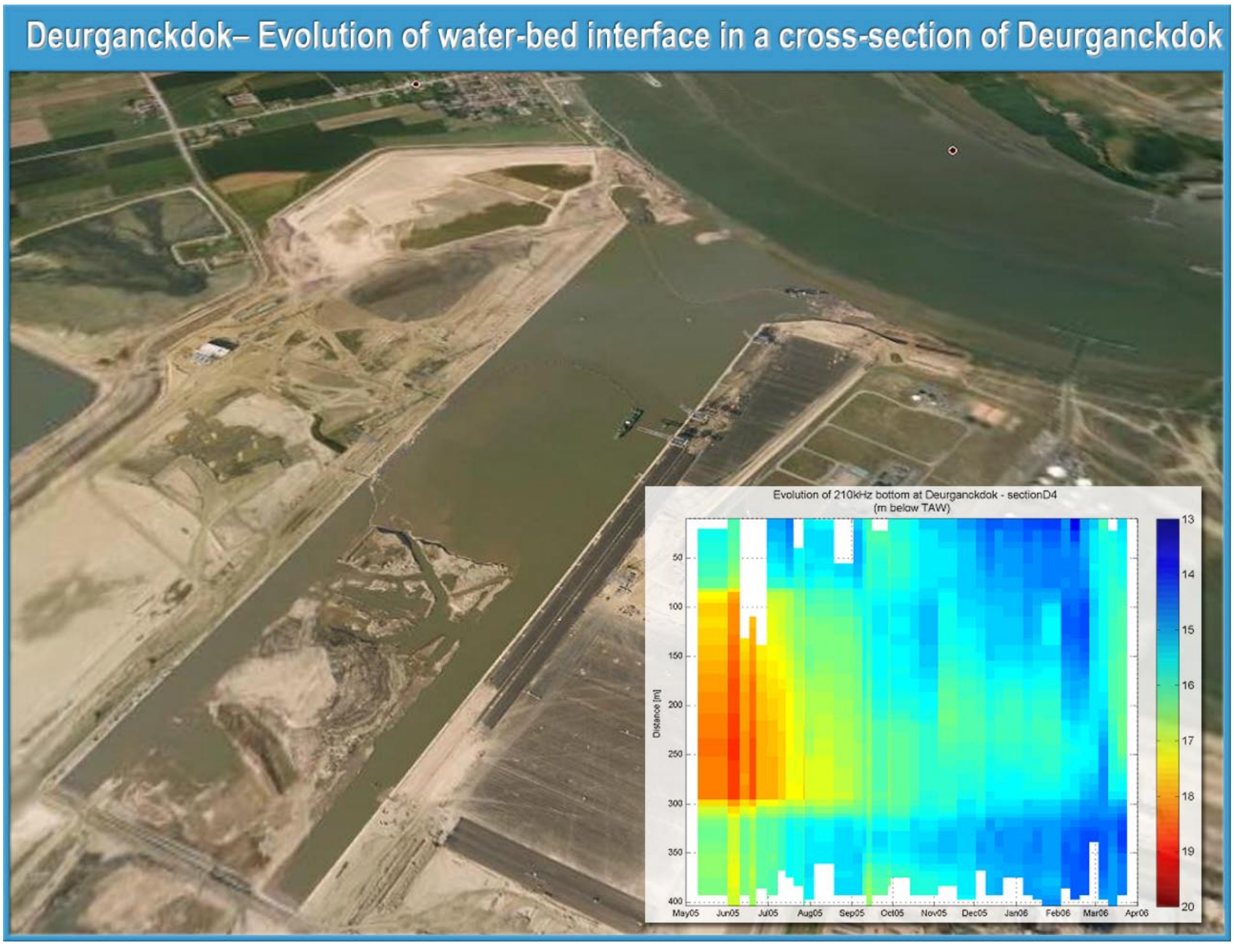
# Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing

Bestek 16EB/05/04




Deelrapport 1.24 : **Sediment jaarbalans 01/04/2008 – 31/03/2009**

Report 1.24 : **Annual sediment balance 01/04/2008 – 31/03/2009**

International Marine & Dredging Consultants

i.s.m.

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# Document Control Sheet

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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] |
| $\rho_s$ | density of the solid minerals [kg/dm³] |
| $\rho_w$ | density of clear water [kg/dm³] |
| $t_{0d}$ | Reference situation for densimetric analysis (empty dock) |
| $t_{0e}$ | Reference situation for volumetric analysis (24 March 2006) |
| TDS | Ton of dry solids [ton] |
| V | volume of dredged sediment [m³] |

# 1. INTRODUCTION

## 1.1. The assignment

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

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

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

The execution of the study involves a twofold assignment:

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

## 1.2. Purpose of the study

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

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

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

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

## 1.3. Overview of the reports

### 1.3.1. Reports

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

*Table 1-1: Overview of Deurganckdok Reports*

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

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

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

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

### 1.3.2. Measurement actions

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

1. Monitoring upstream discharge in the Scheldt river
2. Monitoring Salinity 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 salinity 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, salinity and sediment transport at the entrance of Deurganckdok for which ADCP backscatter intensity over a full cross section are calibrated with the Sediview procedure and vertical sediment and salt profiles are recorded with the SiltProfiler equipment
7. Through tide measurements of vertical sediment concentration profiles -including near bed highly concentrated suspensions- with the SiltProfiler equipment. Executed over a grid of points near the entrance of Deurganckdok.
8. Monitoring dredging activities at entrance channels towards the Kallo, Zandvliet and Berendrecht locks
9. Monitoring dredging and dumping activities in the Lower Sea Scheldt

In situ calibrations were conducted on several dates to calibrate all turbidity and conductivity sensors (see Table 1-1 for relevant reports).

## 1.4. Structure of the report

This report is the sediment balance of the Deurganckdok for the period of April 2008 till March 2009. For convenience and to study trends, the data of April 2007 – March 2008 are included as well. However, the focus is on the former measurement year though. The first chapter comprises an introduction. The second chapter describes the project. Chapter 3 describes the methodology.

The measurement results and processed data are presented in Chapter 4, whereas chapter 5 gives a preliminary analysis of the data.

# 2. SEDIMENTATION IN DEURGANCKDOK

## 2.1. Project Area: Deurganckdok

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

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

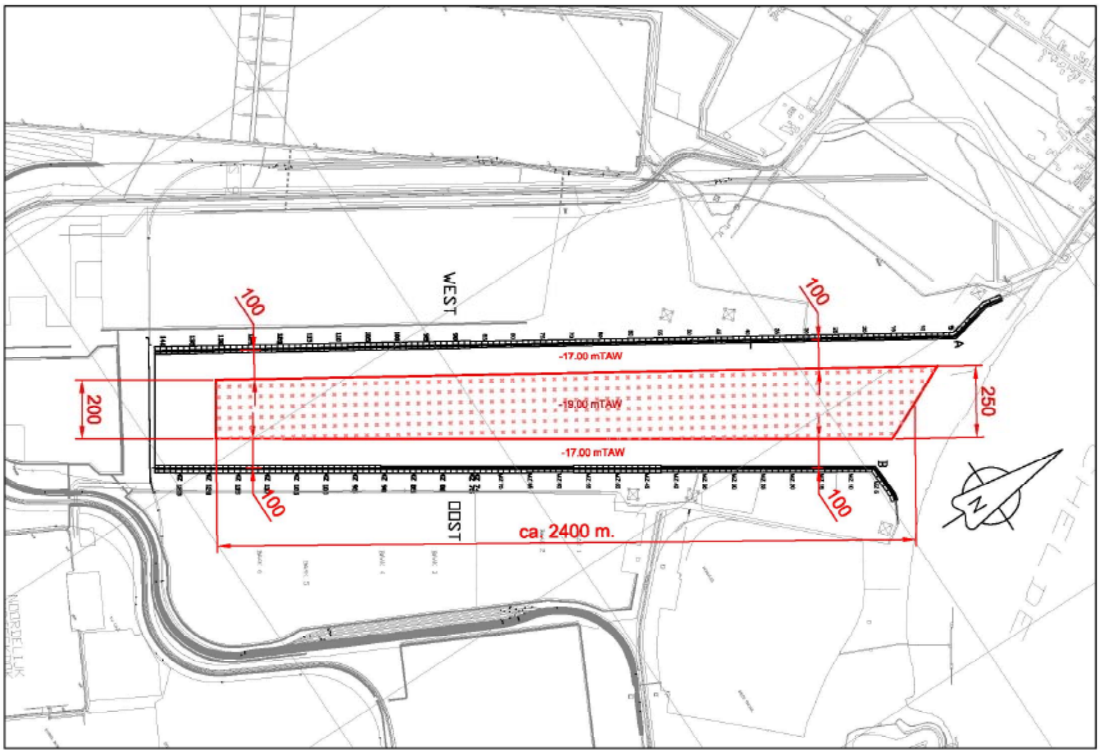


*Figure 2-1: Overview of Deurganckdok*

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

## 2.2. Overview of the studied parameters

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

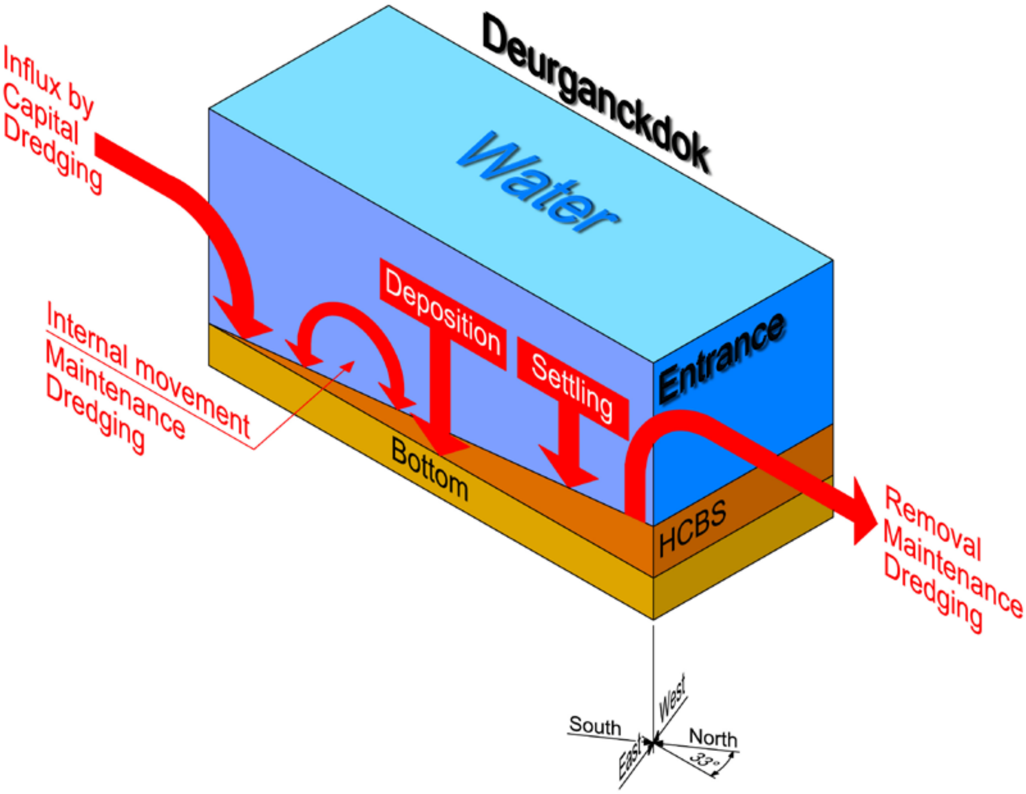


*Figure 2-2: Elements of the sediment balance*

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

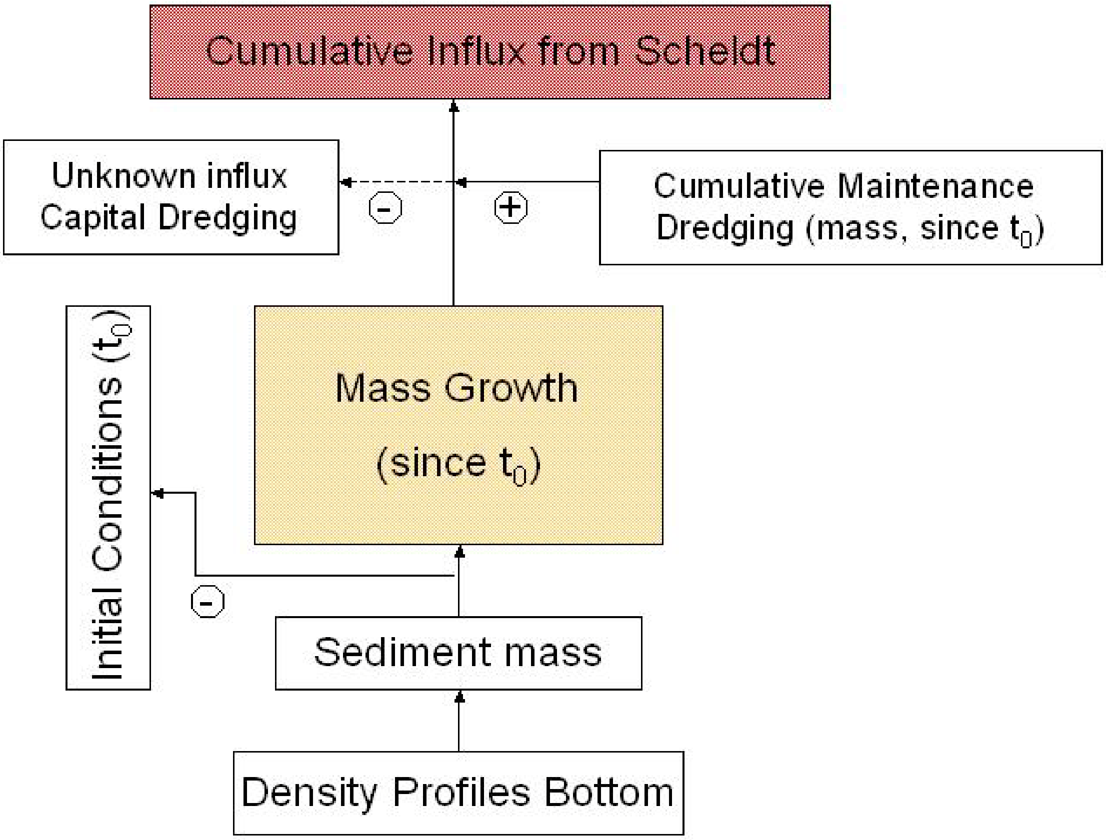


*Figure 2-3: Determining a sediment balance*

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

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

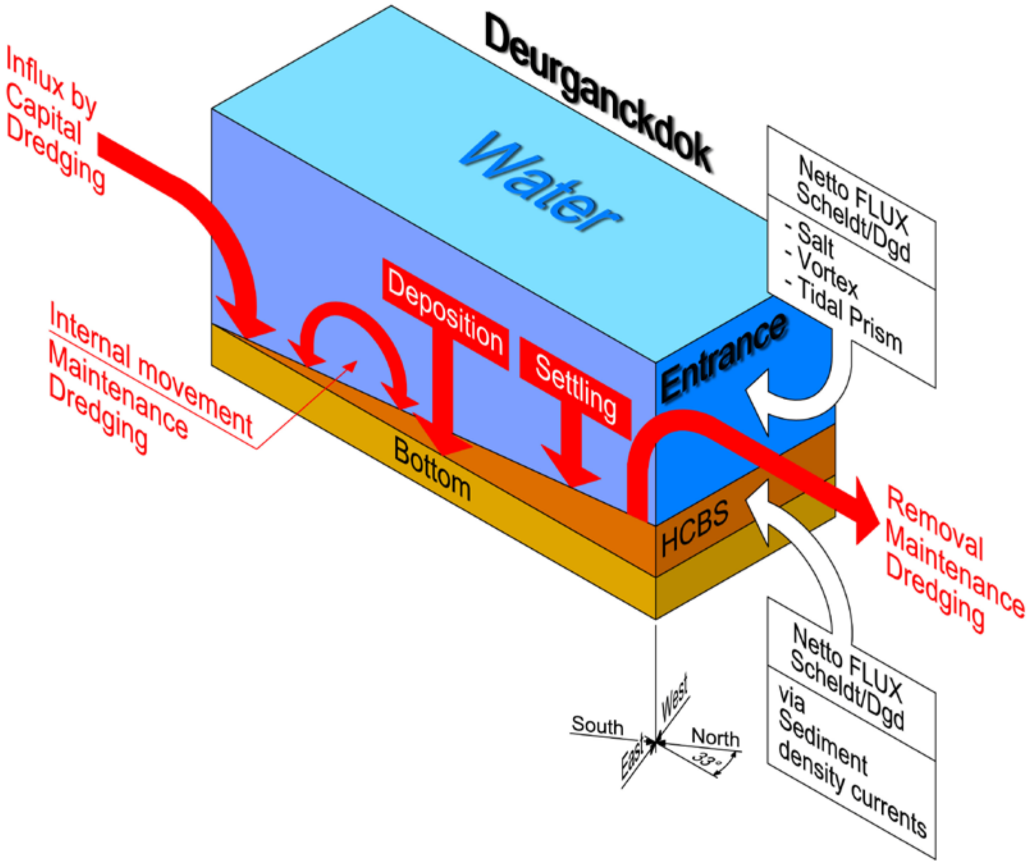


*Figure 2-4: Transport mechanisms*

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

Following data are being collected to understand these mechanisms:

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

# 3. MEASUREMENTS

## 3.1. Depth soundings

The client executes dual-frequency echo-sounder measurements on a frequently basis. 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 01/10/2008 – 31/12/2008*

| ***date*** | ***type of measurement*** | ***signal*** | ***Source*** |
|---|---|---|---|
| 13/03/2008* | dual frequency 210-33 kHz | 210 | Afdeling Kust |
| 11/04/2008 | dual frequency 210-33 kHz | 210 | Afdeling Kust |
| 9/05/2008 | dual frequency 210-33 kHz | 210 | Afdeling Kust |
| 4/06/2008 | dual frequency 210-33 kHz | 210 | Afdeling Kust |
| 15/07/2008 | dual frequency 210-33 kHz | 210 | Afdeling Kust |
| 11/08/2008 | dual frequency 210-33 kHz | 210 | Afdeling Kust |
| 26/08/2008 | dual frequency 210-33 kHz | 210 | Afdeling Kust |
| 3/09/2008 | dual frequency 210-33 kHz | 210 | Afdeling Kust |
| 22/09/2008 | dual frequency 210-33 kHz | 210 | Afdeling Kust |
| 6/10/2008 | dual frequency 210-33 kHz | 210 | Afdeling Kust |
| 20/10/2008 | dual frequency 210-33 kHz | 210 | Afdeling Kust |
| 7/11/2008 | dual frequency 210-33 kHz | 210 | Afdeling Kust |
| 28/11/2008 | dual frequency 210-33 kHz | 210 | Afdeling Kust |
| 15/01/2009 | dual frequency 210-33 kHz | 210 | Afdeling Kust |
| 11/02/2009 | dual frequency 210-33 kHz | 210 | Afdeling Kust |
| 03/03/2009 | dual frequency 210-33 kHz | 210 | Afdeling Kust |
| 17/03/2009 | dual frequency 210-33 kHz | 210 | Afdeling Kust |

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

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

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

A reference level was chosen from all depth sounding measurements. The previous annual report used the earliest measurement as reference level, i.e. 24 March 2006. In February 2008, the capital dredging of the dock was finalized such that a significant larger measurement area became applicable. A new reference situation, initial condition $t_{0e}$, therefore seemed plausible for which the depth sounding of 13 March 2008 was selected. However, when dealing with different measurement years (2007-2009), a single reference situation needed 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 §4.4).

## 3.2. Density measurements

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

### 3.2.1. Navitracker

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

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

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

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

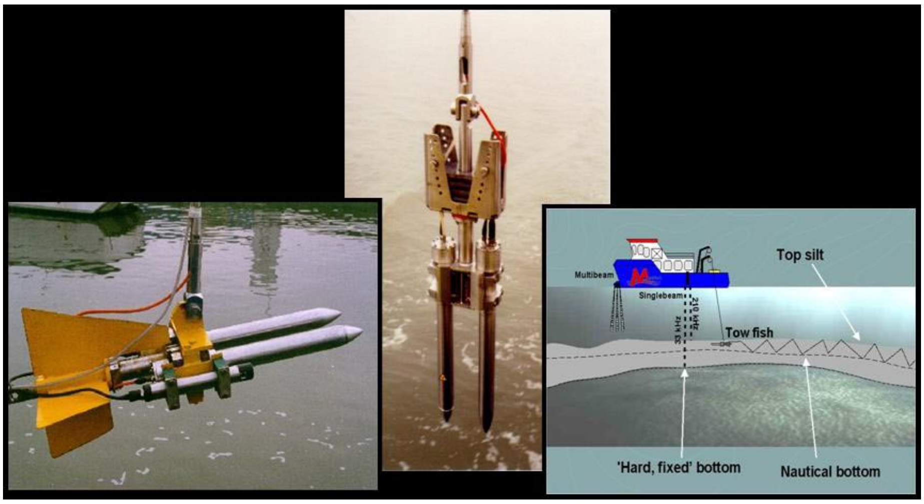


*Figure 3-1: Navitracker*

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

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

### 3.2.2. DensiTune

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

From previous research (IMDC, 2005), 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.

### 3.2.3. Data analysis

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

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 (measured by Navitracker). 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, Navitracker measurements were performed on:

- 28 April 2008;
- 5 June 2008;
- 11 August 2008;
- 26 August 2008

DensiTune measurements were performed at the following dates:

- 11 September 2008;
- 20 October 2008;
- 6 November 2008;
- 30 January 2009; and
- 12 March 2009.

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

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

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

## 3.3. Maintenance Dredging Data

All maintenance dredging (except sweep beam) activities in Deurganckdok were collected in the BIS-system. This system gives a standardised output per week, that states the weight, volume and V'[1] removed/dumped in every 5*5m grid cell in the area. In case the density of the dredged sediment in the hopper bin is larger or equal to 1.6 kg/dm³, V' is equal to the volume in the bin. In case the density is smaller than 1.6 kg/dm³, V' is equal to the reduced volume which is defined as the volume the dredged sediment would have in case the density would be equal to 2 kg/dm³ (AWZ 2000). These dredged volumes are important to have an overall view on the sediment balance. Maintenance dredging occurred between 11 February and 2 March 2009.

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 3-3 of where and when a sweep beam dredger was working in Deurganckdok (DGD) or on the sill of Deurganckdok (sill DGD) for the period March 2008-2009.

*Table 3-3: Sweep beam maintenance dredging activities in Deurganckdok and on the sill of Deurganckdok between April 2008 and March 2009 (source: Afdeling Maritieme Toegang)*

| **From** | **Till** | **Duration (days)** | **Location** |
|---|---|---|---|
| 1/04/2008 | 5/04/2008 | 5 | northern/southern quays (zones A-D) |
| 7/04/2008 | 9/04/2008 | 3 | Sill DGD + northern/southern quays (zones A-D) |
| 14/04/2008 | 16/04/2008 | 3 | Sill DGD + sediment bump at 2/3'rd of the dock |
| 21/04/2008 | 21/04/2008 | 1 | Sill DGD |
| 28/04/2008 | 28/04/2008 | 1 | Sill DGD |
| 5/05/2008 | 5/05/2008 | 1 | Sill DGD |
| 19/05/2008 | 20/05/2008 | 2 | Sill DGD |
| 26/05/2008 | 27/05/2008 | 2 | Sill DGD |
| 2/06/2008 | 2/06/2008 | 1 | Sill DGD |
| 23/6/2008 | 23/6/2008 | 1 | Sill DGD |

[1] V' = Reduced Volume

| ***From*** | ***Till*** | ***Duration (days)*** | ***Location*** |
|---|---|---|---|
| 30/6/2008 | 30/6/2008 | 1 | Sill DGD |
| 7/07/2008 | 7/07/2008 | 1 | sill DGD |
| 14/07/2008 | 14/07/2008 | 1 | sill DGD + northern/southern quays (first third of dock from entrance) |
| 16/07/2008 | 17/07/2008 | 2 | sill DGD + northern/southern quays (first third of dock from entrance) |
| 22/07/2008 | 26/07/2008 | 5 | sill DGD + northern/southern quays (first third of dock from entrance) |
| 28/07/2008 | 28/07/2008 | 1 | Sill DGD |
| 5/08/2008 | 5/08/2008 | 1 | Sill DGD |
| 11/08/2008 | 11/08/2008 | 1 | Sill DGD |
| 18/08/2008 | 18/08/2008 | 1 | Sill DGD |
| 25/08/2008 | 30/08/2008 | 6 | sill DGD + northern/southern quays (first half of dock from entrance) |
| 1/9/2008 | 1/09/2008 | 1 | Sill DGD |
| 5/09/2008 | 6/09/2008 | 2 | Sill DGD |
| 8/09/2008 | 11/09/2008 | 4 | Sill DGD |
| 17/09/2008 | 20/09/2008 | 4 | sill DGD + northern/southern quays (first half of dock from entrance) |
| 22/09/2008 | 27/09/2008 | 6 | sill DGD + northern/southern quays (first four-fifth of dock from entrance) |
| 6/10/2008 | 11/10/2008 | 5 | sill DGD |
| 13/10/2008 | 18/10/2008 | 6 | sill DGD + northern/southern quays (first two-third of dock from entrance) |
| 20/10/2008 | 24/10/2008 | 5 | sill DGD + northern (zoneA) / southern (zones A-B) quays |
| 27/10/2008 | 31/10/2008 | 5 | sill DGD + northern/southern quays (zones A-D) |
| 3/11/2008 | 8/11/2008 | 6 | sill DGD + northern/southern quays (zones A-D) |
| 17/11/2008 | 18/11/2008 | 2 | Sill DGD |
| 24/11/2008 | 25/11/2008 | 2 | Sill DGD |
| 9/12/2008 | 12/12/2008 | 4 | Sill DGD |
| 15/12/2008 | 20/12/2008 | 6 | Sill DGD |
| 5/01/2009 | 5/01/2009 | 1 | sill DGD |
| 12/01/2009 | 12/01/2009 | 1 | sill DGD |
| 19/01/2009 | 19/01/2009 | 1 | sill DGD |
| 28/01/2009 | 29/01/2009 | 2 | sill DGD |
| 2/02/2009 | 3/02/2009 | 2 | sill DGD |
| 9/02/2009 | 10/02/2009 | 2 | sill DGD |
| 16/02/2009 | 17/02/2009 | 2 | sill DGD |
| 23/02/2009 | 24/02/2009 | 2 | sill DGD |
| 2/03/2009 | 3/03/2009 | 2 | sill DGD |
| 10/03/2009 | 11/03/2009 | 2 | sill DGD |
| 16/03/2009 | 16/03/2009 | 1 | sill DGD |
| 23/03/2009 | 24/03/2009 | 2 | sill DGD |
| 30/03/2009 | 31/03/2009 | 2 | sill DGD |

## 3.4. Overview of activities and processes

To facilitate the data analysis in Chapter 5, Table 3-4 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 3-4: Overview of measurements and dredging activities in Deurganckdok*

| | April 07 | | May 07 | | June 07 | | July 07 | | August 07 | | September 07 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **activity** | **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* | ■ | | ■ | ■ | ■ | ■ | | ■ | ■ | ■ | ■ | ■ |

| | October 07 | | November 07 | | December 07 | | January 08 | | February 08 | | March 08 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **activity** | **1 - 15** | **16 - 31** | **1 - 15** | **16 - 30** | **1 - 15** | **16 - 31** | **1 - 15** | **16 - 31** | **1 - 15** | **16 - 28** | **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.
- Zone 3: Central trench in DGD with a design depth at –19 m TAW (including slope to –17 m TAW)
- Zone 4: Transition between central trench and berthing zones with a design depth at –17.00 m TAW: on both (North (N) and South (Z)) sides of DGD (55 m wide).
- Zone 5: Berthing zones next to quay walls on both (North (N) and South (Z)) sides of DGD (40 m wide)

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

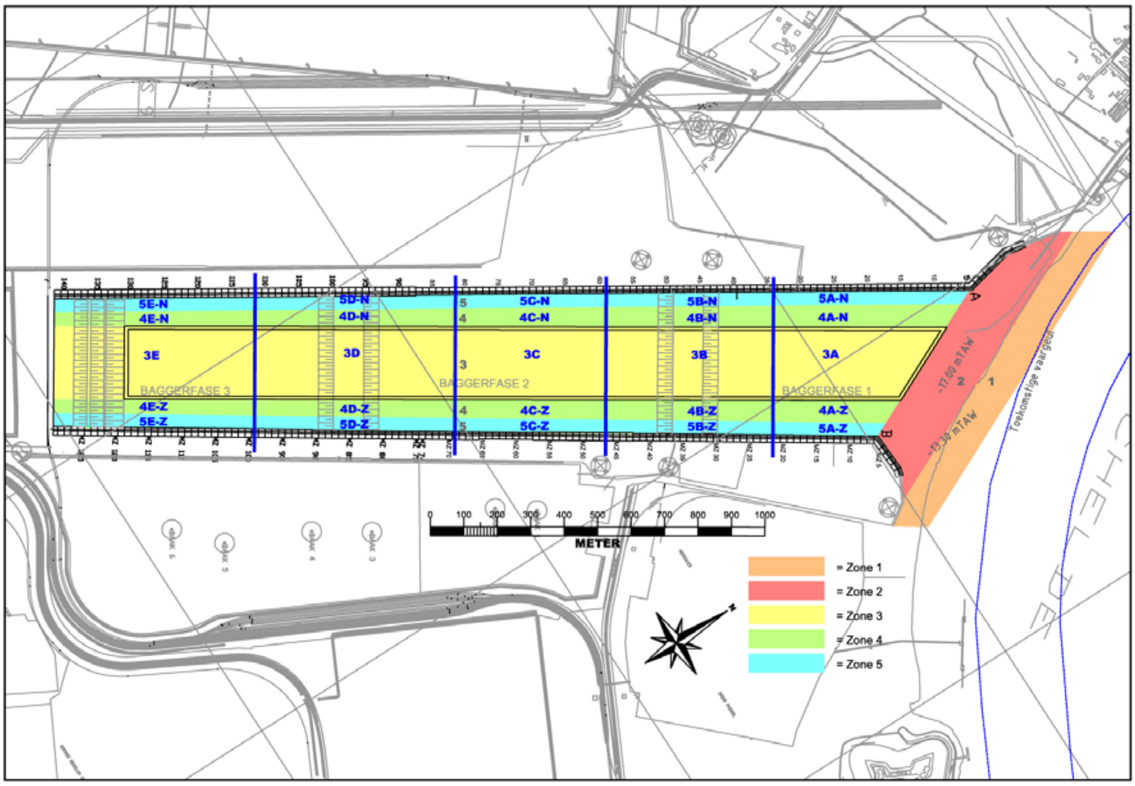


*Figure 4-1: Deurganckdok: Zones and Subzones*

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

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

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

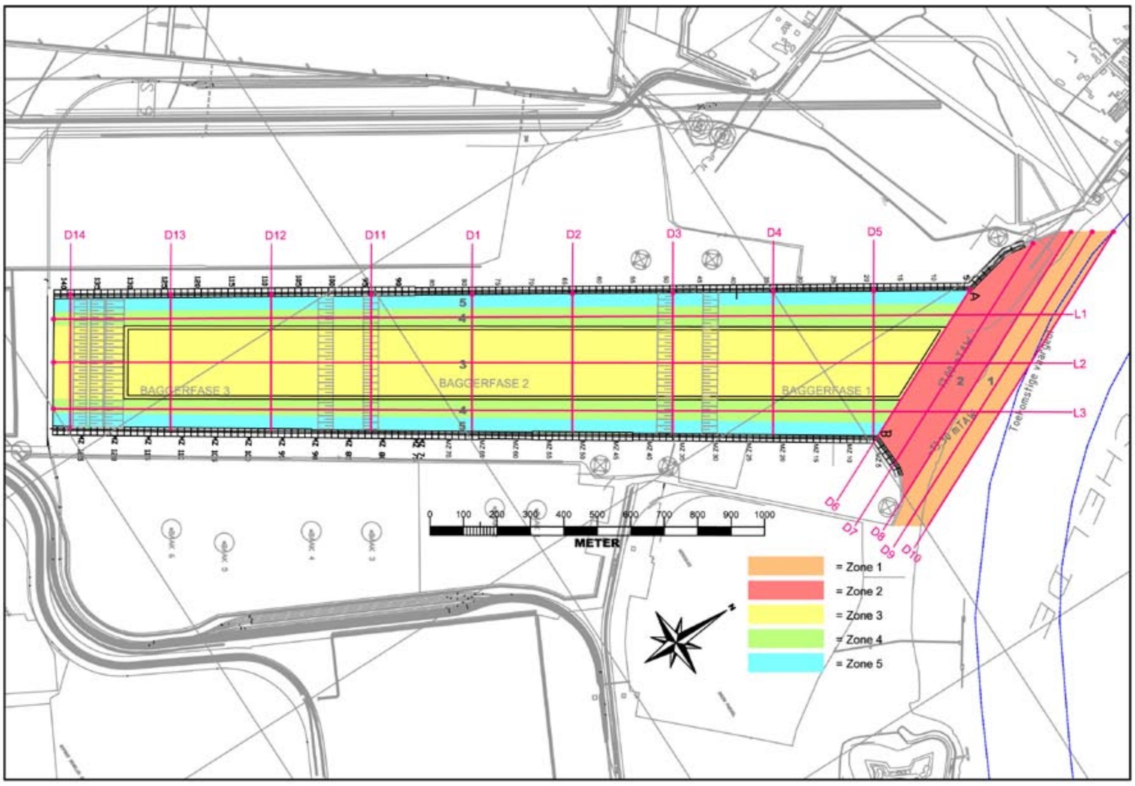


*Figure 4-2: Deurganckdok: D and L Sections*

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

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

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

This is shown as a GIS grid map generated directly from the depth sounding data. The initial and final bathymetries are shown in Figure 4-3, and the enlarged format can be found in APPENDIX A. Only these depth soundings are considered in this report because the annual trend is aimed at. All other collected depth sounding dataset can be found in IMDC (2009a-d).

