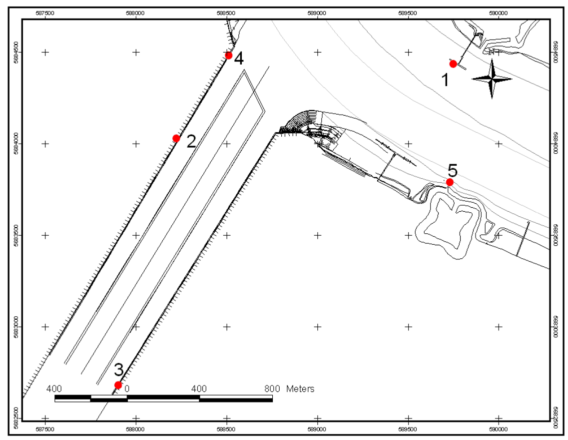
VLAAMSE OVERHEID
DEPARTEMENT MOBILITEIT EN OPENBARE WERKEN

WATERBOUWKUNDIG LABORATORIUM

Langdurige metingen Deurganckdok 2: Opvolging en analyse aanslibbing

Bestek 16EB/05/04

Calibration Frame set-up (left) & Measurement locations (right)



Deelrapport 2.09: Calibratie stationaire toestellen Herfst 10 september 2007

Report 2.09: Calibration stationary equipment Autumn 10 September 2007

1 February 2008

I/RA/11283/07.095/MSA

IMDC i.s.m. wl | delft hydraulics en GEMS International

International Marine and Dredging Consultants (IMDC)
Wilrijkstraat 37-45 Bus 4 - 2140 Antwerpen – België
tel: +32.3.270.92.95 - fax: +32.3.235.67.11
E-mail : info@imdc.be

Document Control Sheet

Document Identification

Title:	Report 2.09: Calibration stationary equipment Autumn 10 September 2007
Project:	Langdurige metingen Deurganckdok 2: Opvolging en analyse aanslibbing
Client	Waterbouwkundig Laboratorium
File reference:	I/RA/11283/07.095/MSA
File name	K:\PROJECTS\11\11283 - Opvolging aanslibbing dgd\10-Rap\DGD2\2_09_RA07.095_Calibration_Autumn\RA07095 CalibratieHerfst_v01.doc

Revisions

Version	Date	Author	Description
1.0	01/02/08	SRI, MBO	Concept

Distribution List

Name	# ex.	Company/authorities	Position in reference to the project
Joris Vanlede	1	Waterbouwkundig Laboratorium	client

Approval

Version	Date	Author	Project manager	Commissioner
1.0	01/02/08	SRI	MBO	MSA

TABLE OF CONTENTS

1. INTRODUCTION 1

1.1. THE ASSIGNMENT 1
1.2. PURPOSE OF THE STUDY 1
1.3. OVERVIEW OF THE STUDY 2
1.3.1. Reports 2
1.3.2. Measurement actions 3
1.4. STRUCTURE OF THE REPORT 4

2. THE MEASUREMENT CAMPAIGN 5

2.1. CALIBRATION STRATEGY 5
2.1.1. Suspended Sediment Concentration 5
2.1.2. Salinity 5
2.2. CALIBRATION SET UP 6
2.2.1. Frame set-up 6
2.2.2. Measurement locations 7
2.2.3. Calibration protocol 7
2.2.4. Sample analysis 7
2.2.5. Validation, Drifting and extra Sensors 7
2.3. INSTRUMENTS 7
2.3.1. D & A OBS 3A 7
2.3.2. SiltProfiler 8
2.3.3. Argus ASM-IV 9
2.3.4. Aanderaa RCM-9 10
2.3.5. CTD-Diver datalogger 10
2.3.6. Pump Sampler 10

3. COURSE OF THE MEASUREMENTS 12

3.1. HYDROMETEOROLOGICAL CONDITIONS 12
3.2. LOCATIONS 12
3.3. MEASURED CONCENTRATIONS 13

4. PROCESSING OF DATASETS 14

4.1. INTRODUCTION 14
4.2. SAND CONTENT OF SAMPLES 14
4.3. SSC CALIBRATION RESULTS 15
4.4. MANUFACTURER'S CALIBRATION & CROSS-CHECK OF SILTPROFILER 18
4.4.1. Manufacturer's calibration of Silt Profiler 18
4.4.2. Cross-check of SiltProfiler 18
4.5. MANUFACTURER'S CALIBRATION & CROSS CHECK OF ARGUS ASM-IV 19
4.5.1. Manufacturer's calibration of Argus ASM IV 19
4.5.2. Cross check of Argus ASM IV 19
4.6. CONDUCTIVITY, TEMPERATURE AND SALINITY CROSS-CHECK 23
4.6.1. Calibration day 1: 23 June 2006 23
4.6.2. Cross-calibration SiltProfiler 31

5. CONCLUSION OF AUTUMN CALIBRATION 32

6. REFERENCES 33

APPENDICES

APPENDIX A. MEASUREMENT EQUIPMENT **A-1**

A.1 CTD-DIVER DATALOGGER A-2
A.2 ARGUS ASM IV A-3

APPENDIX B. CALIBRATION GRAPHS **B-1**

B.1 IN SITU CALIBRATION GRAPHS B-2
B.2 MANUFACTURERS CALIBRATION B-17

LIST OF TABLES

TABLE 1-1: OVERVIEW OF DEURGANCKDOK REPORTS 2
TABLE 2-1: OVERVIEW OF INSTRUMENTS MEASURING SS CONCENTRATION 5
TABLE 2-2: SET UP FOR CALIBRATION 6
TABLE 3-1: HIGH AND LOW TIDE AT LIEFKENSHOEK TIDAL GAUGE ON BOTH MEASUREMENT DAYS 12
TABLE 3-2: COORDINATES CALIBRATION LOCATIONS [UTM ED50] 12
TABLE 4-1: OVERVIEW OF TOTAL SS CONCENTRATION [MG/L], SAND CONCENTRATION [>63 µM MG/L] AND MASS PERCENTAGE SAND IN SAMPLES 14
TABLE 4-2: OVERVIEW OF CALIBRATION RESULTS FOR 10/09/2007 INCLUDING INSTRUMENT DESCRIPTION, FORMULAS, R² AND RMSE VALUES AND REMARKS 16
TABLE 4-3: CALIBRATION EQUATIONS AS DERIVED FOR BOTH SEAPOINT AND SILTPROFILER SENSORS (LOW AND HIGH RANGE), X=AD COUNTS, Y=SAMPLE SUSPENDED SEDIMENT CONCENTRATION 18
TABLE 4-4: RMSE VALUES [MS/CM] FOR CONDUCTIVITY SENSORS 26
TABLE 4-5: RMSE VALUES [°C] TEMPERATURE SENSORS 23/06/2006 29
TABLE 4-6: RMSE VALUES [PPT] SALINITY 31

LIST OF FIGURES

FIGURE 2-1: CALIBRATION FRAME WITH DOUBLE PUMP SET-UP 6
FIGURE 2-2: HIGH RESOLUTION SILTPROFILER 8
FIGURE 2-3: ARGUS ASM-IV 10
FIGURE 3-1: CALIBRATION LOCATIONS 13
FIGURE 4-1: SAND CONTENT OF SELECTED SAMPLES 14
FIGURE 4-2:COMPARISON OF SAMPLE SSC TO SILTPROFILER SSC FOR 10 SEPTEMBER 2007 19
FIGURE 4-3: COMPARISON OF SAMPLE SSC TO ARGUS SSC FOR S/N 61 20
FIGURE 4-4: TIMESERIES IN A HIGH SSC ENVIRONMENT (340 MG) FOR 3 SENSORS OF ARGUS: X-AXIS SHOWS TIME, Y-AXIS SHOWS SSC: ARGUS SN 61. 21
FIGURE 4-5: HORIZONTAL VARIATION OF THE SSC DURING A SAMPLING EVENT AT LOW (TOP) AND HIGH (BOTTOM) CONCENTRATIONS FOR ARGUS S/N 61 22
FIGURE 4-6: OBS 3A CONDUCTIVITY MEASUREMENTS 23
FIGURE 4-7: RCM-9 CONDUCTIVITY MEASUREMENTS 24
FIGURE 4-8: CTD-DIVER CONDUCTIVITY MEASUREMENTS 24
FIGURE 4-9: ALL CONDUCTIVITY MEASUREMENTS 23/06/2006 25
FIGURE 4-10: OBS 3A TEMPERATURE MEASUREMENTS 26
FIGURE 4-11: RCM-9 TEMPERATURE MEASUREMENTS 27
FIGURE 4-12: CTD-DIVER TEMPERATURE MEASUREMENTS 27
FIGURE 4-13: TEMPERATURE MEASUREMENTS 28
FIGURE 4-14: SALINITY VALUES 23/06/06 30
FIGURE 4-15: COMPARISON CONDUCTIVITY MEASUREMENTS OF THE (SILTPROFILER AND AVERAG) 31

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 prolonged with an extra year from April 2007 till March 2008, ‘Opvolging aanslibbing Deurganckdok’.

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

The execution of the study involves a twofold assignment:

- Part 1: Setting up a sediment balance of Deurganckdok covering a period of one year, i.e. 04/2007 – 03/2008
- Part 2: An analysis of the parameters contributing to siltation in Deurganckdok

1.2. Purpose of the study

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

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

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

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

1.3. Overview of the study

1.3.1. Reports

Reports of the project 'Opvolging aanslibbing Deurganckdok 2' for the period April 2007 – March 2008 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	
1.10	Sediment Balance: Three monthly report 1/4/2007 - 30/06/2007 (I/RA/11283/07.081/MSA)
1.11	Sediment Balance: Three monthly report 1/7/2007 – 30/09/2007 (I/RA/11283/07.082/MSA)
1.12	Sediment Balance: Three monthly report 1/10/2007 – 31/12/2007 (I/RA/11283/07.083/MSA)
1.13	Sediment Balance: Three monthly report 1/1/2007 – 31/03/2007 (I/RA/11283/07.084/MSA)
1.14	Annual Sediment Balance (I/RA/11283/07.085/MSA)
Factors contributing to salt and sediment distribution in Deurganckdok: Salt-Silt (OBS3A) & Frame measurements, Through tide measurements (SiltProfiling & ADCP) & Calibrations	
2.09	Calibration stationary equipment autumn (I/RA/11283/07.095/MSA)
2.10	Through tide measurement Siltprofiler winter (I/RA/11283/07.086/MSA)
2.11	Through tide measurement Salinity Profiling winter (I/RA/11283/07.087/MSA)
2.12	Through tide measurement Sediview winter (I/RA/11283/07.088/MSA)
2.13	Through tide measurement Sediview winter (I/RA/11283/07.089/MSA)
2.14	Through tide measurement Sediview winter (I/RA/11283/07.090/MSA)
2.15	Through tide measurement Siltprofiler (to be scheduled) (I/RA/11283/07.091/MSA)
2.16	Salt-Silt distribution Deurganckdok summer (21/6/2007 – 30/07/2007) (I/RA/11283/07.092/MSA)
2.17	Salt-Silt distribution & Frame Measurements Deurganckdok autumn (17/09/2007 - 10/12/2007) (I/RA/11283/07.093/MSA)
2.18	Salt-Silt distribution & Frame Measurements Deurganckdok winter (18/02/2008 - 31/3/2008) (I/RA/11283/07.094/MSA)
2.19	Calibration stationary & mobile equipment winter (I/RA/11283/07.096/MSA)

Report	Description
Boundary Conditions: Upriver Discharge, Salt concentration Scheldt, Bathymetric evolution in access channels, dredging activities in Lower Sea Scheldt and access channels	
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)
Analysis	
4.10	Analysis of Siltation Processes and Factors (I/RA/11283/07.102/MSA)

1.3.2. Measurement actions

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

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

In situ calibrations were conducted on several dates (15 March 2006; 14/04/2006; 23/06/2006; 18/09/2006 and 10/9/2007) to calibrate all turbidity and conductivity sensors (IMDC, 2006b & IMDC, 2007).

1.4. Structure of the report

This report is the factual data report of winter calibration measurements on the 10th of September, 2007. The first chapter comprises an introduction. The second chapter describes the measurement campaign and the equipment. Chapter 3 describes the course of the actual measurements. The measurement results and processed data are presented in Chapter 4, whereas chapter 5 gives the conclusion of the summer calibrations.

2. THE MEASUREMENT CAMPAIGN

2.1. Calibration Strategy

2.1.1. 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 2-1 gives an overview of all the instruments used for measurement of SSC in long term and through tide measurement campaigns.

Table 2-1: Overview of instruments measuring SS concentration

Instrument	***Quantity***	***Principle***	***Long term (LT) /Through Tide (TT)***
D&A Instruments OBS 3A*	9	Turbidity Backscatter Sensor	TT / LT
Siltprofiler* (Extinction Sensors)	2	Turbidity Extinction sensor	TT
SiltProfiler* (Seapoint Sensor)	1	Turbidity Backscatter Sensor	TT
Argus ASM-IV*	1	Turbidity Backscatter Sensor	LT
Aanderaa RCM-9* 0-500 NTU	6	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.

2.1.2. Salinity

Salinity is not measured directly but calculated using a UNESCO formula that incorporates conductivity, temperature and depth measurements (Unesco, 1991). 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.

2.2. Calibration set up

2.2.1. Frame set-up

A special frame was used to calibrate all mobile sensors and long-term sensors. 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 2-1: Calibration frame with double pump set-up

The next set up was realised. Two pumps have been used to calibrate the turbidity sensors. Pump discharge velocities have been tested in advance with dye ($KMnO_4$).

Table 2-2: Set up for calibration

Calibration 10/09/2007
2 pumps
8 OBS 3A (IMDC) 1 SiltProfiler (IMDC) 12 CTD-diver (IMDC) 1 Argus ASM IV (IMDC) 6 RCM-9: 4 IMDC (0-500 NTU) 2 AMT (0-500 NTU)

2.2.2. 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).

2.2.3. 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 which as such can be considered as pre-calibrated 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 each pump sampler for laboratory analysis. This procedure was carried out twice for each concentration.

2.2.4. Sample analysis

The NEN 6484 standard for total suspended sediment analysis was used for all water samples. On a limited number of samples the sample was sieved over a 63 µm filter to determine the sand content of these samples.

2.2.5. Validation, Drifting and extra Sensors

It has to be mentioned that the SiltProfiler and the Argus have 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.

These instruments have a high concentration range and are difficult to calibrate in situ, therefore these instruments were not be calibrated as such, and were 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.

While processing the data it appeared that one of the OBS 3A instruments (sn 221) did not measure during the calibration measurements. However when the instrument was set up this didn’t show. Consequently this instrument was not calibrated on 10/09/2007 and will be calibrated during the next calibration.

2.3. Instruments

2.3.1. 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.

2.3.2. 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 2-2: High Resolution SiltProfiler

The sensors are:

- one 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).
- one 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.

2.3.3. Argus ASM-IV

The Argus ASM-IV is used to detect the vertical structure of the suspended sediment concentration in the zone of 0-1 meter above the bed.

The ARGUS ASM-IV was developed for high resolution measuring of accretion and erosion of the riverbed. (ARGUS UMWELT-MEATECHNIK, 2005). The instrument operates with backscatter infrared laser sensors embedded in a stainless steel rod. The 96 sensors are placed on an active board at a distance of 0.01m of each other. There are three additional sensors: an inclinometer, a pressure gauge and a on board temperature sensor.

A battery powered central unit in the head of the instrument controls activation and power supply of the sensors as well as the transmission of the signals. The sealed in unit consists of a microprocessor, a data memory, the additional sensors and the energy supply.

The measurement range of the ARGUS ASM-IV is from 0 to 5000mg/l. The instrument was calibrated by the manufacturer in a laboratory set up as mentioned in § 2.2.5.

APPENDIX A gives more details on the ARGUS ASM-IV (ARGUS UMWELT-MEATECHNIK, 2005; Gilpin 2003).

Figure 2-3: ARGUS ASM-IV

2.3.4. 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.

2.3.5. CTD-Diver datalogger

CTD-Diver dataloggers were used.

Measured parameters by the CTD-Diver datalogger are:

- temperature (℃),
- conductivity (µS/cm)
- absolute depth (m)

APPENDIX A gives more details on the CTD-Diver datalogger.

2.3.6. 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.

3. COURSE OF THE MEASUREMENTS

3.1. Hydrometeorological conditions

Measurements were conducted during flood. The vertical tide is given for the tidal gauge at Liefkenshoek (see Table 3-1).

Table 3-1: High and Low Tide at Liefkenshoek Tidal Gauge on 10/09/2007

Liefkenshoek Tidal Gauge		
	10 september 2007	
	Time [MET]	Water level [m TAW]
HW (1)	2:50	5.37
LW (2)	9:10	0.43
HW (3)	15:10	5.72
LW (4)	21:30	0.57

Meteorological data at Deurne was obtained from the Weather Underground website (Wunderground, 2007). Information of the Royal Meteorological Institute is not yet available.

On the 10th of September, the air temperature varied between 10 and 18 °C. The wind blew at an average velocity of 11 km/h swinging from SW to NW. There was no rain (Wunderground, 2007).

3.2. Locations

The following locations were visited to obtain the necessary concentrations (see Figure 3-1).

Table 3-2: Coordinates Calibration locations [UTM ED50]

nr	Name	EASTING	NORTHING
1	Lillo	589751	5684437
2	Deurganckdok Middle	588223	5684026
3	Deurganckdok Deep End	587903	5682679
4	Deurganckdok Entrance	588514	5684481
5	Liefkenshoek	589731	5683787

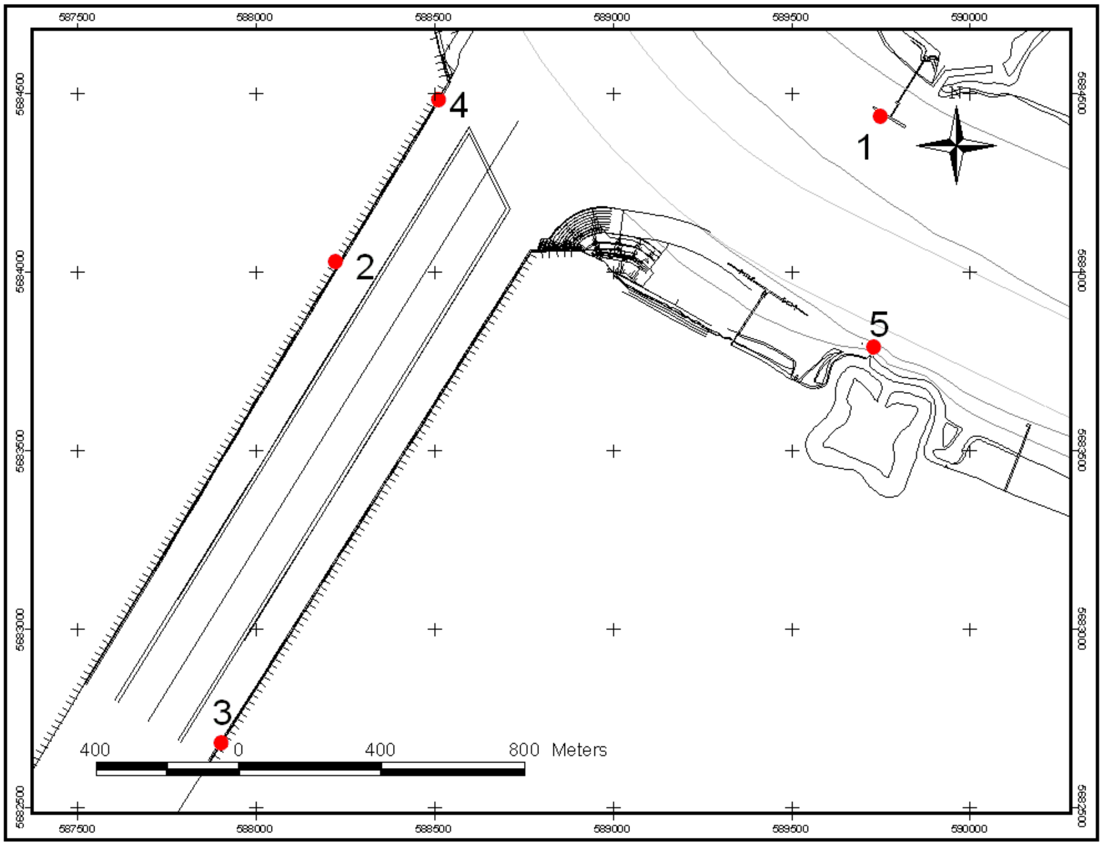


Figure 3-1: Calibration Locations

3.3. Measured Concentrations

Direct read out of one of the instruments allowed to aim for the predetermined concentrations (see § 2.2.3).

