REPORT

**Vlaamse overheid Departement Mobiliteit en Openbare werken**

Afdeling Maritieme Toegang

# Evaluation of the external effects on the siltation in Deurganckdok

Report 2.12: Calibration of mobile and stationary instruments on 16 march 2011

1st of June 2012 - version 2.0

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## Verdeellijst

| | | |
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| 5 | Analoog | AMT, Kirsten Beirinckx |
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# 0. SUMMARY

Stationary and mobile instruments were calibrated for turbidity, temperature and conductivity.

For turbidity, instruments were calibrated relative to a reference instrument, of which the relation between turbidity and SSC was determined precisely during the calibration campaign. Only low concentrations were found in the water column at various tidal phases during the incoming tide. The highest concentration sampled was 240 mg/l. RMSE values for the SSC calibration are acceptable (from 10 to 20 mg/l.

For instruments with a very high turbidity range (SiltProfiler and ASM IV) an in situ calibration is not recommended. It is very hard to find very high concentrations in a homogenous mixture in the Lower Sea Scheldt. Therefore, the siltprofiler and both ASM IV probes have been calibrated in labo conditions and been cross checked afterwards with the in-situ calibration.

The conductivity and the temperature cross-check is limited due to the small range of conductivities/temperatures that were measured. Conductivity of CTD-divers and RCM-9 instruments is accurate, but the conductivity sensors of OBS 3A instruments are showing higher variations and will therefoe not be used for salinity measurements during the project.

Temperature measurements show no large discrepancies between the different instruments, except for RCM 9 sn 1170.

# 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 a set of reports concerning the project 'Evaluation of the external effects on the siltation in Deurganckdok'. The terms of reference were prepared by 'Departement Mobiliteit en Openbare Werken van de Vlaamse Overheid, Afdeling Maritieme Toegang (16EF/2009/14). The study was awarded to International Marine and Dredging Consultants NV in association with Deltares and Gems International on 8 December 2009.

This study is a follow-up study on the study 'Opvolging aanslibbing Deurganckdok' that ran from January 2006 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 provided depth sounding and density profile measurements.

## 1.2 PURPOSE OF THE STUDY

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

- The construction of the Current Deflecting Wall downstream of the entrance of the Deurganckdok.
- The deepening and widening of the navigational channel in the Lower Sea Scheldt between the entrance of the Deurganckdok and the access channels to the locks of Zandvliet-Berendrecht.
- The deepening of the entrance to the Deurganckdok by removing the sill at the entrance.

## 1.3 OVERVIEW OF THE STUDY

This study constitutes of 3 parts:

- Reporting and analysis of existing documents and measurement data
- Execution of specific measurement campaigns to map the siltation and its environmental factors.
- Support in numerical modelling efforts

## 1.4 STRUCTURE OF THE REPORT

Reports of the project 'Evaluation of the external effects on the siltation in the Deurganckdok' are summarized in Table 1-1.

This report is one of a set of reports that gains insight in sediment and water transport between Deurganckdok and the river Scheldt, which belongs to the second part of this project. This report Describes the calibration measurement performed on 16/03/2011 near Deurganckdok. The goal is to calibrate all the stationary and mobile instruments that will be used in the course of this project.

*Table 1-1: Overview of the External Effects Deurganckdok Reports*

| Report | Description |
|---|---|
| **1.** | **Reporting** |
| **I.1 Annual Sediment Balance: Bathymetry surveys, Density measurements, Maintenance and construction dredging activities** | |
| 1.1 | Annual Sediment Balance: year 1: 1/4/2009-31/3/2010 (I/RA/11354/10.067/NZI) |
| 1.2 | Annual Sediment Balance: year 2: 1/4/2010-31/3/2011 (I/RA/11354/10.100/MBO/ANF) |
| 1.3 | Annual Sediment Balance: year 3: 1/4/2011-31/3/2012 (I/RA/11354/10.101/MBO/ANF) |
| **I.2 Boundary Conditions: Upriver Discharge, Salt concentration Scheldt, Bathymetric evolution in access channels, dredging activities in Lower Sea Scheldt and access channels** | |
| 1.4 | Boundary Conditions year 1: 01/04/2009 – 31/3/2010 (I/RA/11354/10.102/MBO/ANF) |
| 1.5 | Boundary Conditions year 2: 01/04/2010 – 31/3/2011 (I/RA/11354/10.103/MBO/ANF) |
| 1.6 | Boundary Conditions year 3: 01/04/2011 – 31/3/2012 (I/RA/11354/10.104/MBO/ANF) |
| **I.3 Synthesis of CDW research** | |
| 1.7 | Synthesis report of research on Current Deflecting Wall (I/RA/11354/10.063/MBO) |
| **I.4 Analysis: evaluation of external effects on siltation in Deurganckdok** | |
| 1.8 | Analysis of external effects on siltation processes and factors (I/RA/11354/10.105/MBO/ANF) |
| **2.** | **Measurement campaigns: Factors contributing to salt and sediment distribution in Deurganckdok: Salt-Silt (OBS3A) & Frame measurements, Through tide measurements (SiltProfiling & ADCP) & Calibrations** |
| **II.1 Through tide measurements fixed transects** | |
| 2.1 | Through tide Sediview measurement: Entrance DGD during spring tide Autumn 2011 (I/RA/11354/10.106/MBO/ANF) |
| 2.2 | Through tide Sediview measurement: Entrance DGD during neap tide Autumn 2011 (I/RA/11354/10.107/MBO/ANF) |
| 2.3 | Through tide Sediview measurement: Entrance DGD during spring tide Spring 2012 (I/RA/11354/10.108/MBO/ANF) |
| 2.4 | Through tide Sediview measurement: Entrance DGD during neap tide Spring 2012 (I/RA/11354/10.109/MBO/ANF) |
| **II.2 Through tide measurements eddy currents** | |
| 2.5[2] | Through tide measurements: Eddy Currents DGD 02/03/2010 (I/RA/11283/10.051/MSA) |
| 2.6 | Through tide measurements: Eddy Currents DGD Autumn I/RA/11354/10.110/MBO/ANF) |
| 2.7 | Through tide measurements: Eddy Currents DGD Spring 2012 (I/RA/11354/10.111/MBO/ANF) |
| **II.3 Salt Silt Distribution entrance Deurganckdok** | |
| 2.8[3] | Salt-Silt distribution Deurganckdok 1/4/2009-31/3/2010 (I/RA/11354/10.068/NZI) |
| 2.9 | Sal-Silt distribution Deurganckdok 1/6/2011-31/03/2012 (I/RA/11354/10.112/MBO/ANF) |
| **II.4 Current Salt Silt Distribution CDW Deurganckdok** | |
| 2.10 | Salt Silt & Current Distribution entrance Deurganckdok: frame measurements and throughtide measurements: Autumn 2011 (I/RA/11354/11.131/BQU) |
| 2.11 | Salt Silt & Current Distribution entrance Deurganckdok: frame measurements and throughtide measurements: Spring 2012 (I/RA/11354/10.114/MBO/ANF) |
| **II.5 Quality Control instruments** | |
| 2.12 | Calibration stationary & mobile equipment 16/03/2011 (I/RA/11354/10.113/MBO/ANF) |
| 2.13 | Calibration stationary equipment 2012 (I/RA/11354/12.011/JCA) |

[2]: this report is part of the project Siltation Deurganckdok (11283)

[3]: this report contains report 2.35 of project Siltation Deurganckdok (I/RA/11283/09.085/MSA)

# 2. SEDIMENTATION IN DEURGANCKDOK

## 2.1 PROJECT AREA: DEURGANCKDOK

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

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

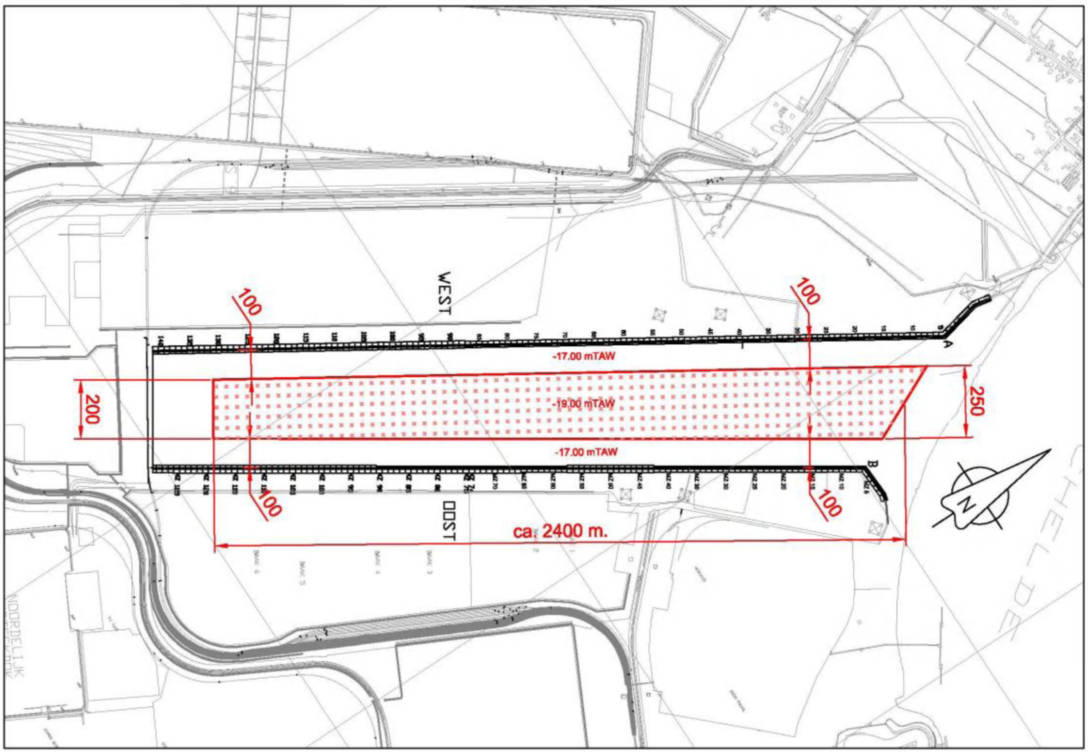



*Figure 2-1: Overview of Deurganckdok*

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 2-1).

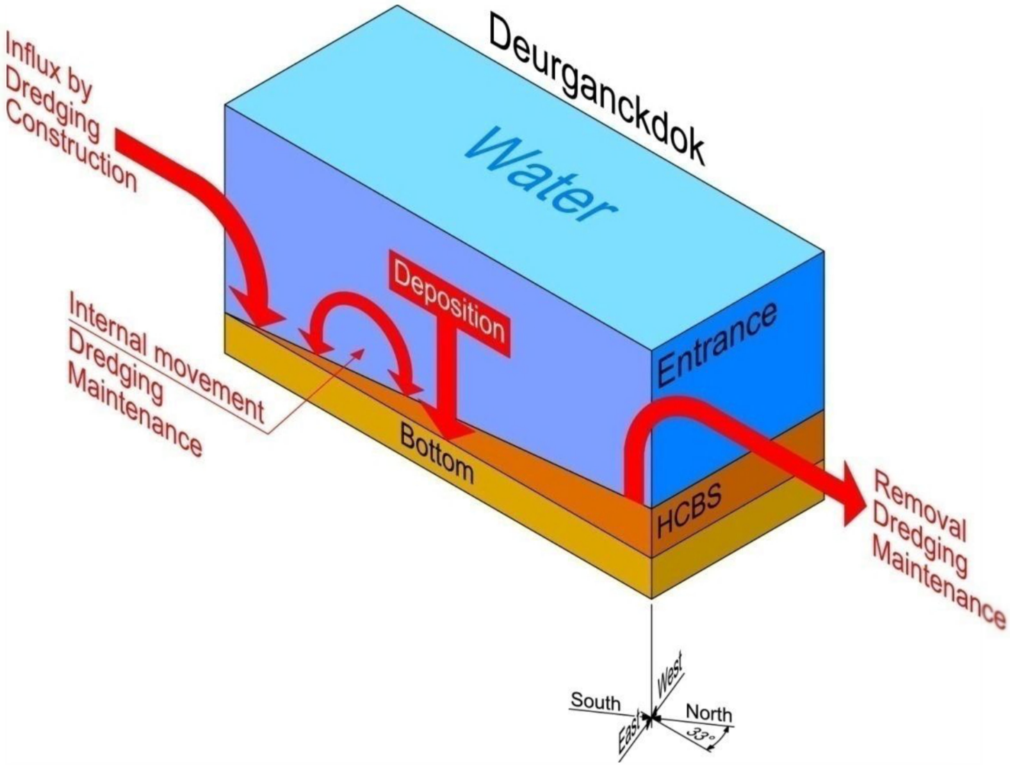



*Figure 2-2: Elements of the sediment balance*

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 river Scheldt since $t_0$.

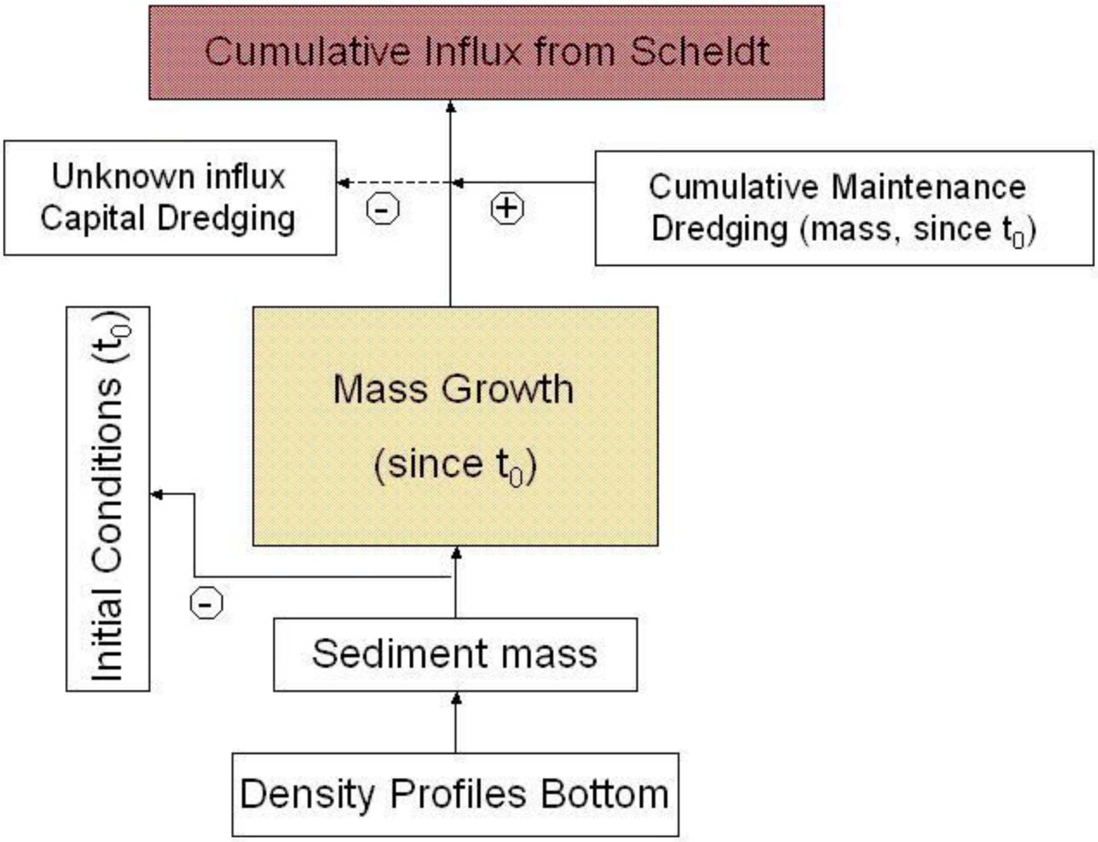



*Figure 2-3: Determining a sediment balance*

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 salinity gradient between the Scheldt river and the dock
Density currents due to highly concentrated benthic suspensions

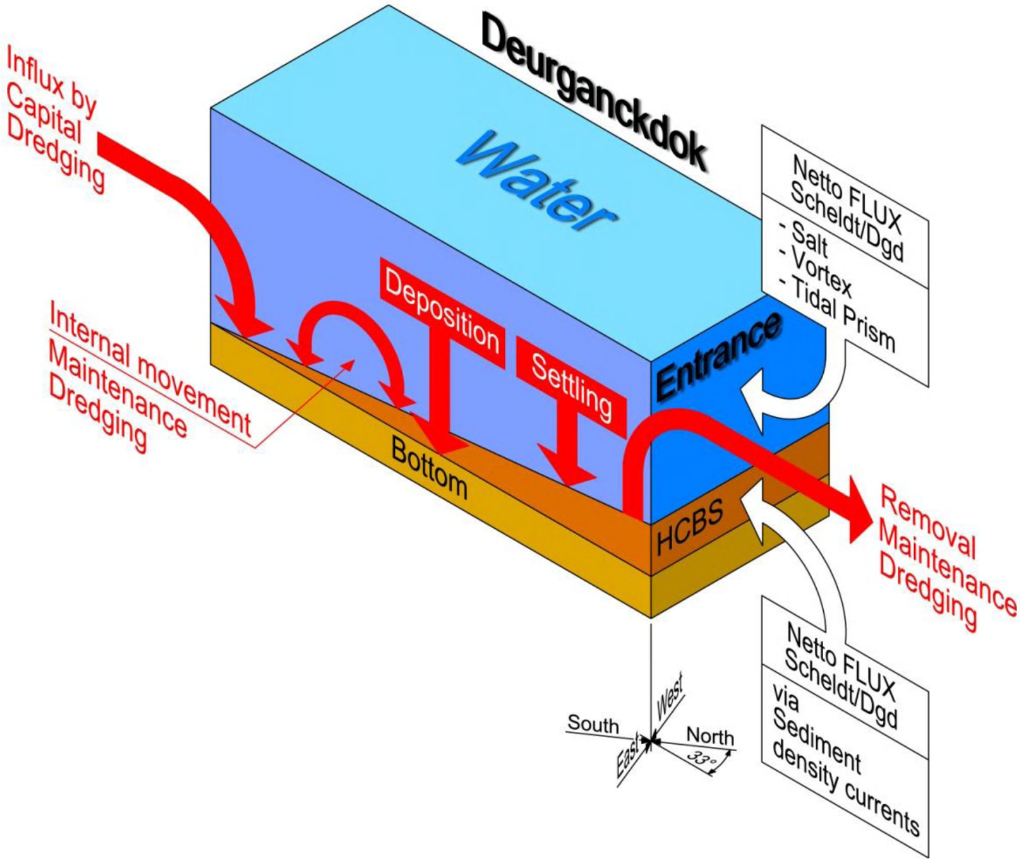



*Figure 2-4: Transport mechanisms*

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

Following data are being collected to understand these mechanisms:

- Monitoring upstream discharge in the river Scheldt.
- Monitoring Salinity and sediment concentration in the Lower Sea Scheldt at permanent measurement locations at Oosterweel, up- and downstream of the Deurganckdok.
- Long term measurement of salinity 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, salinity 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. THE MEASUREMENT CAMPAIGN

## 3.1 CALIBRATION STRATEGY

### 3.1.1 Suspended Sediment Concentration

A calibration strategy for the Siltation Study in Deurganckdok for the measurement of Suspended Sediment Concentration (SSC) and Salinity was set up.

