Description of the turbulence measurements conducted in the tidal channel "Groote Gat" (Ems/Dollard) in 1995 and 1996

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report no. 5-99

TU Delft
Technische Universiteit Delft

Faculteit der Civiele Techniek

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May 1999

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Preface

In 1993 an interdisciplinary research programme on the behaviour of mud in tidal waters was initiated by the Board of NWO-BOA. The programme aims at obtaining more detailed insight in the dominant processes that govern the transport behaviour of mud. These processes have strong time variability and therefore the general approach is to obtain long-term in situ measurements on a number of key parameters in a tidal channel and on a tidal flat. One of the surplus values of this research programme is that it contributes to an interdisciplinary perception of the behaviour of intertidal areas, in which the relevance of biological, physical and chemical processes and human activities is represented in a well-balanced way.

This report provides a description of the field measurements of flow velocities and suspended sediment concentrations carried out in the tidal channel “Groote Gat” in the Ems/Dollard estuary in 1995 and 1996. It is addressed in the first place to those who want to make use of the turbulence data recorded in the tidal channel which is stored on CD Recordables which can be made available by the Hydromechanics Section of the Department of Civil Engineering of the Delft University of Technology.

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Chapter 1 Introduction

Concentrations of suspended sediment and water velocities were measured for periods of several tides in 1995 and in 1996 in the tidal channel "Groote Gat" in order to study their interaction (Figure 1). The tides were selected from spring and neap tides of different seasons to investigate variations in flow velocities and SSCs (see also Ridderinkhof et al., in prep.). An experimental set-up was developed for this purpose in collaboration with Rijkswaterstaat Meetdienst Noord and Utrecht University. It consists of a pole RWS208 with sets of high-frequency flow meters and high-frequency fibre optical turbidity sensors attached at three levels above the sediment bed.

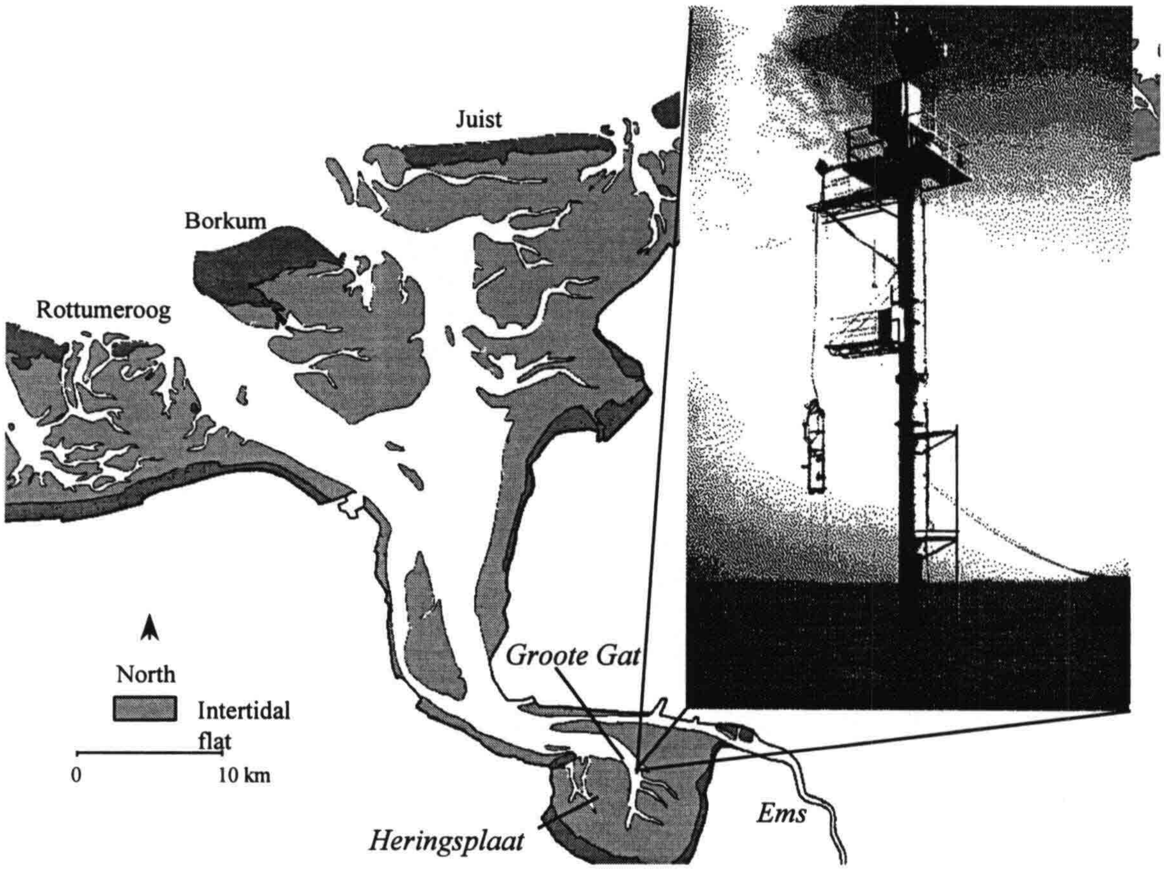

Figure 1. The Ems/Dollard Estuary and the measuring pole RWS208 equipped with a rigid frame (to the right) for turbulence measurements.

The fibre optical turbidity sensors were newly developed by WL | delft hydraulics, and they were tested and adjusted in collaboration with this institute. The main advantage of this experimental set-up is that turbulence properties, the local vertical transport of sediment and momentum for instance, can be measured directly instead of deducing them from the averaged velocity and concentration profiles.

Chapter 2 describes the measuring facilities and the instruments used in the field and Chapter 3 explains the methodology of the field measurements, which includes the testing of the fibre optical turbidity sensors and the measuring technique in 1995. On the basis of the experience gained from these tests, a field program for 1996 was developed, which is presented in Chapter 4. Chapter 5 presents the quality assessment of the time series of velocities and SSCs obtained in 1996.

Chapter 2 Measuring facilities and instrumentation

2.1 Introduction

Two measuring frames were attached to the measuring pole RWS208: a Rijkswaterstaat frame for long term turbidity and velocity measurements, and a rigid frame for turbulence measurements. These frames are shown in Figure 1 to the left and to the right of the pole, respectively (see also Appendix A). Pole RWS208 was located in a straight reach of the channel approximately 30 m to the east of the mean low water level (about -1.7 m N.A.P.) at 7°09'43''E 53°17'14''N in 1995 and 7°09'43''E 53°17'15''N in 1996. The average bottom elevation was 3.3 m below N.A.P. and the channel width 600 m. Visual observations of the borders of the Heringsplaat during low low water spring tide showed that the bed surface was very smooth. The bed level showed only small variations of typically 0.05 m over a 10 m distance. The slope of the bank perpendicular to the channel axis was approximately 1:30. Sediment samples taken from positions directly adjacent to the measuring pole showed that the channel bed was composed of silt and clay.

2.2 Electromagnetic flow meters (EMFs)

The EMFs used in this study are discoid twin-axis type electromagnetic flow meters manufactured by WL | delft hydraulics. They are coded as D232, D233 and D334, have 5 cm diameter sensing heads and operate with a cut-off frequency of approximately 7 Hz.

This type of EMF has been found to be suitable for measuring two normal components of the velocity fluctuations under field conditions (Soulsby, 1980; West et al., 1986; French and Clifford, 1992). One of the limitations of the instruments is their spatial resolution. Soulsby (1980) found severe attenuation of measurements of vertical velocity intensities due to sensor averaging under typical field conditions, whereas measurements of horizontal intensities and of the Reynolds stress in the vertical plane in flow direction were relatively unaffected. This resulted in too low values of the ratio w'/u_*, where u_* is the friction velocity.

The EMFs D232-D234 were calibrated in April 1994 by WL | delft hydraulics and in February 1996 by the Laboratory of Hydromechanics of Delft University of Technology (see also Appendix D). The linear responses (≈1.0V/(m/s)) measured in 1996 did not differ significantly from the original responses measured in 1994 except for the D333 X-channel, the response of which was found to be 1.5 % higher. A possible explanation for this inconsistency could be the relatively large scatter in the original towing tank data of the D333 X-channel. The linear responses of the 1996 calibration were used for the data-processing. The maximum "root mean square values" or noise levels measured in still water were approximately 0.004 m/s.

The offsets of the EMFs were measured in the laboratory in a large tank, and in-situ in advance of each measuring period. An appreciable difference of 0.05±0.02 m/s was found between the offsets measured in February 1996 in the Laboratory and in April 1996 in-situ. This difference was most likely due to bias errors in the laboratory estimates resulting from electrical or magnetic fields, which presumably were not present in the field. From April to August 1996, long term changes in measured offsets in-situ were found to be 0.02±0.01 m/s at most. It was therefore decided to use the in-situ measured offsets, instead of the manufacturer's offsets, for data-processing.

2.3 Fibre optical turbidity meters (FOSLIMs)

Reports on high-frequency recordings of SSC are scarce and are mostly based on acoustic back scatter techniques (Thorne et al., 1996), or on back scatter of infra-red light (Kawanisi and Yokosi, 1993). West and Oduyemi (1989) and Darbyshire and West (1993) do neither mention the principle of their measuring technique, nor the limitations or advantages.

FOSLIMs use the principle of light attenuation for measuring SSCs. They were applied in this research because sediment flocs composed of clay, silt and biological components absorb light instead of reflecting it, contrary to sand particles, for example, and therefore back scatter techniques are less useful.

The FOSLIMs have been manufactured by WL | delft hydraulics. A sketch of the original sensor head of the FOSLIM is shown in Figure 2a. The sensor consists of two glass fibres mounted on a rigid rod in such a way that both alignment of the fibres and the distance between the fibres can be altered. One of the fibres is connected to a light emitting diode and sends an infra-red light beam through the measuring volume (see Figure 2). The fibre opposite to the transmitted light emitting fibre collects the light and passes it on to a photo diode where the light intensity received is measured. The difference between the emitted and received infra-red light intensities is a measure for the water turbidity, which is related to the SSC through in-situ calibration (see Section 3.2 and Appendix D). A daylight filter prevents influences of daylight on the turbidity measurement. The FOSLIM output voltage is approximately linearly related to the concentration of fine sediments.

a) b)

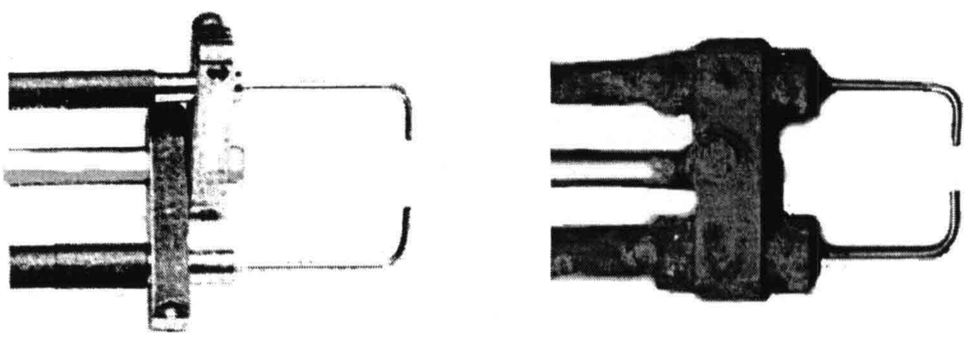

Figure 2. The original sensor head (a) used until April 1996, and the adapted sensor head (b) used after April 1996.

A prototype FOSLIM was tested in the early nineties by M. Christie and K. Dyer of Plymouth University. It was found not suitable for field measurements (personal communication). Long wiggling fibres presumably caused losses of light in the fibres which were incorrectly interpreted as turbidity fluctuations.

Different prototypes were purchased in July 1995. They had short fibres which were tightened thoroughly when attached to the measuring frame. However, this design also proved to be not suitable for field measurements: during the April 1996 measurements the fibre heads metal coating corroded, which allowed the fibres to twist. Slight changes in the positions of the fibre heads alter the characteristics of the instrument completely. From then on WL | delft hydraulics fixed the fibre heads with a synthetic resin at a separating distance of approximately 6 mm (see Figure 2b).

The adapted FOSLIMs were tested in the laboratory in June 1996. The measuring range was limited, as a result of fixing the fibre heads, to approximately 0-30 g/l for mud from the Heringsplaat. The upper range, 20-30 g/l, showed increased noise levels and was therefore removed. This was done by increasing the amplification in such a way that the maximum output signal of 10 Volt was obtained at 20 g/l. The noise level measured in clear water did not exceed 0.8×10^{-4} V. The offset drift measured over a period of 90 hours in still tap water was approximately 0.03 g/l per hour. The accuracy of the SSC measurements is mainly determined by the calibration procedure. The cut-off frequency was about 3 Hz of the FOSLIM prototype used in the feasibility test in July 1995. The FOSLIMs used in the measurements of August 1995 and of 1996 had cut-off frequencies of 10 Hz.

Under field conditions it is quite possible that the fibre heads remain clear from fouling in periods of relatively high water velocities, but the heads may foul during low and high water slack. It was found that seaweed can easily cover the small fibre heads (see also Chapter 5). Therefore, FOSLIMs are calibrated in-situ since fouling and suspended sediment characteristics depend on the in-situ conditions. The in-situ calibration procedure is described in Section 3.2.

2.4 Additional instrumentation

The Rijkswaterstaat Pole 208 is equipped with three turbidity meters of the MEX-type (WL | delft hydraulics, MEX-3 RD-10/5 sensor) and three spherical EMFs fixed at 0.3 m, 0.7 m and 1.4 m (1.0 m in 1995) above the bed. The frame is shown in Figure 1 to the left of the pole.

The MEXs are used in this study for long-term turbidity measurements. They provide fouling correction through a two-way measuring system. The light attenuation is measured over two different path ways and the values obtained are subtracted, which compensates for contributions of the fouling (Van Rijn, 1993). Furthermore the relatively large measuring volume and the sensor shape make the MEX less sensitive to fouling, when compared to the FOSLIM. Therefore the MEX is considered as a robust measuring device for low-frequency turbidity measurements. A data-logger calculates and stores the 10 minute averages and standard deviations of the MEX and EMF signals.

The water level was recorded at the Rijkswaterstaat stations “Dollard Noord” and “Skansker Diep”, 2 km north and 1 km south of Pole 208, respectively. The wind velocity was obtained from a measuring platform (BOA Measuring Bridge) located on the Heringsplaat (+0.2 m N.A.P.), 400 m south west of Pole 208. Turbidity, water velocity, salinity, water level and the temperature were also recorded.

Chapter 3 Methodology

3.1 Data collection

Three combinations of EMFs and FOSLIMs were fixed at approximately 0.1 m, 0.4 m and 1.0 m above the channel bed, the distance between a FOSLIM and EMF fixed at the same level being approximately 0.05 m (see Figure 3). The small separation distance between a FOSLIM and an EMF allowed both velocity and turbidity fluctuations to be measured in approximately the same "measuring volume". A consequence of this set-up was that the velocity measurements were hindered by the turbidity sensor heads during flood and vice versa during ebb for the smaller scales of turbulence (< ~0.1 m). If this mutual hindrance had a significant effect on the measurements, it would have resulted in differences in the turbulence parameters during ebb and flood. The largest differences would occur at the lowest sensor position where small scales become important. In Appendix F it is shown that noise contributions to the velocity signals were independent of flow velocities and flow direction and appeared to be most pronounced at the highest level of 1.0 m. These noise contributions could therefore not be linked to the presence of the FOSLIM sensor head. The relatively large Reynolds stresses measured during flood in June and August 1996 at the 0.1 m level is explained from the presence of a scour hole which is further discussed in Van der Ham (1999).

The measuring frame was lowered along the measuring pole during low water (LW). The sensors were aligned visually with the direction of the flow. The signals were digitized, sampled and stored in files on a PC by the data-log system DASY-Lab (DASYTEC GmbH, Mönchengladbach, Germany). DASY-Lab supports a "sample and hold" system which avoids time lags between the signals. The sampling frequency was set at 20 Hz, which was about twice the cut-off frequency of the instruments. After each measurement the files were saved on computer-tapes which were transported to Delft University of Technology (see also Appendix B).

The offsets of the EMFs were measured in-situ during LW in advance of each measurement (see also Chapter 2). The measuring frame was lifted and a bucket was placed over an EMF transducer head and fastened to the rigid frame so as to minimize water flow along the transducer. Then the frame was lowered into the channel and rotated in such a way that the flow ran into the bottom of the bucket. The signals of the X and Y channels of the EMF were sampled for a period of approximately 5 minutes. This procedure was repeated until all offsets had been determined.

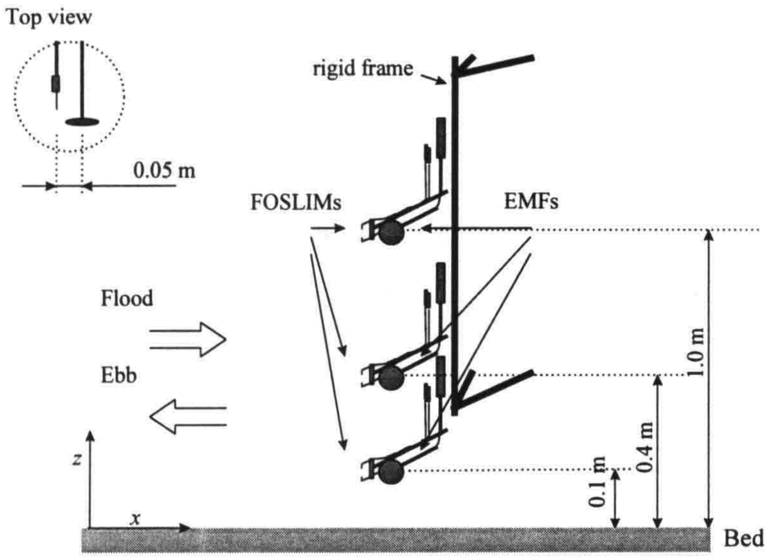

Figure 3. Sketch of the rigid frame for turbulence measurements with the combinations of EMFs and FOSLIMs attached at three heights above the bottom.

Suspended sediment samples for calibration of the FOSLIMs and MEXs were taken on a regular basis during the measurements. The samples were pumped from the sensor positions perpendicular to the direction of the flow by means of small tubes (4 mm diameter) and a peristaltic pump. The intake velocity was approximately 0.1 m/s. Sampling errors due to the inertia of large suspended particles were negligible because the suspended sediments consisted mainly of silt and clay. Following Crickmore and Aked (1975, in Van Rijn, 1993) sampling errors were estimated at 10%. Sampling times were registered in advance of the suspended sediment sampling; the sampling took about 1-2 minutes. The samples were stored in the dark in order to avoid primary production. The SSCs were determined in the Laboratory of Hydromechanics through filtering using mixed celluloid ester filters with 0.15 μm pore size. The errors made in determining the SSCs were found to be much smaller than the sampling errors. For a description of the filtering procedure the reader is referred to De Wit (1992).

For a comprehensive description of all available information about the estuary during the measuring periods in 1995 and 1996, such as water levels, wind velocities, discharges at Pogum and Nieuwe Statenzijl etc., the reader is referred to Ridderinkhof et al. (in prep.).

3.2 Data processing

The time records of the EMFs and FOSLIMs were processed with the software packages MATLAB 5.0 (see Appendix E) and EXCEL 7.0. Three processing stages are explained in this section: spike identification and removal, calibration, and determination and correction of possible sensor tilt.

Spikes are typically identified as a small number of outlyers in a signal which result from other processes than the process under investigation, such as instrument vibration, interference etc. These processes probably influence the signal to a certain extent in the range of the signal itself, but this is neither easily noticed nor remedied afterwards. Spikes have a relatively large impact on some of the turbulence properties. The procedure followed in this study is therefore to identify the spikes and to check their influence on the parameters under investigation. If removal of the spikes alters the conclusions drawn, it will be brought up for discussion.

The identification of spikes is based on estimates of the probability density distributions of representative parts of the signals. The probability density distributions showed that temporal turbulence fluctuations seldom exceeded a threshold of about five times the standard deviation. This finding is in agreement with probability density distributions presented by Kwanisi and Yokosi (1993), French and Clifford (1992) and West and Shiono (1985). It was therefore decided to use the threshold of five times the standard deviation away from the mean as a criterion for spike identification. Each signal was divided into 10 minute records of which standard deviations were determined. Peaks were removed from the records if they exceeded the threshold. A complete 10 minute record was rejected if spike removal lowered the standard deviation by more than 10%.

The EMF responses were obtained from laboratory calibrations (Chapter 2, Appendix D) and the offsets were determined in-situ (Section 3.1). Using the calibrations, a computer program calculated the horizontal and vertical velocity components (U and W respectively) and the SSC (C).

The FOSLIMs were calibrated in-situ by taking samples of suspended sediment at the FOSLIM positions at time intervals of approximately 15 minutes (see also Chapter 2). The one minute averaged FOSLIM signals were compared directly to the SSCs obtained from sampling (see also Appendix D). If necessary, small corrections were made for the sampling times: always in the same direction and over the same time interval for all turbidity meters. Offsets and responses were obtained from least squares fits through the plots of SSC against FOSLIM output voltages. For the calibration of the MEXs a similar procedure was followed.

In order to correct for possible tilt of the EMF sensor heads the EMF axes were rotated over an angle φ such that there was no longer a correlation between U and W when evaluated over the measuring period (see also Darbyshire, 1993). The velocities were corrected according to:

$$U = U_m \cos\varphi + W_m \sin\varphi \tag{3.1}$$

$$W = -U_m \sin\varphi + W_m \cos\varphi \tag{3.2}$$

where the subscript m denotes the measured values.

3.3 Feasibility test in July 1995

After some small scale laboratory tests an in-situ measurement was conducted in the tidal channel "Groote Gat" in July 1995 in order to test the feasibility of the instruments for measuring the turbulence parameters of interest: turbulence intensities, Reynolds stress, turbulent transport of sediment, and related parameters. WL | delft hydraulics took part in this test because of their expertise in the matter of turbidity measurements with the FOSLIM and field measurements in general.

3.3.1 Data collection and processing

The test was carried out at pole RWS208 for a two hour period during flood tide at 7 July 1995 starting from 14:54h local time. The water depth changed from 2.5 m to 4 m during the measuring period. The weather conditions were very moderate and during the measuring period the wind from the south decreased from 5 to 3 m/s.

A single prototype FOSLIM and a single EMF of WL | delft hydraulics were mounted on the measuring frame and were lowered to a level of approximately 1 m above the sediment bed. The time series of the SSCs were obtained through calibration of the one minute averaged FOSLIM signal with 7 suspended sediment samples. All sampling times were shifted backward for 5 minutes in order to get better agreement between the FOSLIM signal and the samples. The calibrated signal and the sediment samples are shown in Figure 4.

The manufacturer's calibration data of the EMF were used: 10 V/(m/s) for the responses and zero offsets. The EMF axes were rotated such that there was no correlation between U and W evaluated over the measuring period, see Section 3.2. In this way it was found that the velocity data had been collected at a tilt of -2.9°.

A visual inspection of the signals revealed that some spikes were present in the X-channel of the EMF. The next section addresses, amongst other things, the influence of their removal on some of the turbulence properties.