The following concentration ranges were obtained:

10 – 15 – 50 – 70 – 120 – 150 – 200 – 300 – 340 mg/l.

4. PROCESSING OF DATASETS

4.1. Introduction

Sand content of samples will be discussed in §4.2. The SSC calibration results are given in the next paragraph (§4.3). Paragraph 4.4 and 4.5 covers SiltProfiler calibration checks, respectively Argus ASM IV calibration checks. Conductivity and temperature comparisons are made in §4.6.

4.2. Sand content of samples

A number of water samples (varying concentrations) taken on 10 September 2007 were analysed for sand content. Figure 4-1 and Table 4-1 show the results of this analysis. It can be seen that the sand content (mg/l) is negligible compared to the SSC (mg/l).

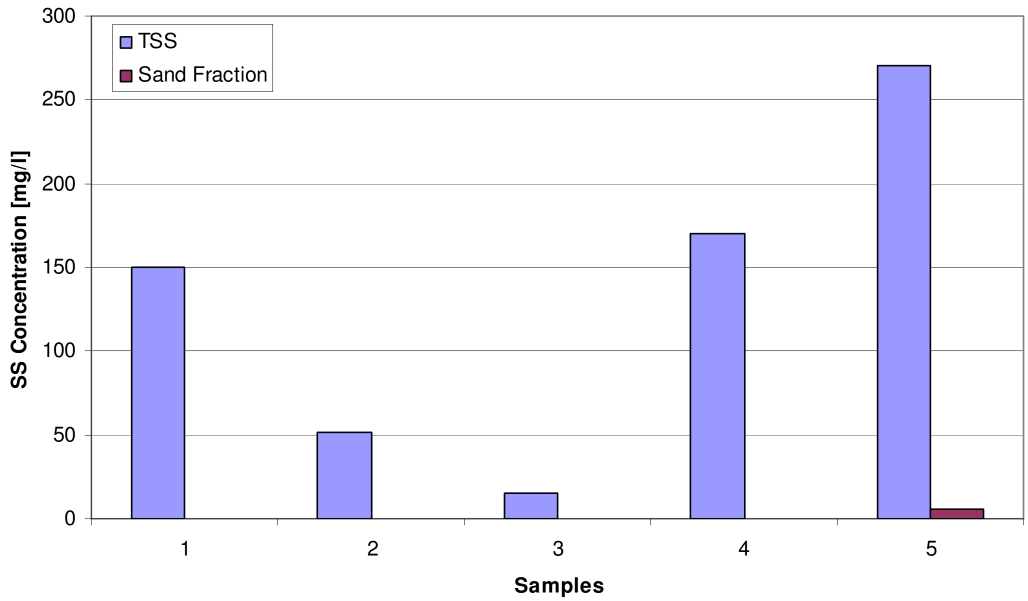


Figure 4-1: Sand content of Selected Samples

Table 4-1: Overview of Total SS Concentration [mg/l], Sand Concentration [>63 µm mg/l] and mass percentage sand in samples

Suspended Sediment Concentration [mg/l]		**% Sand**
Total SS Conc.	***Sand Content(>63µm)***	
150	< 5.0	-
52	< 5.0	-
15	< 5.0	-
170	< 5.0	-
270	6.2	2.30

4.3. SSC Calibration results

The calibration results for all sensors are given in Table 4-2. In this table the conversion formulas are given to convert turbidity counts, NTU, FTU to SSC [mg/l].

It was chosen to use second order fits to define the calibration curves. The R square value is added as well.

The calibration graphs show the suspended sediment sample concentration in mg/l on the Y-axis and the instrument readout in AD counts, or Turbidity Units (NTU/FTU) on the X-axis and can be found in APPENDIX B.

Table 4-2: Overview of Calibration Results for 10/09/2007 including instrument description, formulas, R^2 and RMSE values and remarks

Instrument	Serial no.	Range	Unit	Function	R^2	RMSE	Remarks
OBS3A	185	0-2000	FTU	$y = 0.0716x^2 + 8.6651x - 3.8252$	$R^2 = 0.9848$	13.13	IMDC
OBS3A	222	0-500	FTU	$y = -0.0005x^2 + 2.3009x - 7.6556$	$R^2 = 0.9675$	19.23	IMDC
OBS3A	223	0-500	FTU	$y = 0.0016x^2 + 2.117x - 3.7044$	$R^2 = 0.9858$	12.71	IMDC
OBS3A	224	0-2000	FTU	$y = 0.0007x^2 + 1.8659x - 3.6476$	$R^2 = 0.9881$	11.62	IMDC
OBS3A	225	0-2000	FTU	$y = 0.0008x^2 + 1.8788x - 4.287$	$R^2 = 0.9648$	20.02	IMDC
OBS3A	247	0-2000	FTU	$y = 0.0009x^2 + 1.8937x - 5.9214$	$R^2 = 0.9760$	16.53	IMDC
OBS3A	261	0-500	FTU	$y = 0.0005x^2 + 2.3007x - 5.5177$	$R^2 = 0.9945$	7.91	IMDC
OBS3A	262	0-2000	FTU	$y = 0.0021x^2 + 1.6874x - 4.1322$	$R^2 = 0.9772$	16.10	IMDC
RCM-9	0579_560	0-500	NTU	$y = 0.0012x^2 + 2.745x - 13.187$	$R^2 = 0.9765$	16.36	AMT
RCM-9	1153_1019	0-500	NTU	$y = 0.0099x^2 + 1.6274x - 5.1173$	$R^2 = 0.9970$	5.81	AMT
RCM-9	1165_1025	0-500	NTU	$y = 0.0102x^2 + 1.3724x - 6.5228$	$R^2 = 0.9978$	4.97	IMDC
RCM-9	1220_1052	0-500	NTU	$y = 0.0085x^2 + 1.1845x - 2.2841$	$R^2 = 0.9924$	9.31	IMDC
RCM-9	1225_1051	0-500	NTU	$y = 0.0068x^2 + 1.4937x - 5.7035$	$R^2 = 0.9954$	7.25	IMDC
RCM-9	1229_1054	0-500	NTU	$y = 0.0091x^2 + 1.2548x - 1.5907$	$R^2 = 0.9965$	6.31	IMDC

Instrument	Serial no.	Range	Unit	Function	R^2	RMSE	Remarks
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			
ARGUS ASM IV	sn61			horizontal variation, timeseries, comparison calibrated concentrations			

4.4. Manufacturer's Calibration & Cross-check of Siltprofiler

4.4.1. Manufacturer's calibration of Silt Profiler

The manufacturer's calibration was done at WL|Delft Hydraulics 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 0.28386 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℃, 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 APPENDIX B.

Table 4-3: 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	$Y= 0.000158x^2+ 0.54808x+1.2$	0.999
SiltProfiler – Low range	$Y = 0.000207x^2 + 0.42995x – 267.3$	0.999
SiltProfiler – High range	$Y=-4.93.10^{-7}x^3 + 0.00364x^2 + 2.74479x – 124.1$	0.999

4.4.2. Cross-check of SiltProfiler

The Siltprofiler was cross-checked during the in situ calibration. Figure 4-2 shows the comparison of the Siltprofiler measurement for 10 September 2007. The X-axis shows the sample SSC, the Y-axis shows the Siltprofiler SSC (determined by the manufacturer's calibration).

Turbidity values were converted to suspended sediment concentration using the equation of the calibration curve determined at the pre-calibration done by WL|Delft. These were compared to sample concentrations. Only Seapoint measurements were used, because of the low concentrations.

There should be mentioned that due to some problems with the wireless connection the communication cable was used to retrieve the data from the instrument. Measured values were written down in real time. Consequently a time-shift of some seconds may occur between the intake of the water sample and the measurement due to the pumping speed.

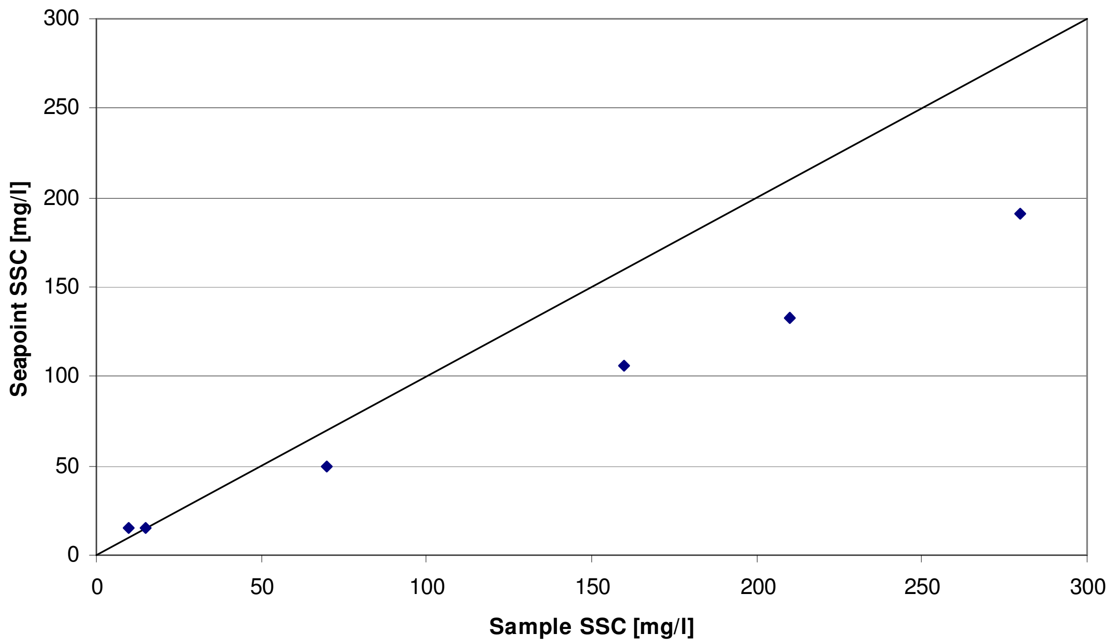


Figure 4-2:Comparison of Sample SSC to SiltProfiler SSC for 10 September 2007

4.5. Manufacturer's Calibration & Cross check of Argus ASM-IV

4.5.1. Manufacturer's calibration of Argus ASM IV

The manufacturer's calibration was completed by Argus GESELLSCHAFT FUER UMWELTMESSTECHNIK MBH. Because of the special nature of this instrument, 96 OBS sensors spread out over a length of a meter a specialized calibration tank was used, that can be seen in APPENDIX A.

Wet sediment was sieved with a 63 µm filter.. The resulting mud was used as base material. In the calibration tank measurements were made at various concentrations between 0-10000 mg/l.

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℃, cooled and weighed (NEN 6484).

The calibration graph can be found in APPENDIX B- B.2. The calibration graph of the ARGUS ASM IV sn 79 is also given. This instrument was still deployed for other measurements at the moment of the calibration measurements. Calibration tank measurements for the ARGUS ASM IV sn 79 were made at various concentration between 0-5000 mg/l.

4.5.2. Cross check of Argus ASM IV

The ARGUS ASM IV was also tested for cross-checking the manufacturer's calibration. It must be mentioned that this instrument is very hard to calibrate in situ, because of its size, shape and the spatial spread of its sensors. Therefore the cross-check was limited to concentrations which were spread homogenously throughout the water column, being low concentrations (stable conditions).

Figure 4-3 shows the comparison of the Argus measurement in stable conditions for 10 september 2007. The X-axis shows the Sample SSC, the Y-axis shows the average Argus SSC of all the 96 sensors (determined by the manufacturer's calibration).

It can be seen that at low concentrations the manufacturer's calibration and the in situ calibration correspond (near the 1:1 diagonal).

To illustrate the difficulty in this comparison, and its interpretation, the next figure (Figure 4-4) shows a time series in a high concentration for a sensor on the left side, middle and right side of the ARGUS. The ARGUS was positioned horizontally, so this graph shows a temporal variation for 3 sensors, two at each end of the instrument (left (sensor 1) right (sensor 96), and one in the middle (sensor 48). The main trend of the measurements is comparable, but previous calibrations showed that the higher the concentration of suspended sediment, the higher the difference between the measurements of the sensors.

Figure 4-5 shows the horizontal variation of the SSC environment at a low and a high sample concentration. As the Argus was positioned horizontally, this figure shows the horizontal variation between sensor 96 and sensor 1. Both concentrations show relative constant measurement values for all backscatter sensors.

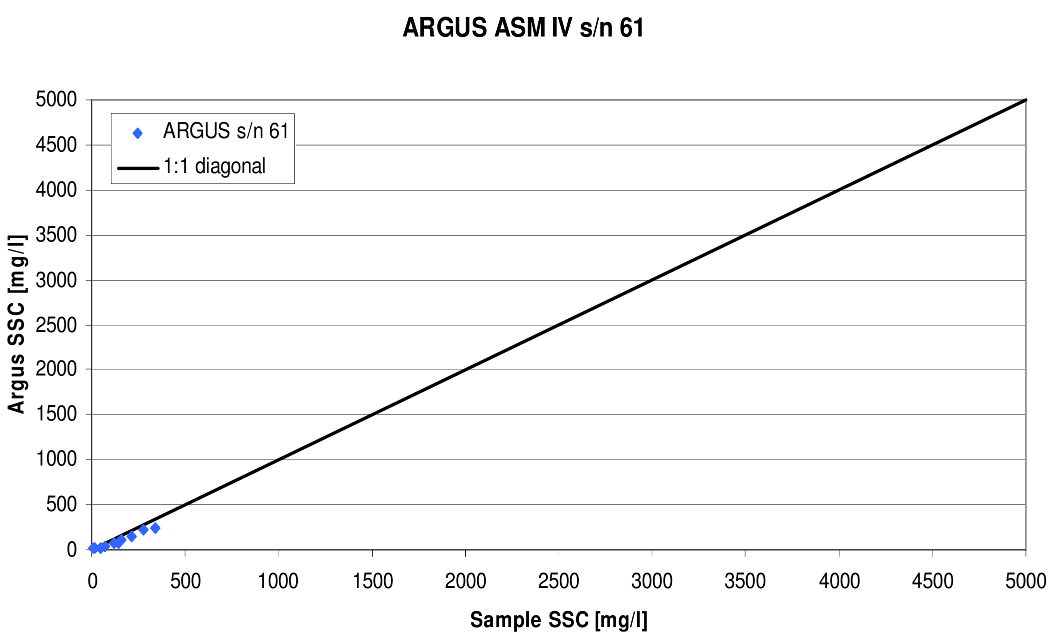


Figure 4-3: Comparison of Sample SSC to Argus SSC for s/n 61

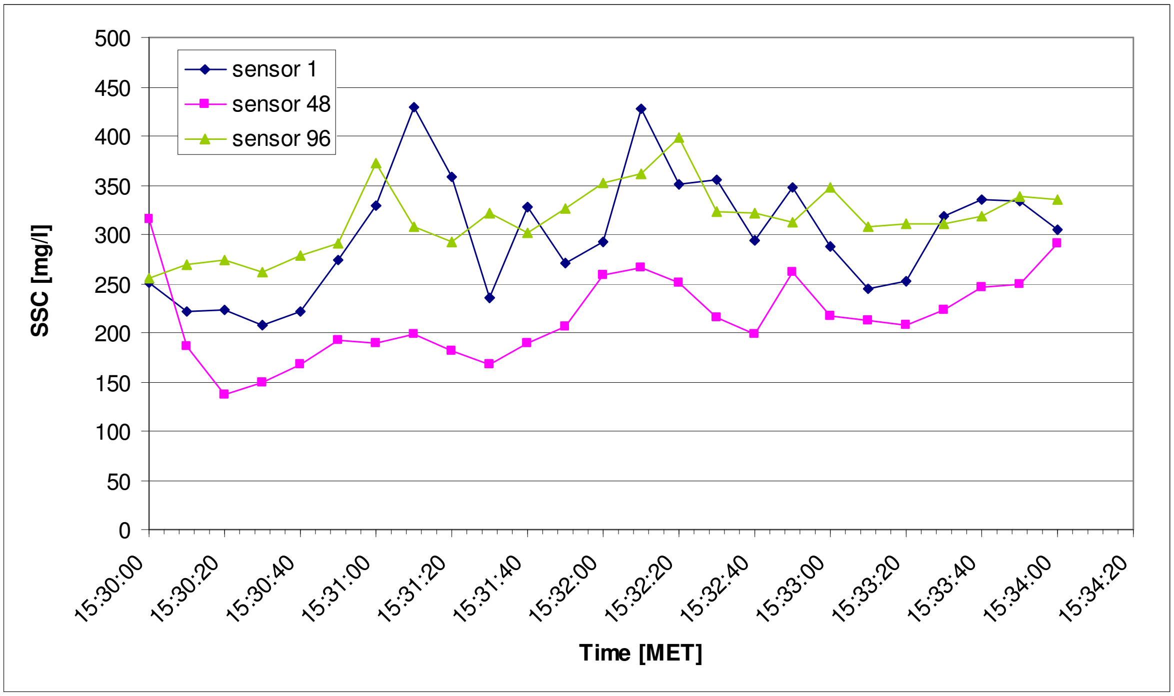
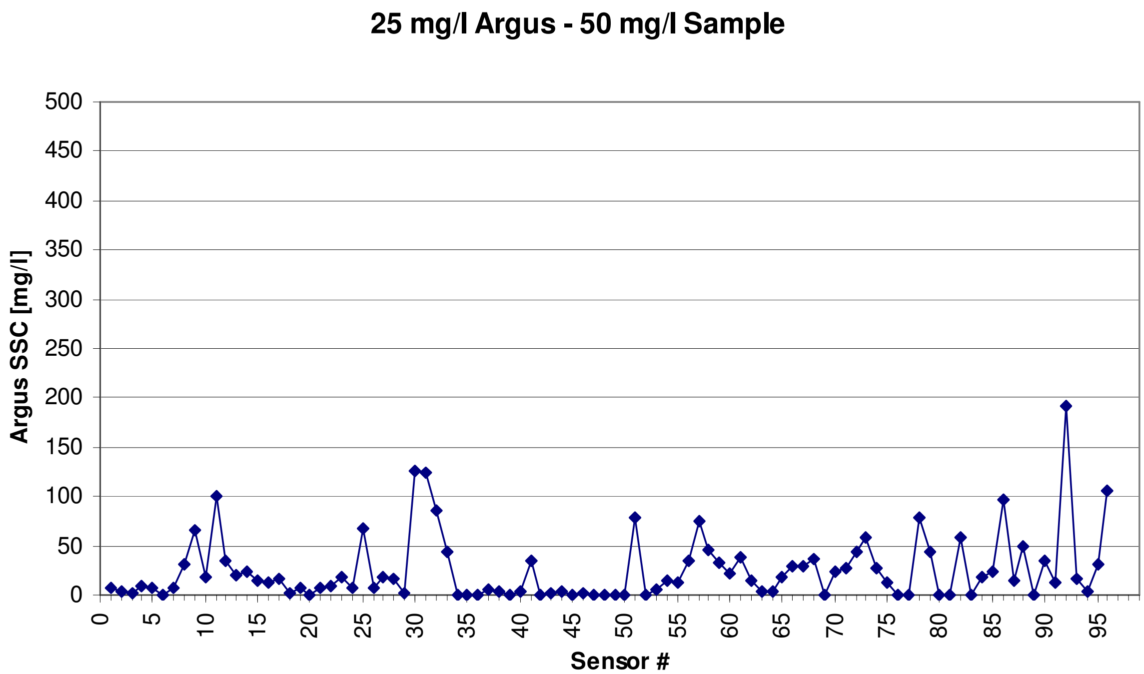


Figure 4-4: Timeseries in a high SSC environment (340 mg) for 3 sensors of Argus: X-axis shows time, Y-axis shows SSC: Argus sn 61.



