

Measurement of suspended sediment characteristics in an embanked flood plain environment of the River Rhine

IVO THONON & MARCEL VAN DER PERK

Centre for Geo-ecological Research (ICG), Faculteit Ruimtelijke Wetenschappen, Universiteit Utrecht, Postbus 80115, 3508 TC, Utrecht, The Netherlands. E-mail: i.thonon@geog.uu.nl

Introduction

During the last years, flood plains have increasingly become acknowledged as major sinks for both sediments and pollutants (e.g., Walling, 1999). Attempts to quantify the amount of (sediment-associated) pollution of lowland flood plains often proceed through modelling. However, data on suspended matter characteristics in flood plain environments are scarce, yet important for the calibration of flood plain sedimentation models and the assessment of the fate of sediment-associated pollutants in riverine environments.

Therefore we deployed a portable particle sizer and settling tube during two discharge peaks of the River Waal, which is the major distributary of the River Rhine in The Netherlands (mean discharge of 2400 m³/s at the Dutch-German border). The fieldwork area at the flood plain of the Afferdensche & Deestsche Waarden in the east of The Netherlands (Fig. 1) was inundated two times in Spring 2002 (Fig. 2). From 27–02 to 21–03 (rendering the ‘March’ data) and from 24–03 to 03–04 (the ‘April’ data), the instrument was deployed in its steel construction located in a meadow at about 100 m distance of the minor embankment.

The aim of this paper is to outline the use of the device, give an overview of the recent data gathered in the field campaign and discuss the opportunities for further use of the data in near future research.



Fig. 1. Location of the fieldwork area within The Netherlands.

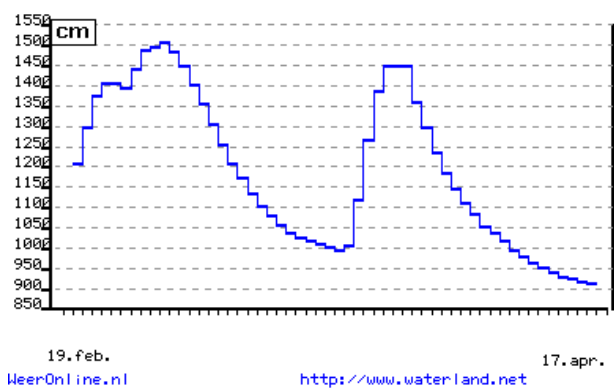


Fig. 2. Stage in cm a.s.l. of Rhine at Dutch-German border during March and April 2002.

Description of the measurement device

The portable particle sizer/settling tube we used is the LISST-ST Type C manufactured by Sequoia Scientific, Inc. (Redmond, WA, USA) (Fig. 3). This instrument has been used in

several marine, coastal and estuarine studies but has not often been deployed in a riverine environment. The LISST-ST measures particle sizes and settling velocities of particles ranging from 2.5 to 500 μm using laser diffraction principles following the ‘exact Mie theory’. In addition, a photo-diode measures the transmissivity (clearness) of the water. At the beginning of each experiment, the settling tube is opened for four seconds and water with suspended matter is taken in. Next, the suspended matter settles within the settling tube and the grain size distribution is measured 71 times during 12 hours at logarithmically spaced time intervals. The settling velocity is calculated from the decrease of the volume concentration of the different particles fractions in time. For a more comprehensive description of the LISST-ST device, we refer to Agrawal & Pottsmith (2000).

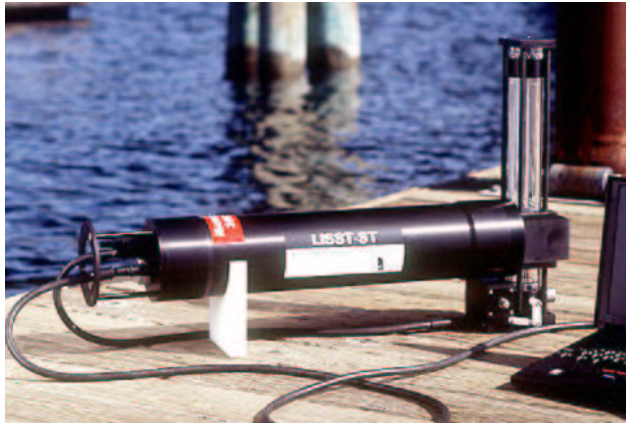


Fig. 3. The LISST-ST combined particle sizer and settling tube measures 86.36×48.90 cm. The horizontal tubing holds the laser. The settling tube can be seen on the right. Photograph: Sequoia Scientific, Inc.