3.3.2 Data analysis and discussion

The time series of one minute averaged longitudinal velocity component and SSC, $\overline{U}$ and $\overline{C}$, respectively, are presented in Figure 4. The agreement between the samples and the calibrated signal is fair, except for a sample taken at 16:15 hours which had an extremely large standard deviation. This points to errors made during filtration and this sample was therefore omitted. The measured time series of $\overline{U}$ and $\overline{C}$ seemed realistic, which enhanced confidence in the measuring technique and in the performance of the FOSLIM.

After calibration the data were divided into 10 data-records of 10 minutes. Trends were computed and subsequently removed from the records. The turbulence intensities were computed from the variances, and the Reynolds stress and the vertical turbulent transport of suspended sediment were computed from the covariances, of u, w, and c. The stationarity of each 10 minute record was examined by dividing it into 1 minute segments and then applying a run test thereby following a standard procedure (see Bendat and Piersol, 1971 or Van der Ham, 1999).

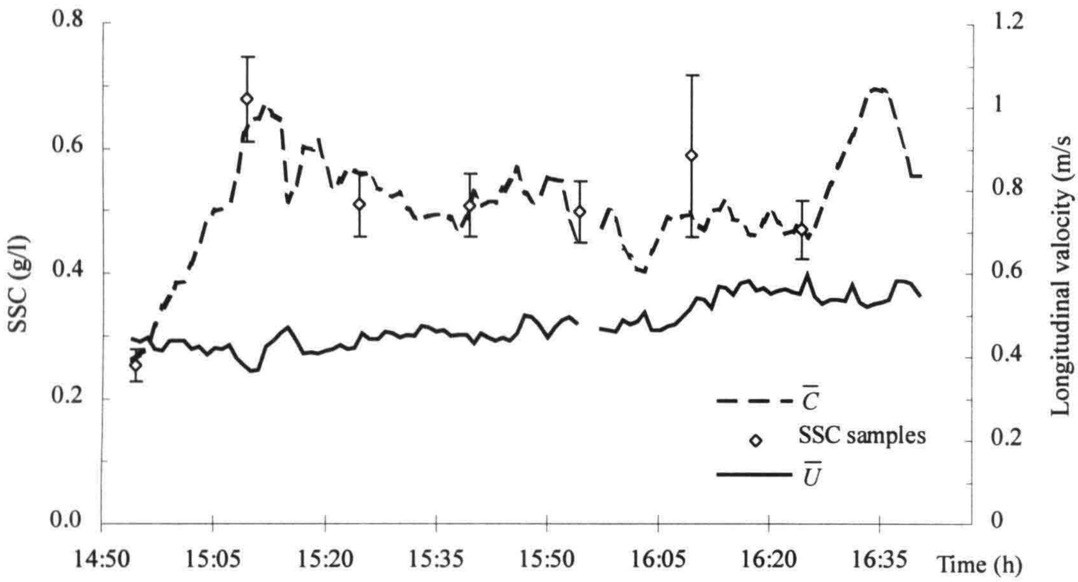

Figure 4. Test measurement during flood, July 7 1995. The vertical bars denote the estimated sampling errors in the samples.

Table 1. Outcome of the applied run test.

	1	2	3	4	5	6	7	8	9	10
u'	S*	S	S	S	S	S	S	N**	N	S
w'	S	N	S	S	N	S	S	S	S	S
c'	N	N	N	S	S	N	S	S	S	N
$\overline{uw}$	S	S	S	S	S	S	S	S	S	S
$\overline{cw}$	S	S	S	S	N	S	S	S	N	S

*S = stationary, **N = non-stationary.

Table 1 shows, for example, that the first three records of c', and the sixth record are non-stationary. This is in agreement with the trends in the averaged SSC during these periods shown in Figure 4. Records 4 and 7 can be considered stationary for "all" turbulence properties and are selected for spectral analysis.

Auto-spectral density functions (auto-spectra) and the cumulative auto-spectra and co-spectra are calculated for records 4 and 7 (see also Van der Ham, 1999). The auto-spectra for u and c, normalized with their variances, plotted against the wave number, k, are shown in Figure 5, and the cumulative spectra are shown in Figure 6. The wave number $k = 2\pi f/\overline{U}$ where f is the frequency. For computational aspects of the spectra the reader is referred to Van der Ham (1999).

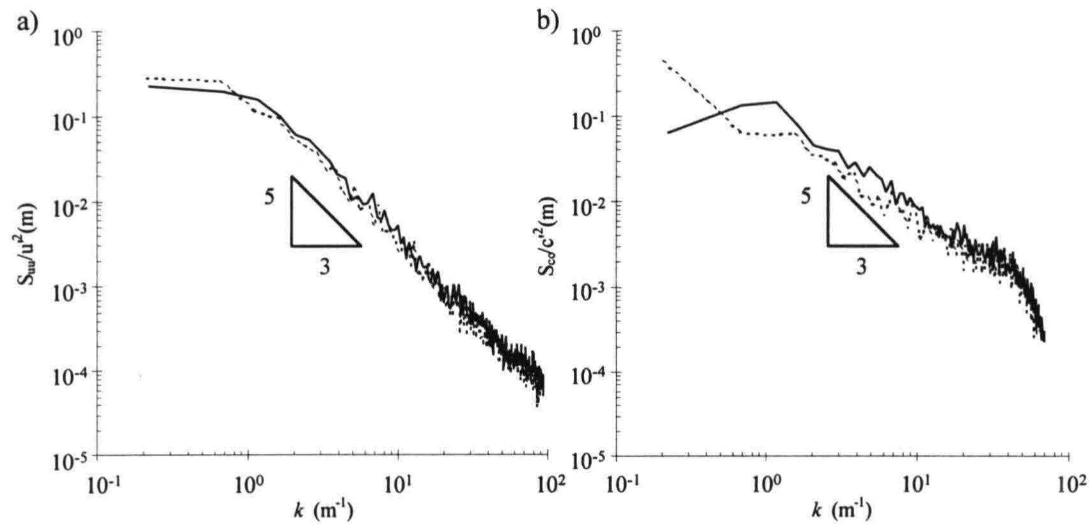

Figure 5. Normalised auto-spectra of records 4 and 7: (a) normalised auto-spectrum S_{uu} of u; (b) normalised auto-spectrum S_{cc} of c; —, record 4; ---, record 7; the wave number is defined as $k = 2\pi f/\overline{U}$, f is the frequency.

The sharp decrease of S_{cc} at $k = 50$ m^{-1} is the result of analogue filtering beyond the cut-off frequency of ~3 Hz of this FOSLIM prototype. The FOSLIMs used in the measurements of August 1995 and of 1996 had cut-off frequencies of 10 Hz (see Section 2.3).

The slopes of S_{uu} over 1 m^{-1} < k < 100 m^{-1} for both records 4 and 7 are in agreement with the expected -5/3 behaviour in the inertial subrange (Nieuwstadt, 1992; Hinze, 1975). The slope of S_{cc} is about -5/4 whereas the -5/3 behaviour is expected for spectra of passive scalars (Hinze, 1975). The slope of -5/4 is more or less in agreement with auto-spectra of c presented by West (1989). The difference between the "scalar" and "suspended sediment" slopes is addressed in Van der Ham (1999).

The cumulative spectra shown in Figure 6 are plotted against kz, in which z is elevation above the bottom. According to Soulsby (1980) it can be assumed that through this scaling the normalised spectra measured at different heights in the water column collapse into a single curve. Nezu and Nagagawa (1993) show that better results are obtained if k is multiplied by the integral scale L_x. This subject is further discussed in (Van der Ham,1999). In this Chapter we follow the work of Soulsby (1980) which is common practice in field research.

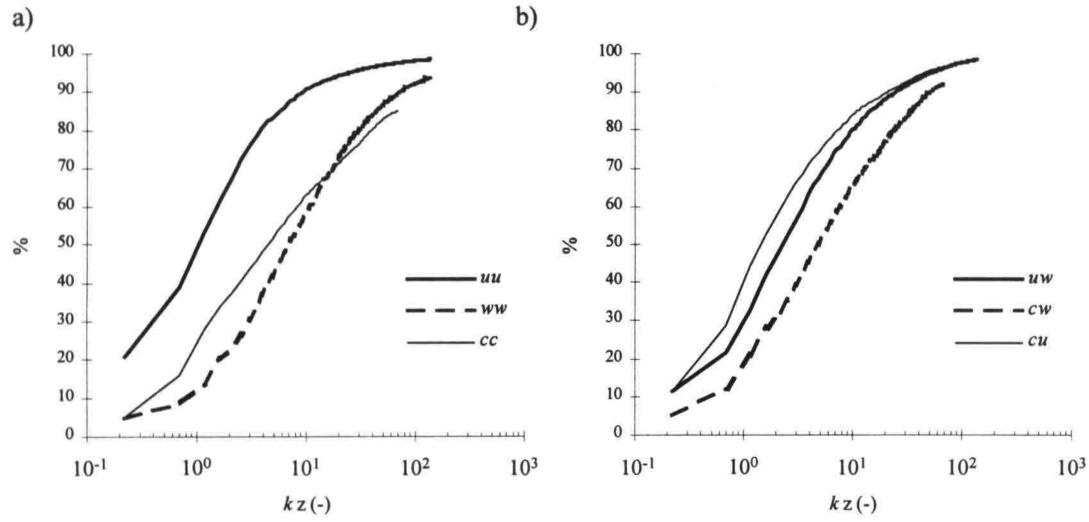

Figure 6. Cumulative spectra for record 4: (a) cumulative normalised auto-spectra; (b) cumulative normalised co-spectra.

High-frequency losses are corrected for and are computed by extrapolating the tails of the spectra, according to the $k^{-5/3}$ and the $k^{-7/3}$ dependence for the auto-spectra and co-spectra respectively, down to the Kolmogorov wave number k_d, defined as $2\pi/\eta$, where $\eta = (\nu^3/\varepsilon)^{1/4}$, ν is the kinematic viscosity, and ε is the turbulence dissipation rate. The turbulence dissipation rate ε is determined assuming local equilibrium between turbulence production and dissipation so that it may be calculated from the multiplication of the measured Reynolds stresses and the mean velocity gradient, which is here calculated from a log-velocity distribution.

The highest losses are 15% for c'^2, 8% for $\overline{cw}$ and 6% for w'^2. The loss of c'^2 is mainly due to the relatively low cut-off frequency of about 3 Hz of the prototype FOSLIM. The spectral losses for these measurements are therefore considered small.

If measurements are made closer to bed, the losses increase due to cut-off losses and sensor size. If, for example, the measuring height z is reduced from 1 m to 0.2 m it can be derived (from Figure 6) that cut-off losses are approximately 20% for both c'^2 and

$\overline{cw}$, for infinitely small sensor size and 30% if the "sensor size" of the combination of EMF and FOSLIM is estimated at 0.1 m ($kz \approx 13$).

Figure 7 shows the corrected Reynolds stress and turbulent transport of sediment. The trend in Reynolds stress shows on average an increase over the measuring period which is in agreement with the increase in the velocity $\overline{U}$ shown Figure 4.

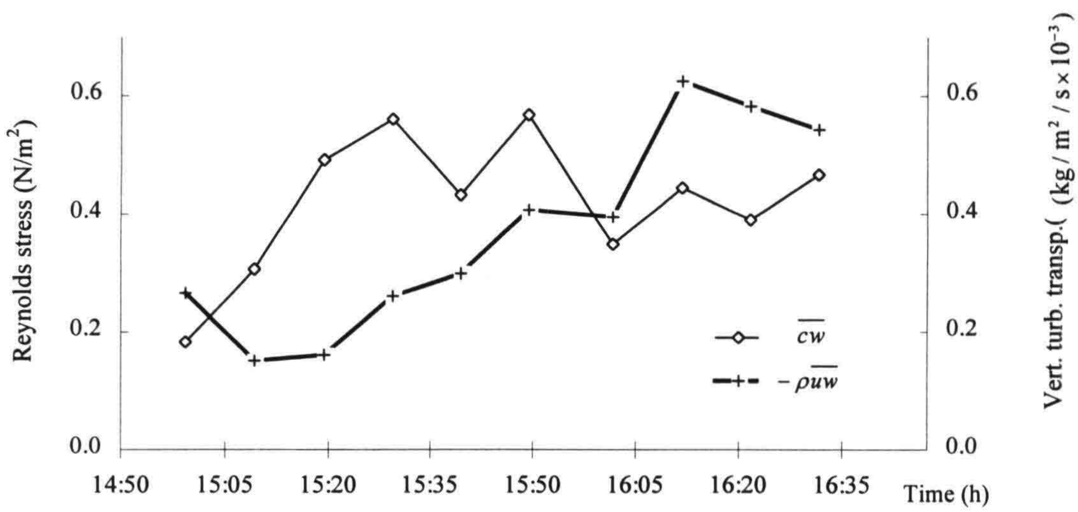

Figure 7. Time series of Reynolds stress and the turbulent transport of sediment (flood tide July 7); z / h varies from 0.4 to 0.2, where h is the water depth.

At the start of the measuring period, at 15:05h, a decrease in Reynolds stress is observed. This decrease cannot be explained from changes in the velocity $\overline{U}$ since $\overline{U}$ is almost constant during this period. The trend in $\overline{cw}$ shows an increase until 15:30h, while Figure 4 shows that $\overline{C}$ already starts to decrease at 15:10h. This can be explained from a limited amount of sediment available for transport. The sediment is resuspended in the first part of the flood but remains close to the bed thereby creating a density gradient. This gradient could affect the turbulence structure. When the flood velocities become larger the available amount of sediment becomes homogeneously distributed over the entire water column. The SSC near the bed then decreases (see also Chapter 5).

The correlation coefficients for the Reynolds stress and the turbulent transport of sediment are defined as:

$$R_{uw} = \frac{|\overline{uw}|}{u' w'} \tag{3.3}$$

$$R_{cw} = \frac{|\overline{cw}|}{c' w'} \tag{3.4}$$

These coefficients were also corrected for high-frequency losses as explained above. The noise levels of the EMF and the FOSLIM (see Chapter 2) do not change the turbulence intensities significantly (increase less than 5%) and are neglected.

Spike removal was found to have no significant influence on the turbulence parameters except for u' and R_{uw}. u' decreases by 40% at 15:00h and by approximately 10 % at 15:30h and 15:40h, whereas R_{uw} increases from 0.32 to 0.38 at 15:00h. The first 10 minute data-record of u is therefore rejected.

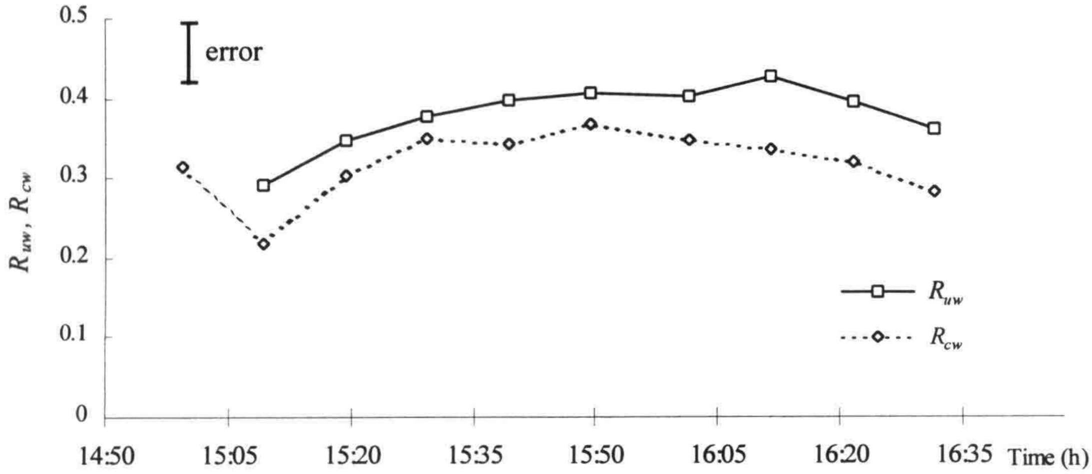

Figure 8. The correlation coefficients for the Reynolds stress and the turbulent transport of sediment.

Figure 8 shows the time histories of R_{uw} and R_{cw} for this test. The trends of R_{uw} and R_{cw} are very similar. The small values of R_{uw} and R_{cw} directly after the start of the measuring period can tentatively be explained from stratification effects. This would be in agreement with the decrease in Reynolds stress during this period whilst $\overline{U}$ remains constant (see Figures 4 and 7). Stratification effects are considered in greater detail in Van der Ham (1999). The maximum values of approximately 0.40 for R_{uw} and 0.35 for R_{cw} would then represent correlation coefficients for unstratified flow. The magnitudes as well as R_{uw} being larger than R_{cw} are in agreement with measurements of Komori et al. (1983) and West and Oduyemi (1989). Komori et al. (1983) found from laboratory experiments values for R_{uw} of about 0.4 and for the correlation coefficient for the heat flux, $R_{w\theta}$, about 0.25. West and Oduyemi (1989) found from in-situ measurements in the Cowny and Tamar estuaries values for R_{uw} of about 0.5 and for R_{cw} of about 0.25 (see Van der Ham, 1999).

This test demonstrated the feasibility of combining a FOSLIM and an EMF for measuring turbulence parameters in-situ, so that insight into the turbulence structure in a tidal channel can be obtained. The results of this test were promising, though tentative since the measuring period covered only two hours and measurements were made at only one level in the water column.

3.4 Test measurement of August 1995

This measurement was made to test the complete measuring system as shown in Figure 3. In addition to this set-up, two MEX turbidity sensors were mounted at z = 0.7 m and z = 1.3 m. The installation of this heavy equipment was carried out using the vessel Regulus of Rijkswaterstaat Meetdienst Noord.

The test was carried out at pole RWS208 during a three and a half hour period during flood on Thursday August 31, 1995 starting from 11:31h local time, and during a nine hour period on Friday September 1, 1995 starting from 11:51h local time. The tidal range was 3.3 m. The weather conditions were moderate: cloudy but no rain, relatively large wind speeds from the north ranged from 8 m/s to 12 m/s (Beaufort 5 - 6).

These measurements showed that the complex measuring system, consisting of equipment and instrumentation from the BOA Measuring Bridge, from the Laboratory of Hydromechanics of the Delft University of Technology, and from Utrecht University needed further development before it could be used successfully. The FOSLIMs and MEXs worked well but the EMFs did not function properly, probably because of a connector failure between the EMFs and the datalog-computer. In the winter of 1996 a new, smaller, datalog-system was purchased replacing some of the heavy BOA equipment. This made the installation of the measuring system much simpler. The MEX sensors were omitted for the sake of convenience. Their task, performing long term turbidity measurements, was taken over by the three MEX sensors of the Rijkswaterstaat measuring frame.

Figure 9 shows the calibrated one minute averaged signals of two FOSLIMs and two MEXs located at approximately the same level during flood at August 31, 1995. Even the short term variations in the FOSLIM signals are in agreement with those of the MEXs, especially at $z = 0.7$ m. The data do not show significant offset drift.

Twelve suspended sediment samples were taken in total, four at each level. The errors of the calibrations are relatively small for all instruments despite the small number of sample points. The errors for the FOSLIM calibrations were even smaller compared to those of the MEX calibrations (Figure 9). This can be explained from the fact that the suspended sediment samples were taken exactly at the FOSLIM positions. These errors being small also indicates that the sampling errors were probably somewhat smaller than the estimated 10% (see Section 3.1). These results show that FOSLIMs are suitable instruments for measuring suspended sediment concentrations up to a few grams per litre in the field.

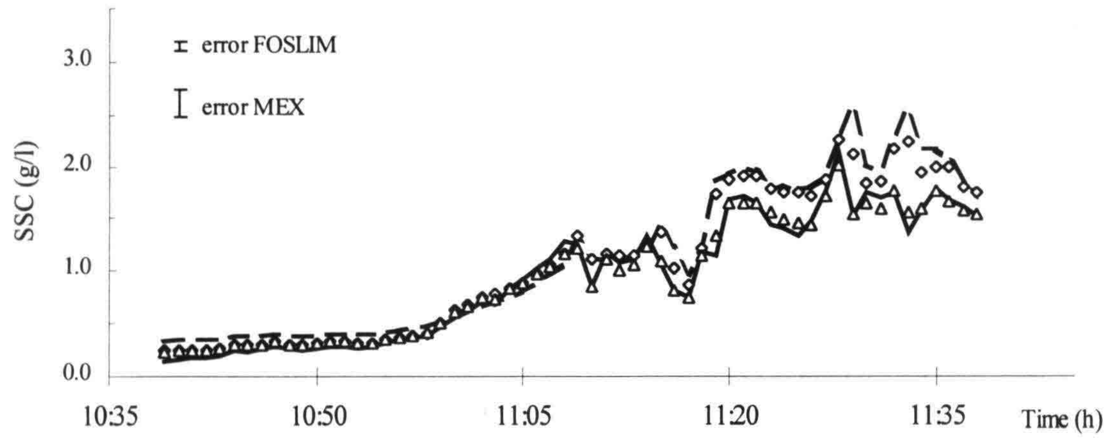

Figure 9. Comparison of one minute averaged data of FOSLIM and MEX turbidity sensors during the test measurement August 31, 1995 : – – –, MEX at $z = 0.7$ m; ——, MEX $z = 1.3$ m; ◊ , FOSLIM at $z = 0.7$ m; Δ , FOSLIM at $z = 1.1$ m.

Chapter 4 Measuring periods in 1996

Measuring periods during neap and spring tides of different seasons were selected in order to study variations in maximum flow velocities and SSCs. The precise dates were determined in consultation with the colleague researchers of the BOA-theme project for reasons of logistics and synchronism of the measurements. Some mutual interests were to be harmonised. The EMFs, for example, were not only needed for turbulence measurements in the channel "Groote Gat" but also for flow velocity measurements on the adjacent tidal flat "Heringsplaat" during joint field measurements of physicists and biologists. Because simultaneous channel and flat measurements would greatly enhance the value of the total BOA data-set, a compromise was made such that the turbulence measurements were carried out simultaneously with in-situ settling velocity measurements in the tidal channel (Van der Lee, in prep.) and directly after the joint measurements on the tidal flat.

Table 2. The measurements made in 1996.

Season	Period	Tide, max.(ebb) velocity	Concentration range	Wind conditions	Remarks
Spring	16-20 April (5 tides)	spring, 0.8 m/s	0.1 - 0.5 g/l	4 - 5 m/s, S	- VIS* measurement - malfunction of FOSLIM
Summer	25-28 June (4 tides)	neap, 0.7 m/s	0.2 - 1.2 g/l	0 - 8 m/s, N - W	- adapted FOSLIMs - small amounts of seaweed
	4-6 July (3 tides)	spring	0.3 - 3.0 g/l	5 -12 m/s, SW	- large amounts of seaweed
	7-9 August (3 tides)	neap, 0.7 m/s	0.2 -0.8 g/l	3 - 8 m/s, S - SW	- VIS measurement

* Video In-situ, system for floc size and settling velocity measurements.

Dates of the field surveys carried out in the Groote Gat in 1996 together with the prevailing conditions are listed in Table 2. Table 2 shows that a considerable number of tides could be measured in 1996. This offered the possibility to select parts of the data-set with relatively high quality (see Chapter 5) and to verify certain findings by applying similar analyses to comparable parts of the data-set. The differences in maximum velocities during spring and neap tides were not particularly large. The SSCs were not very high, especially not for the spring tide of April.