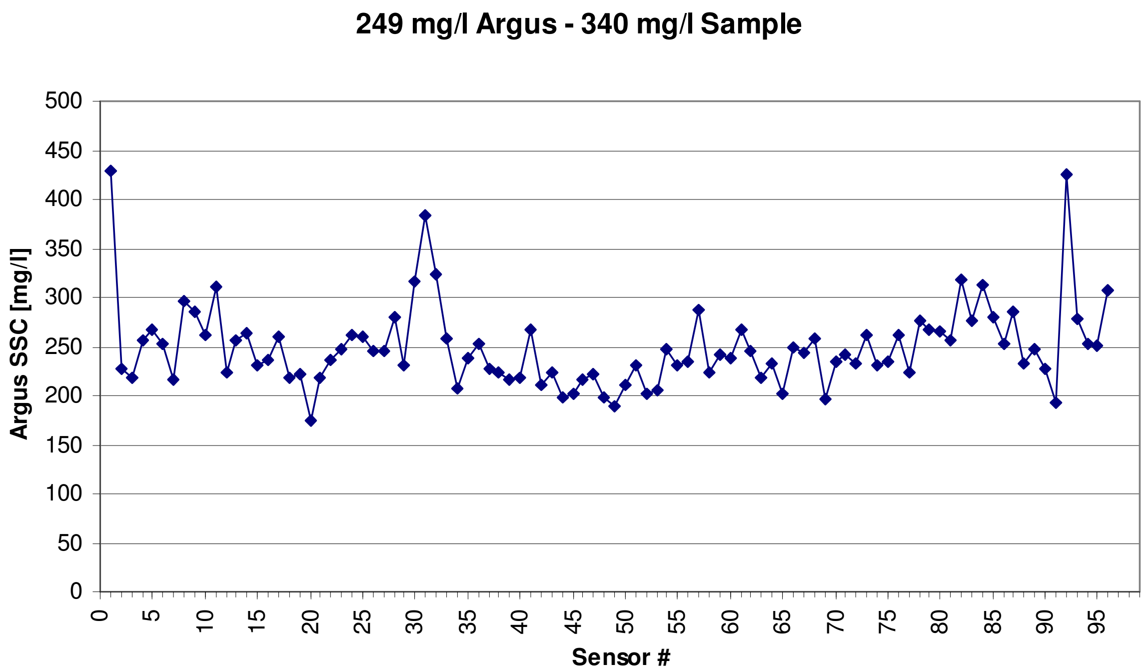


Figure 4-5: Horizontal variation of the SSC during a sampling event at low (top) and high (bottom) concentrations for Argus s/n 61

4.6. Conductivity, temperature and salinity 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.

4.6.1. Calibration day 1: 23 June 2006

Figure 4-6 shows the conductivity read out of all OBS 3A instruments deployed at the same level on the measurement frame. Ony one OBS 3A instrument measured lower conductivity values. This was the instrument that was used for the read- out in real time. In the mean time the conductivity sensor of this instrument was replaced. So for further analyse of the conductivity this sensor will not be taken into account.

Figure 4-7 shows the conductivity read out of 6 RCM-9 instruments deployed at the same level on the measurement frame. All IMDC RCM-9 conductivity sensors measure similar conductivity values. The two RCM-9 conductivity sensors installed on the instruments of AMT give al slightly higher value

Figure 4-8 shows the conductivity read out of all the CTD – Divers deployed at the same level on the measurement frame. All sensors measure similar conductivity values.

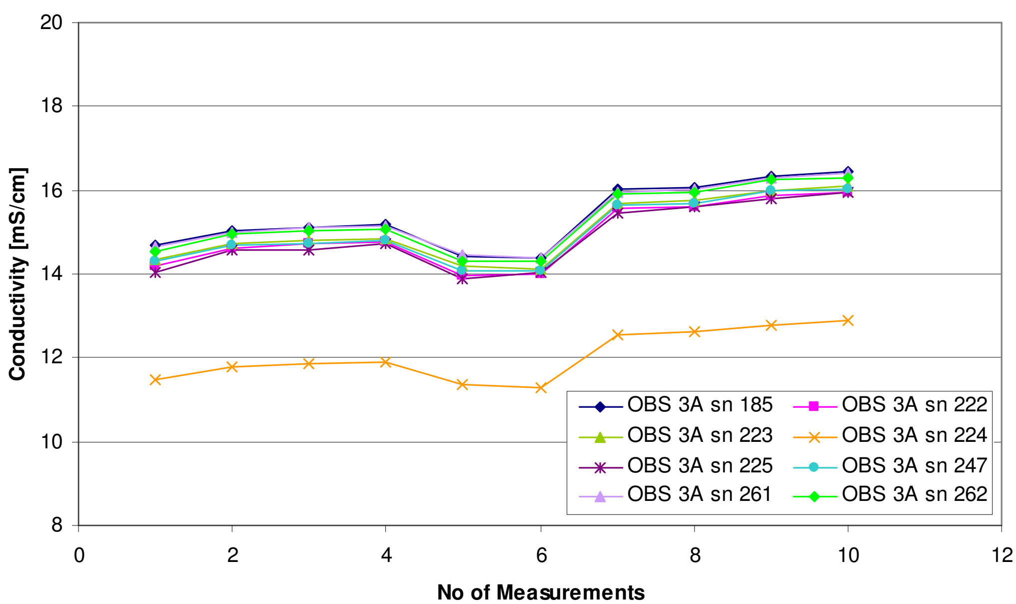


Figure 4-6: OBS 3A Conductivity Measurements

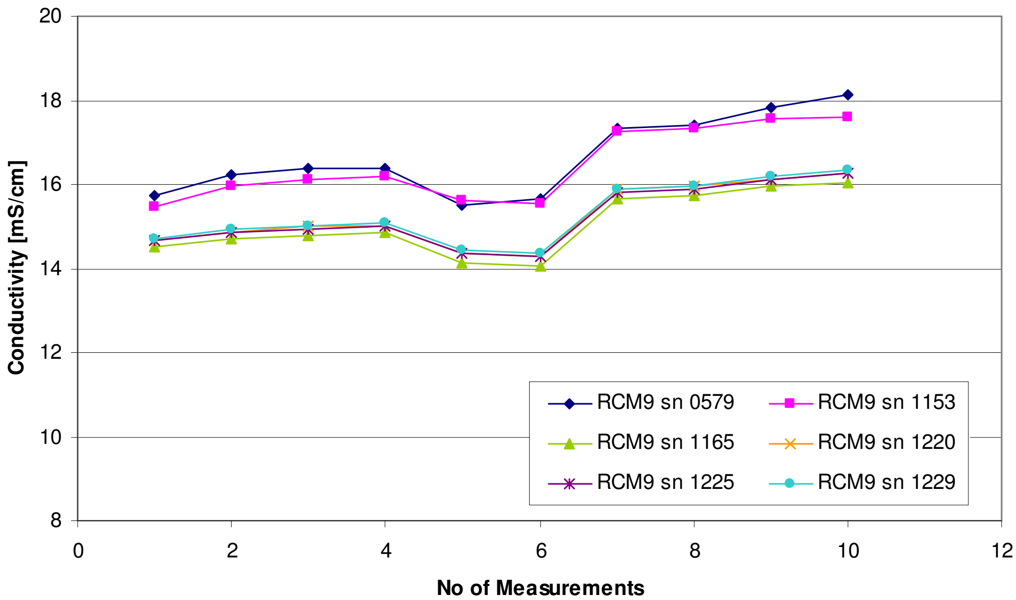


Figure 4-7: RCM-9 Conductivity Measurements

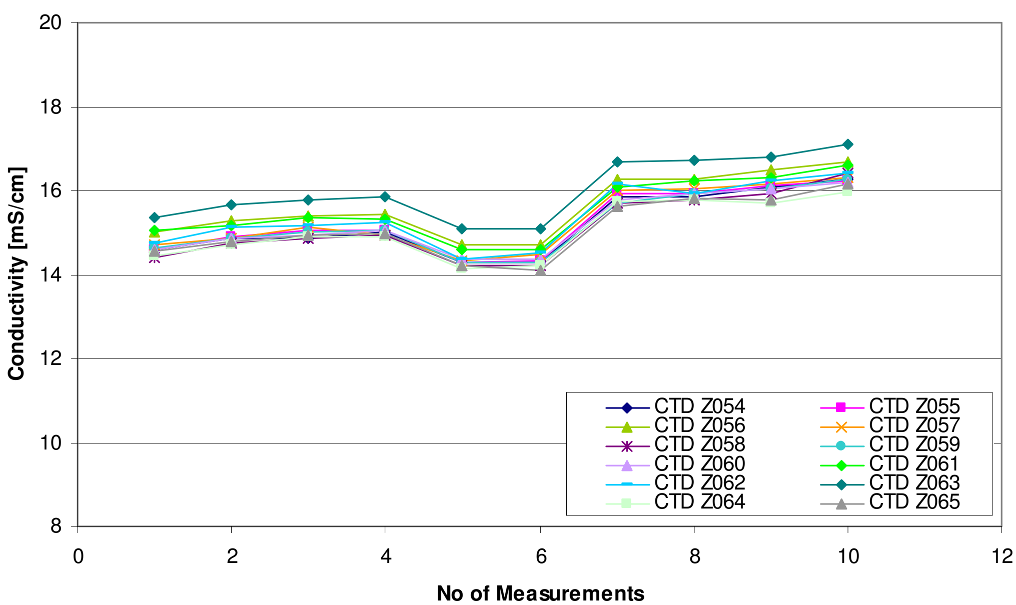


Figure 4-8: CTD-Diver Conductivity Measurements

Figure 4-9 shows all conductivity measurements and the average conductivity on 10/09/07. All instruments show similar trends and are spread out over 2 mS/cm, each instrument is fairly consistent respective to the average.

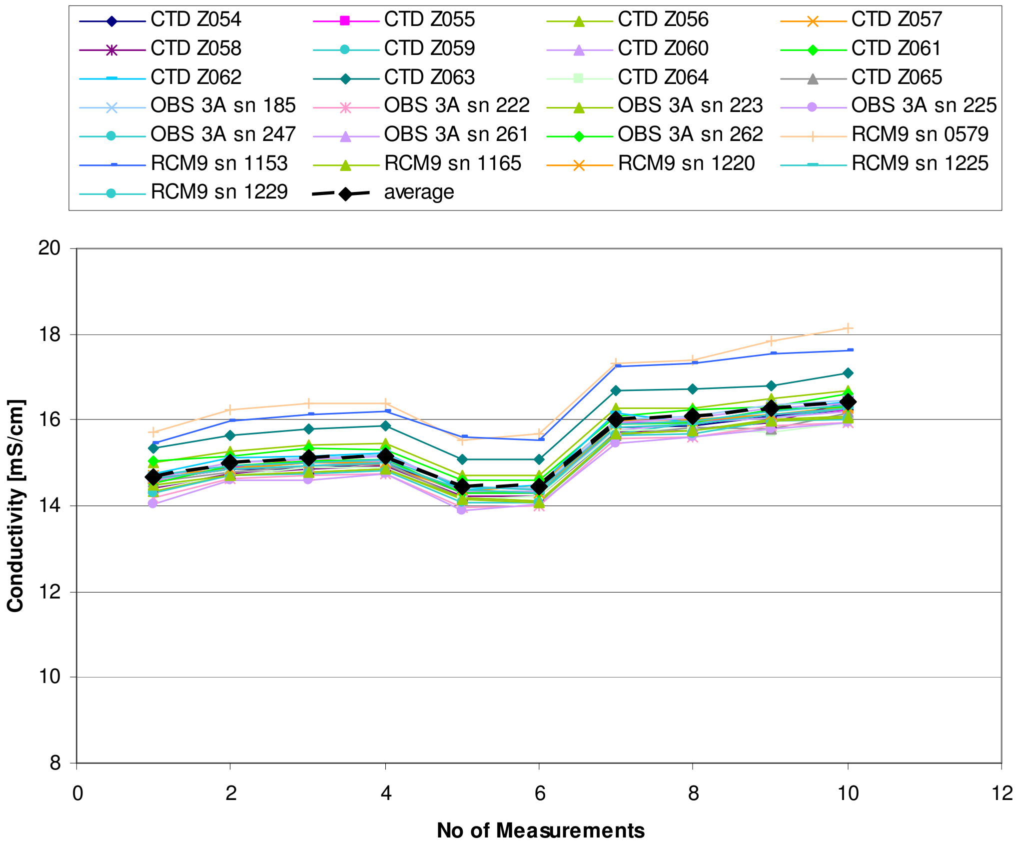


Figure 4-9: All Conductivity Measurements 23/06/2006

When comparing the conductivity measurements a good resemblance can be seen. Only the RCM-9 sn 0579, the RCM-9 sn 1153 and the CTD-Diver sn Z063 measure slightly higher values.

The Root Mean Square Error (RMSE) was calculated for each correctly working instrument. The average of every conductivity measurement was calculated using all correctly working conductivity sensors. The RMSE was calculated for each instrument comparing its measurement to the average conductivity measurement (this average is based on all CORRECT measurements).

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

X_i = measured conductivity value for a given instrument

$\overline{X}$ = average conductivity value for each measurement

n = number of measurements

Table 4-4: RMSE values [mS/cm] for Conductivity sensors

Instrument	***RMSE***	***Instrument***	***RMSE***
OBS3A 185	0.05	**CTD Z054**	0.18
OBS3A 222	0.45	**CTD Z055**	0.13
OBS3A 223	0.31	**CTD Z056**	0.26
OBS3A 224	3.32	**CTD Z057**	0.12
OBS3A 225	0.50	**CTD Z058**	0.26
OBS3A 247	0.37	**CTD Z059**	0.18
OBS3A 261	0.04	**CTD Z060**	0.17
OBS3A 262	0.11	**CTD Z061**	0.18
RCM-9 sn 0579	1.31	**CTD Z062**	0.09
RCM-9 sn 1153	1.11	**CTD Z063**	0.64
RCM-9 sn 1165	0.32	**CTD Z064**	0.34
RCM-9 sn 1220	0.13	**CTD Z065**	0.29
RCM-9 sn 1225	0.15		
RCM-9 sn 1229	0.09		

Temperature measurements were compared as well. Figure 4-10, Figure 4-11 and Figure 4-12 show the temperature measurements of the OBS 3A, the RCM-9 and the CTD-Diver instruments. The CTD-Diver temperature measurements show a spread of 0.2℃ up to 0.3 ℃, which is the largest but still is small. All temperature sensors are compared in Figure 4-13. All measurements follow the same trend, except for the third measurement where some CTD-Divers measure lower values. RMSE values are given in Table 4-5.

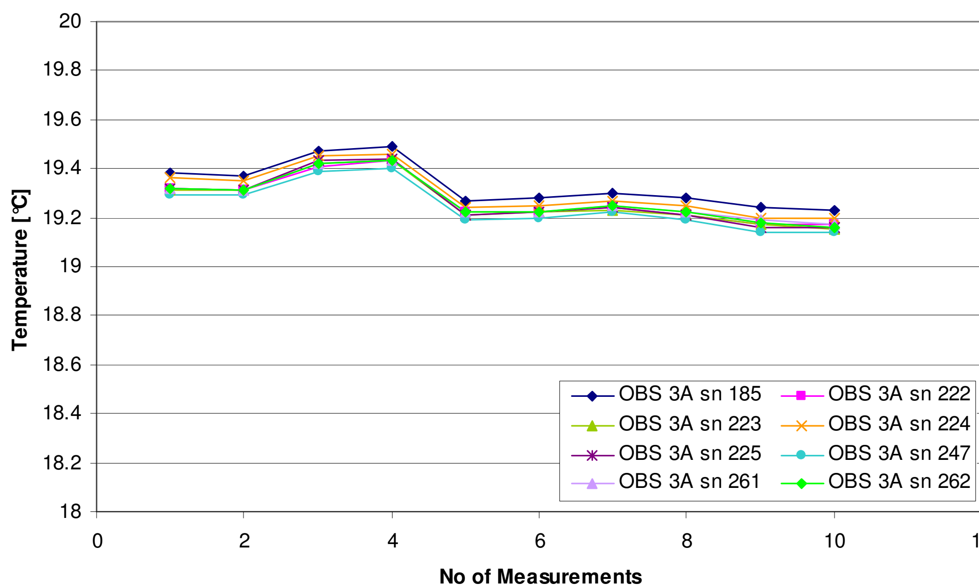


Figure 4-10: OBS 3A Temperature Measurements

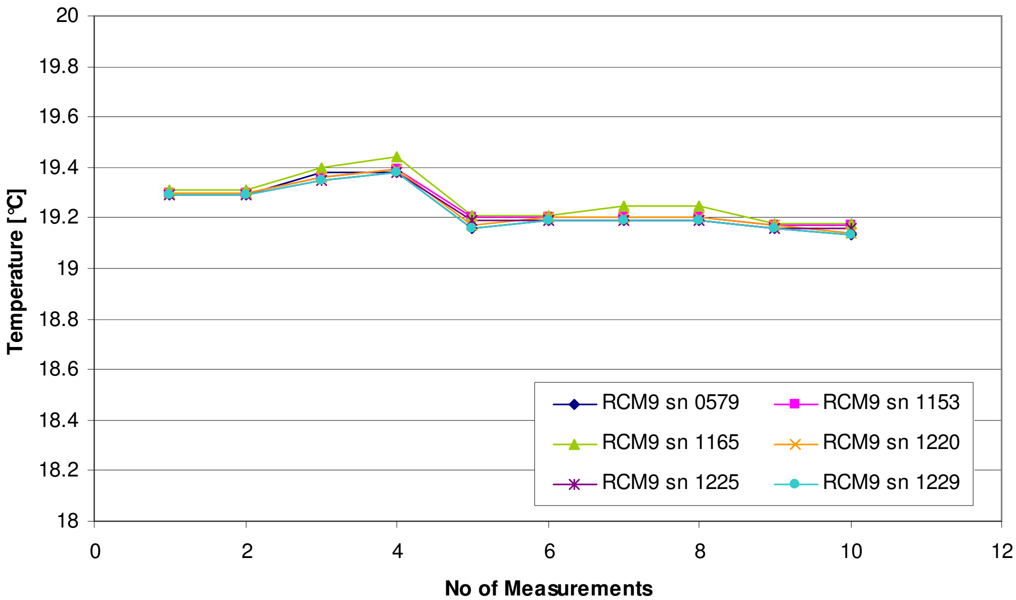


Figure 4-11: RCM-9 Temperature Measurements

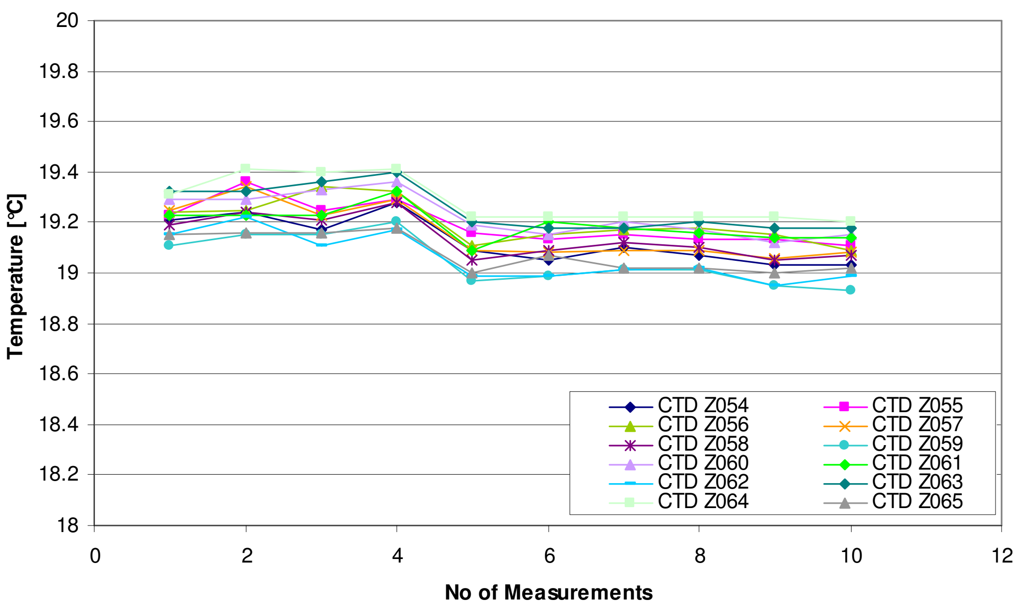


Figure 4-12: CTD-Diver Temperature Measurements

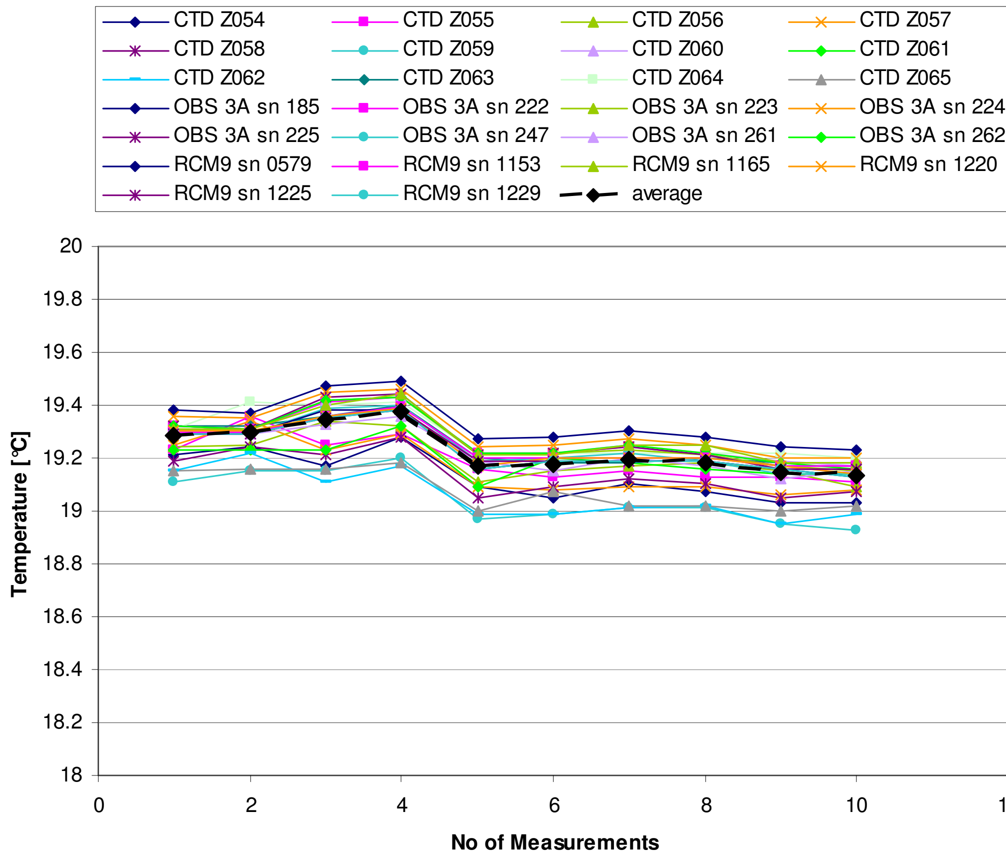


Figure 4-13: Temperature measurements

Table 4-5: RMSE values [°C] temperature sensors 23/06/2006

Instrument	***RMSE***	***Instrument***	***RMSE***
OBS3A 185	0.10	**CTD Z054**	0.11
OBS3A 222	0.04	**CTD Z055**	0.06
OBS3A 223	0.04	**CTD Z056**	0.04
OBS3A 224	0.07	**CTD Z057**	0.08
OBS3A 225	0.05	**CTD Z058**	0.09
OBS3A 247	0.02	**CTD Z059**	0.18
OBS3A 261	0.05	**CTD Z060**	0.02
OBS3A 262	0.05	**CTD Z061**	0.06
RCM-9 sn 0579	0.01	**CTD Z062**	0.17
RCM-9 sn 1153	0.02	**CTD Z063**	0.03
RCM-9 sn 1165	0.05	**CTD Z064**	0.06
RCM-9 sn 1220	0.02	**CTD Z065**	0.15
RCM-9 sn 1225	0.01		
RCM-9 sn 1229	0.01		

