**Bachelor Earth Sciences**
**Examination Course: GEO3-4306 Coastal Morphodynamics**

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## Question 1 Waves and currents

Figure 1.1 provides a spatial map of the significant wave height over complicated sea bed morphology. The black lines are depth contours in meter depth. The brown colours represent the coast, in this case comprised of cliffs and sandy beaches. As you can see, the sea bed morphology is characterized by a submarine canyon, which branches into two separate canyons close to the shore. The map represents an approximately 5 x 5 km area.

In deep water ("the upper left of the figure"), the waves have a significant wave height of approximately 1 m and a period of 15 s. The arrow indicates the propagation direction of the waves in deep water. The colours in the map represent the significant wave height, varying from dark blue = 0 m to dark red = 2 m. Please disregard the blue rectangular in the upper right of the figure.

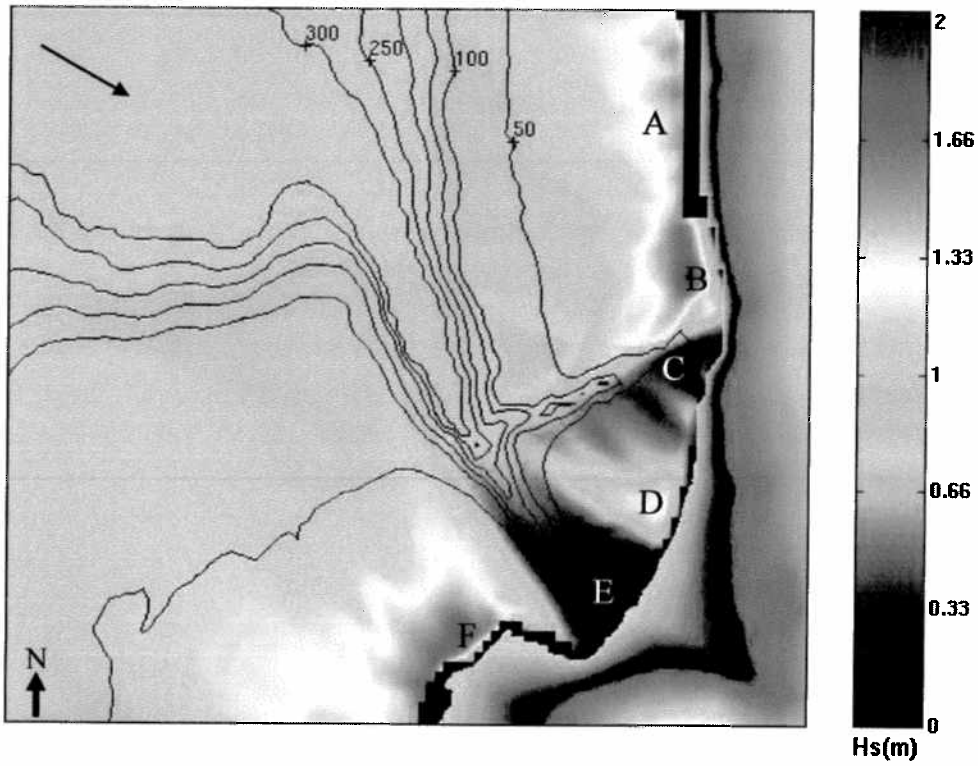



*Figure 1.1. Map of significant wave height, Hs, over a sea bed with a submarine canyon. The letters A to F represent locations used in questions d and e below.*

a) What is the definition of "significant wave height"?

b) Show that waves in the upper left corner of Figure 1 are indeed deep-water waves. → formule uit boek

c) Are waves with a height of 1 m and a period of 15 s likely to be "sea waves" or "swell waves"? Explain your answer.

↓ opzoeken

d) As you can see in Figure 1.1, the wave height along the coast is highly variable, between approximately 0.3 at locations C and E, and over 1.3 m at locations B, D and F. Explain why the wave height at locations C and E is lower than at locations B, D and F.

e) What will be the current direction at locations A, B, C, D, E and F? Pay attention to both cross-shore (onshore versus offshore) and alongshore currents. Explain your answer. Assume that wave-driven and tide-driven currents are absent.