Transmissivity data

It can be seen in a transmissivity graph (Fig. 4) that there is progressive clearing of the water as particles settle. However, 100 % transmissivity is not reached, because the finest particles have not settled yet after 12 hours (i.e., the measuring period we used) and still attenuate the laser beam. On the one hand, this means that we did not measure the characteristics of the smallest particles, i.e., those particles that have a diameter up to about one micron. On the other hand, it allows more insight in the temporal variation during a flood event because of a larger amount of data than in the case of the use of e.g. 24-hour periods.

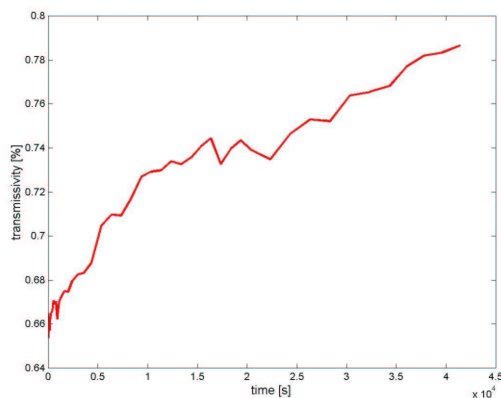


Fig. 4. Transmissivity graph for experiment 9 (out of 9) of the April data set.

Volume concentration data

During a settling experiment, the volume concentration of particles in each of the 32 size classes is measured. This is resampled afterwards to eight size classes for convenience. An example of the development in time during one experiment of the volume distribution of these eight classes is depicted in Fig. 5. The concentration of the three classes that include the smallest particles is considerably higher than that of the particle classes including the largest particles. The concentrations of all classes decrease during the experiment due to gradual settling. These concentrations can be summed up in order to obtain total suspended sediment concentration.

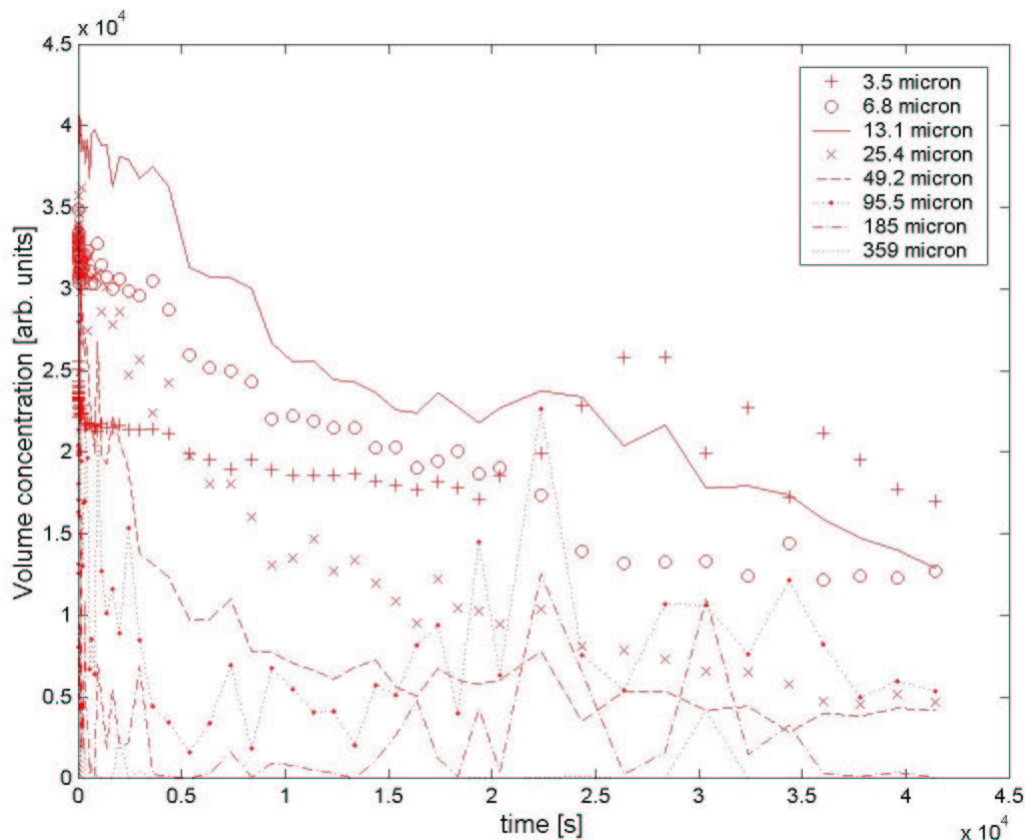


Fig. 5. Volume concentrations of the eight resampled size classes (named after their class mean) during the ninth and last experiment in the April data set.