Salinity is also calculated and compared between the different instruments. The RMSE values are given in Table 4-6. A graph with calculated salinity values is given together with the average salinity value in Figure 4-14.

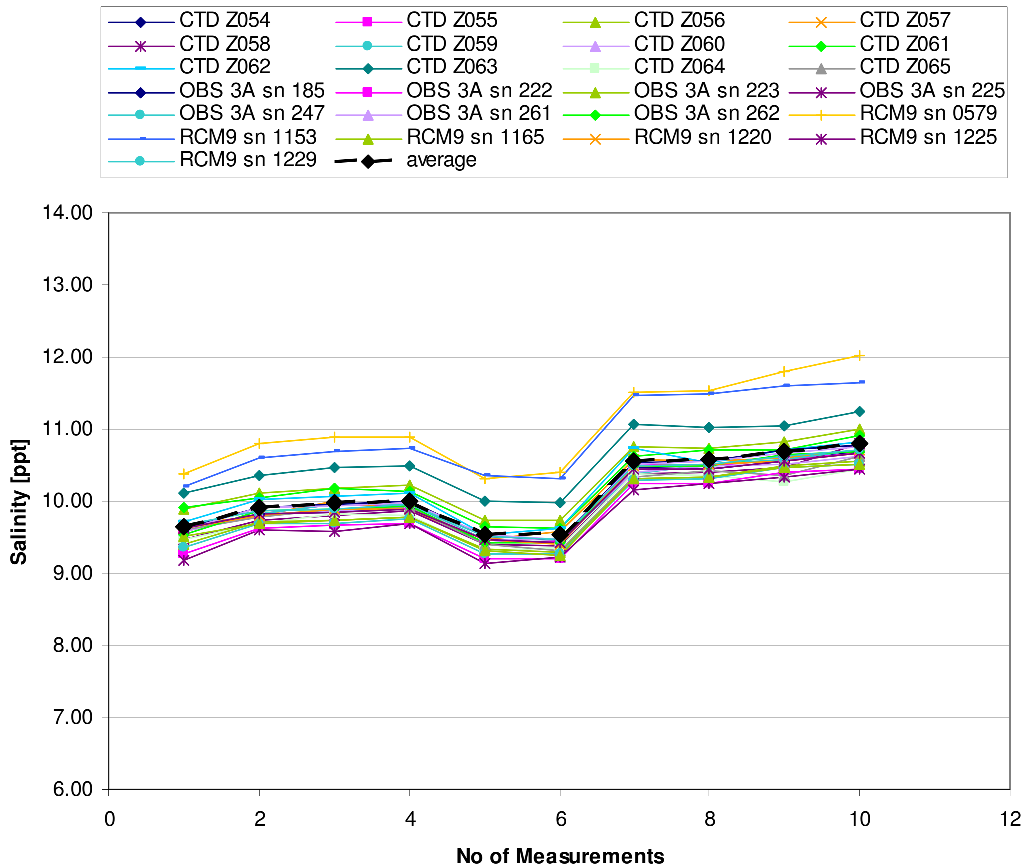


Figure 4-14: Salinity values 23/06/06

Table 4-6: RMSE values [ppt] salinity

Instrument	***RMSE***	***Instrument***	***RMSE***
OBS3A 185	0.03	**CTD Z054**	0.11
OBS3A 222	0.33	**CTD Z055**	0.09
OBS3A 223	0.23	**CTD Z056**	0.19
OBS3A 225	0.37	**CTD Z057**	0.08
OBS3A 247	0.27	**CTD Z058**	0.17
OBS3A 261	0.04	**CTD Z059**	0.09
OBS3A 262	0.09	**CTD Z060**	0.12
RCM-9 sn 0579	0.94	**CTD Z061**	0.14
RCM-9 sn 1153	0.79	**CTD Z062**	0.08
RCM-9 sn 1165	0.24	**CTD Z063**	0.45
RCM-9 sn 1220	0.11	**CTD Z064**	0.25
RCM-9 sn 1225	0.10	**CTD Z065**	0.18
RCM-9 sn 1229	0.06		

4.6.2. Cross-calibration SiltProfiler

Due to the read out in real-time of the SiltProfiler only few values are available. Therefore no cross calibration equation is derived. Comparison of the conductivity measured by the SiltProfiler and the average conductivity, calculated as the average of the conductivity measurements by the several instruments that measured conductivity, is shown in Figure 4-15. A cross calibration is needed. When deploying the SiltProfiler for throughtide measurements a CTD diver will be attached for cross-calibration purposes.

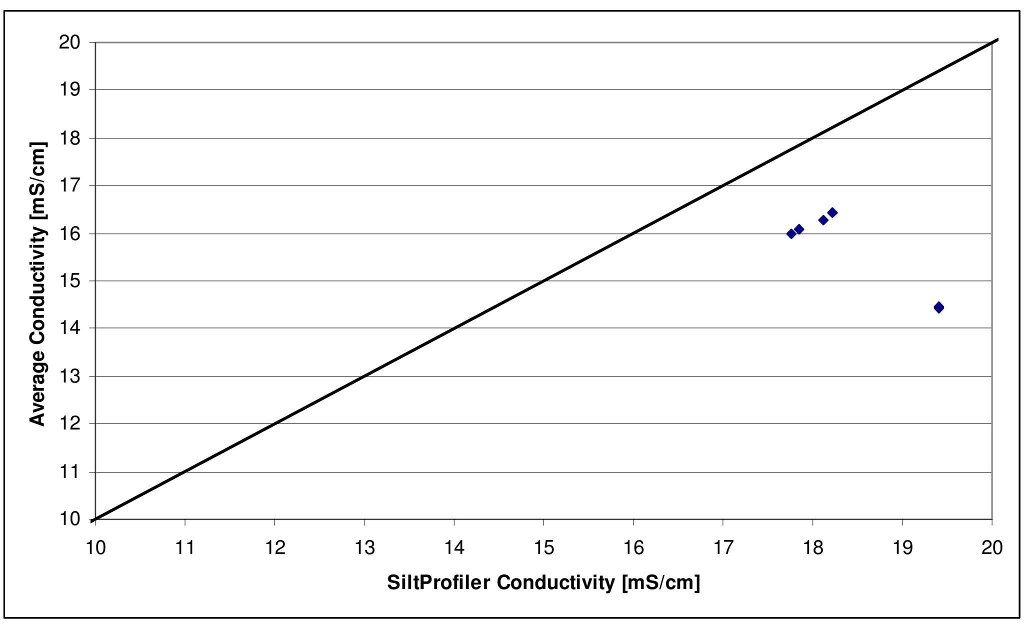


Figure 4-15: Comparison Conductivity Measurements of the (SiltProfiler and averag)

5. CONCLUSION OF AUTUMN CALIBRATION

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 340 mg/l.

RMSE values for the SSC were within acceptable boundaries (maximum 20 mg/l).

Higher 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 sand content of the suspended sediment samples is negligible.

The conductivity cross-check was limited due to the small range of conductivities that were measured. The conductivity comparison of 12 CTD-Divers, 8 OBS 3A instruments and 6 RCM-9 instruments showed similar trends but the range of values during each measurement varied between 1.5 to 2 mS/cm. The RMSE of these instruments varied between 0.1 and 0.7 mS/cm, except for two RCM-9 instruments that constantly measured higher values.. It can be seen in Figure 4-9 that every instrument is quite consistent in relation to the average of the conductivity measurements.

Temperature measurements were also compared. No large discrepancies were found. All RMSE values for the instruments were lower than 0.12 ℃. All together the temperature measurements by each instrument are acceptable.

The salinity RMSE values were a bit smaller when compared to the conductivity RMSE values. Again the same two RCM-9 instruments had higher values compared to the other instruments measuring conductivity and temperature.

6. REFERENCES

ABB Instrumentation (2005) Principles of a Nephelometric Turbidity Monitor.

ARGUS UMWELT-MEATECHNIK (2005), ASM-IV-laser, ARGUS surface meter manual, 31p.

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

IMDC (2006b). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 7.4 23/3 Parel 2 – Schelle (I/RA/11291/06.097/MSA), in opdracht van AWZ.

IMDC (2007). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 12 Report concerning the presence of HCBS layers in the Scheldt river (I/RA/11291/06.109/MSA), in opdracht van AWZ.

Unesco (1991). Processing of Oceanographic Station Data.

Wunderground (2007).Weather Underground: www.wunderground.com.

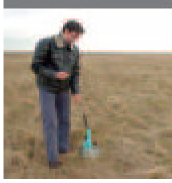
APPENDIX A.

MEASUREMENT EQUIPMENT

A.1 CTD-Diver datalogger

CTD-Diver datalogger

Schlumberger WATER SERVICES

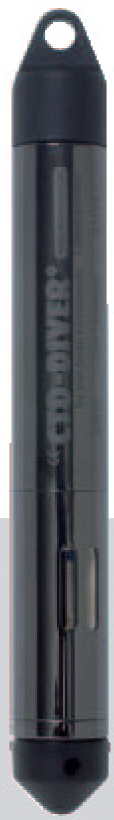


Applications

- Aquifer recharge projects
- Saltwater intrusion projects
- Surveillance against (illegal) discharges
- Surveillance on waste disposal sites
- Monitoring groundwater or surface water quality

CTD-Diver: reliable in all conditions

Where there is a need to monitor not only groundwater levels but also salinization, salt-water intrusion or contamination in the case of (illegal) discharges and landfill sites, the CTD-Diver is the instrument of choice. Besides a pressure and temperature sensor, the CTD-Diver has a four-electrode conductivity sensor for determining conductivity across a substantial measurement range (0-80 mS/cm). For each measurement, the date and time, groundwater level, temperature and conductivity are recorded. There are two options for conductivity measurement: display the measured conductivity or a specific conductivity at 25 °C. The CTD-Diver is accommodated in a ceramic casing which is resistant to corrosive conditions. The CTD-Diver has a memory with a maximum storage capacity of 16,000 measurement data per parameter.



Highlights:

- 3 year warranty
- Long-term and frequent measurements
- Various measurement methods:
  - fixed
  - event dependent
  - pumping tests
- Simple calibration
- Temperature corrected measurement
- Reliable and accurate measurement data
- Compact size
- Robust construction:
  - ceramic
  - corrosion resistant
- Measures three parameters:
  - conductivity
  - temperature
  - pressure

Specifications:

Dimensions	Ø22 mm x 183 mm
Memory	16,000 measurements (non-volatile)
Sample rate *	0.5 sec to 99 hours
Housing material	ceramic (ZrO_2)
Temperature range	-20 °C to 80 °C
- accuracy	±0.1 °C
- resolution	0.01 °C
Conductivity:	
- range	0 to 80 mS/cm
- accuracy	±1% of reading
- resolution	0.1% of reading
Battery life	10 years (depending on use)
Weight	150 grams

CTD-Diver® Technical specifications (pressure)

Type	DI 261	DI 263	DI 265	DI 500 (Baro)
Range	10 m H_2O	30 m H_2O	100 m H_2O	1.5 m H_2O
- accuracy**	1 cm H_2O	3 cm H_2O	10 cm H_2O	0.5 cm H_2O
- resolution	0.2 cm H_2O	0.6 cm H_2O	2 cm H_2O	0.1 cm H_2O

* various measuring methods available (fixed, event based and pumping tests)

** within temperature compensated range (0°C to 40°C)

A.2 Argus ASM IV

ARGUS Gesellschaft für Umweltmeßtechnik mbH

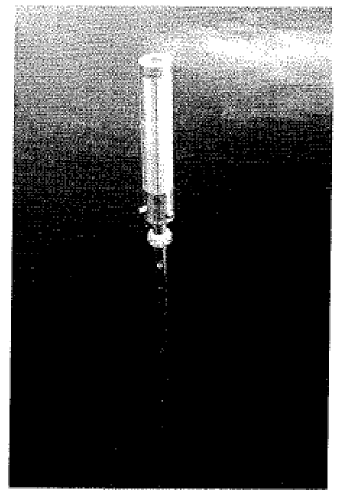
The ARGUS ASM-IV was primarily developed for high resolution measurements of erosion and accretion at the sea bed in ocean or riverine locations.

The instrument records the reflectivity and it's associated variability in the instruments measuring plane caused by particles moving through the instruments field of view. It thus provides an independent measurement of the transport of solids in the benthic boundary layer between the solid bottom, the layer of mobile sediments and the main water column.

As with conventional single point optical backscatter sensors the instrument determines the reflectivity of the water column by means of the backscattered light generated by the infrared sensors embedded in the stainless steel body of the instrument.

Each sensor is placed on an active board with a distance of 10 mm between each sensor with the result that over 100 sensors are mounted per meter of the measurement section, allowing a detailed picture to be built up of the sediment water interface at high resolution.

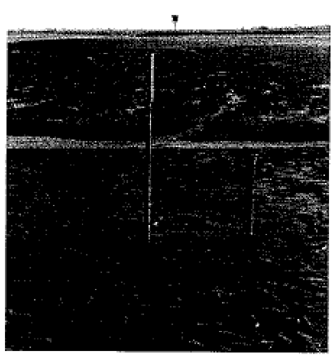
Each sensor in the measurement section consists of an infrared transmitter and detector. The sampling volume for each sensor in the array is approx. 0.5 cm³ and located at a distance between 5 and 10 mm in front of the instruments window.



Optical filters and a high current transmitting light source prevent interference by other light sources. This makes the instrument suitable for locations such as inter-tidal areas where the instrument is exposed at low water.

In addition to these optical sensors three additional sensors are also included.

- An inclinometer for two directions will give the actual angle between ground and instrument. (maximum range of 60° in all directions).
- A pressure gauge which senses the actual depth of the instrument and which provides information on water depth.
- A temperature sensor detects the temperature of the steel housing and which provides a measure of the water temperature.



Control of data acquisition and power is controlled by a battery powered central unit sealed-in the head of the instrument. This comprises of a microprocessor, data memory, and the additional sensors as well as 9V battery the energy supply.

The energy consumption of the instrument is very low and < 6 mA/s. which allows a single 9V alkaline battery to provide enough energy to run the instrument for 2 months, at a sample rate of 10 full profiles of the measurements section every 5 minutes, or for a standby status of approx. 6 months whilst the memory capacity of 4 Mb in the standard model provides a deployment duration of approx. 4 weeks at these sampling rates

To facilitate control the instrument and offload acquired data an optical serial port is integrated in the instrument head allowing the instrument to be configured and data offloaded without having to open the instrument.

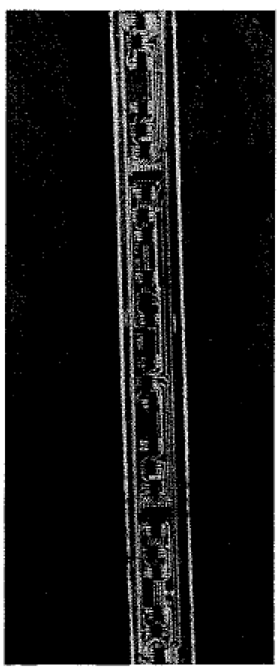
All communication with the instrument, including configuration and data offload is achieved through the powerful windows based software which also serves for the analysis and presentation of the data.

ARGUS

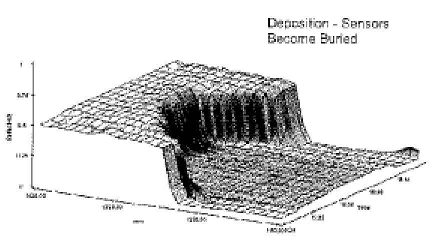
- Measuring method: optical
- Sensors: backscatter infrared sensors
- Sensor distance:10 mm
- Number of sensors:100 per meter
- Measuring section:

  0.96 m (Type S),
  1.44 m (Type N),
  1.92 m (Type L)
- Overall Length of instrument:

  1.9 m (Type S),
  2.4 m (Type N),
  2.9 m (Type L)



Detail of Instrument's Measurement Section showing Embedded Optical Sensors

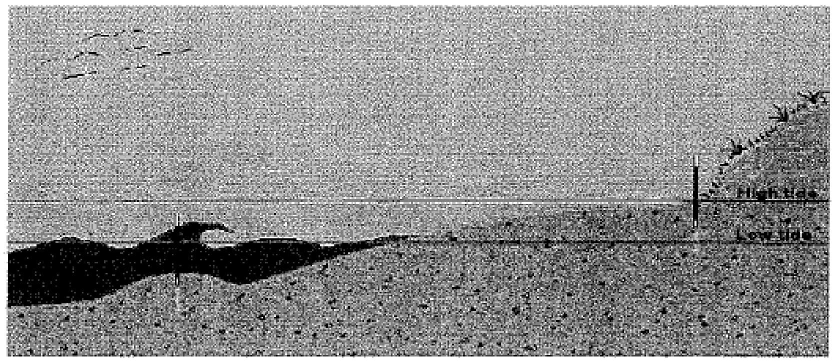


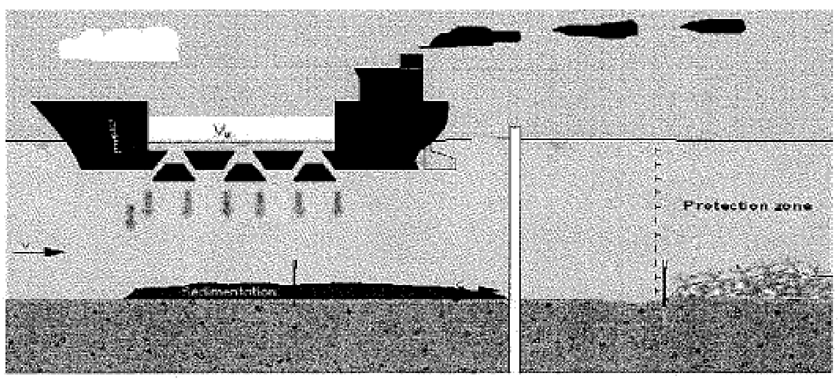
Plot of Time-series of Erosion and Deposition of Sediment at Deployment Site showing material entrained into suspension by currents achieved using ASM's ASMA software.