## Question 2 Shoreface nourishment

Terschelling is a barrier island along the northern part of the Dutch coast (Figure 2.1). On its northern side it faces the North Sea, while on its southern side it is bordered by the Wadden Sea, an extensive area characterized by tidal flats and channels. Figure 2.2 provides information on the North Sea wave climate just north of Terschelling, schematized as wave roses for various significant-wave-height classes. During storms, the significant wave height offshore of Terschelling can reach values of 5 to 6 m, with corresponding periods of 10 to 15 s. The tide at Terschelling is semi-diurnal, with an approximately 2.5-m range during spring tide. The tide propagates from west to east along the island.

The nearshore zone of Terschelling is characterized by 3 subtidal sandbars, see the black line in Figure 2.1 denoted 23-04-1993. The grain size in the nearshore zone is approximately 200 μm. The intertidal beach has a low slope, about 1:100. The dunes along Terschelling are between 10 to 25 m high.

Large parts of the Terschelling coast experienced severe erosion over the last decades. To combat this erosion, a shoreface nourishment was implemented (see Figure 2.1, dotted line denoted 06-10-1993) between beachpoles 14 and 18. This nourishment filled up the trough between the outer and middle sandbar. The total volume of the nourishment was 2.5 $Mm^3$. To the east and to the west of this nourishment, the trough remained unaltered.