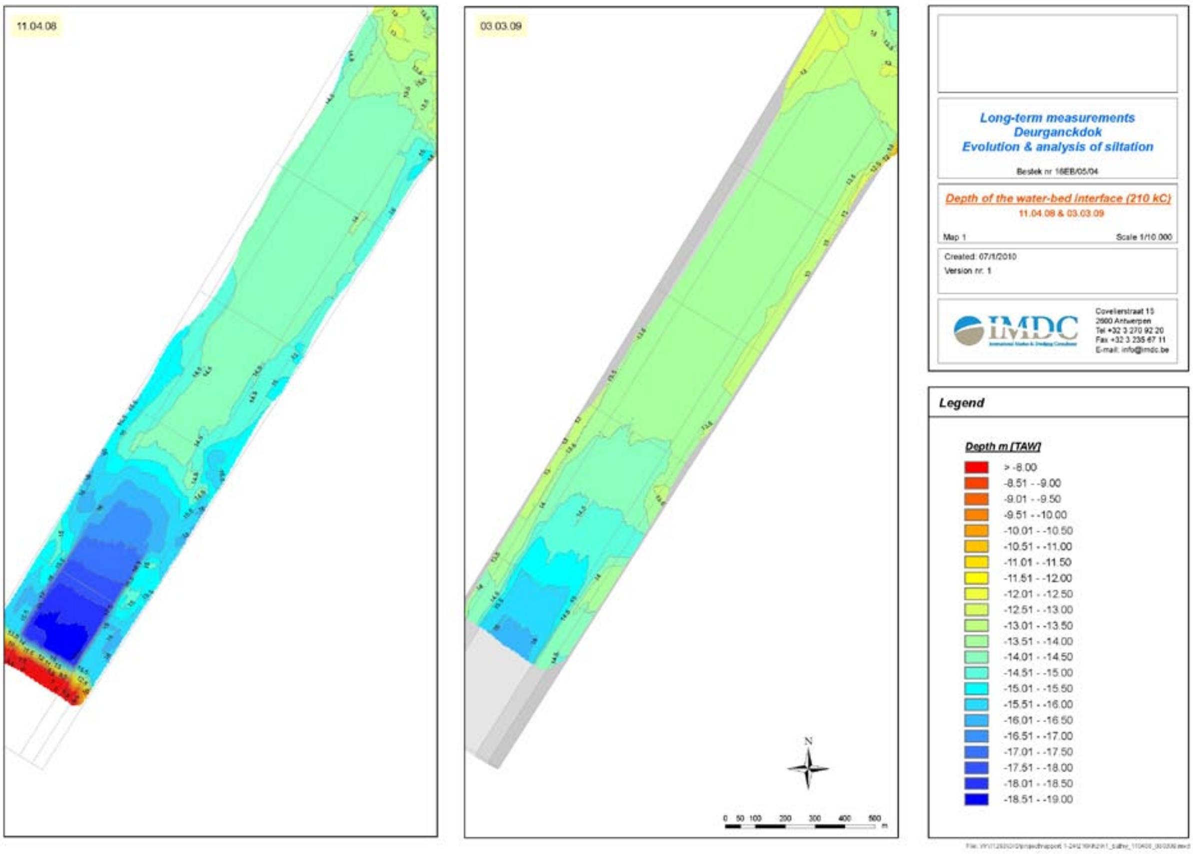


*Figure 4-3: Example of a map showing depth of water-bed interface (210 kC) for 11/4/08 and 3/3/09*

## 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. Figure 4-4 shows such a difference chart covering the period of one year. Note that intermediate difference charts can be found in IMDC (2009a-d).

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 APPENDIX B.

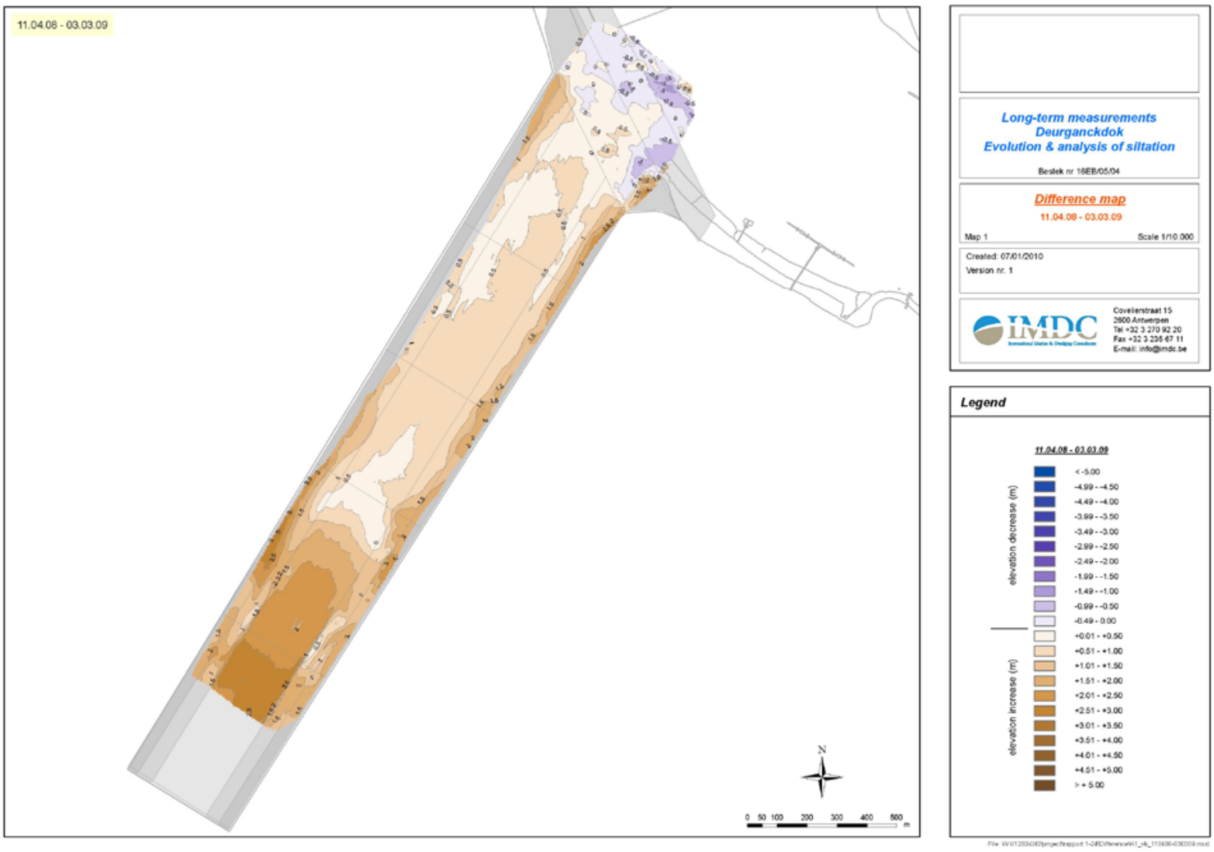


*Figure 4-4: Difference charts of the depth sounding on 3/03/09 in reference to 11/04/08*

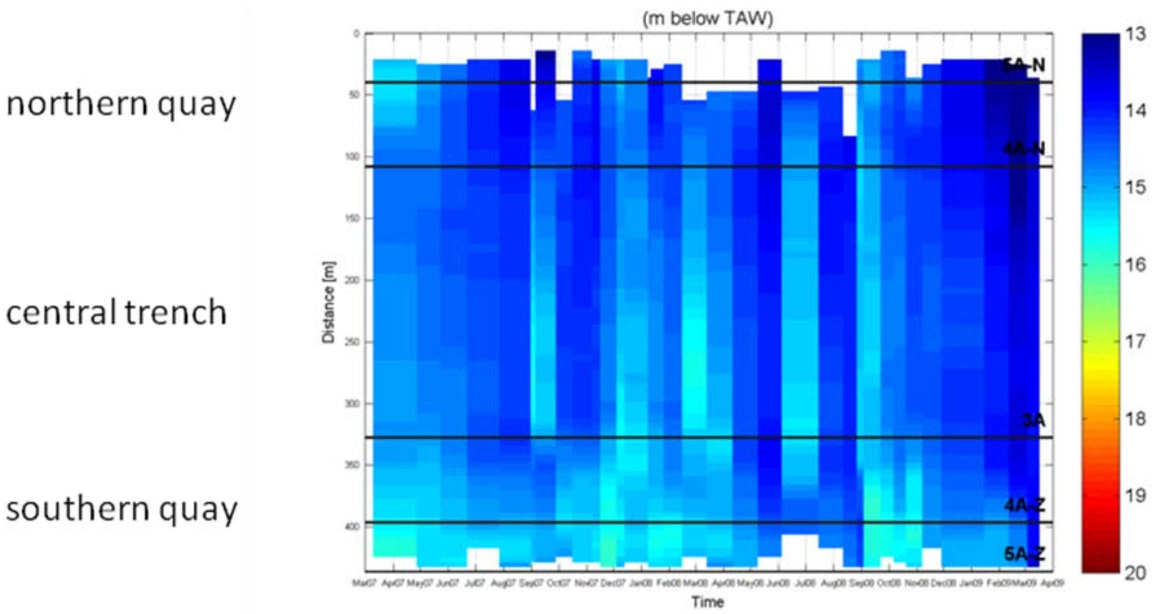


*Figure 4-5: Graph of Evolution of the water-bed interface (210 kC) for section D5*

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

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

Graphs in APPENDIX C show two parameters:

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

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

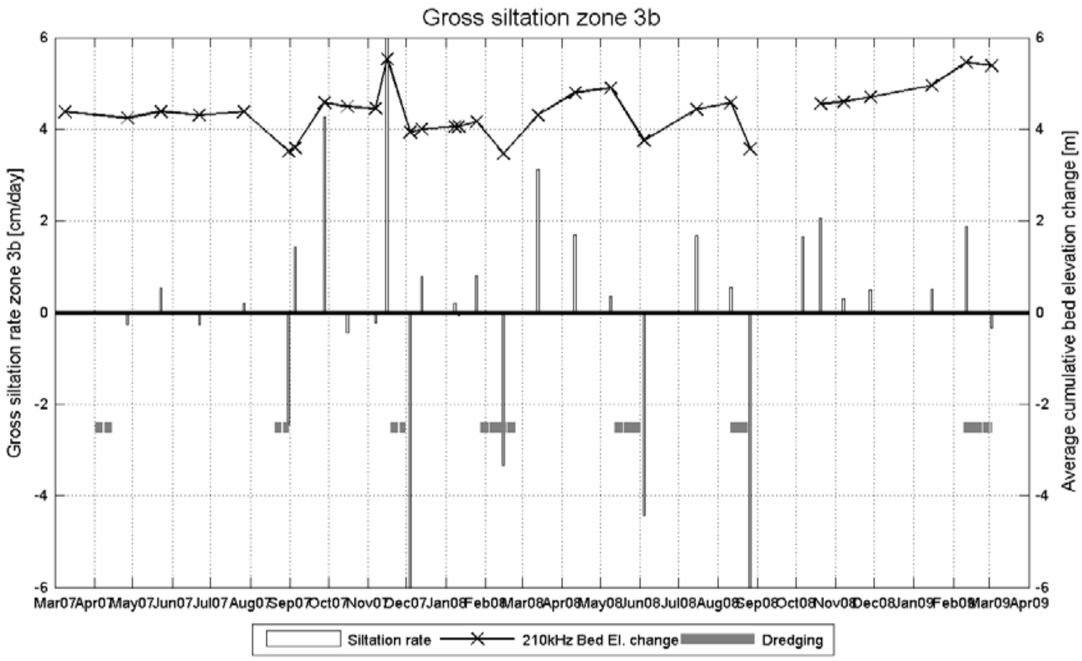


*Figure 4-6: Volumetric siltation rate for zone 3B*

## 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/m² or Ton Dry Solids/m²). Division of the net mass growth of a zone by the number of days in between measurements leads to the averaged net mass growth rate. Note that the last measurement of the previous measurement campaign, i.e. 6 November 2008, is added to the present data series in order to have a good view on the net mass evolution.

Averaged net mass growth rate [kg/m²/day] is computed for each zone and subzone and is shown in APPENDIX D. An example is shown for zone 3C in Figure 4-8.

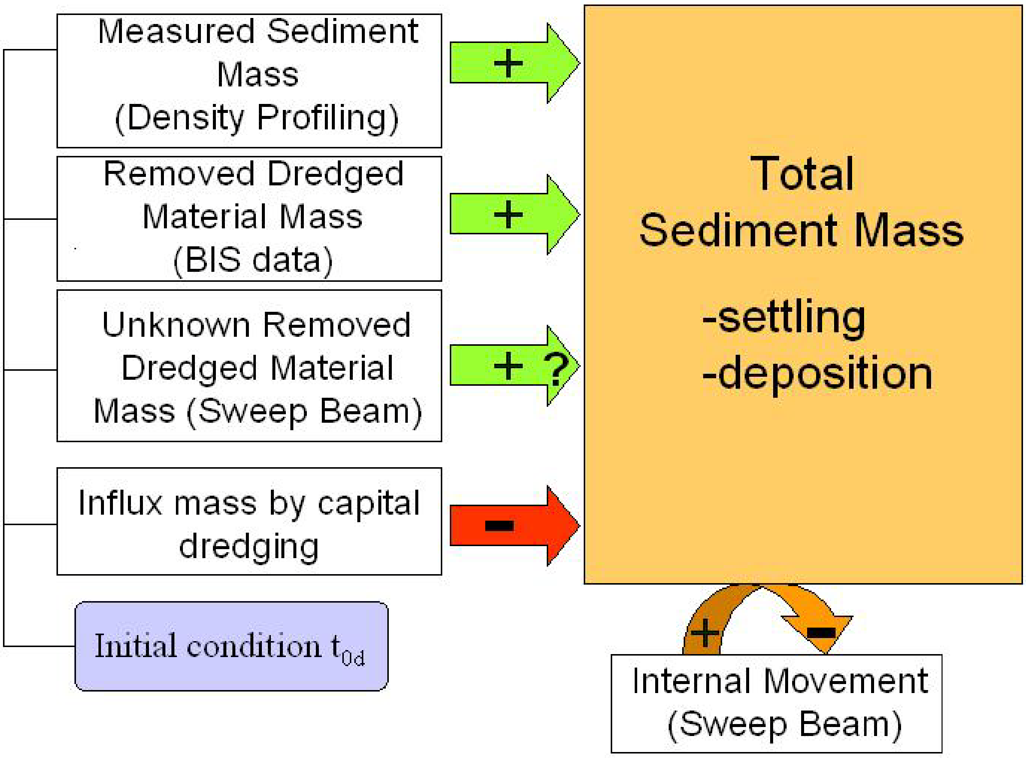


*Figure 4-7: Flow chart with different elements contributing to total sediment mass for (sub)zones and total area*

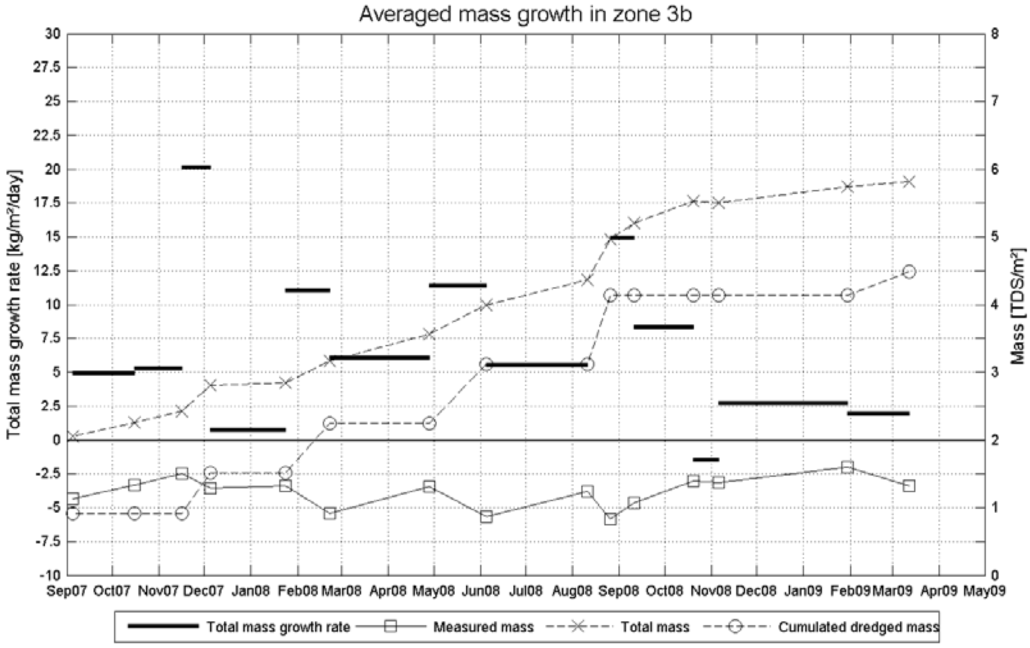


*Figure 4-8: Example of averaged mass growth and mass evolution for subzone 3B*

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

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

# 5. PRELIMINARY ANALYSIS OF THE DATA

## 5.1. Introduction

This chapter discusses the measurements on a yearly basis. Three-monthly trends that are already covered in previous reports are not dealt with, cf. IMDC (2009a-d). Instead, more long-term evolutions are focused, or evolutions and phenomena bridging these three-monthly periods.

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:

$$\frac{dM_s}{dt} = R_{siltation} - R_{erosion} \pm R_{sweepbeam} - R_{maintenanc\ e} \pm R_{capitaldre\ dging}$$

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]
- $R_{capital\ dredging}$ = 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 process;
- gross siltation rate: is computed from a time period in which other 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.

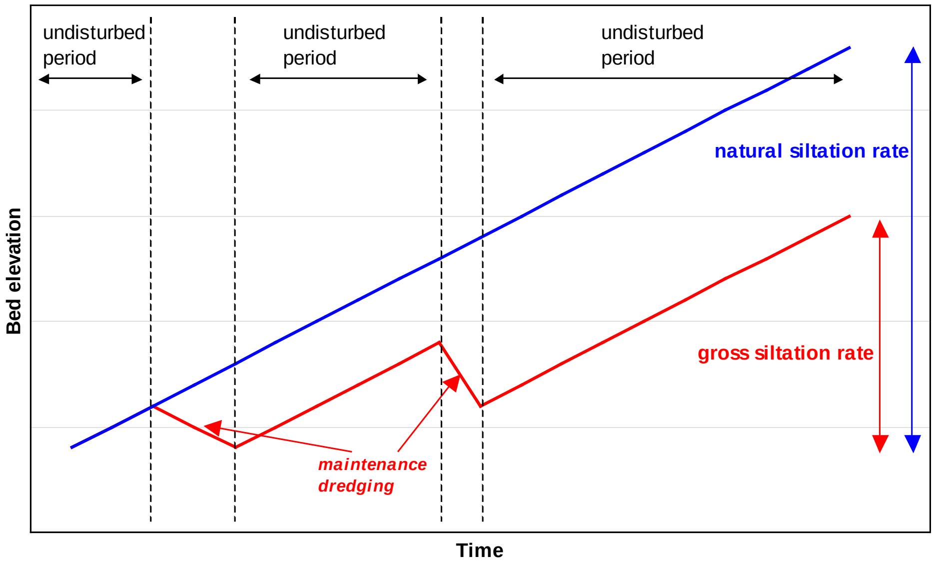


*Figure 5-1: difference between natural and gross (volumetric) siltation rate*

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:

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

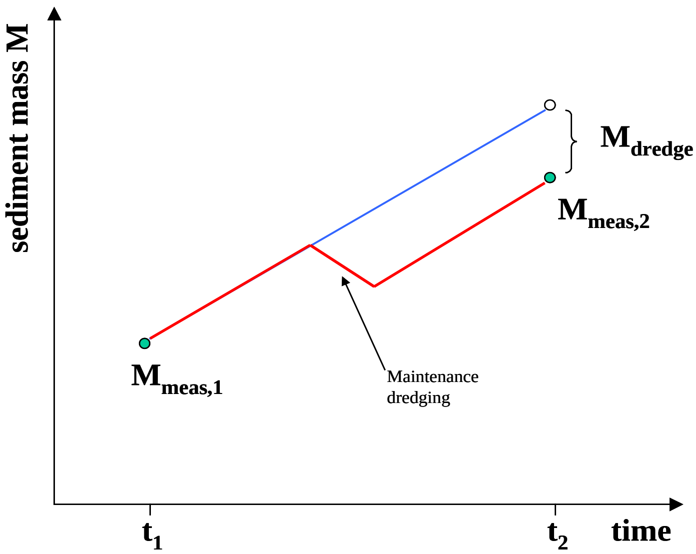


*Figure 5-2: Principle of total deposited sediment mass calculated from the measured mass $M_{meas}$ and dredged mass $M_{dredge}$*

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. These data can be found in APPENDIX C.

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. This gross siltation rate is valid for the time period between these subsequent depth soundings. 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. The results are shown in Table 5-1, which indicates that, in general, gross siltation rates are very small and positive. The mean gross siltation rate measured 0.2 cm/day, averaged over zones A, B and C. The temporal evolution of the sediment bed level indeed indicates that the levels observed in April 2008 are smaller than those of March 2009 (see Appendix B.1), which is in agreement with the positive value for mean gross siltation rate. Table 5-1 also shows that the gross siltation rate generally increases when going further inside the dock. This is in contradiction to the natural siltation rate as discussed in §5.2.2.

*Table 5-1: gross yearly averaged siltation rates for every zone*

| ZONE | ***gross yearly averaged siltation rate [cm/day]*** |
|---|---|
| **3a** | 0.14 |
| **3b** | 0.18 |
| **3c** | 0.19 |
| **3d** | 0.48 |
| **3e** | 0.51 |
| **4Na** | 0.23 |
| **4Nb** | 0.18 |
| **4Nc** | 0.34 |
| **4Nd** | 0.41 |
| **4Ne** | 0.91 |
| **4Za** | 0.21 |
| **4Zb** | 0.23 |
| **4Zc** | 0.29 |
| **4Zd** | 0.35 |
| **5Na** | 0.46 |
| **5Nb** | 0.50 |

| ZONE | *gross yearly averaged siltation rate [cm/day]* |
|---|---|
| **5Nc** | 0.57 |
| **5Nd** | 0.63 |
| **5Za** | 0.53 |
| **5Zb** | 0.55 |
| **5Zc** | 0.49 |
| **5Zd** | 0.51 |

### 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).

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. Remark 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 - C (cf. APPENDIX C.4), four periods can be identified being undisturbed by maintenance dredging, i.e.

- Period 1: 11/4/2008 – 9/5/2008;
- Period 2: 4/6/2008 – 11/8/2008;
- Period 3: 26/8/2008 – 20/10/2008; and
- Period 4: 7/11/2008 – 15/1/2009.

Comparing Table 5-1 with Table 5-2 reveals that the natural siltation rate is larger than the gross yearly averaged siltation rate. This is simply due to the absence of dredging activities. Table 5-2 also clearly indicates that natural siltation rates in the central trench, observed in Period 2 and Period 3, are significantly larger than those of the other two observation periods. This can be attributed to the intensity of dredging. Periods 2 and 3 showed dredging activities of a couple of days prior to the time periods of analysis, whereas Periods 1 and 4 experienced (i) dredging taking place more than two weeks before the measurements, and (ii) dredging amounts in the order of 80,000 TDS being smaller than those for the other two periods. As a result, the initial bed level in the central trench was lower for Periods 2 and 3 than for the other periods; it is therefore assumed that the trench acted more as a sediment trap in which sediment rapidly accumulated and resulted in larger siltation rates. Siltation rates in Period 3 were much larger than for Period 2 because more than 2.5 times the dredged mass of Period 2 was removed.

Table 5-2 also indicates that the natural siltation rate decreased when going from the sill to the back-end of the dock, although it was not as obvious as from previous measurements (cf. IMDC, 2007n). A gradient in the transverse direction was only clear for (again) Periods 2 and 3. Such a transverse trend could also be observed in the period April 2006 – March 2007 (IMDC, 2007e).

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. This spatial trend of siltation rates inside the dock is similar to the present observations in Periods 2 and 3, being unaffected by preceding dredging actions.

Further, the hydrodynamic sediment transport model returned an estimation of the sedimentation volume to be dredged annually. It was calculated at approximately 4.3 million $m^3$/year if the sediment is dredged immediately (at a bulk density of around 1.15 kg/l) after sedimentation. This results in an area-averaged mean volume of 3.4 $m^3/m^2$.year to be dredged. The actual observations return a value of 2.4, 4.0, 4.6 and 2.6 $m^3/m^2$.year when using the natural siltation rates for Periods 1-4 respectively. Clearly, an absolute correspondence between the simulation study and the actual measurements is not present. The order of magnitude and the trends are however quite similar.

*Table 5-2: natural siltation rates obtained from undisturbed measurement periods*

| ZONE | Natural siltation rates [cm/day] | | | |
|---|---|---|---|---|
| | **11/4/08 - 9/5/08** | **4/6/08 - 11/8/08** | **26/8/08 - 20/10/08** | **7/11/08 - 15/1/09** |
| **3a** | 0.49 | 1.59 | 1.38 | 0.63 |
| **3b** | 0.35 | 1.22 | 1.77 | 0.51 |
| **3c** | 0.25 | 0.80 | 1.85 | 0.61 |
| **3d** | 0.77 | 0.31 | 1.17 | 1.22 |
| **4Na** | 1.86 | 1.03 | 1.08 | 1.09 |
| **4Nb** | 0.77 | 0.89 | 0.92 | 0.79 |
| **4Nc** | 0.97 | 0.67 | 0.70 | 0.90 |
| **4Nd** | 0.18 | 0.18 | 0.23 | 0.98 |
| **4Za** | 1.70 | 1.37 | | 0.92 |
| **4Zb** | 1.09 | 1.00 | | 1.21 |
| **4Zc** | 0.59 | 0.23 | 0.08 | 0.76 |
| **4Zd** | 0.06 | 0.11 | 0.22 | 0.54 |

## 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. Below, 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 5-3), it can be concluded that almost 1.1 million TDS was dredged over the entire measurement period. This is approximately 14.5% more sediment mass withdrawn from the dock in comparison with the corresponding measurement period of 2007-2008 (IMDC, 2007n). According to Table 5-3, intense weekly dredging occurred in the second half of May 2008 and the second half of August 2008 during which 45% of the annual total amount was removed from the dock. These weeks of intense dredging were characterised by dredged masses of more than 140,000 TDS per week. Other periods with dredged masses exceeding 100,000 TDS per week are the second half of May 2008 and the second half of February 2009. When the geographical distribution of dredged mass in the Deurganckdok is considered, it was observed that 80% of the total mass originated from zones 3A, 3B, 3C and 3D, being the central trench of the dock. Subzone 4NA contributed more than 4% to the total dredged amount.

*Table 5-3: Amounts of dredged mass per zone and dredging period*

| | Total dredged mass in covered area (TDS) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 12-May-08 | 19-May-08 | 26-May-08 | 11-Aug-08 | 18-Aug-08 | 20-Oct-08 | 09-Feb-09 | 16-Feb-09 | 24-Feb-09 | 02-Mar-09 | | |
| ZONE | 18-May-08 | 25-May-08 | 01-Jun-08 | 17-Aug-08 | 24-Aug-08 | 26-Oct-08 | 15-Feb-09 | 23-Feb-09 | 01-Mar-09 | 02-Mar-09 | Total (TDS) | % |
| 1 | 0 | 0 | 0 | 39 | 0 | 0 | 28 | 0 | 0 | 0 | 67 | 0.0 |
| 2 | 523 | 989 | 746 | 483 | 346 | 0 | 115 | 673 | 623 | 0 | 4497 | 0.4 |
| 3a | 59931 | 36320 | 21332 | 59941 | 80335 | 0 | 7478 | 12311 | 35768 | 2122 | 315538 | 28.9 |
| 3b | 34338 | 36401 | 25286 | 33300 | 77573 | 0 | 2268 | 9991 | 25328 | 1597 | 246082 | 22.5 |
| 3c | 17708 | 25536 | 20847 | 11229 | 55195 | 25424 | 2341 | 7773 | 18303 | 1151 | 185506 | 17.0 |
| 3d | 946 | 5952 | 8877 | 3508 | 13759 | 53894 | 3608 | 12843 | 17634 | 779 | 121799 | 11.1 |
| 3e | 0 | 0 | 541 | 0 | 0 | 0 | 283 | 499 | 1987 | 0 | 3311 | 0.3 |
| 4Na | 8337 | 4706 | 2455 | 11052 | 6768 | 0 | 5137 | 9582 | 1789 | 0 | 49826 | 4.6 |
| 4Nb | 5739 | 5745 | 5503 | 5866 | 2514 | 0 | 4629 | 12123 | 629 | 0 | 42748 | 3.9 |
| 4Nc | 2594 | 2216 | 2962 | 1249 | 421 | 23 | 3763 | 7966 | 537 | 0 | 21733 | 2.0 |
| 4Nd | 39 | 157 | 1242 | 0 | 75 | 101 | 2700 | 6081 | 281 | 0 | 10677 | 1.0 |
| 4Ne | 0 | 0 | 64 | 0 | 0 | 0 | 65 | 9 | 16 | 0 | 155 | 0.0 |
| 4Za | 7668 | 6137 | 1054 | 8679 | 1918 | 0 | 1930 | 6477 | 1438 | 0 | 35300 | 3.2 |
| 4Zb | 5496 | 8591 | 887 | 5103 | 2083 | 0 | 3055 | 7731 | 749 | 0 | 33695 | 3.1 |
| 4Zc | 949 | 3290 | 239 | 487 | 803 | 1 | 2500 | 5327 | 217 | 0 | 13813 | 1.3 |
| 4Zd | 302 | 230 | 15 | 13 | 0 | 27 | 1514 | 5288 | 217 | 0 | 7605 | 0.7 |
| 4Ze | 0 | 0 | 2 | 0 | 0 | 0 | 56 | 22 | 15 | 0 | 94 | 0.0 |
| 5Na | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0.0 |
| 5Nc | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 4 | 0.0 |
| **Total** | **144573** | **136270** | **92053** | **140949** | **241789** | **79470** | **41468** | **104701** | **105533** | **5649** | **1092453** | |
| **%** | **13.2** | **12.5** | **8.4** | **12.9** | **22.1** | **7.3** | **3.8** | **9.6** | **9.7** | **0.5** | | |

## 5.3.2. Densimetric growth rate

Appendix D.3 shows the time evolution of the settled sediment mass as quasi linearly increasing in time. In mid-August 2008, a jump in the temporal trend occurred due to the change of density measurement technique, i.e. changing from Navitracker to the DensiTune device, see §3.2. Note that this was pronounced for the measurements in the central trench only. The range of observed growth rates for some zones in the central trench are shown in Table 5-4. Similarly to the natural siltation rates, the growth rates become smaller when going more inside the dock.

*Table 5-4: Range of densimetric growth rates in the central trench area*

| ZONE | kg/m²/day |
|---|---|
| 3A | 5 - 15 |
| 3B | 0 - 12.5 |
| 3C | 0 - 7.5 à 10 |

Previous results showed a mass growth rate in the central trench (zones 3A, 3B and 3C) in the range of 11 to 20 kg/m²/day for the period November – December 2007 and January – February 2008 when dredging activities occurred. Without any dredging activities, total sediment mass growth rates approximately ranged between 2 and 8 kg/m²/day in the central trench (see also Table 5-5).
In the measurement year 2008-2009 (Table 5-5), the increased growth rate due to dredging has been observed as well. In the central trench, densimetric growth rates artificially increased by 5-10 kg/m²/day, which was (in order of magnitude) in accordance to previous measurements. This significant difference can be attributed to a combination of the two dredging processes, i.e. hopper and sweepbeam maintenance dredging. Whereas sweepbeam operations result in an artificial influx of sediment in the central trench, the continuous hopper maintenance dredging in this period leads to a lower bed level and, therefore, to a possible more rapid siltation.

Densimetric growth rates were smaller near the quays in comparison to the values observed in the central trench, and generally measured up to 7.5 kg/m²/day. These observations are in accordance to the measurements in 2007-2008 (see IMDC, 2007n).

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

| kg/m²/day | 2007 - 2008 | 2008 - 2009 |
|---|---|---|
| no dredging | 2 – 8 | 1 – 15 |
| dredging | 11 – 20 | 8 – 25 |
| difference | ~10 | ~5 à 10 |

### 5.3.3. Total deposited mass

An overview of the total mass settled over time is shown in Table 5-6 and Table 5-7. Zones 3A-D and 4ZB-D have been covered for more than 85%, whereas the other zones show coverages of at least 50%. Additionally, total masses are given for subzones of zone 5 too of which the zone coverage was more than 50%. For these subzones, the coverage never exceeded 85% though.

From Table 5-7, it is concluded once more that the settled mass decreased from zone A to D. This confirms again the hypothesis of a gradual decrease in siltation with distance from the Scheldt river.