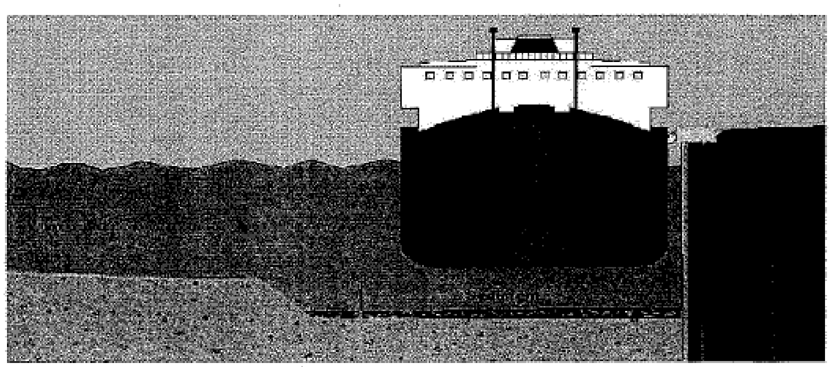
- Instrument Diameter :
  - Sensor area: 32 mm
  - Head: 60mm
- Measuring interval: 1 sec. minimum
- Sampling rate: 1/sec - 255/sec
- Memory capacity:4 MB standard
- Power:
  - Main supply: Single alkaline 9 V block battery (minimum) two lithium 9 V block battery for extended deployment capability
  - Memory backup: CR 1220 lithium 3 V battery
- Weight:13 kg (Type N)
- Ambient temperature:-15...+45°C
- Maximum Installation depth: 50 m water depth

ARGUS, Gesellschaft für Umweltmeßtechnik mbH
Goethestrasse 35, D-27721 Ritterhude, Germany
E-Mail: info@argusnet.de
Phone: +49 4292 992335
Fax: +49 4292 992365

ASM-IV Applications





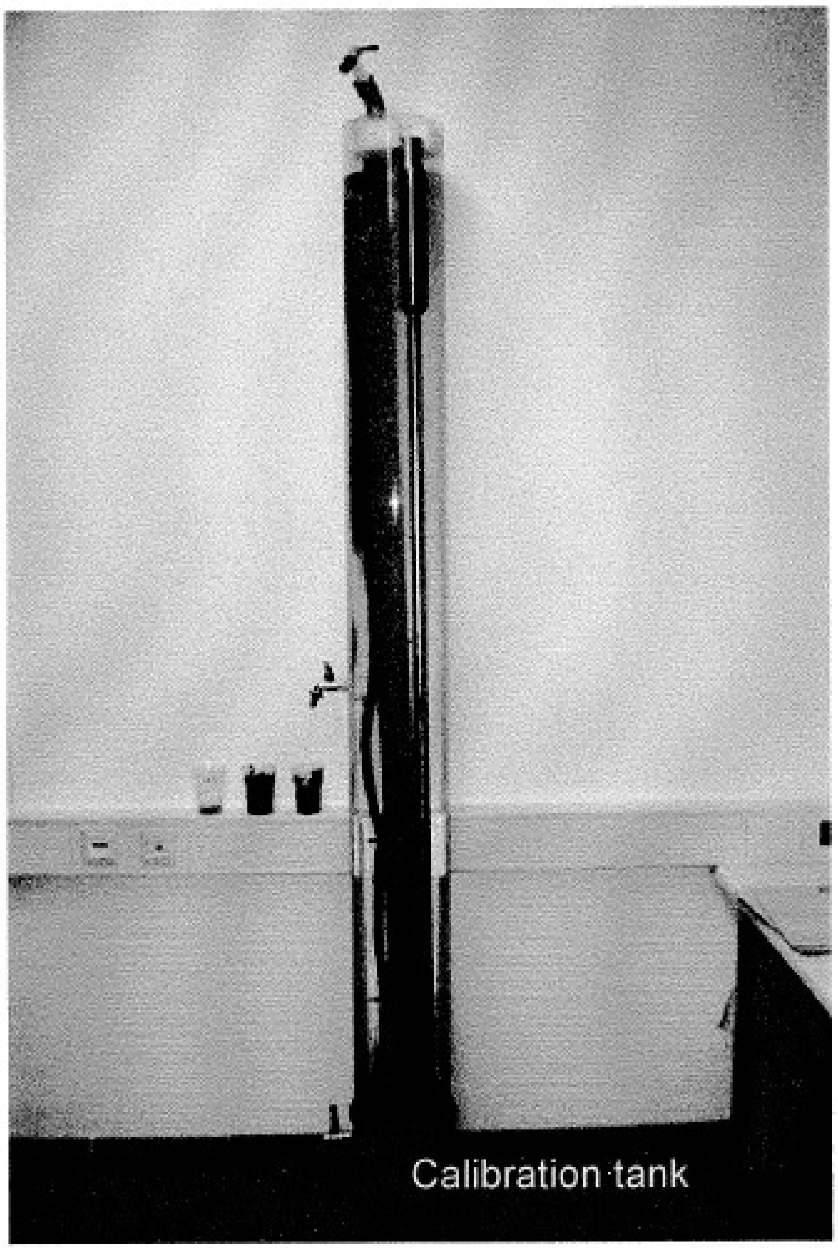


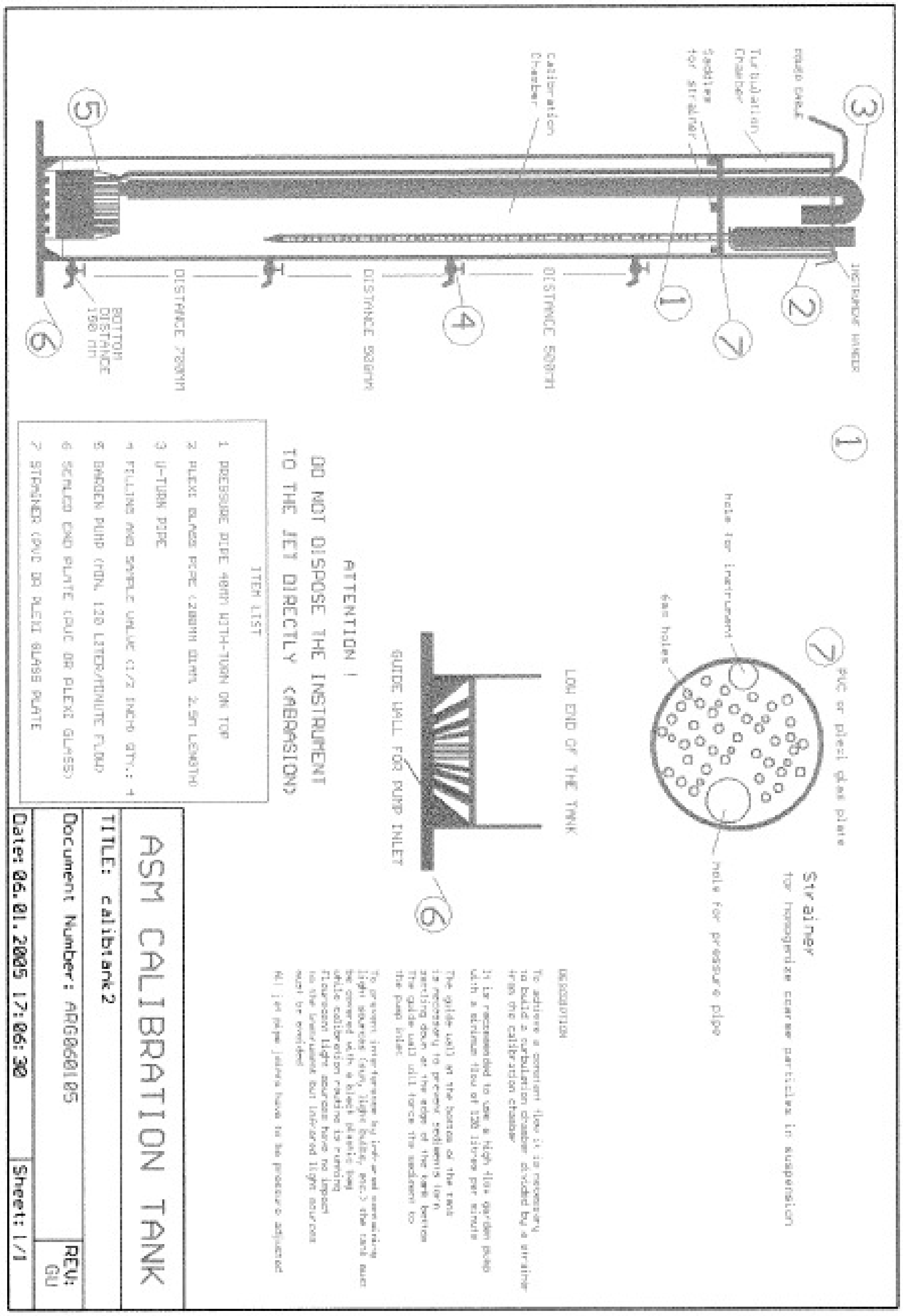
Calibration Tank

To keep particles in suspension a circulation facility and high power pump is recommended, it becomes more important the coarser the particles in suspension are, due to gravitation processes.

A single OBS calibration can be carried out easily by using a simple bucket and a stir propeller as is used for mixing wall paint.

To calibrate a multi stage OBS system (ASM) all sensors have to be calibrated submerged in a homogeneous suspension. At the same time all individual OBS sensors need to be equalised as well.


Calibration tank

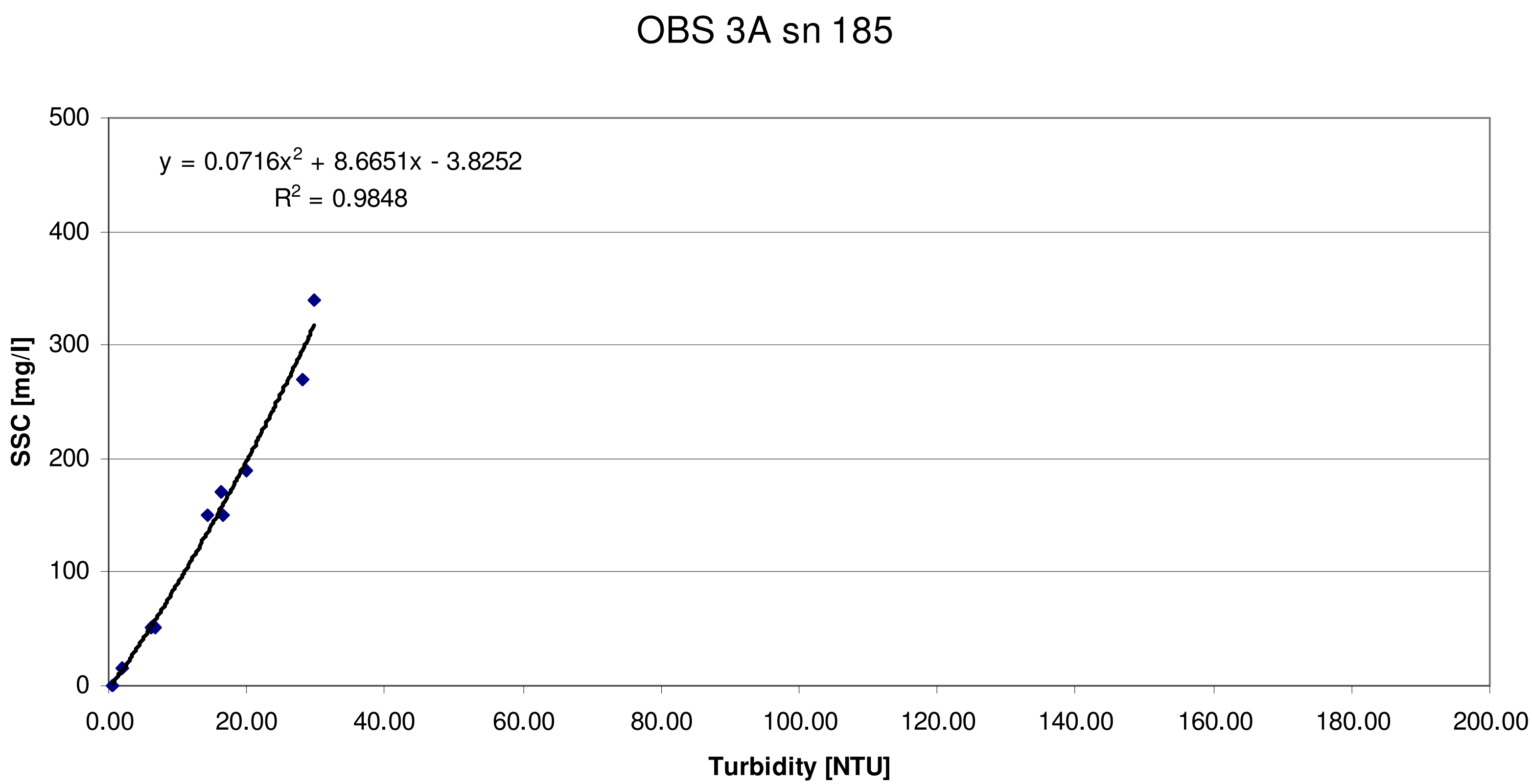

Calibration tank ASMCT
ATTENTION !
DO NOT DISPOSE THE INSTRUMENT
TO THE JET DIRECTLY (ABRASION)
ITEM LIST
LOW END OF THE TANK
GUIDE WALL FOR PUMP INLET
Strainer
for homogenize coarse particles in suspension
hole for pressure pipe
ASM CALIBRATION TANK
TITLE: calibtank2
Document Number: ARG060105
Date: 06.01.2005 17:06:30
Sheet: 1/1
REV:
GU

APPENDIX B.