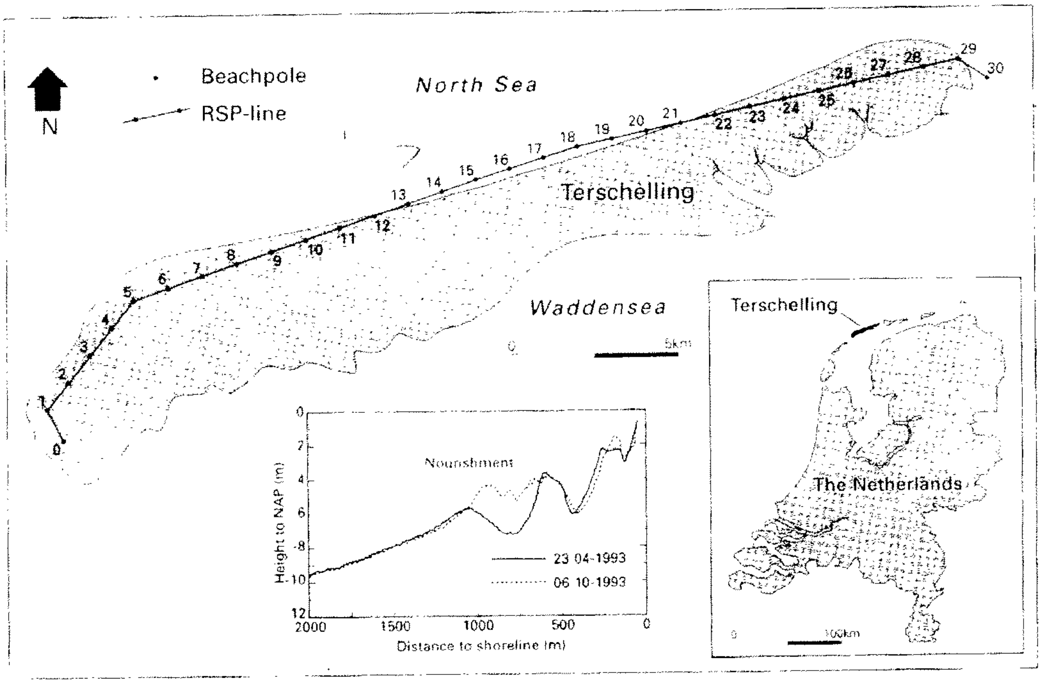



*Figure 2.1 Location of Terschelling.*

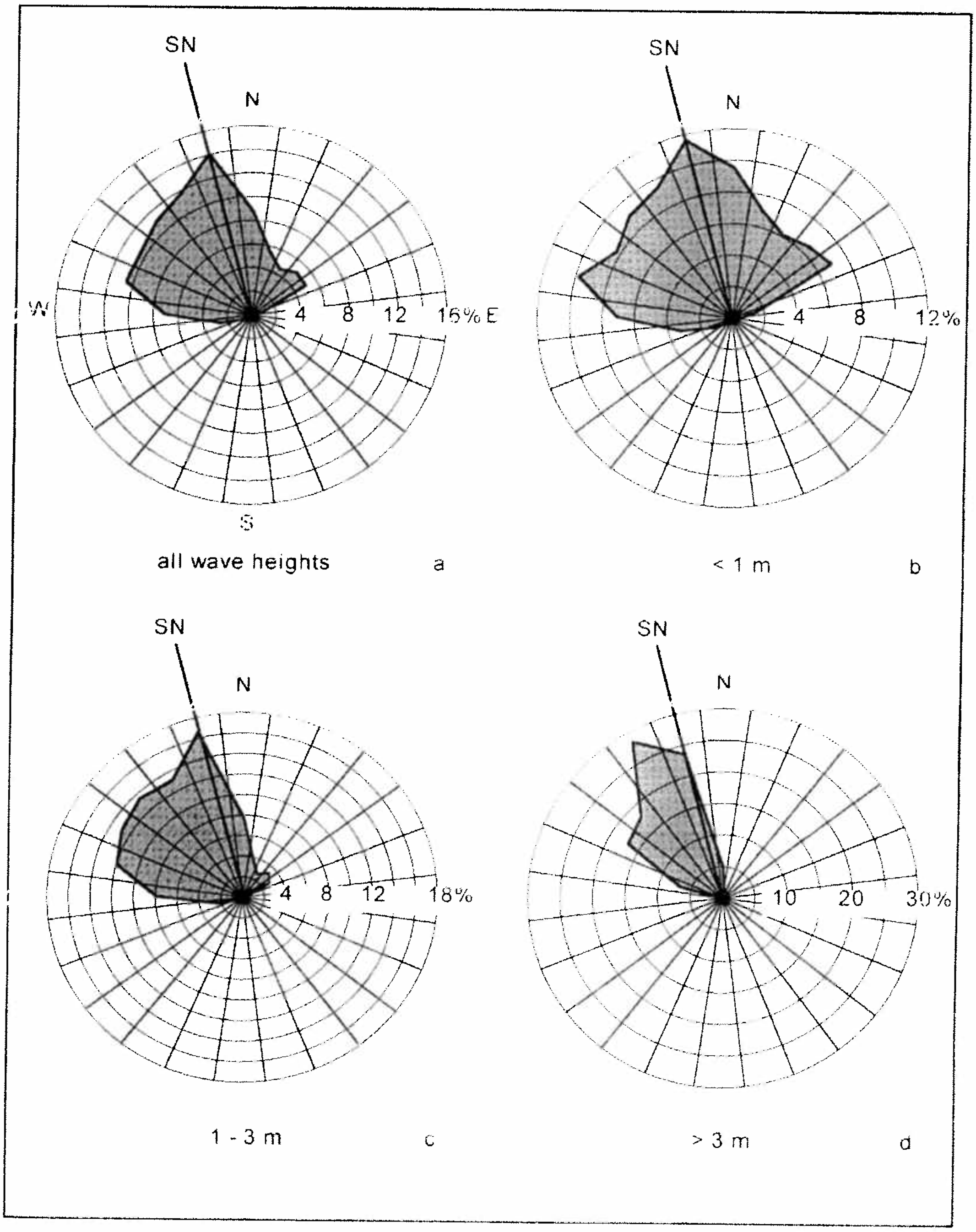



*Figure 2.2. Directional frequency of occurrence ('wave roses) of the offshore significant wave height $H_s$ at Terschelling: (a) for all $H_s$, (b) for $H_s < 1$ m, (c) for $1 < H_s < 3$ m, and (d) $H_s > 3$ m. SN stands for the shore-normal direction. N, E, S, W are North, East, South, and West, respectively.*

a) Measurements of the water motion on the intertidal beach during various storms showed that the energy of waves with periods of about 2 minutes was much larger than the energy of waves with periods of 10 to 15 s. Why is the water motion on the intertidal beach during a storm dominated by these 2-minute waves and not by the ordinary sea waves with periods of 10 to 15 s?