*Table 5-6: Total sediment mass (measured + dredged, in 10³ TDS) in some zones*

| | 28-Apr-08 | 05-Jun-08 | 11-Aug-08 | 26-Aug-08 | 11-Sep-08 | 20-Oct-08 | 06-Nov-08 | 30-Jan-09 | 12-Mar-09 |
|---|---|---|---|---|---|---|---|---|---|
| **3a** | 441 | 491 | 552 | 622 | 656 | 711 | 705 | 746 | 762 |
| **3b** | 391 | 439 | 480 | 546 | 572 | 608 | 605 | 630 | 639 |
| **3c** | 328 | 357 | 382 | 419 | 437 | 462 | 483 | 504 | 530 |
| **3d** | 162 | 171 | 173 | 185 | 199 | 216 | 249 | 298 | 322 |
| **3e** | | | | | 130 | 139 | 160 | 419 | 285 |
| **4Na** | 79 | 85 | 94 | 99 | 107 | 113 | 113 | 126 | 130 |
| **4Nb** | 63 | 70 | 78 | 81 | 85 | 93 | 91 | 97 | 108 |
| **4Nc** | 43 | 46 | 51 | 50 | 49 | 62 | 55 | 57 | 69 |
| **4Nd** | 24 | 22 | 28 | 29 | 24 | 35 | 30 | 38 | 45 |
| **4Ne** | | | | | 27 | 29 | | 58 | 78 |
| **4Za** | 45 | 49 | 57 | 58 | 67 | 64 | 65 | 74 | 82 |
| **4Zb** | 50 | 57 | 62 | 63 | 70 | 74 | 71 | 77 | 89 |
| **4Zc** | 32 | 30 | 34 | 35 | 36 | 42 | 43 | 47 | 59 |
| **4Zd** | 21 | 18 | 22 | 21 | 23 | 30 | 31 | 41 | 51 |
| **4Ze** | | | | | 17 | 32 | 40 | 72 | 44 |
| **5Na** | | | | | 18 | | | | |
| **5Nb** | 17 | 10 | 16 | | 16 | 15 | 14 | 18 | 22 |
| **5Nc** | 10 | 8 | 13 | 15 | 9 | 16 | 11 | 12 | 19 |
| **5Nd** | 8 | 6 | 12 | | 5 | | 9 | 16 | 22 |
| **5Zb** | 12 | 15 | 17 | 17 | 15 | 12 | 10 | 17 | 22 |
| **5Zc** | 11 | 8 | 12 | 13 | 13 | 13 | 13 | 13 | 19 |
| **5Zd** | 8 | 5 | 12 | | 13 | 14 | 13 | 10 | 27 |
| **Total** | 1743 | 1887 | 2095 | 2255 | 2587 | 2780 | 2810 | 3368 | 3425 |

*Table 5-7: Mass settled per subzone in zones 3 and 4 (measured + dredged, in 10³ TDS)*

| | settled mass (10³ TDS) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **22-Feb-08<br>28-Apr-08** | **28-Apr-08<br>05-Jun-08** | **05-Jun-08<br>11-Aug-08** | **11-Aug-08<br>26-Aug-08** | **26-Aug-08<br>11-Sep-08** | **11-Sep-08<br>20-Oct-08** | **20-Oct-08<br>06-Nov-08** | **06-Nov-08<br>30-Jan-09** | **30-Jan-09<br>12-Mar-09** | **Total** |
| **zone A** | 59 | 59 | 80 | 72 | 48 | 62 | -7 | 61 | 31 | 465 |
| **zone B** | 55 | 62 | 53 | 71 | 36 | 48 | -8 | 38 | 32 | 387 |
| **zone C** | 48 | 31 | 33 | 37 | 19 | 44 | 14 | 26 | 51 | 303 |
| **zone D** | 31 | 5 | 11 | 13 | 11 | 35 | 29 | 67 | 42 | 244 |
| **Total** | 192 | 156 | 178 | 193 | 113 | 189 | 28 | 192 | 155 | 1396 |

# 6. SEDIMENT MASS BALANCE: LIMITATIONS

As mentioned in Chapter 1.2, the aim of this study is twofold. Firstly, setting up the sediment balance of the Deurganckdok is focused. Secondly, the mechanisms causing siltation in the dock are to be investigated. The latter is the subject of other reports (see §1.3), and the confrontation of both the sediment balance and the siltation contributing factors for the period 2008-2009 will be dealt with in Report 4.20 “Analysis of Siltation Processes and Factors” (I/RA/11283/08.098/MSA).

The actual 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.

In contradiction to previous measurement campaigns, the 2008-2009 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, it is difficult to estimate the transport capacity of it. The question indeed remains whether the rake introduces a momentum so the sediment flows in the direction of the rake movement, or the rake pushes the sediment. The sweep beam data has therefore only been used for data interpretation.

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# APPENDIX A.

# DEPTH OF THE WATER-BED INTERFACE (210 KC)

# APPENDIX B.

# EVOLUTION OF DEPTH OF WATER-BED INTERFACE

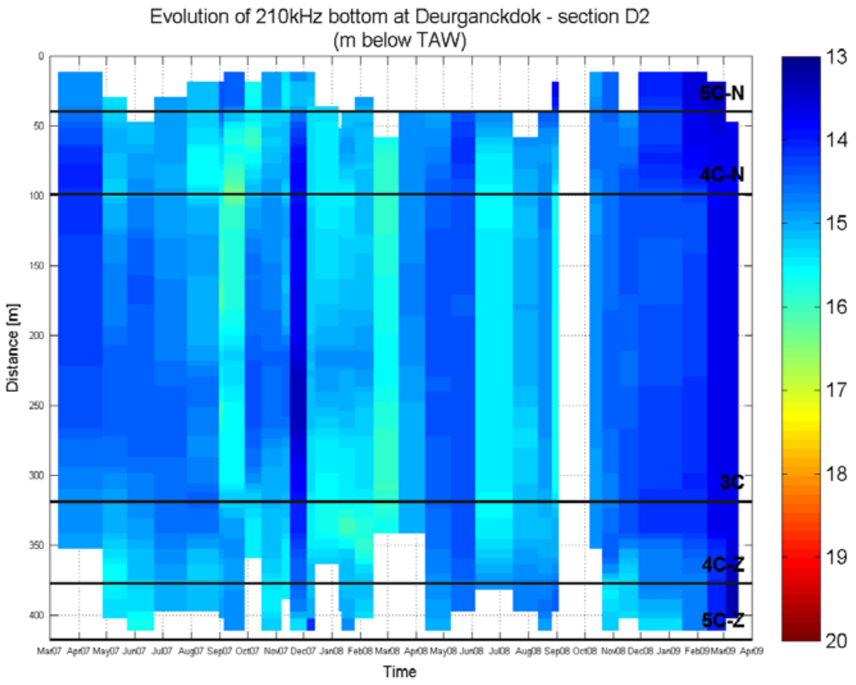
# (210 KC)

## B.1 Difference maps

## B.2 Bed elevation evolution per section

## Long-term monitoring siltation Deurganckdok

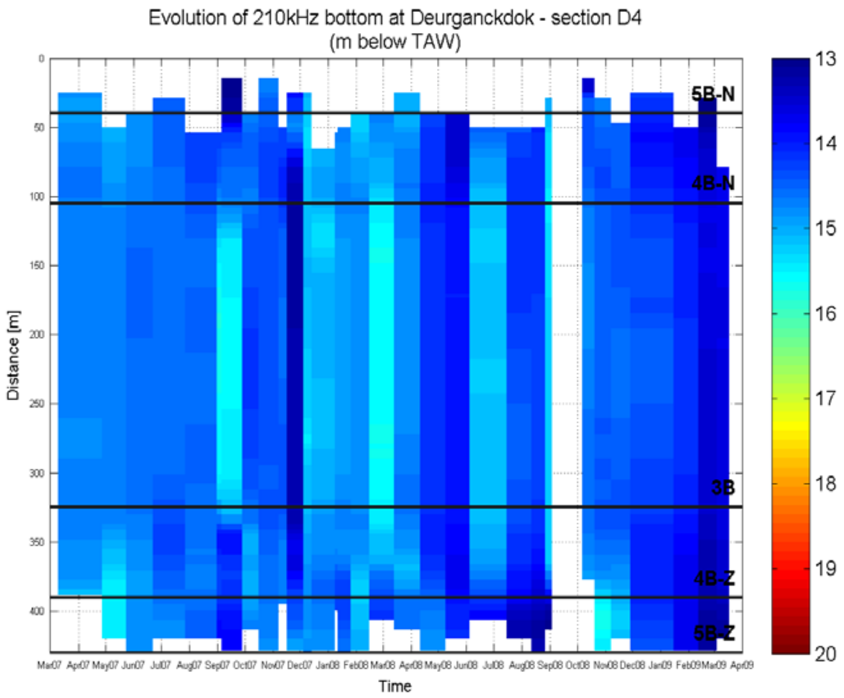
| | |
|---|---|
| Evolution 210kHz bottom | Equipment(s): 210kHz depth sounder |
| | Location: DGD |




Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.080/MSA

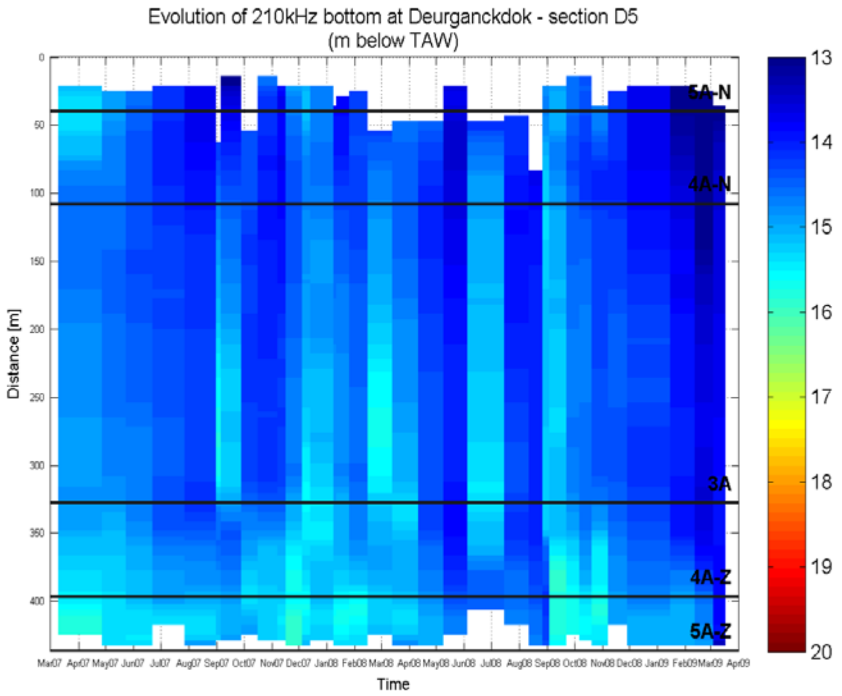
## Long-term monitoring siltation Deurganckdok

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



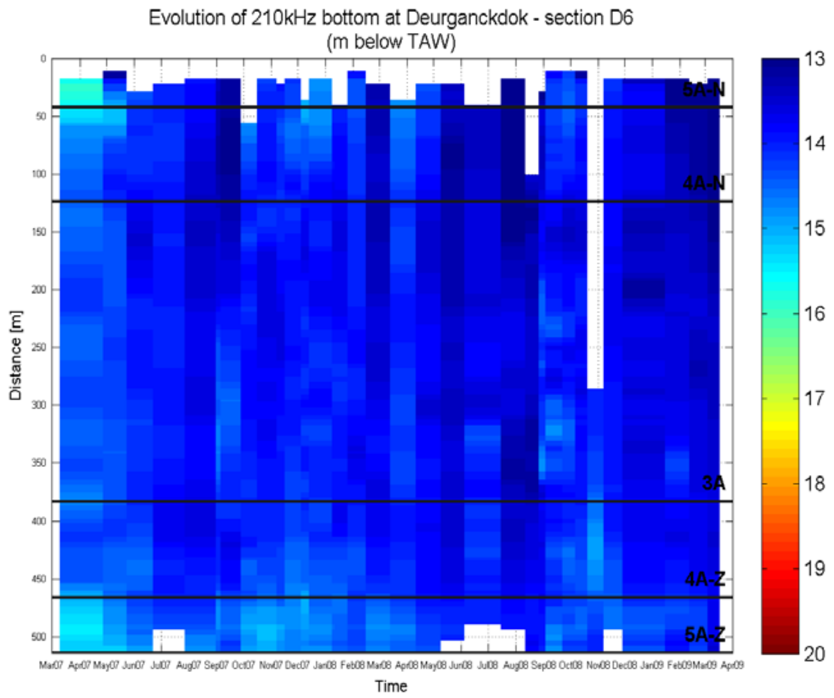

Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.080/MSA

| Long-term monitoring siltation Deurganckdok | |
|---|---|
| Evolution 210kHz bottom | Equipment(s): 210kHz depth sounder |
| | Location: DGD |




Data Processed by: IMDC
In association with: WL | delft hydraulics
I/RA/11283/08.080/MSA

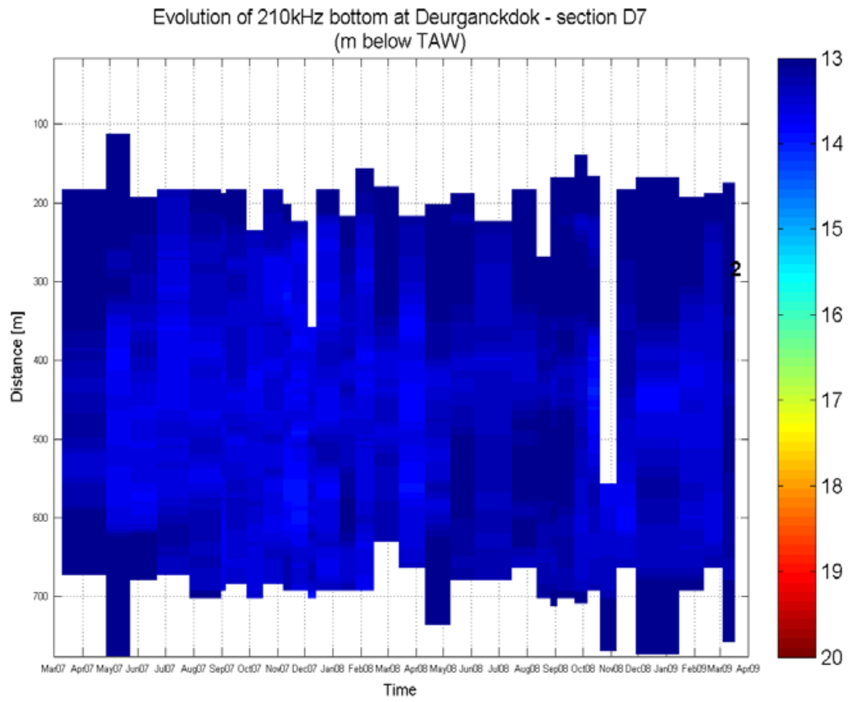
| Long-term monitoring siltation Deurganckdok | |
|---|---|
| Evolution 210kHz bottom | Equipment(s): 210kHz depth sounder |
| | Location: DGD |




Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.080/MSA

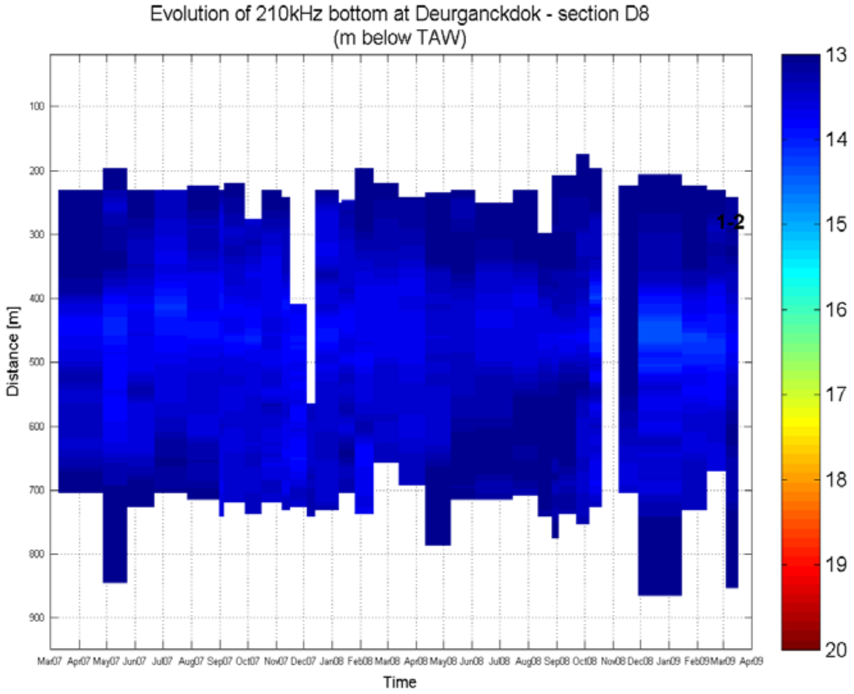
## Long-term monitoring siltation Deurganckdok

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




Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.080/MSA

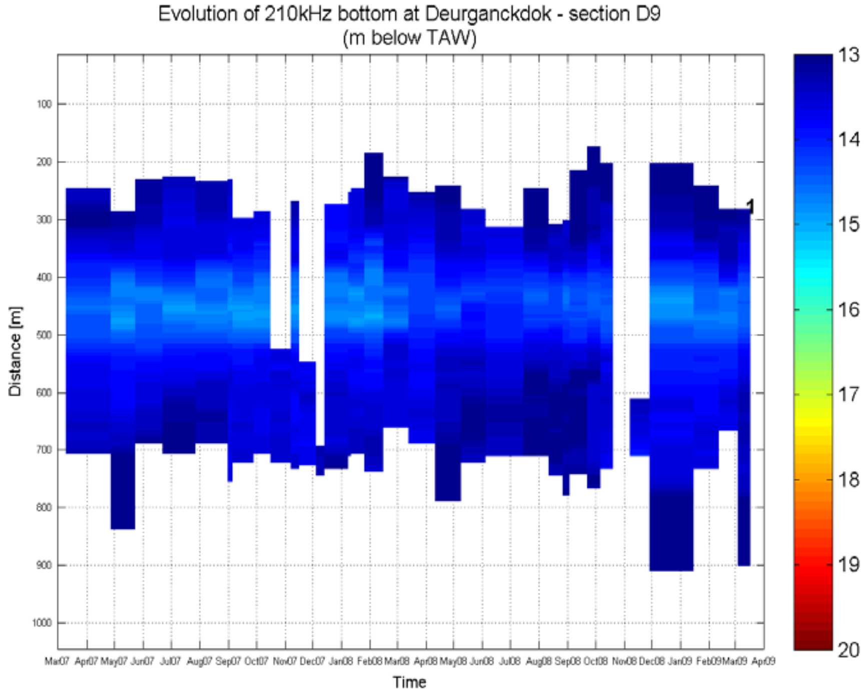
| Long-term monitoring siltation Deurganckdok | |
|---|---|
| Evolution 210kHz bottom | Equipment(s): 210kHz depth sounder |
| | Location: DGD |




| | |
|---|---|
| | Data Processed by: IMDC<br>In association with : WL \| delft hydraulics<br>I/RA/11283/08.080/MSA |

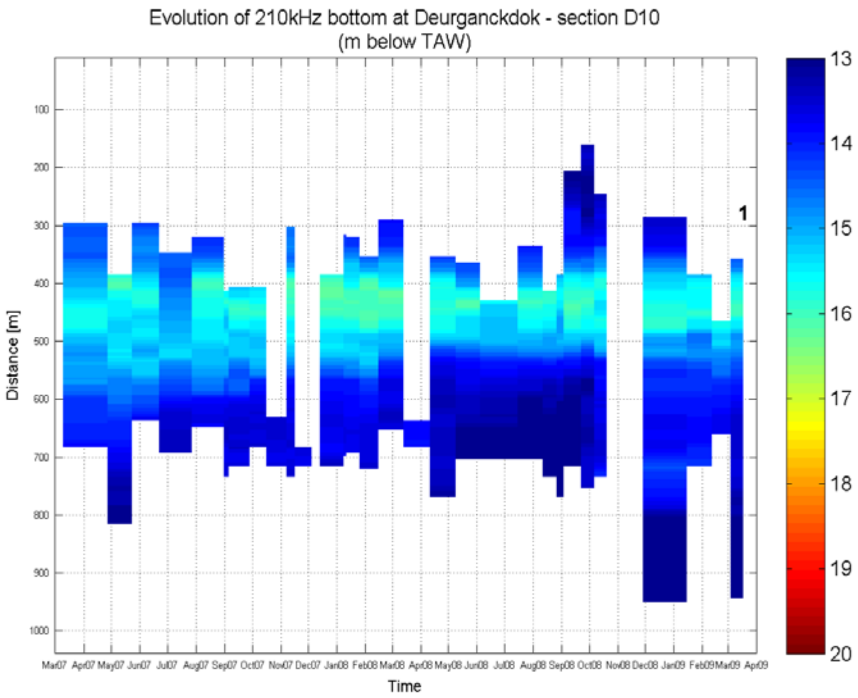
Long-term monitoring siltation Deurganckdok

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



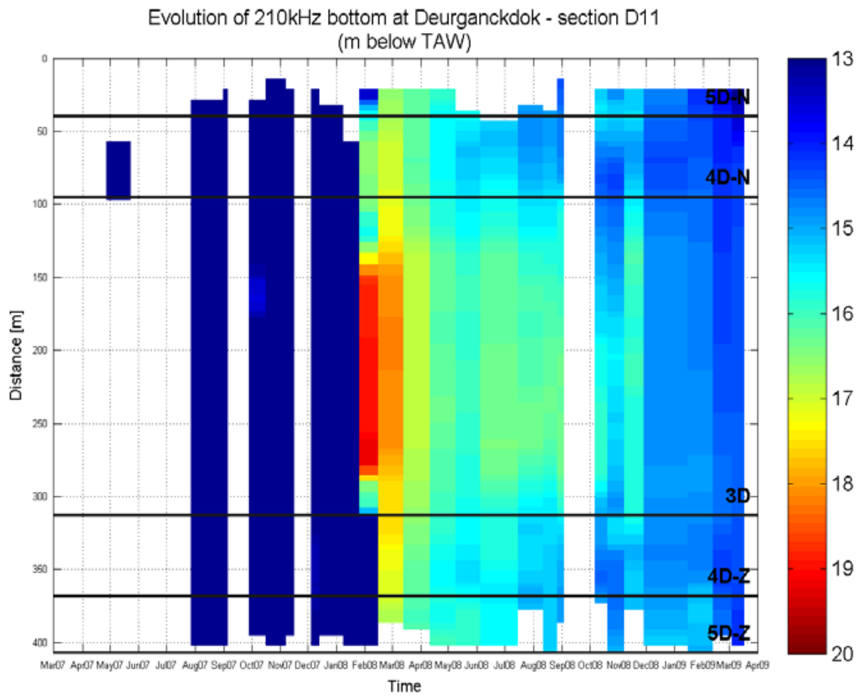

Data Processed by:
In association with :
I/RA/11283/08.080/MSA

| Long-term monitoring siltation Deurganckdok | |
|---|---|
| Evolution 210kHz bottom | Equipment(s): 210kHz depth sounder |
| | Location: DGD |




Data Processed by: IMDC
In association with: WL | delft hydraulics
I/RA/11283/08.080/MSA

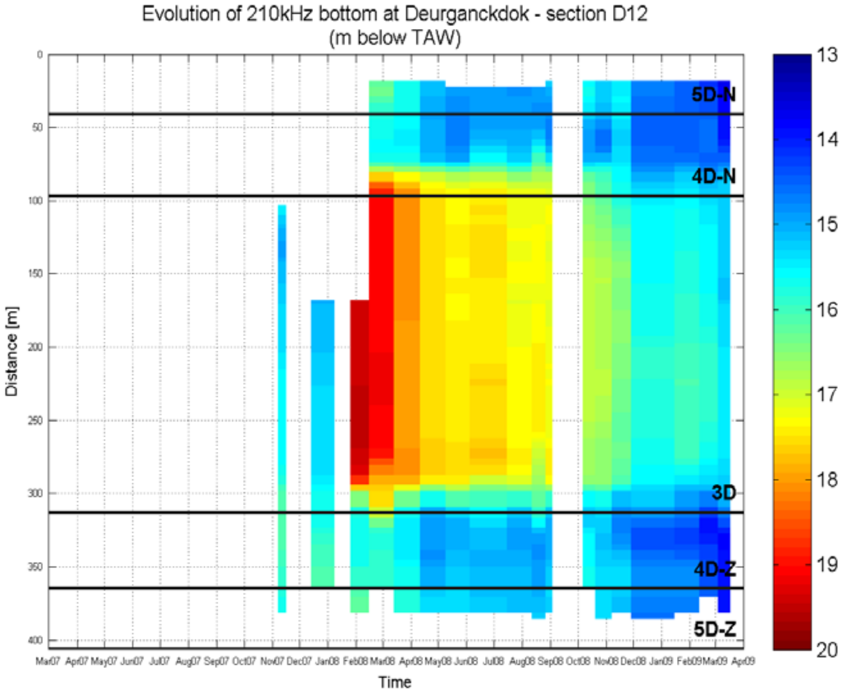
| Long-term monitoring siltation Deurganckdok | |
|---|---|
| Evolution 210kHz bottom | Equipment(s): 210kHz depth sounder |
| | Location: DGD |




| | |
|---|---|
| | Data Processed by: IMDC<br>In association with : WL \| delft hydraulics<br>I/RA/11283/08.080/MSA |

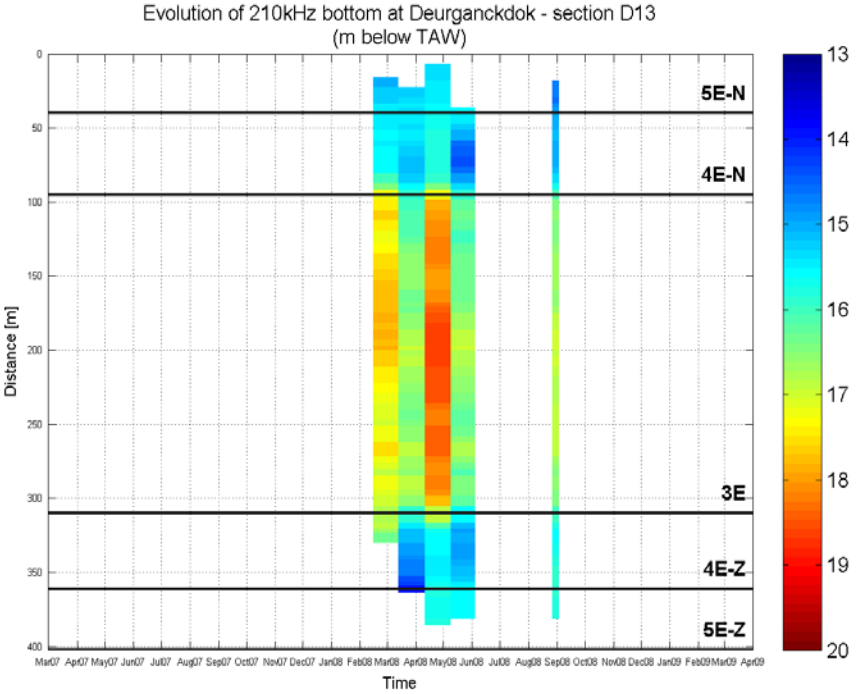
Long-term monitoring siltation Deurganckdok

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




Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.080/MSA

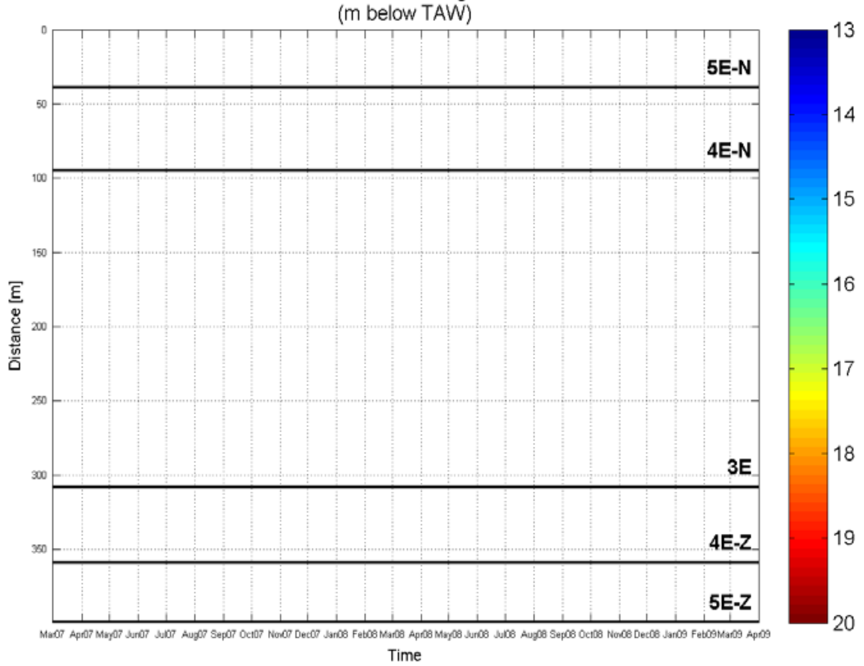
| Long-term monitoring siltation Deurganckdok | |
|---|---|
| Evolution 210kHz bottom | Equipment(s):<br>210kHz depth sounder |
| | Location:<br>DGD |




Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.080/MSA

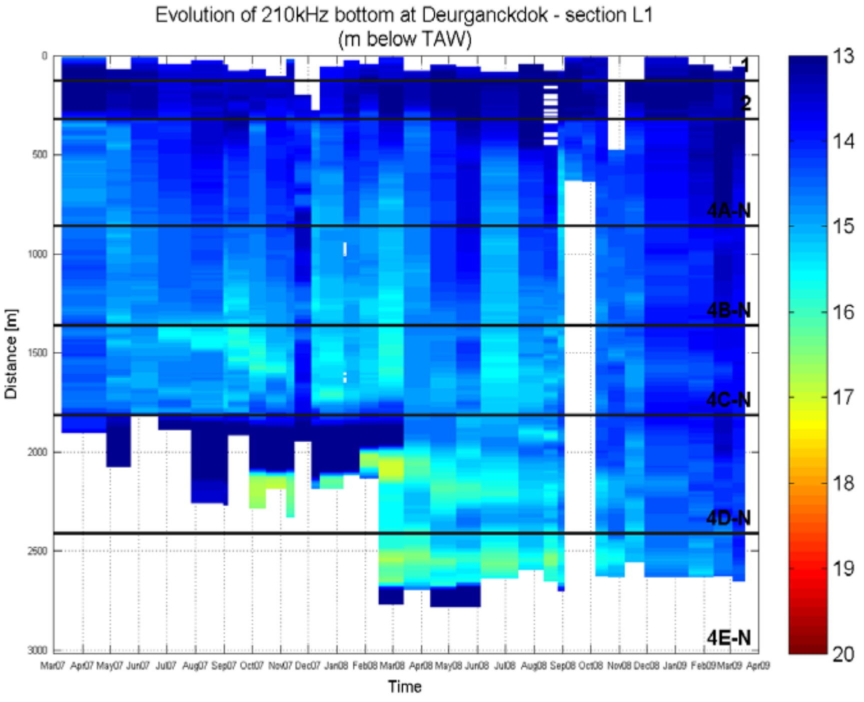
| Long-term monitoring siltation Deurganckdok | |
|---|---|
| Evolution 210kHz bottom | Equipment(s): 210kHz depth sounder |
| | Location: DGD |

Evolution of 210kHz bottom at Deurganckdok - section D14
(m below TAW)




Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.080/MSA

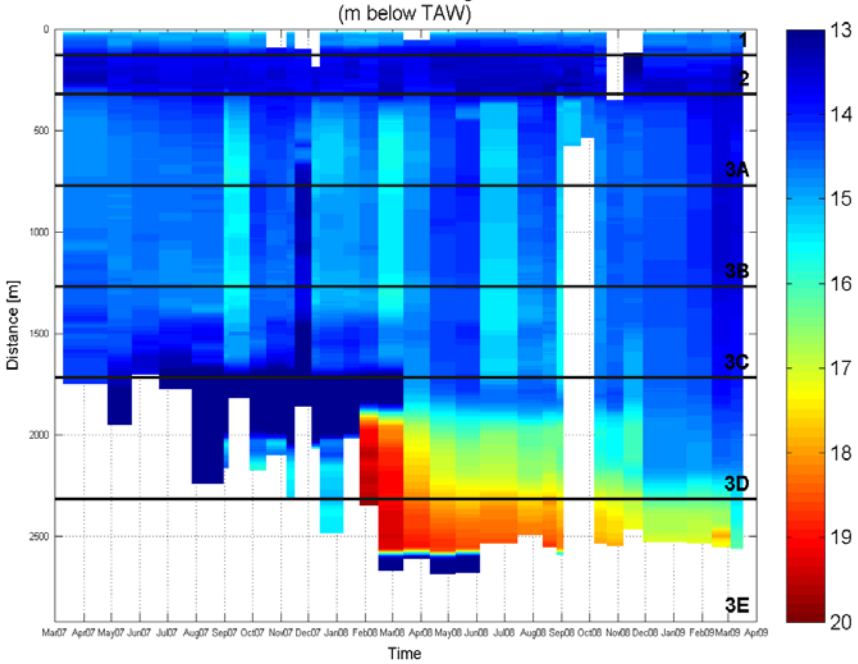
| Long-term monitoring siltation Deurganckdok | |
|---|---|
| Evolution 210kHz bottom | Equipment(s): 210kHz depth sounder |
| | Location: DGD |




Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.080/MSA

| Long-term monitoring siltation Deurganckdok | |
|---|---|
| Evolution 210kHz bottom | Equipment(s): 210kHz depth sounder |
| | Location: DGD |