Table 3-1 gives an overview of all the instruments used for measurement of SSC in long term and through tide measurement campaigns.

*Table 3-1: Overview of instruments measuring SS concentration*

| ***Instrument*** | ***Quantity*** | ***Principle*** | ***Long term (LT) /Through Tide (TT)*** |
|---|---|---|---|
| D&A Instruments OBS 3A* | 7 | Turbidity Backscatter Sensor | TT / LT |
| Siltprofiler* (Extinction Sensors) | 2 | Turbidity Extinction sensor | TT |
| SiltProfiler* (Seapoint Sensor) | 1 | Turbidity Backscatter Sensor | TT |
| Aanderaa RCM-9* (0-500 NTU ) | 2 | Turbidity Backscatter Sensor | LT |
| Aanderaa RCM-9* (Seapoint sensor ) | 1 | Turbidity Backscatter Sensor | LT |
| Argus ASM IV | 2 | Turbidity Backscatter Sensor | LT |

**These instruments also contain conductivity sensors*

This overview shows that all instruments measure turbidity. Therefore these instruments had to be calibrated to link turbidity to SSC.

This can be done in 2 ways:

- Laboratory calibration
- In situ calibration

Both methods have advantages and disadvantages. In a laboratory all conditions (concentration, circulation, siltation) are controllable but not identical to the situation in the field. An in situ calibration is more representative of the actual measurement conditions but less controllable. Lab calibrations almost guarantee to cover the whole measurement range of the instrument (very low to very high SSC), which is more difficult to guarantee during field calibrations.

In situ conditions allow all instruments to be calibrated simultaneously and in the same calibration mixture. This is almost unachievable in a laboratory condition.

A good knowledge of the study area can enhance the measurement range that could be attained in an in situ calibration. Knowing where and when certain concentrations are occurring is vital in order to cover a wide range of concentrations. For this reason a preliminary SSC survey was foreseen in Deurganckdok.

### 3.1.2 Salinity

Salinity is not measured directly but calculated using a UNESCO formula that incorporates conductivity, temperature and depth measurements (Unesco, 1991, see Annex A). All sensors, which measure conductivity and temperature, have also been cross-checked with each other. This means that simultaneous measurements of conductivity and temperature are compared in brackish Scheldt water during the calibration.

## 3.2 CALIBRATION SET UP

### 3.2.1 Frame set-up

A special frame was used to calibrate all stationary and mobile equipment. A rectangular frame, measuring 2 meters by 1 meter, is covered with a wire mesh. In the middle there is a vertical mesh wire wall that divides the frame in 2 parts (2*0.5m), which was used to line up all turbidity sensors to measure at the same vertical level on the frame. All the turbidity sensors were aligned to measure in a horizontal orientation. To avoid interference between backscatter turbidity sensors, a minimum distance between sensors of the same type was respected.

*Figure 3-1: Calibration frame with pump set-up*

A pump has been used to calibrate the turbidity sensors. The pump discharge velocity has been tested in advance with dye (coffee powder).

*Table 3-2: Set up for calibration on 16/03/2011*

| ***Calibration day 16/03/2011*** |
|---|
| 1 ADCP |
| 2 Argus |
| 5 CTD-divers |
| 7 OBS 3A |
| 1 RBR |
| 4 RCM-9 |
| 1 SiltProfiler (IMDC) |
| 1 pump |

### 3.2.2 Measurement locations

Previous measurement campaigns in the Lower Sea Scheldt demonstrate what concentration ranges can be expected at certain locations, depths and tidal phases. It was decided to measure during incoming tide and at places with high gradients in suspended sediment concentrations between Deurganckdok (downstream) and Liefkenshoek (upstream).

### 3.2.3 Calibration protocol

The aim was to calibrate the turbidity sensors at 8 predetermined SS concentrations.

25 – 50 – 100 - 200 – 400 – 800 – 1200 – 1600 mg/l.

During the survey one instrument which has already been used in previous surveys and recently been sent to the manufacture for inspection, was chosen as reference instrument. This instrument was connected with an external data cable and as such had real time read-out facilities, so that the frame could be positioned in the appropriate SSC environment as mentioned above. One OBS 3A was used for this purpose.

When the instruments are positioned in the layer with the required SSC, 1 liter water samples were taken from a pump sampler for laboratory analysis. This procedure was carried out twice for each concentration.

All the remaining turbidity sensors are mounted at the same height as the reference turbidity sensor and the inlet of the pump bowel.

The reference sensor will be calibrated from NTU to mg/l by defining a linear relationship between the measured NTU values and the collected watersamples.

All the remaining turbidity sensors will be crosscalibrated from NTU to reference NTU by defining a linear relationship between the measured NTU values of each sensor and the measured NTU values of the reference sensor. These calculated reference NTU values can then be converted to mg/l by using the first obtained calibration curve of the reference sensor.

The advantages of this method are:

- No error due to no exact time match between low frequency sensor records and time of watersampling
- Much more points are available to establish calibration equation
- The relative error between different sensors is minimal

- The absolute error is based on the quality of the calibration of the reference sensor, these calibration can be expected to be more accurate since now only one sensor has to be monitored closely.

### 3.2.4 Sample analysis

The NEN 6484 standard for total suspended sediment analysis was used for all water samples.

### 3.2.5 Validation, Drifting and extra Sensors

It has to be mentioned that the SiltProfiler has been calibrated in a laboratory set up by the manufacturer using wet mud of the measurement location (Lower Sea Scheldt). The calibration mixtures were analysed using the NEN 6484 standard.

The SiltProfiler has a high concentration range and is difficult to calibrate in situ, therefore this instruments was not be calibrated as such, but was only be validated by the calibration procedure described above.

Long term measuring equipment (i.e. RCM-9; OBS 3A) will be tested for drifting by IMDC at each redeployment, by performing a zeroing measurement in clean tap water.

## 3.3 INSTRUMENTS

### 3.3.1 D & A OBS 3A

D&A Instruments type OBS-3A were calibrated. Measured parameters by the OBS 3A sensor:

- temperature (°C),
- conductivity (µS/cm)
- turbidity (counts/FTU)
- absolute depth (m)

IMDC (2006a) gives more technical details on the OBS 3A sensors.

### 3.3.2 SiltProfiler

For the HCBS measurements on the river Scheldt a new instrument has been developed, the SiltProfiler.

The SiltProfiler has the following general specifications. The data collection is executed locally (i.e. on the profiler) by an integrated data logger. Sensor cables are kept very short and connect to the interfacing electronics of the data logger. The data logger collects the sensor signals and records the same in internal memory. Simultaneously the data are transmitted via a serial communication cable (if connected). Emphasis is on fast data collection and less on the absolute accuracy of the sensors.

In case the communication cable is not connected, the data can be retrieved upon recovery of the profiler via a short range wireless connection. As soon as the profiler breaks the water surface the data can be accessed and transferred to the operator's PC, whereupon the profiler is ready for a new profiling session. The retrieved profile data are visualised immediately in depth profile graphs. This operational mode requires no electrical cables to be attached to the profiler. However, a small box (diameter in the order of 20 cm) with electronics, data logger and batteries is attached to the profiler. The hoisting cable is attached to sturdy structure above the electronics box.

*Figure 3-2: High Resolution SiltProfiler*

The sensors are:

- 1 Conductivity and Temperature sensor with measuring ranges adequate for use in seawater.
- multiple turbidity sensors to cover the entire range of 0 to 35 000 mg/L suspended solids: 2 transmittance sensors (type FOSLIM) are used, in combination with a Seapoint turbidity sensor (0-400 mg/l).
- 1 pressure sensor.

As such the SiltProfiler is anticipated to rapidly profile the suspended sediment concentration as well as the salinity structure. The SiltProfiler can measure at variable speed up to 100 measurements per second (100 Hz).

The data collection rate is adjustable to optimise for the required vertical / temporal resolution. Further, the data acquisition rate will be depth dependent in such a way that the rate is low in the upper section of the profile and higher in de lower section. Both rates and the changeover depth are user adjustable. The duration of data retrieval depends upon the amount of collected data and the effective data transfer rate.

### 3.3.3 Aanderaa RCM-9

The Aanderaa Recording Current Meter RCM-9 MkII is a multi-parameter instrument that consists of a CTD probe, Doppler Current Sensors and a Turbidity Sensor. This instrument is used in a moored set up for long term measurements in this project. IMDC (2006a) gives more details on the RCM-9. The 4 Instruments are from IMDC. The RCM 9 with serial number 1225 (IMDC) is equipped with an additional seapoint sensor (0-750 NTU).

### 3.3.4 CTD-Diver datalogger

CTD-Diver dataloggers were used.

Measured parameters by the CTD-Diver datalogger are:

- temperature (°C),
- conductivity (µS/cm)

- absolute depth (m)

IMDC (2008a) gives more details on the CTD-Diver datalogger.

### 3.3.5 Argus ASM IV

Argus ASM IV probes were used.

Measured parameters by the CTD-Diver datalogger are:

- temperature (°C),
- 96 turbidity sensors (mg/l)
- absolute depth (m)

IMDC (2008a) gives more details on the ASM IV Argus.

### 3.3.6 Pump Sampler

A water sampler was attached nearby the turbidity sensor taking water samples. Samples were collected in 1 litre sampling bottles. The pumping speed of the water sampler was tested at the start of the measurement campaign on board. Dye was used to time the duration between the intake of the dye and exit at the sampling end of the sampler on board.

# 4. COURSE OF THE MEASUREMENTS

## 4.1 HYDROMETEOROLOGICAL CONDITIONS

Measurements were conducted during flood. The vertical tide is given for the tidal gauge at Prosperpolder (see Table 4-1).

*Table 4-1: High and Low Tide at Prosperpolder Tidal Gauge on 16/03/2011*

| ProsperpolderTidal Gauge | | |
|---|---|---|
| | 16 March 2011 | |
| | Time [MET] | Water level [m TAW] |
| HW (1) | 23:58 | 4.42 |
| LW (2) | 6:32 | 0.32 |
| HW (3) | 12:34 | 4.79 |
| LW (4) | 19:03 | 0.34 |

Meteorological data at Stabroek was obtained from the Weather Underground website (Wunderground, 2011). Information of the Royal Meteorological Institute is not yet available.

On the 16$^{th}$ of March, the air temperature varied between 6 and 12 °C. The wind blew at an average velocity of 30 km/h from NE. There was no rain.

## 4.2 LOCATIONS

The location where the calibration was performed is situated near de current deflecting wall at the entrance of Deurganckdok (see Figure 4-1).

*Table 4-2: Coordinates Calibration locations [UTM ED50]*

| Name | EASTING | NORTHING |
|---|---|---|
| Deurganckdok Entrance | 588672 | 5684623 |

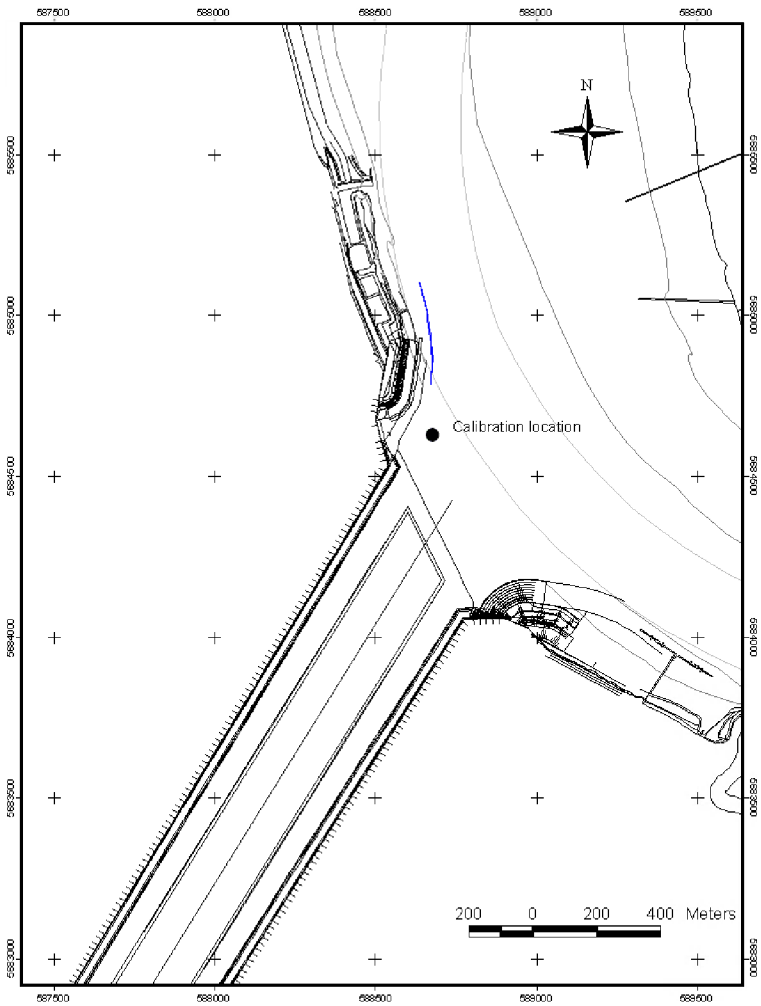



*Figure 4-1: Calibration Location*

## 4.3 MEASURED CONCENTRATIONS

Direct read out of one of the instruments allowed to aim for the predetermined concentrations (see § 3.2.3).

The following concentration ranges were obtained:

30 – 40 – 60 – 100 - 150 – 200 – 250 mg/l.

# 5. PROCESSING OF DATASETS

## 5.1 INTRODUCTION

The SSC calibration results are given in the next paragraph (§5.2). Paragraph 5.3 covers SiltProfiler calibration checks. Conductivity and temperature comparisons are made in §5.4.

## 5.2 SSC CALIBRATION RESULTS

### 5.2.1 IMDC instruments

OBS3A sn 307 turbidity sensor has been selected as reference instrument on 16th March, because this instrument was recently been checked by manufacturer and showed reliable turbidity values. This sensor was logged by direct reading at a high frequency (2 measurements/sec). The calibration curve for this reference sensor from NTU to mg/l has been derived from the collected watersamples and is presented in Figure 5-1.

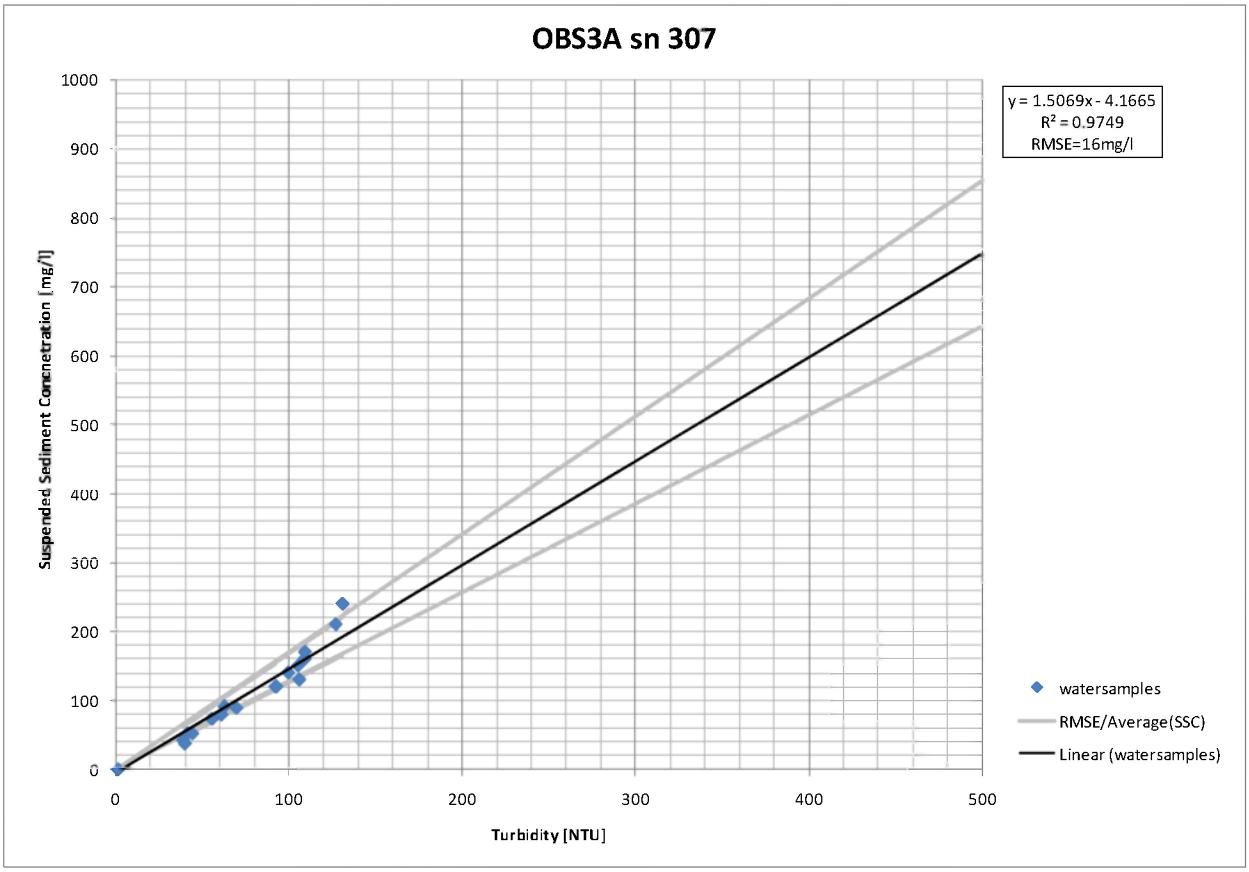



*Figure 5-1: Calibration of reference turbidity sensor*

The RMSE (root mean square error) has been calculated for low turbidity values (0-100 NTU), high turbidity values (> 100 NTU) and for all the points. These RMSE values are presented in Table 5-1. To estimate the error on the estimation of SSC the total RMSE is divided by the total averaged sampled SSC which results in 14%. This calculated error is also illustrated in Figure 5-1 and will increase when the estimated SSC values are higher than 240 mg/l.

*Table 5-1 RMSE values calculated from the calibration curve for the reference turbidity sensor*

| class | RMSE (mg/l) | Average SSC (mg/l) |
|---|---|---|
| 0-100 NTU | 11 | 81 |
| >100 NTU | 22 | 173 |
| Total | 16 | 116 |

For OBS3A and RCM 9 turbidity sensors, raw FTU/NTU values are cross calibrated to reference NTU. For Argus turbidity sensors, raw mg/l values can only be extracted from the instruments. These raw values are based on a calibration performed by the manufacturer in a tank with sediment scraped from the bottom in Kallo. These raw mg/l values are cross calibrated with the mg/l values of the reference instrument.

The calibration results for all sensors are given in Table 5-2. In this table the conversion formulas are given to convert turbidity counts, NTU, FTU to reference NTU. The R square value and the RMSE is added as well.