b) Explain how these waves with periods of about 2 minutes are generated. Start your answer seaward of the surf zone.

c) Use Figure 2.2 to explain whether the net alongshore sand transport along Terschelling is to the east or to the west. Or is there no net alongshore transport?

d) Shoreface nourishments are implemented under the assumption that the amount of sediment shoreward of the nourishment will slowly increase with time and, hence, will make the coast safer. One process that can move sediment from the nourishment toward the shore is the skewness of the orbital motion of the waves. Explain why skewed waves transport sediment onshore.

e) After 3 years, a total of 0.8 $Mm^3$ of sand had been lost from the nourishment area and presumably been transported onshore. The area shoreward of the nourishment, however, had gained a total of 2.4 $Mm^3$ of sand. This implies that 2.4 - 0.8 = 1.6 $Mm^3$ of the deposited sand did not come directly from the nourishment. What is the most likely source of the additional 1.6 $Mm^3$ of sand? Explain your answer.

## Question 3 Tides and Deltas

The Gulf of Tonkin (Fig. 3.1) is located in South East Asia, near the coast of North Vietnam and South China; the Red River flows into the Gulf of Tonkin and has created a large river delta with its apex NW of Hanoi (near Son Tay). The Red River Delta (Fig. 3.2) has developed several river branches; each subdelta will have its own morphological characteristics based on the local fluvial and marine conditions. Tidal conditions in the Gulf of Tonkin are also depicted in Fig. 3.1.

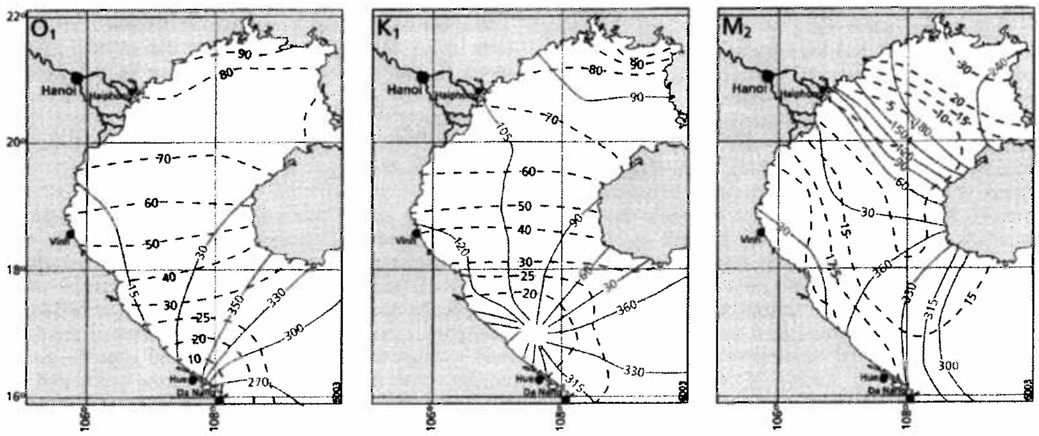



Fig. 3.1: Tidal conditions for different tidal constituents $O_1$, $K_1$ and $M_2$ in the Gulf of Tonkin, near the coast of the Red River Delta (north Vietnam). Indicated are co-tidal and co-range lines.