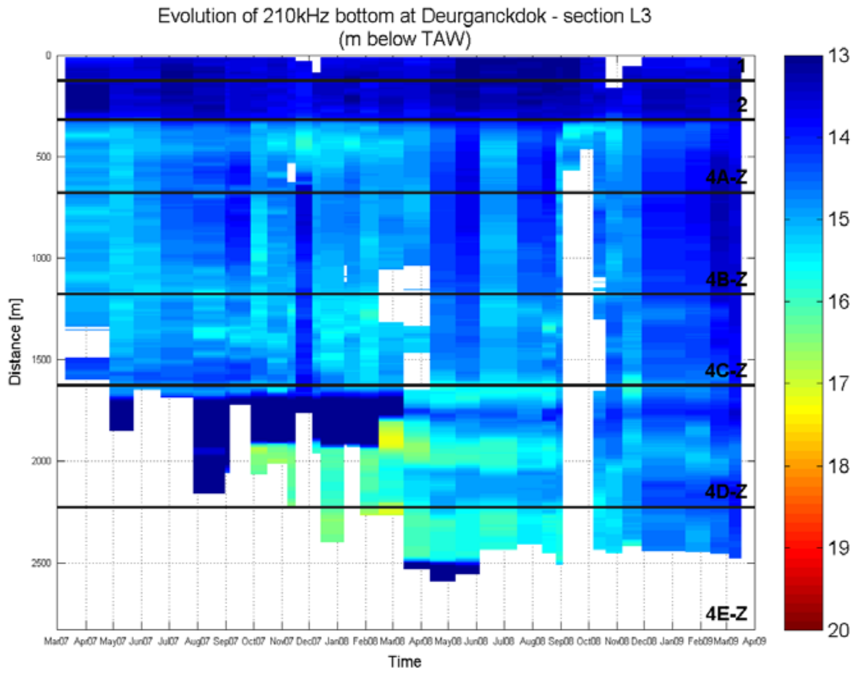
Evolution of 210kHz bottom at Deurganckdok - section L2
(m below TAW)




| | |
|---|---|
| | Data Processed by: IMDC<br>In association with : WL \| delft hydraulics<br>I/RA/11283/08.080/MSA |

## Long-term monitoring siltation Deurganckdok

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




Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.080/MSA

# APPENDIX C.

# VOLUMETRIC SILTATION RATES IN DIFFERENT ZONES AND SECTIONS

## C.1 Siltation rates (tabular)

1/ Per zone (cm/day)

| | 11-Apr-08 | 09-May-08 | 04-Jun-08 | 15-Jul-08 | 11-Aug-08 | 26-Aug-08 | 03-Sep-08 | 22-Sep-08 | 06-Oct-08 | 20-Oct-08 | 07-Nov-08 | 28-Nov-08 | 15-Jan-09 | 11-Feb-09 | 03-Mar-09 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.44 | - | - | - | - | - | 0.04 | 0.10 | -1.87 | - | - | 2.29 | - | - | 0.00 |
| 2 | 2.11 | -0.21 | -0.72 | 0.46 | 0.04 | 1.21 | -1.69 | 0.92 | -2.13 | - | 0.06 | 3.60 | -1.85 | -0.47 | 4.31 |
| 3a | 1.96 | 0.49 | -4.23 | 2.29 | 0.53 | -7.53 | 1.58 | - | 1.45 | 1.10 | 0.38 | 0.56 | 0.66 | 1.44 | -0.86 |
| 3b | 1.71 | 0.35 | -4.43 | 1.67 | 0.54 | -6.66 | - | - | 1.67 | 2.07 | 0.29 | 0.49 | 0.52 | 1.88 | -0.33 |
| 3c | 1.55 | 0.25 | -4.19 | 0.96 | 0.56 | -4.64 | - | - | 1.89 | 1.72 | -0.62 | 1.30 | 0.31 | 1.91 | -0.24 |
| 3d | 1.92 | 0.77 | -0.86 | 0.56 | -0.08 | -0.63 | - | - | 1.16 | 1.22 | -1.81 | 4.00 | 0.00 | 1.22 | -0.14 |
| 3e | 1.45 | 0.51 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 4Na | 1.51 | 1.86 | -3.44 | 1.66 | 0.07 | -7.98 | 6.24 | 0.77 | 0.99 | -1.36 | 0.93 | 1.91 | 0.74 | 1.70 | -1.78 |
| 4Nb | 1.80 | 0.77 | -3.68 | 1.23 | 0.38 | -4.05 | - | - | 0.89 | 1.03 | 0.06 | 1.90 | 0.31 | 1.68 | -0.98 |
| 4Nc | -0.23 | 0.97 | -2.69 | 0.59 | 0.78 | -0.03 | - | - | 0.48 | 1.34 | -1.35 | 2.45 | 0.22 | 1.23 | -0.08 |
| 4Nd | 0.30 | 0.18 | 0.23 | 0.50 | -0.32 | 2.02 | - | - | -0.13 | 1.28 | -1.97 | 3.03 | 0.09 | 1.47 | -0.20 |
| 4Ne | 1.37 | 0.91 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 4Za | 2.03 | 1.70 | -3.64 | 1.75 | 0.79 | -5.58 | -5.53 | - | 1.14 | -1.74 | 1.95 | 2.06 | 0.42 | 1.42 | 0.04 |
| 4Zb | 1.60 | 1.09 | -3.40 | 1.41 | 0.37 | -3.74 | - | - | 0.37 | -2.21 | 0.92 | 3.26 | 0.32 | 1.93 | -0.69 |
| 4Zc | 1.26 | 0.59 | -2.15 | 0.67 | -0.43 | 1.27 | - | - | - | 0.30 | -1.49 | 2.43 | 0.04 | 1.50 | 1.39 |
| 4Zd | 0.96 | 0.06 | 0.10 | 0.39 | -0.31 | 1.75 | - | - | 0.08 | 0.63 | -0.91 | 2.18 | -0.18 | 1.01 | 0.88 |
| 4Ze | 4.98 | -2.22 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 5Na | - | 2.25 | - | - | - | -1.07 | - | 0.56 | 3.06 | - | -0.42 | 2.47 | 1.05 | 1.76 | - |
| 5Nb | - | - | - | - | - | 0.27 | - | - | -0.18 | -1.58 | - | 1.67 | - | 1.05 | - |
| 5Nc | -0.65 | - | - | - | - | 0.94 | - | - | -2.19 | 1.14 | - | 1.13 | 0.62 | 1.73 | - |
| 5Nd | -0.42 | - | - | - | - | 0.46 | - | - | -0.94 | 1.50 | -1.59 | 3.13 | 0.65 | 1.74 | 2.17 |
| 5Ne | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 5Za | 0.46 | 2.30 | - | 1.01 | 0.14 | -0.04 | -24.25 | - | - | -0.12 | 2.84 | 2.02 | 0.67 | 1.45 | 3.64 |

1/ Per zone (cm/day)

| | 11-Apr-08 | 09-May-08 | 04-Jun-08 | 15-Jul-08 | 11-Aug-08 | 26-Aug-08 | 03-Sep-08 | 22-Sep-08 | 06-Oct-08 | 20-Oct-08 | 07-Nov-08 | 28-Nov-08 | 15-Jan-09 | 11-Feb-09 | 03-Mar-09 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5Zb | 0.45 | 1.81 | - | 0.47 | 0.26 | - | - | - | - | -2.24 | 1.00 | 3.24 | 1.34 | 1.79 | 0.76 |
| 5Zc | 0.68 | 0.77 | - | - | -0.02 | 2.13 | - | - | - | -0.73 | -2.63 | 2.52 | 0.27 | 2.07 | 3.65 |
| 5Zd | 0.77 | 0.21 | 0.42 | - | 0.36 | 1.06 | - | - | - | -0.12 | - | 0.98 | -0.20 | 1.05 | 2.85 |
| 5Ze | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

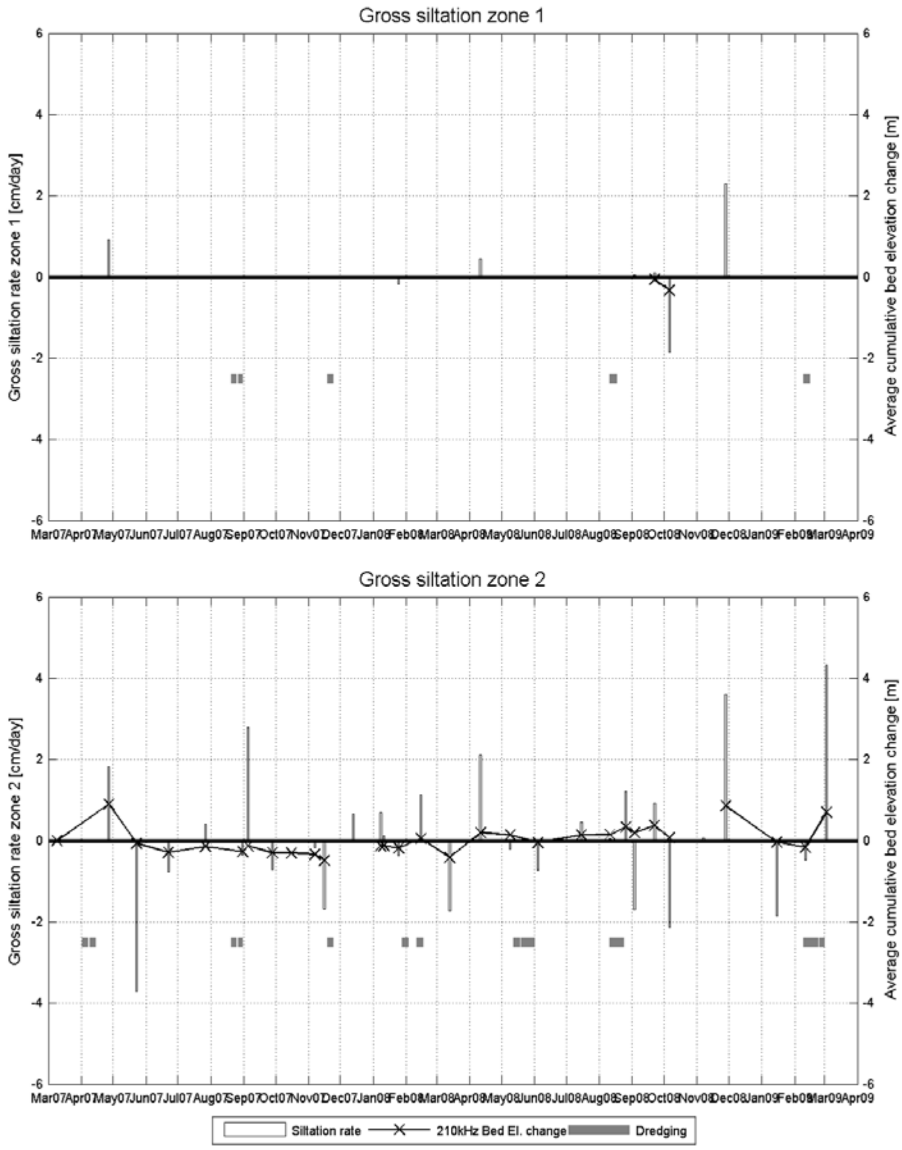
2/ Per section (cm/day)

| | 11-Apr-08 | 09-May-08 | 04-Jun-08 | 15-Jul-08 | 11-Aug-08 | 26-Aug-08 | 03-Sep-08 | 22-Sep-08 | 06-Oct-08 | 20-Oct-08 | 07-Nov-08 | 28-Nov-08 | 15-Jan-09 | 11-Feb-09 | 03-Mar-09 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D1 | 0.61 | 0.79 | -2.90 | 0.65 | 0.34 | -1.39 | - | - | 0.99 | 1.15 | -2.49 | 2.63 | 0.39 | 1.34 | 0.19 |
| D2 | 1.11 | 0.59 | -3.90 | 0.88 | 0.73 | -3.07 | - | - | 1.22 | 1.24 | 0.27 | 0.93 | 0.42 | 1.57 | 0.46 |
| D3 | 1.51 | 0.44 | -3.85 | 1.37 | 0.48 | -4.98 | - | - | 1.19 | 0.53 | 0.62 | 1.10 | 0.57 | 1.90 | -0.52 |
| D4 | 1.96 | 1.20 | -4.28 | 1.97 | 0.47 | -6.86 | - | - | 1.22 | -0.17 | 0.28 | 1.53 | 0.60 | 1.83 | -0.63 |
| D5 | 1.65 | 1.65 | -4.27 | 2.08 | 0.21 | -5.96 | -2.65 | 2.36 | 0.92 | 0.03 | 1.18 | 0.95 | 0.61 | 1.47 | -0.62 |
| D6 | 1.26 | 1.43 | -1.20 | 0.94 | -0.34 | -2.86 | -2.57 | 0.10 | 1.09 | - | -0.06 | 1.25 | 0.12 | 0.38 | 1.24 |
| D7 | 2.26 | -0.42 | -1.00 | 0.72 | -0.14 | 2.10 | -2.62 | 1.07 | -3.22 | - | 0.31 | 3.85 | -2.04 | -0.54 | 5.31 |
| D8 | 0.39 | -0.69 | - | 0.06 | - | 0.39 | -0.51 | 0.64 | -2.45 | - | 1.88 | 2.59 | -2.49 | - | 1.65 |
| D9 | 0.48 | - | - | - | - | - | 0.03 | -0.33 | -1.48 | - | - | 2.11 | - | - | -0.05 |
| D10 | - | - | - | - | - | - | - | - | - | - | - | 1.48 | - | - | 0.27 |
| D11 | 2.08 | 0.84 | -0.72 | 0.69 | 0.04 | 0.34 | - | - | 0.93 | 1.49 | -3.37 | 3.90 | 0.09 | 1.54 | 0.22 |
| D12 | 1.80 | 0.25 | -0.42 | 0.49 | -0.19 | 0.44 | - | - | 0.43 | 1.36 | 1.11 | 2.98 | -0.20 | 0.61 | 1.63 |
| D13 | -3.94 | 4.09 | - | - | - | -0.18 | - | - | - | - | - | - | - | - | - |
| D14 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| L1 | 1.86 | 0.89 | -3.35 | 1.19 | -0.39 | -1.15 | - | - | 0.70 | -0.57 | 0.53 | 1.89 | 0.20 | 1.08 | -0.39 |
| L2 | 2.30 | 0.49 | -3.25 | 1.26 | -0.21 | -3.45 | - | - | 1.21 | 0.45 | 0.73 | 1.19 | 0.28 | 1.21 | 0.42 |
| L3 | 1.92 | 0.35 | -2.24 | 0.97 | 0.09 | -1.78 | - | - | 0.25 | -0.90 | 0.10 | 2.51 | 0.04 | 1.22 | 0.63 |

## C.2 Water-bed interface evolution for all zones

Long-term monitoring siltation Deurganckdok

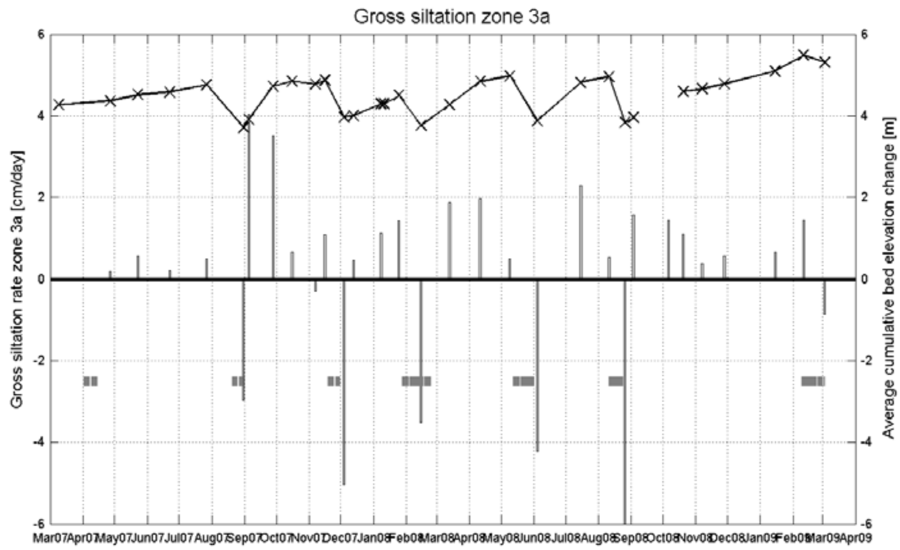
| | |
|---|---|
| Siltation height / gross siltation rate | Equipment(s): 210kHz depth sounder |
| | Location: DGD |

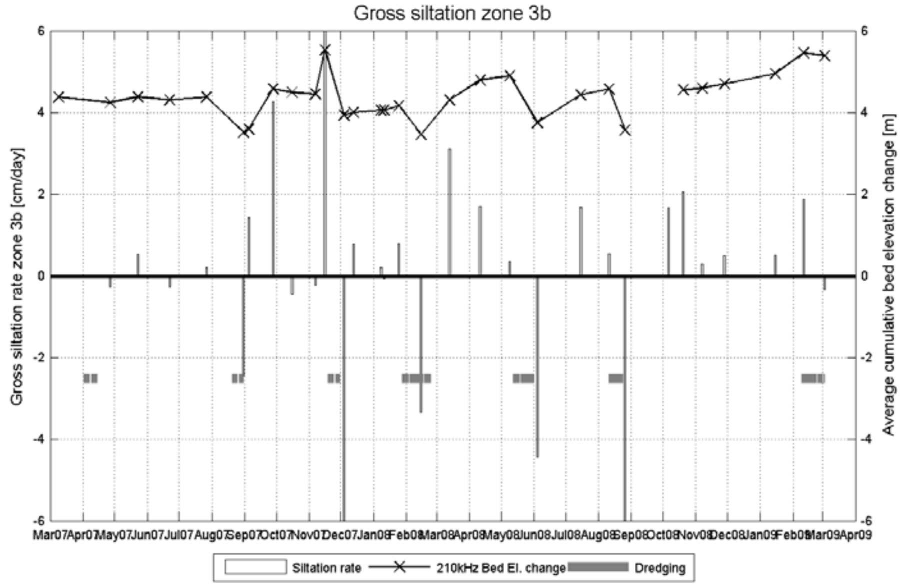



| | |
|---|---|
| Reference level: design depth | Data Processed by: IMDC<br>In association with : WL \| delft hydraulics<br>I/RA/11283/08.080/MSA |

## Long-term monitoring siltation Deurganckdok

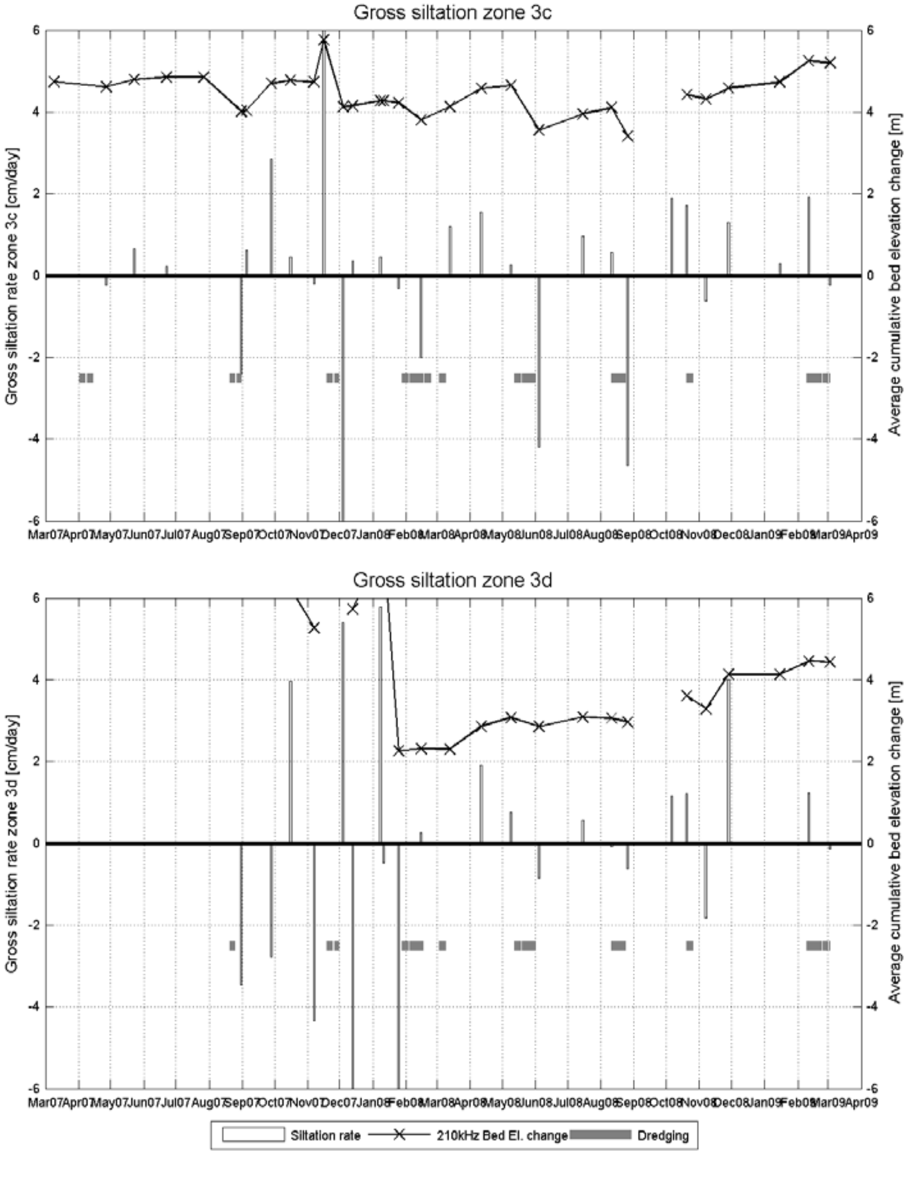
| Siltation height / gross siltation rate | Equipment(s): 210kHz depth sounder |
|---|---|
| | Location: DGD |



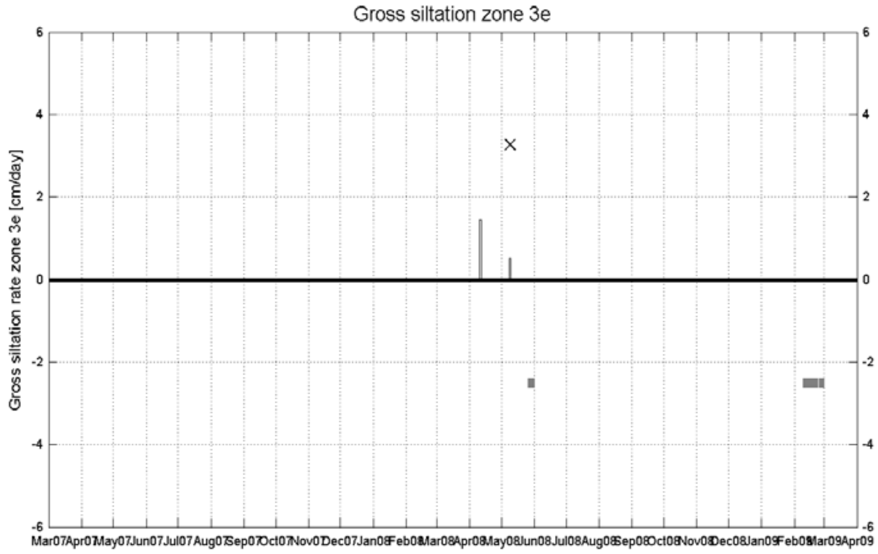

| Reference level: design depth | Data Processed by: IMDC<br>In association with : WL \| delft hydraulics<br>I/RA/11283/08.080/MSA |
|---|---|

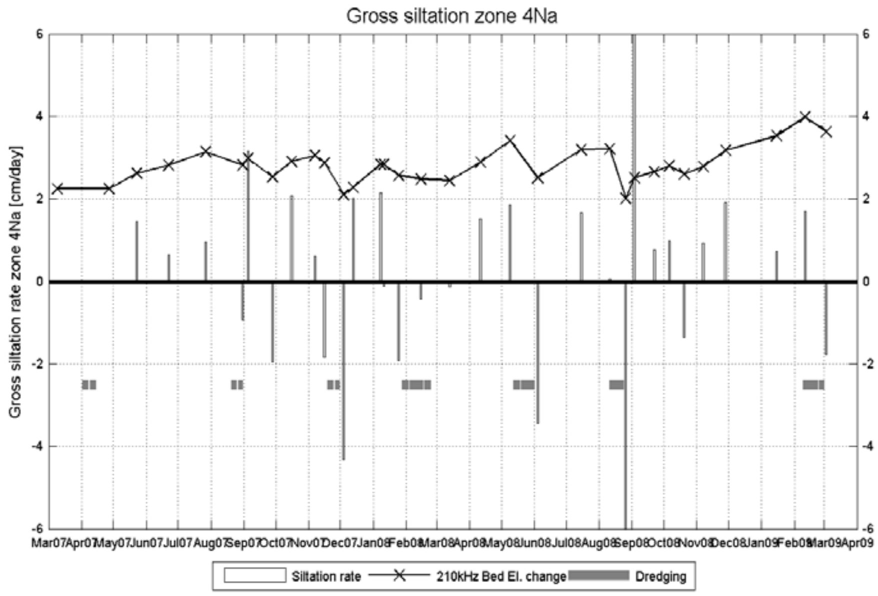
| Long-term monitoring siltation Deurganckdok | |
|---|---|
| Siltation height / gross siltation rate | Equipment(s): 210kHz depth sounder |
| | Location: DGD |




| Reference level: design depth | Data Processed by: IMDC<br>In association with : WL \| delft hydraulics<br>I/RA/11283/08.080/MSA |
|---|---|

| Long-term monitoring siltation Deurganckdok | |
|---|---|
| Siltation height / gross siltation rate | Equipment(s): 210kHz depth sounder |
| | Location: DGD |

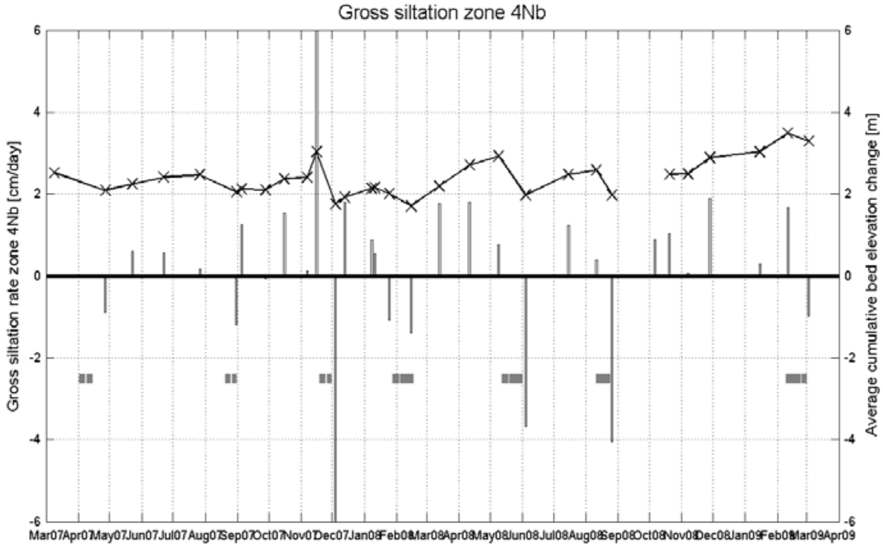


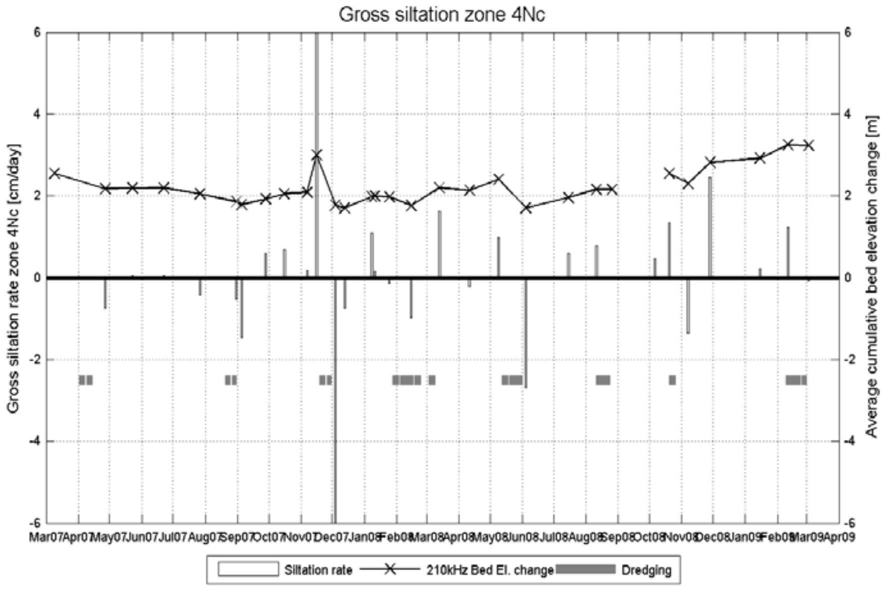




| Reference level: design depth | Data Processed by: IMDC<br>In association with : WL \| delft hydraulics<br>I/RA/11283/08.080/MSA |
|---|---|

## Long-term monitoring siltation Deurganckdok

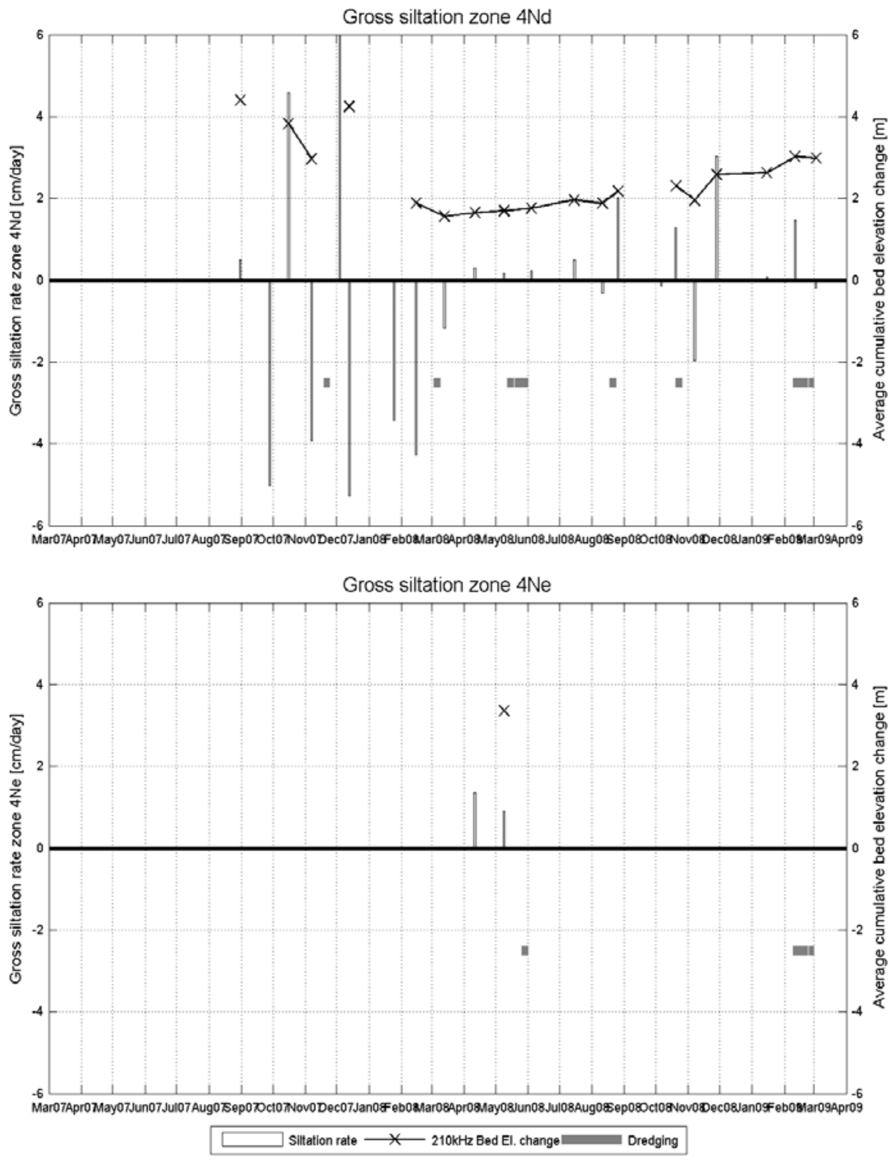
| | |
|---|---|
| Siltation height / gross siltation rate | Equipment(s): 210kHz depth sounder |
| | Location: DGD |