Chapter 5 Quality of 1996 data

5.1 Introduction

High-quality data are required for the analysis of effects of stratification on turbulence properties. High-quality data in this study stands for data which are free of unwanted influences, such as imperfections of the measuring system and unsuitable measuring conditions for this type of research. Criteria for the assessment of the quality of the data concern, for example, the number of spikes, high-frequency losses, sensor tilt, wave activity, SSC etc. In this section parts of the data-set are selected for further analysis. Both the performance of the measuring system and the measuring conditions are evaluated. Not all considerations are presented herein: only some discussions about the quality of the data of June 1996 are presented. This discussion is representative of the assessment of the quality of the data of other measuring periods. A summary of the data qualities of measurements made in 1996 is presented at the end of this section.

5.2 Discussion of the quality of the data of June 1996

Figure 10 shows the time series of SSCs and velocities close to the channel bed during June 27. The FOSLIMs were calibrated in-situ during ebb and the MEXs were calibrated during flood on June 26 (coefficients of determination (R^2) > 0.95).

Small differences between the MEX results and FOSLIM results shown in Figure 10 can be attributed to the different measuring sites (separating distance is 5 m) and to the errors of approximately 0.05 g/l which result from the calibration procedure. Large differences (> 0.1 g/l) can only be explained from large gradients in the SSC or from sensor malfunctioning. The peak at 19:00h in the FOSLIM signal is in agreement with the peak at 12:00h and might be explained from the build-up of high SSCs close to the bottom as the result of the reduction in the tidal flow velocity. However, the MEX-signal does not show such a peak at 19:00h. Moreover, the peak in the FOSLIM signal that occurs at 21:00h is unrealistically high. These large increases in turbidity are most likely caused by fouling owing to seaweed.

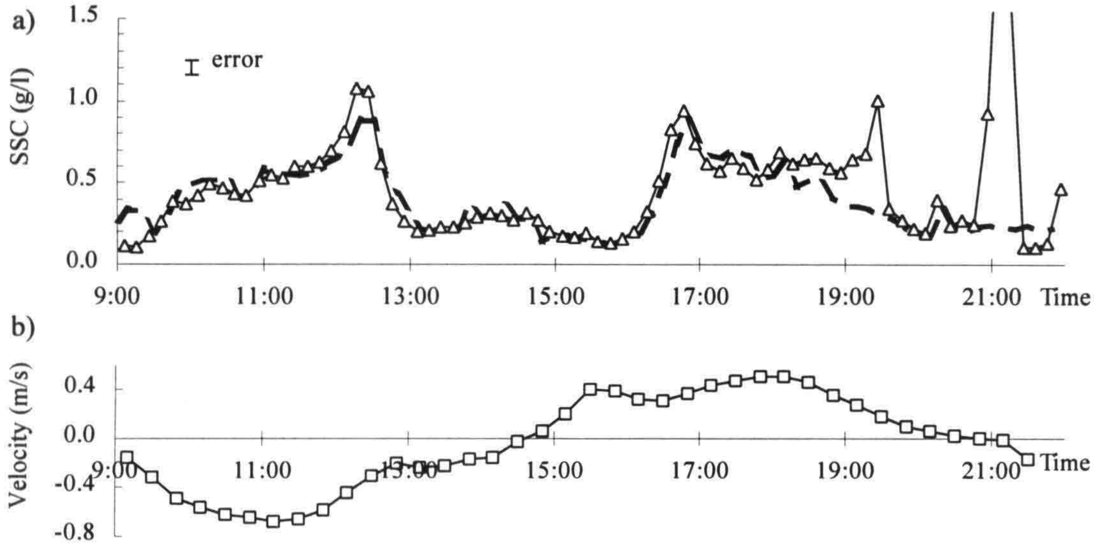

Figure 10. Ten minute averaged values of SSC and flow velocities during neap tide on June 27, 1996: (a) SCC near the bed; –Δ–, FOSLIM at z = 0.1 m; – – –, MEX at z = 0.3 m; (b) flow velocity at 1.0 m; – –, EMF at z = 1.0 m.

The wind from the north reaches speeds of 8 m/s (4-5 Beaufort) and is directed along the channel. The LW period is marked in Figure 10 by a low velocity, and a short increase in the suspended sediment concentration. Auto-spectra of u .during LW show distinct peaks at about 0.5 Hz, the peak at 1.0 m being larger than the peak at 0.1 m above the bottom (see Figure 11). These peaks are attributed to wave activity. The wave activity disappears from the auto-spectra, when the flow velocity increases from approximately zero to 0.5 m/s and the water depth increases from 1.8 m to 2.5 m. However, it is mentioned herein that the spikes in the tails of the spectra remain present. This subject is further discussed in Appendix F.

To be on the safe side, only those parts of the June data are included in the data-set for further research which display only small differences between the recordings of MEX and FOSLIM, and which show no evidence of wave activity.

5.3 Summary of data quality of measurements made in 1996

The data of the April measurements showed large differences in quality. The velocity time series were of relatively good quality: only a limited number of spikes and minor wave activity were present. The SSCs were extremely low so that suspended sediment-induced stratification effects were fully absent. Time series of SSC of the FOSLIMs were unreliable due to malfunctioning of these instruments (see also Chapter 2 and Chapter 4). The data of the April measurements were therefore not included in the data-set for further research.

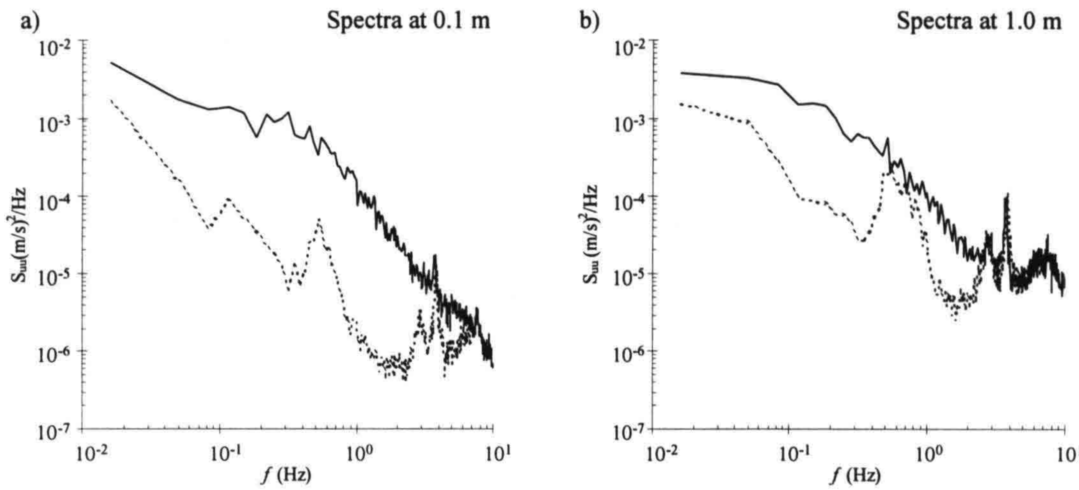

Figure 11. Auto-spectra of 10 minute records at June 27, 1996: ---, S_{uu} at 14:45u, $\overline{U}$ < 0.1 m/s, h = 1.8 m; —, S_{uu} at 15:45u, $\overline{U}$ = 0.5 m/s, h = 2.5 m; (a) S_{uu} at z = 0.1 m; (b) S_{uu} at z = 1.0 m.

The data of the June measurements are of considerably better quality, when compared to the April data. Good in-situ calibrations were available for MEX and FOSLIM sensors and the velocity time series were of good quality. Nevertheless, not all data are suitable because of the influence of seaweed and wave activity already mentioned.

The data of the July measurements are of low quality, since large amounts of seaweed were found on the instruments when the measuring frame was lifted (see photo 10 Appendix A and also see the log presented in Appendix C). The FOSLIM at z = 1.0 m was damaged in such a way that it could not be fixed.

The data of the August measurements, on the contrary, are of good quality as seaweed was no longer present and most instrumentation worked properly. Some parts of the FOSLIM signals, which were recorded at z = 0.1 m and z = 0.4 m, were rejected because spikes removal resulted in relatively large changes in the turbulence intensities (> 10%, see Section 3.2). Some influence of wave activity was present during LW. However, the major part of the August data set was used for further analysis (see Chapter 4). Figure 12 shows an example of the time histories of SSCs and velocities.

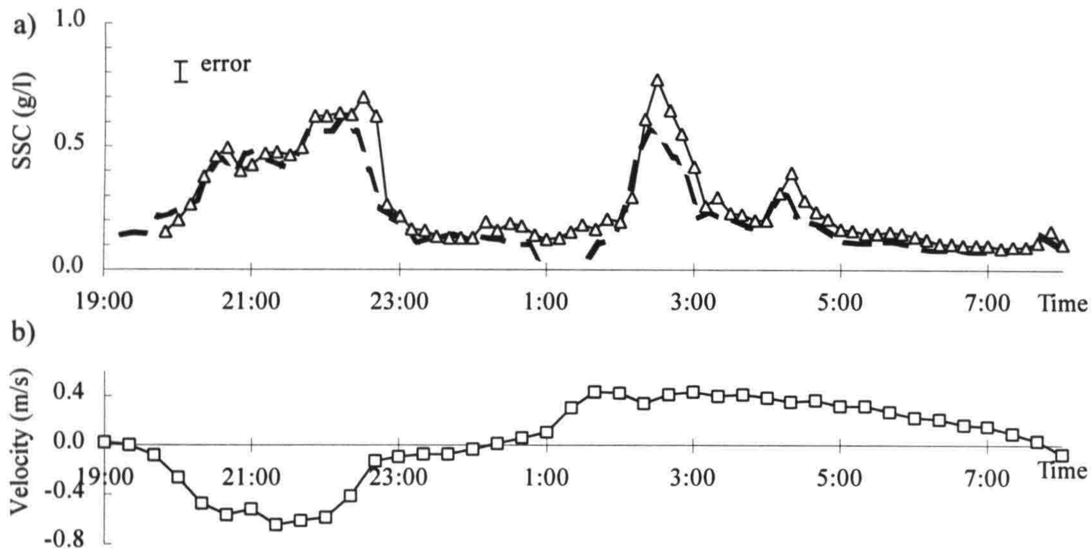

Figure 12. Ten minute averaged values of SSC and flow velocities during neap tide on August 7-8, 1996: (a) SCC near the bed; –Δ–, FOSLIM at z = 0.1 m; – – –, MEX at z = 0.3 m; (b) flow velocity at 1.0 m; – –, EMF at z = 1.0 m.

Chapter 6 Conclusions

The test measurements in June and August 1995 showed that the FOSLIM is a useful high-frequency device for measuring SSC. Direct comparison with another robust turbidity sensor of the MEX type showed that drifts in offset and response were almost absent during the test period. It was found that the accuracy of the FOSLIM depends to a large extent on the in-situ calibration procedure.

It has been shown that by combining a FOSLIM and an EMF it is possible to measure vertical turbulent fluxes of fine sediments. The value of the correlation coefficient R_{cw} for neutral flow conditions was about 0.35 which is in agreement with values presented in literature. High-frequency losses, estimated from the co-spectra, are relatively small, about 15% for c'^2 and about 8% for $\overline{cw}$. According to Soulsby (1980), higher losses should be anticipated if measurements are made near the bed.

The data sets obtained from the field measurements in 1996 showed large quality differences. In April 1996 SSCs were extremely low so that suspended sediment-induced stratification effects were fully absent. These low SSCs were ascribed to biogenic stabilisation of the sediment beds (Kornman and De Deckere, 1998). Part of the measurements made in June and July 1996 were hindered by the presence of seaweed. The data obtained in August 1996 showed a good quality except for some parts of the FOSLIM signals, which contained a large number of spikes; these parts were excluded. Part of the June data and the major part of the August data were used for further analysis, the results of which are presented by Van der Ham (1999).

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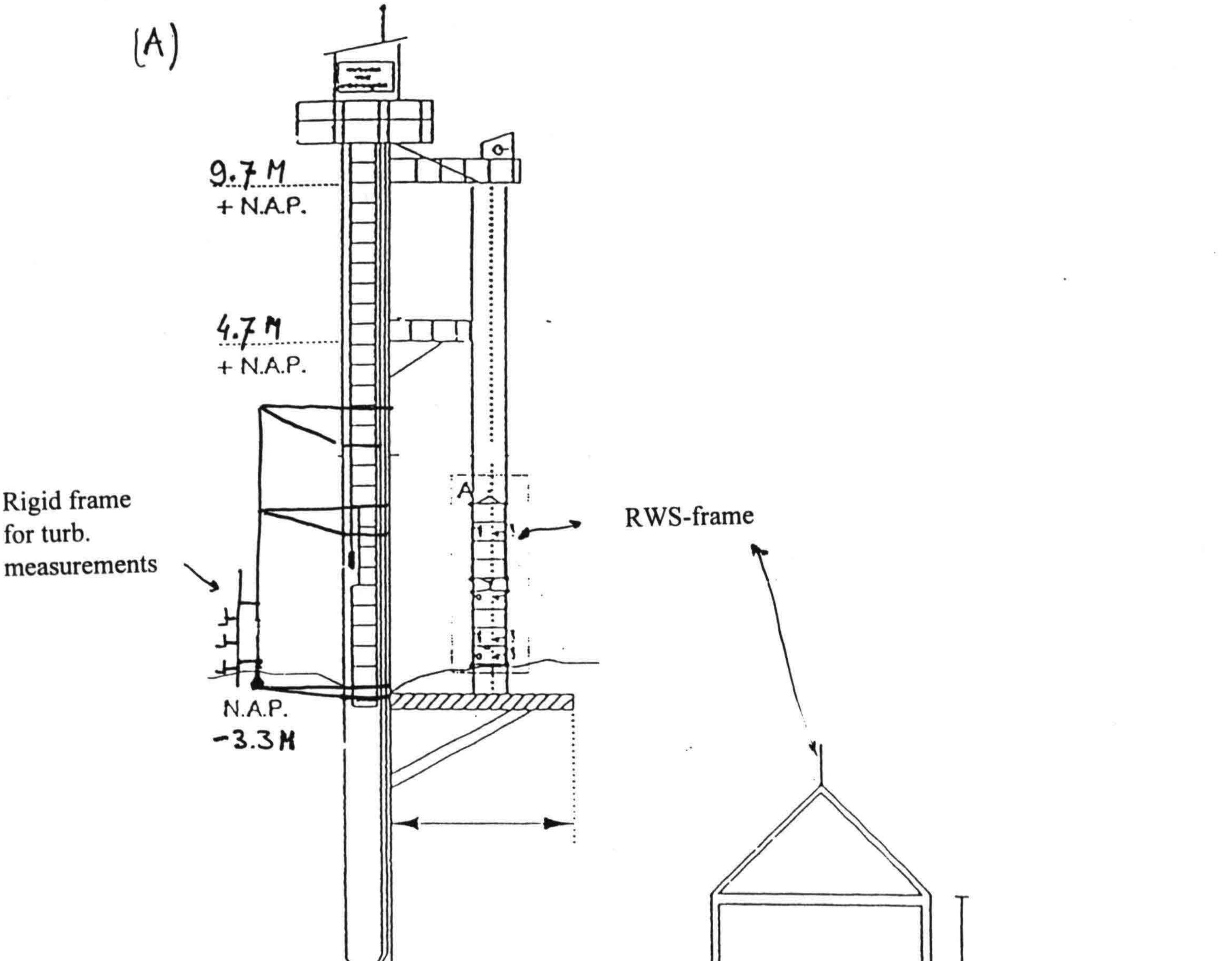
Acknowledgements

This work was supported by the Netherlands Geosciences Foundation (GOA) with financial aid from the Netherlands Organisation for Scientific Research.

Safe and successful measurements were made possible through professional logistics backup and support of the Laboratory of Physical Geography of the Utrecht University and Laboratory of Hydromechanics of the Delft University. The latter laboratory also provided financial support. Rijkswaterstaat Meetdienst Noord made their measuring pole RWS208 available, and adapted it for the turbulence measurements in the Groote Gat in 1995 and 1996. The spring tide measurements in April and July were made possible through the support of The Netherlands Institute for Sea Research (NIOZ). This institute made its research vessel "Navicula" available to the BOA theme-project for these periods.

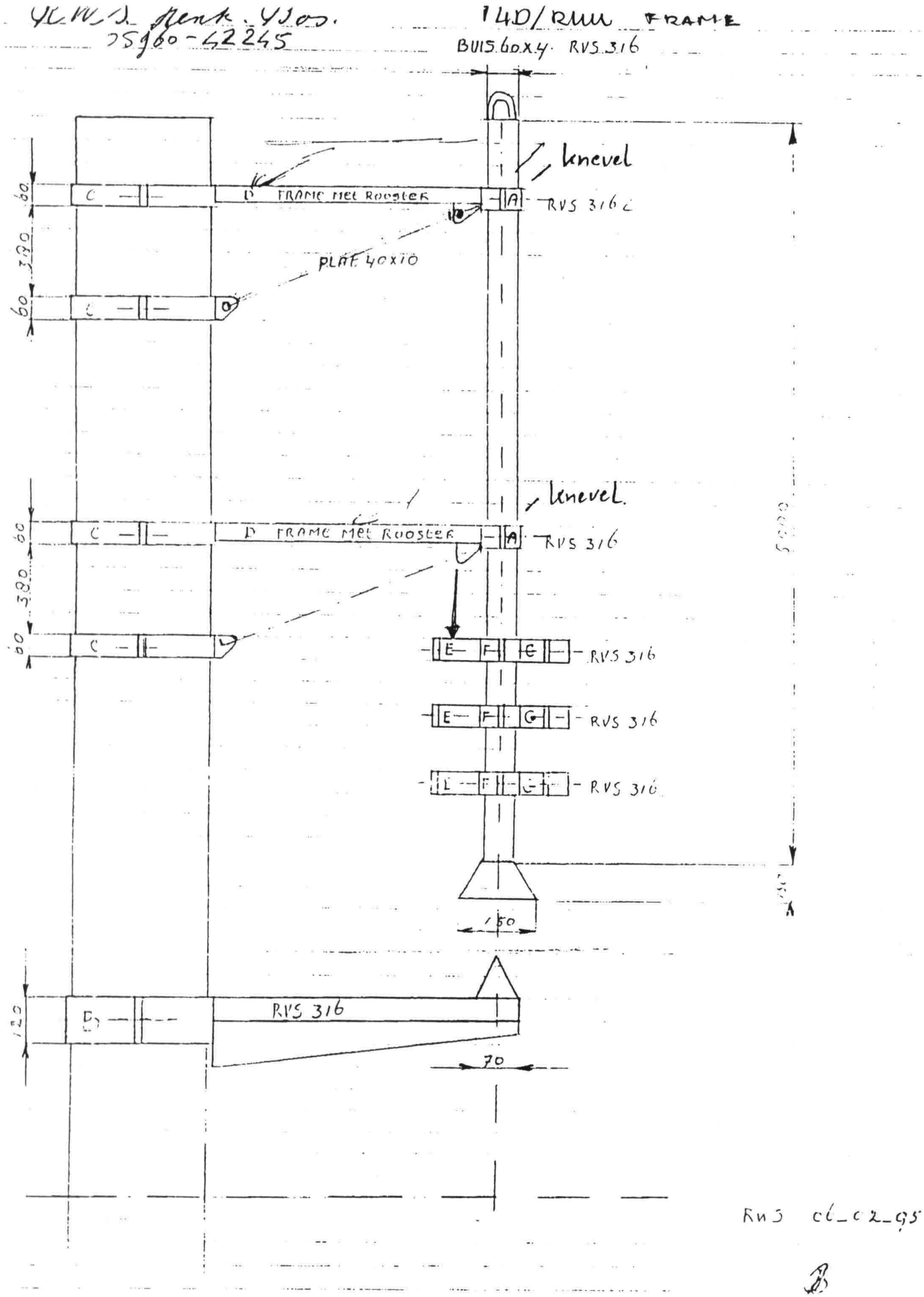
I gratefully thank J.M. Cornelisse, T.G.M. Tiemissen, H.L. Fontijn, M. Moot, A.M. den Toom, K. de Bruin, T. van Kessel, colleagues of the BOA theme-project and the Hydromechanics laboratory who contributed to the measurements.

Appendix A
Descriptions of the facilities, instrumentation and measuring location

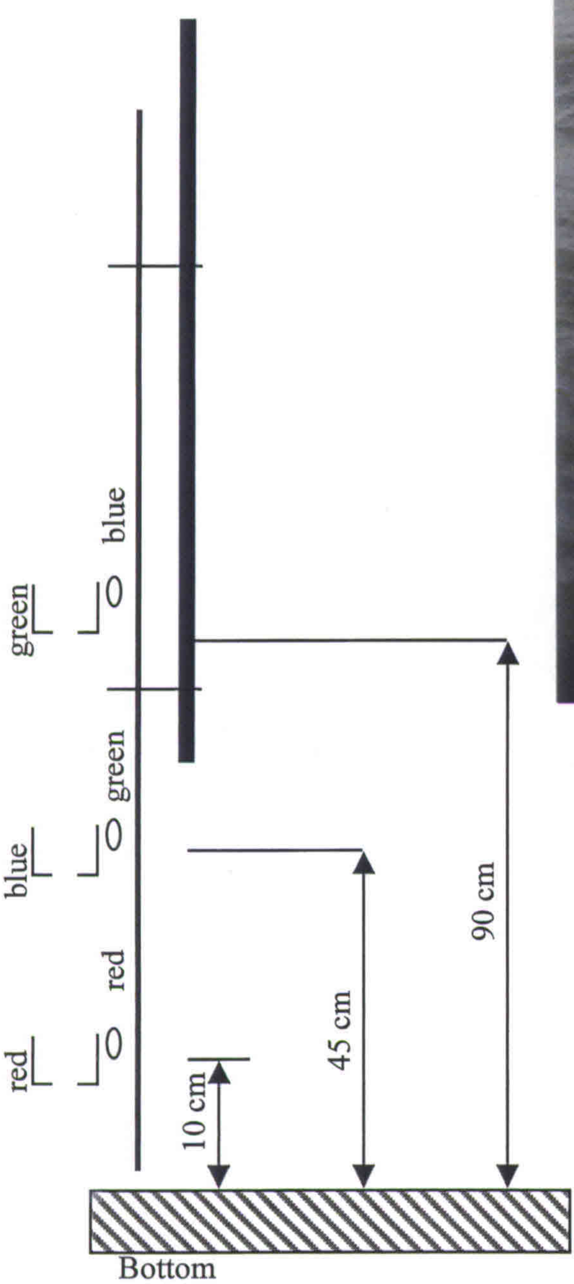


Sketch of the measuring pole RWS208: (a) The pole with two measuring frames attached: the TUD/RUU rigid frame for turbulence measurements (to the left), and the RWS-frame of which only the turbidity sensors of the MEX type functioned properly; (b) some details of the RWS frame. MEX sensors were purchased at Delft Hydraulics, Delft, The Netherlands.