The calibration graphs show the reference NTU values on the Y-axis and the instrument readout in AD counts, or Turbidity Units (NTU/FTU) on the X-axis. These graphs can be found in Annex B.

The final calibration equations, which convert the raw value (FTU/NTU/raw mg/l) to mg/l are given in Table 5-3.

*Table 5-2: Overview of Calibration Results to reference instrument for 16/03/2011 including instrument description, formulas, R² and RMSE values and remarks*

| Instrument | Serial no. | Range | Unit | Function | R² | RMSE | Unit RMSE | Remarks |
|---|---|---|---|---|---|---|---|---|
| OBS3A | 221 | 0-500 | FTU to FTU reference | y = 1.19x | $R^2 = 0.91$ | 18 | FTU | IMDC |
| OBS3A | 222 | 0-500 | FTU to FTU reference | y = 1.11x | $R^2 = 0.87$ | 11 | FTU | IMDC |
| OBS3A | 223 | 0-500 | FTU to FTU reference | y = 1.17x | $R^2 = 0.88$ | 17 | FTU | IMDC |
| OBS3A | 224 | 0-2000 | FTU to FTU reference | y = 1.05x | $R^2 = 0.85$ | 10 | FTU | IMDC |
| OBS3A | 225 | 0-2000 | FTU to FTU reference | y = 1.02x | $R^2 = 0.87$ | 9 | FTU | IMDC |
| OBS3A | 261 | 0-500 | FTU to FTU reference | y = 1.23x | $R^2 = 0.86$ | 20 | FTU | IMDC |
| OBS3A | 307 | 0-2000 | FTU to mg/l | y = 1.51x-4.17 | $R^2 = 0.97$ | 49 | mg/l | IMDC |
| RCM-9 | 1165_1025 | 0-500 | NTU to FTU reference | y = 1.22x-10.41 | $R^2 = 0.87$ | 14 | FTU | IMDC |
| RCM-9 | 1170_1126 | 0-100 | NTU to FTU reference | y = 1.06 | $R^2 = 0.85$ | 11 | FTU | IMDC |
| RCM-9 | 1170_1051 | 0-500 | NTU to FTU reference | y = 1.10x | $R^2 = 0.88$ | 13 | FTU | IMDC |
| RCM-9 | 1225_11619 | 0-500 | NTU to FTU reference | y = 0.65x | $R^2 = 0.92$ | 49 | FTU | IMDC |
| Argus | 061 | 0-10000 | mg/l to mg/l reference | y = 0.82x | $R^2 = 0.82$ | 66 | mg/l | IMDC |
| Argus | 079 | 0-5000 | mg/l to mg/l reference | y = 0.70x | $R^2 = 0.70$ | 24 | mg/l | IMDC |
| SiltProfiler | Seapoint | 0-700 | mg/l | | comparison calibrated concentrations | | | |
| | Long Range | 400-5000 | mg/l | | comparison calibrated concentrations | | | |
| | Short Range | 4500 – 38300 | mg/l | | comparison calibrated concentrations | | | |

*Table 5-3: Overview of Calibration Results to mg/l for 16/03/2011 including instrument description and formulas*

| Instrument | Serial no. | Range | Unit | Function |
|---|---|---|---|---|
| OBS3A | 221 | 0-500 | FTU to mg/l | y = 1.78x-4.17 |
| OBS3A | 222 | 0-500 | FTU to mg/l | y = 1.62x-4.17 |
| OBS3A | 223 | 0-500 | FTU to mg/l | y = 1.77x-4.17 |
| OBS3A | 224 | 0-2000 | FTU to mg/l | y = 1.58x-4.17 |
| OBS3A | 225 | 0-2000 | FTU to mg/l | y = 1.54x-4.17 |
| OBS3A | 261 | 0-500 | FTU to mg/l | y = 1.85x-4.17 |
| OBS3A | 307 | 0-2 000 | FTU to mg/l | y = 1.51x-4.17 |
| RCM-9 | 1165_1025 | 0-500 | FTU to mg/l | y = 2.20x-19.85 |
| RCM-9 | 1170_1126 | 0-100 | FTU to mg/l | y = 1.84x-4.17 |
| RCM-9 | 1170_1051 | 0-500 | FTU to mg/l | y = 1.59x-4.17 |
| RCM-9 | 1225_11619 | 0-500 | FTU to mg/l | y = 0.99x-4.17 |
| Argus | 61 | 0-10 000 | mg/l to mg/l | y = 1.06x-4.17 |
| Argus | 79 | 0-5 000 | mg/l to mg/l | y = 1.38x-4.17 |

### 5.2.2 Instruments of Waterbouwkundig Laboratorium

In this project long term measurements of Waterbouwkundig Laboratorium (WL) are processed by IMDC and reported in the Boundary conditions reports. The turbidity sensors of these instruments are calibrated by Hydrologisch InformatieCentrum of WL and the calibration results are given in Table 5-4 and Annex B. The same type of instrument which are used on a specific measurement location are combined to get one conversion formula for this specific location and instrument type.

*Table 5-4: Overview of Calibration Results of the Hydrologisch InformatieCentrum (Vlaanderen - WL) instruments including instrument description and formulas.*

| Instrument | Serial no. | Range | Unit | Location | Function |
|---|---|---|---|---|---|
| RCM-9 | 248 | 0-500 | NTU to mg/l | Boei 84 | $y=0.0052x^2+1.98x$ |
| Seaguard | 65 and 173 | 0-500 | FTU to mg/l | Boei 84 | $y=0.0014x^2+0.96x$ |
| RCM-9 | 152 and 173 | 0-500 | NTU to mg/l | Oosterweel | $y=0.0021x^2+1.86x$ |
| Seauguard | 65, 171 and 152 | 0-500 | FTU to mg/l | Oosterweel | $y=0.0002x^2+1.11x+24.98$ |

## 5.3 MANUFACTURER'S CALIBRATION & CROSS-CHECK OF SILTPROFILER

### 5.3.1 Manufacturer's calibration of Silt Profiler

The manufacturer's calibration was done at Deltares at 15/12/2011 following a procedure set forward by IMDC. This procedure is set up as follows: The sediment was sieved with a 63 µm filter. The filtrate was desalinated, and was allowed to settle and to evaporate. The resulting mud was used as base material. It was analysed for dry content, which resulted in a ratio of 0.43800 grams of dry material per gram base material.

The calibration was done in a 5 L solution of DEMI (demineralised) water in which the base material was dissolved and kept in suspension. This was done for increasing concentrations. From every calibration mixture a sample was taken to be analysed for suspended sediment concentration. Samples were filtered over a preweighed desiccated 0.45 micron filter, after which the filter is dried in an oven at 105°C, cooled and weighed (NEN 6484).

This approach was chosen for its close resemblance to an in situ calibration. Manipulation of the basis material was limited.

The calibration graphs can be found in Annex B..

*Table 5-5: Calibration Equations as derived for both Seapoint and SiltProfiler sensors (low and high range), x=AD counts, y=sample suspended sediment concentration*

| ***Instrument*** | ***Equation*** | $R^2$ |
|---|---|---|
| **Siltprofiler – Seapoint** | $Y= 0.00001x^2+ 0.6987x+0.919$ | 0.999 |
| **SiltProfiler – Low range – long (50mm)** | $Y = 0.000307x^2 + 0.2194 x – 159.318$ | 0.999 |
| **SiltProfiler – High range – short (10mm)** | $Y=0.002501x^2 + 3.7597x – 133.110$ | 0.999 |

### 5.3.2 Cross-check of SiltProfiler

The Siltprofiler was cross-checked during the in situ calibration, by performing a profile simultaneously with both the Siltprofiler and the reference instrument. Figure 5-2 shows the results of both profiles while Figure 5-3 shows the comparison of the Siltprofiler SSC (determined by the manufacturer's calibration) with the reference instrument SSC. The X-axis shows the sample SSC, the Y-axis shows the depth.

Turbidity values were converted to suspended sediment concentration using the equation of the calibration curve determined at the pre-calibration done by Deltares. These were compared to sample concentrations. Only Seapoint measurements were used, because of the low concentrations. The results of both instruments are almost identical and is an argument for the accuracy of both calibration methods.

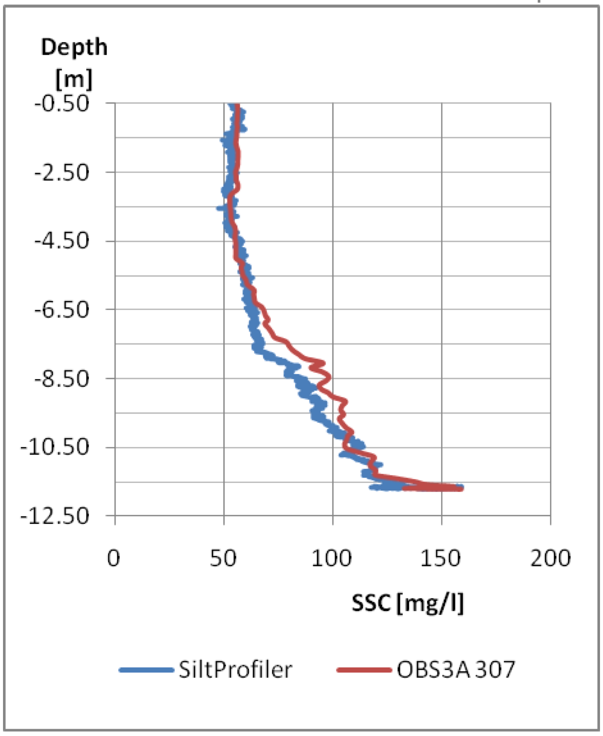



*Figure 5-2 Comparison between profile of Reference OBS3A SSC to SiltProfiler SSC for 16 March 2011*

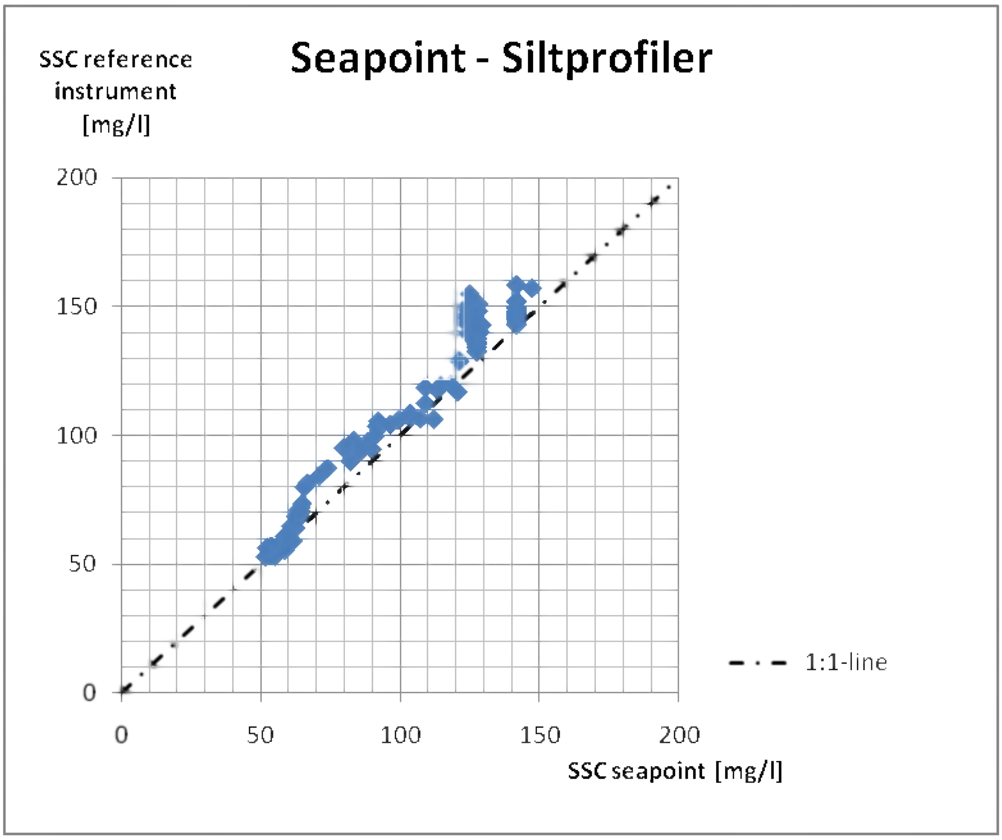



*Figure 5-3:Comparison of Reference OBS3A SSC to SiltProfiler SSC for 16 March 2011*

# 5.4 CONDUCTIVITY AND TEMPERATURE CROSS-CHECK

Conductivity and temperature measurements were conducted during this measurement campaign, however it was not possible to obtain a wide range of conductivity/salinity levels in the area that was frequented for the calibration. A limited analysis will include a comparison of simultaneous conductivity and temperature measurements by the different instruments that were mounted on the frame.

The CTD Diver Z060 sensor with serial number 308 was chosen as a reference.

During analysis of the data, it appeared the conductivity measurements of the SiltProfiler were erroneous. Cross calibrating the measurements was also impossible. Usually a CTD – Diver is installed on the SiltProfiler during measurements, so conductivity values can be obtained this way.

## 5.4.1 Conductivity

Figure 5-4 shows the conductivity read out of all CTD diver instruments deployed at the same level on the measurement frame. All these conductivity sensors measure similar conductivity values, except for Diver Z259, which measures slightly higher values. The conductivity sensor of CTD Diver Z060 has chosen as reference sensor.

Figure 5-5 shows the conductivity read out of the RCM-9 instruments and the OBS3A instruments deployed at the same level on the measurement frame. OBS 3A sn 225 & 307 were not equipped with a conductivity sensor. All the other instruments measure similar conductivity values, except for OBS3a sn 223. In general, OBS 3A conductivity sensors are more sensitive to pollution, therefore, conductivity measurements will always be performed with CTD Divers and RCM 9 sensors. The RSME values of these 2 types of sensors vary between 0.05 and 0.19, which is acceptable.

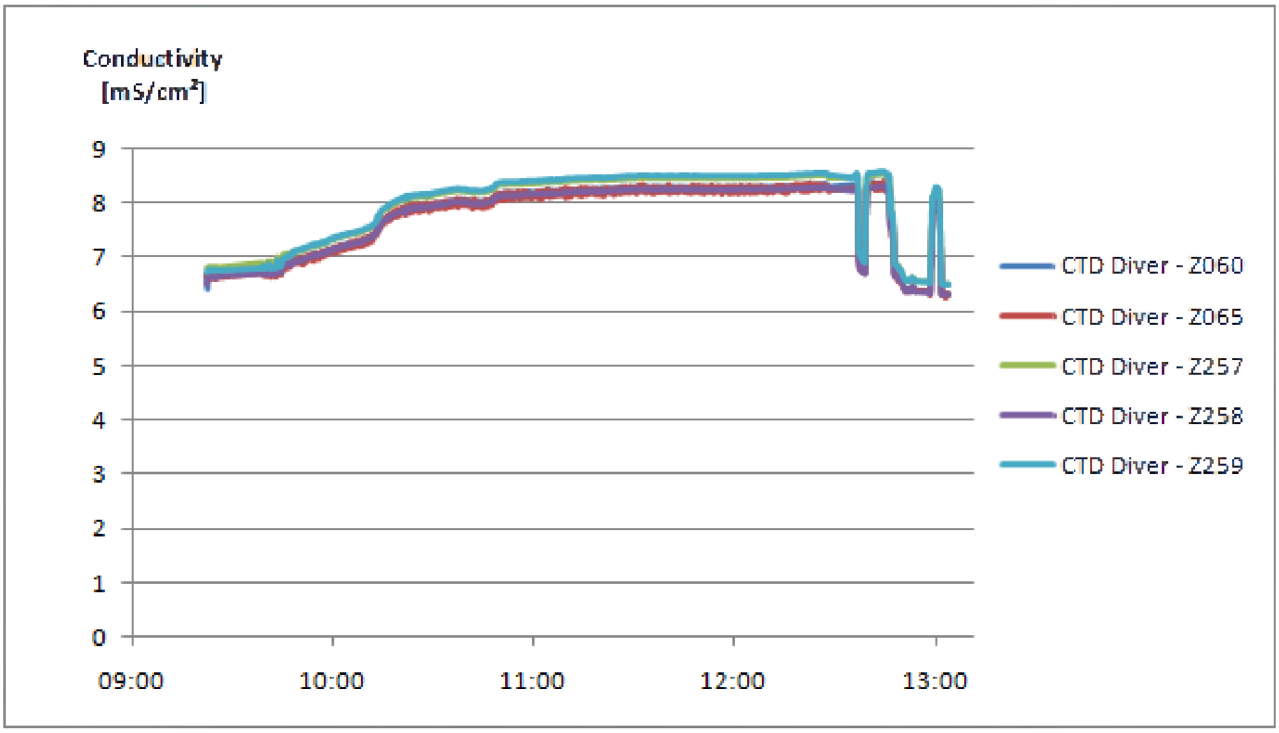



*Figure 5-4: CTD diver conductivity measurements 16/03/2011*

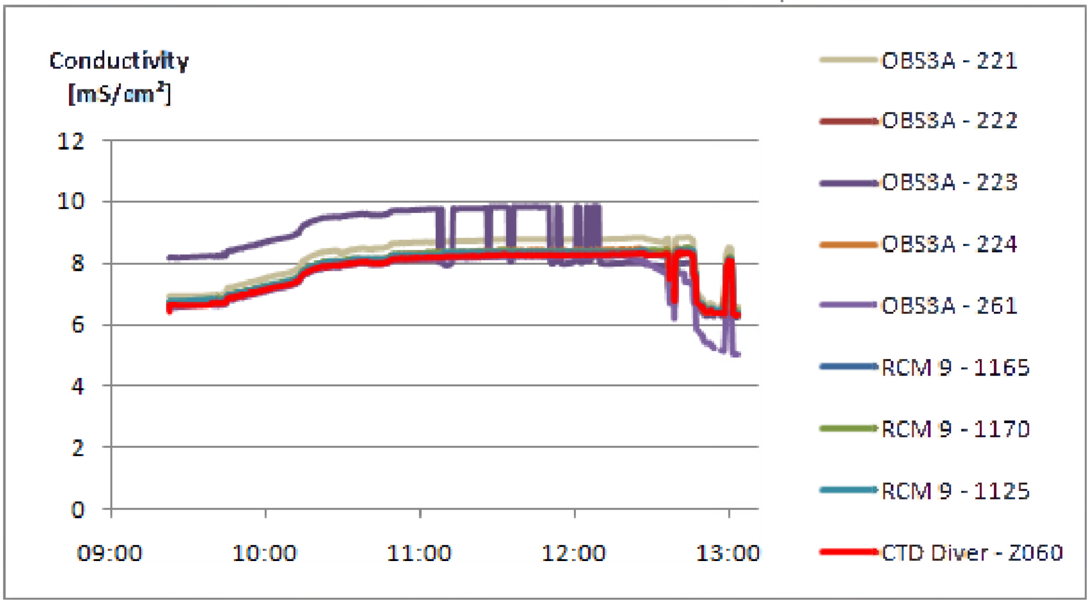



*Figure 5-5: OBS 3A, RCM 9 and Reference CTD diver conductivity measurements 16/03/2011*

The Root Mean Square Error (RMSE) was calculated for each correctly working instrument. The RMSE was calculated for each instrument comparing its measurement to the reference conductivity measurement (CTD diver Z060). (see Table 5-6).