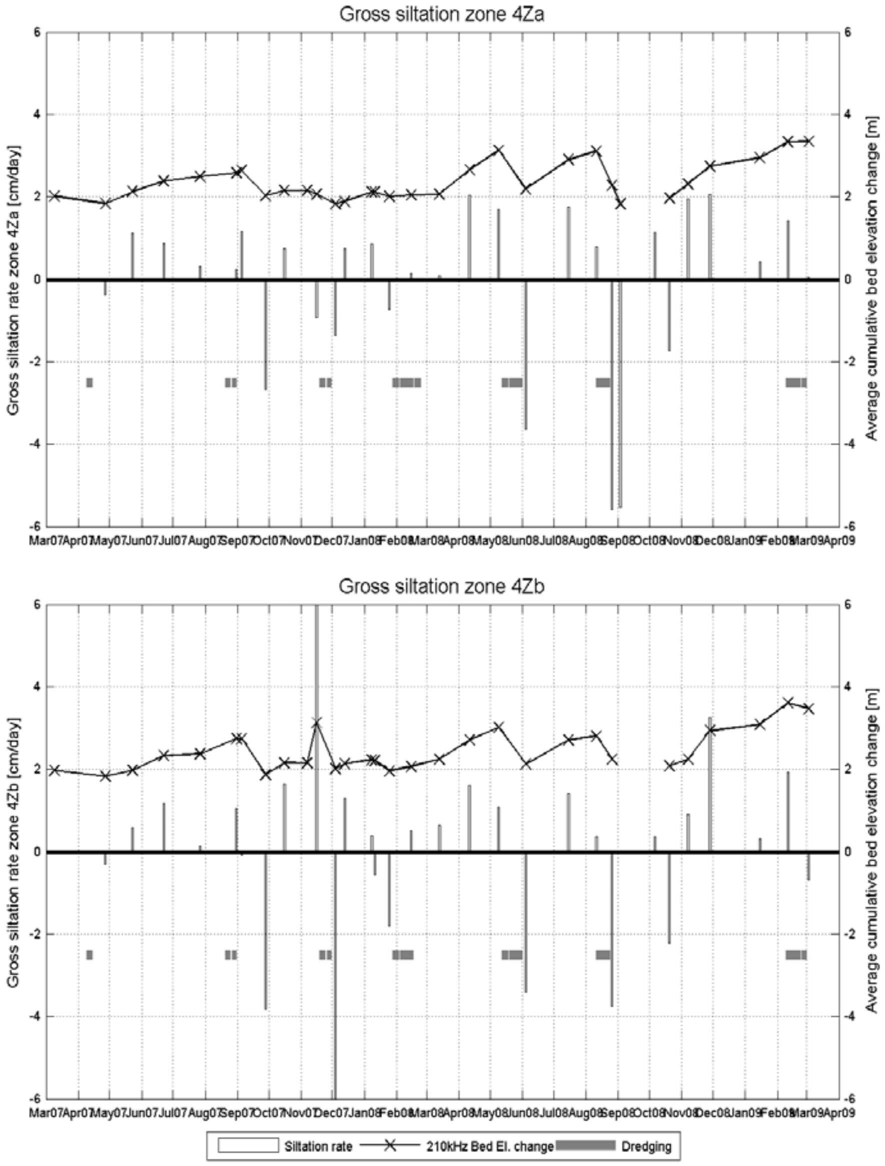

| | |
|---|---|
| Reference level: design depth | Data Processed by: IMDC<br>In association with : WL \| delft hydraulics<br>I/RA/11283/08.080/MSA |

| Long-term monitoring siltation Deurganckdok | |
|---|---|
| Siltation height / gross siltation rate | Equipment(s): 210kHz depth sounder |
| | Location: DGD |



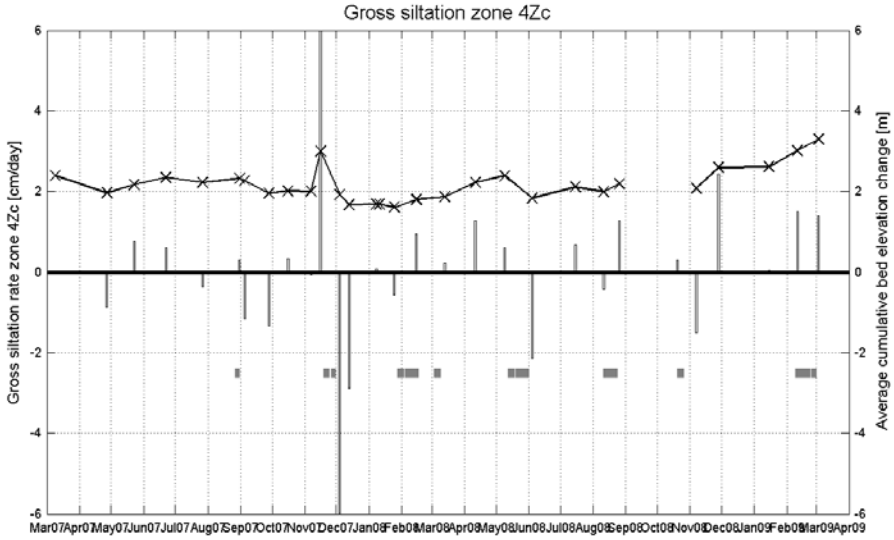

| Reference level: design depth | Data Processed by: IMDC<br>In association with : WL \| delft hydraulics<br>I/RA/11283/08.080/MSA |
|---|---|

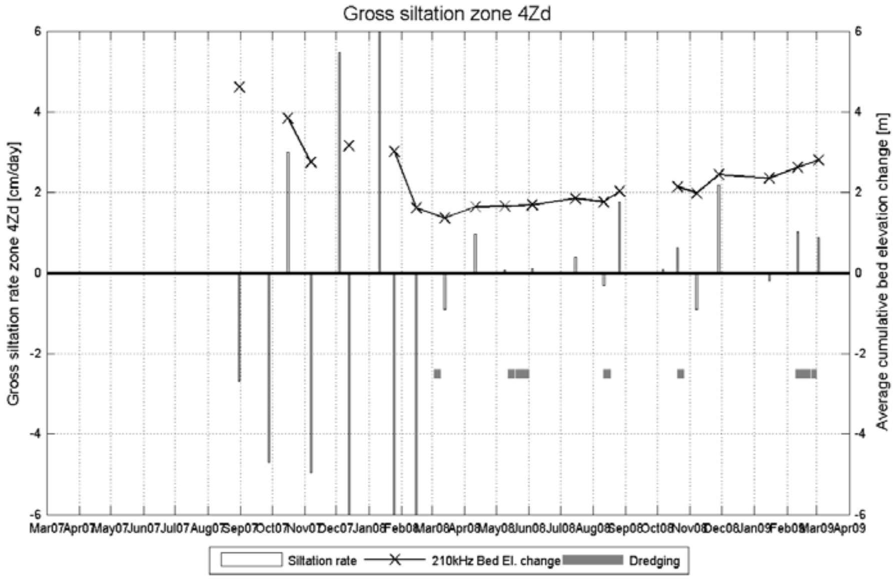
| Long-term monitoring siltation Deurganckdok | |
|---|---|
| Siltation height / gross siltation rate | Equipment(s): 210kHz depth sounder |
| | Location: DGD |




| | |
|---|---|
| Reference level: design depth | Data Processed by: IMDC<br>In association with : WL \| delft hydraulics<br>I/RA/11283/08.080/MSA |

| Long-term monitoring siltation Deurganckdok | |
|---|---|
| Siltation height / gross siltation rate | Equipment(s): 210kHz depth sounder |
| | Location: DGD |

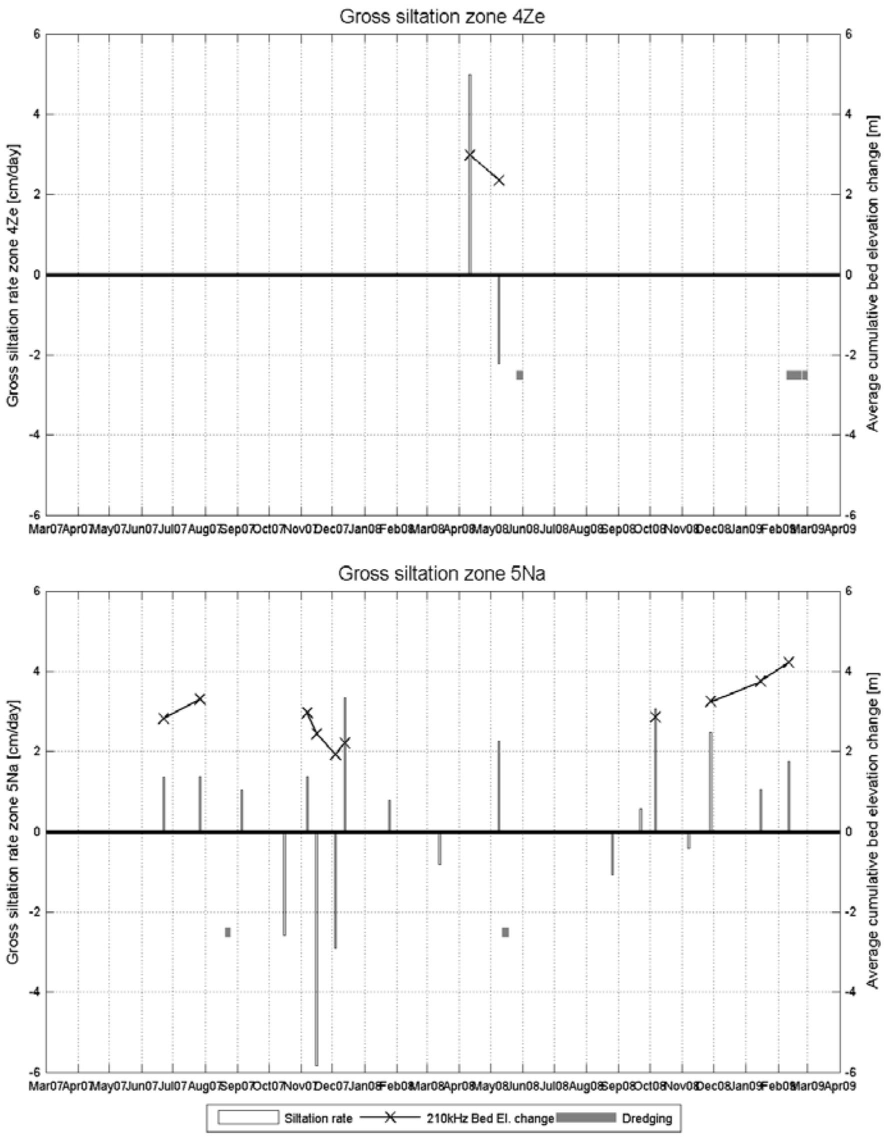



| Reference level: design depth | Data Processed by: IMDC<br>In association with : WL \| delft hydraulics<br>I/RA/11283/08.080/MSA |
|---|---|

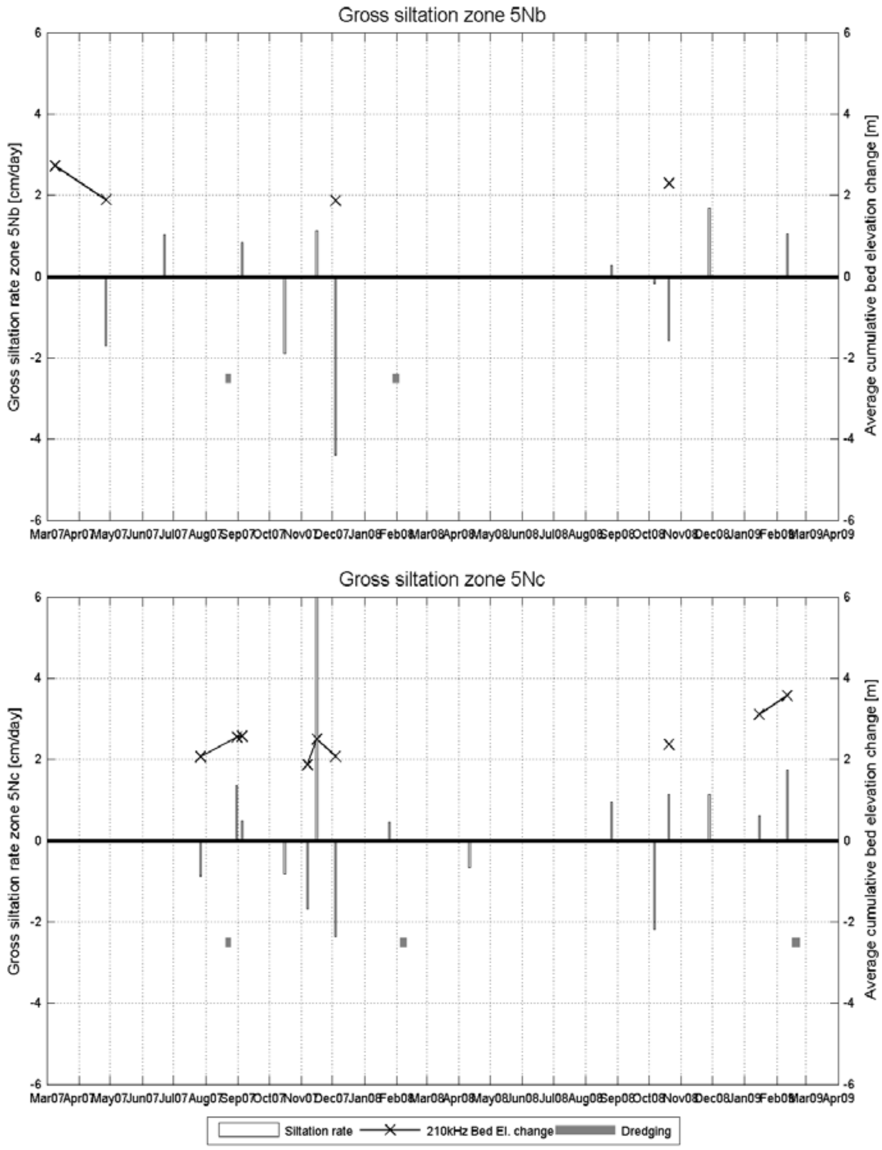
## Long-term monitoring siltation Deurganckdok

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




| | |
|---|---|
| Reference level: design depth | Data Processed by: IMDC<br>In association with : WL \| delft hydraulics<br>I/RA/11283/08.080/MSA |

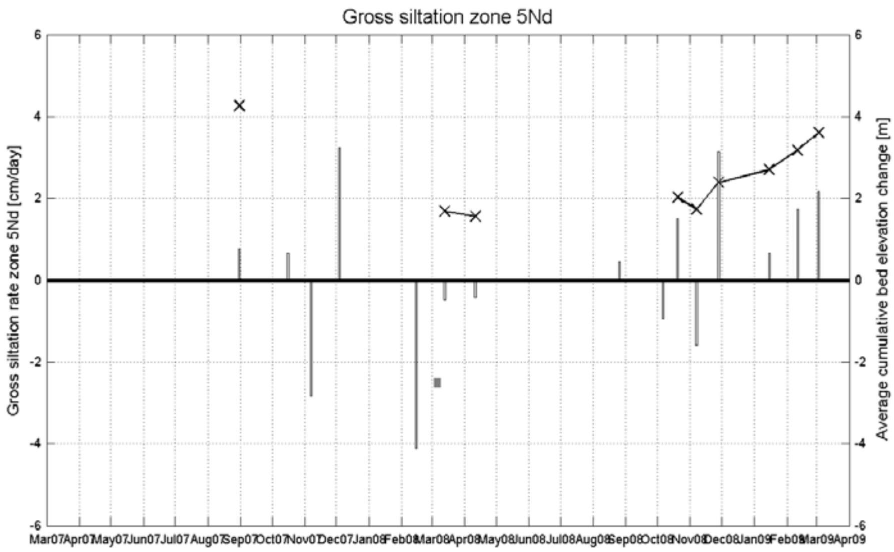
| Long-term monitoring siltation Deurganckdok | |
|---|---|
| Siltation height / gross siltation rate | Equipment(s): 210kHz depth sounder |
| | Location: DGD |

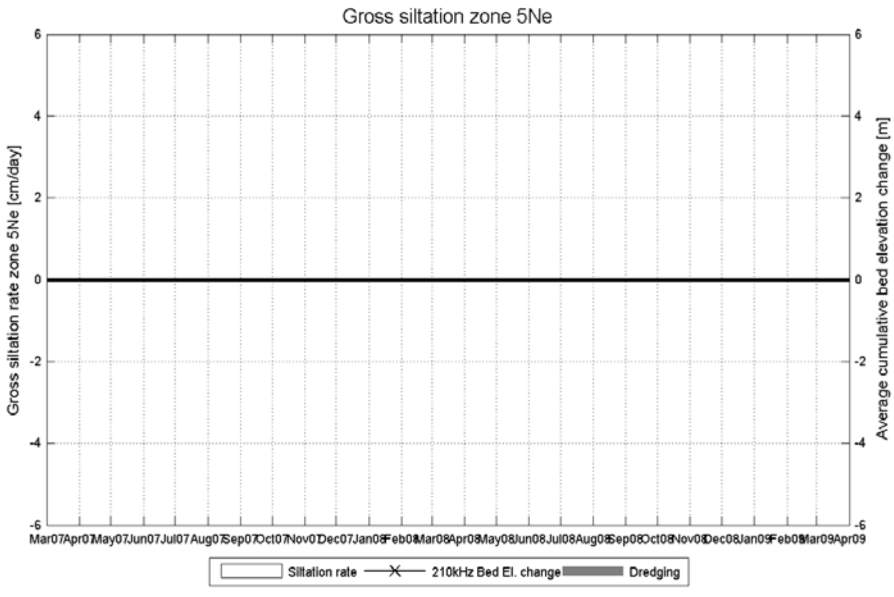



| Reference level: design depth | Data Processed by: IMDC<br>In association with : WL \| delft hydraulics<br>I/RA/11283/08.080/MSA |
|---|---|

## Long-term monitoring siltation Deurganckdok

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

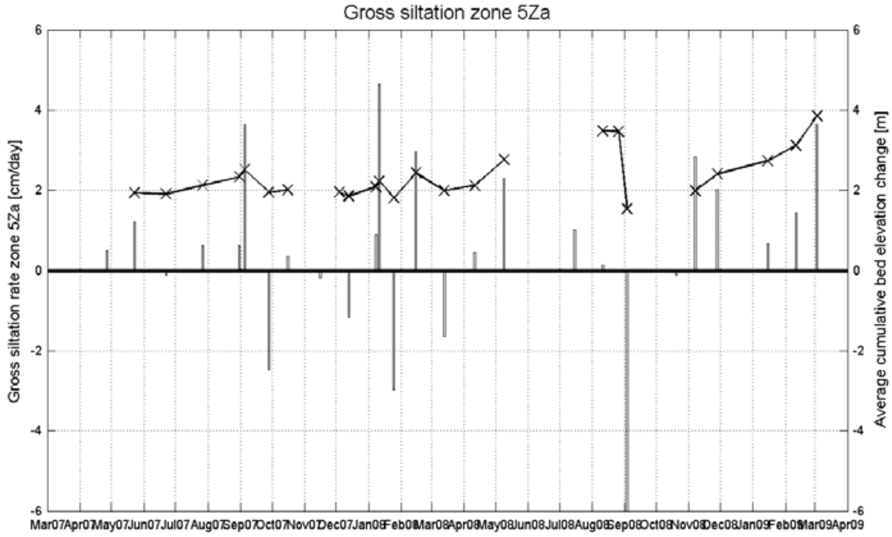


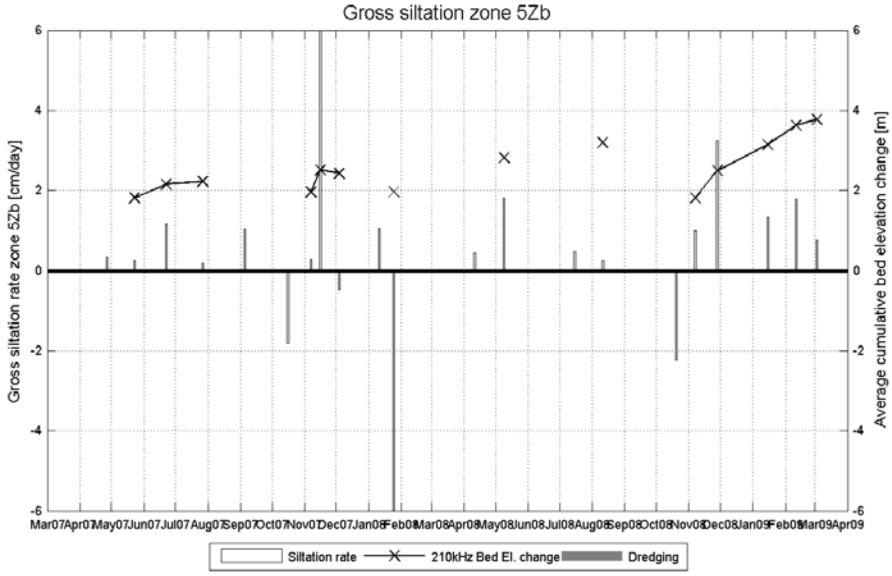




| | |
|---|---|
| Reference level: design depth | Data Processed by: IMDC<br>In association with : WL \| delft hydraulics<br>I/RA/11283/08.080/MSA |

## Long-term monitoring siltation Deurganckdok

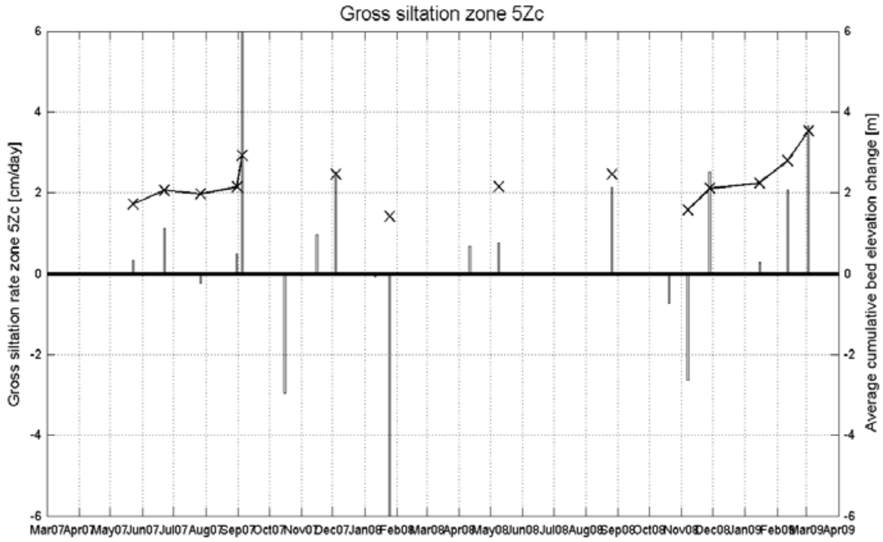
| | |
|---|---|
| Siltation height / gross siltation rate | Equipment(s): 210kHz depth sounder |
| | Location: DGD |

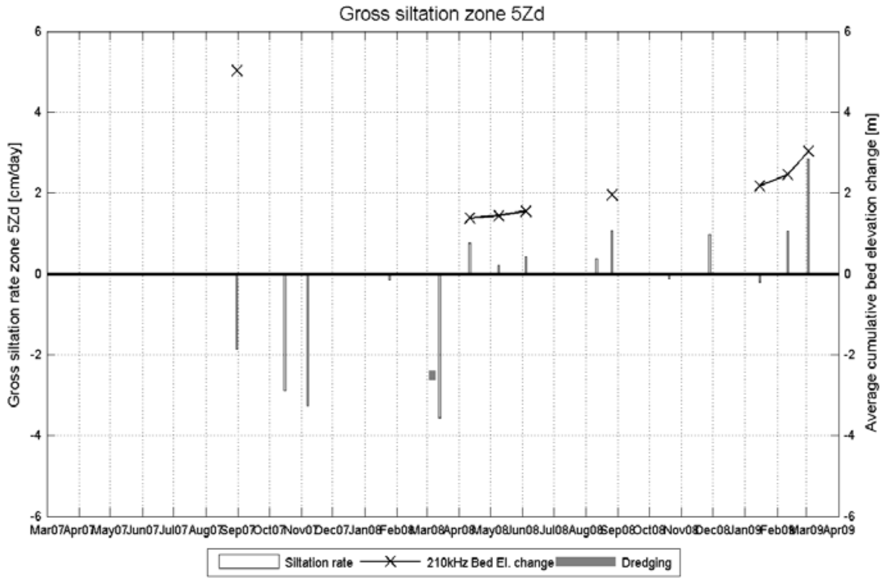



| | |
|---|---|
| Reference level: design depth | Data Processed by: IMDC<br>In association with : wl \| delft hydraulics<br>I/RA/11283/08.080/MSA |

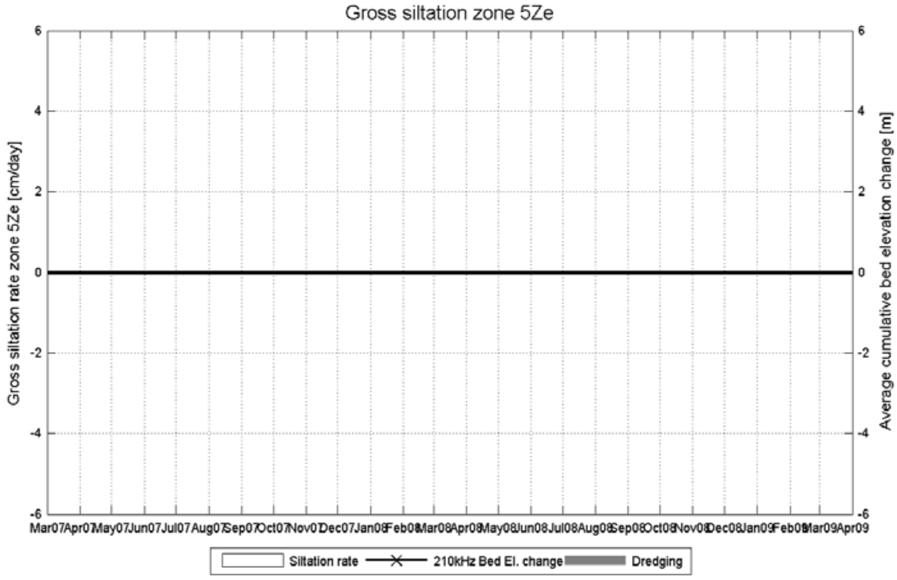
| Long-term monitoring siltation Deurganckdok | |
|---|---|
| Siltation height / gross siltation rate | Equipment(s): 210kHz depth sounder |
| | Location: DGD |




| Reference level: design depth | Data Processed by: IMDC<br>In association with : WL \| delft hydraulics<br>I/RA/11283/08.080/MSA |
|---|---|

| Long-term monitoring siltation Deurganckdok | |
|---|---|
| Siltation height / gross siltation rate | Equipment(s): 210kHz depth sounder |
| | Location: DGD |

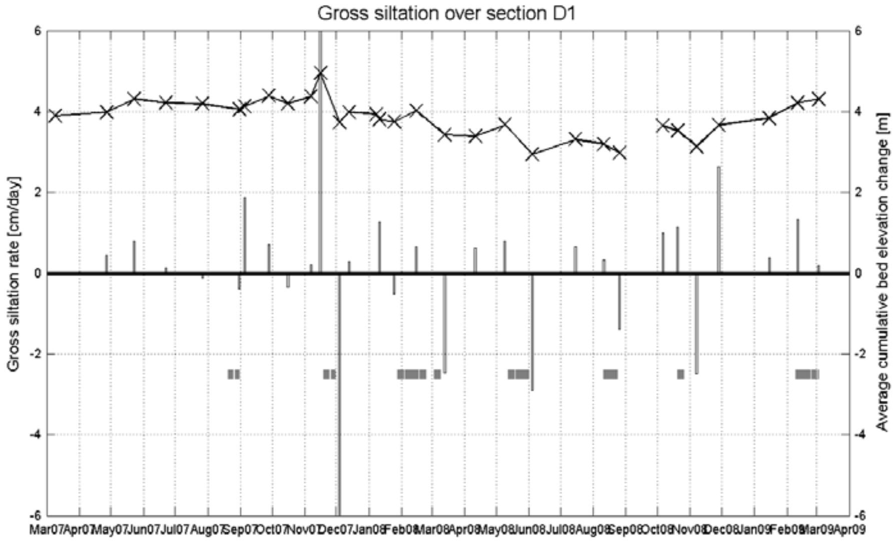


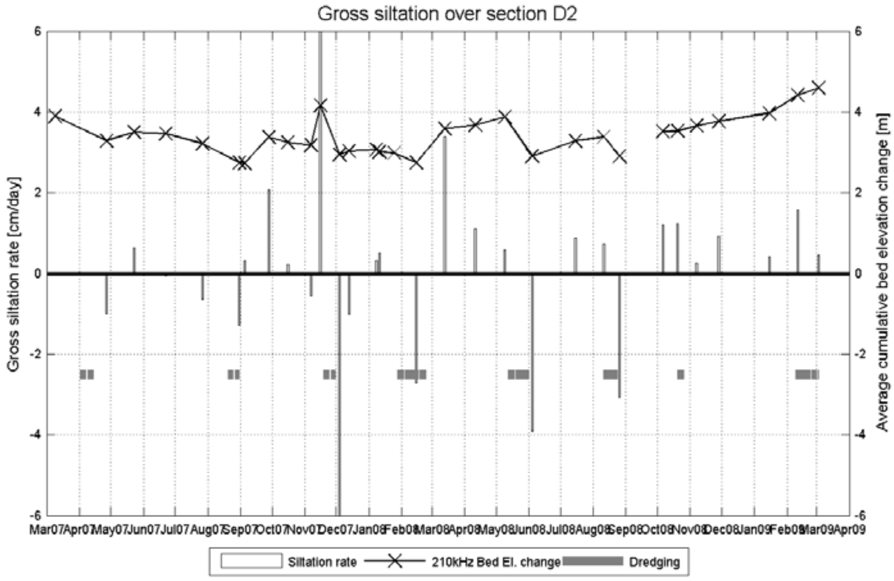

| | |
|---|---|
| Reference level: design depth | Data Processed by: IMDC<br>In association with : WL \| delft hydraulics<br>I/RA/11283/08.080/MSA |

## C.3 Water-bed interface evolution for all sections

Long-term monitoring siltation Deurganckdok

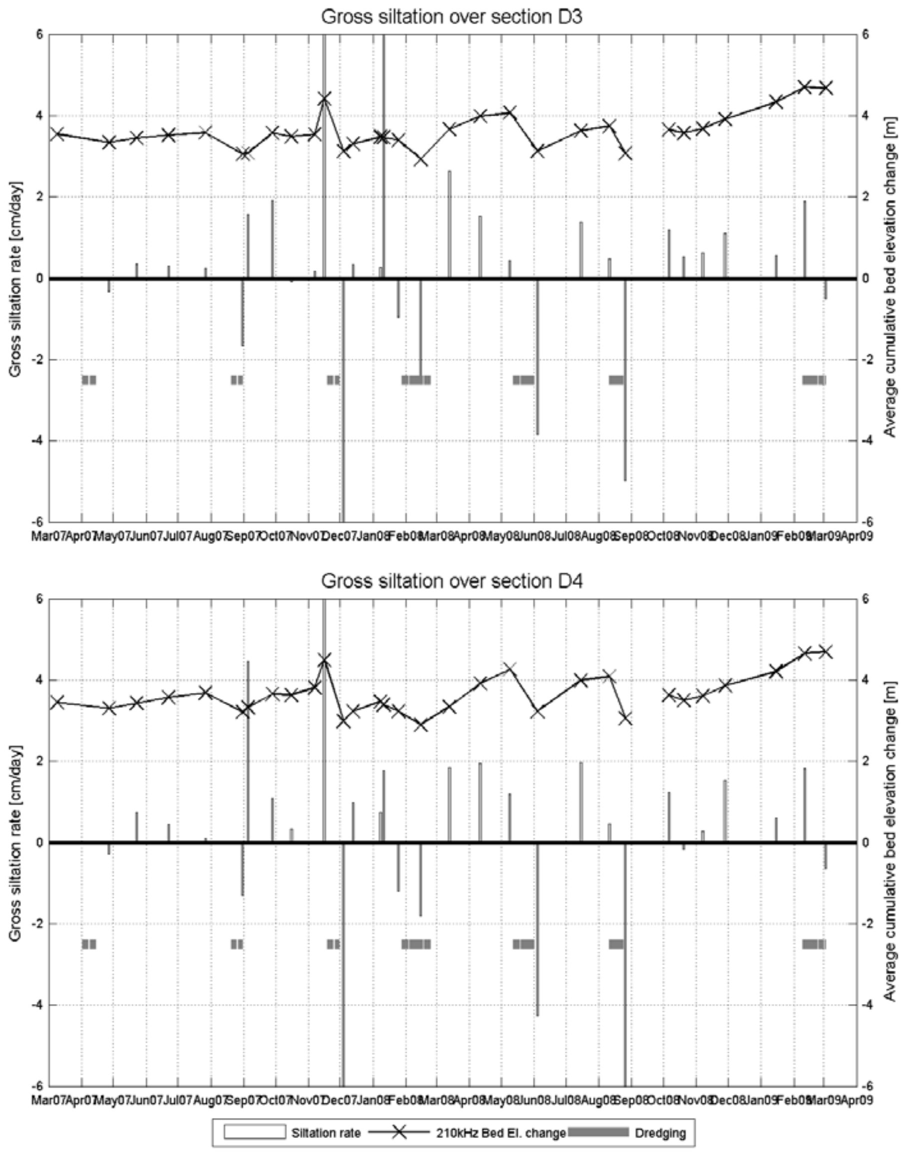
| | |
|---|---|
| Siltation height / gross siltation rate | Equipment(s): 210kHz depth sounder |
| | Location: DGD |




| | |
|---|---|
| Reference level: design depth | Data Processed by: IMDC<br>In association with : WL \| delft hydraulics<br>I/RA/11283/08.080/MSA |