CALIBRATION GRAPHS

B.1 In situ Calibration Graphs

11283 DGD2 – CALIBRATION AUTUMN



Calibration Graph of OBS 3A s/n 185

Location:
Lower Sea Scheldt

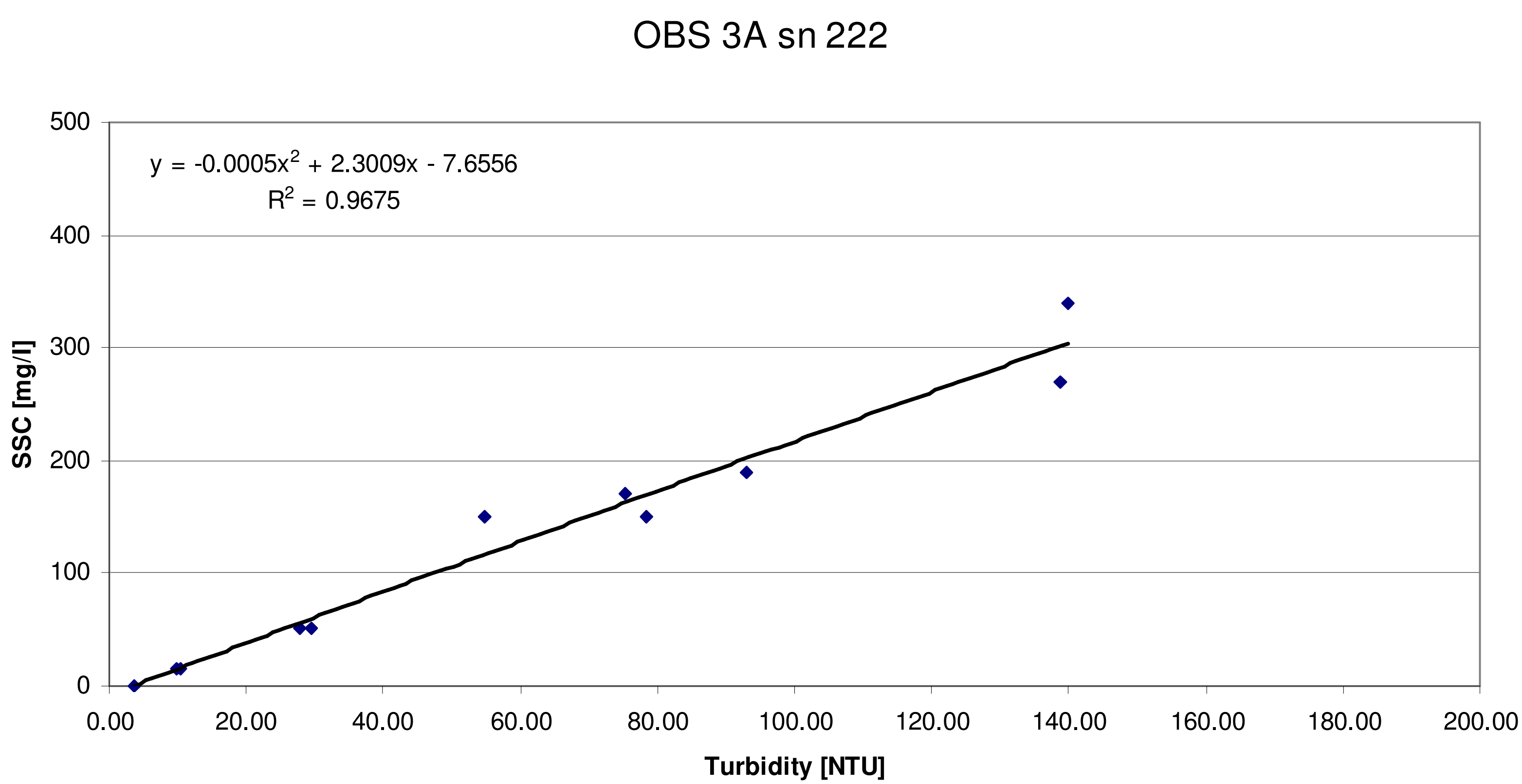
Date:
10/09/07

Data processed by: IMDC

In association with: WL | delft hydraulics, GEMS International

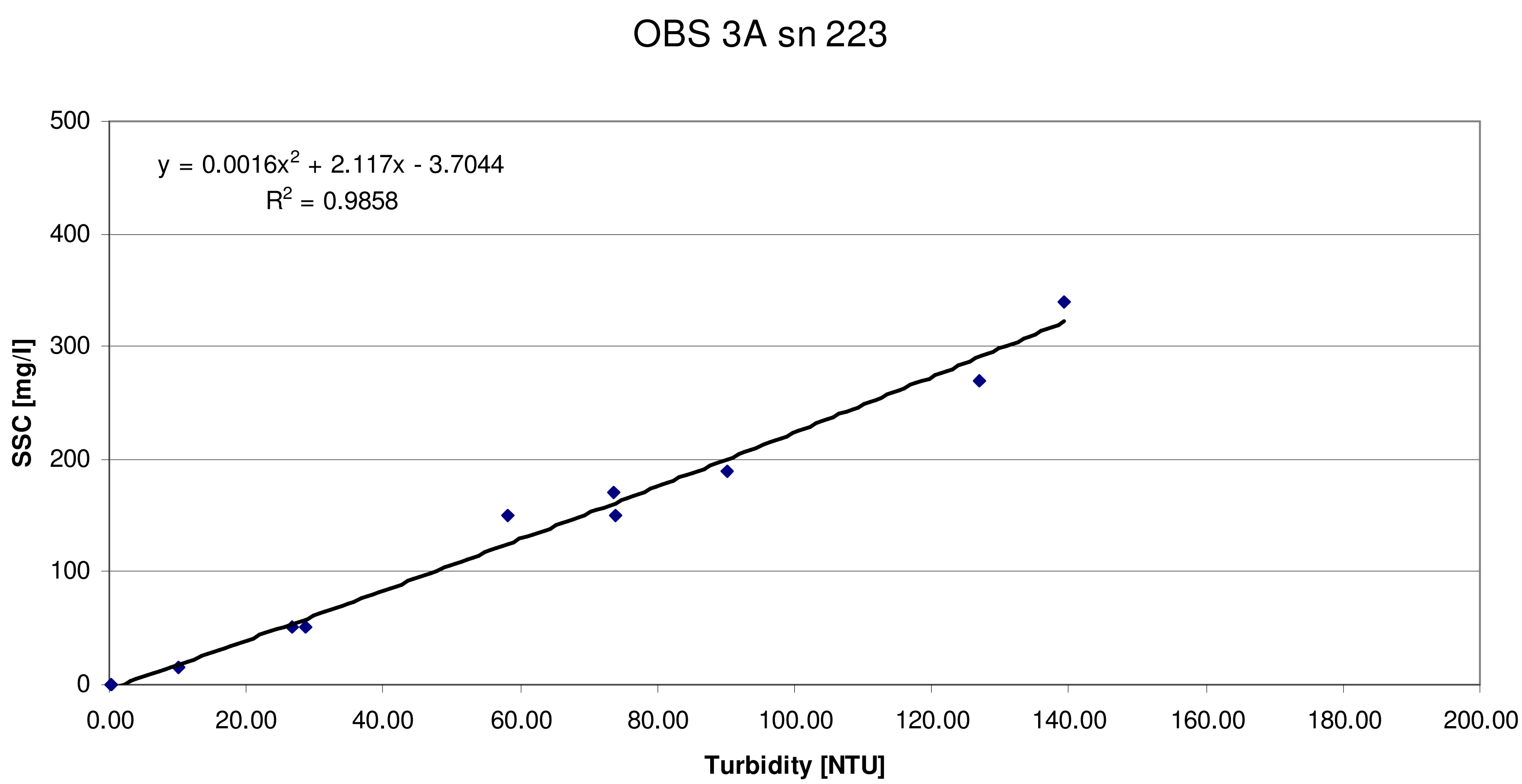
I/RA/11283/07.095/MSA

11283 DGD2 – CALIBRATION AUTUMN



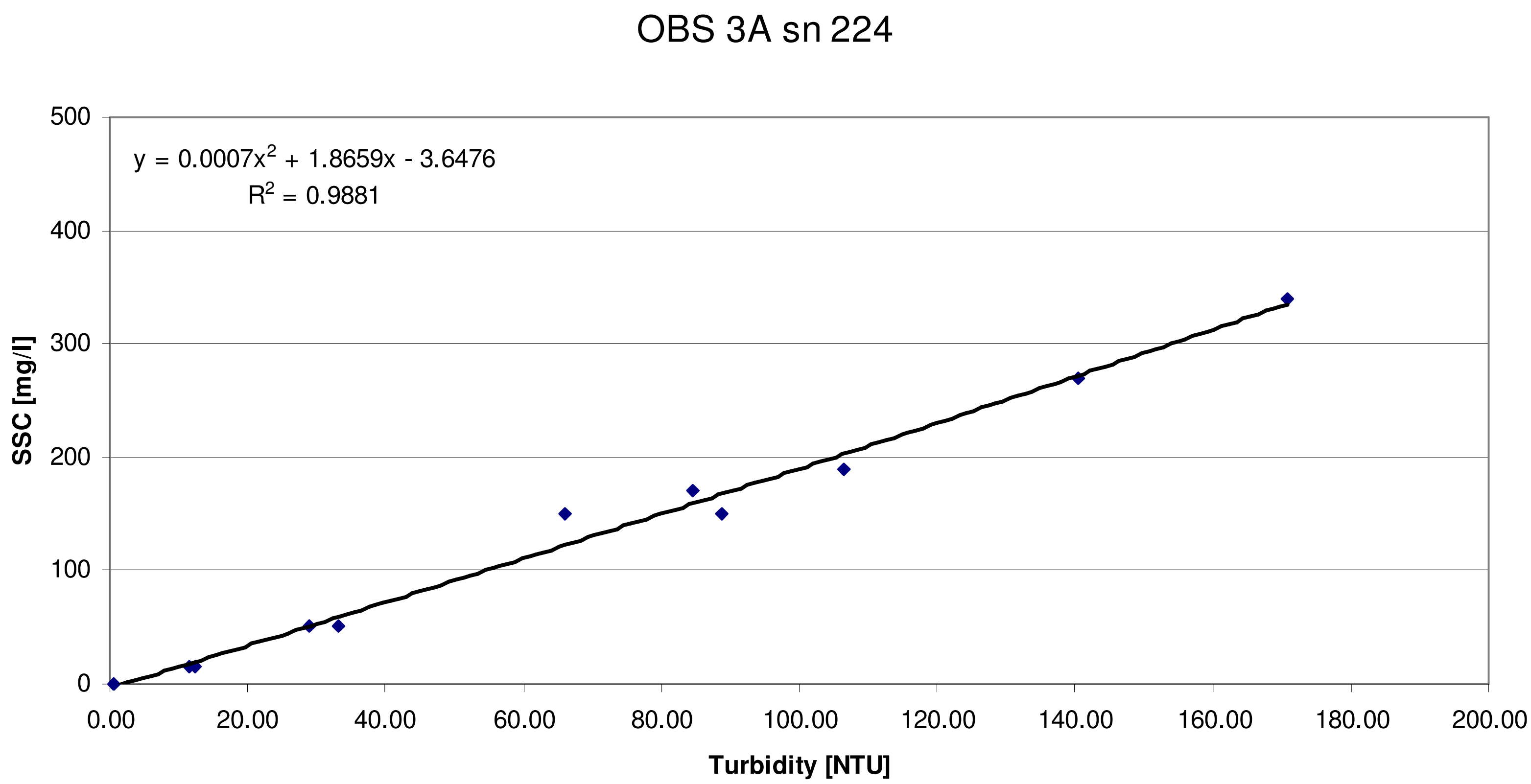
Calibration Graph of OBS 3A s/n 222		Data processed by: IMDC
Location: Lower Sea Scheldt	Date: 10/09/07	In association with: WL | delft hydraulics, GEMS International
		I/RA/11283/07.095/MSA

11283 DGD2 – CALIBRATION AUTUMN



Calibration Graph of OBS3A s/n 223	*Data processed by:* IMDC
Location: Lower Sea Scheldt / Date: 10/09/07	*In association with:* WL | delft hydraulics, GEMS International *I/RA/11283/07.095/MSA*

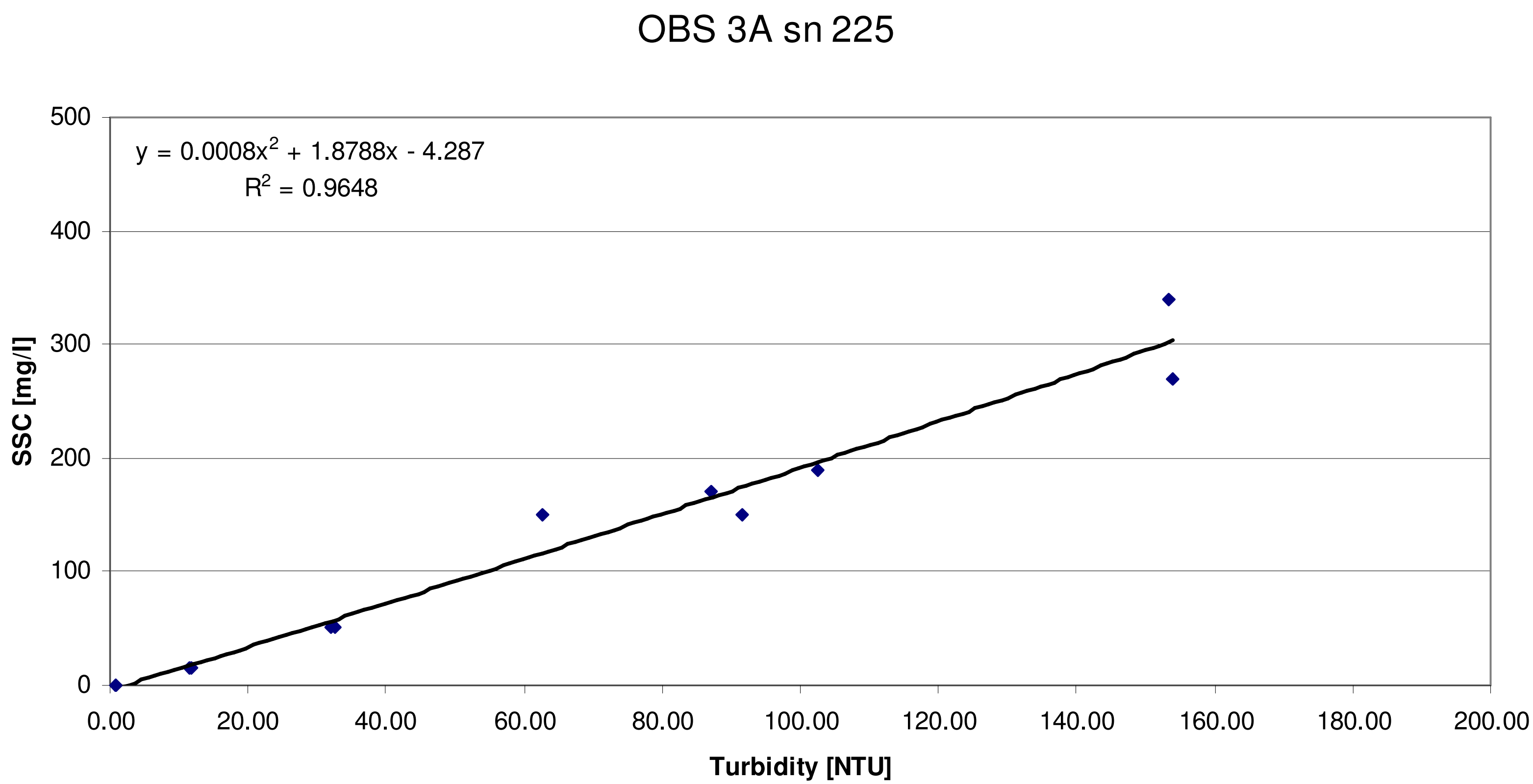
11283 DGD2 – CALIBRATION AUTUMN



Calibration Graph of OBS 3A s/n 224

Location: Lower Sea Scheldt	Date: 10/09/07	*Data processed by:* IMDC *In association with:* WL | delft hydraulics, GEMS International *I/RA/11283/07.095/MSA*

11283 DGD2 – CALIBRATION AUTUMN



Calibration Graph of OBS 3A s/n 225

Location:
Lower Sea Scheldt

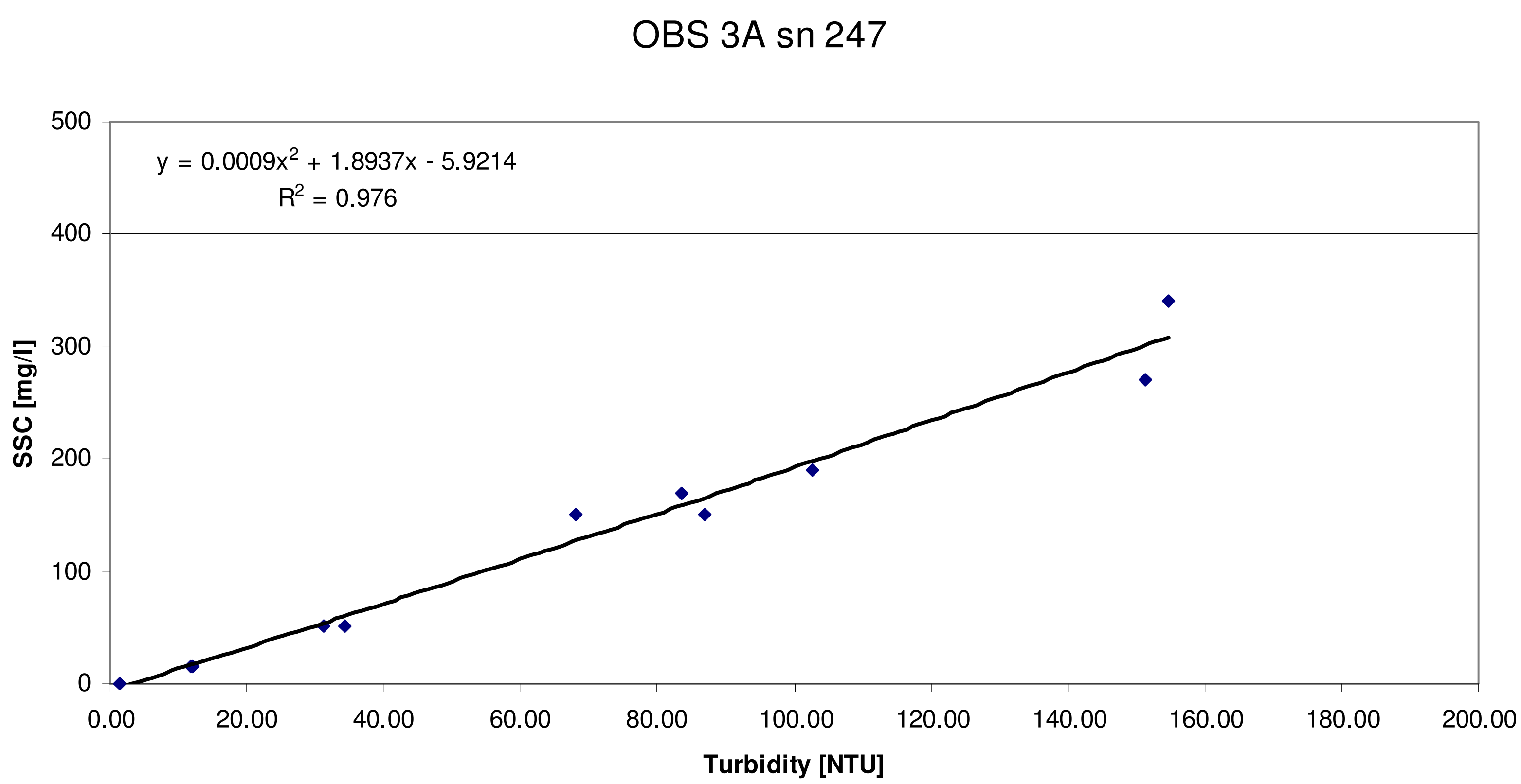
Date:
10/09/07

Data processed by:

In association with:

I/RA/11283/07.095/MSA

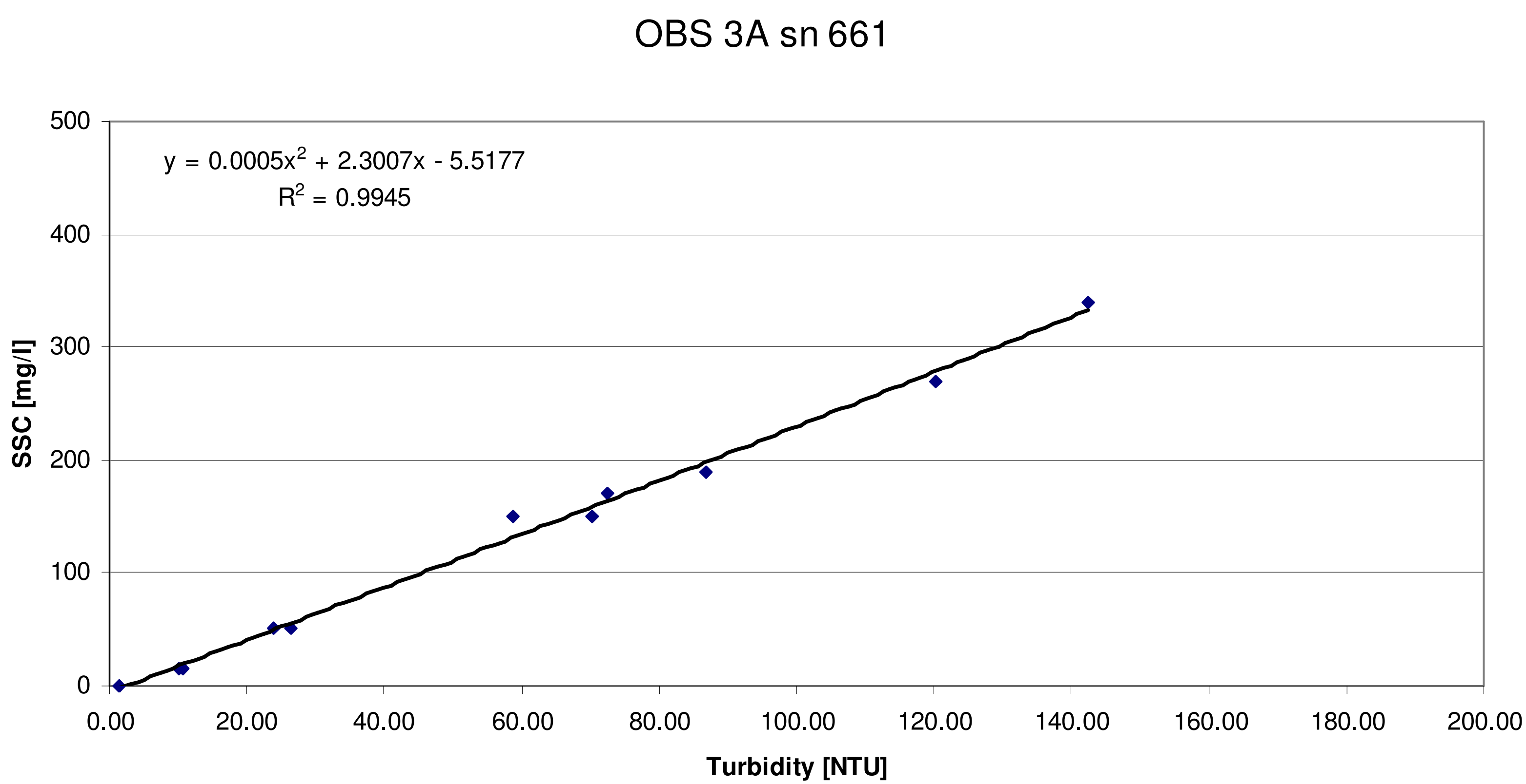
11283 DGD2 – CALIBRATION AUTUMN



Calibration Graph of OBS 3A s/n 247		*Data processed by:* IMDC
Location: Lower Sea Scheldt	Date: 10/09/07	*In association with:* WL | delft hydraulics, GEMS International

I/RA/11283/07.095/MSA

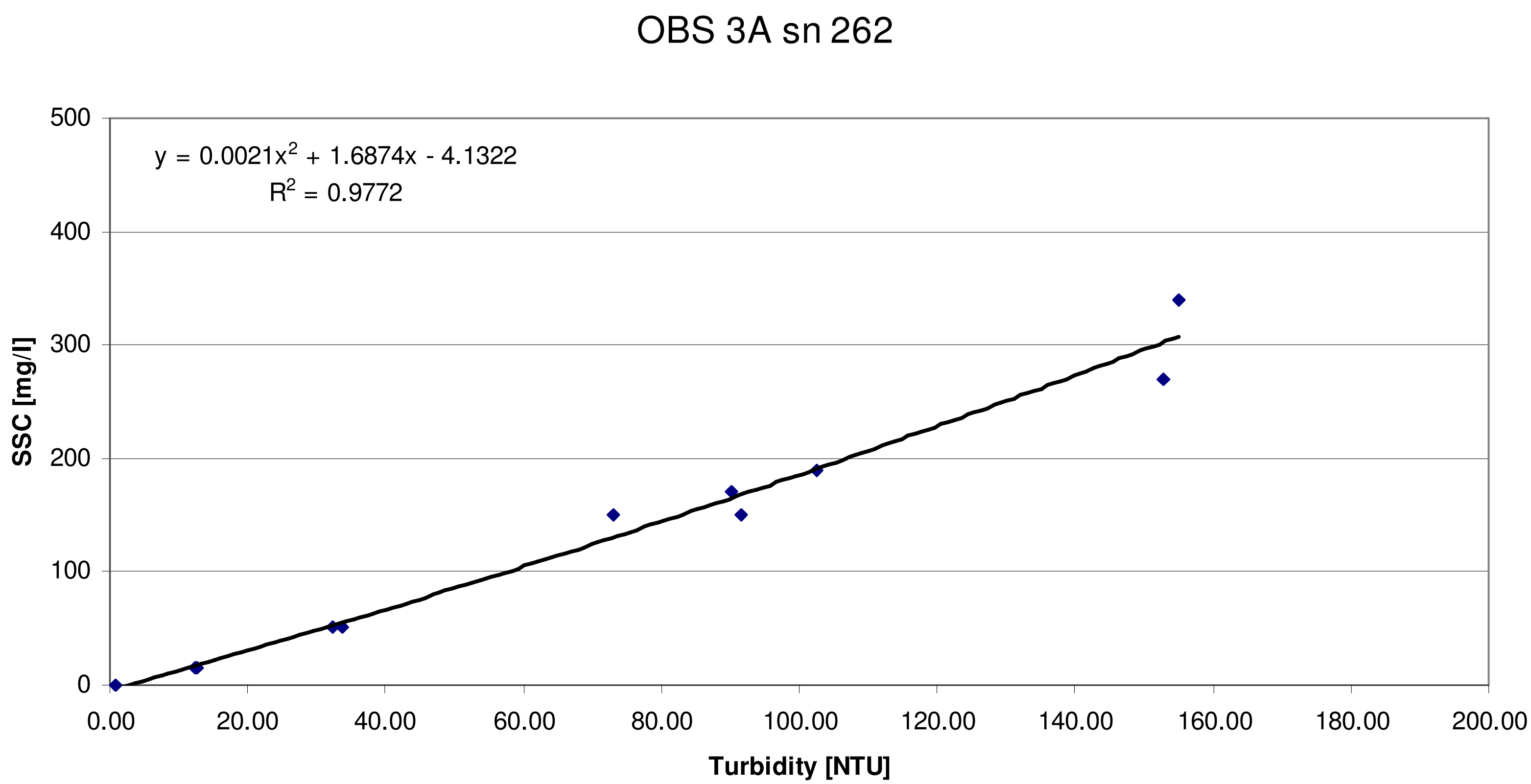
11283 DGD2 – CALIBRATION AUTUMN



Calibration Graph of OBS 3A s/n 261		*Data processed by:* IMDC
Location: Lower Sea Scheldt	Date: 10/09/07	*In association with:* WL | delft hydraulics, GEMS International