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(X_i - \overline{X})^2}$$ in which

$X_i$ = measured conductivity value for a given instrument

$\overline{X}$ = CTD diver Z060 conductivity value for each measurement

n = number of measurements

*Table 5-6: RMSE values [mS/cm] for Conductivity sensors*

| ***Instrument*** | ***RMSE*** | ***Instrument*** | ***RMSE*** |
|---|---|---|---|
| CTD diver Z060 | 0.00 | OBS3A sn 223 | 1.26 |
| CTD diver Z065 | 0.05 | OBS3A sn 222 | 0.08 |
| CTD diver Z257 | 0.15 | OBS3A sn 221 | 0.43 |
| CTD diver Z258 | 0.03 | RCM 9 sn 1165 | 0.10 |
| CTD diver Z259 | 0.19 | RCM 9 sn 1170 | 0.12 |
| OBS3A sn 261 | 0.40 | RCM 9 sn 1225 | 0.12 |
| OBS3A sn 224 | 0.09 | | |

### 5.4.2 Temperature

Temperature measurements were compared as well. Figure 5-6 and Figure 5-7 show the temperature measurements of the OBS 3A, the RCM-9 and the CTD-Diver instruments. The RCM 9 sensor sn 1170 doesn't measure correct temperature. This sensor will be removed from the RCM9 platform and as such rejected from further measurements. The other temperature sensors are showing a spread of 0.14°C up to 0.37 °C, which is acceptable. All measurements follow the same trend. RMSE values are given in Table 5-7 and are calculated with reference to the CTD diver sn Z060 temperature sensor.

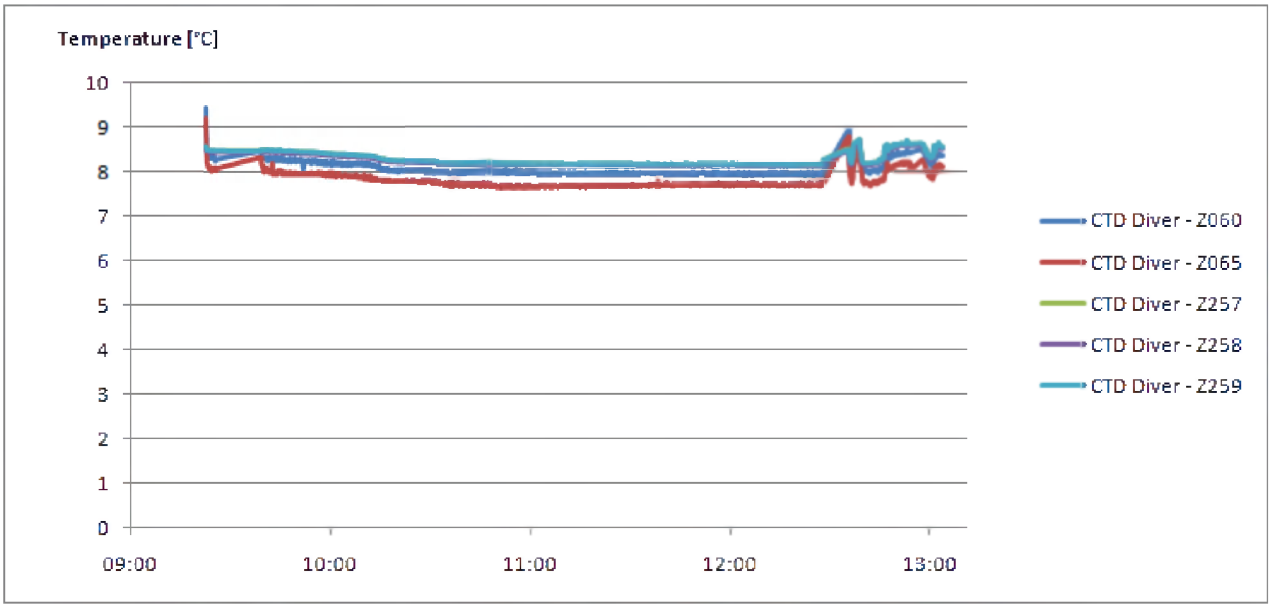



*Figure 5-6: CTD Diver temperature measurements 16/03/2011*

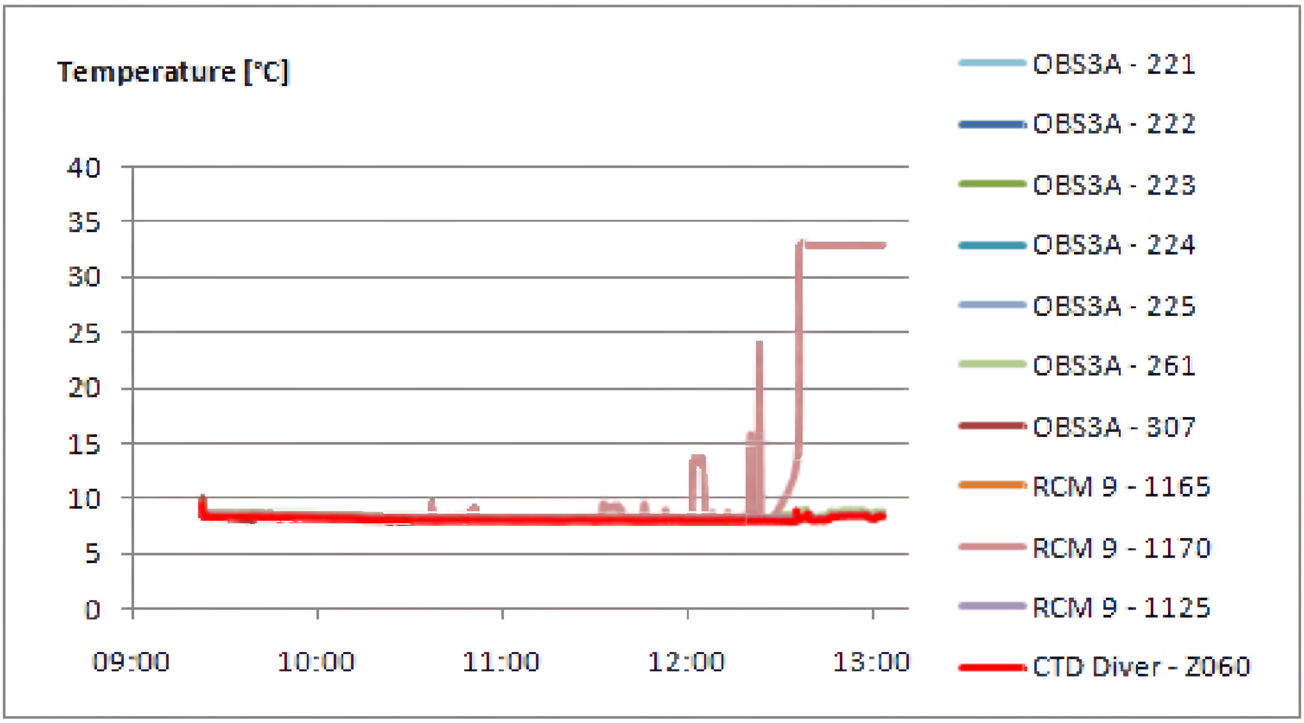



*Figure 5-7: OBS 3A, RCM 9 and Reference CTD diver temperature measurements 16/03/2011*

*Table 5-7: RMSE values [°C] temperature sensors*

| Instrument | RMSE | Instrument | RMSE |
|---|---|---|---|
| CTD diver Z060 | 0.00 | OBS3A sn 224 | 0.20 |
| CTD diver Z065 | 0.29 | OBS3A sn 223 | 0.37 |
| CTD diver Z257 | 0.19 | OBS3A sn 222 | 0.23 |
| CTD diver Z258 | 0.14 | OBS3A sn 221 | 0.14 |
| CTD diver Z259 | 0.18 | RCM 9 sn 1165 | 0.19 |
| OBS3A sn 307 | 0.17 | RCM 9 sn 1170 | 8.36 |
| OBS3A sn 261 | 0.36 | RCM 9 sn 1225 | 0.19 |
| OBS3A sn 225 | 0.18 | | |

### 5.4.3 Salinity

Salinity is calculated according to the Unesco pps-78 formula (see Annex A), using the measured conductivity, temperature and depth. Therefore, no calibration is necessary since all the input parameters have been cross checked.

# 6. CONCLUSION OF THE CALIBRATION ON 16 MARCH 2011

The technical realization of the in situ calibration for turbidity measurements was carried out with variable success. Only low concentrations were found in the water column at various tidal phases during the incoming tide. The highest concentration sampled was 240 mg/l.

RMSE values for the SSC are acceptable (from 10 to 20 mg/l). Only for both Argus instruments are the RMSE values for SSC rather high (from 20 to 60 mg/l). This was mainly due to the samples with the highest concentration, but deviation of the calibration graphs is not noticed for these samples. This could be due to a higher sand content of the samples with high SS concentrations. The sand content of the suspended sediment samples is negligible in general. But as mentioned before, the sand content runs up when aiming for high concentrated samples.

High concentrations can only be found near the bottom. Disturbance of the soft bottom at these depths is inevitable and therefore not recommended for calibration. For instruments with a very high turbidity range (SiltProfiler) an in situ calibration is not recommended. It is very hard to find very high concentrations in a homogenous mixture in the Lower Sea Scheldt. Only in situ cross-checks are useful in this case, with the widest range of concentrations possible.

The conductivity cross-check is limited due to the small range of conductivities that were measured. The conductivity comparison of the CTD-Divers and the RCM-9 instruments are showing similar trends, the range of values during each measurement is about 0.2 mS/cm. The conductivity of the OBS3A instruments has more variation (about 0.5 to 2 mS/cm) and will therefore not be used for salinity measurements during the project. Salinity will be measured by CTD-divers, attached to the OBS3A instruments.

Temperature measurements is also compared. No large discrepancies were found, except for RCM 9 sn 1170, which shows bad temperature data. All RMSE values for the remaining instruments are lower than 0.36 °C.

# 7. REFERENCES

AMT (2003). Intern rapport, Getij-informatie Scheldebekken 1991-2000.

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

Wunderground (2011). Weather Underground: www.wunderground.com

# Annex A unesco PPs-78 formula for calculating salinity

## Practical Salinity Scale (PPS 78) Salinity in the range of 2 to 42

**Constants from the 19th Edition of Standard Methods**

| | | |
|---|---|---|
| R cond.ratio | 0.0117 | $R = \frac{C}{42.914 mS/cm}$ |
| **C Cond at t** | **0.5** | **Input conductivity in mS/cm of sample** |
| **t deg. C** | **22.00** | **Input temperature of sample solution** |
| **P dBar** | **20** | **Input pressure at which sample is measured in decibars** |
| Rp | 1.0020845 | $R_p = 1 + \frac{p(e_1 + e_2 p + e_3 p^2)}{1 + d_1 t + d_2 t^2 + (d_3 + d_4 t)R}$ |
| rt | 1.1641102 | $r_t = c_0 + c_1 t + c_2 t^2 + c_3 t^3 + c_4 t^4$ |
| Rt | 0.0099879 | $R_t = \frac{R}{R_p \times r_t}$ |
| Delta S | -0.0010 | $\text{Delta S} = \frac{(t-15)}{1+k(t-15)}(b_0 + b_1 R_t^{1/2} + b_2 R_t + b_3 R_t^{3/2} + b_4 R_t^2 + b_5 R_t^{5/2})$ |
| **S = Salinity** | **0.257** | $S = a_0 + a_1 R_t^{1/2} + a_2 R_t + a_3 R_t^{3/2} + a_4 R_t^2 + a_5 R_t^{5/2} + \text{delta S}$ |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| a0 | 0.0080 | b0 | 0.0005 | c0 | 0.6766097 | d1 | 3.426E-02 | e1 | 2.070E-04 |
| a1 | -0.1692 | b1 | -0.0056 | c1 | 2.00564E-02 | d2 | 4.464E-04 | e2 | -6.370E-08 |
| a2 | 25.3851 | b2 | -0.0066 | c2 | 1.104259E-04 | d3 | 4.215E-01 | e3 | 3.989E-12 |
| a3 | 14.0941 | b3 | -0.0375 | c3 | -6.9698E-07 | d4 | -3.107E-03 | | |
| a4 | -7.0261 | b4 | 0.0636 | c4 | 1.0031E-09 | | | | |
| a5 | 2.7081 | b5 | -0.0144 | | | | | | |
| | | k | 0.0162 | | | | | | |

**R** = ratio of measured conductivity to the conductivity of the Standard Seawater Solution

Conductivity Ratio R is a function of salinity, temperature, and hydraulic pressure. So that we can factor R into three parts i.e.

**R = Rt x Rp x rt**

**R = C(S,t,p)/C(35,15,0)**

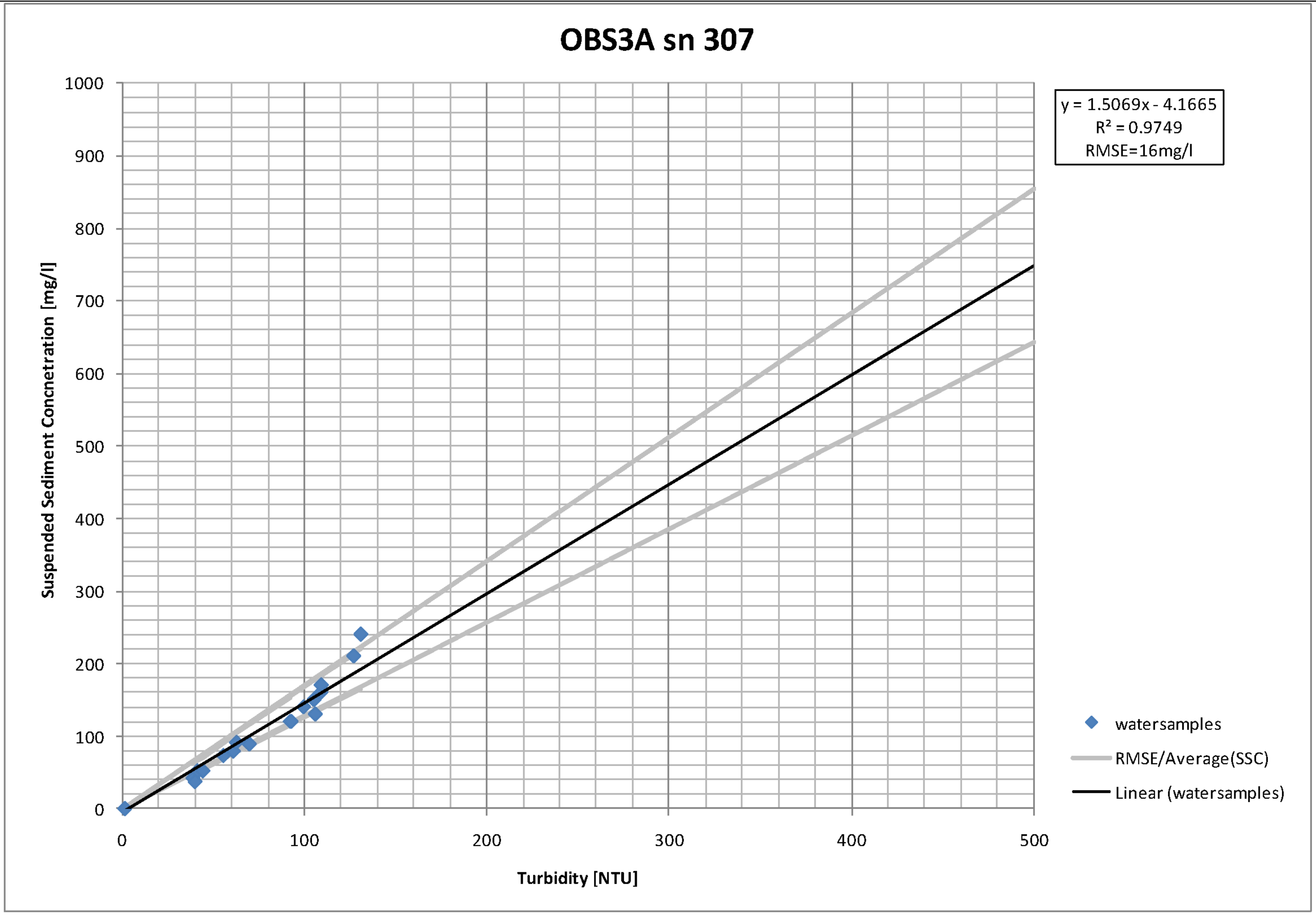
**C = 42.914 mS/cm at 15 deg C and 0 dbar pressure ie C(35,15,0) where 35 is the salinity**