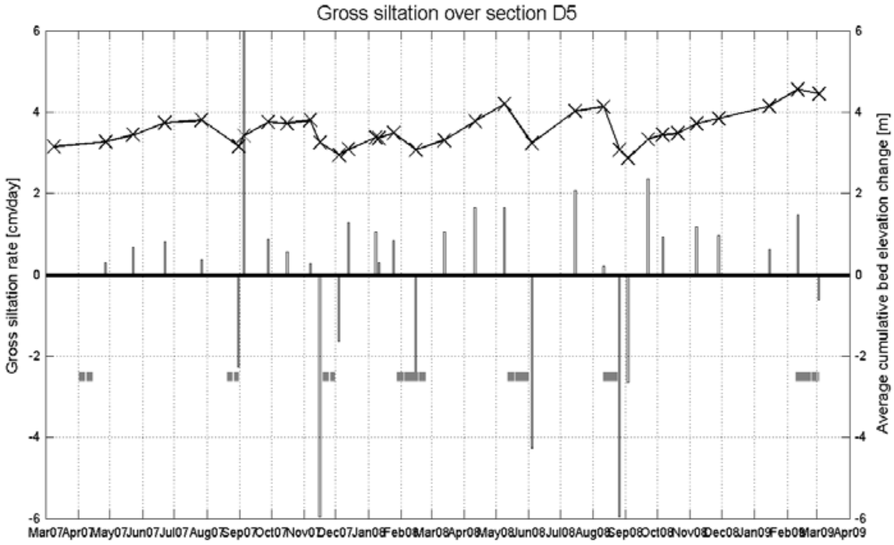
| Long-term monitoring siltation Deurganckdok | |
|---|---|
| Siltation height / gross siltation rate | Equipment(s):<br>210kHz depth sounder |
| | Location:<br>DGD |

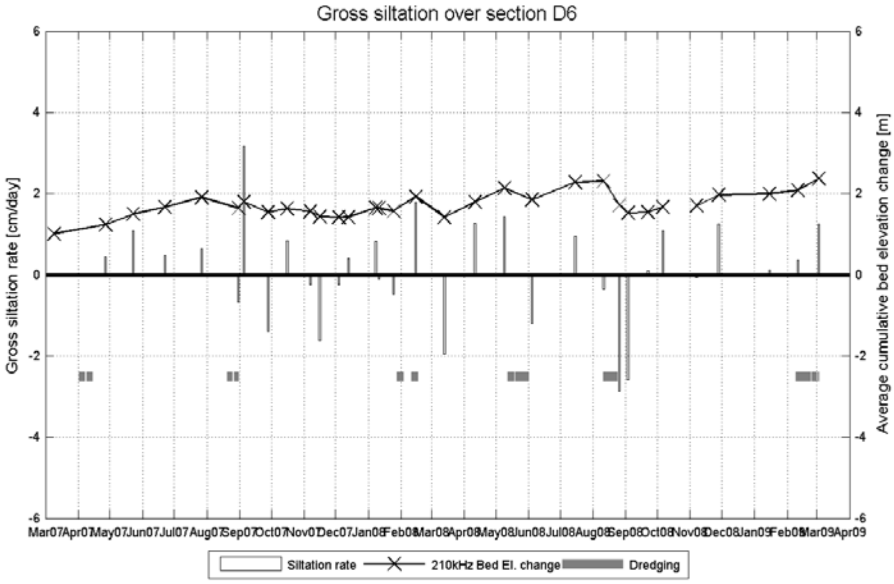



| | |
|---|---|
| Reference level: design depth | Data Processed by:<br>In association with :<br>I/RA/11283/08.080/MSA |

## Long-term monitoring siltation Deurganckdok

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

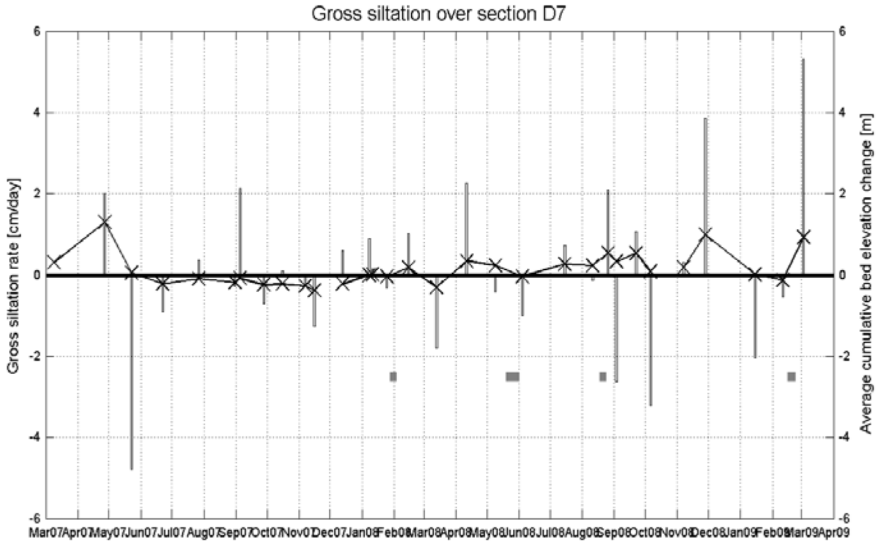


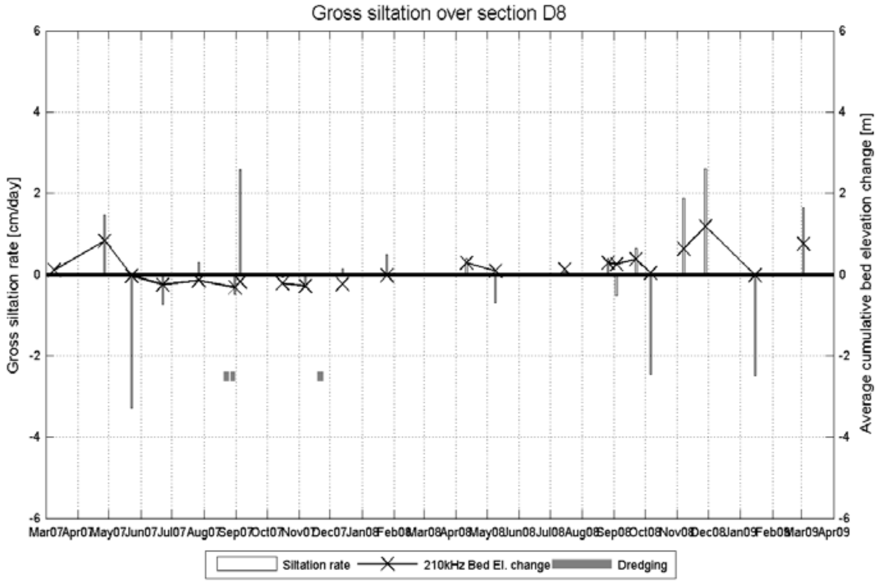




| | |
|---|---|
| Reference level: design depth | Data Processed by: IMDC<br>In association with : WL \| delft hydraulics<br>I/RA/11283/08.080/MSA |

## Long-term monitoring siltation Deurganckdok

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



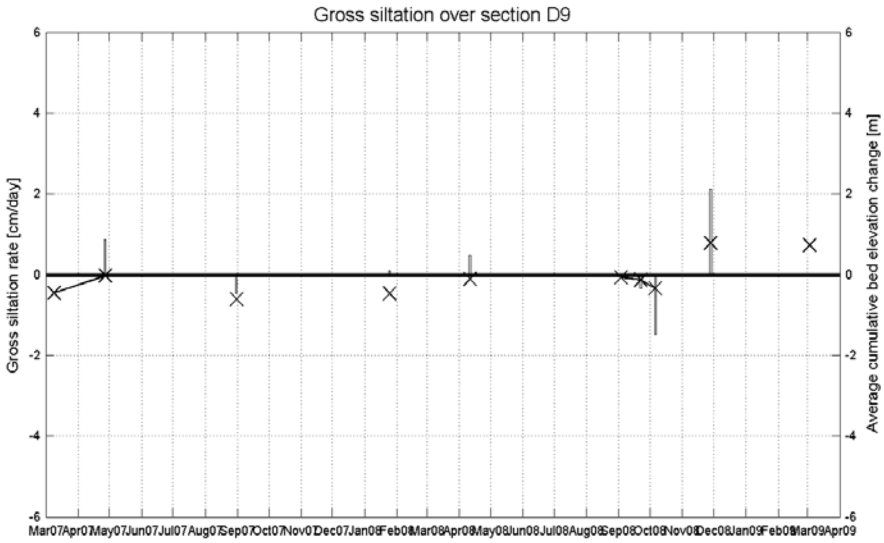

Reference level: design depth

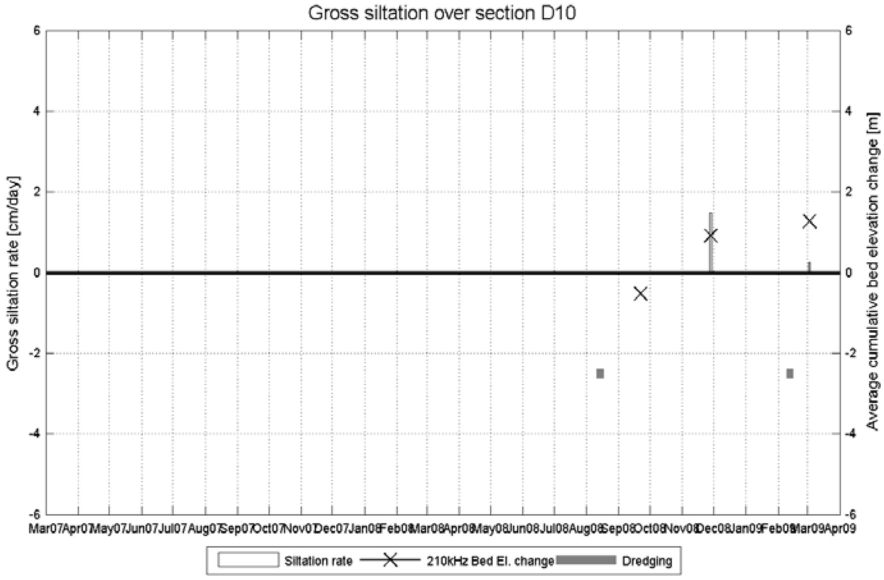
Data Processed by: IMDC
In association with : WL | delft hydraulics

I/RA/11283/08.080/MSA

## Long-term monitoring siltation Deurganckdok

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



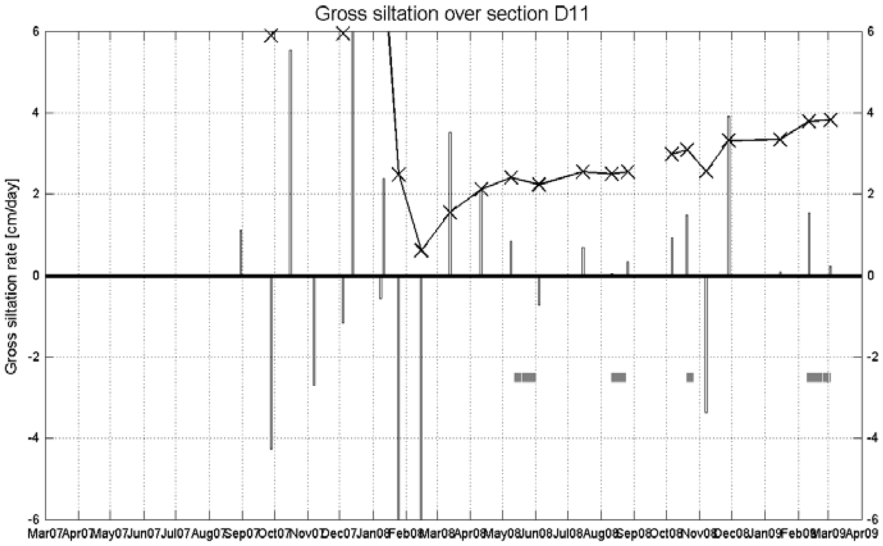



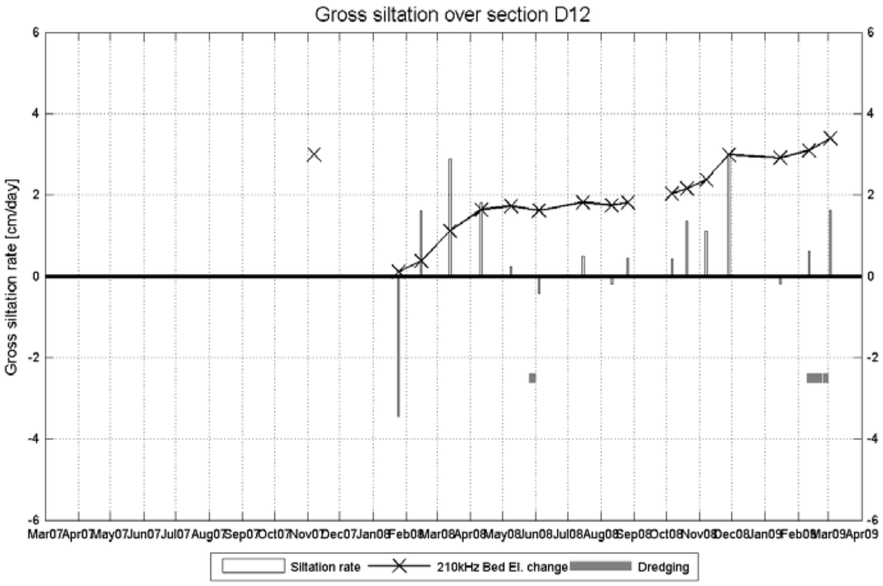

Reference level: design depth

Data Processed by:
In association with :
I/RA/11283/08.080/MSA

## Long-term monitoring siltation Deurganckdok

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

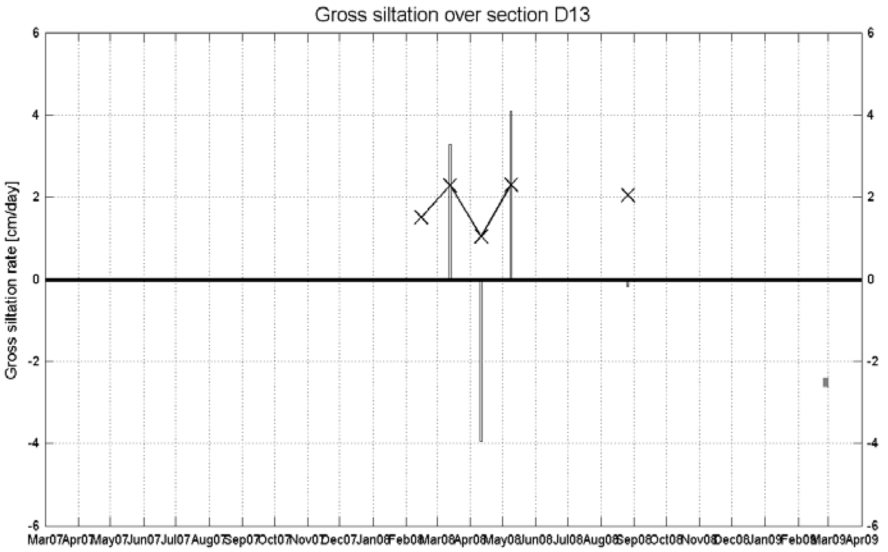


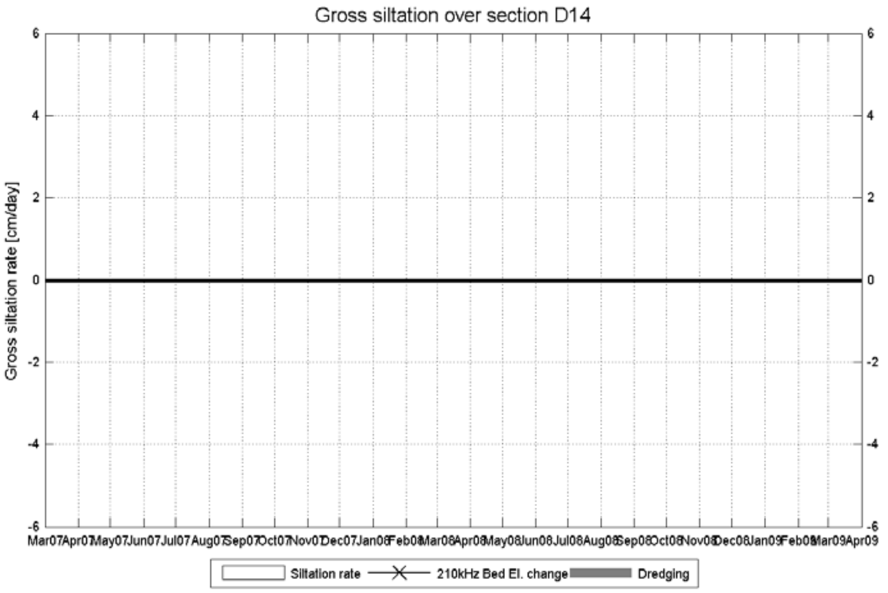




| | |
|---|---|
| Reference level: design depth | Data Processed by: IMDC<br>In association with : WL \| delft hydraulics<br>I/RA/11283/08.080/MSA |

## Long-term monitoring siltation Deurganckdok

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

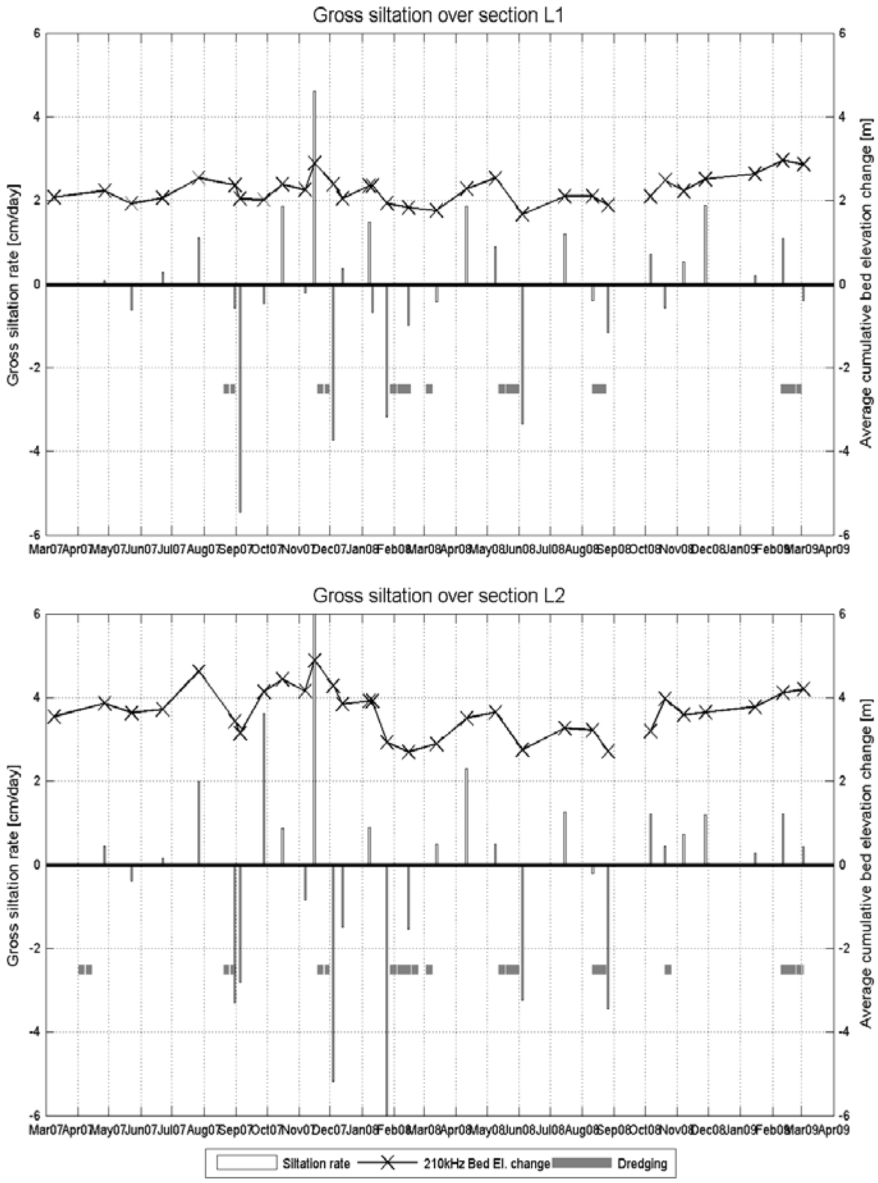



| Reference level: design depth | Data Processed by: IMDC<br>In association with : WL \| delft hydraulics<br>I/RA/11283/08.080/MSA |
| --- | --- |

## Long-term monitoring siltation Deurganckdok

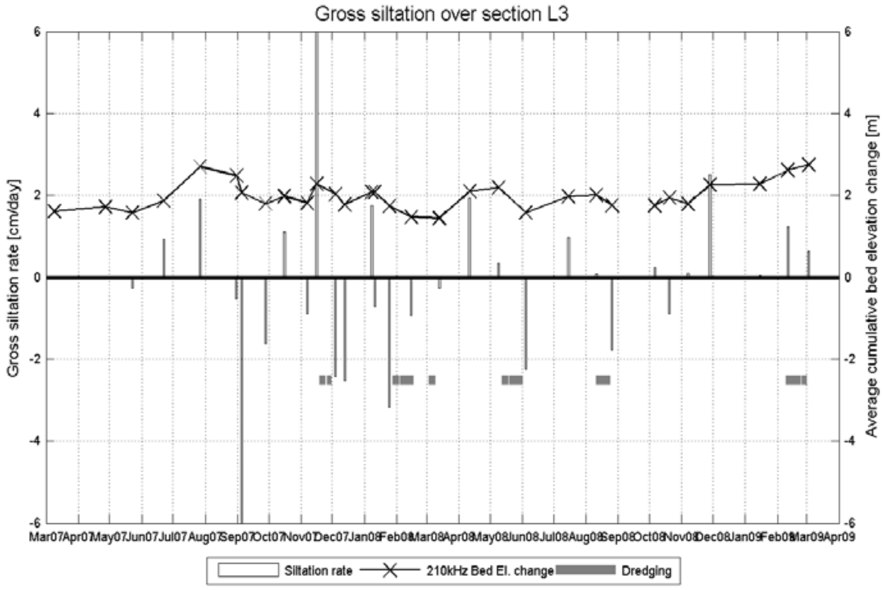
| | |
|---|---|
| Siltation height / gross siltation rate | Equipment(s): 210kHz depth sounder |
| | Location: DGD |




| | |
|---|---|
| Reference level: design depth | Data Processed by: IMDC<br>In association with: WL \| delft hydraulics<br>I/RA/11283/08.080/MSA |

Long-term monitoring siltation Deurganckdok

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

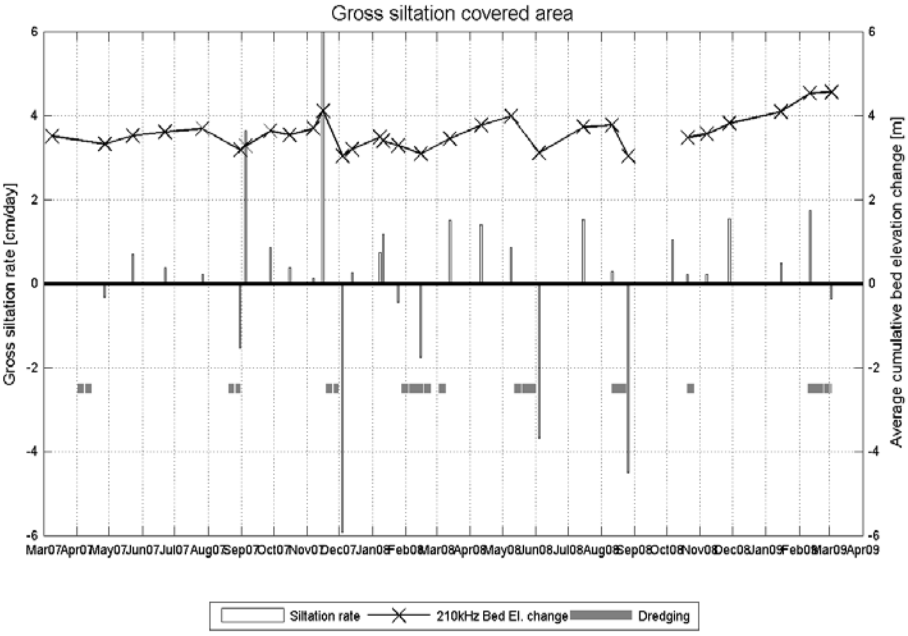



Reference level: design depth

Data Processed by:
In association with :
I/RA/11283/08.080/MSA

## C.4 Siltation rate complete Deurganckdok

| Long-term monitoring siltation Deurganckdok | |
|---|---|
| Siltation height / gross siltation rate | Equipment(s): 210kHz depth sounder |
| | Location: DGD |




| Reference level: design depth | Data Processed by: IMDC<br>In association with : WL \| delft hydraulics<br>I/RA/11283/08.080/MSA |
|---|---|

# APPENDIX D.

# AVERAGE MASS GROWTH AND GROWTH RATE

## D.1 Difference maps

## D.2 Tabular results

****Measured Mass (TDS/m²)**

------------

| | 05-Sep-07 | 16-Oct-07 | 16-Nov-07 | 05-Dec-07 | 24-Jan-08 | 22-Feb-08 | 28-Apr-08 | 05-Jun-08 | 11-Aug-08 | 26-Aug-08 | 11-Sep-08 | 20-Oct-08 | 06-Nov-08 | 30-Jan-09 | 12-Mar-09 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2 | 0.52 | 0.58 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 3a | 1.41 | 1.73 | 1.94 | - | 1.72 | 1.19 | 1.68 | 1.00 | 1.62 | 0.88 | 1.20 | 1.77 | 1.69 | 2.10 | 1.69 |
| 3b | 1.13 | 1.34 | 1.50 | 1.29 | 1.32 | 0.91 | 1.31 | 0.87 | 1.24 | 0.83 | 1.07 | 1.40 | 1.37 | 1.60 | 1.33 |
| 3c | 1.28 | 1.40 | 1.46 | 1.26 | 1.25 | 1.03 | 1.22 | 0.86 | 1.12 | 0.82 | 1.01 | 1.25 | 1.21 | 1.42 | 1.38 |
| 3d | - | - | - | - | - | 0.92 | 0.90 | 0.85 | 0.86 | 0.82 | 0.93 | 1.05 | 0.89 | 1.27 | 1.19 |
| 3e | - | - | - | - | - | - | - | - | - | - | 1.00 | 1.08 | 1.23 | 3.22 | 2.18 |
| 4Na | 1.17 | 1.04 | 1.20 | - | 0.94 | 0.74 | 0.98 | 0.70 | 0.98 | 0.60 | 0.80 | 0.98 | 1.01 | 1.34 | 1.02 |
| 4Nb | 0.95 | 0.86 | 0.94 | - | 0.82 | 0.58 | 0.81 | 0.50 | 0.74 | 0.59 | 0.69 | 0.95 | 0.89 | 1.09 | 0.89 |
| 4Nc | 0.75 | 0.77 | 0.82 | - | 0.75 | 0.62 | 0.68 | 0.51 | 0.68 | 0.59 | 0.54 | 1.07 | 0.79 | 0.85 | 0.87 |
| 4Nd | - | - | - | - | - | 0.88 | 0.48 | 0.39 | 0.55 | 0.60 | 0.43 | 0.79 | 0.63 | 0.86 | 0.80 |
| 4Ne | - | - | - | - | - | - | - | - | - | - | 0.80 | 0.87 | - | 1.75 | 2.37 |
| 4Za | 1.02 | 0.88 | 1.06 | - | 0.94 | 1.00 | 1.07 | 0.60 | 0.97 | 0.56 | 0.92 | 0.85 | 0.85 | 1.22 | 1.16 |
| 4Zb | 0.93 | 0.77 | 0.91 | - | 0.75 | 0.68 | 0.79 | 0.53 | 0.69 | 0.52 | 0.74 | 0.87 | 0.75 | 0.96 | 0.98 |
| 4Zc | 0.74 | 0.74 | 0.79 | - | 0.55 | 0.62 | 0.72 | 0.50 | 0.62 | 0.62 | 0.68 | 0.91 | 0.94 | 1.07 | 1.24 |
| 4Zd | - | - | - | - | - | 0.82 | 0.54 | 0.42 | 0.54 | 0.52 | 0.57 | 0.78 | 0.81 | 1.13 | 1.22 |
| 4Ze | - | - | - | - | - | - | - | - | - | - | 0.56 | 1.04 | 1.30 | 2.31 | 1.42 |
| 5Na | 1.24 | 0.88 | - | - | 0.84 | - | - | - | - | - | 0.76 | - | - | - | - |
| 5Nb | 1.14 | 0.90 | - | - | 0.70 | - | 0.82 | 0.52 | 0.81 | - | 0.79 | 0.76 | 0.70 | 0.90 | 1.08 |
| 5Nc | 0.89 | 1.11 | - | - | - | - | 0.55 | 0.46 | 0.74 | 0.84 | 0.52 | 0.90 | 0.60 | 0.69 | 1.05 |
| 5Nd | - | - | - | - | - | - | 0.32 | 0.24 | 0.51 | - | 0.20 | - | 0.38 | 0.67 | 0.91 |
| 5Ne | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

**Measured Mass (TDS/m²)**

------------

| | 05-Sep-07 | 16-Oct-07 | 16-Nov-07 | 05-Dec-07 | 24-Jan-08 | 22-Feb-08 | 28-Apr-08 | 05-Jun-08 | 11-Aug-08 | 26-Aug-08 | 11-Sep-08 | 20-Oct-08 | 06-Nov-08 | 30-Jan-09 | 12-Mar-09 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5Za | 0.82 | - | 0.84 | - | 0.68 | - | - | - | - | - | - | - | - | - | - |
| 5Zb | 0.91 | 0.61 | 0.73 | - | 0.69 | - | 0.62 | 0.73 | 0.83 | 0.87 | 0.77 | 0.59 | 0.48 | 0.85 | 1.10 |
| 5Zc | - | 0.59 | - | - | - | - | 0.59 | 0.44 | 0.68 | 0.73 | 0.71 | 0.71 | 0.74 | 0.70 | 1.08 |
| 5Zd | - | - | - | - | - | - | 0.32 | 0.23 | 0.50 | - | 0.54 | 0.57 | 0.53 | 0.43 | 1.10 |
| 5Ze | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Trench area mean | 1.64 | 1.74 | 1.71 | 1.34 | 1.43 | 1.00 | 1.25 | 0.89 | 1.18 | 0.83 | 1.04 | 1.35 | 1.26 | 1.57 | 1.38 |

****Cumulative dredged mass in covered area (TDS)**

\-----------

| | 05-Sep-07 | 16-Oct-07 | 16-Nov-07 | 05-Dec-07 | 24-Jan-08 | 22-Feb-08 | 28-Apr-08 | 05-Jun-08 | 11-Aug-08 | 26-Aug-08 | 11-Sep-08 | 20-Oct-08 | 06-Nov-08 | 30-Jan-09 | 12-Mar-09 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 168 | 168 | 168 | 196 | 196 | 196 | 196 | 196 | 196 | 236 | 236 | 236 | 236 | 236 | 264 |
| 2 | 1397 | 1397 | 1397 | 1427 | 1427 | 1767 | 1767 | 4025 | 4025 | 4854 | 4854 | 4854 | 4854 | 4854 | 6264 |
| 3a | 100012 | 100012 | 100012 | 183532 | 183532 | 276927 | 276927 | 394510 | 394510 | 534785 | 534785 | 534785 | 534785 | 534785 | 592465 |
| 3b | 101145 | 101145 | 101145 | 166723 | 166723 | 247239 | 247239 | 343264 | 343264 | 454137 | 454137 | 454137 | 454137 | 454137 | 493322 |
| 3c | 69888 | 69888 | 69888 | 120397 | 120397 | 186486 | 207151 | 271242 | 271242 | 337665 | 337665 | 337665 | 363089 | 363089 | 392657 |
| 3d | 2 | 2 | 2 | 567 | 567 | 1056 | 45001 | 60776 | 60776 | 78042 | 78042 | 78042 | 131936 | 131936 | 166799 |
| 3e | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 541 | 541 | 541 | 541 | 541 | 541 | 541 | 3311 |
| 4Na | 13417 | 13417 | 13417 | 30401 | 30401 | 43770 | 43770 | 59267 | 59267 | 77087 | 77087 | 77087 | 77087 | 77087 | 93596 |
| 4Nb | 11963 | 11963 | 11963 | 25875 | 25875 | 37656 | 37656 | 54643 | 54643 | 63023 | 63023 | 63023 | 63023 | 63023 | 80405 |
| 4Nc | 5772 | 5772 | 5772 | 15231 | 15231 | 23121 | 25297 | 33070 | 33070 | 34740 | 34740 | 34740 | 34764 | 34764 | 47030 |
| 4Nd | 0 | 0 | 0 | 14 | 14 | 14 | 8056 | 9494 | 9494 | 9570 | 9570 | 9570 | 9671 | 9671 | 18733 |
| 4Ne | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 155 |
| 4Za | 505 | 505 | 505 | 11308 | 11308 | 18930 | 18930 | 33788 | 33788 | 44385 | 44385 | 44385 | 44385 | 44385 | 54230 |
| 4Zb | 144 | 144 | 144 | 16474 | 16474 | 25109 | 25109 | 40083 | 40083 | 47269 | 47269 | 47269 | 47269 | 47269 | 58804 |
| 4Zc | 28 | 28 | 28 | 6767 | 6767 | 10684 | 12990 | 17467 | 17467 | 18757 | 18757 | 18757 | 18758 | 18758 | 26802 |
| 4Zd | 0 | 0 | 0 | 0 | 0 | 0 | 4048 | 4594 | 4594 | 4607 | 4607 | 4607 | 4635 | 4635 | 11653 |
| 4Ze | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 94 |
| 5Na | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |
| 5Nb | 29 | 29 | 29 | 29 | 29 | 98 | 98 | 98 | 98 | 98 | 98 | 98 | 98 | 98 | 98 |
| 5Nc | 19 | 19 | 19 | 19 | 19 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 30 |
| 5Nd | 0 | 0 | 0 | 0 | 0 | 0 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 | 26 |