I/RA/11283/07.095/MSA

11283 DGD2 – CALIBRATION AUTUMN



Calibration Graph of OBS 3A s/n 262

Location:
Lower Sea Scheldt

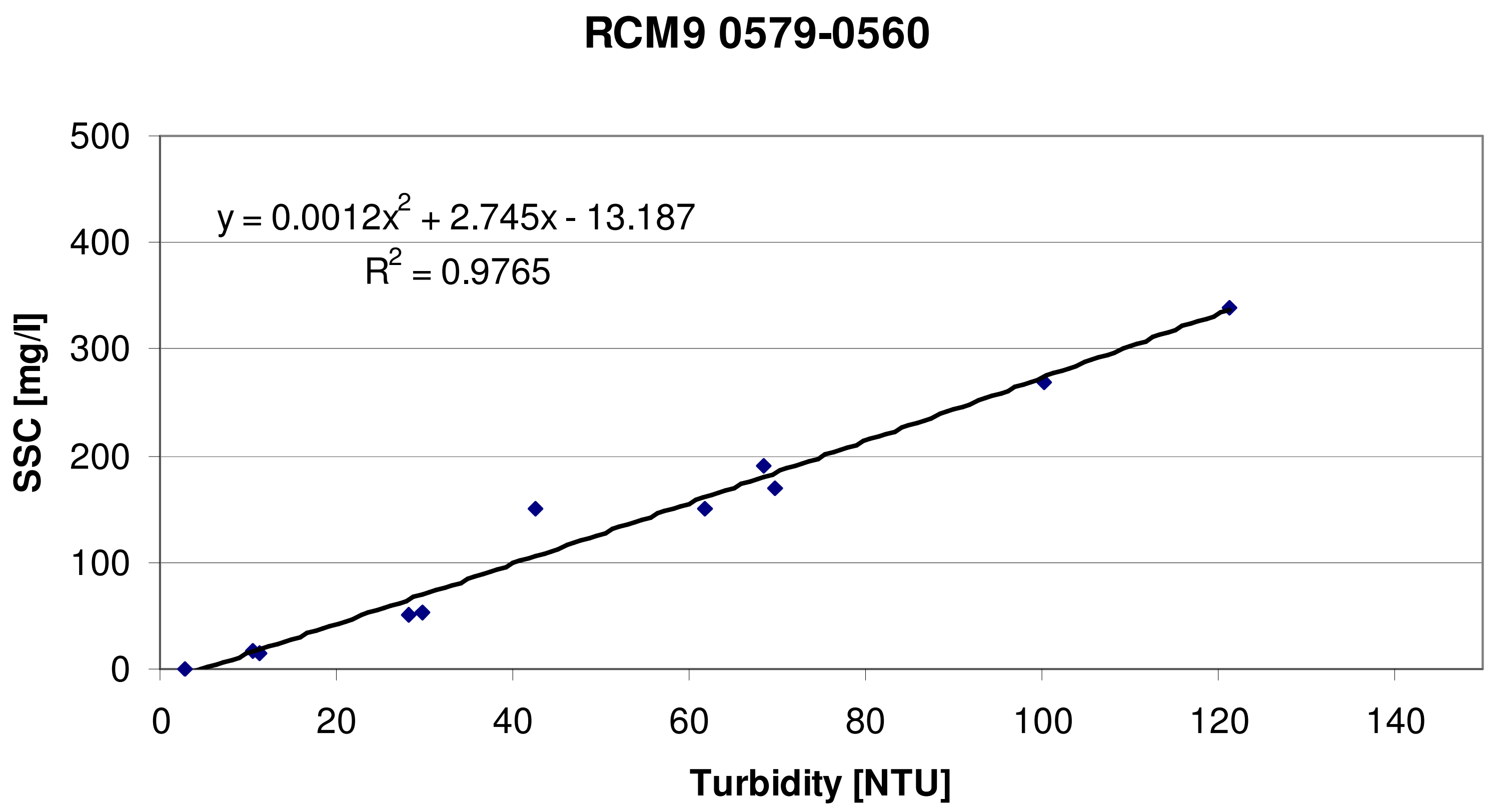
Date:
10/09/07

Data processed by: IMDC

In association with: WL | delft hydraulics, GEMS International

I/RA/11283/07.095/MSA

11283 DGD2 – CALIBRATION AUTUMN



Calibration Graph of RCM-9 0579_0560

Location: Lower Sea Scheldt

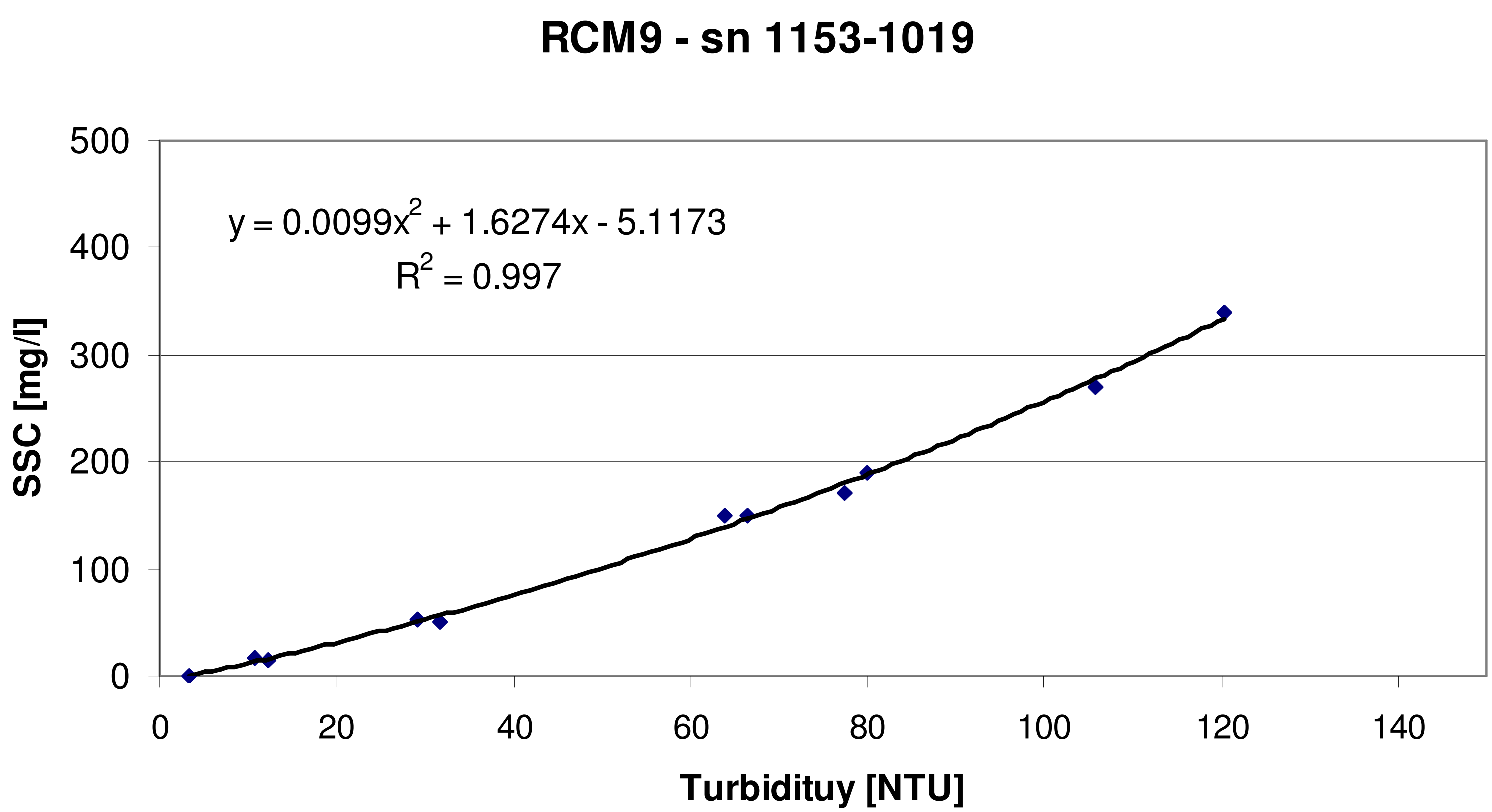
Date: 10/09/07

Data processed by: IMDC

In association with: WL | delft hydraulics, GEMS International

I/RA/11283/07.095/MSA

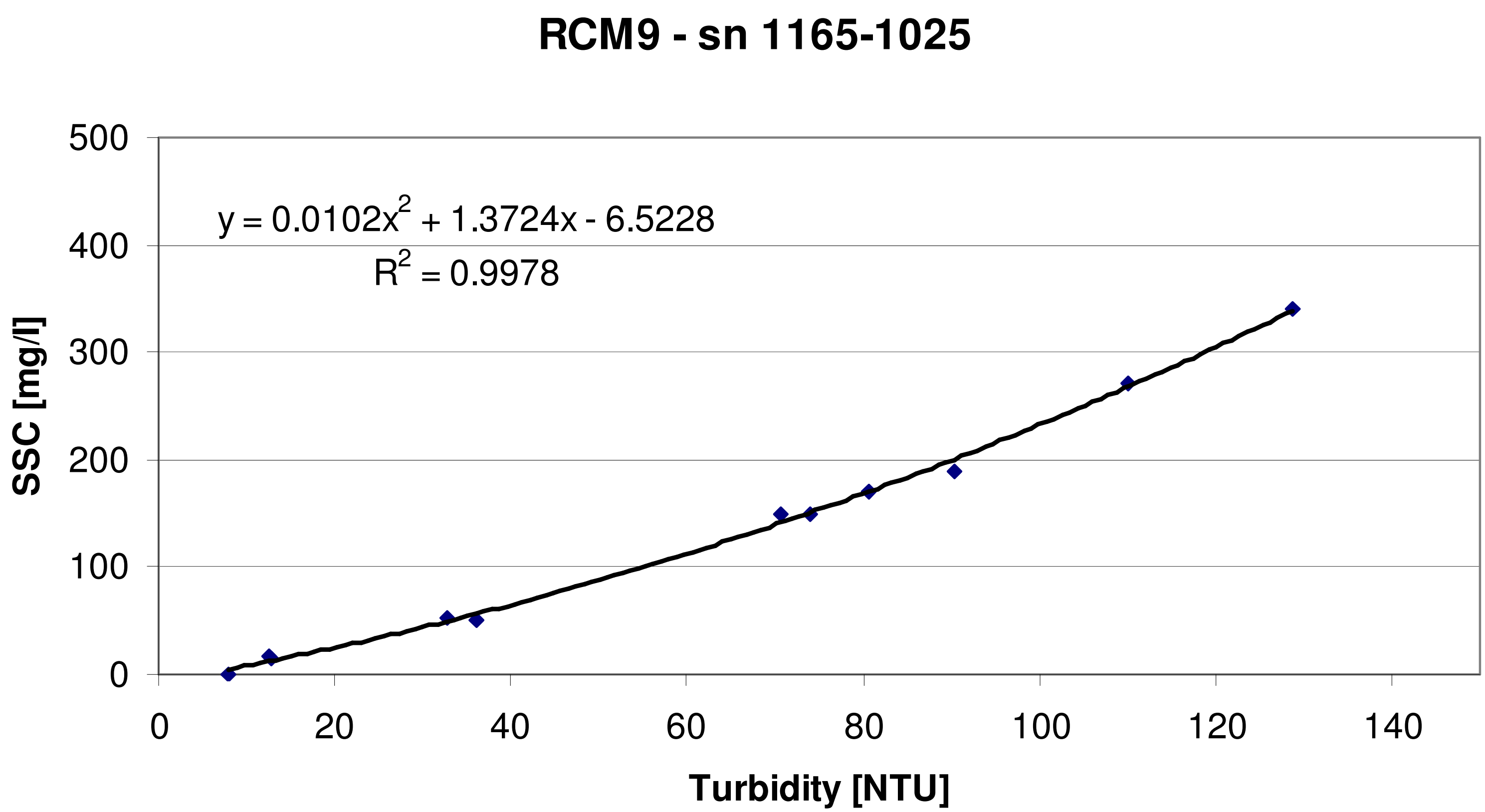
11283 DGD2 – CALIBRATION AUTUMN



Calibration Graph of RCM-9 1153_1019		*Data processed by:*
Location: Lower Sea Scheldt	Date: 10/09/07	*In association with:*

I/RA/11283/07.095/MSA

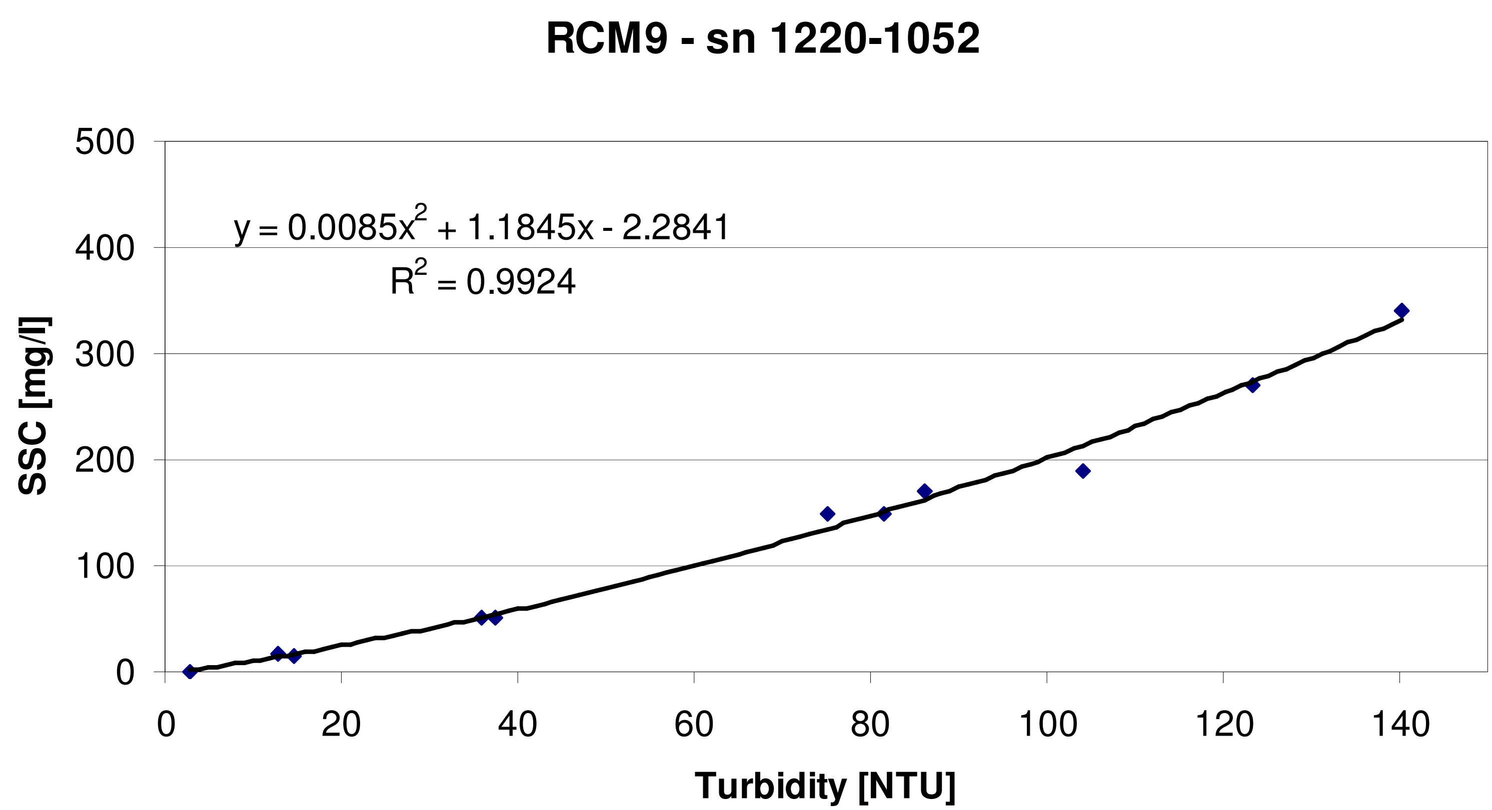
11283 DGD2 – CALIBRATION AUTUMN



Calibration Graph of RCM-9 1165_1025		*Data processed by:* IMDC
Location: Lower Sea Scheldt	Date: 10/09/07	*In association with:* WL | delft hydraulics, GEMS International