Settling velocity data

In Fig. 6, an example of the relation between settling velocity and particle size is depicted. The settling velocity for larger particle sizes strongly deviates from the theoretical particle size/settling velocity relationship, depicted here as ‘Gibbs settling velocity’. This is most probably due to the fact that the larger particle sizes largely consist of flocs (i.e., sediment and organic matter that have coagulated). These are known to have a much lower density than 2.65 g/cm^3 (the density with which the Gibbs settling velocity was calculated) because of a high degree of porosity (Droppo *et al.* 1997). This causes the settling velocity to be lower than the theoretically derived velocity.

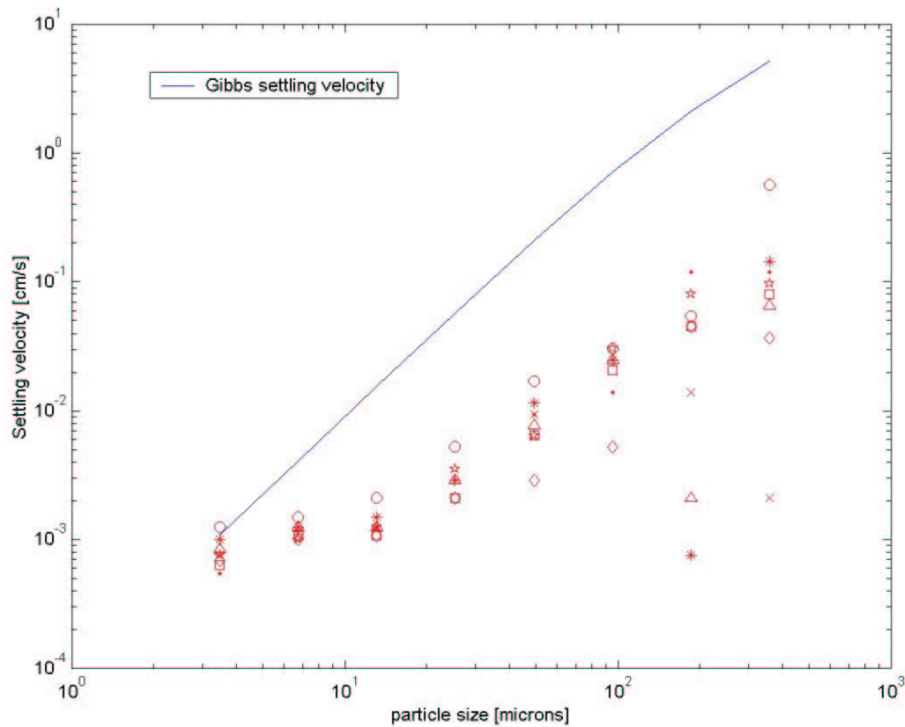


Fig. 6. Relation between particle size and settling velocity for the eight resampled particle size classes. Each point symbol represents measurements derived during one 12h experiment from the April data set. Note the deviation from the theoretical relationship for quartz sediments (Gibbs settling velocity). Also note the increase in standard deviation with particle size.

Perspective

Using a combined portable particle sizer/settling tube, several important particle properties such as volume concentration and settling velocity could be measured in an inundated flood plain environment. Here, mainly data for one out of nine measurements during the deployment in April have been presented. In the near future, the settling velocities and particle sizes will be used to calculate the particle density variations during a flood event. The temporal variation of the sediment concentrations, particle size distributions, and particle densities during a flood event will be further explored to assess the effect of discharge, influx of sediment, hydraulic conditions during the different inundation stages in the floodplain environment. The data from the March and April deployments will be mutually compared to assess the differences in particle characteristics as a result of flood magnitude and duration. In addition, the sediment characteristics will be related to turbidity and stream velocity measurements that were carried out during the April deployment using an Optical Backscatter Sensor (OBS) and Electromagnetic Field current meter (EMF), respectively. The particle size distributions will be compared to the grain size distributions of suspended sediment from a 60 litre water sample collected during peak discharge of the March flood event, and of deposited sediment collected from sediment traps in the study area during both flood events. The total suspended sediment concentration data will be compared to the sediment concentrations in 500 ml water samples taken at various places on the flood plain during the March deployment.

Acknowledgements

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