****Cumulative dredged mass in covered area (TDS)**

------------

| | 05-Sep-07 | 16-Oct-07 | 16-Nov-07 | 05-Dec-07 | 24-Jan-08 | 22-Feb-08 | 28-Apr-08 | 05-Jun-08 | 11-Aug-08 | 26-Aug-08 | 11-Sep-08 | 20-Oct-08 | 06-Nov-08 | 30-Jan-09 | 12-Mar-09 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5Ne | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5Za | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5Zb | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5Zc | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5Zd | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 5Ze | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | | |
| Total | 304494 | 304494 | 304494 | 578963 | 578963 | 873083 | 954291 | 1327186 | 1327186 | 1709924 | 1709924 | 1709924 | 1789394 | 1789394 | 2046744 |

****Total cumulative mass(TDS/m²)**

\-----------

| | 05-Sep-07 | 16-Oct-07 | 16-Nov-07 | 05-Dec-07 | 24-Jan-08 | 22-Feb-08 | 28-Apr-08 | 05-Jun-08 | 11-Aug-08 | 26-Aug-08 | 11-Sep-08 | 20-Oct-08 | 06-Nov-08 | 30-Jan-09 | 12-Mar-09 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2 | 0.53 | 0.59 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 3a | 2.42 | 2.74 | 2.95 | - | 3.58 | 3.99 | 4.48 | 5.00 | 5.61 | 6.29 | 6.62 | 7.19 | 7.11 | 7.51 | 7.69 |
| 3b | 2.05 | 2.26 | 2.42 | 2.80 | 2.84 | 3.16 | 3.56 | 3.99 | 4.37 | 4.96 | 5.20 | 5.53 | 5.50 | 5.74 | 5.82 |
| 3c | 1.99 | 2.10 | 2.17 | 2.48 | 2.47 | 2.91 | 3.31 | 3.60 | 3.86 | 4.23 | 4.41 | 4.66 | 4.87 | 5.08 | 5.35 |
| 3d | - | - | - | - | - | 0.93 | 1.24 | 1.31 | 1.32 | 1.41 | 1.53 | 1.65 | 1.91 | 2.28 | 2.47 |
| 3e | - | - | - | - | - | - | - | - | - | - | 1.00 | 1.08 | 1.24 | 3.22 | 2.21 |
| 4Na | 1.54 | 1.41 | 1.56 | - | 1.78 | 1.95 | 2.18 | 2.33 | 2.61 | 2.72 | 2.92 | 3.10 | 3.13 | 3.46 | 3.59 |
| 4Nb | 1.34 | 1.24 | 1.33 | - | 1.65 | 1.79 | 2.02 | 2.25 | 2.50 | 2.61 | 2.71 | 2.98 | 2.91 | 3.11 | 3.47 |
| 4Nc | 0.97 | 0.99 | 1.04 | - | 1.34 | 1.52 | 1.66 | 1.79 | 1.97 | 1.94 | 1.89 | 2.42 | 2.14 | 2.20 | 2.70 |
| 4Nd | - | - | - | - | - | 0.88 | 0.72 | 0.68 | 0.84 | 0.89 | 0.72 | 1.08 | 0.93 | 1.15 | 1.38 |
| 4Ne | - | - | - | - | - | - | - | - | - | - | 0.81 | 0.88 | - | 1.75 | 2.37 |
| 4Za | 1.04 | 0.90 | 1.08 | - | 1.41 | 1.78 | 1.85 | 1.99 | 2.37 | 2.40 | 2.76 | 2.68 | 2.68 | 3.05 | 3.40 |
| 4Zb | 0.93 | 0.77 | 0.92 | - | 1.28 | 1.49 | 1.60 | 1.81 | 1.97 | 2.03 | 2.25 | 2.38 | 2.26 | 2.47 | 2.87 |
| 4Zc | 0.74 | 0.74 | 0.79 | - | 0.81 | 1.04 | 1.22 | 1.17 | 1.30 | 1.35 | 1.40 | 1.64 | 1.66 | 1.80 | 2.27 |
| 4Zd | - | - | - | - | - | 0.82 | 0.66 | 0.56 | 0.69 | 0.66 | 0.72 | 0.92 | 0.96 | 1.28 | 1.58 |
| 4Ze | - | - | - | - | - | - | - | - | - | - | 0.56 | 1.04 | 1.30 | 2.31 | 1.42 |
| 5Na | 1.24 | 0.88 | - | - | 0.84 | - | - | - | - | - | 0.76 | - | - | - | - |
| 5Nb | 1.14 | 0.90 | - | - | 0.70 | - | 0.83 | 0.52 | 0.81 | - | 0.80 | 0.76 | 0.70 | 0.91 | 1.09 |
| 5Nc | 0.89 | 1.12 | - | - | - | - | 0.55 | 0.46 | 0.74 | 0.84 | 0.52 | 0.91 | 0.61 | 0.70 | 1.05 |
| 5Nd | - | - | - | - | - | - | 0.32 | 0.24 | 0.51 | - | 0.20 | - | 0.38 | 0.67 | 0.92 |

****Total cumulative mass(TDS/m²)**

------------

| | 05-Sep-07 | 16-Oct-07 | 16-Nov-07 | 05-Dec-07 | 24-Jan-08 | 22-Feb-08 | 28-Apr-08 | 05-Jun-08 | 11-Aug-08 | 26-Aug-08 | 11-Sep-08 | 20-Oct-08 | 06-Nov-08 | 30-Jan-09 | 12-Mar-09 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5Ne | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 5Za | 0.82 | - | 0.84 | - | 0.68 | - | - | - | - | - | - | - | - | - | - |
| 5Zb | 0.91 | 0.61 | 0.73 | - | 0.69 | - | 0.62 | 0.73 | 0.83 | 0.87 | 0.77 | 0.59 | 0.48 | 0.85 | 1.10 |
| 5Zc | - | 0.59 | - | - | - | - | 0.59 | 0.44 | 0.68 | 0.73 | 0.71 | 0.71 | 0.74 | 0.70 | 1.08 |
| 5Zd | - | - | - | - | - | - | 0.32 | 0.23 | 0.51 | - | 0.54 | 0.57 | 0.53 | 0.43 | 1.10 |
| 5Ze | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Trench area mean | 2.26 | 2.36 | 2.33 | 2.87 | 2.96 | 2.63 | 3.02 | 3.33 | 3.63 | 4.04 | 4.25 | 4.55 | 4.65 | 4.96 | 5.14 |

****Growth rate (kg/m²/day)**

-----------

| | 05-Sep-07 | 16-Oct-07 | 16-Nov-07 | 05-Dec-07 | 24-Jan-08 | 22-Feb-08 | 28-Apr-08 | 05-Jun-08 | 11-Aug-08 | 26-Aug-08 | 11-Sep-08 | 20-Oct-08 | 06-Nov-08 | 30-Jan-09 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 16-Oct-07 | 16-Nov-07 | 05-Dec-07 | 24-Jan-08 | 22-Feb-08 | 28-Apr-08 | 05-Jun-08 | 11-Aug-08 | 26-Aug-08 | 11-Sep-08 | 20-Oct-08 | 06-Nov-08 | 30-Jan-09 | 12-Mar-09 |
| 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2 | 1.41 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 3a | 7.90 | 6.70 | - | - | 14.36 | 7.47 | 13.46 | 9.19 | 45.39 | 20.19 | 14.69 | -4.51 | 4.74 | 4.24 |
| 3b | 4.96 | 5.29 | 20.16 | 0.76 | 11.04 | 6.05 | 11.39 | 5.54 | 39.91 | 14.94 | 8.38 | -1.48 | 2.75 | 1.92 |
| 3c | 2.92 | 2.06 | 16.25 | -0.24 | 15.35 | 6.00 | 7.72 | 3.83 | 24.64 | 11.77 | 6.34 | 12.32 | 2.51 | 6.45 |
| 3d | - | - | - | - | - | 4.76 | 1.86 | 0.21 | 6.01 | 6.93 | 3.23 | 14.92 | 4.43 | 4.56 |
| 3e | - | - | - | - | - | - | - | - | - | - | 2.09 | 9.13 | 23.34 | -24.65 |
| 4Na | -3.19 | 5.11 | - | - | 5.86 | 3.54 | 3.86 | 4.22 | 7.17 | 12.43 | 4.71 | 1.54 | 3.87 | 3.35 |
| 4Nb | -2.22 | 2.65 | - | - | 4.67 | 3.58 | 6.07 | 3.63 | 7.53 | 6.42 | 6.76 | -3.70 | 2.36 | 8.61 |
| 4Nc | 0.50 | 1.65 | - | - | 6.09 | 2.15 | 3.48 | 2.67 | -1.76 | -3.44 | 13.73 | -16.83 | 0.75 | 12.23 |
| 4Nd | - | - | - | - | - | -2.31 | -1.06 | 2.36 | 3.52 | -10.95 | 9.29 | -8.95 | 2.63 | 5.49 |
| 4Ne | - | - | - | - | - | - | - | - | - | - | 1.80 | - | - | 15.19 |
| 4Za | -3.48 | 5.74 | - | - | 12.90 | 1.12 | 3.69 | 5.57 | 2.01 | 22.54 | -1.87 | 0.05 | 4.31 | 8.43 |
| 4Zb | -3.92 | 4.59 | - | - | 7.13 | 1.67 | 5.71 | 2.41 | 3.89 | 13.58 | 3.34 | -6.87 | 2.46 | 9.56 |
| 4Zc | -0.03 | 1.49 | - | - | 7.88 | 2.82 | -1.28 | 1.88 | 3.23 | 3.29 | 6.11 | 1.36 | 1.61 | 11.56 |
| 4Zd | - | - | - | - | - | -2.33 | -2.61 | 1.82 | -1.69 | 3.53 | 5.17 | 2.18 | 3.79 | 7.39 |
| 4Ze | - | - | - | - | - | - | - | - | - | - | 12.30 | 15.08 | 11.88 | -21.58 |
| 5Na | -8.70 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 5Nb | -5.69 | - | - | - | - | - | -8.08 | 4.39 | - | - | -0.85 | -3.64 | 2.44 | 4.31 |
| 5Nc | 5.39 | - | - | - | - | - | -2.27 | 4.15 | 6.45 | -19.80 | 9.83 | -17.67 | 1.06 | 8.73 |

**Growth rate (kg/m²/day)**

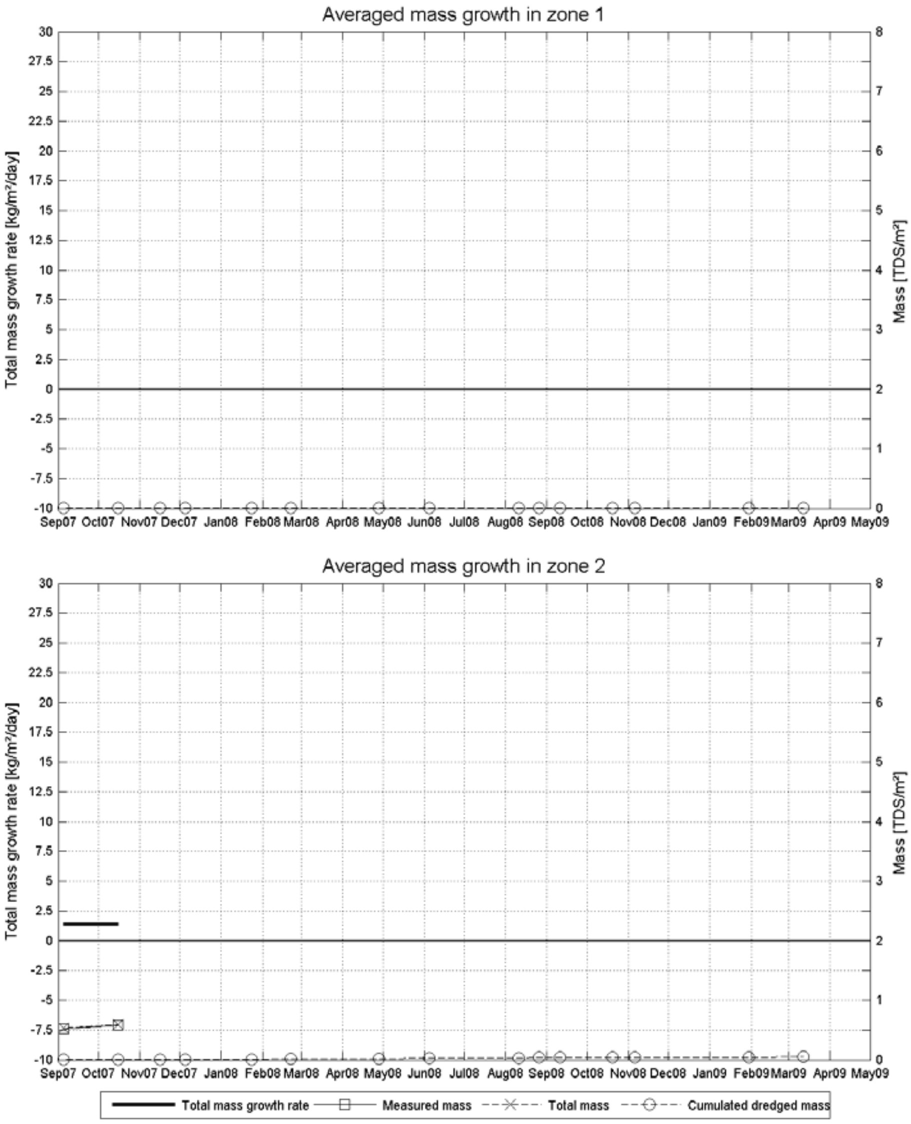
------------

| | 05-Sep-07<br>16-Oct-07 | 16-Oct-07<br>16-Nov-07 | 16-Nov-07<br>05-Dec-07 | 05-Dec-07<br>24-Jan-08 | 24-Jan-08<br>22-Feb-08 | 22-Feb-08<br>28-Apr-08 | 28-Apr-08<br>05-Jun-08 | 05-Jun-08<br>11-Aug-08 | 11-Aug-08<br>26-Aug-08 | 26-Aug-08<br>11-Sep-08 | 11-Sep-08<br>20-Oct-08 | 20-Oct-08<br>06-Nov-08 | 06-Nov-08<br>30-Jan-09 | 30-Jan-09<br>12-Mar-09 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5Nd | - | - | - | - | - | - | -2.21 | 4.12 | - | - | - | - | 3.34 | 6.05 |
| 5Ne | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 5Za | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 5Zb | -7.24 | 3.76 | - | - | - | - | 2.85 | 1.54 | 2.36 | -6.00 | -4.59 | -6.33 | 4.29 | 6.13 |
| 5Zc | - | - | - | - | - | - | -3.91 | 3.56 | 3.56 | -1.03 | -0.08 | 1.60 | -0.43 | 9.18 |
| 5Zd | - | - | - | - | - | - | -2.36 | 4.13 | - | - | 0.76 | -2.34 | -1.22 | 16.48 |
| 5Ze | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | | | | | | | | | | | | |
| Trench area mean | 2.55 | -0.94 | 28.06 | 1.80 | -11.38 | 5.97 | 8.19 | 4.39 | 27.59 | 13.02 | 7.80 | 5.84 | 3.64 | 4.25 |

## D.3 For each zone

Long-term monitoring siltation Deurganckdok

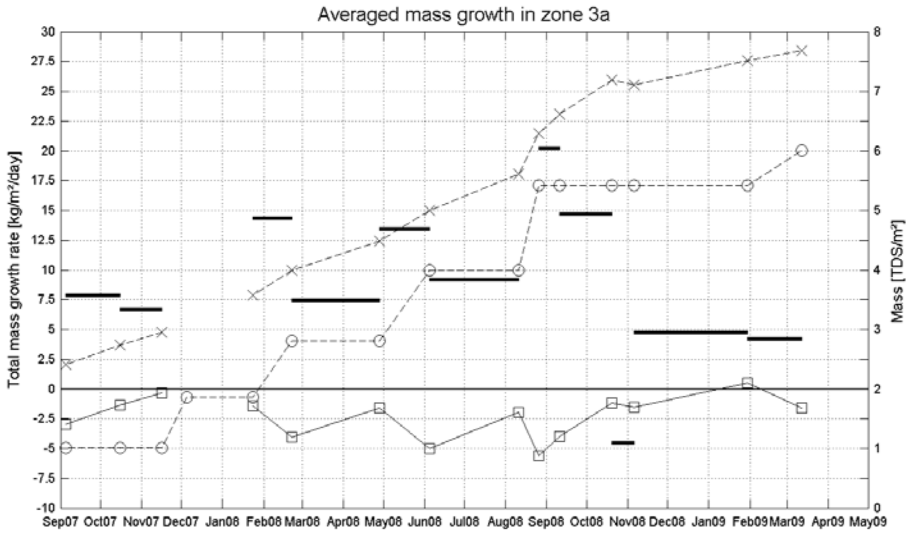
| | |
|---|---|
| Measured/Dredged/Total Mass | Equipment(s): NaviTracker (until 11/9/2008) and Densitune |
| | Location: DGD |

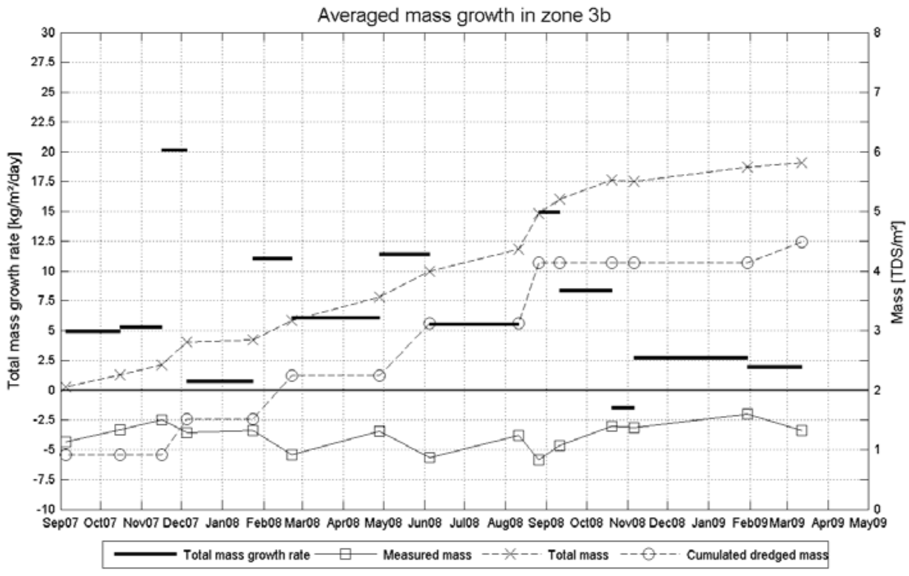



Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.080/MSA

Long-term monitoring siltation Deurganckdok

| | |
|---|---|
| Measured/Dredged/Total Mass | Equipment(s): NaviTracker (until 11/9/2008) and Densitune |
| | Location: DGD |

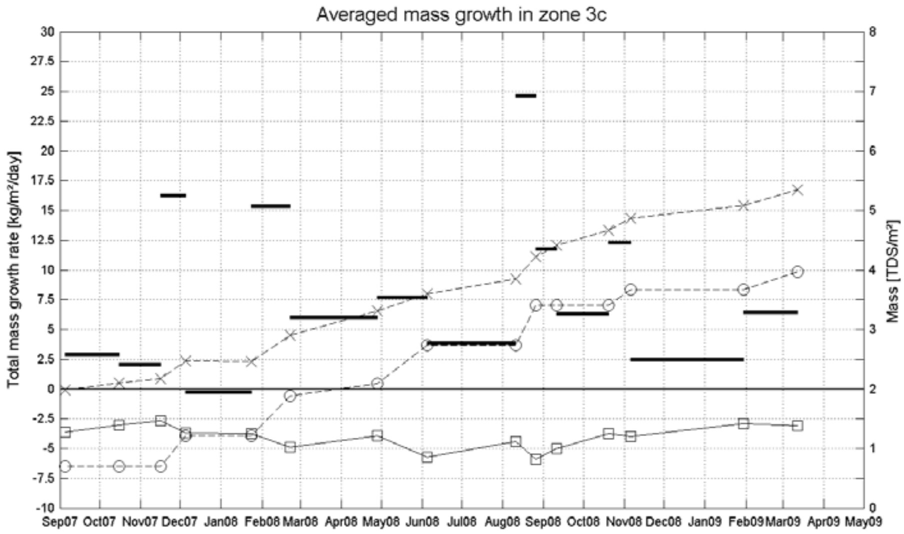


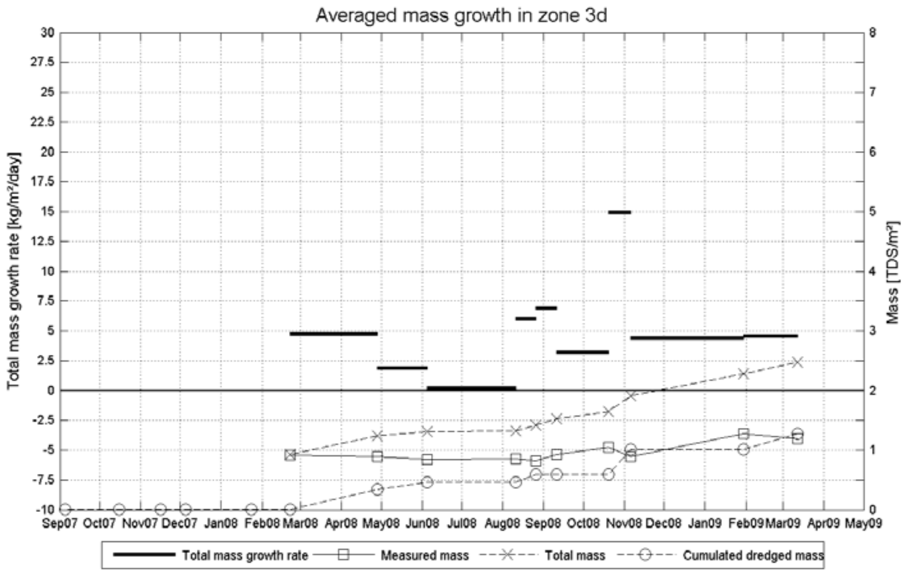




Data Processed by:
In association with :
I/RA/11283/08.080/MSA

## Long-term monitoring siltation Deurganckdok

| Measured/Dredged/Total Mass | Equipment(s): NaviTracker (until 11/9/2008) and Densitune |
|---|---|
| | Location: DGD |

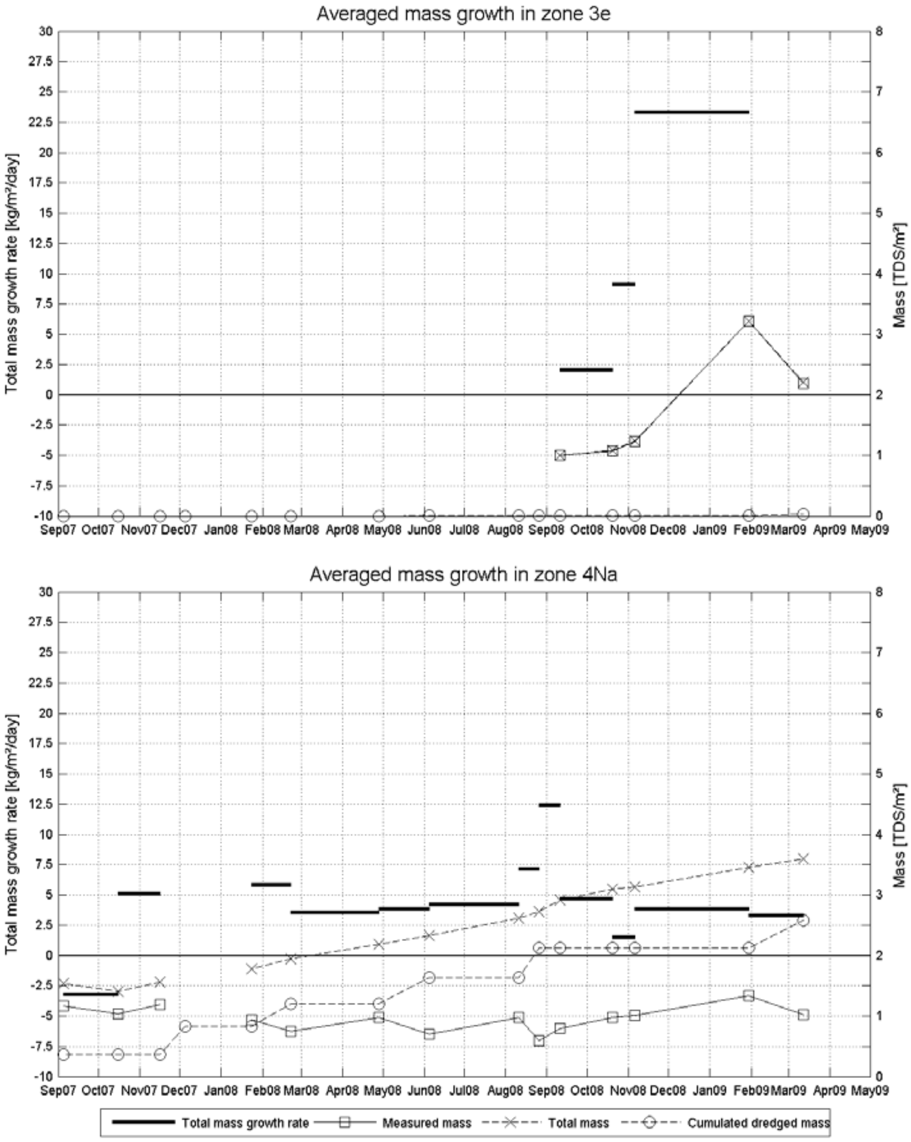



Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.080/MSA

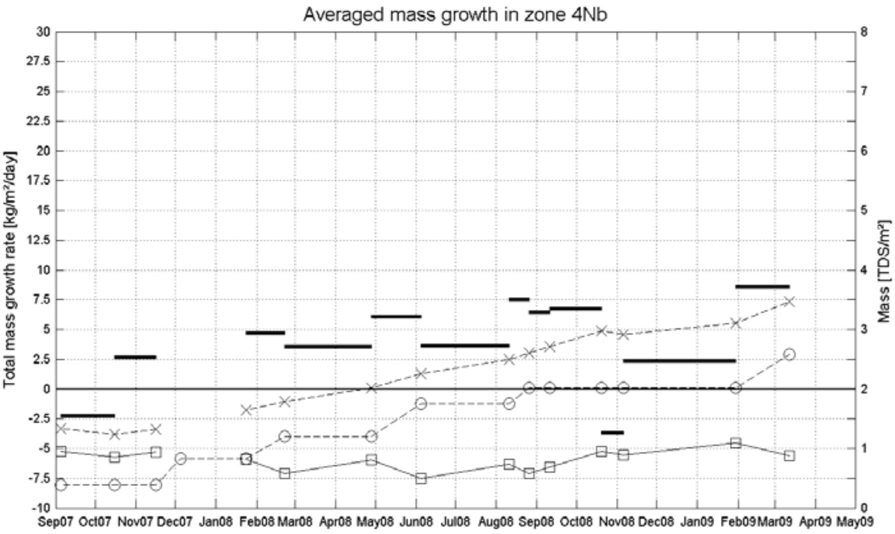
Long-term monitoring siltation Deurganckdok

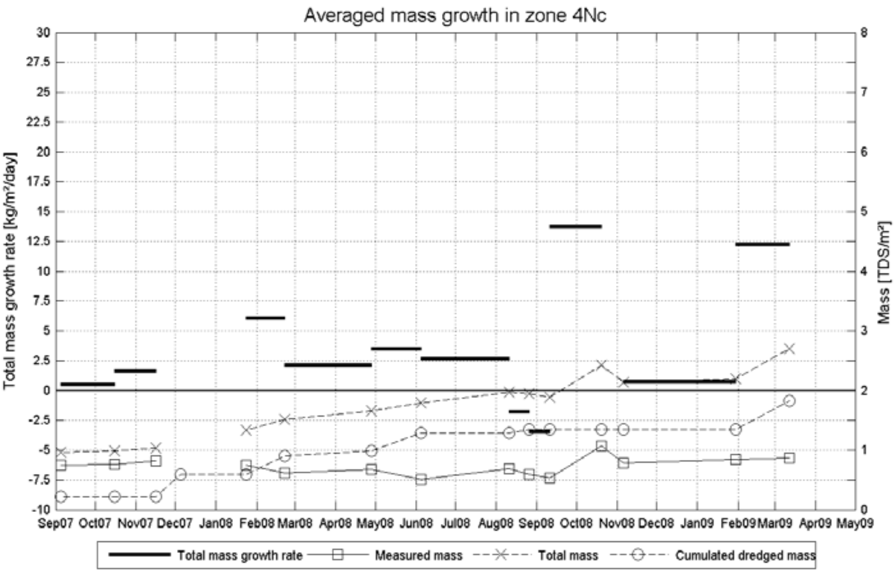
| | |
|---|---|
| Measured/Dredged/Total Mass | Equipment(s): NaviTracker (until 11/9/2008) and Densitune |
| | Location: DGD |




Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.080/MSA

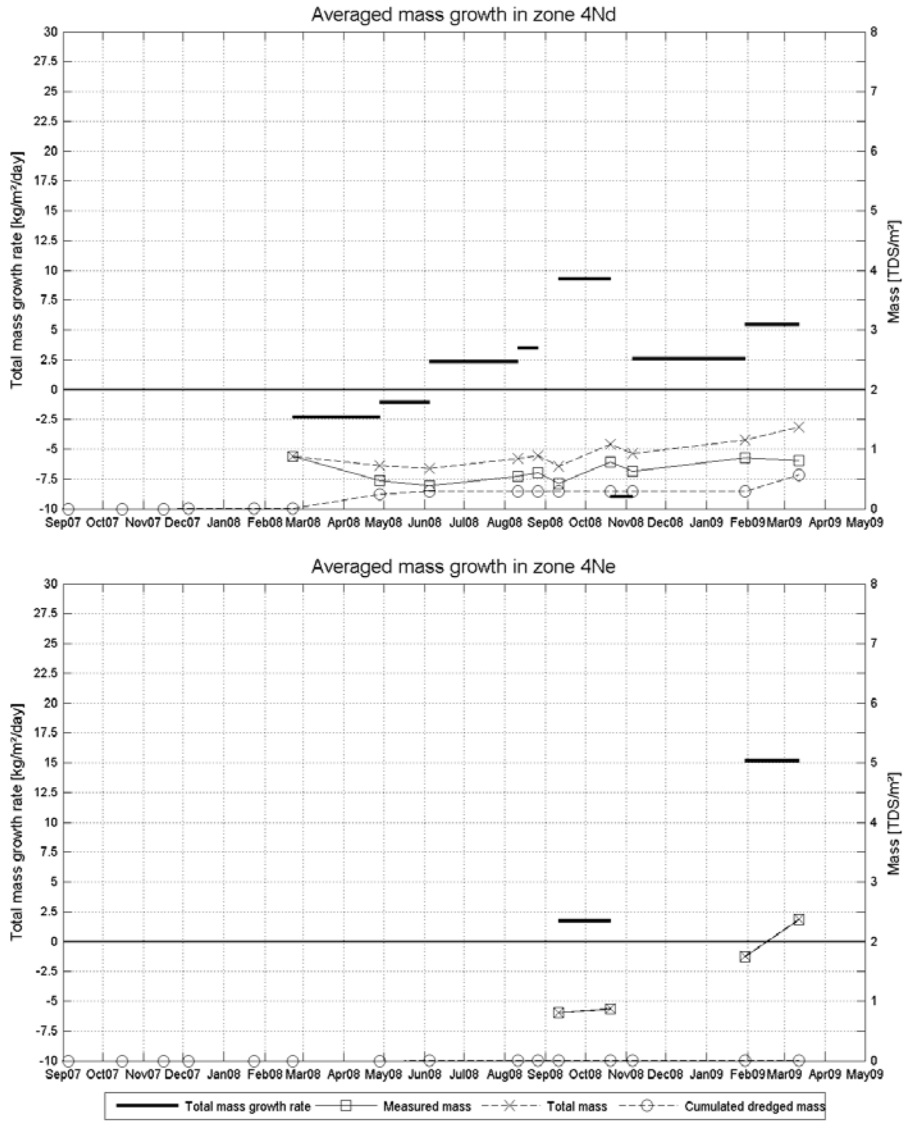
| Long-term monitoring siltation Deurganckdok | |
|---|---|
| Measured/Dredged/Total Mass | Equipment(s): NaviTracker (until 11/9/2008) and Densitune |
| | Location: DGD |