Rigid frame for turbulence measurements



20 Hz Configuration Pole RWS208

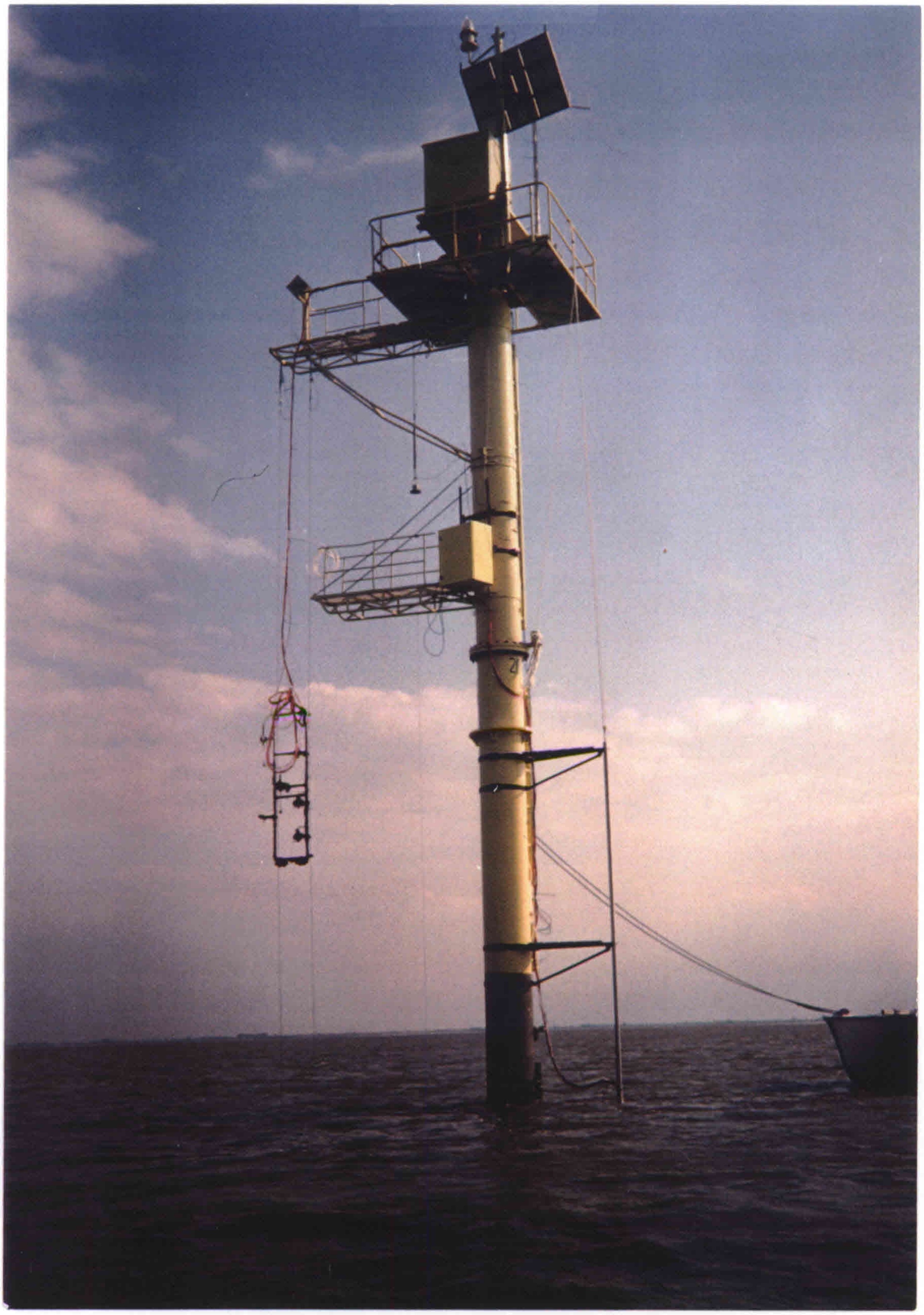


EMF D223 (red), D233 (green), D234 (blue) FOSLIMS are prototypes and have no serial numbers. (Both EMFs and FOSLIMs were manufactured by Delft Hydraulics, Delft, The Netherlands)

Error +/- 5 cm

0 EMF 20 Hz

FOSLIM 20 Hz



Measuring pole RWS208. (This photograph was made in August 1995).

CAPTIONS OF PHOTOGRAPHS TO FOLLOW

1) Aerial view of the BOA measuring platform located on the inter tidal flat "Heringsplaat", about 400 m south west of the measuring pole RWS208, where turbidity, current velocity, salinity, water level, temperature, wind speed and direction were recorded.

2) Aerial view of the measuring pole RWS208 in the tidal channel "Groote Gat". Location pole in 1995: 53 17'14'' 7 9'43''; in 1996: 53 17' 15'' 7 9'43''.

3) Aerial view of the position of the BOA measuring platform with respect to the RWS measuring pole.

4) The measuring pole RWS208 in the " Groote Gat" during low water in August 1995 (looking in the direction of the ebb current, i.e. north). Clearly visible are the tracks left behind by fishing nets that erode that top layer of the sediment bed (to the left).

5) The BOA measuring platform observed from the pole RWS208 during low water in June 1996. The remains of large biological activity show as a dark region below the platform parallel to the tidal channel. The borders of the tidal flat are covered with soft mud. Creeks are present on the lower part of the tidal flat at regular intervals of about 100m.

6) The "Groote Gat" observed from the pole RWS208 with NIOZ research vessel "Navicula" in the background (looking south, June/July 1996).

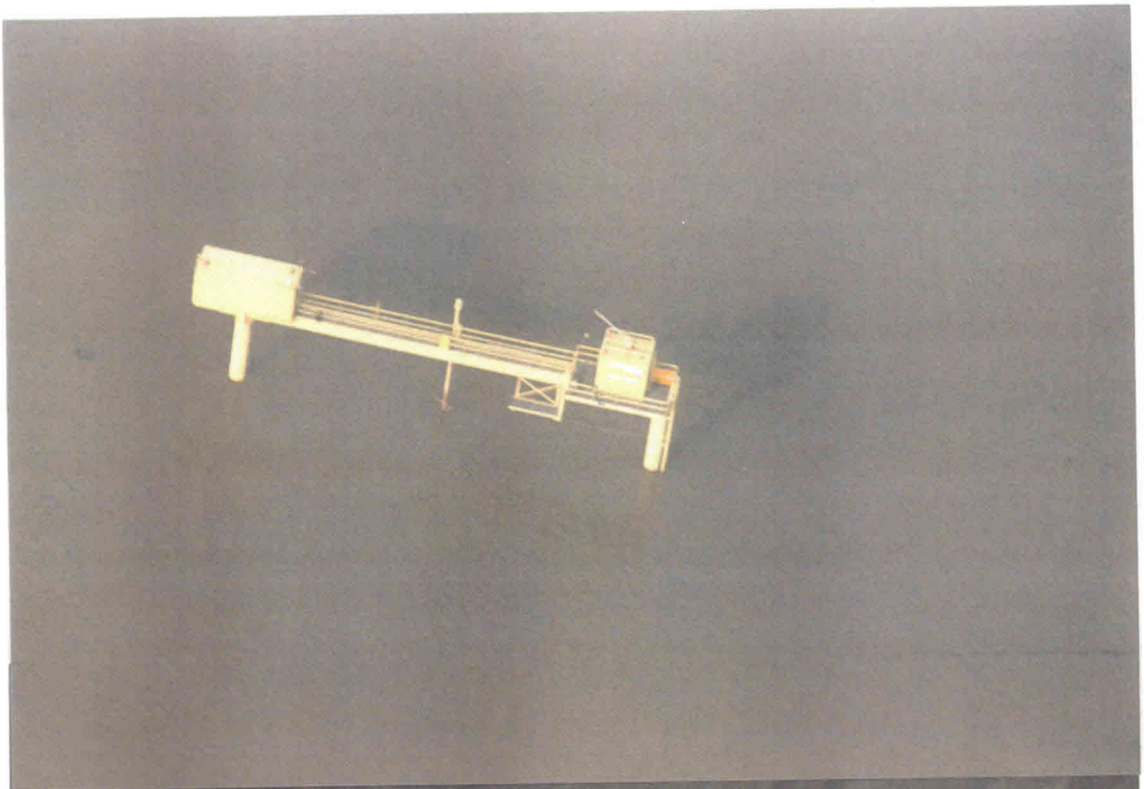
7) The immersion of the "Heringsplaat" observed from the BOA measuring platform (looking south east, June/July 1996). The water just reached the region with the remains of the large biological activity. (Note the patchy structure of the top layer of the sediment bed).

8) The same view as on photograph 5) but now when almost the entire intertidal flat is immersed (June/July 1996).

9) Photograph of the steep ridge of the “Hooge Plaat” about 4 km upstream of the measuring location.

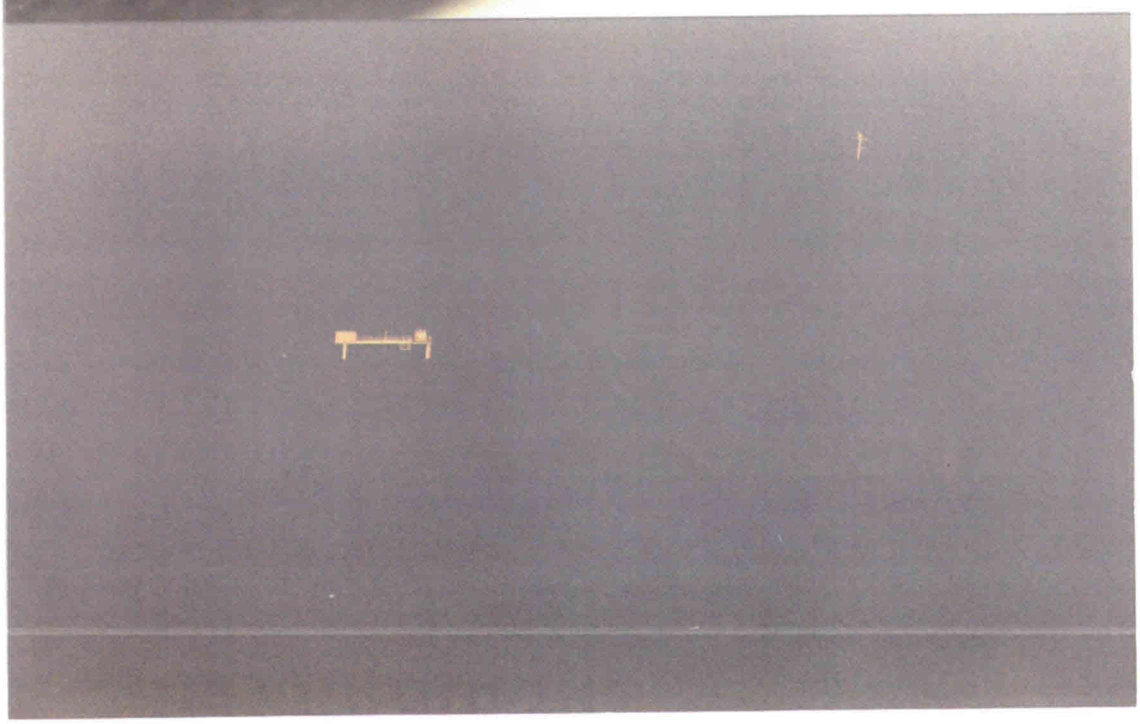
10) An example of fouling by seaweed (July 1996).

11) Another example of fouling of the RWS-frame (August 1995).



1)

2)



3)


4)


5)


6)

7)

8)

9)

10)

11)

Appendix B
Database of the turbulence recordings at the Hydromechanics Section (TU Delft)

Place: Hydromechanics Section, Department of Civil Engineering, Delft University of Technology

Tubulence data

CDROMs *The next pages provide a description of the data on these CDROMs*:

SV74-6:	turbulence data 1995
BOA-96-1:	turbulence data April 1996
SV-74-3:	turbulence data June 1996
BOA-96-3:	turbulence data July 1996
SV74-4:	turbulence data August 1996

Data of 10 minute averaged variables in the tidal channel "Groote Gat":

CDROMs *The next pages provide a description of the data on these CDROMs*:

SV74-11:	10 minute averaged water level and turbidity recordings in 1996

Reports:

- Ham, R. van der, *Turbulent exchange of fine sediments in tidal flow*. PhD thesis, Delft University of Technology, 1999.

(- This report)

For additional data on mean suspended sediment concentrations, current velocities, wind speeds and direction etc. above the adjacent tidal flat in 1996, the reader is referred to the NIOZ database.

Internet address: http//www.nioz.nl

Address: NIOZ, P O Box 591790 AB, Den Burg, The Netherlands.

SV74-6 Informatie over de data in dit blok

projectnaam: BOA research theme on intertidal areas
projectnr: TU:sv74/NWO680625-301-005:

namen: experimentator: R v.d. Ham
projectleider: Cees Kranenburg/ Han Winterwerp (WL)

periode experimenten: juli week 27 1995 -jd188
plaats experimenten: Dollard, Grote Gat paal 208
gebruikte apparatuur: 1 EMF type S, 1 FOSLIMs (20Hz data-aquisitie met Dasylab)
3 MEX 3 EMF RWS 10 min. gemiddeld/

Agemene opzet:

- Deel 1 Voorbereiding van de bewerking/analyse en 1 min. gemiddelde data
- Deel 2 Calibratie
- Deel 3 Processing
- Deel 4 Analyse van de turbulentie-data

Overzicht gemeten grootheden per kanaal.
1:FOSLIM
2:EMF1_X
3:EMF1_Y
4:
5
6:
7:

Database files turbulentie-metingen paal in week 27 1995

7-Jul-95 Wintertijd

file nr.		begin	eind	
	0	7/7/95 13:54	7/7/96 14:54	1
	1	7/7/96 14:58	7/7/96 15:49	1

SV74-6 Informatie over de data in dit blok

projectnaam: BOA research theme on intertidal areas
projectnr: TU:sv74 GOA(NWO680625-301-005):

namen: experimentator: R v.d. Ham
projectleider: Cees Kranenburg/ Han Winterwerp (WL)

periode experimenten: augustus 1995
plaats experimenten: Dollard, Grote Gat paal 208
gebruikte apparatuur:3 EMF type S, 2 MEX, 3 FOSLIMs (20Hz data-aquisitie met Dasylab)

Directory en subdirectory structuur en indeling.
Dollard/jd_year_julianday

Overige opmerkingen: EMF'en hebben niets geregistreerd
gecorrigeerde tijden staan in deze file
(=computertijd - 68 min.)

Data files met gemeten data
AD conversie

gebruikte kanalen: 0 t/m
Overzicht gemeten grootheden per kanaal.

0:time	8:EMF_3Y
1:MEX1	9:FOSLIM1
2:MEX2	10:FOSLIM2
3:EMF1_X	11:FOSLIM3
4:EMF1_Y	12:-
5:EMF2_X	13:-
6:EMF2_Y	14:-
7:EMF3_X	15:-

headerinformatie van datafiles (indien geen headers bij de files)
geen header

Database files turbulentie-metingen paal in augustus 1995

jd95243 (wintertijd)

file nr.	begin	eind
0	8/31/95 10:31	8/31/95 11:01
1	8/31/95 11:01	8/31/95 11:31
2	8/31/95 11:31	8/31/95 12:01
3	8/31/95 12:01	8/31/95 12:31
4	8/31/95 12:31	8/31/95 13:01
5	8/31/95 13:01	8/31/95 13:31
6	8/31/95 13:31	8/31/95 14:01
7	8/31/95 14:01	8/31/95 14:31

jd95244

file nr.	begin	eind
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1	9/1/95 11:21	9/1/95 11:51
2	9/1/95 11:51	9/1/95 12:21
3	9/1/95 12:21	9/1/95 12:51
4	9/1/95 12:51	9/1/95 13:21
5	9/1/95 13:21	9/1/95 13:51
6	9/1/95 13:51	9/1/95 14:21
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12	9/1/95 16:51	9/1/95 17:21
13	9/1/95 17:21	9/1/95 17:51
14	9/1/95 17:51	9/1/95 18:21
15	9/1/95 18:21	9/1/95 18:51
16	9/1/95 18:51	9/1/95 19:21
17	9/1/95 19:21	9/1/95 19:51
17	9/1/95 19:51	9/1/95 20:17

BOA-96-1 Informatie over de data in dit blok

projectnaam: BOA research theme on intertidal areas
projectnr: TU:sv74/NWO680625-301-005:

namen: experimentator: R v.d. Ham
projectleider: Cees Kranenburg/ Han Winterwerp (WL)

periode experimenten: april 1996
plaats experimenten: Dollard, Grote Gat paal 208
gebruikte apparatuur: 3 EMF type S, 3 FOSLIMs (20Hz data-aquisitie met Dasylab)
3 MEX RWS 10 min. gemiddeld

Agemene opzet:
- Deel 1 Voorbereiding van de bewerking/analyse en 1 min. gemiddelde data
- Deel 2 Calibratie
- Deel 3 Processing
- Deel 4 Analyse van de turbulentie-data

Overzicht gemeten grootheden per kanaal.

0:time	8:FOSLIM2
1:EMF1_X	9:FOSLIM3
2:EMF1_Y	10:-
3:EMF2_X	11:-
4:EMF2_Y	12:-
5:EMF3_X	13:-
6:EMF3_Y	14:-
7:FOLSIM1	15:-

Database files turbulentie-metingen paal in april 1996
afwijking max 30 seconden t.o.v. **zomertijd**

jd 96107

file nr.	begin	eind
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2	4/16/96 19:30	4/16/96 21:30
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5	4/17/96 1:30	4/17/96 3:30
6	4/17/96 3:30	4/17/96 5:30
7	4/17/96 5:30	4/17/96 7:30
8	4/17/96 7:30	4/17/96 9:30
9	4/17/96 9:30	4/17/96 11:30
10	4/17/96 11:30	4/17/96 13:30
11	4/17/96 13:30	4/17/96 15:30
12	4/17/96 15:30	4/17/96 17:30

jd 96110

file nr.	begin	eind
3	4/19/96 9:34	4/19/96 11:34
4	4/19/96 11:34	4/19/96 13:34
5	4/19/96 13:34	4/19/96 15:34
6	4/19/96 15:34	4/19/96 17:34
7	4/19/96 17:34	4/19/96 19:34
8	4/19/96 19:34	4/19/96 21:34
9	4/19/96 21:34	4/19/96 23:34
10	4/19/96 23:34	4/20/96 1:34
11	4/20/96 1:34	4/20/96 3:34
12	4/20/96 3:34	4/20/96 5:34
13	4/20/96 5:34	4/20/96 7:34

jd 96109

file nr.	begin	eind
0	4/18/96 11:27	
1	4/18/96 11:41	
3	4/18/96 12:09	4/18/96 14:09
4	4/18/96 14:09	4/18/96 16:09
5	4/18/96 16:09	4/18/96 18:09
6	4/18/96 18:09	4/18/96 20:09
7	4/18/96 20:09	4/18/96 22:09
8	4/18/96 22:09	4/19/96 0:09
9	4/19/96 0:09	4/19/96 2:09
10	4/19/96 2:09	4/19/96 4:09
11	4/19/96 4:09	4/19/96 6:09
12	4/19/96 6:09	4/19/96 8:09
13	4/19/96 8:09	4/19/96 9:33

jd 96112

file nr.	begin	eind
0	4/21/96 13:55	4/21/96 15:55
1	4/21/96 15:55	4/21/96 17:55
2	4/21/96 17:55	4/21/96 19:55
3	4/21/96 19:55	4/21/96 21:38

jd 96113

file nr.	begin	eind
0	4/22/96 15:54	4/22/96 17:54
1	4/22/96 17:54	4/22/96 18:49

SV-74-3 Informatie over de data in dit blok

projectnaam: BOA research theme on intertidal areas
projectnr: TU:sv74/NWO680625-301-005:

namen: experimentator: R v.d. Ham
projectleider: Cees Kranenburg/ Han Winterwerp (WL)

periode experimenten: juli week 26 1996
plaats experimenten: Dollard, Grote Gat paal 208
gebruikte apparatuur: 3 EMF type S, 3 FOSLIMs (20Hz data-aquisitie met Dasylab)
3 MEX RWS 10 min. gemiddeld

Agemene opzet:

Deel 1	Voorbereiding van de bewerking/analyse en 1 min. gemiddelde data
Deel 2	Calibratie
Deel 3	Processing
Deel 4	Analyse van de turbulentie-data

Overzicht gemeten grootheden per kanaal.

0:time	8:FOSLIM2
1:EMF1_X	9:FOSLIM3
2:EMF1_Y	10:-
3:EMF2_X	11:-
4:EMF2_Y	12:-
5:EMF3_X	13:-
6:EMF3_Y	14:-
7:FOLSIM1	15:-

Database files turbulentie-metingen paal in week 26 1996

25-Jun-96 afwijking maximaal 30 sec. t.o.v. Wintertijd

file nr.	begin	eind	
0	6/25/96 20:01	6/25/96 22:01	1
1	6/25/96 22:01	6/26/96 0:01	1
2	6/26/96 0:01	6/26/96 2:01	1
3	6/26/96 2:01	6/26/96 4:01	1
4	6/26/96 4:01	6/26/96 6:01	1
5	6/26/96 6:01	6/26/96 8:01	1
6	6/26/96 8:01	6/26/96 10:01	1
7	6/26/96 10:01	6/26/96 11:13	1

26-Jun-96

file nr.	begin	eind	
0	6/26/96 12:11	6/26/96 14:11	1
1	6/26/96 14:11	6/26/96 16:11	1
2	6/26/96 16:11	6/26/96 18:11	1
3	6/26/96 18:11	6/26/96 20:11	1
4	6/26/96 20:11	6/26/96 22:11	1
5	6/26/96 22:11	6/27/96 0:11	1
6	6/27/96 0:11	6/27/96 2:11	1
7	6/27/96 2:11	6/27/96 4:11	1
8	6/27/96 4:11	6/27/96 6:11	1
9	6/27/96 6:11	6/27/96 8:11	1
10	6/27/96 8:11	6/27/96 10:11	1
11	6/27/96 10:11	6/27/96 12:11	1
12	6/27/96 12:11	6/27/96 14:11	1

VERVOLG

13	6/27/96 14:11	6/27/96 16:11
14	6/27/96 16:11	6/27/96 18:11
15	6/27/96 18:11	6/27/96 20:11
16	6/27/96 20:11	6/27/96 22:11
17	6/27/96 22:11	6/28/96 0:11
18	6/28/96 0:11	6/28/96 2:11
19	6/28/96 2:11	6/28/96 4:11
20	6/28/96 4:11	6/28/96 6:11
21	6/28/96 6:11	6/28/96 8:11
22	6/28/96 8:11	6/28/96 10:11
23	6/28/96 10:11	6/28/96 10:34

BOA-96-3 Informatie over de data in dit blok

projectnaam: BOA research theme on intertidal areas
projectnr: TU:sv74/NWO680625-301-005:

namen: experimentator: R v.d. Ham
projectleider: Cees Kranenburg/ Han Winterwerp (WL)

periode experimenten: juli week 27 1996 -jd186/187/188
plaats experimenten: Dollard, Grote Gat paal 208
gebruikte apparatuur: 3 EMF type S, 3 FOSLIMs (20Hz data-aquisitie met Dasylab)
3 MEX RWS 10 min. gemiddeld

Agemene opzet:

Deel 1 Voorbereiding van de bewerking/analyse en 1 min. gemiddelde data
Deel 2 Calibratie
Deel 3 Processing
Deel 4 Analyse van de turbulentie-data

Overzicht gemeten grootheden per kanaal.