**Ocean pressure is usually measured in decibars. 1 dbar = 10^-1 bar = 10^5 dyne/cm^2 = 10^4 Pascal.**

# Annex B Calibration Graphs

# B.1 In situ Calibration Graphs

# 11354 - Opvolging aanslibbing Deurganckdok




Calibration Graph of reference instrument OBS 3A s/n 307

Location:
Lower Sea Scheldt

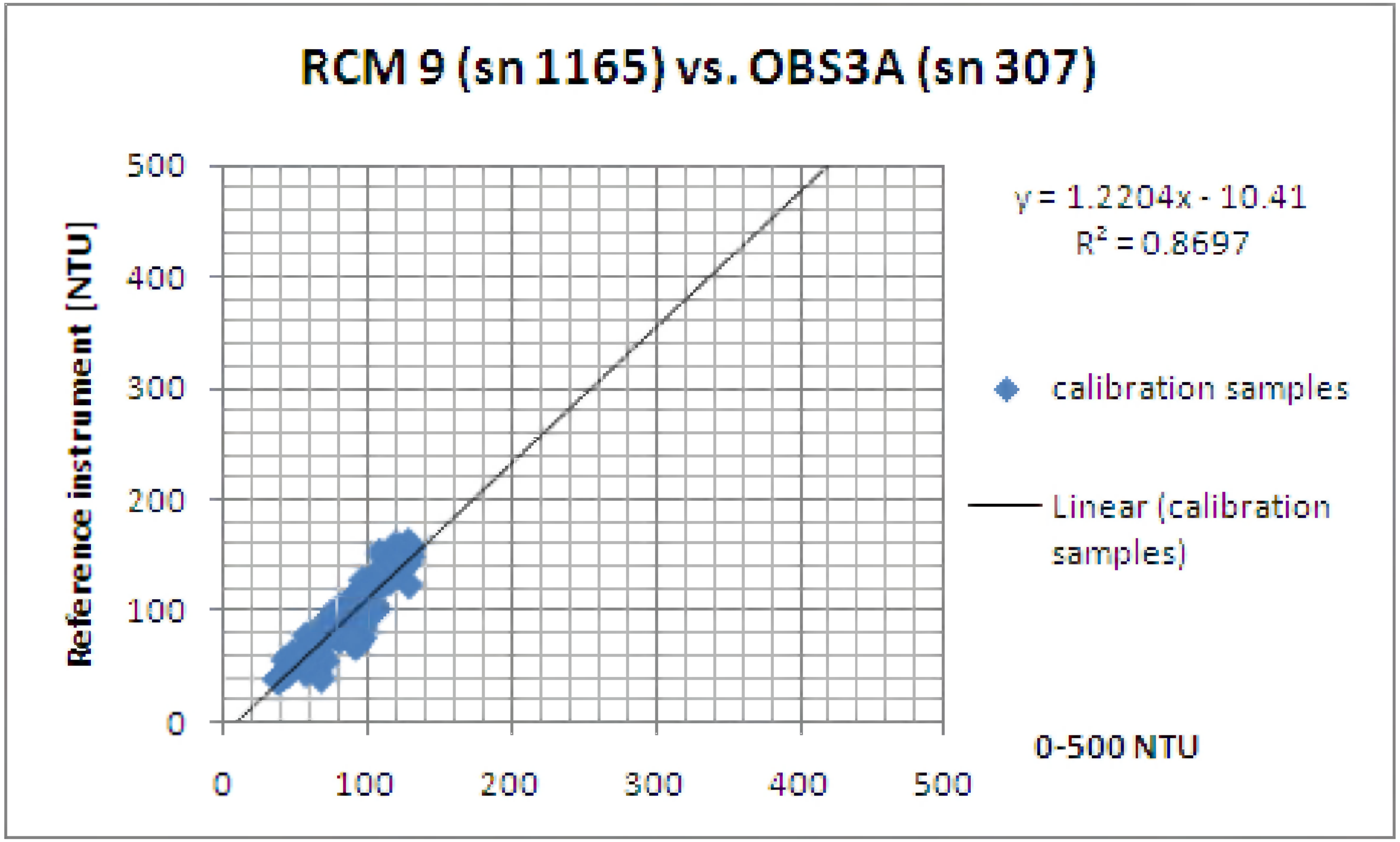
Date:
16/03/11

*Data processed by:* IMDC International Marine & Dredging Consultants

*In association with:* GEMS International, Deltares

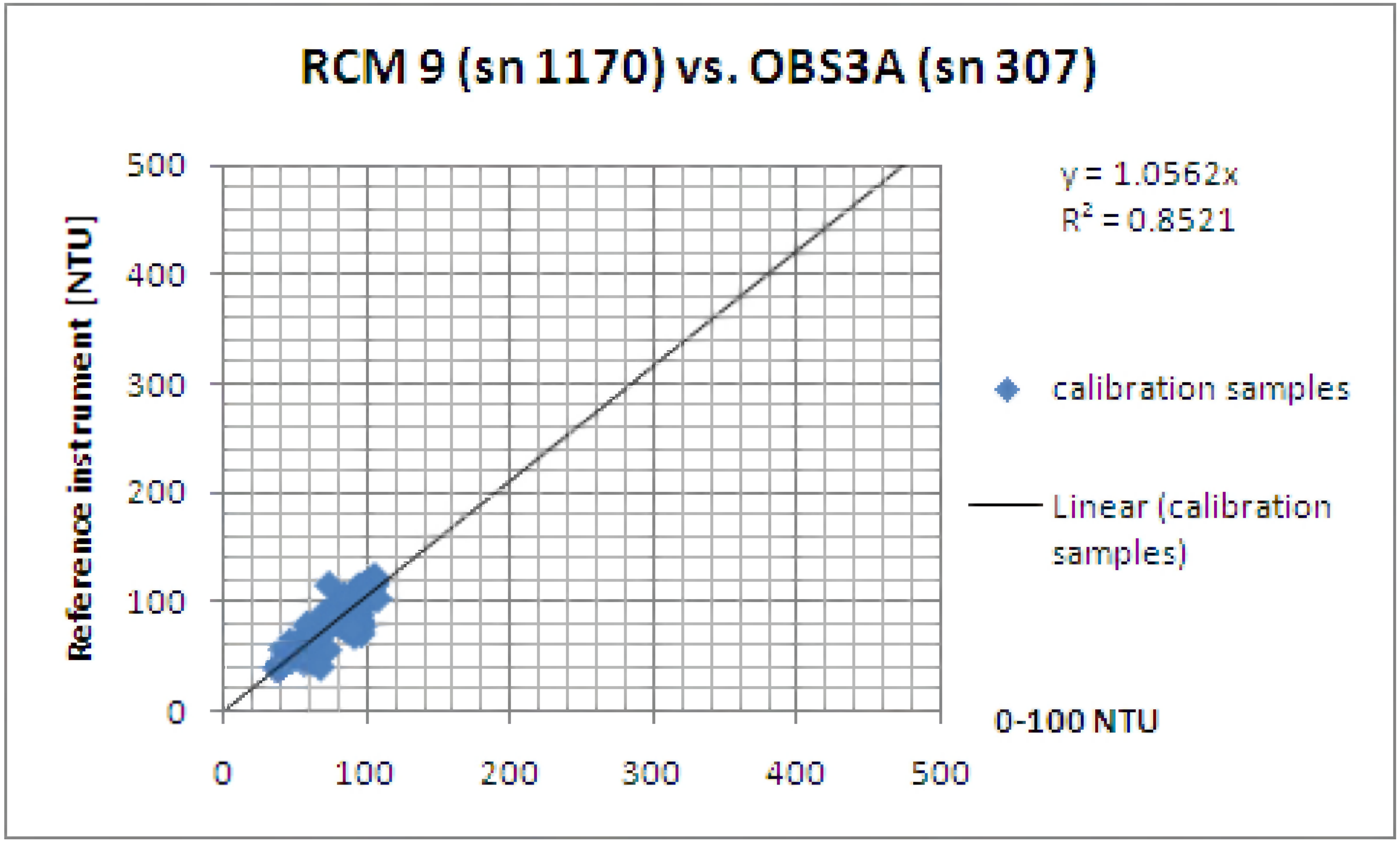
*I/RA/11354/10.113/MBO*

11354 - Opvolging aanslibbing Deurganckdok




| Calibration Graph of RCM 9 s/n 1165 | | *Data processed by:* IMDC International Marine & Dredging Consultants |
|---|---|---|
| Location: Lower Sea Scheldt | Date: 16/03/11 | *In association with:* GEMS International, Deltares<br>*I/RA/11354/10.113/MBO* |

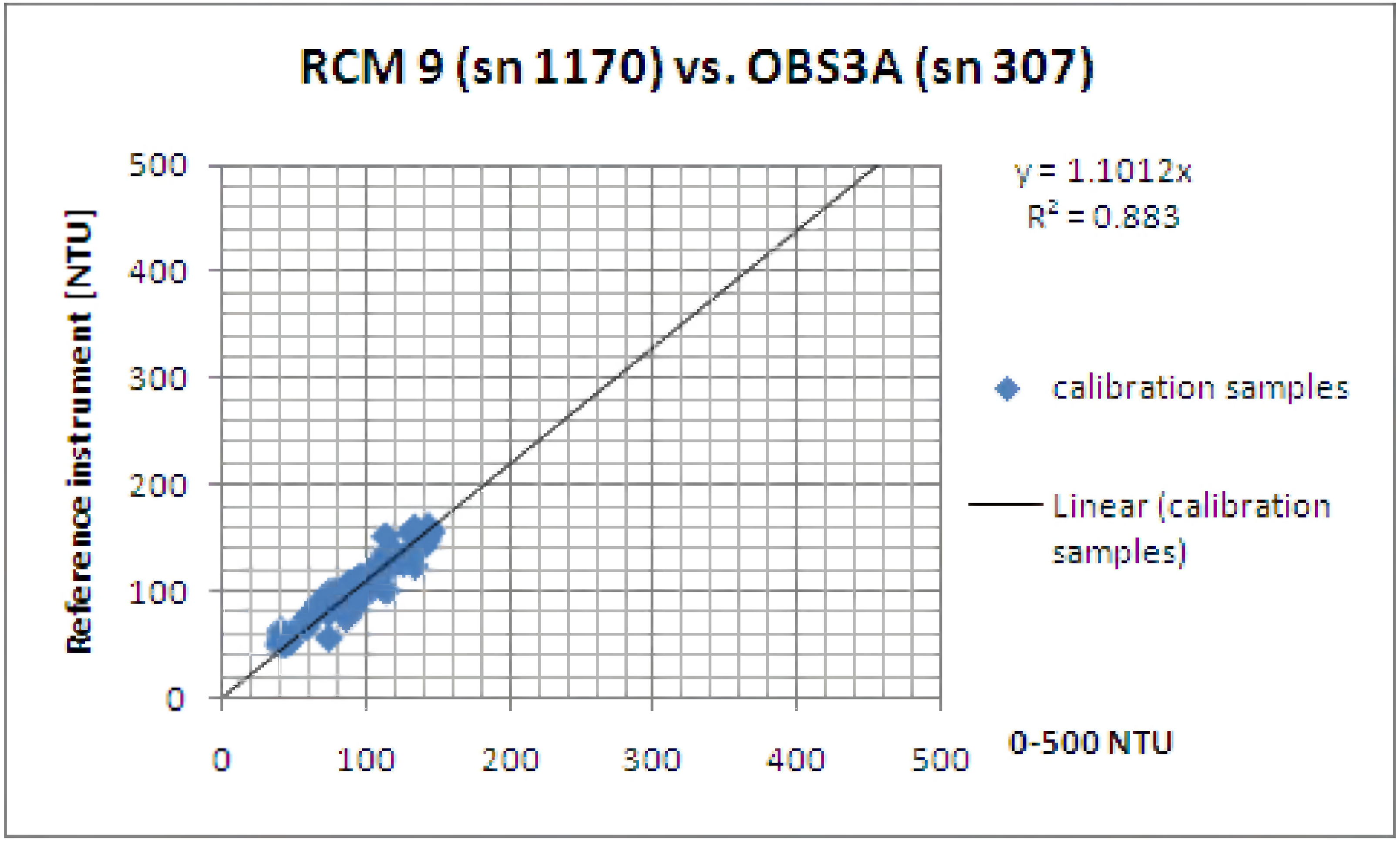
# 11354 - Opvolging aanslibbing Deurganckdok




| Calibration Graph of RCM 9 s/n 1170 0-100NTU | | *Data processed by:* IMDC |
|---|---|---|
| Location: Lower Sea Scheldt | Date: 16/03/11 | *In association with:* GEMS International, Deltares |

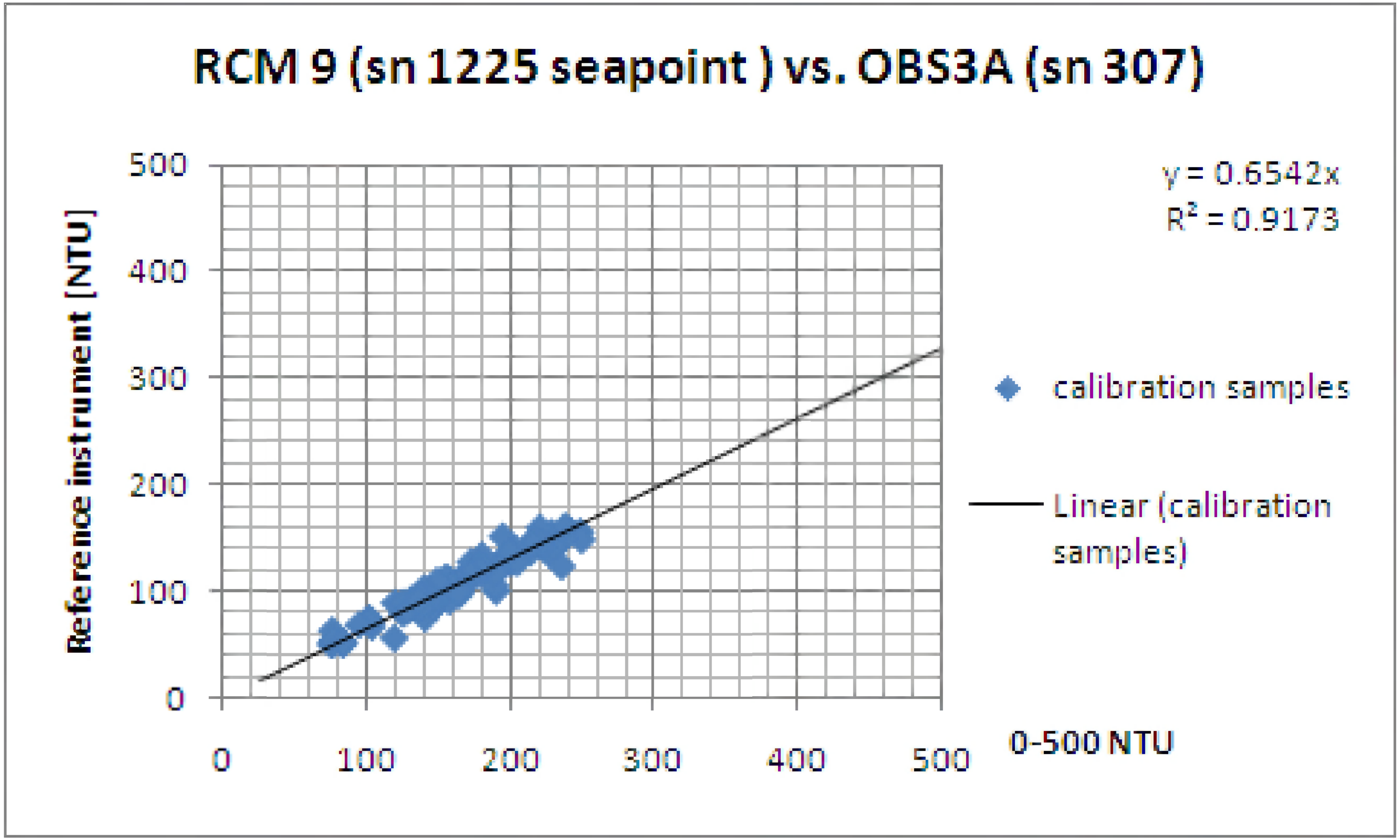
*I/RA/11354/10.113/MBO*

11354 - Opvolging aanslibbing Deurganckdok



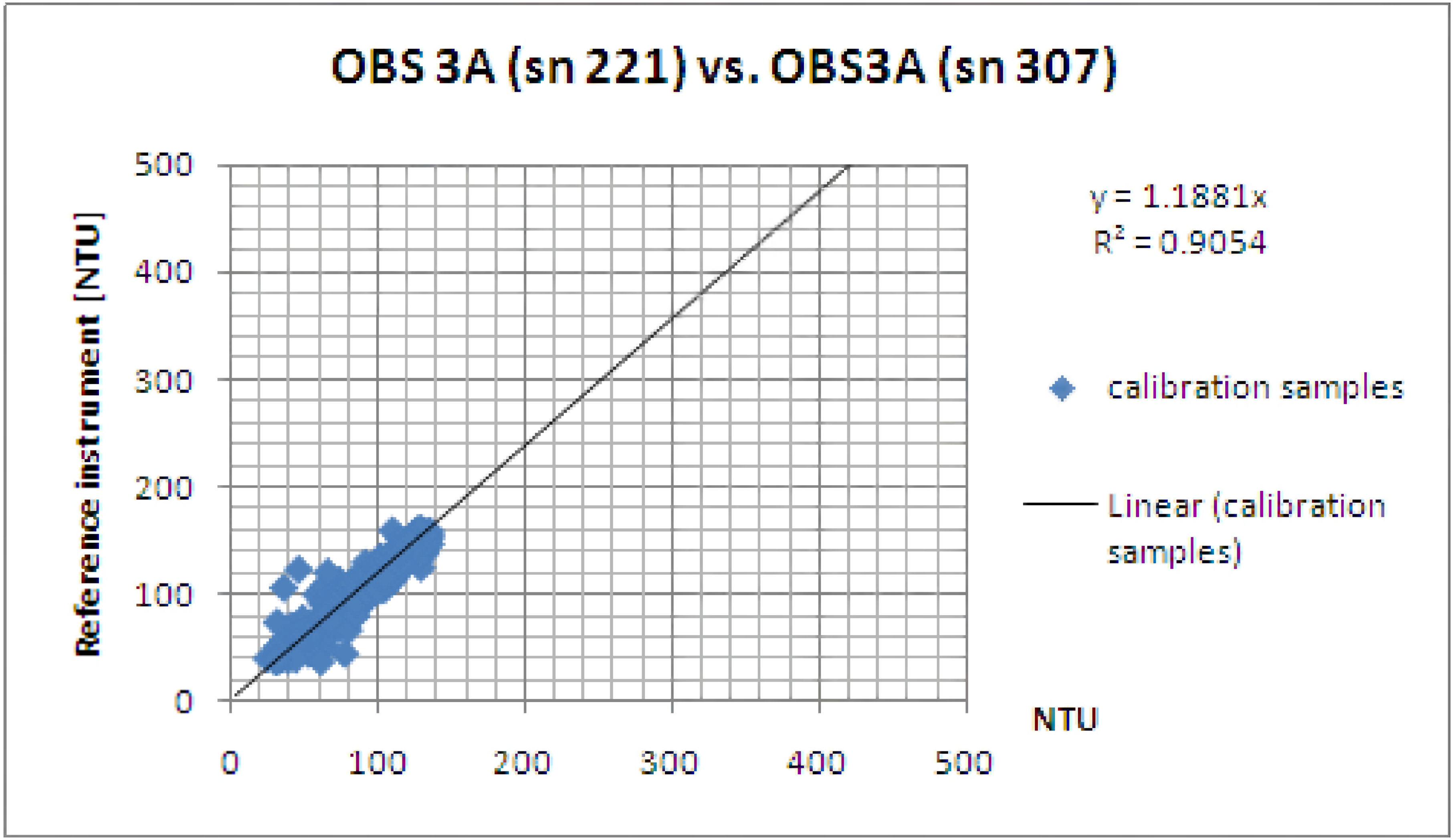

| | | |
|---|---|---|
| Calibration Graph of RCM 9 s/n 1170 0-500NTU | | *Data processed by:* IMDC International Marine & Dredging Consultants |
| Location:<br>Lower Sea Scheldt | Date:<br>16/03/11 | *In association with:* GEMS International, Deltares<br>*I/RA/11354/10.113/MBO* |