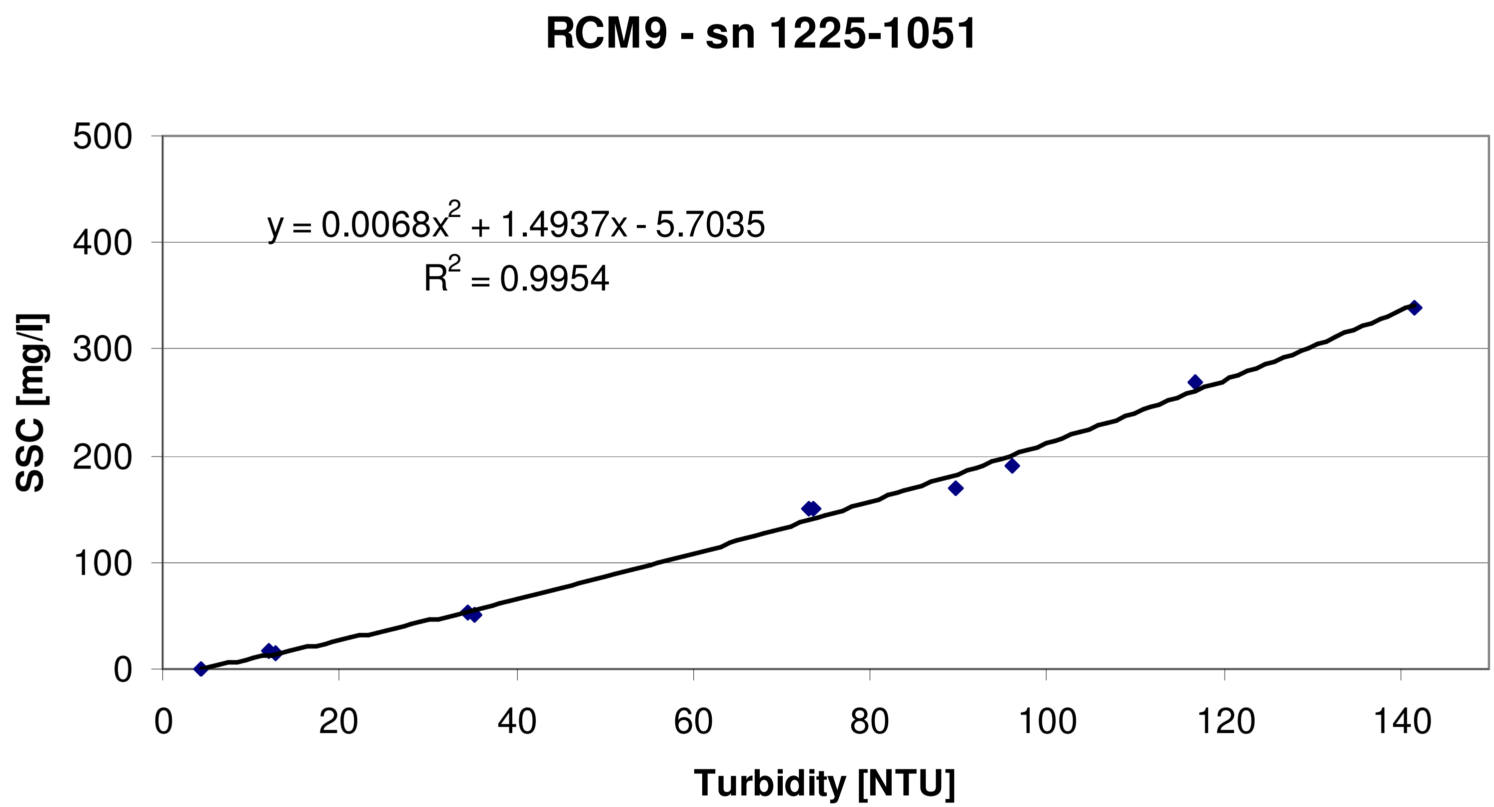
I/RA/11283/07.095/MSA

11283 DGD2 – CALIBRATION AUTUMN



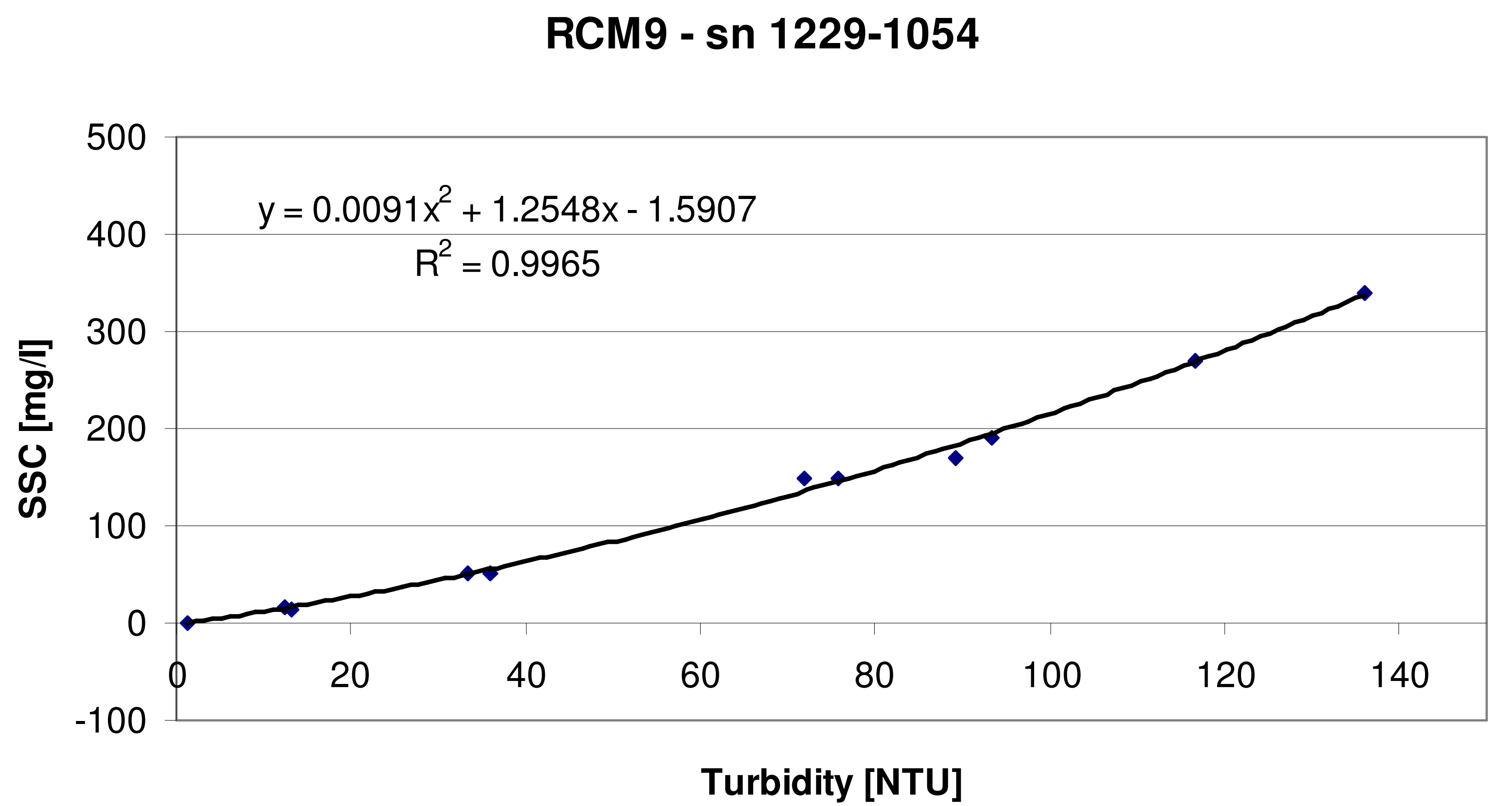
Calibration Graph of RCM-9 1220_1052	*Data processed by:* IMDC
Location: Lower Sea Scheldt / Date: 10/09/07	*In association with:* WL | delft hydraulics, GEMS International
	I/RA/11283/07.095/MSA

11283 DGD2 – CALIBRATION AUTUMN



Calibration Graph of RCM-9 1225_1051		Data processed by: IMDC
Location: Lower Sea Scheldt	Date: 10/09/07	In association with: WL | delft hydraulics, GEMS International I/RA/11283/07.095/MSA

11283 DGD2 – CALIBRATION AUTUMN

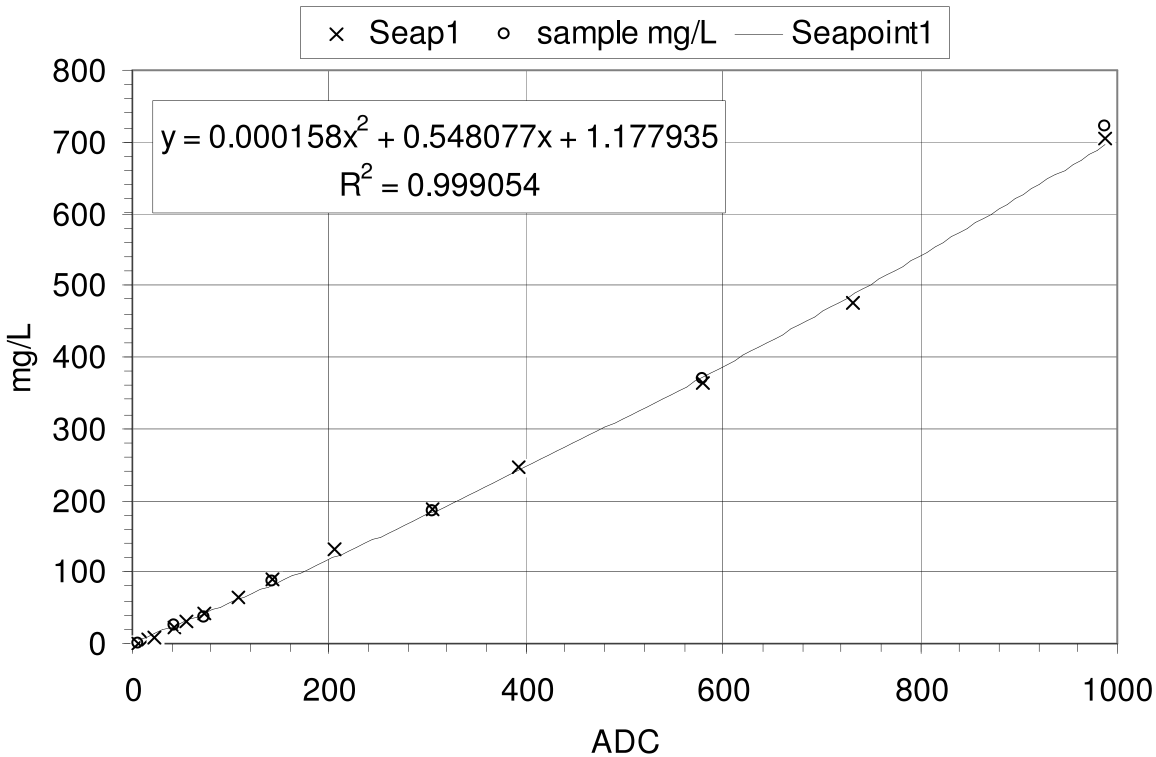


Calibration Graph of RCM-9 1229_1054	Data processed by:
Location: Lower Sea Scheldt — Date: 10/09/07	In association with:

I/RA/11283/07.095/MSA

B.2 Manufacturers Calibration

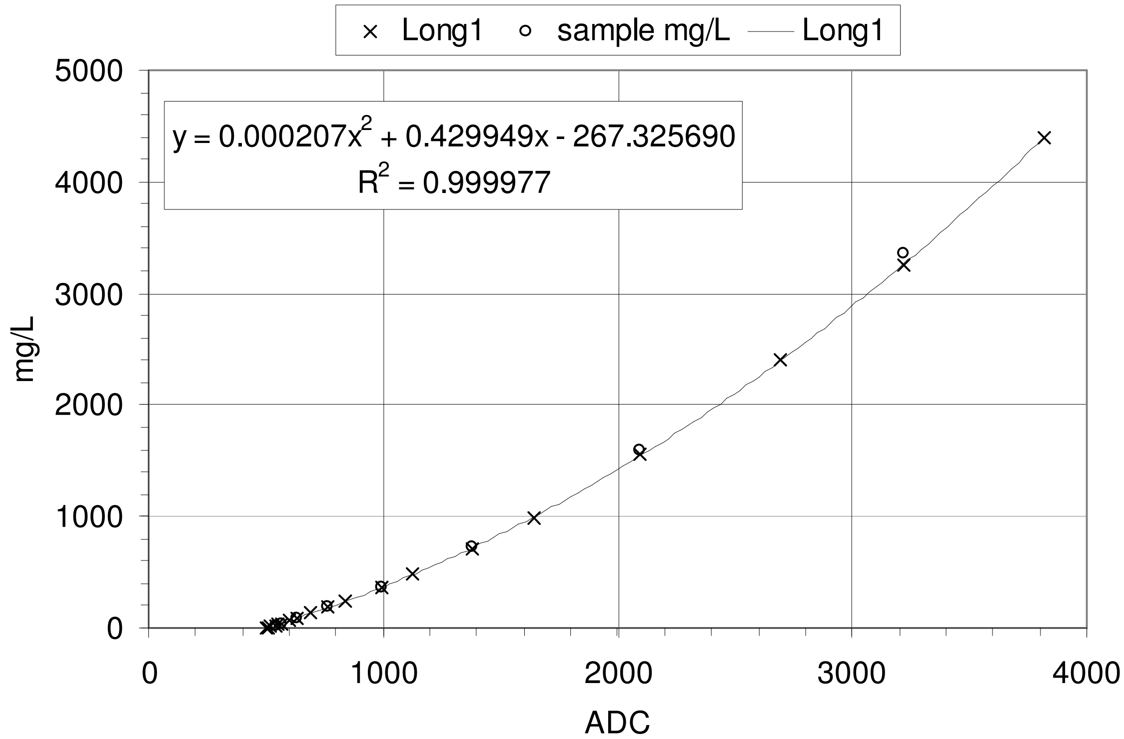
11283 DGD2 – CALIBRATION AUTUMN



Calibration Graph of Siltprofiler - Seapoint

Location: WL|Delft Hydraulics	Date: 27/01/06	*Data processed by:* IMDC *In association with:* WL | delft hydraulics, GEMS International *I/RA/11283/07.095/MSA*

11291 HCBS – CALIBRATION WINTER



Calibration Graph of Siltprofiler – Long Range

Location:
WL|Delft Hydraulics

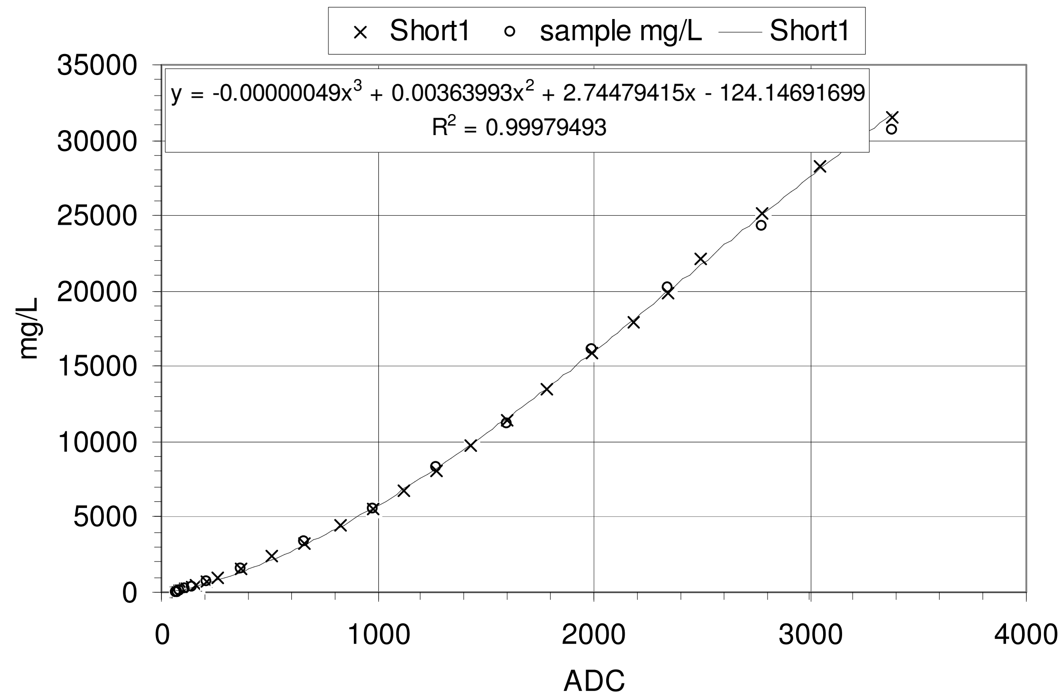
Date:
27/01/2006

Data processed by:

In association with:

I/RA/11291/06.088/MBO

11291 HCBS – CALIBRATION WINTER



Calibration Graph of Siltprofiler – Short Range

Location:
WL|Delft Hydraulics

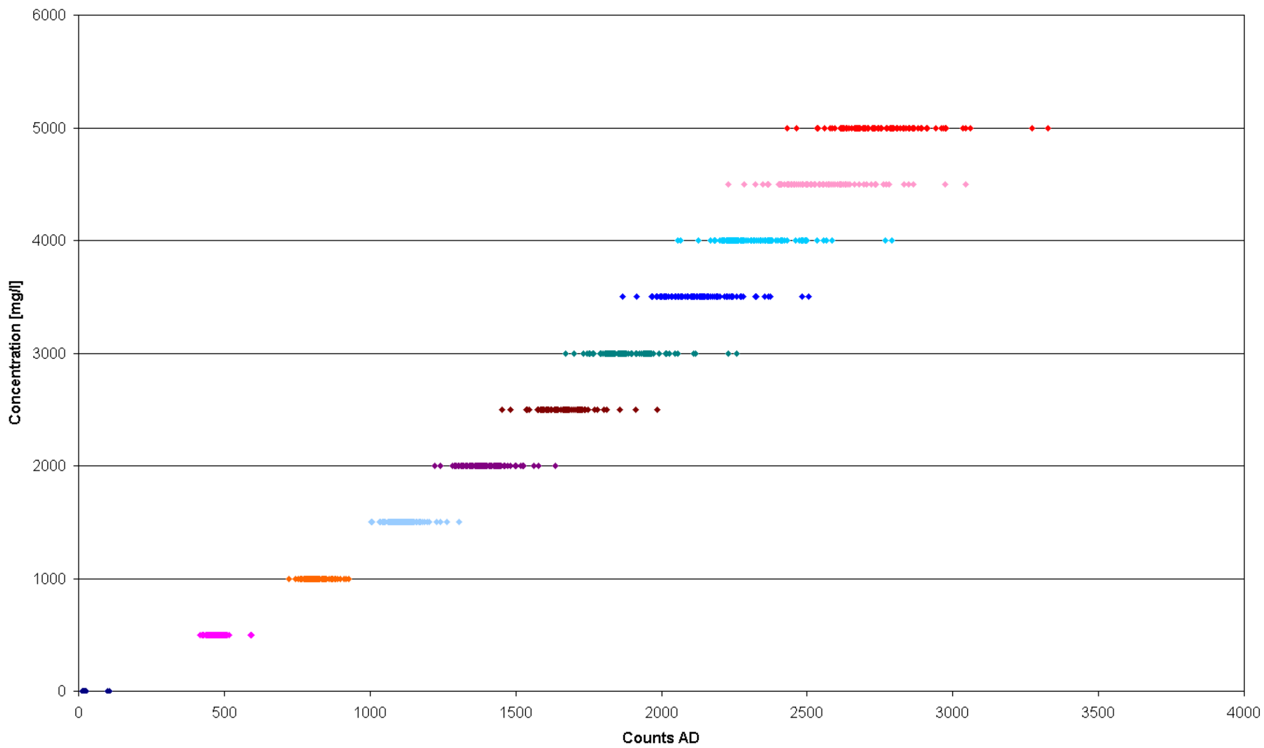
Date:
27/01/2006

Data processed by:

In association with:

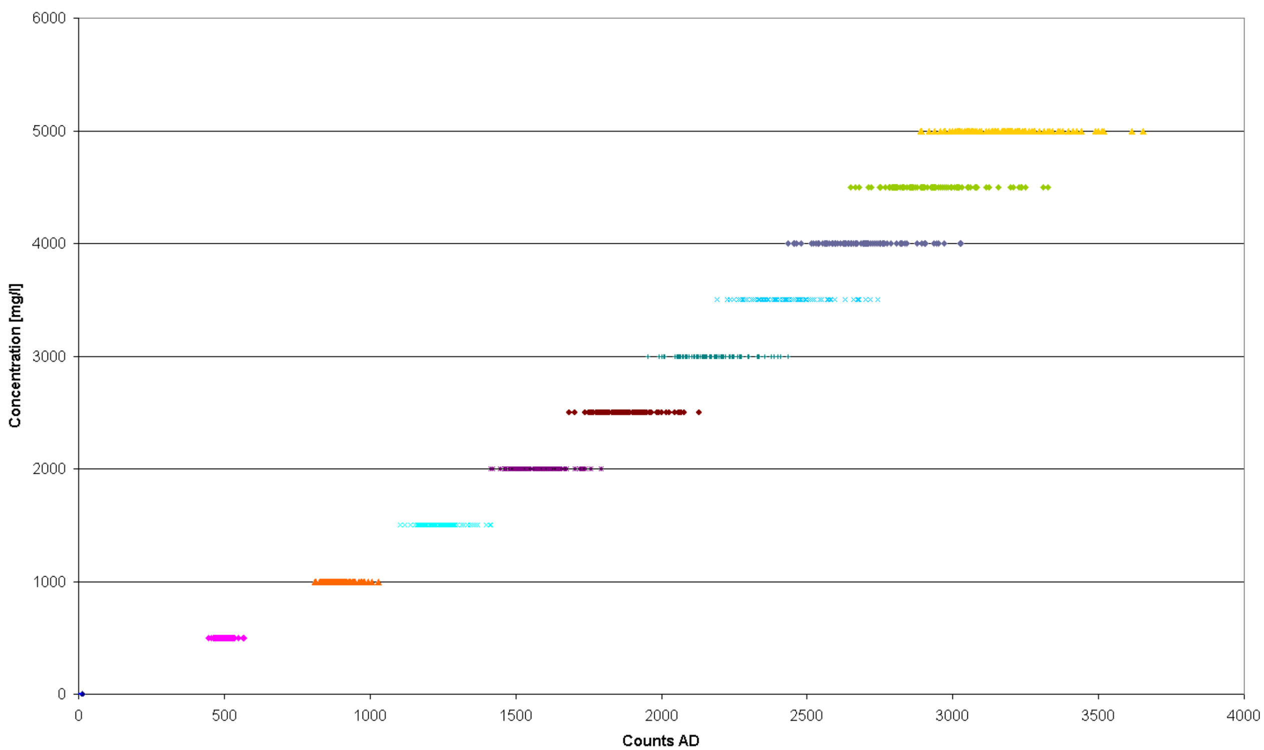
I/RA/11291/06.088/MBO

11291 HCBS – CALIBRATION WINTER



Calibration Graph of ARGUS ASM IV sn 61		Data processed by:
Location: ARGUS gMBH	Date: 02/02//2007	In association with:
		I/RA/11283/07.095/MSA

11291 HCBS – CALIBRATION WINTER



Calibration Graph of ARGUS ASM IV sn 79

Location:
ARGUS gMBH

Date:
21/05/2007

Data processed by:

In association with:

I/RA/11283/07.095/MSA