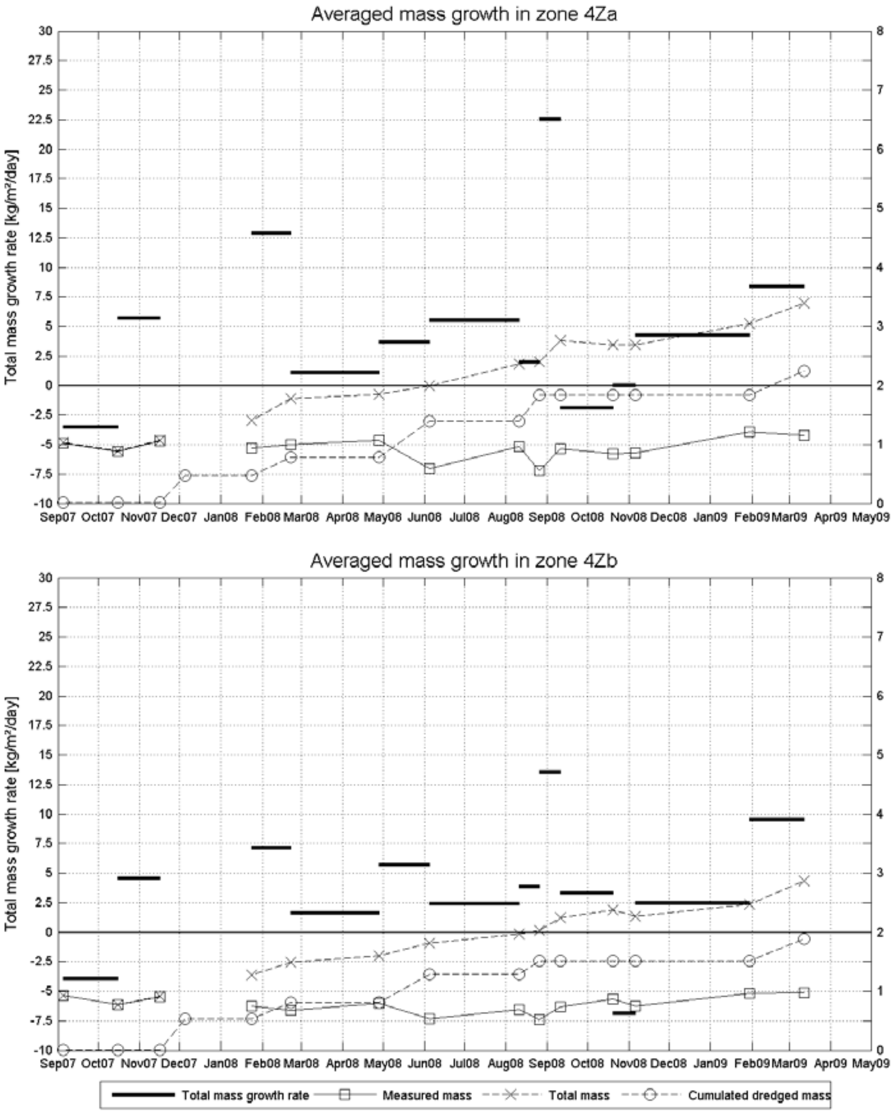

Data Processed by: IMDC
In association with: WL | delft hydraulics
I/RA/11283/08.080/MSA

| Long-term monitoring siltation Deurganckdok | |
|---|---|
| Measured/Dredged/Total Mass | Equipment(s): NaviTracker (until 11/9/2008) and Densitune |
| | Location: DGD |



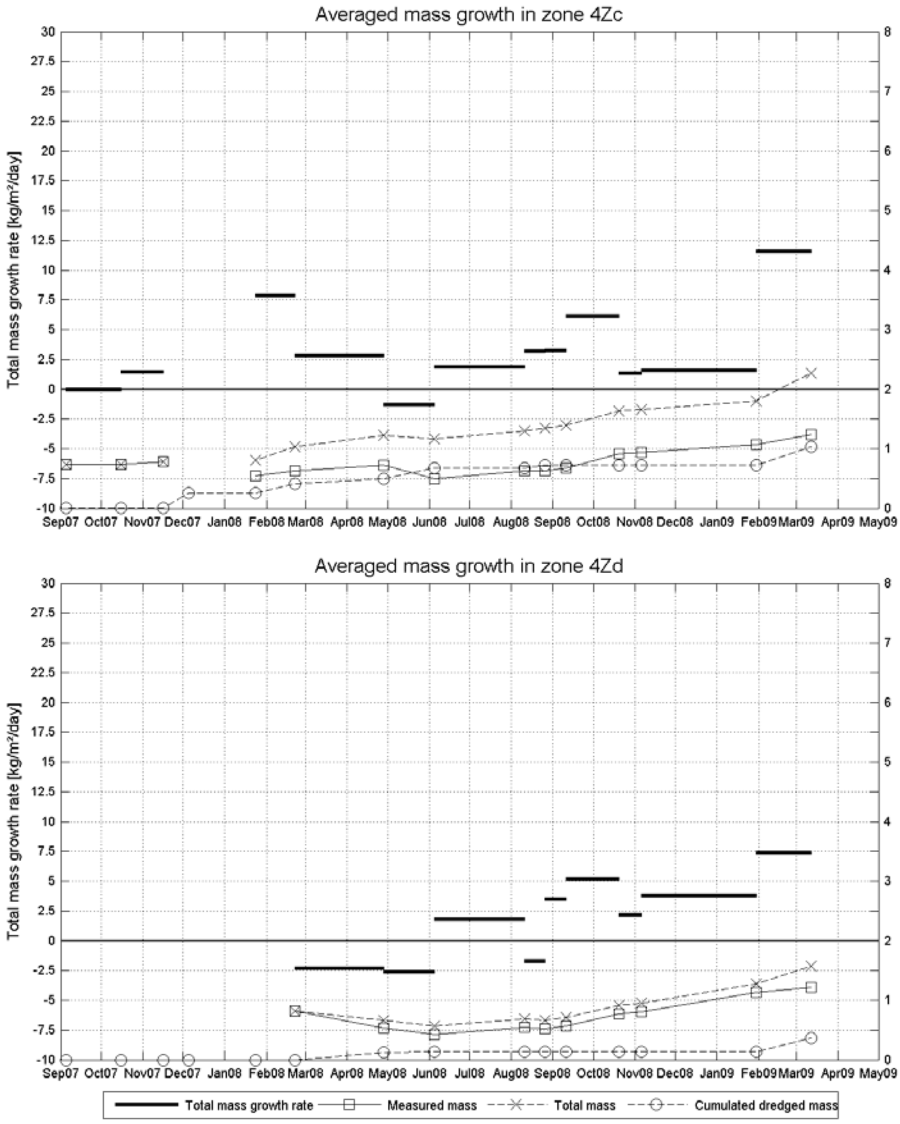

Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.080/MSA

| Long-term monitoring siltation Deurganckdok | |
|---|---|
| Measured/Dredged/Total Mass | Equipment(s): NaviTracker (until 11/9/2008) and Densitune |
| | Location: DGD |



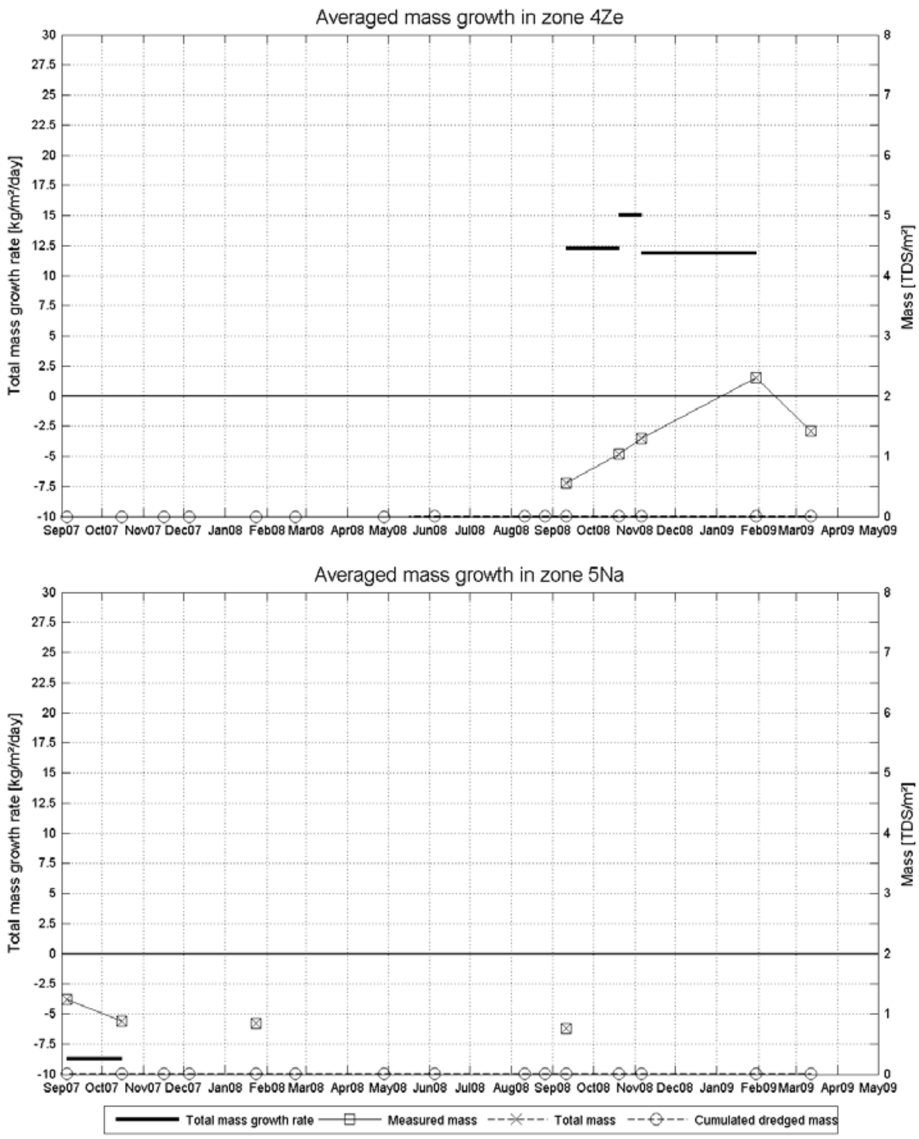

| | |
|---|---|
| | Data Processed by: IMDC<br>In association with : WL \| delft hydraulics<br>I/RA/11283/08.080/MSA |

| Long-term monitoring siltation Deurganckdok | |
|---|---|
| Measured/Dredged/Total Mass | Equipment(s): NaviTracker (until 11/9/2008) and Densitune |
| | Location: DGD |



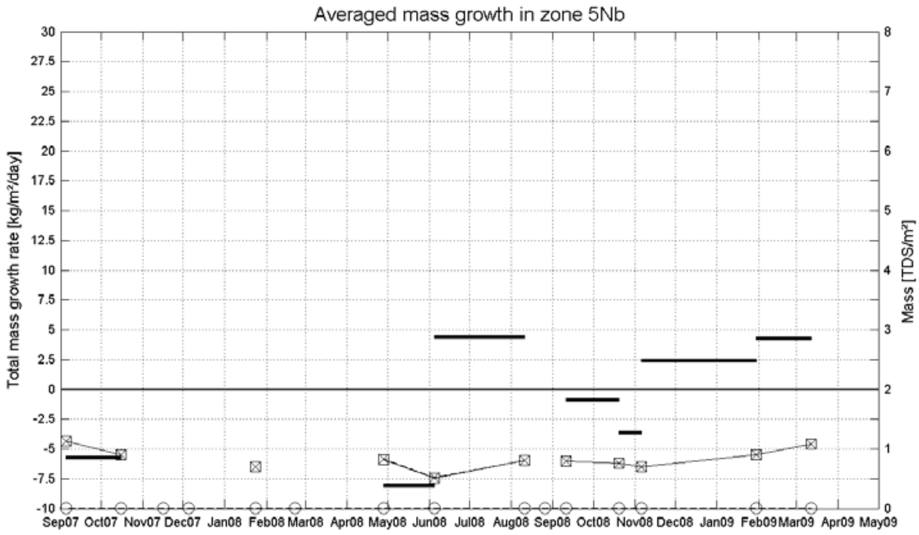

Data Processed by: IMDC
In association with : wl | delft hydraulics
I/RA/11283/08.080/MSA

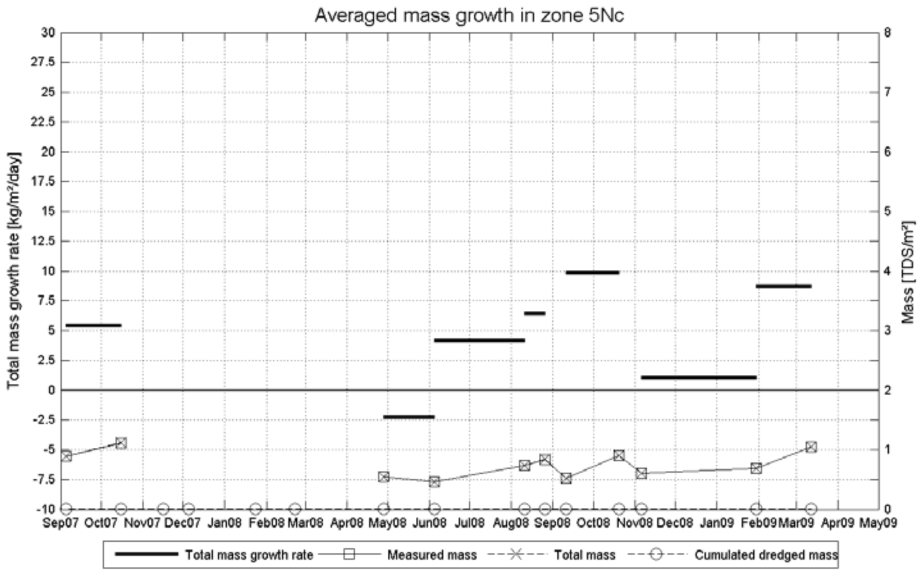
| Long-term monitoring siltation Deurganckdok | |
|---|---|
| Measured/Dredged/Total Mass | Equipment(s): NaviTracker (until 11/9/2008) and Densitune |
| | Location: DGD |




Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.080/MSA

| Long-term monitoring siltation Deurganckdok | |
|---|---|
| Measured/Dredged/Total Mass | Equipment(s): NaviTracker (until 11/9/2008) and Densitune |
| | Location: DGD |

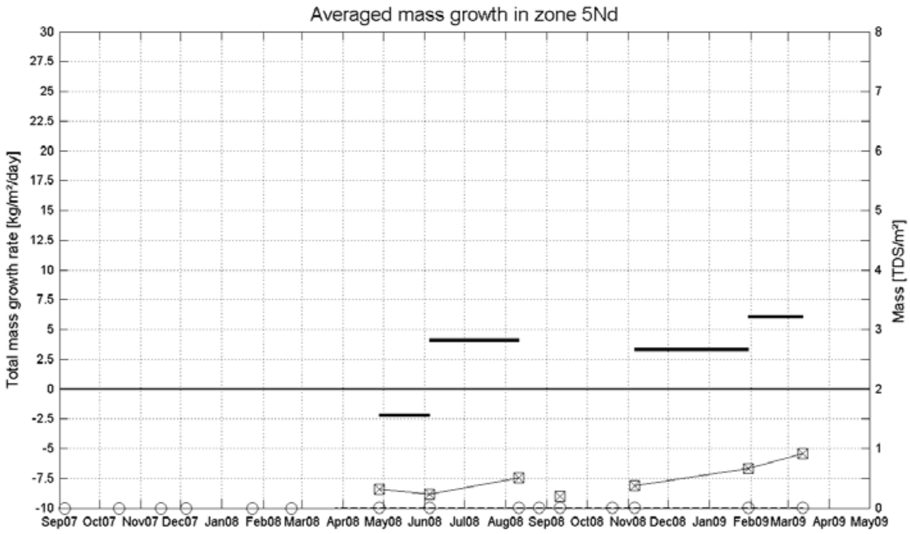


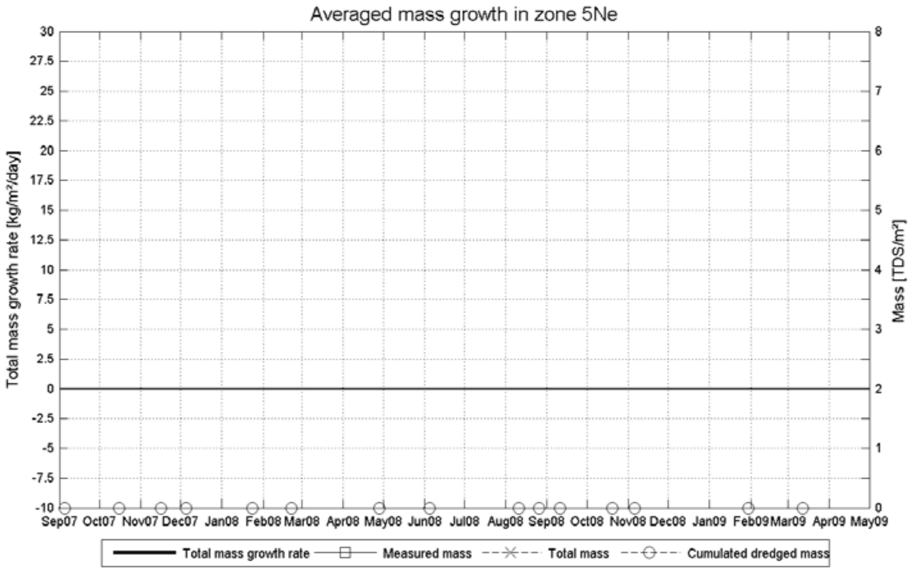




Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.080/MSA

Long-term monitoring siltation Deurganckdok

| | |
|---|---|
| Measured/Dredged/Total Mass | Equipment(s): NaviTracker (until 11/9/2008) and Densitune |
| | Location: DGD |



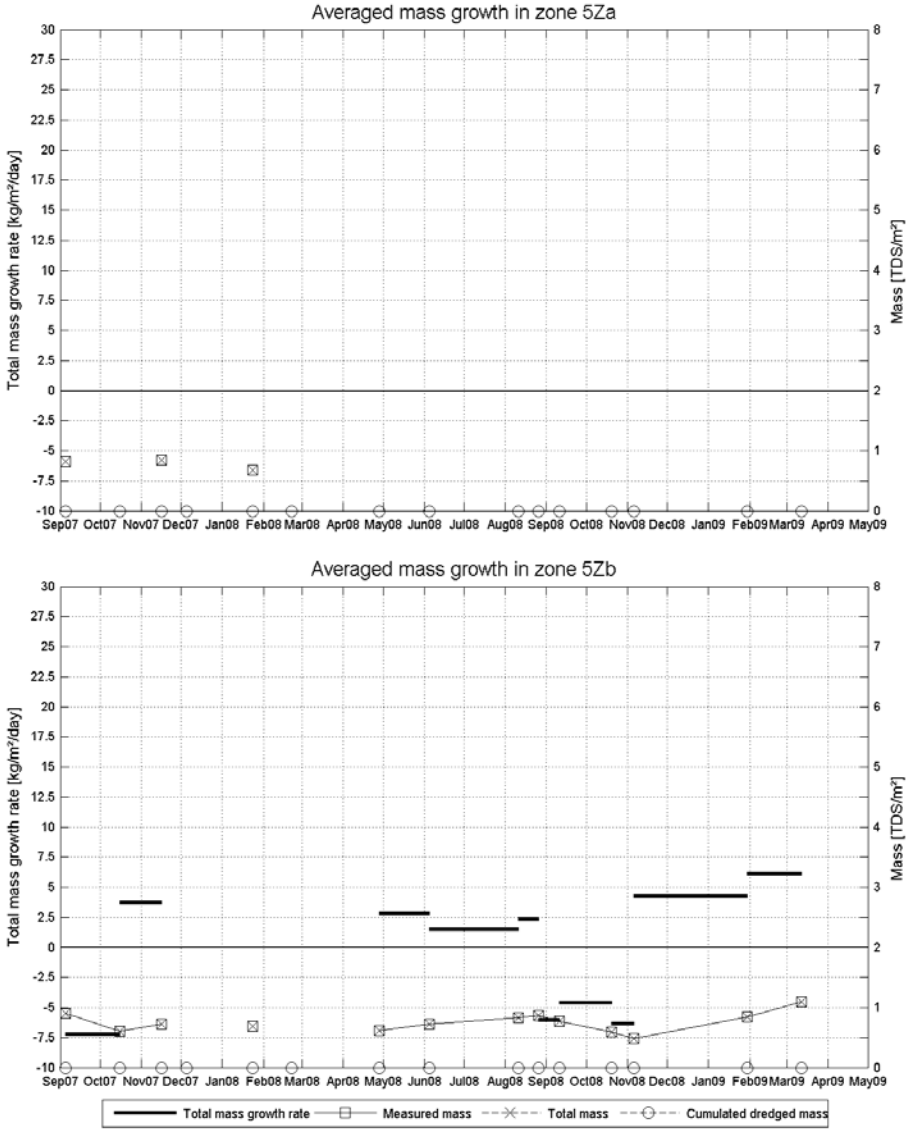

Data Processed by: IMDC

In association with : WL | delft hydraulics

I/RA/11283/08.080/MSA

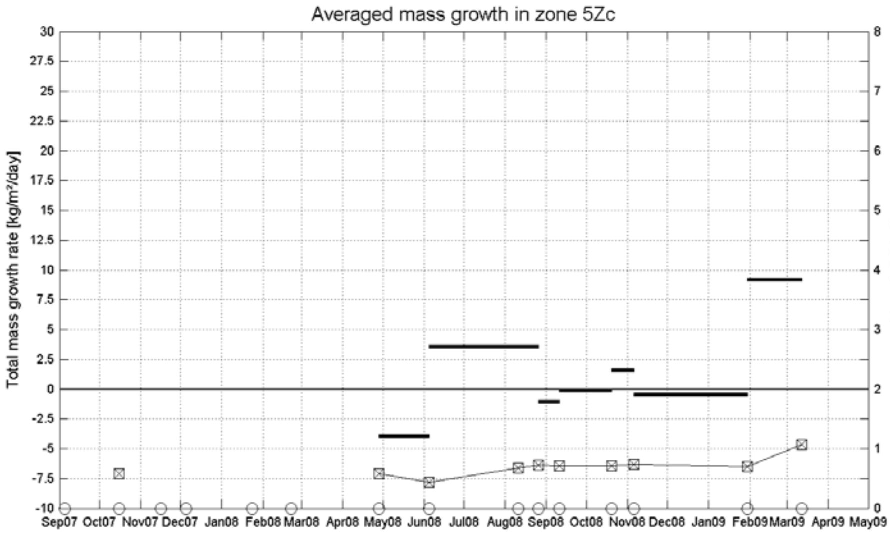
Long-term monitoring siltation Deurganckdok

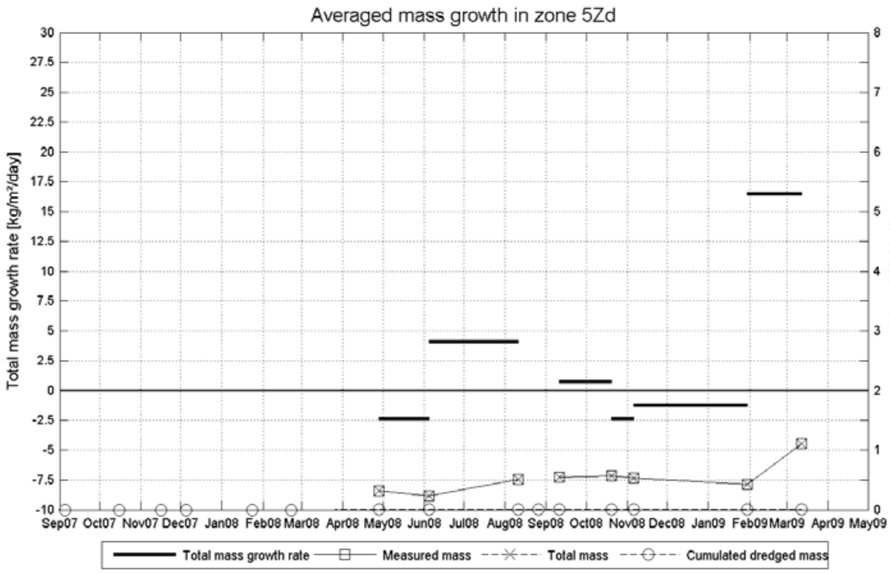
| Measured/Dredged/Total Mass | Equipment(s): NaviTracker (until 11/9/2008) and Densitune |
|---|---|
| | Location: DGD |




Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.080/MSA

| Long-term monitoring siltation Deurganckdok | |
|---|---|
| Measured/Dredged/Total Mass | Equipment(s):<br>NaviTracker (until 11/9/2008) and Densitune |
| | Location:<br>DGD |



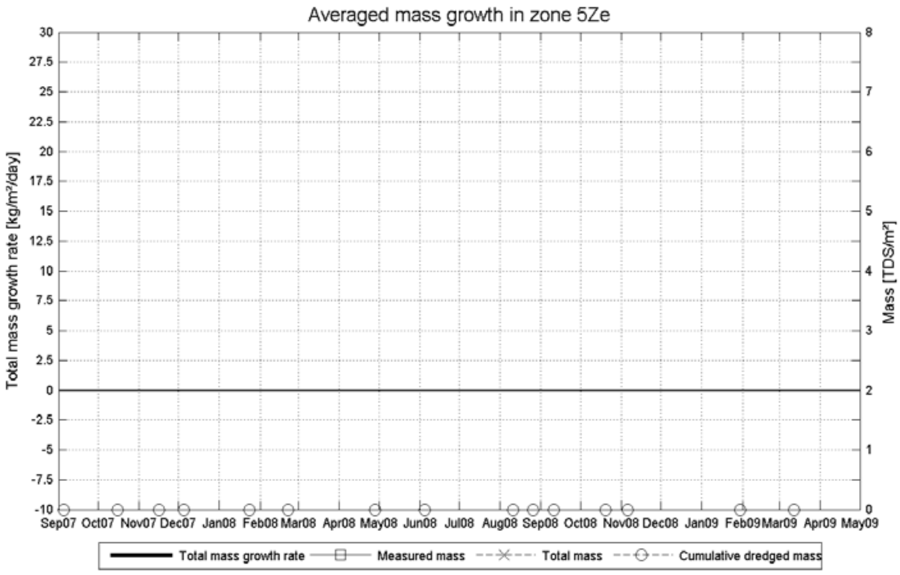




Data Processed by:
In association with :

I/RA/11283/08.080/MSA

Long-term monitoring siltation Deurganckdok

| | |
|---|---|
| Measured/Dredged/Total Mass | Equipment(s): NaviTracker (until 11/9/2008) and Densitune |
| | Location: DGD |

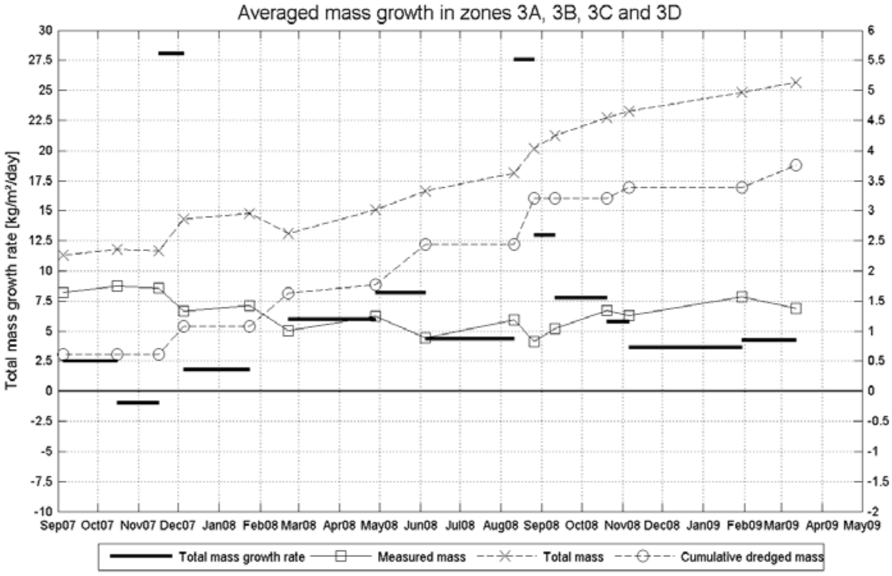



Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.080/MSA

## D.4 For complete Deurganckdok

## Long-term monitoring siltation Deurganckdok

| | |
|---|---|
| Measured/Dredged/Total Mass | Equipment(s): NaviTracker (until 11/9/2008) and Densitune |
| | Location: DGD |




Data Processed by: IMDC
In association with : WL | delft hydraulics
I/RA/11283/08.080/MSA

# APPENDIX E.

# DREDGING DATA

**Total dredged mass in covered area (TDS)**

| | 02-Apr-07 | 09-Apr-07 | 20-Aug-07 | 27-Aug-07 | 19-Nov-07 | 26-Nov-07 | 28-Jan-08 | 04-Feb-08 | 11-Feb-08 | 18-Feb-08 | 03-Mar-08 | 12-May-08 | 19-May-08 | 26-May-08 | 11-Aug-08 | 18-Aug-08 | 20-Oct-08 | 09-Feb-09 | 16-Feb-09 | 24-Feb-09 | 02-Mar-09 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **ZONE** | **07-Apr-07** | **14-Apr-07** | **25-Aug-07** | **31-Aug-07** | **24-Nov-07** | **30-Nov-07** | **03-Feb-08** | **10-Feb-08** | **17-Feb-08** | **24-Feb-08** | **09-Mar-08** | **18-May-08** | **25-May-08** | **01-Jun-08** | **17-Aug-08** | **24-Aug-08** | **26-Oct-08** | **15-Feb-09** | **23-Feb-09** | **01-Mar-09** | **02-Mar-09** | **Total (TDS)** | **%** |
| **1** | 0 | 0 | 141 | 28 | 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 39 | 0 | 0 | 28 | 0 | 0 | 0 | 264 | 0.0 |
| **2** | 57 | 23 | 1140 | 177 | 30 | 0 | 72 | 0 | 268 | 0 | 0 | 523 | 989 | 746 | 483 | 346 | 0 | 115 | 673 | 623 | 0 | 6264 | 0.3 |
| **3a** | 3111 | 23207 | 46059 | 27635 | 40406 | 43114 | 29277 | 24258 | 35827 | 4033 | 0 | 59931 | 36320 | 21332 | 59941 | 80335 | 0 | 7478 | 12311 | 35768 | 2122 | 592465 | 28.9 |
| **3b** | 7854 | 36043 | 28619 | 28630 | 45720 | 19857 | 24791 | 32056 | 22571 | 1099 | 0 | 34338 | 36401 | 25286 | 33300 | 77573 | 0 | 2268 | 9991 | 25328 | 1597 | 493322 | 24.1 |
| **3c** | 7213 | 16162 | 25493 | 21020 | 38674 | 11835 | 22477 | 17659 | 24994 | 959 | 20665 | 17708 | 25536 | 20847 | 11229 | 55195 | 25424 | 2341 | 7773 | 18303 | 1151 | 392657 | 19.2 |
| **3d** | 0 | 0 | 2 | 0 | 470 | 95 | 162 | 52 | 274 | 0 | 43945 | 946 | 5952 | 8877 | 3508 | 13759 | 53894 | 3608 | 12843 | 17634 | 779 | 166799 | 8.1 |
| **3e** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 541 | 0 | 0 | 0 | 283 | 499 | 1987 | 0 | 3311 | 0.2 |
| **4Na** | 25 | 435 | 8759 | 4198 | 5662 | 11322 | 4564 | 5226 | 3524 | 54 | 0 | 8337 | 4706 | 2455 | 11052 | 6768 | 0 | 5137 | 9582 | 1789 | 0 | 93596 | 4.6 |
| **4Nb** | 60 | 427 | 7704 | 3772 | 6984 | 6928 | 5206 | 4737 | 1838 | 0 | 0 | 5739 | 5745 | 5503 | 5866 | 2514 | 0 | 4629 | 12123 | 629 | 0 | 80405 | 3.9 |
| **4Nc** | 127 | 141 | 3396 | 2108 | 5861 | 3598 | 2659 | 3765 | 1440 | 27 | 2176 | 2594 | 2216 | 2962 | 1249 | 421 | 23 | 3763 | 7966 | 537 | 0 | 47030 | 2.3 |
| **4Nd** | 0 | 0 | 0 | 0 | 14 | 0 | 0 | 0 | 0 | 0 | 8042 | 39 | 157 | 1242 | 0 | 75 | 101 | 2700 | 6081 | 281 | 0 | 18733 | 0.9 |
| **4Ne** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 64 | 0 | 0 | 0 | 65 | 9 | 16 | 0 | 155 | 0.0 |
| **4Za** | 0 | 143 | 359 | 3 | 7480 | 3323 | 4483 | 1118 | 2008 | 13 | 0 | 7668 | 6137 | 1054 | 8679 | 1918 | 0 | 1930 | 6477 | 1438 | 0 | 54230 | 2.6 |
| **4Zb** | 0 | 69 | 14 | 61 | 12214 | 4116 | 5141 | 2847 | 646 | 0 | 0 | 5496 | 8591 | 887 | 5103 | 2083 | 0 | 3055 | 7731 | 749 | 0 | 58804 | 2.9 |
| **4Zc** | 0 | 0 | 0 | 28 | 4699 | 2040 | 1947 | 1525 | 445 | 0 | 2305 | 949 | 3290 | 239 | 487 | 803 | 1 | 2500 | 5327 | 217 | 0 | 26802 | 1.3 |
| **4Zd** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4048 | 302 | 230 | 15 | 13 | 0 | 27 | 1514 | 5288 | 217 | 0 | 11653 | 0.6 |
| **4Ze** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 56 | 22 | 15 | 0 | 94 | 0.0 |
| **5Na** | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0.0 |
| **5Nb** | 0 | 0 | 29 | 0 | 0 | 0 | 68 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 98 | 0.0 |
| **5Nc** | 0 | 0 | 19 | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 30 | 0.0 |
| **5Nd** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 26 | 0.0 |
| **5Ne** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |
| **5Za** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |
| **5Zb** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |
| **5Zc** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |
| **5Zd** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0.0 |
| **5Ze** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |
| **Total** | **18447** | **76649** | **121738** | **87660** | **168243** | **106227** | **100846** | **93251** | **93837** | **6185** | **81209** | **144573** | **136270** | **92053** | **140949** | **241789** | **79470** | **41468** | **104701** | **105533** | **5649** | **2046744** | |
| **%** | **0.9** | **3.7** | **5.9** | **4.3** | **8.2** | **5.2** | **4.9** | **4.6** | **4.6** | **0.3** | **4.0** | **7.1** | **6.7** | **4.5** | **6.9** | **11.8** | **3.9** | **2.0** | **5.1** | **5.2** | **0.3** | | |