0:time	8:FOSLIM2
1:EMF1_X	9:FOSLIM3
2:EMF1_Y	10:-
3:EMF2_X	11:-
4:EMF2_Y	12:-
5:EMF3_X	13:-
6:EMF3_Y	14:-
7:FOLSIM1	15:-

Database files turbulentie-metingen paal in week 27 1996

4-Jul-96 Afwijking maximaal 30 sec. t.o.v. Wintertijd

file nr.	Begin	eind	
0	7/4/96 9:34	7/4/96 11:34	1
1	7/4/96 11:34	7/4/96 13:34	1
2	7/4/96 13:34	7/4/96 15:34	1
3	7/4/96 15:34	7/4/96 17:34	1
4	7/4/96 17:34	7/4/96 19:34	1
5	7/4/96 19:34	7/4/96 21:34	1
6	7/4/96 21:34	7/4/96 23:34	1
7	7/4/96 23:34	7/5/96 1:34	1
8	7/5/96 1:34	7/5/96 3:34	1
9	7/5/96 3:34	7/5/96 5:34	1
10	7/5/96 5:34	7/5/96 7:34	1
11	7/5/96 7:34	7/5/96 9:34	1
12	7/5/96 9:34	7/5/96 11:34	1
13	7/5/96 11:34	7/5/96 13:34	1
14	7/5/96 13:34	7/5/96 15:34	1
15	7/5/96 15:34	7/5/96 17:34	1
16	7/5/96 17:34	7/5/96 19:34	1
17	7/5/96 19:34	7/5/96 21:34	1
18	7/5/96 21:34	7/5/96 23:34	1
19	7/5/96 23:34	7/6/96 1:34	1
20	7/6/96 1:34	7/6/96 3:34	1
21	7/6/96 3:34	7/6/96 5:34	1
22	7/6/96 5:34	7/6/96 7:34	1
23	7/6/96 7:34	7/6/96 7:37	1

SV-74-4 Informatie over data in dit blok (week 32)

projectnaam: BOA research theme on intertidal areas
projectnr: TU:sv74 GOA(NWO680625-301-005):

namen: experimentator: R v.d. Ham
projectleider: Cees Kranenburg/ Han Winterwerp (WL)

periode experimenten: augustus 1996
plaats experimenten: Dollard, Grote Gat paal 208
gebruikte apparatuur: 3 EMF type S, 3 FOSLIMs (20Hz data-aquisitie met Daisy Lab)

Directory en subdirectory structuur en indeling.
Dollard/jd_year_julianday

Overige opmerkingen: een minuut gemiddelde waarden van alle 20Hz op deze cd-rom staan in de file: min_gem.asc

Data files met gemeten data
AD conversie

gebruikte kanalen: 0 t/m
Overzicht gemeten grootheden per kanaal.

0:time	8:FOSLIM2
1:EMF1_X	9:FOSLIM3
2:EMF1_Y	10:-
3:EMF2_X	11:-
4:EMF2_Y	12:-
5:EMF3_X	13:-
6:EMF3_Y	14:-
7:FOLSIM1	15:-

headerinformatie van datafiles (indien geen headers bij de files)
geen header

Database files turbulentie-metingen paal in augustus 1996
afwijking max. 1 min. t.o.v. wintertijd

Werkelijke sample-rate:20.01 Hz, dwz dat de tijd over 48 uur 1min verschoven is, dit wordt verwaarloosd.
jd96220

file nr.	begin	eind
0	8/7/96 13:37	8/7/96 15:37
1	8/7/96 15:37	8/7/96 17:37
2	8/7/96 17:37	8/7/96 19:37
3	8/7/96 19:37	8/7/96 21:37
4	8/7/96 21:37	8/7/96 23:37
5	8/7/96 23:37	8/8/96 1:37
6	8/8/96 1:37	8/8/96 3:37
7	8/8/96 3:37	8/8/96 5:37
8	8/8/96 5:37	8/8/96 7:37
9	8/8/96 7:37	8/8/96 9:37
10	8/8/96 9:37	8/8/96 11:37

file nr.	begin	eind
11	8/8/96 11:37	8/8/96 13:37
12	8/8/96 13:37	8/8/96 15:37
13	8/8/96 15:37	8/8/96 17:37
14	8/8/96 17:37	8/8/96 19:37
15	8/8/96 19:37	8/8/96 21:37
16	8/8/96 21:37	8/8/96 23:37
17	8/8/96 23:37	8/9/96 1:37
18	8/9/96 1:37	8/9/96 3:37
19	8/9/96 3:37	8/9/96 5:37
20	8/9/96 5:37	8/9/96 7:37
21	8/9/96 7:37	8/9/96 7:54

Informatie over de data in RWS BOA-dagfiles (SV74-11)

projectnaam: BOA research theme on intertidal areas
projectnr: TU:sv74/NWO680625-301-005:

namen: experimentator: Rijkswaterstaat/ijking MEX sensoren R. van der Ham
projectleider: Cees Kranenburg/ Han Winterwerp (WL)

periode experimenten: 1996
plaats experimenten: Dollard, Grote Gat paal 208
gebruikte apparatuur: 3 EMF type bol, 10 min. gem.(niet werkzaam)
3 MEX 10 min. gem.
CAP (niet werkzaam)

Overzicht gemeten grootheden per kanaal.
1:NR
2:JD
3:TIJD
4:VOLT(ACCU)
5:MEX1
6:std_MEX1
7:MEX2
8:std_MEX2
9:MEX3
10:std_MEX3
11:EMF1X
12:EMF1Y
13:EMF2X
14:EMF2Y
15:EMF3X
16:EMF3Y
17:CAP
18:std_CAP
19:std_EMF1X
20:std_EMF1Y
21:std_EMF2X
23:std_EMF2Y
24:std_EMF3X
25:std_EMF3Y

Informatie over de data in RWS peilschalen

projectnaam: BOA research theme on intertidal areas
projectnr: TU:sv74/NWO680625-301-005:

namen: experimentator: Rijkswaterstaat, Meetdienst Noord
projectleider:

periode experimenten: 1996
plaats experimenten: Dollard, Skanskerdiep, Dollard Noord
gebruikte apparatuur: Capaciteitsdraad .

Overzicht gemeten grootheden per kanaal.
Alleen waterstanden t.o.v. N.A.P. in cm.

Opmerking van RWS t.a.v. peilschalen:DOLLARD NOORD i.p.v. Schanskerdiep, omdat rond 960515 is ontdekt,

dat er in de peilschaal Schanskerdiep een onbekend? verloop in bleek te zitten.

Appendix C
An overview of the most important notes from the log (in Dutch)

Log 4 July 1995, Julian Day 188

Try Out Measurement Tidal Channel near the RWS pole 108
Weather: Wind: 2-3 Beaufort, direction changes from SW to N at 15:29u (summer time), Temperature: estimated 24 C.
10:00u Trouble with starting the motor
12:00u LWS, we manage to sail through the mud in the Skanskerdiep (Buiten Aa, 1999-05-26)
13:00u Arrival at the pole, we wait before we can anchor at the pole: build up of the equipment
15:00u Start of the measurements the estimated flood velocity is 0.2 m/s
Taking of samples at 15:00u/15:15u/15:30u/15:45u/16:00u/16:15u/16:30u by means of a tube located near the FOSLIM (times aren't very precise), pump time: 1-2 minutes.
Offset FOSLIM 0.101 Volt
16:45u Stop the measurements, the water gets to my knees when I dismantle the experimental set-up
Offset FOSLIM 0.293 Volt
At 1010 Sec. Large Vessel passes by
At 1175 Sec. Very small waves present from unknown source

Logboek **week 35 1995** (jd243 -jd244)

Opbouw meetpaal week 34 m.b.v. het RWS schip 'Regulus'
Ontmanteling week 37
Problemen met de kabelverbinding tussen 'data-aquisitiekast' van BOA en de meetpc uit Delft (gesignaleerd op 30 Augustus)

Donderdag 31 Augustus (jd 243)

- 9.00u aankomst meetpaal
- Matige wind, bewolkt maar geen regen
- 10:00u Foslims op nul gezet.
- 11:31u start metingen (locale tijd)
- 15:00u stop metingen

Vrijdag 1 September (jd 244)

- 7.00u vertek Nieuwe Statenzijl (NS)
- Vrij harde wind (we kunnen dus geen offsets meten en geen monsters nemen)
- Back-up gemaakt
- 10:00u Foslims op nul gezet.
- 11:51u start metingen (locale tijd)

Woensdag 6 September (jd 249)

- 12.00u vertek Nieuwe Statenzijl (NS)

- Aggregaat krijgen we niet aan de praat (Vrijdag blijkt dat het aggregaat beveiligd is tegen een olie tekort)
- Back-up gemaakt

Logboek **week 26 1996** (jd 177-180)

(+ mondelinge overlevering van boa-collega's)

Dinsdag 25 juni (jd 177)

- 10:15u afvaart richting Dollard vanuit Delfzijl met de NAV.
- Weinig wind, gehele dag bewolkt
- 12:00u (?) ADCP geplaatst nabij de paal.
- 14:45u paal omhoog: eerste kennismaking met het wier.
- Het water is een stuk troebeler
- 20:00u backup van de proefmeting do 20 juni.
- 21:00u start meting (=20:00 wintertijd!)
- eerste tien minuten met het bereik van de FOLSIMs gestoeid:
  Rood offset switch stand 3, 10*, 420
  Groen offset switch stand 3, 10*, 420
  Blauw offset switch stand 1, 10*, 420

Na deze instelling heb ik niets meer verandert, ook niet in week 27
(opmerking: Blauw blijkt op 6 juli op stand 2 te staan!)

- Navicula ligt in de geul, op behoorlijke afstand (200m)

Woensdag 26 juni (jd 178)

- In de loop van de dag wat meer wind, overwegend bewolkt
- 8:00-8:30 Moorings
- 9:30u aankomst paal, rubberboot aan lang touw stroom afwaarts
- 11:00u weer plukken water met hoge concentraties sediment, plukken zitten nu veel dichter opelkaar dan in week 16. Front is paal gepasseert, het front is zichtbaar doordat er een smalle strook water bedekt is met windgolfjes (foto 6).
- 11:13 golven door Waterschaps boot, plukken sediment zijn al niet meer zichtbaar
- 11:50 viezigheid i.h.water (foto 9)
- er zijn twee golfbewegingen te onderscheiden: 1 kleine golven vanuit de windrichting, langere golven in het verlengde van de geul.
- 12:30 meting gestopt om te nullen, 13:15u meting weer gestart, daarna afvaart
- 12:50u water staat op 150 cm boven de bodem bij de meetopstelling
- 15:30 aankomst t.b.v. monsteren
- 17:45 afvaart
- hoogten sensoren 10 cm, 40 cm, 100 cm

Aantekeningen Marco Wilpshaar NIOZ:

- Bijna windstil, geen golven
- 10:00u Grote sediment wolken in oppervlakte water stromen in een vrij smal deel langs de geulrand. De paal staat net binnen deze troebel water-rand. De verankering ligt er net buiten ?
- 10:05u Strook breidt zich uit, nu ook tot voorbij de verankering

- 10:20u Snelheden EMF'en +/- 0.5m/s
- 10:35u front van plaat-materiaal +/- midden op de plaat

Donderdag 27 juni (jd 179)
- 8:30-9:00 moorings nabij de paal ADCP weggehaald
- 10:00u aankomst paal voor monsteren, Blau nog verder weggelopen
- 11:30u wind trekt aan, fris!, af en toe een zonnetje
- 13:15u afvaart paal
- 18:00u monsters opgehaald

Vrijdag 28 juni (jd 180)
- 11:00u NAV vaart vlak langs
- 11:30u Aankomst paal
  Foslims buiten bereik
  Meting gestopt
  Mex'en RWS redelijk schoon

Opm. Veel zeewier i.h. water deze dagen, de dikke lagen slib (knie-diep) zijn alleen aanwezig op plaatsen waar prielen overgaan in de geul. Voor de rest is de bodem vrij hard. Hier en daar op het eerste stuk van de plaat zak je nog weg.

Logboek **week 27 1996** (jd 186-188)

(+ mondelinge overlevering uit samenkomsten met boa-collega's)

Donderdag 3 juli (jd 186)
- Harde wind, miezer, grauw
- 9:45u aankomst paal
- 10:30u meting gestart
- 15:05 Navicula vaart weer vlak langs
- Weinig kunnen doen vandaag vanwege de wind

Vrijdag 4 juli (jd 187)
- Eerst zonnig, daarna wolkenvelden, nog steeds stevige wind.
- 9:00u aankomst paal, alle FOLSIMs buiten hun bereik
- 9:45u uit opgepomte monsters blijkt dat er niet echt veel gesuspendeerd sediment aanwezig is en dus de outoffrange waarden aan bijv. wier toegeschreven worden.
- 11:00u FOSLIMs schoongemaakt (zie foto's!)
- 11:08u pompen aangezet geeft pieken i.h. signaal
- in de loop van de tijd zeer troebel water omhoog gepompt
- 11:30u FOSLIM rood lijkt het niet te doen, zat ook er dicht bij de EMF, monsteren gestart
- 12: 30u EMF2 kapt ermee
- 14:00u afvaart

(Erosie plekken/diatomeen zie foto 18)

Zaterdag 5 juli (jd 188)

- 8:15u Aankomst: EMF2 doet het nog steeds niet
- Stand offset switches FOSLIM kastjes: Rood:3, Groen:3, Blauw:2
- 9:00u ? meting gestopt
- 13:15 backup opgehaald: MEX'en zien er goed uit

Samenvattend: veel wind, veel wier rondom de sensoren geconstateerd, EMFGroen/2 is er halverwege mee gestopt, zeer troebel water

Logboek **week 32 1996** (jd 220-222)

aangevuld met mondelinge overlevering van BOA-collega's (tijden zijn in zomertijd)

Woensdag 7 augustus (jd 220)

- Stevige wind eerst zon, later bewolkt
- 8:00u vertrokken uit Niewe Schans
- Zodiak lek op de naad stuurboord voor
- 10:15u rek RWS opgehesen, MEX'en schoongemaakt
- 10:45u EMF'en gemonteerd
- hoogten intrumenten opgemeten t.o.v. onderk:EMF R/G/B 6/40/91cm, FOS R/G/B 8.5/40/91cm
- Na kentering Callypso aan zuidzijde gelegd.
- 13:00u nullen EMF'en
- 14:45u ijken FOSLIMs
- 17:00u afvaart paal

Donderdag 8 augustus (jd 221)

- 8:00u vertrokken NS
- 9:30u saliniteits/temperatuur meting
- 9:30u-11:30u Gelijktijdig ijking FOSLIM/MEX
- spullen van brug gehaald
- laatste monster genomen +/-15:30 u
- +/- 16:00u AP door de sluis!

Vrijdag 9 augustus (jd 222)

- 10:30 vertrokken NS
- aggregaat stil, 2 uur aan gewerkt
- 13:45 demontage sensoren
- 15:00 klaar met demontage
- bovenkant paal (2m) op 210 cm van de bodem
- gat rondom RWS208 heeft zich uitgebreid
- (tussenruimte tussen rood en groen: 25cm kan niet)
- positie senoren is iets gedraaid met de klok mee, loodrecht op de plaatrand
- 16:00u afvaart
- 17:15u i.d. haven 20:15u op onze plek i.v.m. waterstand

Appendix D
Summaries of the calibration results of EMF, FOSLIM and MEX sensors and the full record of all suspended sediment samples taken near pole RWS208 in 1996.

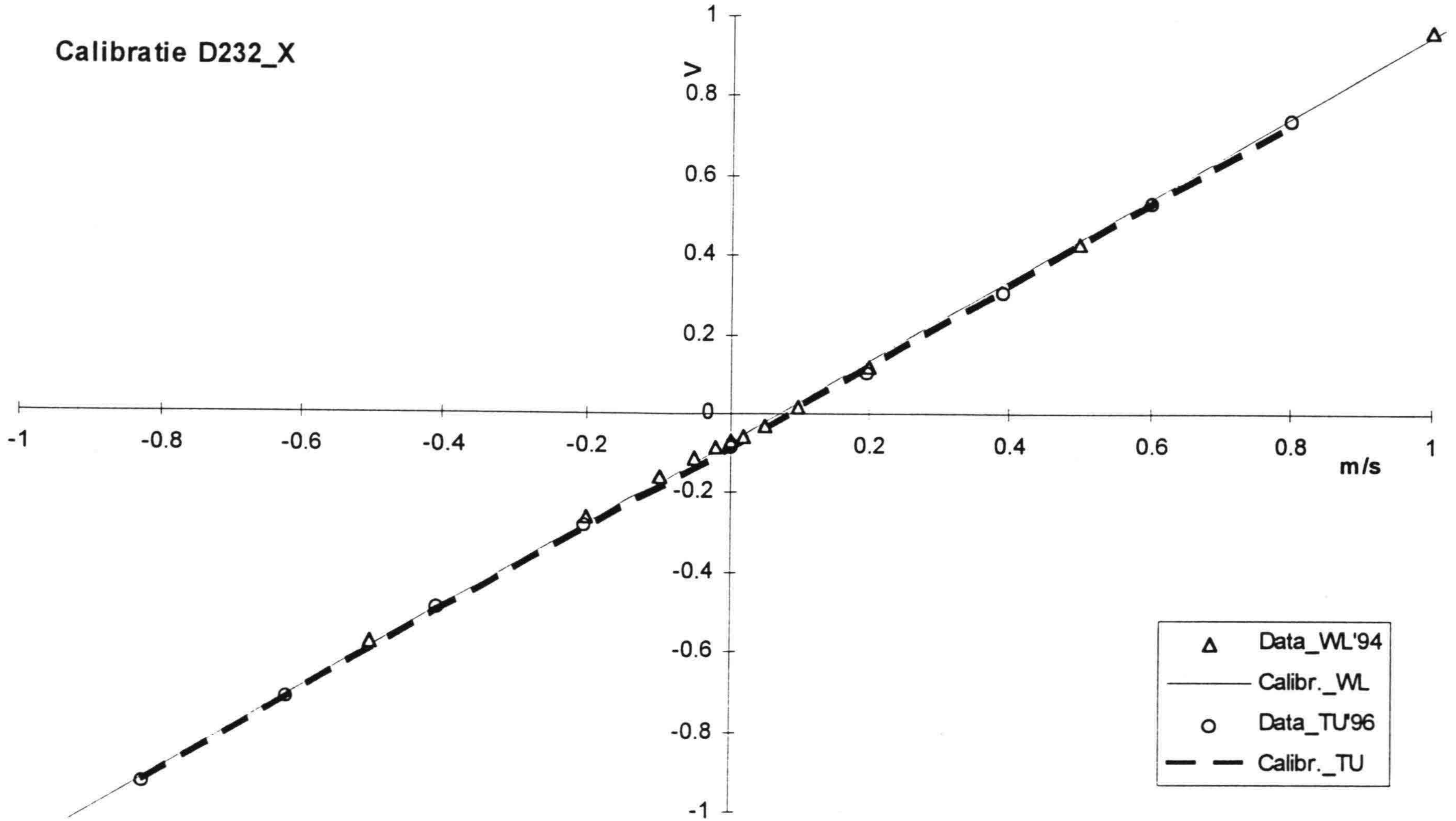
Vergelijk van ijkingen EMF D232, D233, en D234 op 21 apr. '94 (WL) en 27 feb. '96 (TU)
(lineraire regressie voor EMF output van -1m/s tot +1m/s (van -1Volt tot + 1Volt))

Response (Volt/ (m/s))	EMF 232,233,234					
	D232 X	D232 Y	D233 X	D233 Y	D234 X	D234 Y
4/1/1994, goot WL	1.026	1.021	0.981	1.006	0.972	0.982
std. dev._response	0.007	0.007	0.008	0.009	0.006	0.007
std. dev. y_value	0.012	0.011	0.010	0.011	0.010	0.011
2/1/1996, goot TU	1.021	1.015	0.996	1.011	0.979	0.990
std. dev._response	0.005	0.005	0.005	0.005	0.004	0.005
std. dev. y_value	0.008	0.008	0.008	0.008	0.006	0.008
Afw. (%)	-0.48	-0.52	1.56	0.44	0.70	0.83

OFFSET (Volt)	EMF 232,233,234					
	D232 X	D232 Y	D233 X	D233 Y	D234 X	D234 Y
4/1/1994, goot WL	-0.072	0.004	-0.015	-0.033	-0.044	-0.008
2/1/1996, goot TU	-0.085	-0.031	-0.028	-0.038	-0.040	-0.051
lab_bak, geaard	-0.077	-0.041	-0.010	-0.042	-0.033	-0.064
21/4/1996, Dollard	-0.057	-0.033	-0.008	-0.058	-0.009	-0.005
std. dev. offset	0.006	0.009	0.009	0.009	0.016	0.018
26/6/1996, Dollard	-0.066	-0.024	-0.008	-0.039	-0.026	-0.017
std. dev. offset	0.003	0.003	0.003	0.003	0.005	0.019
7/8/1996, Dollard	-0.072	-0.022	-0.019	-0.042	-0.029	-0.020
std. dev. offset	0.009	0.010	0.008	0.009	0.012	0.024

Nauwkeurigheid van het totale ijksysteem is ongeveer 0.005 Volt

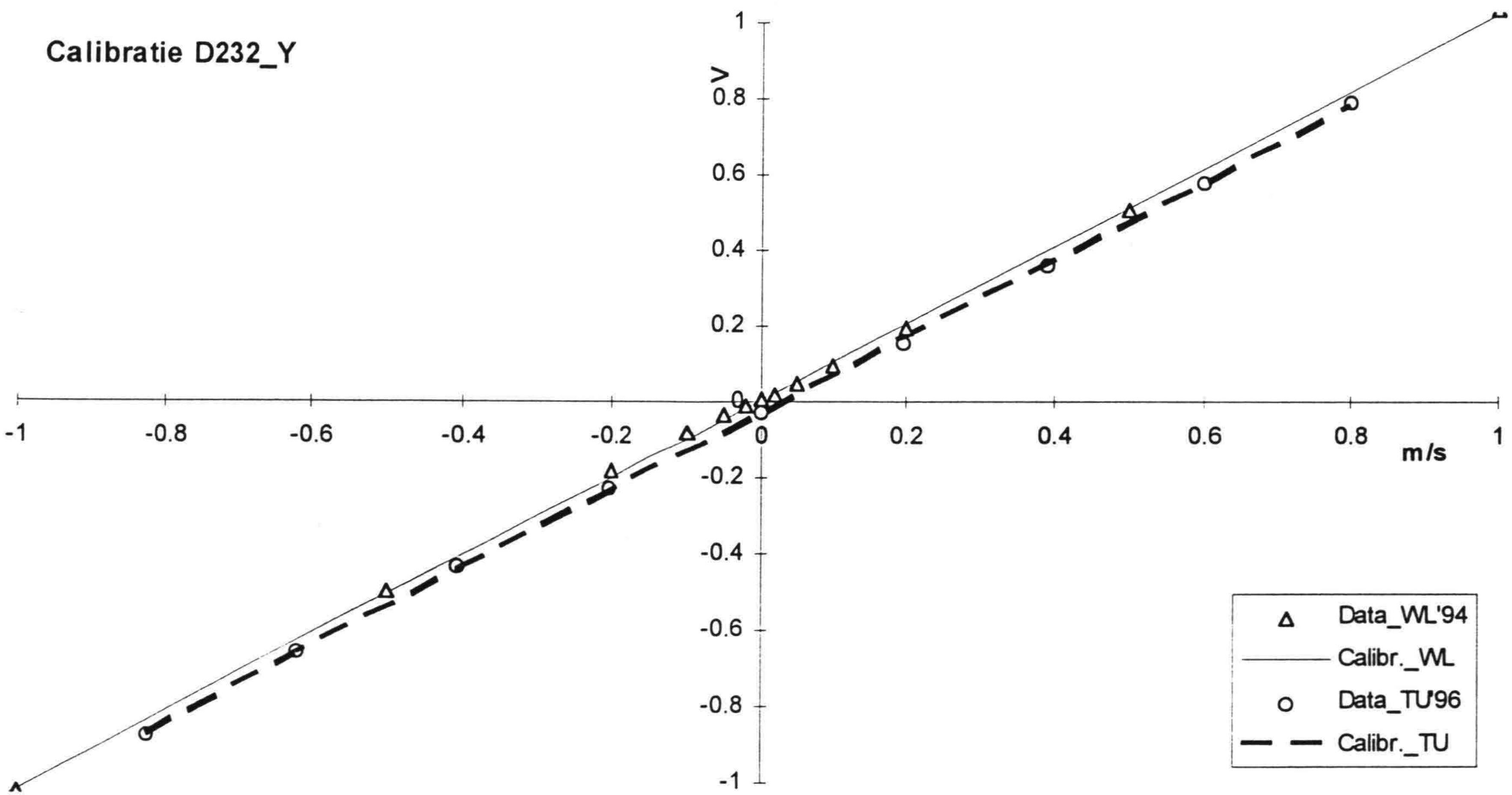
Rotaties in graden			
	EMF_r	EMF_g	EMF_b
rotaties jd 109	0.4	-0.1	0.8
rotaties jd 177	-1.1	-0.5	0.3
rotaties jd 186	-3.9	2.7	-1.7
rotaties jd 220	-3.1	-0.8	0.0