11354 - Opvolging aanslibbing Deurganckdok



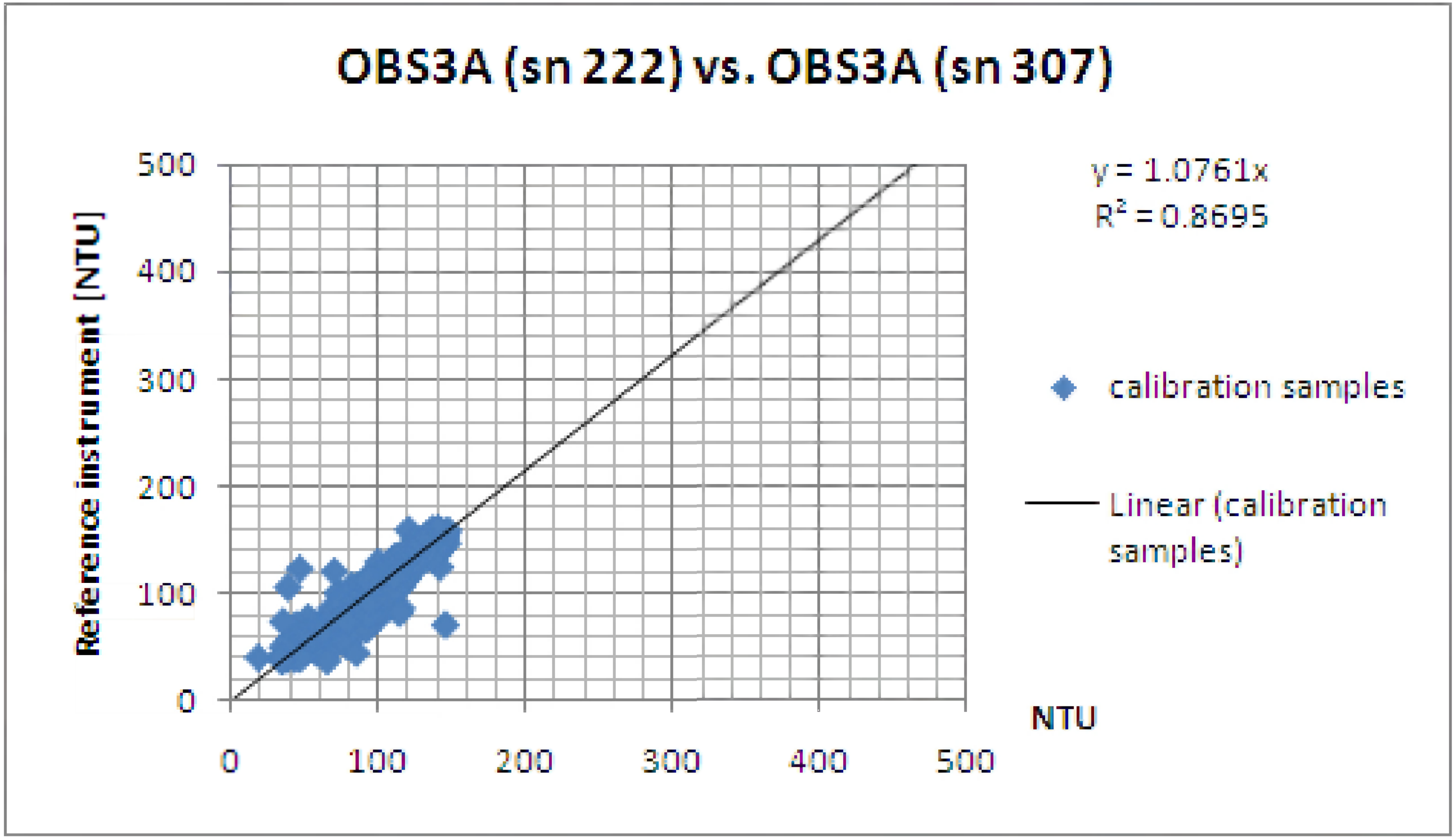

| Calibration Graph of Seapoint RCM 9 s/n 1225 | | *Data processed by:* IMDC International Marine & Dredging Consultants |
|---|---|---|
| Location: Lower Sea Scheldt | Date: 16/03/11 | *In association with:* GEMS International, Deltares<br>*I/RA/11354/10.113/MBO* |

# 11354 - Opvolging aanslibbing Deurganckdok



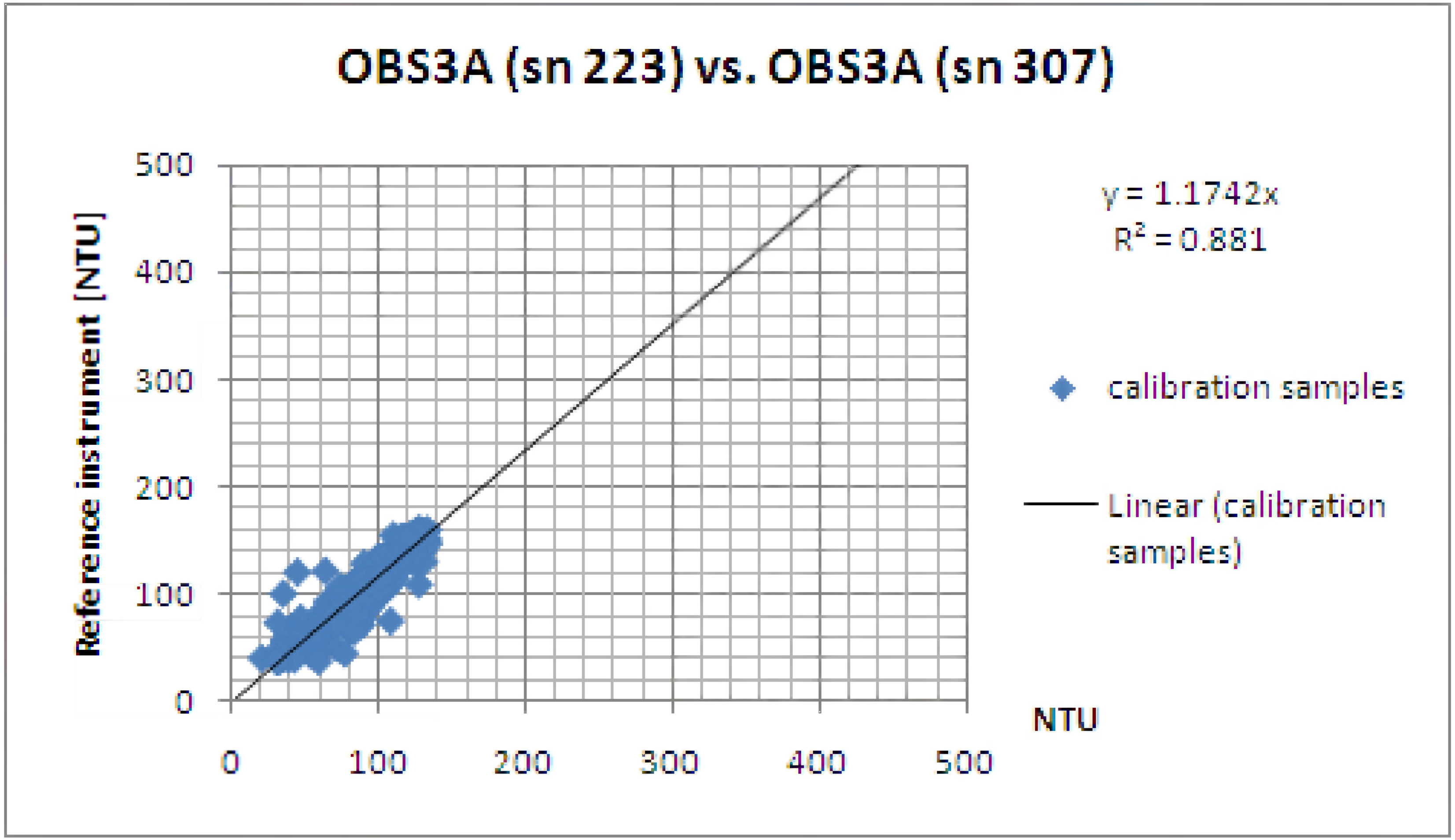

| Calibration Graph of OBS 3A s/n 221 | | *Data processed by:* IMDC International Marine & Dredging Consultants |
|---|---|---|
| Location: Lower Sea Scheldt | Date: 16/03/11 | *In association with:* GEMS International, Deltares Enabling Delta Life |
| | | *I/RA/11354/10.113/MBO* |

11354 - Opvolging aanslibbing Deurganckdok



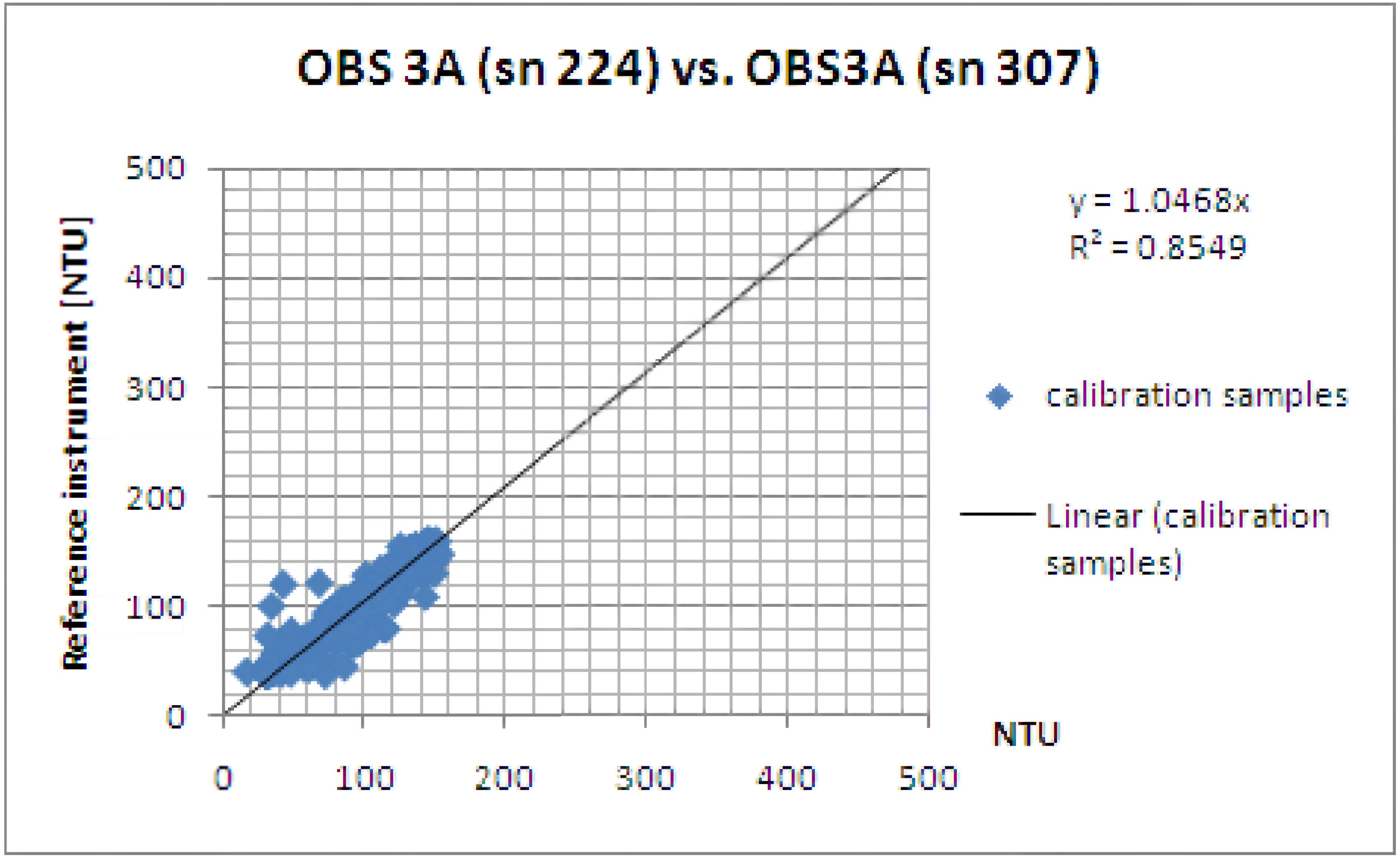

| Calibration Graph of OBS 3A s/n 222 | | *Data processed by:* IMDC International Marine & Dredging Consultants |
|---|---|---|
| Location: Lower Sea Scheldt | Date: 16/03/11 | *In association with:* GEMS International, Deltares Enabling Delta Life |
| | | *I/RA/11354/10.113/MBO* |

11354 - Opvolging aanslibbing Deurganckdok




| Calibration Graph of OBS 3A s/n 223 | | *Data processed by:* IMDC International Marine & Dredging Consultants |
|---|---|---|
| Location: Lower Sea Scheldt | Date: 16/03/11 | *In association with:* GEMS International, Deltares |
| | | *I/RA/11354/10.113/MBO* |

# 11354 - Opvolging aanslibbing Deurganckdok




Calibration Graph of OBS 3A s/n 224

Location:
Lower Sea Scheldt

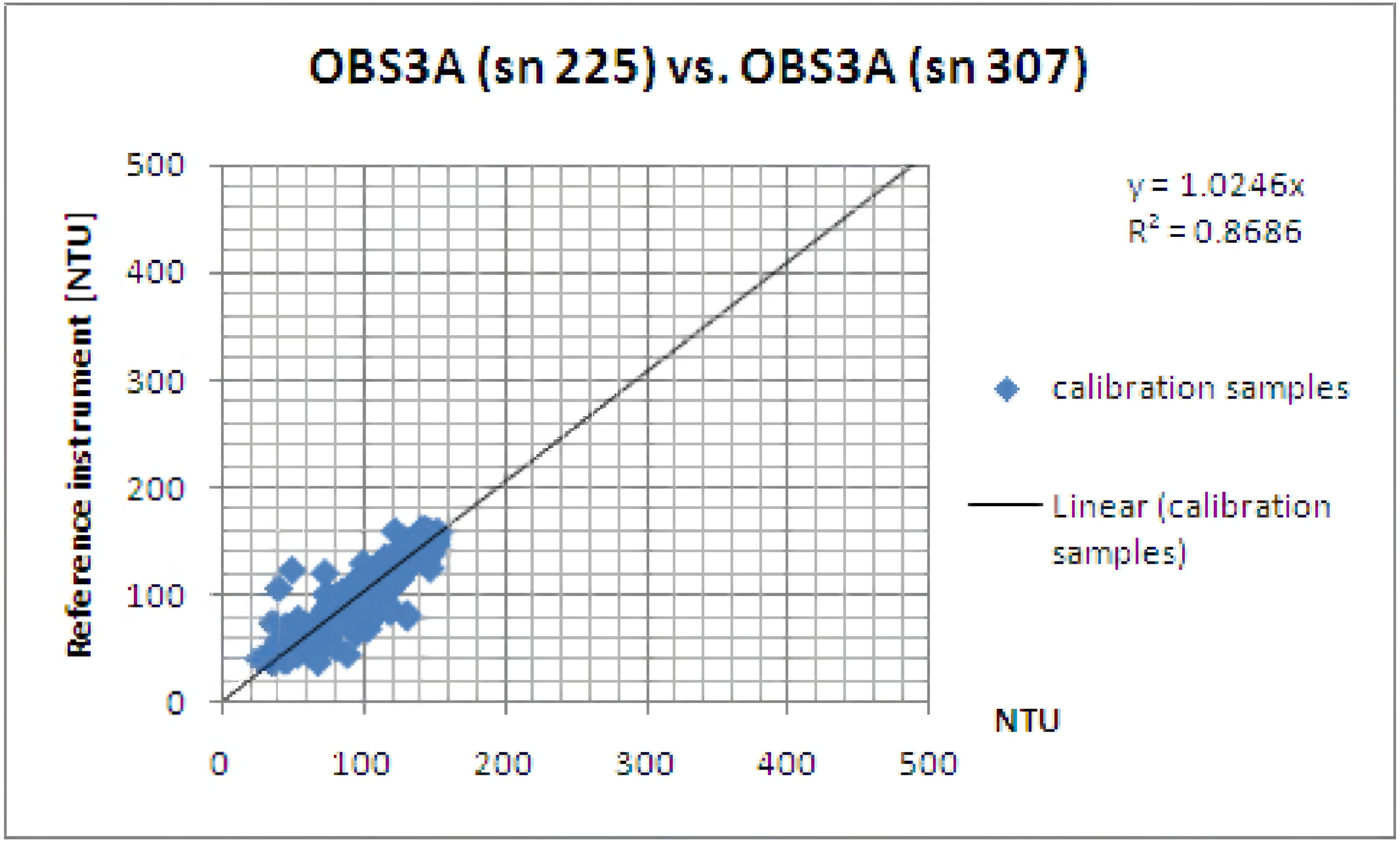
Date:
16/03/11

*Data processed by:* IMDC International Marine & Dredging Consultants

*In association with:* GEMS International, Deltares

*I/RA/11354/10.113/MBO*

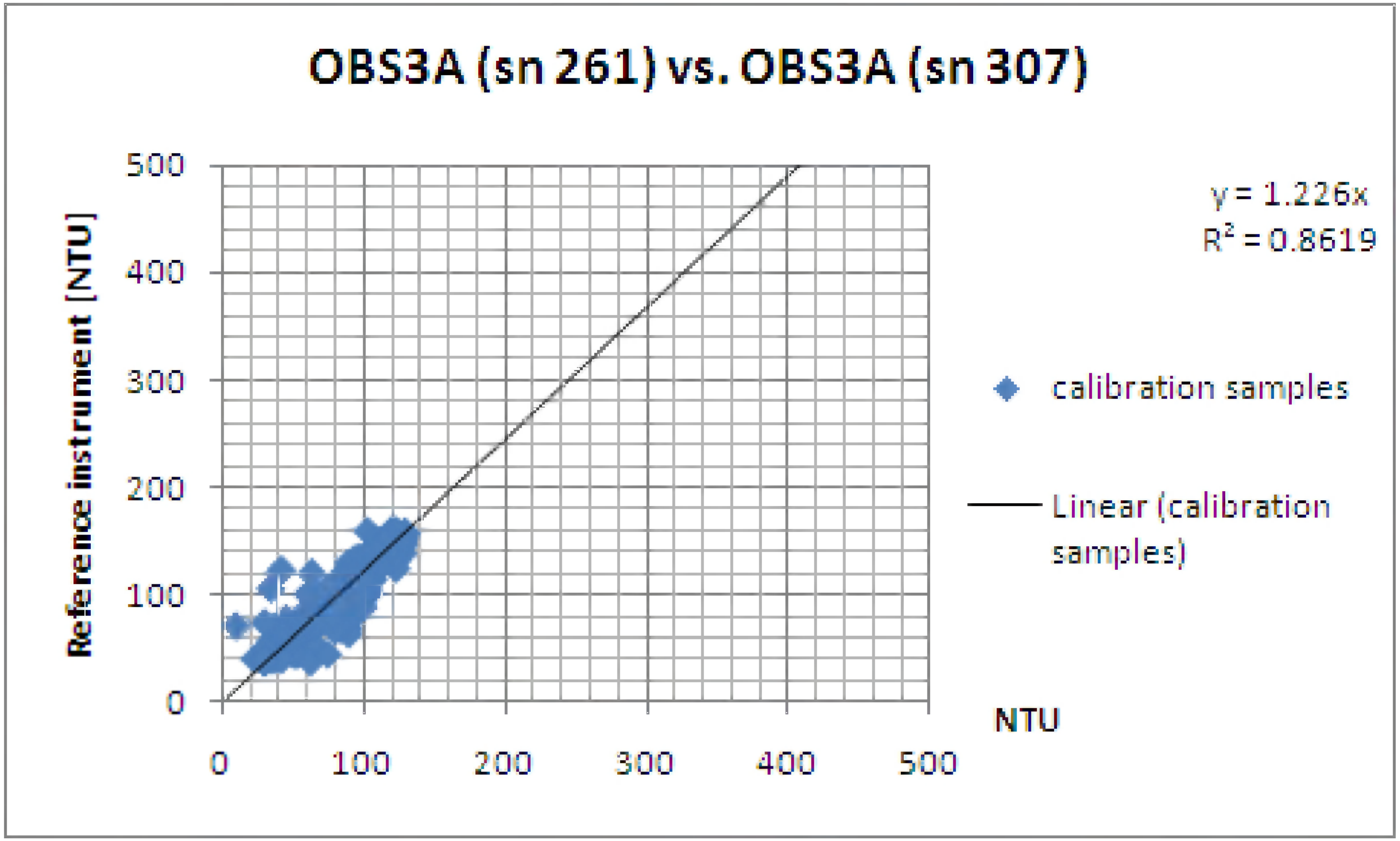
11354 - Opvolging aanslibbing Deurganckdok




| Calibration Graph of OBS 3A s/n 225 | | Data processed by: IMDC |
|---|---|---|
| Location: Lower Sea Scheldt | Date: 16/03/11 | In association with: GEMS International, Deltares |

