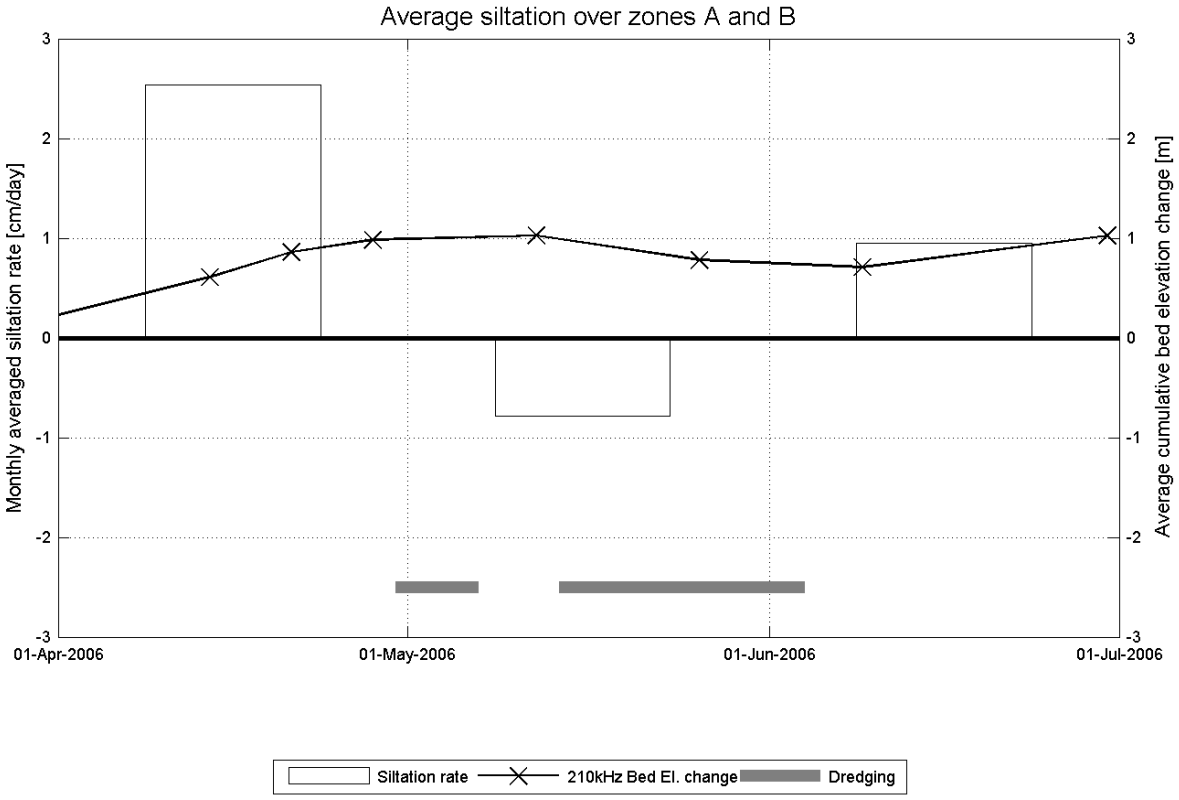
In association with :

I/RA/11283/06.113/MSA

C.4 Siltation rate complete Deurganckdok

Long-term monitoring siltation Deurganckdok

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



Average siltation for zones 3A/3B/4A/4B/5A/5B
Reference level: depth sounding 24-Mar-2006

Data Processed by:

In association with :

I/RA/11283/06.113/MSA

APPENDIX D. MAINTENANCE DREDGING DATA

**Total dredged mass in covered area per week (TDS)				
	30-apr-06	**14-mei-06**	**21-mei-06**	**28-mei-06**
ZONE	**7-mei-06**	**21-mei-06**	**28-mei-06**	**4-jun-06**
1	3680	0	0	0
2	15990	1260	2753	4196
3a	28696	37894	47040	55435
3b	17300	41729	41997	54071
3c	11144	17837	2604	16035
4Na	14278	178	302	266
4Nb	10324	271	122	1908
4Nc	1893	0	0	150
4Za	15692	12	0	1195
4Zb	22804	0	0	0
4Zc	5996	0	0	0
5Na	1345	0	0	0
5Nb	961	0	0	0
5Nc	555	0	0	0
5Za	1830	0	0	0
5Zb	3359	0	0	0
5Zc	824	0	0	0
Total	**156673**	**99181**	**94818**	**133255**

APPENDIX E. HCBS2 REPORTS WINTER CAMPAIGN

Report	*Description*
Ambient Conditions Lower Sea Scheldt	
5.3	Overview of ambient conditions in the river Scheldt – January-June 2006 (I/RA/11291/06.088/MSA)
5.4	Overview of ambient conditions in the river Scheldt – July-December 2006 (I/RA/11291/06.089/MSA)
5.5	Overview of ambient conditions in the river Scheldt : RCM-9 buoy 84 & 97 (1/1/2007 - 31/3/2007) (I/RA/11291/06.090/MSA)
5.6	Analysis of ambient conditions during 2006 (I/RA/11291/06.091/MSA)
Calibration	
6.1	Winter Calibration (I/RA/11291/06.092/MSA)
6.2	Summer Calibration and Final Report (I/RA/11291/06.093/MSA)
Through tide Measurements Winter 2006	
7.1	21/3 Scheldewacht – Deurganckdok – Salinity Distribution (I/RA/11291/06.094/MSA)
7.2	22/3 Parel 2 – Deurganckdok (I/RA/11291/06.095/MSA)
7.3	22/3 Laure Marie – Liefkenshoek (I/RA/11291/06.096/MSA)
7.4	23/3 Parel 2 – Schelle (I/RA/11291/06.097/MSA)
7.5	23/3 Laure Marie – Deurganckdok (I/RA/11291/06.098/MSA)
7.6	23/3 Veremans Waarde (I/RA/11291/06.099/MSA)
HCBS Near bed continuous monitoring (Frames)	
8.1	Near bed continuous monitoring winter 2006 (I/RA/11291/06.100/MSA)
8.2	Near bed continuous monitoring summer 2006 (I/RA/11291/06.101/MSA)
INSSEV	
9	Settling Velocity - INSSEV summer 2006 (I/RA/11291/06.102/MSA)
Cohesive Sediment	
10	Cohesive sediment properties summer 2006 (I/RA/11291/06.103/MSA)
Through tide Measurements Summer	
11.1	Measurement Day 27/9 Vessel 1 (I/RA/11291/06.104/MSA)
11.2	Measurement Day 27/9 vessel 2 (I/RA/11291/06.105/MSA)
11.3	Measurement Day 28/9 vessel 1 (I/RA/11291/06.106/MSA)
11.4	Measurement Day 28/9 vessel 2 (I/RA/11291/06.107/MSA)
11.5	Measurement Day 28/9 vessel 3 (I/RA/11291/06.108/MSA)
Analysis	
12	Report concerning the presence of HCBS layers in the Scheldt river (I/RA/11291/06.109/MSA)