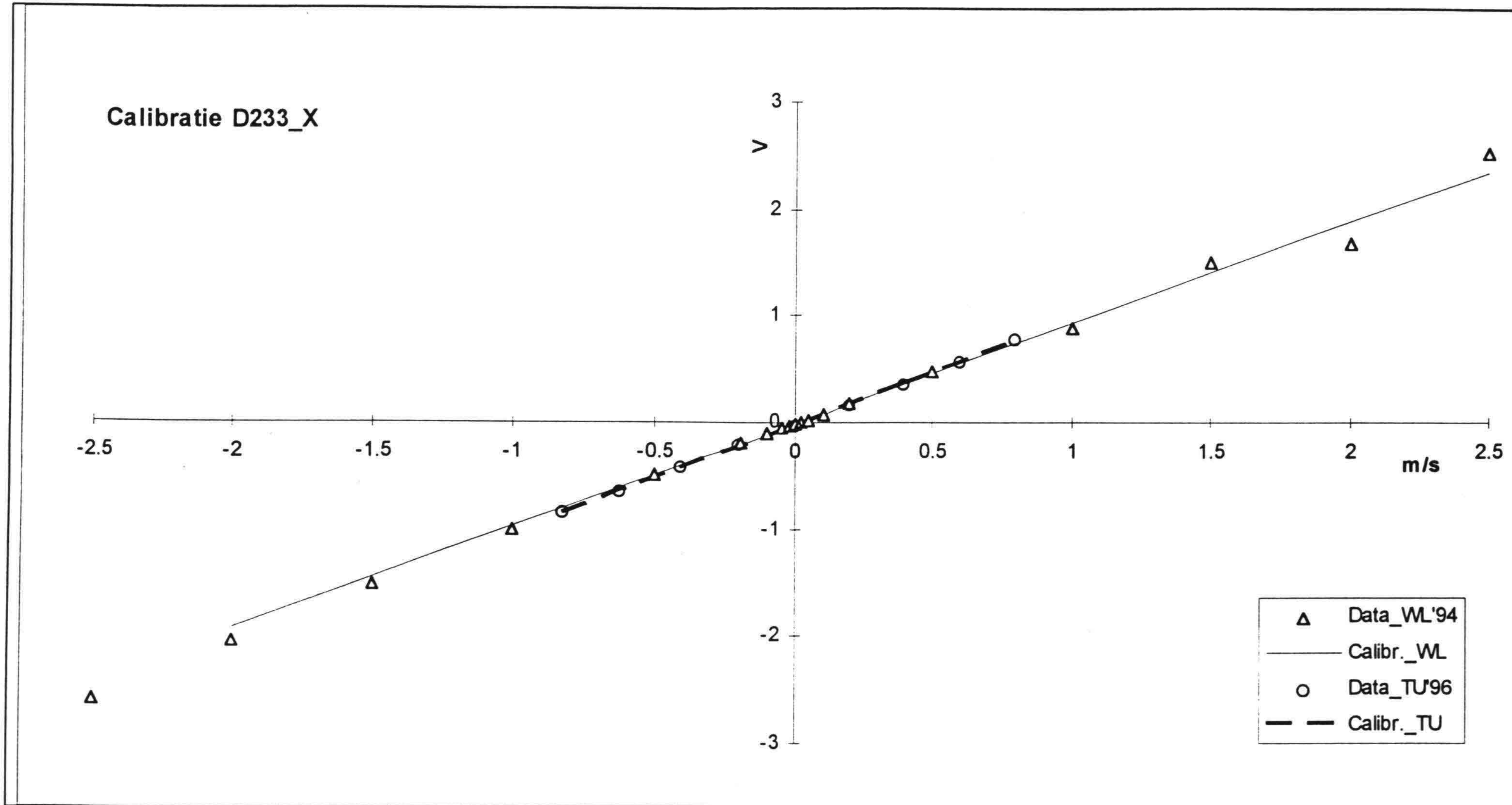
TUDelft

Calibration curves for EMF 232X
TU '96: Overdr=1.021 Vs/m Offset=-0.085 V
WL '94: Overdr=1.026 Vs/m Offset=-0.073 V

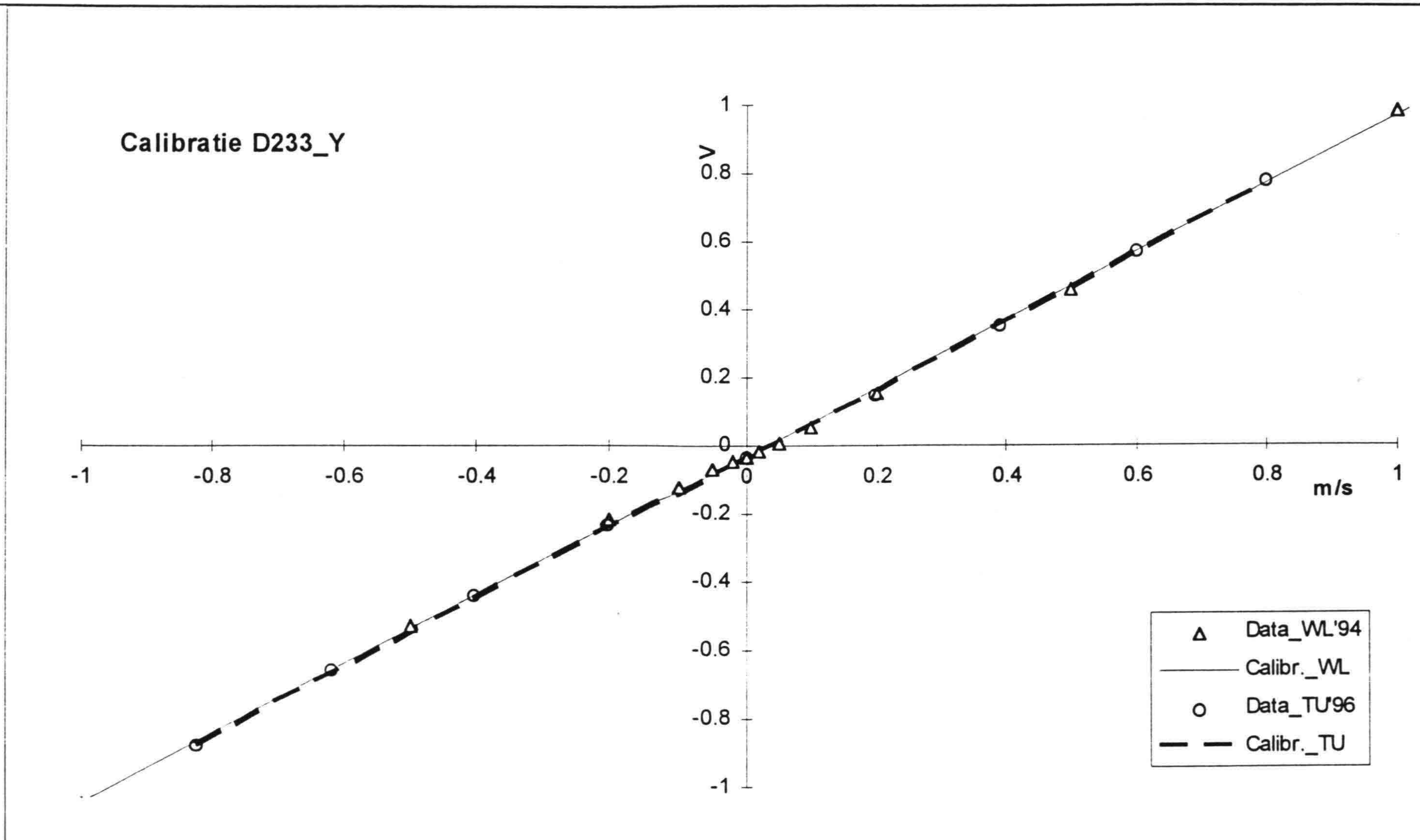
Note VLM 96-1
Appendix A1



TUDelft	Calibration curves for EMF 232Y TU '96: Overdr=1.015 Vs/m Offset=-0.031 V WL '94: Overdr=1.021 Vs/m Offset=0.004 V	Note VLM 96-1 Appendix A2



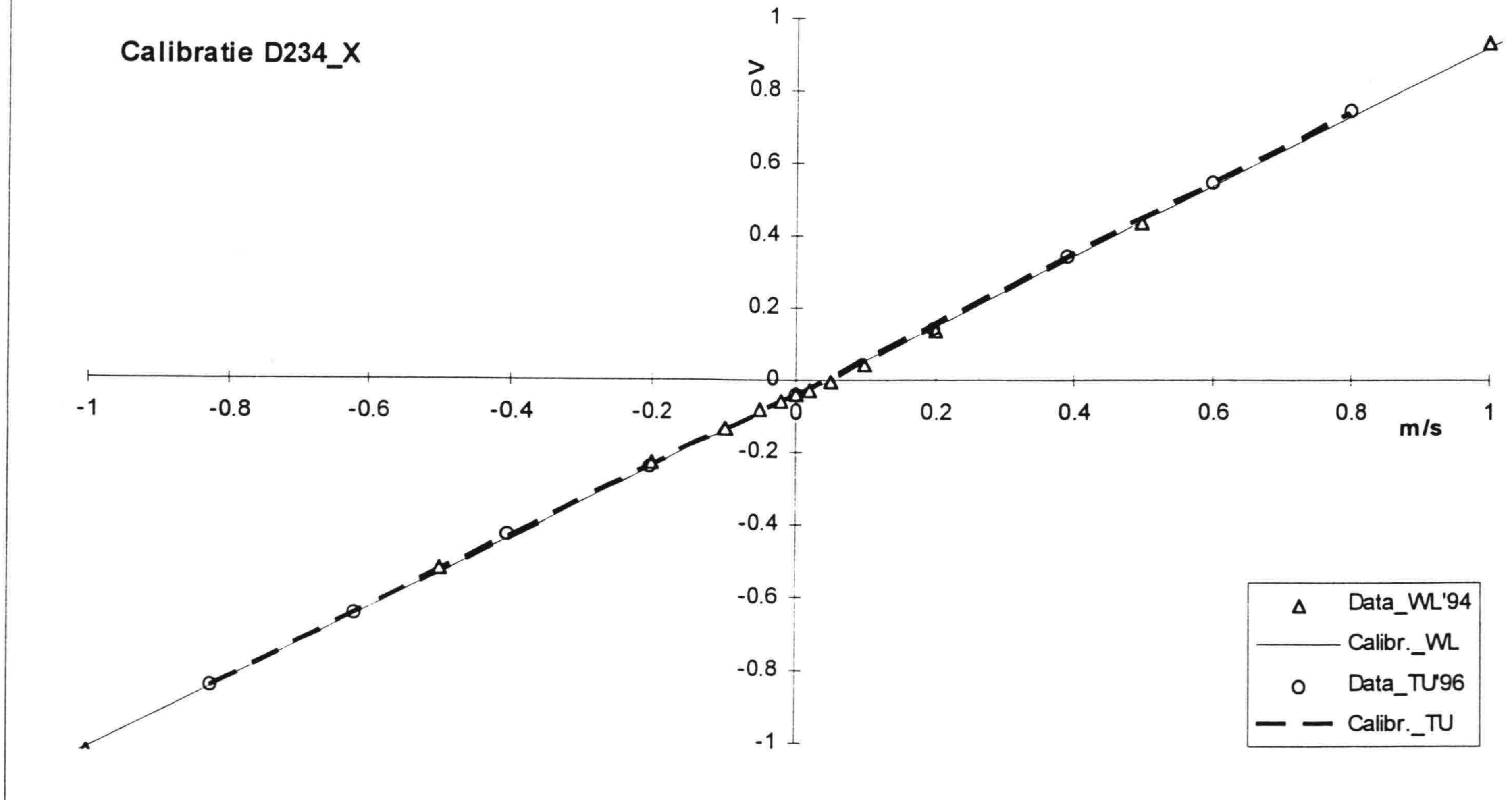
TUDelft	Calibration curves for EMF 233X TU '96: Overdr=0.996 Vs/m Offset=-0.028 V WL '94: Overdr=0.951 Vs/m Offset=-0.021 V	Note VLM 96-1 Appendix A3



TUDelft

Calibration curves for EMF 233Y
TU '96: Overdr=1.011 Vs/m Offset=-0.038 V
WL '94: Overdr=1.006 Vs/m Offset=-0.033 V

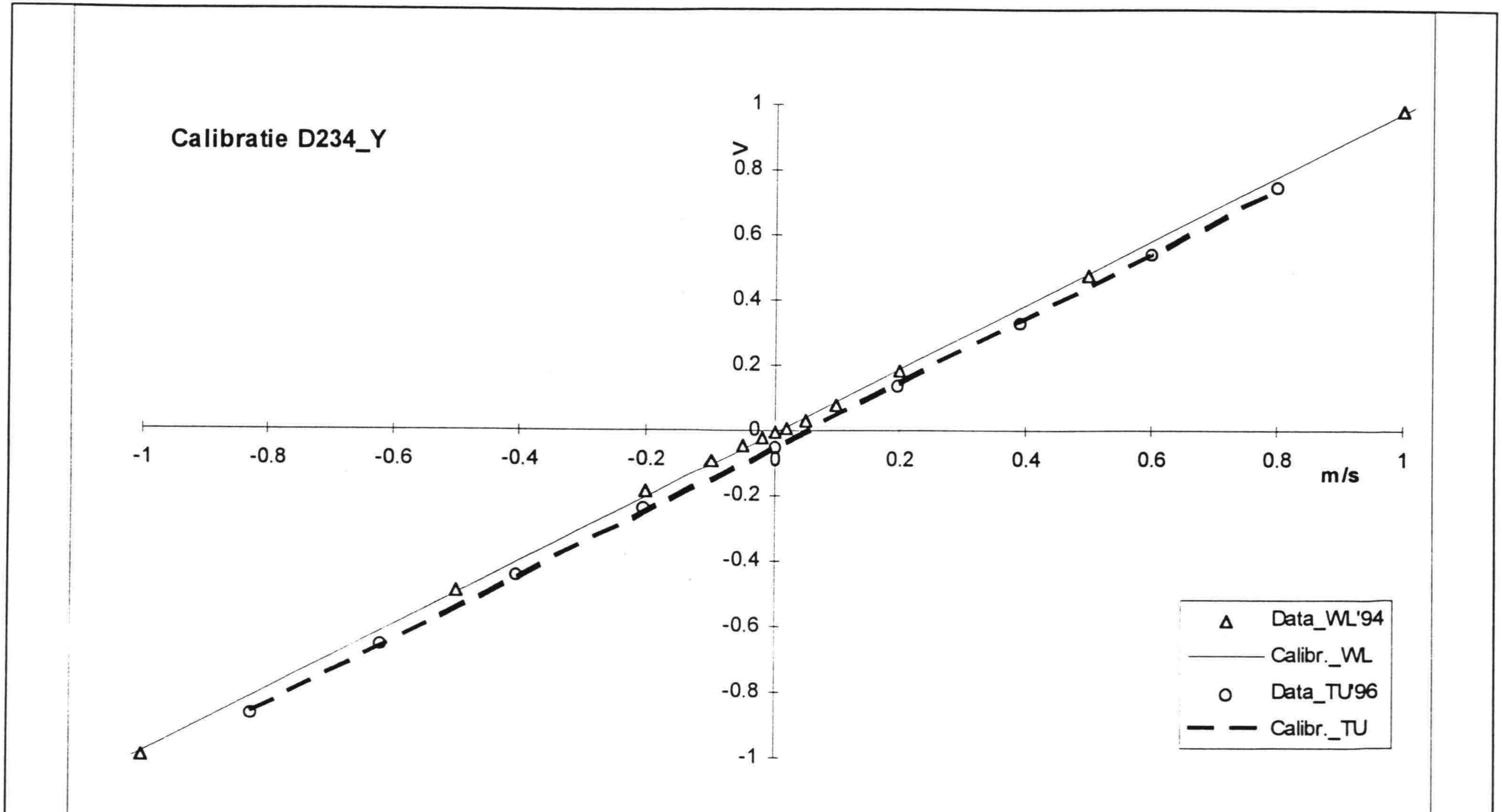
Note VLM 96-1
Appendix A4



TUDelft

Calibration curves for EMF 234X
TU '96: Overdr=0.979 Vs/m Offset=-0.040 V
WL '94: Overdr=0.972 Vs/m Offset=-0.046 V

Note VLM 96-1
Appendix A5



TUDelft	Calibration curves for EMF 234Y TU '96: Overdr=0.990 Vs/m Offset=-0.051 V WL '94: Overdr=0.982 Vs/m Offset=-0.008 V	Note VLM 96-1 Appendix A6

Summary of calibrations of turbidity sensors (FOSLIM type) in 1996

(Concentration (g/l)= Measured value (V)*Response (g/l/V) - Offset (g/l))

(FOSLIMs are coded as red, green, and blue, respectively)

Positioned at 0.1m, 0.4m, and 1.0m above the bottom in June, and at 0.2m, 0.5m, and 1.0 m above the bottom in August of the Grote Gat RWS pole 208 (turb. frame)

	Response (g/l/~~m~~V)	Error Resp. (%)	Offset (g/l)	Error in Conc. (g/l)	R^2	# points	Range (g/l)	Remarks
Summary June measuring period								
FOSLIM red:	0.734	4	0.049	0.041	0.99	11	0.11-1.15	
FOSLIM green:	0.957	8	2.925	0.038	0.96	9	0.08-0.67	
FOSLIM blue:	0.419	9	0.423	0.050	0.97	6	0.31-0.99	
Summary August measuring period								
FOSLIM red:	0.55	8	0.11	0.056	0.93	14	0.14-0.74	
FOSLIM green:	0.72	8	0.22	0.058	0.93	14	0.09-0.72	

Calibrations FOSLIMs June 1996

(Concentration (g/l)= Measured value (V)*Response (g/l/V) - Offset (g/l))

FOSLIMs labeled red, green, and blue were positioned in the turbulence measuring frame at 0.1, 0.4 and 1.0 m, receptively

Period	Response (g/l/V)	Error Resp. (%)	Offset (g/l)	Error in Conc. (g/l)	R^2	# points	Range (g/l)	Remarks
jd 178								
FOSLIM red:	0.690	6	-0.018	0.038	0.99	6	0.33-1.15	ok
FOSLIM green:	-	-	-	-		-	-	out of range
FOSLIM blue:	0.419	9	0.423	0.050	0.97	6	0.31-0.99	poor
jd 179								
FOSLIM red:	0.663	11	0.025	0.032	0.96	5	0.11-0.44	ok
FOSLIM green:	0.957	8	2.925	0.038	0.96	9	0.08-0.67	high reponse
FOSLIM blue:	-	-	-	-		-	-	out of range
jd 178+179								
FOSLIM red:	0.734	4	0.049	0.041	0.99	11	0.11-1.15	best
jd 162, Lab.	**ratio**							
FOSLIM red:	1.000		~0				0-20	lot of sand in the test sample, there-
FOSLIM green:	0.890		~0				0-20	fore, the responses are not relevant
FOSLIM blue:	0.950		~0				0-10	(>10 g/l > 7 Volt FOSLIM niet linear)

Summary June measuring period

FOSLIM red:	0.734	4	0.049	0.041	0.99	11	0.11-1.15	ok
FOSLIM green:	0.957	8	2.925	0.038	0.96	9	0.08-0.67	high reponse
FOSLIM blue:	0.419	9	0.423	0.050	0.97	6	0.31-0.99	poor

Calibrations FOSLIMs August 1996

(Concentration (g/l)= Measured value (V)*Response (g/l/V) - Offset (g/l))

FOSLIMs labeled red, green, and blue were positioned in the turbulence measuring frame at 0.1, 0.4 and 1.0 m, receptively

Period	Response (g/l/V)	rror Resp (%)	Offset (g/l)	Error in Conc. (g/l)	R^2	# points	Range (g/l)	Remarks
jd 220								
FOSLIM red:	0.58	7	0.16	0.033	0.97	8	0.32-0.74	
FOSLIM green:	0.65	6	0.15	0.032	0.98	8	0.28-0.72	
jd 221,								
FOSLIM red:	0.95	4	0.35	0.015	0.99	6	0.14-0.57	high response, similar to
FOSLIM green:	1.22	10	0.53	0.038	0.96	6	0.09-0.56	MEX
jd 220 + jd 221,								
FOSLIM red:	0.55	8	0.11	0.056	0.93	14	0.14-0.74	ok, but same large error
FOSLIM green:	0.72	8	0.22	0.058	0.93	14	0.09-0.72	as the MEXs

Summary August measuring period

FOSLIM red:	0.55	8	0.11	0.056	0.93	14	0.14-0.74
FOSLIM green:	0.72	8	0.22	0.058	0.93	14	0.09-0.72

Summary of calibrations of turbidity sensors (MEX type) in 1996

(Concentration (g/l)= Measured value (mV)*Response (g/l/mV) - Offset (g/l))

(MEX 90-3, 90-7,and 90-8, are coded as red, green, and blue, respectively)
Positioned at 0.3m, 0.7m and 1.4m above the bottom of the Grote Gat RWS pole 208