I/RA/11354/10.113/MBO

# 11354 - Opvolging aanslibbing Deurganckdok




Calibration Graph of OBS 3A s/n 261

*Data processed by:* IMDC

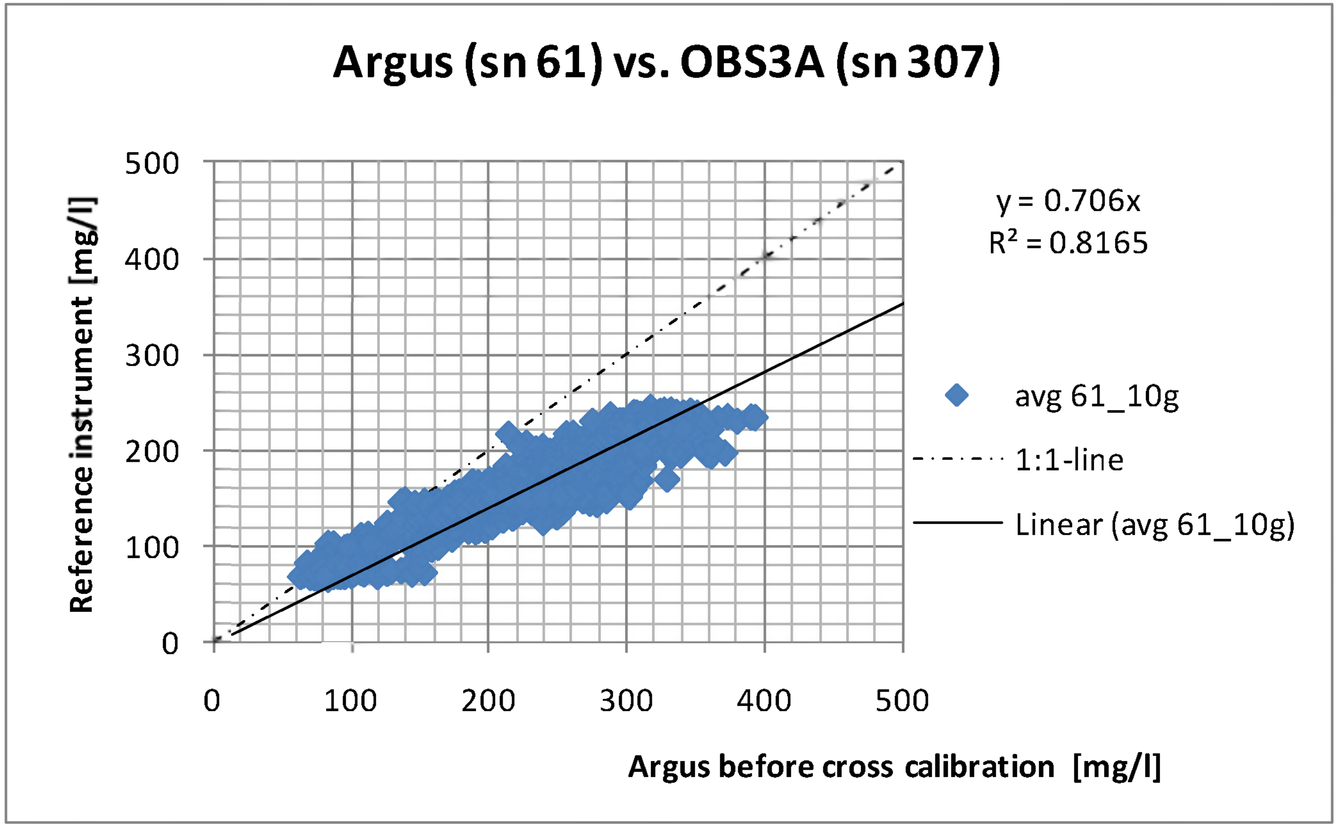
Location:
Lower Sea Scheldt

Date:
16/03/11

*In association with:* GEMS International, Deltares

*I/RA/11354/10.113/MBO*

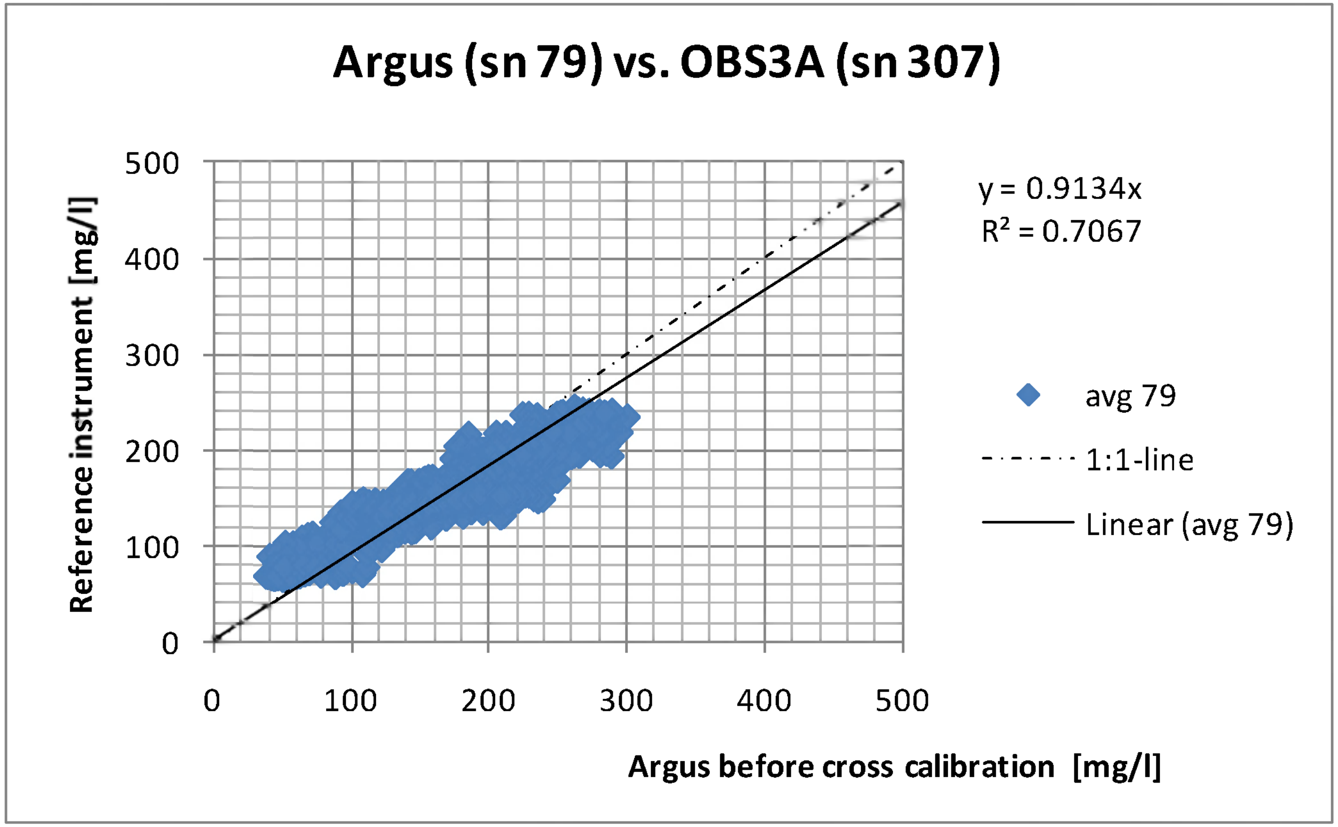
# 11354 - Opvolging aanslibbing Deurganckdok




| Calibration Graph of Argus s/n 61 | | *Data processed by:* IMDC International Marine & Dredging Consultants |
|---|---|---|
| Location: Lower Sea Scheldt | Date: 16/03/11 | *In association with:* GEMS International, Deltares |

*I/RA/11354/10.113/MBO*

# 11354 - Opvolging aanslibbing Deurganckdok




Calibration Graph of Argus s/n 79

*Data processed by:* IMDC International Marine & Dredging Consultants

Location:
Lower Sea Scheldt

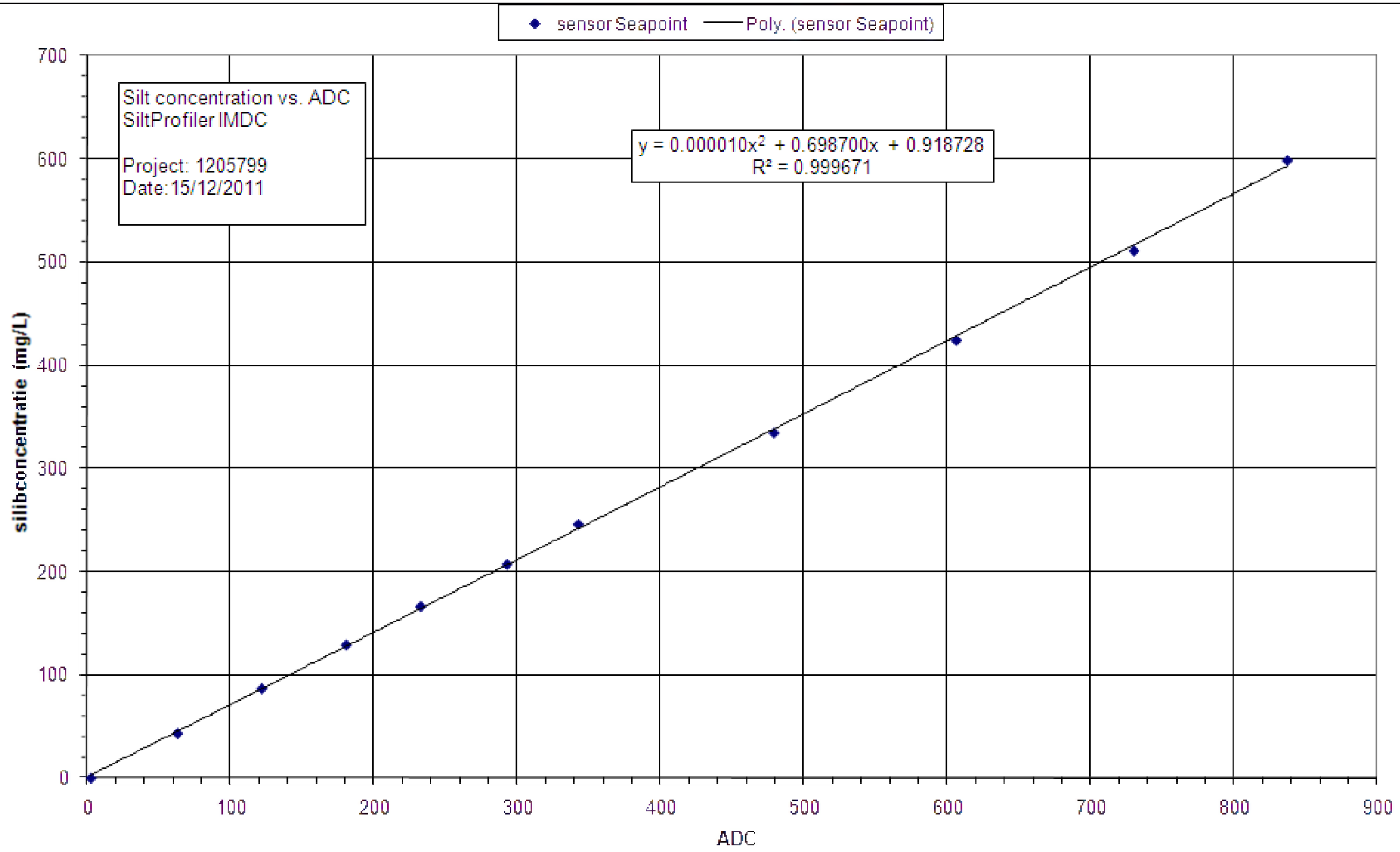
Date:
16/03/11

*In association with:* GEMS International, Deltares

*I/RA/11354/10.113/MBO*

## B.2 Manufacturers Calibration curves

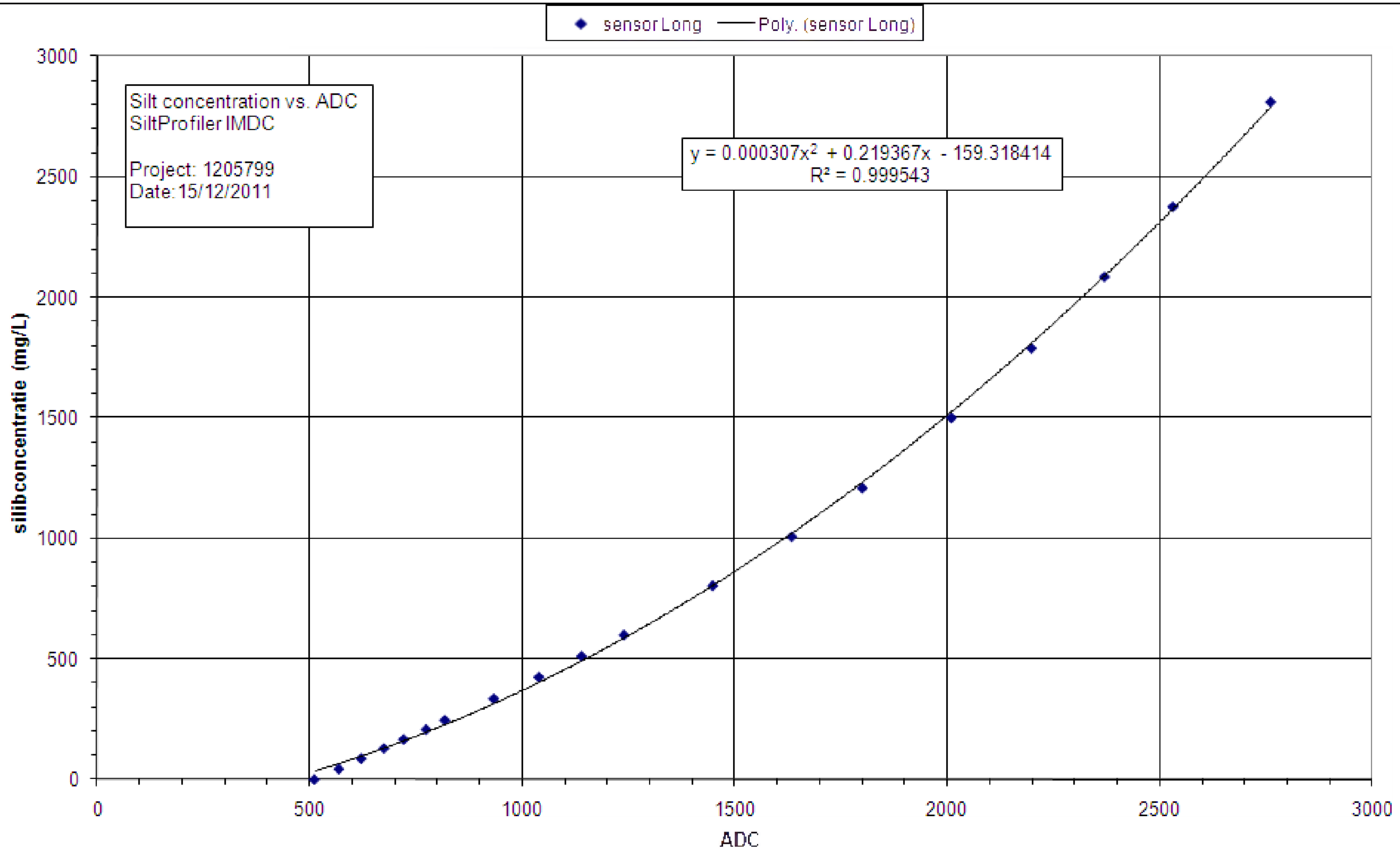
# 11354 Evaluatie externe effecten DGD




| Calibration Graph of Siltprofiler - Seapoint | | Data reported by: IMDC |
|---|---|---|
| Processed by: Deltares | Date: 15/12/2011 | In association with: GEMS International, Deltares |