	Response (g/l/mV)	Error Resp. (%)	Offset (g/l)	Error in Conc. (g/l)	R^2	# points	Range (g/l)	Remarks
jd 177 t/m jd 179 1996 (June measuring period)								
MEX red:	0.0020	23	4.87	0.031	0.83	6	0.16-0.34	voor jd 177
MEX red:	0.0022	4	5.32	0.036	0.99	12	0.10-1.12	voor jd 178 + jd 179
MEX green:	0.0020	4	4.74	0.036	0.98	18	0.06-0.96	whole meas. period
MEX blue:	0.0021	22	4.59	0.086	0.69	11	0.06-0.58	whole meas. period
jd 205 (samples of van RUU)								
MEX red:	0.0021	19	4.29	0.107	0.93	4	0.59-1.35	
MEX green:	0.0020	21	4.54	0.096	0.92	4	0.31-0.95	
MEX blue:	0.0024	45	5.33	0.047	0.72	4	0.37-0.55	
jd 220 t/m jd 221 1996 (August measuring period)								
MEX red:	0.0019	8	4.16	0.061	0.916	15	0.11-0.74	whole meas. period
MEX green:	0.0021	9	5.05	0.059	0.899	15	0.07-0.72	whole meas. period
MEX blue:	0.0019	11	4.19	0.021	0.943	7	0.06-0.3	whole meas. period
jd 291 (samples of van RUU)								
MEX red:	0.0021	16	4.57	0.046	0.89	7	0.22-0.59	
MEX green:	0.0020	11	4.52	0.026	0.94	7	0.23-0.50	
MEX blue:	0.0019	17	4.25	0.030	0.88	7	0.20-0.43	
Laboratory-calibration 19-02-1990 (Delft Hydraulics),								
MEX red:	0.0032	4	7.06	0.038	0.99	6	0-1.14	
MEX green:	0.0030	3	6.93	0.027	1.00	6	0-1.14	
MEX blue:	0.0029	6	6.38	0.052	0.99	6	0-1.14	

Calibrations MEXs June 1996

(Concentration (g/l)= Measured value (mV)*Response (g/l/mV) - Offset (g/l))
(MEX 90-3, 90-7,and 90-8, are coded as red, green, and blue, respectively)

Period	Response (g/l/mV)	ror Res (%)	Offset (g/l)	rror in Conc (g/l)	R^2	# points	Range (g/l)	Remarks
jd 177,								
MEX red: (90-3)	0.00197	23	4.87	0.031	0.83	6	0.16-0.34	not much
MEX green: (90-7)	0.00237	5	5.70	0.014	0.99	6	0.08-0.41	ok
MEX blue: (90-8)	0.00179	6	3.88	0.014	0.98	6	0.07-0.37	ok
jd 178								
MEX red:	0.00219	4	5.32	0.036	0.99	12	0.10-1.12	not in agreement with jd 178
MEX green:	0.00197	5	4.70	0.043	0.98	12	0.06-0.96	ok
MEX blue:	0.00213	22	4.59	0.086	0.69	11	0.06-0.58	large error
jd 177+178								
MEX red:	0.00214	7	5.24	0.070	0.92	18	0.10-1.12	no improvement
MEX green:	0.00199	4	4.74	0.036	0.98	18	0.06-0.96	still very good
MEX blue:	0.00200	18	4.33	0.078	0.69	17	0.06-0.58	for MEX blue: oke
jd 179, using 'FOSLIM samples'								
MEX blauw:	0.00191	14	4.11	0.066	0.80	13	0.06-0.62	not a real improvement

Summary June measuring period

MEX red:	0.00197	23	4.87	0.031	0.83	6	0.16-0.34	for jd 177
MEX red:	0.00219	4	5.32	0.036	0.99	12	0.10-1.12	for jd 178 + jd 179
MEX green:	0.00199	4	4.74	0.036	0.98	18	0.06-0.96	whole meas. period
MEX blue:	0.00213	22	4.59	0.086	0.69	11	0.06-0.58	whole meas. period

Calibrations MEXs, August 1996

(Concentration (g/l)= Measured value (mV)*Response (g/l/mV) - Offset (g/l))
(MEX 90-3, 90-7,and 90-8, are coded as red, green, and blue, respectively)

Period	Response (g/l/mV)	rror Resp (%)	Offset (g/l)	Error in Conc. (g/l)	R^2	# points	Range (g/l)	Remarks
jd 220, using FOSLIM samples								
MEX red:	0.00184	15	4.081	0.066	0.89	8	0.32-0.74	poor
MEX green:	0.00275	38	6.726	0.089	0.70	8	0.28-0.72	comp. June: high response
jd 221								
MEX red:	0.00246	16	5.528	0.054	0.89	7	0.11-0.53	poor
MEX green:	0.00272	6	6.653	0.018	0.99	7	0.07-0.46	response still high
MEX blue:	0.00192	11	4.190	0.021	0.94	7	0.06-0.3	only available
jd 220 + jd 221								
MEX red:	0.00187	8	4.164	0.061	0.92	15	0.11-0.74	better
MEX green:	0.00211	9	5.053	0.059	0.90	15	0.07-0.72	more in agreement with June cal.

Summary August measuring period

MEX red:	0.00187	8	4.164	0.061	0.92	15	0.11-0.74
MEX green:	0.00211	9	5.053	0.059	0.90	15	0.07-0.72
MEX blue:	0.00192	11	4.190	0.021	0.94	7	0.06-0.3

Lab-ijking 19-02-1990

Resultaat	**Overdracht**	**Offset**	**R^2**	**no. point**	**range (g/l)**
MEX rood:	313.89	2214.90	0.99	6	0-1.14
MEX groen:	331.27	2296.65	1.00	6	0-1.14
MEX blauw:	339.68	2166.95	0.99	6	0-1.14

Commentaar:

Data verkregen met natuurslib

DATA WL, project nr. B0189 (Van der Pot/A. van den Assem)

g/l	90-3	90-7	90-8
0	2219	2305	2186
0.431	2336	2430	2284
0.614	2414	2500	2376
0.745	2450	2544	2423
0.896	2510	2585	2477
1.142	2562	2684	2556

1996 suspended sediment concentrations (g/l) MEX 1 MEX 2 MEX 3 (also referred to as red, green blue)

This sheet contains:
-TUD samples:
April period : samples taken at MEX positions (jd 113) and FOSLIMS positions (jd 109 and jd 110)
June period: samples taken at MEX positions (jd 177 and jd 178) and FOSLIMS positions (jd 178 and jd 109)
August period: samples taken at MEX positions (jd 221) and FOSLIMS positions (jd 220 and jd 221)

-Rijks Univeristeit Utrecht data sheets (MEX):jd 205 and jd 291

Remarks TUD data:
Sampling error estimated at +/- 10% (see Nelson and Benedict (1950) in Van Rijn, 1993)
Samples stored in absence of daylight (max. 1-2 weeks)
Error of determination +/- 0.01 g/l (Manon Moot Laboratory of Hydromechanics Delft Univ. of Techn.(TUD))
Duration of each sample taking +/- 1-2 min, sample speed 0.1 m/s (in the tubes).
Samples were taken at all three positions at the same time except for the April period.

April period

Samples at taken at MEX positions at 0.3, 0.7 and 1.4 m

jd 113

time (Summer)	sample-num.	Wintertime	samples_red	samples_green	samples_blue
16:30	1	4/22/96 15:30	0.0933		
16:34	2	4/22/96 15:34		0.0323	
16:37	3	4/22/96 15:37			0.0322
16:50	4	4/22/96 15:50	0.0325		
16:55	5	4/22/96 15:55		0.0116	
16:58	6	4/22/96 15:58			0.0166
17:28	7	4/22/96 16:28	0.0300		
17:29	8	4/22/96 16:29		0.0256	
17:31	9	4/22/96 16:31			0.0197
17:40	10	4/22/96 16:40	0.0300		
17:42	11	4/22/96 16:42		0.0275	

Samples at taken at FOSLIMs positions at 0.1 0.3 and 0.9 m, at about a 5 m distance perpendicular to the flow direction. (Turbulence measuring frame)

jd 109

time (Summer)	sample-num.	Wintertime	samples_red	samples_green	samples_blue
9:45	1	4/18/96 8:45	0.230		
9:49	2	4/18/96 8:49		0.150	
9:52	3	4/18/96 8:52			0.153
9:59	4	4/18/96 8:59	0.240		
10:04	5	4/18/96 9:04		0.298	
10:07	6	4/18/96 9:07			0.147
10:36	7	4/18/96 9:36	0.196		
10:38	8	4/18/96 9:38		0.188	
10:41	9	4/18/96 9:41			0.155

11:22	10	4/18/96 10:22	0.361		
11:25	11	4/18/96 10:25		0.260	
11:28	12	4/18/96 10:28			0.098
12:13	13	4/18/96 11:13	0.429		
12:15	14	4/18/96 11:15		0.216	
12:16	15	4/18/96 11:16			0.138

jd 110

time (Summer)	sample-num.	Wintertime	samples_red	samples_green	samples_blue
8:59	1	4/19/96 7:59	0.0772		
9:02	2	4/19/96 8:02		0.11	
9:05	3	4/19/96 8:05			0.0732
9:59	4	4/19/96 8:59	0.2344		
10:01	5	4/19/96 9:01		0.1932	
10:05	6	4/19/96 9:05			0.1332
10:15	7	4/19/96 9:15	0.3488		
10:16	8	4/19/96 9:16		0.2168	
10:18	9	4/19/96 9:18			0.176
10:32	10	4/19/96 9:32	0.176		
10:35	11	4/19/96 9:35		0.1868	
10:38	12	4/19/96 9:38			0.1472
10:56	13	4/19/96 9:56	0.212		
10:59	14	4/19/96 9:59		0.1288	
11:02	15	4/19/96 10:02			0.1248
11:21	16	4/19/96 10:21	0.2704		
11:23	17	4/19/96 10:23		0.1892	
11:25	18	4/19/96 10:25			0.2136

June period

Samples at taken simultaneously at MEX positions at 0.3 0.7 and 1.4 m

jd 177

time (Summer)	sample-num.	Wintertime	Correction +10 min.	samples_red	samples_green	samples_blue
20:46	1	6/25/96 19:46	6/25/96 19:56	0.164	0.0852	0.0674
21:19	2	6/25/96 20:19	6/25/96 20:29	0.306	0.262	0.2338
21:29	3	6/25/96 20:29	6/25/96 20:39	0.3122	0.2576	0.2412
21:42	4	6/25/96 20:42	6/25/96 20:52	0.2698	0.2924	0.284
21:57	5	6/25/96 20:57	6/25/96 21:07	0.3432	0.362	0.307
22:08	6	6/25/96 21:08	6/25/96 21:18	0.341	0.4086	0.3692

jd 178

time (Summer)	sample-num.	Wintertime	Correction +10 min.	samples_red	samples_green	samples_blue
9:54	1	6/26/96 8:54	6/26/96 9:04	0.1246	0.1174	0.2404
10:03	2	6/26/96 9:03	6/26/96 9:13	0.1304	0.205	0.1698
10:15	3	6/26/96 9:15	6/26/96 9:25	0.1672	0.192	0.1352
10:27	4	6/26/96 9:27	6/26/96 9:37	0.2664	0.2432	0.213
10:45	5	6/26/96 9:45	6/26/96 9:55	0.3686	0.3038	0.3348
11:03	6	6/26/96 10:03	6/26/96 10:13	0.4724	0.337	0.4204
11:23	7	6/26/96 10:23	6/26/96 10:33	0.3446	0.3002	0.3142
11:39	8	6/26/96 10:39	6/26/96 10:49	0.3776	0.2712	0.379

11:57	9	6/26/96 10:57	6/26/96 11:07	0.3436	0.1774	0.2634
13:13	10	6/26/96 12:13	6/26/96 12:23	0.1016	0.0632	0.0618
16:25	11	6/26/96 15:25	6/26/96 15:35	1.1166	0.9568	0.5824
17:05	12	6/26/96 16:05	6/26/96 16:15	0.715	0.7738	0.5818

Samples at taken at FOSLIMs positions at 0.1 0.4 and 1.0 m, at about a 5 m distance perpendicular to the flow direction. (Turbulence measuring frame)

jd 178

time (Summer)	sample-num.	Wintertime	Correction +10 min.	samples_red	samples_green	samples_blue
15:55	1	6/26/96 14:55	6/26/96 15:05	0.3348	lost.	0.3096
16:07	2	6/26/96 15:07	6/26/96 15:17	0.6584	0.655	0.5732
16:17	3	6/26/96 15:17	6/26/96 15:27	0.9342	0.876	0.7576
16:28	4	6/26/96 15:28	6/26/96 15:38	1.1544	1.1222	0.9902
16:41	5	6/26/96 15:41	6/26/96 15:51	1.0912	1.0256	0.902
16:56	6	6/26/96 15:56	6/26/96 16:06	0.8534	0.7712	0.7006
17:25	7	6/26/96 16:25	6/26/96 16:35	0.4438	0.4338	0.4038
17:45	8	6/26/96 16:45	6/26/96 16:55	0.6908	0.5634	0.5512

jd 179

time (Summer)	sample-num.	Wintertime	Correction +10 min.	samples_red	samples_green	samples_blue
10:13	1	6/27/96 9:13	6/27/96 9:23	0.1084	0.0804	0.0622
11:06	3	6/27/96 10:06	6/27/96 10:16	0.4052	0.3854	0.342
11:16	4	6/27/96 10:16	6/27/96 10:26	0.4372	0.3838	0.341
11:33	5	6/27/96 10:33	6/27/96 10:43	0.442	0.4538	0.385
11:46	6	6/27/96 10:46	6/27/96 10:56	0.4304	0.3976	0.3852
12:04	7	6/27/96 11:04	6/27/96 11:14	0.612	0.5766	0.519
12:20	8	6/27/96 11:20	6/27/96 11:30	0.609	0.5626	0.5154
12:42	9	6/27/96 11:42	6/27/96 11:52	0.6496	0.5882	0.5108
12:53	10	6/27/96 11:53	6/27/96 12:03	0.7202	0.6666	0.616

August period

Samples at taken at MEX positions at 0.3 0.7 and 1.4 m

jd 221

time (Summer)	sample-num.	Wintertime	samples_red	samples_green	samples_blue
9:34	1	8/8/96 8:34	0.116	0.0684	0.0634
9:43	2	8/8/96 8:43	0.1088	0.0886	0.0996
10:01	3	8/8/96 9:01	0.218	0.185	0.1546
10:15	4	8/8/96 9:15	0.278	0.2362	0.2128
10:32	5	8/8/96 9:32	0.353	0.3084	0.234
11:03	6	8/8/96 10:03	0.527	0.4574	0.3024
15:43	7	8/8/96 14:43	0.2494	0.2658	0.1958

Samples at taken at FOSLIMs positions at 0.2 0.5 and 1.0 m, at about a 5 m distance perpendicular to the flow direction. (Turbulence measuring frame)

jd 220

time (Summer)	sample-num.	Wintertime	samples_red	samples_green	samples_blue

14:47	1	8/7/96 13:47	0.747	0.7216	0.5834
14:59	2	8/7/96 13:59	0.7111	0.5538	0.4696
15:13	3	8/7/96 14:13	0.7298	0.778	0.4776
15:29	4	8/7/96 14:29	0.4894	0.4226	0.3946
15:46	5	8/7/96 14:46	0.4278	0.3634	0.342
16:02	6	8/7/96 15:02	0.3278	0.2768	0.2714
16:10	7	8/7/96 15:10	0.322	0.3646	0.2592
16:23	8	8/7/96 15:23	0.3998	0.323	0.3006

jd 221

time	sample-num.	Wintertime (Summer)	samples_red	samples_green	samples_blue
9:29	1	8/8/96 8:29	0.1606	0.1144	geen monster
9:46	2	8/8/96 8:46	0.1396	0.0938	0.106
9:56	3	8/8/96 8:56	0.1568	0.1314	0.127
10:17	4	8/8/96 9:17	0.3106	0.245	0.2492
10:29	5	8/8/96 9:29	0.346	0.3146	0.2936
11:06	6	8/8/96 10:06	0.5674	0.557	0.4072
15:39	7	8/8/96 14:39	0.26	0.2348	0.215

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jd 205

filternr	monsternr	avg conc (g/l)	sd conc (g/l)	fout %	tijd start/stop
x55	mex 1				14:02
x56	mex 1				1406
x57	mex 1	1.350	0.015	1.1	
x58	mex 2				14:07
x59	mex 2				14:10
x60	mex 2	0.953	0.022	2.4	
x61	mex 3				14:12
x62	mex 3				14:16
x63	mex 3	0.455	0.022	4.9	
x64	mex 1				14:26
x65	mex 1				14:29
x66	mex 1	0.860	0.021	2.4	
x67	mex 2				14:31
x68	mex 2				14:34
x69	mex 2	0.788	0.021	2.6	
x70	mex 3				14:37
x71	mex 3				14:42
x72	mex 3	0.475	0.046	9.6	
x73	mex 1				14:51
x74	mex 1				14:53
x75	mex 1	0.595	0.046	7.7	
x76	mex 2				14:55
x77	mex 2				14:58
x78	mex 2	0.309	0.018	5.9	

x79	mex 3				14:59
x80	mex 3				15:05
x81	mex 3	0.375	0.029	7.8	
x82	mex 1				15:21
x83	mex 1				15:24
x84	mex 1	0.665	0.022	3.3	
x85	mex 2				15:25
x86	mex 2				15:28
x87	mex 2	0.629	0.040	6.4	
x88	mex 3				15:30
x89	mex 3				15:34
x90	mex 3	0.552	0.021	3.8	
b1	blanco				
b2	blanco				
b3	blanco				
b4	blanco				
b5	blanco	0.005	0.016	308.4	

NB. tijd is zomertijd (MET+1)
geulpaaltijd is wintertijd!
dus bij 12:45 hoort geulpaaldata van 17 okt. 11:45

jd 291

filternr	monsternr	avg conc (g/l)	sd conc (g/l)	fout %	tijd start/stop
x55	mex 1				14:02
x56	mex 1				1406
x57	mex 1	1.34969	0.01481	1.09763	
x58	mex 2				14:07
x59	mex 2				14:10
x60	mex 2	0.95291	0.02243	2.35412	
x61	mex 3				14:12
x62	mex 3				14:16
x63	mex 3	0.45478	0.02238	4.92049	
x64	mex 1				14:26
x65	mex 1				14:29
x66	mex 1	0.85977	0.02083	2.42291	
x67	mex 2				14:31
x68	mex 2				14:34
x69	mex 2	0.78801	0.02078	2.63711	
x70	mex 3				14:37
x71	mex 3				14:42
x72	mex 3	0.47507	0.04574	9.62794	
x73	mex 1				14:51
x74	mex 1				14:53
x75	mex 1	0.59497	0.0456	7.66448	
x76	mex 2				14:55

x77	mex 2				14:58
x78	mex 2	0.30875	0.01815	5.87703	
x79	mex 3				14:59
x80	mex 3				15:05
x81	mex 3	0.37493	0.02915	7.77399	
x82	mex 1				15:21
x83	mex 1				15:24
x84	mex 1	0.66488	0.02214	3.32937	
x85	mex 2				15:25
x86	mex 2				15:28
x87	mex 2	0.62862	0.04031	6.41249	
x88	mex 3				15:30
x89	mex 3				15:34
x90	mex 3	0.55158	0.02085	3.78041	
b1	blanco				
b2	blanco				
b3	blanco				
b4	blanco				
b5	blanco	0.0052	0.01605	308.404	

Appendix E
MATLAB programs used in the processing of the EMF and FOSLIM recordings

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
□
% MAIN Program for turbulence data from the Dollard (1996), info: R. vander
Ham
% (Is used in combination with the subroutines SR_** and subsubroutines
SSR_** all written in MATLAB code)
%
%
% Outline of the Main Program:
% - read input file number (i)
% - actual computations:
%  - S(ub)R(outine)_.m (short SR_.m)=group of calculations for one data file
%     - S(ub)S(ub)R(outine)_.m=elementary computations
%     - SSR_.m ...etc.
%  - SR_.m etc.
% - add the results to the output files
% - i=i+1
%
% The FORMAT of the info in each SR_.m and SSR_.m is as follows:
% - the required input
% - summary of the operations on the input
% - the output that is produced
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%% MAIN PROGRAM
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%% Call User input file again(name refers to period):
SR_in_0896

while FID~=-1 % (FID is file identifier)

  %%%% U_read subroutine reads the data and stores
  %%%% the 'current file(ii) ' in the matrix called DATA_read
  SR_read

  % quit if the file(ii) is not found
  if FID ==-1  break; end


  %%%% SR_prep subroutine prepares data: renoves spikes,
  %%%% rotates and calibrates the data in matrix DATA_prep
  %%%% we now have g/l, m/s and spike statistics (stores
  %%%% the data in ascii files)
  SR_prep

  SR_save_sp

  %%%% SR_calc subroutine calculates (ensemble) means, fluctuations etc.
  %%%% and applies run-tests for stationairity checks. Not universal, it
  %%%% is specially prepared for the Dollard data-files.

  % detrending and averaging over REC_lenght minute periods
  SR_Calc

  SR_save_dat

  % additional: detrending and averaging over 1/10th REC_lenght periods
  %  B=B/10; SR_Calc; SR_save_10th; B=B*10;

  %%%% next sweep
  ii=ii+1

end
% END OF PROGRAM
```

```
% Subroutine SR_in_08_96
□
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%
□
% Input from the user
%
% - Needs input from the user
% - checks the file lenght/record lenght ratio, must be a whole
number
% - procudes internal variables needed in all other SR_.m and
SSR_.m's
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%
% For the X-channel of the EMF the RESPONSE is taken neg.:

% Convention:         Situation in the field:
%       ^Z upward          (transd.)-------> Y-channel EMF
%       |                        |
%       |         X flood        |
%       |------->                v X-channel EMF
%  _______________________________________________________
%  //////////////// sediment bed /////////////////

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%
% File locations and file names

%Dir_r=sprintf('');      % Directories data (not for UNIX)
%Dir_w=sprintf('');      % (note the double slash
Experiment=sprintf('P');      % File identification: p=pole, b=bridge
Year=sprintf('96');      % File identification year: 95 or 96 for
example
Julianday=sprintf('220');     % File identification julian day: 001 =1
januari
Num=36000;            % File-lenght
Column=10;            % Numb of columns is always 10, if otherwise the
            % alterations of procedures turbul/calibr are necessary
ii=0;FID=3;           % ii is here the number of the frist file for
example 0
            % ii=0
Num_std=5;            % Spike criterium: N=number of times the value can
            % exceeds the standard deviation before it is rejected
FREQ = 20;            % FREQ is the sampling frequency;
REC_LENGHT=600;           % Record lenght (sec.) (based on a reasonalbe
B=REC_LENGHT*20;       % number of 'burst' in a record)

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%
% OFFSETs of EMF's and FOSLIMs obtained by means of calibrations:
% (Columns 1-10)
% The calibration algorithm is the following:
% VARIABLE = (SIGNAL(V) - OFFSET(V)) / RESPONSE(V/(g/l) or V/(m/s))

OFF_TIME=0;
OFF_EMF1X=-0.072*3; OFF_EMF1Y=-0.022*3; % times 3 because of the
amplifier used
OFF_EMF2X=-0.019*3; OFF_EMF2Y=-0.042*3;
OFF_EMF3X=-0.029*3; OFF_EMF3Y=-0.020*3;
OFF_FOS1=0.204;
OFF_FOS2=0.299;
OFF_FOS3=0;

% The RESPONSE of EMFs and FOSLIMs obtained by means of calibrations:
```

```
% (Columns 1-10)

RESP_TIME=1;
RESP_EMF1X=-1.021*3; RESP_EMF1Y=1.015*3;
RESP_EMF2X=-0.996*3; RESP_EMF2Y=1.011*3;
RESP_EMF3X=-0.979*3; RESP_EMF3Y=0.990*3;
RESP_FOS1=1.806;
RESP_FOS2=1.385;
RESP_FOS3=1;

% The sensor rotations of EMFs obtained:
% (Columns 2-7)

angle1 = -5.37e-2;
angle2 = -1.33e-2;
angle3 = 8.64e-4;


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%
% Check if the averaging period REC_LENGHT is valid.

Dummy1=Num/B;Dummy2=round(Dummy1);
Check=Dummy2-Dummy1;
if Check~=0
  fprintf('file lenght in sec. is not a whole number of times
REDUCT\n');break,end
```

```
% SR_read
% This procedure reads the raw data file:
□
% - input are the files with name type: P(ole)96(year)177(julian
day)00(number).asc
□
% - if the datafile is not the specified lenght 'Num' zeros are added
until lenght Num is reached)
% - output is the internal matrix MATLAB


if ii<10 fnum=sprintf('0%s',num2str(ii)); else
fnum=sprintf('%s',num2str(ii)); end
filename=sprintf('%s%s%s%s.ASC',Experiment,Year,Julianday,fnum);
last=ii-1;FID=fopen(filename,'r');

if FID ~= -1
  DATA_read=fscanf(FID,'%g',[Column Num]); DATA_read=DATA_read';
fclose(FID);
  S=size(DATA_read);Num_dum=S(1,1);
  if Num_dum < Num DATA_read(Num_dum+1:Num,:)=zeros(Num-
Num_dum,Column); end
else
  if ii~=0;
   fprintf('the file %s%s%s%s is the last file that has been
processed\n',Experiment,Year,Julianday,num2str(last));
  else
   fprintf('the file %s%s%s%s was not
found\n',Experiment,Year,Julianday,fnum);
  end
end
```

```
% SR_prep
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%
% This is a sub routine from the MATLAB programme COMP_1197.m
% It needs the matrix DATA from the U_read.m
% It needs spike criterium and calibration lines from
T_in_'monthyear'.m
% It does:
%  - removes the spikes and
%  - calibrates the data
%  - rotates the EMF axes
% It produces a matrix 'DATA_prep' (volts are now g/l and m/s)
% and a matrix 'spikes' with spike statistics
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%

%  removes the spikes
SSR_spike

% add matrix 'spI(mpact)N(umber)P(eaks)W(idth)'
fname=sprintf('d_spike');

%  calibrates the data
SSR_calb

%  rotates the EMF axes (columns 2-7)
SSR_rotates

% the final data matrix DATA_prep
DATA_prep(:,2:7)=DATA_rot(:,2:7);
DATA_prep(:,1)=DATA_cal(:,1);
DATA_prep(:,8:10)=DATA_cal(:,8:10);
```

```
% SR_save_sp
% Ndum is for example 12 for a 2 hour data-file if B is 10 minutes.
□

□
Ndum=Num/B;
□
SPIKES((ii)*Ndum+1:(ii+1)*Ndum,1:4*Column)=spINWP;
SPI_dum=SPIKES';S=size(SPI_dum);
filename=sprintf('%s%s.asc',fname,Julianday);
FID=fopen(filename,'w');fprintf(FID,...
'%e %e %e %e %e %e %e %e %e %e %e %e %e %e %e %e %e %e %e %e %e %e %e
%e %e %e %e %e %e %e %e %e %e %e %e %e %e %e %e %e\n', SPI_dum);
fclose(FID);
```

```
% SR_calc
% Turbulence parameters
□

□
% Linear trends over REC_LENGHT seconds
□
 x=1:1:B;x=x';
□
 for j=1:Column
□
   for i=B:B:Num
□
     y=DATA_prep(i-B+1:i,j);
□
     p=polyfit(x,y,1);f=polyval(p,x);
□
     TREND(i-B+1:i,j)=f;
   end
 end

% Linear trend removal
 FLUCT=DATA_prep-TREND;

% Turbulence quatities (T):
 for j=2:Column T(:,j)=FLUCT(:,j).^2; end

% UW position 1,2,3
Corr(:,2)=FLUCT(:,3).*FLUCT(:,2); Corr(:,3)=FLUCT(:,5).*FLUCT(:,4);
Corr(:,4)=FLUCT(:,7).*FLUCT(:,6);

% CW position 1,2,3
Corr(:,5)=FLUCT(:,8).*FLUCT(:,2);Corr(:,6)=FLUCT(:,9).*FLUCT(:,4);%CW
position 2
Corr(:,7)=FLUCT(:,10).*FLUCT(:,6);

% CU position 1,2,3
Corr(:,8)=FLUCT(:,8).*FLUCT(:,3);Corr(:,9)=FLUCT(:,9).*FLUCT(:,5);%CU
position 2
Corr(:,10)=FLUCT(:,10).*FLUCT(:,7);

% Calculate averages
for j=1:Column
 for i=B:B:Num
   average(i/B,j)=mean(DATA_prep(i-B+1:i,j));
   turbo(i/B,j)=mean(T(i-B+1:i,j));
   corr(i/B,j)=mean(Corr(i-B+1:i,j));
 end
end
```

```
% SR_save_dat
% Ndum is for example 12 for a 2 hour data-file if REDUCT is 10
minutes.
□

□
 Ndum=Num/B;
□

□
 fname=sprintf('dat_av');
□
 AVERAGE((ii)*Ndum+1:(ii+1)*Ndum,1:Column)=average;
□
 DUM=AVERAGE';
□
 filename=sprintf('%s%s.asc',fname,Julianday);
 FID=fopen(filename,'w');fprintf(FID, ...
 '%e %e %e %e %e %e %e %e %e %e\n', DUM);
 fclose(FID);clear DUM

 fname=sprintf('dat_tur');
 TURBO((ii)*Ndum+1:(ii+1)*Ndum,1:Column)=turbo;
 DUM=TURBO';
 filename=sprintf('%s%s.asc',fname,Julianday);
 FID=fopen(filename,'w');fprintf(FID, ...
 '%e %e %e %e %e %e %e %e %e %e\n', DUM);
 fclose(FID); clear DUM

 fname=sprintf('dat_corr');
 Ndum=Num/B;
 CORR((ii)*Ndum+1:(ii+1)*Ndum,1:Column)=corr;
 DUM=CORR';
 filename=sprintf('%s%s.asc',fname,Julianday);
 FID=fopen(filename,'w');fprintf(FID, ...
 '%e %e %e %e %e %e %e %e %e %e\n', DUM);
 fclose(FID); clear DUM
```

```
%  SSR_calb
%  This subsubroutine calibrates the data
□
%  Date: 11 Nov.'97
□

□
% - It uses the 'DATA_nospike' matrix
□
% - It uses the OFFSETS and RESPONSES of the SR_in.. file
% - Procedure: VARIABLE = (SIGNAL - OFFSET) / RESPONSE

% - it produces the 'DATA_cal' matrix


% Fill up the calibration vectors:

C_OFF(1)=OFF_TIME;
C_OFF(2)=OFF_EMF1X;C_OFF(3)=OFF_EMF1Y;C_OFF(4)=OFF_EMF2X;
C_OFF(5)=OFF_EMF2Y;C_OFF(6)=OFF_EMF3X;C_OFF(7)=OFF_EMF3Y;
C_OFF(8)=OFF_FOS1;C_OFF(9)=OFF_FOS2;C_OFF(10)=OFF_FOS3;

C_RESP(1)=RESP_TIME;
C_RESP(2)=RESP_EMF1X;C_RESP(3)=RESP_EMF1Y;C_RESP(4)=RESP_EMF2X;
C_RESP(5)=RESP_EMF2Y;C_RESP(6)=RESP_EMF3X;C_RESP(7)=RESP_EMF3Y;
C_RESP(8)=RESP_FOS1;C_RESP(9)=RESP_FOS1;C_RESP(10)=RESP_FOS3;

% calibrate the data

  for j=1:Column
    DATA_cal(:,j)=(DATA_nospike(:,j)-C_OFF(j))/C_RESP(j);
  end

% END
```

```
%  SSR_rotates
%  This subsubroutine makes corrections for axis rotation
%  Date: 11 Nov.'97
% - It uses the 'DATA_cal' matrix
% - It uses ANGLES form the user input file SR_in_'month'.m
% - Procedure:U_real=U_meas*COS(ANGLE) + W_meas*SIN(ANGLE)
%             W_real=-U_meas*SIN(ANGLE) + Y_meas*COS(ANGLE)


% Convention:            Situation in the field:
%       ^Z upward(W)          (transd.)-------> Y-channel EMF
%       |                              |
%       |        X flood(U)            |
%       |------->                      v X-channel EMF
%
%  _____________________________________________________
%  //////////////// sediment bed ////////////////

% - it produces the 'DATA_rot' matrix

DUMMY=DATA_cal;

% Transformation of the vectors
 cs=cos(angle1);sn=sin(angle1);
 DATA_rot(:,2)=(-DUMMY(:,3)*sn+DUMMY(:,2)*cs);% W dir.
 DATA_rot(:,3)=(DUMMY(:,3)*cs+DUMMY(:,2)*sn);% U dir.

 cs=cos(angle2);sn=sin(angle2);
 DATA_rot(:,4)=(-DUMMY(:,5)*sn+DUMMY(:,4)*cs);% W dir.
 DATA_rot(:,5)=(DUMMY(:,5)*cs+DUMMY(:,4)*sn);% U dir.

 cs=cos(angle3);sn=sin(angle3);
 DATA_rot(:,6)=(-DUMMY(:,7)*sn+DUMMY(:,6)*cs);% W dir.
 DATA_rot(:,7)=(DUMMY(:,7)*cs+DUMMY(:,6)*sn);% U dir.

 clear DUMMY

% END
```

```
%  SSR_spike
%  This subsubroutine removes spikes
□
%  Date: 11 Nov.'97
□

□
% - It uses the 'DATA_read' matrix
□
% - in short: if difference with the mean is too large,
%   a spike removal procedure is started
% - it produces the 'DATA_nospike' matrix
% - it produces spike statistics for each record:
%  - number of spikes
%  - average width of the spikes (seconds)
%  - average height of the spikes (devided by the St. dev.)
%  - (over estimated) spike impact on the record (sum of height
mult.w. width/ record lenght  )


sp_Num=zeros(Num/B,Column);sp_Width=zeros(Num/B,Column);
sp_Peak=zeros(Num/B,Column);sp_Impact=zeros(Num/B,Column);


% 'detrend' the signal

 x=1:1:B;x=x';
 for j=2:Column
   for i=B:B:Num
     y=DATA_read(i-B+1:i,j);
     p=polyfit(x,y,1);f=polyval(p,x);
     TREND(i-B+1:i,j)=f;
   end
 end

% Variations to the 'trend':
VAR=DATA_read-TREND;
DUMMY=VAR;
for i=B:B:Num
   STD(i/B,2:Column)=std(VAR(i-B+1:i,2:Column));
end

% Determine the spike/statistics and remove them:

for j=2:Column     % do for each column

  spknum=0;            % set spike counter to zero
  i=1+20;              % first and last second of 2 hour file not
checked
  while i <= Num-20
    k=ceil(i/B);
    if abs(DUMMY(i,j))>Num_std*STD(k,j)    % if the measured value is
too large
                                           % it is called a spike
     % determine the width of the spike:

     forward=1; click=0;
      while click==0
        if abs(DUMMY(i+forward,j))< 2*STD(k,j) click=1;
        else
          forward=forward+1;
          if forward+i > (Num-20) click=1;end
        end
      end
```

```
        click=0;backward=1;
        while click==0
          if abs(DUMMY(i-backward,j))< 2*STD(k,j) click=1;
          else
           backward=backward+1;
           if i-backward < (20) click=1;end
          end
        end
        click=0;
        width=backward+forward-1;


        % Determine spike statistics

        peak=max(abs(DUMMY(i-backward:i+forward,j)))/STD(k,j);
        sp_Num(k,j)=sp_Num(k,j)+1;
        sp_Width(k,j)=sp_Width(k,j)+width;
        sp_Peak(k,j)=sp_Peak(k,j)+peak;
        sp_Impact(k,j)=sp_Impact(k,j)+width*peak/B;

        % Interpolation procedure:

        y1=mean(DUMMY(i-backward-13:i-backward-3,j));
        y2=mean(DUMMY(i+forward+3:i+forward+13,j));
        clear line
        replace=forward+backward+6;
        incr=(y2-y1)/replace;
        for n=1:replace
          line(n)=y1+n*incr;
        end
        DUMMY(i-backward-2:i+forward+3,j)=line';

        % Quit removal if 'Impact' of the spikes on St.dev. is larger
than 10%
        % in a later stage the record is rejected

        if sp_Impact(k,j) > 0.1
%         DUMMY((k-1)*B+1:k*B,j)=0;
          i1=k*B; i2=i+forward-1;
          if i1 > i2 i=i1; else; i=i2; end
        else
          i=i+forward-1;
        end
      end
      i=i+1;
    end
end


% Determine the average height and width of the spikes
for j=1:Column
  for k=1:Num/B
    if sp_Peak(k,j)~=0
        sp_Peak(k,j)=sp_Peak(k,j)./sp_Num(k,j); end
    if sp_Width(k,j)~=0
        sp_Width(k,j)=sp_Width(k,j)./sp_Num(k,j); end
  end
end

spINWP(:,1:Column)=sp_Impact;
spINWP(:,Column+1:2*Column)=sp_Num;
spINWP(:,2*Column+1:3*Column)=sp_Width;
spINWP(:,3*Column+1:4*Column)=sp_Peak;
```

```
% create new data matrix:

DATA_nospike=DUMMY+TREND;

%END
```

Appendix F
Noise levels in velocity recordings

The noise levels in the velocity recordings of June and August 1996 were higher than expected. Laboratory tests showed that noise levels of 2×10^{-5} m^2/s^2 were to be reckoned with (see also Section 3.2), whereas the noise levels found for the June and August measuring period were up to 1×10^{-4} and 1×10^{-3} m^2/s^2, respectively. Some characteristics of the noise contributing to the velocity signals, are shown in the power spectra Figure F.1.

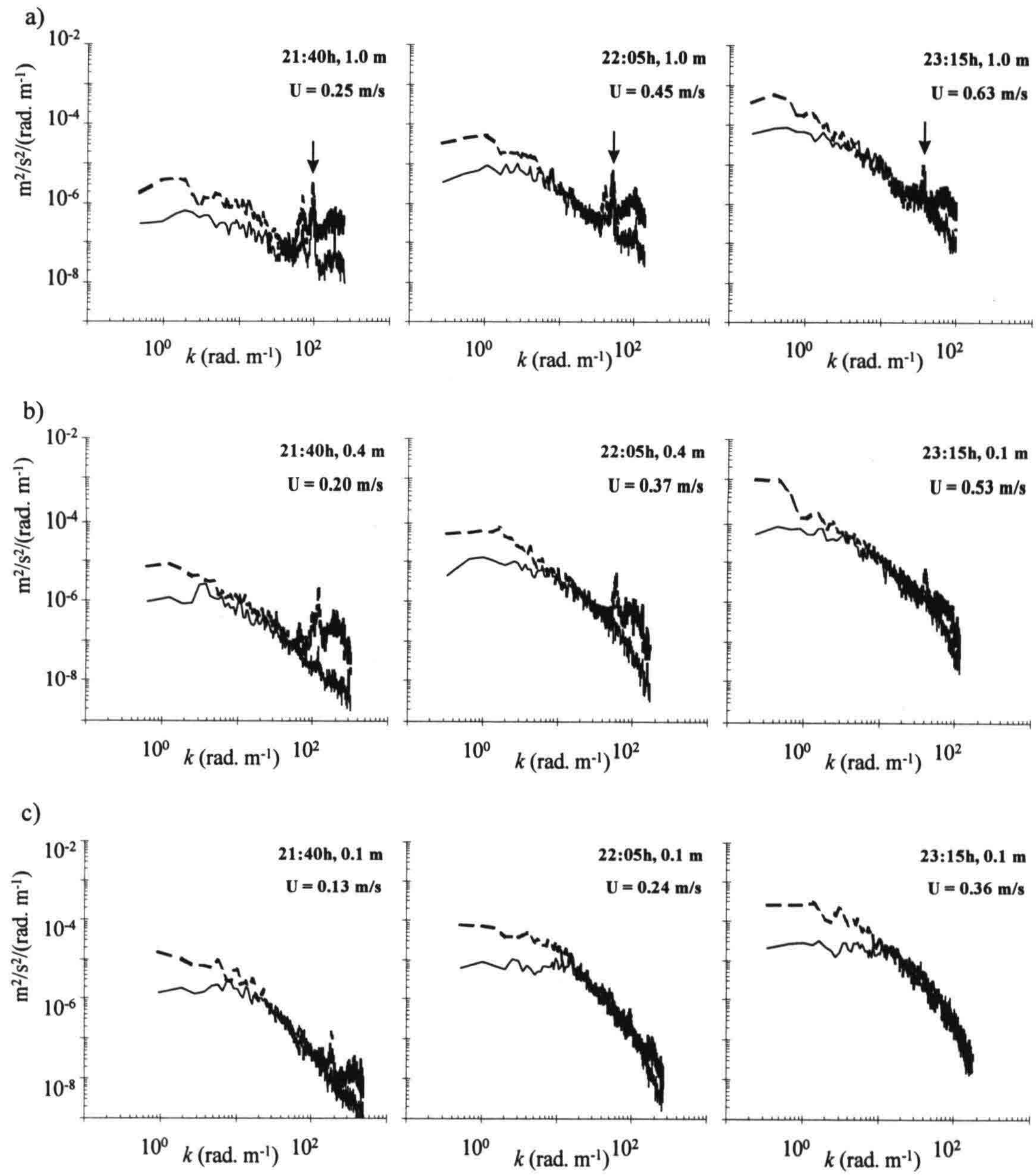

Figure F.1. Power spectra during three different stages of an ebb tide (21:10h - 23:30h June 27th 1996): (a) at 1.0 m, EMF D234; (b) at 0.4m, EMF D233; (c) at 0.1m, EMF D232; ---, *u*-power spectra; ——, *w*-power spectra.

Figure F.1 shows *u* and *w*-power spectra obtained from EMFs D232-D234 during increasing ebb flow. The plots on the left show power spectra for relatively small velocities, the plots in the middle for intermediate velocities, and the plots on the right show power spectra for large velocities (maximum ebb). Noise appears in the power spectra as one, or some times two peaks followed by a "bump". This spectral shape is more or less similar at all three levels, and it is conserved for increasing velocities. In case of increasing velocities, the locations of the peaks shift towards smaller wave numbers; however, the associated frequencies remain constant and are approximately 4 Hz.

Table F.1. Absolute and relative contributions of the noise (u'^2_p) to the variance of *u* (u'^2).

Position/EMF	u'^2_p at 21:40h $m^2/s^2 \times 10^{-4}$, (%)	u'^2_p at 22:05h $m^2/s^2 \times 10^{-4}$, (%)	u'^2_p at 23:15h $m^2/s^2 \times 10^{-4}$, (%)
0.1 m /D232	0.01, (0%)	-0.36, (3%)	-1.62, (-5%)
0.4 m /D233	0.92, (45%)	1.02, (15%)	0.80, (3%)
1.0 m /D234	1.60, (73%)	1.98, (36%)	2.08, (12%)

The relative contributions of noise to the variances of *u*- and *w*-records show large variations and they depend, among other things, on the velocity of the flow and the EMF. For example: noise contributions are clearly present in the u-power spectrum for a relatively low flow velocity at 0.4 m, but are negligible for relatively high flow velocities at the same level (compare the left and the right plots in Figure F.1.b, see also Table F.1.).

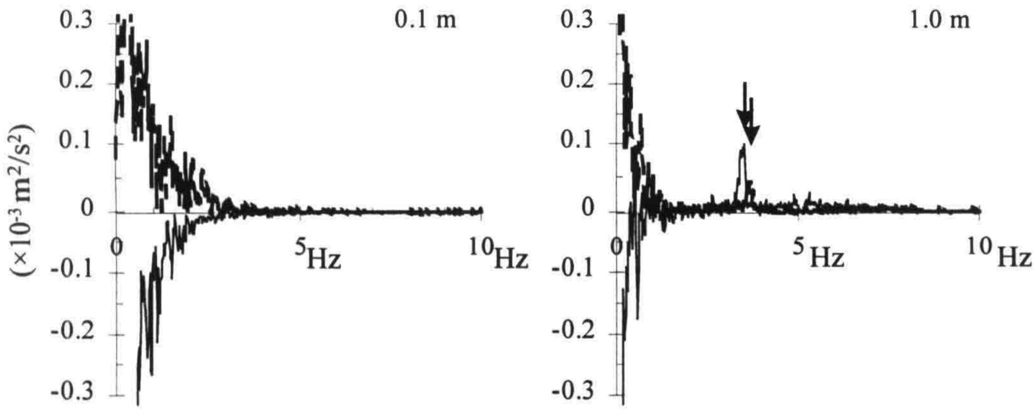

Figure F.2. Co-spectra for maximum ebb and maximum flood, at 0.1 and 1.0 m.: ---, *uw*-spectra for ebb (23:15h June 27th); ——, *uw*-spectra for flood (16:15h June 26th).

The contributions of the noise to the total variance of the signals can be estimated from Figure F.1 in the following manner. The integrated spectral density is subtracted from a hypothetical integrated density which was found from extrapolating the spectra from 2 Hz, according to the $k^{-5/3}$ dependence. The results for the *u*-power spectra are presented in Table F.1.

In Table F.1 the positive numbers are contributions to the variance, the negative numbers represent reductions of the variance resulting from high-frequency losses being larger than the noise contributions. Table F.1 shows that the absolute noise contributions do not change much for increasing flow velocities.

The co-spectra for *u* and *w* for maximum ebb and for maximum flood, are shown in Figure F.2. A remarkable feature of the noise present in *u* and *w* is that it is correlated, and that it always gives a positive contribution to the Reynolds stress $\overline{uw}$ (denoted by the arrows). The absolute contributions are 6×10^{-5} m^2/s^2 and 3×10^{-5} m^2/s^2 for ebb and flood, respectively, and are of the same order of magnitude as the seemingly constant offset for $\overline{uw}_{1.0}$ of approximately 7×10^{-5} m^2/s^2 in June as shown in Figure 4.10. For the August period the offset of $\overline{uw}_{1.0}$ is approximately 2×10^{-4} m^2/s^2.

The correlation coefficients of the noise contributions can be determined from coherency spectra which are defined as $|S_{ij}(k)|^2/S_{ii}(k)S_{jj}(k)$. The peaks and bumps of the *u*- and *w*-spectra show correlations between 0.4 and 0.8 for periods of slack water, the highest values are found for EMF D234 at 1.0 m. No coherence is found for the noise between the different levels.

A number of sources for the noise were examined. Sources which arise from wind, waves or tidal flow velocities, which showed large variations over the measuring periods, were excluded because the noise contributions were approximately constant over the measuring periods in June and August. The most likely source appeared to be increased instrumental noise due to wear and fouling of the EMF sensors heads. When the noise contributions could be considered small, they were assumed constant over the measuring period and were deducted from the turbulence intensities and Reynolds stresses. The velocity records of EMF 234 (at 1.0 m elevation) during the August periods were omitted herein, because the noise contributions were considered too high.