I/RA/11354/10.113/MBO

# 11354 Evaluatie externe effecten DGD




Calibration Graph of Siltprofiler – Long Range

*Data reported by:* IMDC

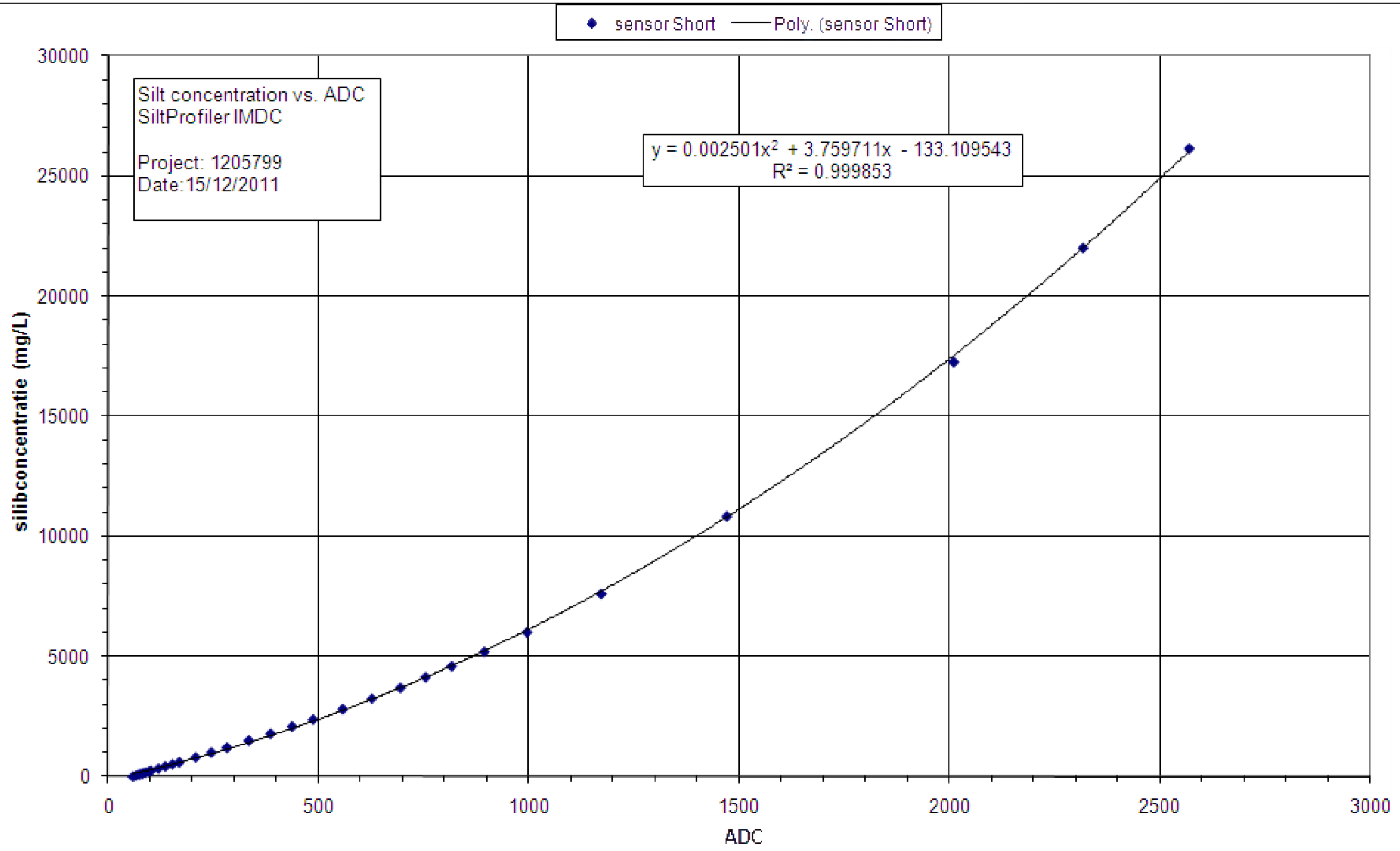
Processed by:
Deltares

Date:
15/12/2011

*In association with:* GEMS International, Deltares

*I/RA/11354/10.113/MBO*

# 11354 Evaluatie externe effecten DGD

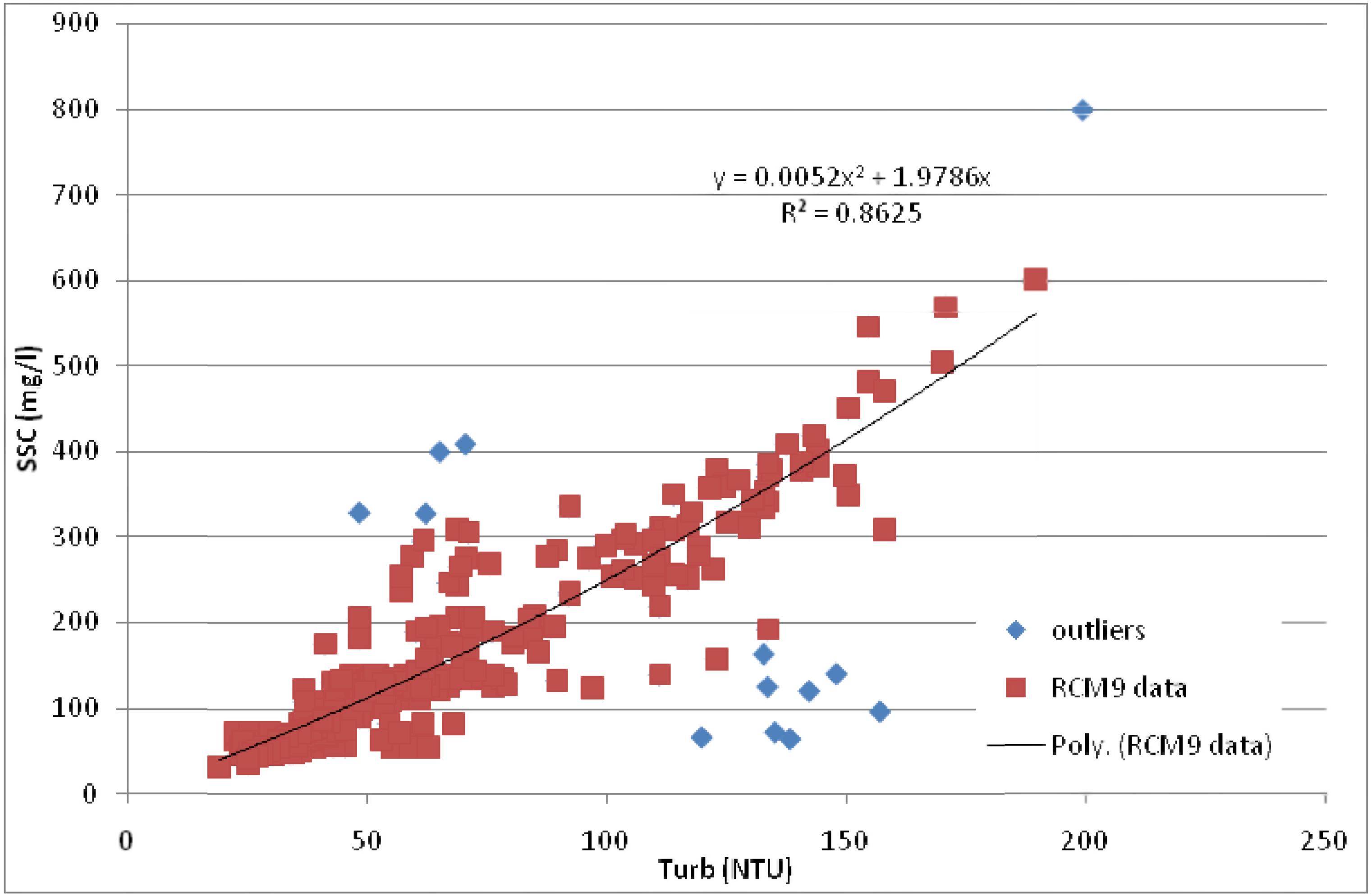



| Calibration Graph of Siltprofiler – Short Range | | *Data reported by:* IMDC |
|---|---|---|
| Processed by: **Deltares** | Date: 15/12/2011 | *In association with:* GEMS International, Deltares |

*I/RA/11354/10.113/MBO*

## B.3 Calibration curves of Hydrologisch InformatieCentrum (Vlaanderen)

# 11354 Evaluatie externe effecten DGD




Calibration Graph of RCM-9 at Boei84 (248)

*Data reported by:* IMDC

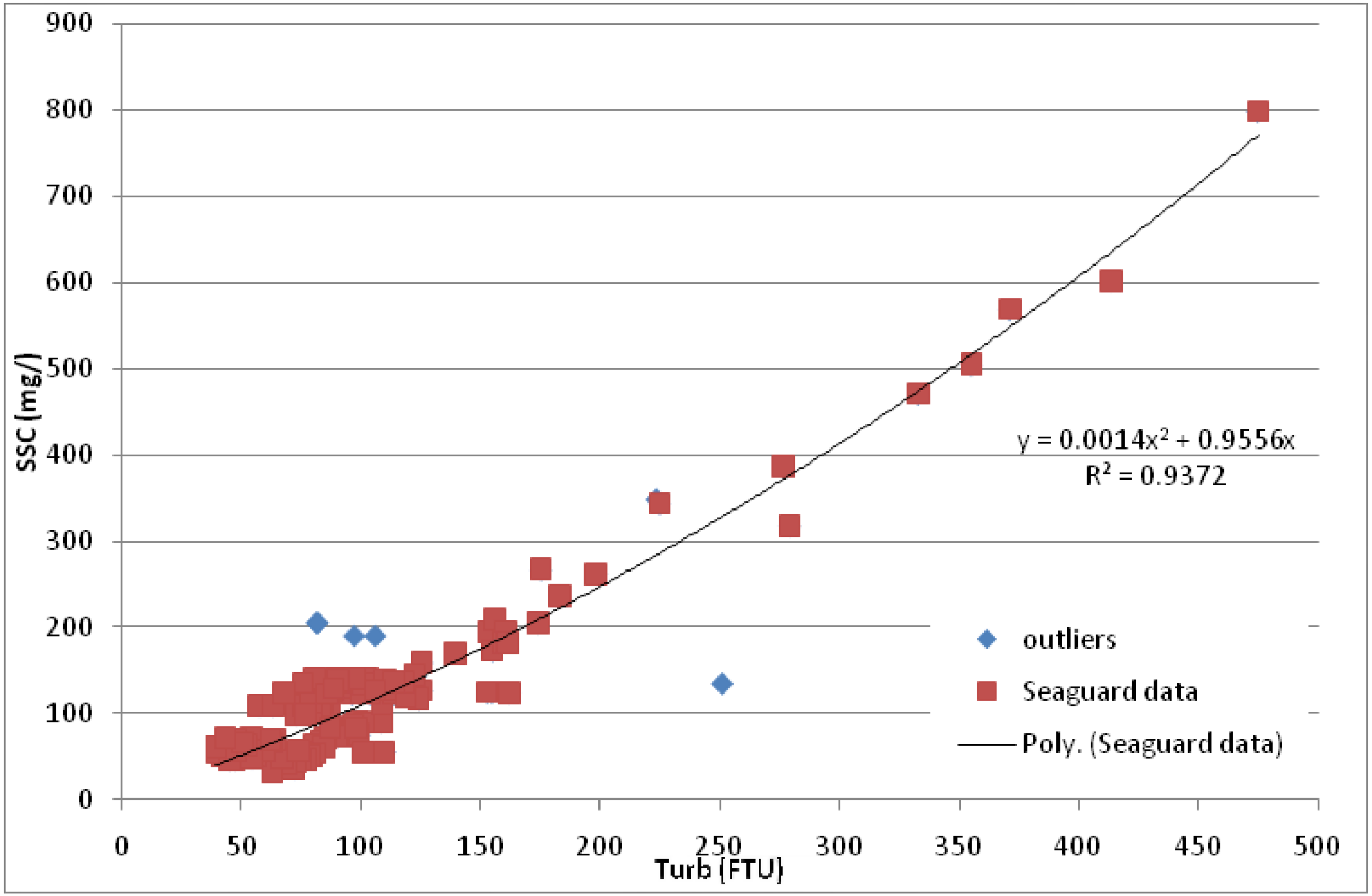
*In association with:* GEMS International, Deltares

Processed by:
Hydrologisch InformatieCentrum (Vlaanderen)

Date:
17/04/2012

*I/RA/11354/10.113/MBO*

# 11354 Evaluatie externe effecten DGD




Calibration Graph of Seaguard at Boei84 (65 and 173)

Data reported by: IMDC

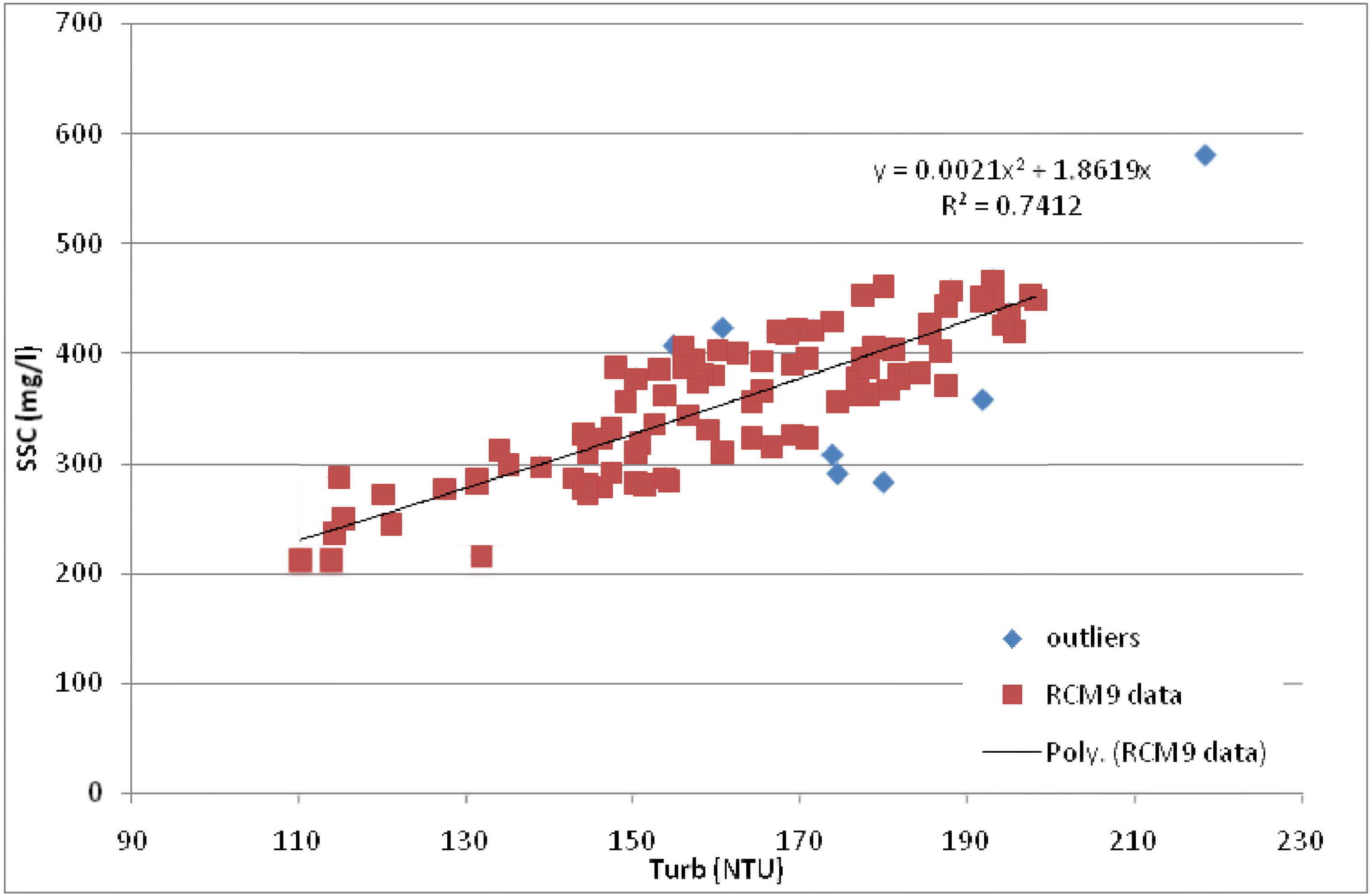
In association with: GEMS International, Deltares

Processed by:
Hydrologisch InformatieCentrum (Vlaanderen)

Date: 17/04/2012

I/RA/11354/10.113/MBO

11354 Evaluatie externe effecten DGD




Calibration Graph of RCM-9 at Oosterweel (152 and 149)

*Data reported by:* IMDC

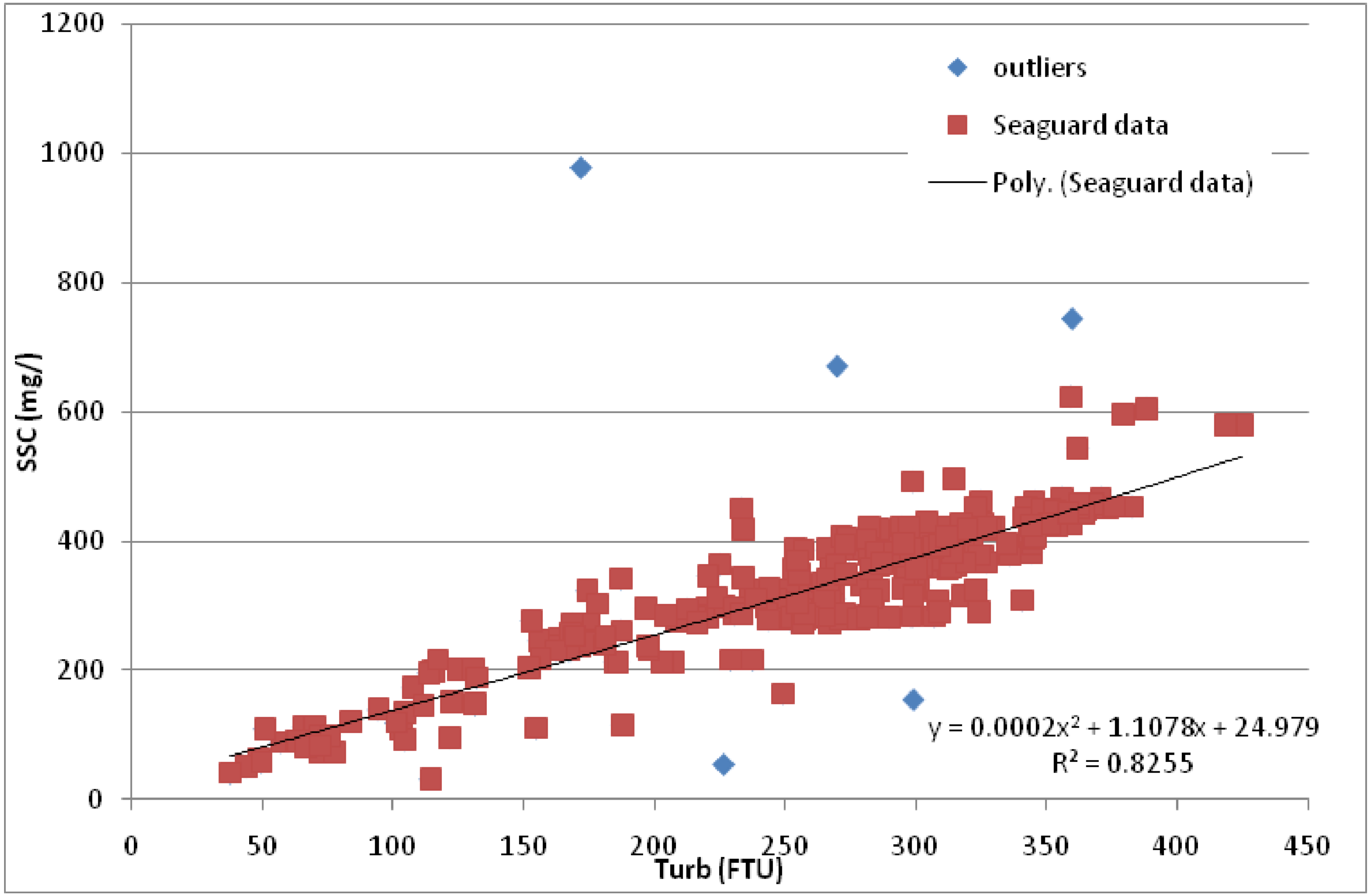
*In association with:* GEMS International, Deltares

Processed by:
Hydrologisch InformatieCentrum (Vlaanderen)

Date:
17/04/2012

*I/RA/11354/10.113/MBO*

# 11354 Evaluatie externe effecten DGD




Calibration Graph of Seaguard at Oosterweel (65, 171 and 152)

Data reported by:

In association with:

Processed by:
Hydrologisch InformatieCentrum (Vlaanderen)

Date:
17/04/2012

I/RA/11354/10.113/MBO