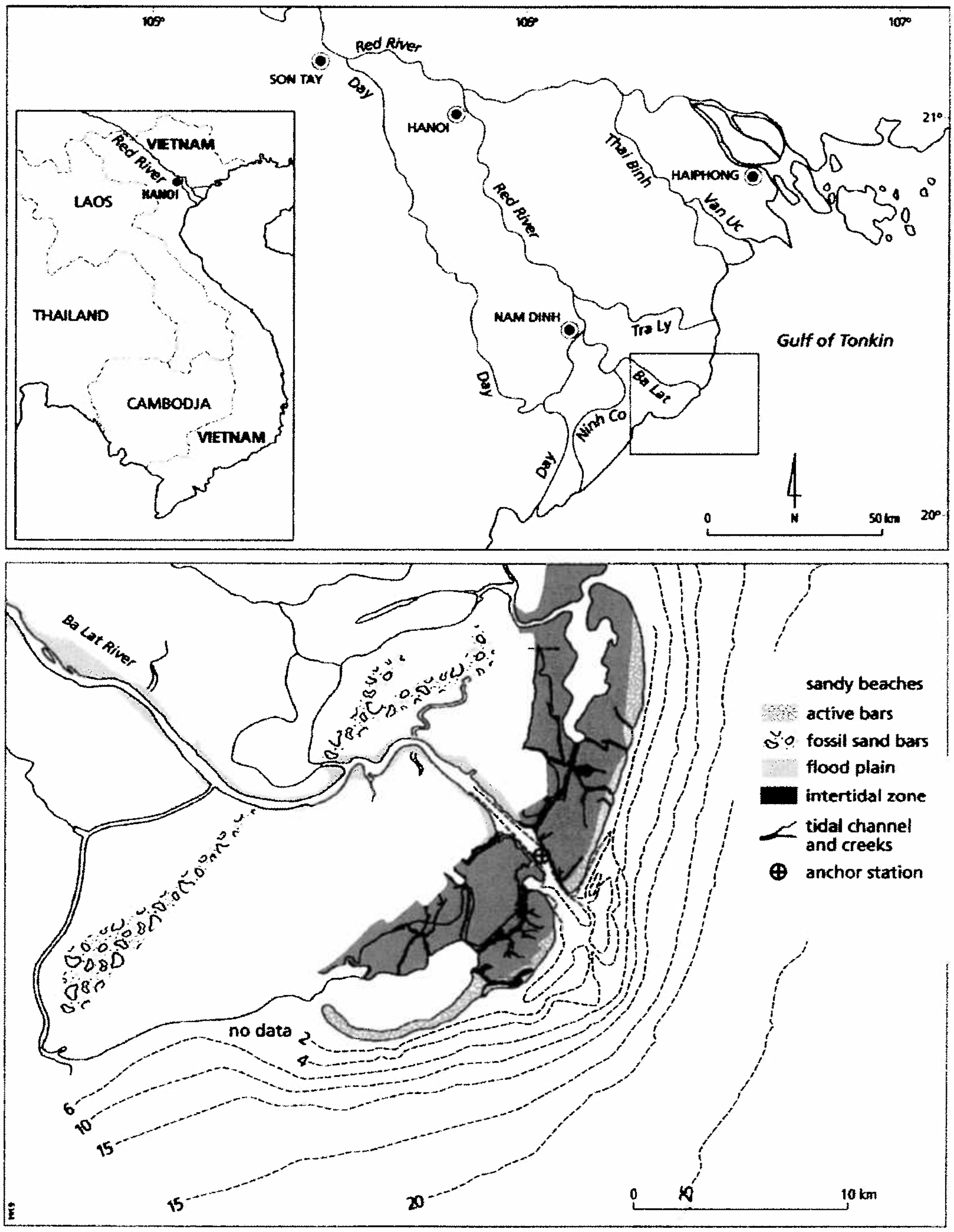
3a) Explain the pattern of co-tidal and co-range lines for the three tidal constituents in the Gulf of Tonkin. Why is there a difference in behaviour for the diurnal and semi-diurnal tides ? Are the tidal conditions near the City of Hue or Da Nang (in the south) diurnal, semidiurnal or mixed. Motivate your answer.

3b) Due to the variability of fluvial and marine, hydrodynamic conditions, morphological characteristics of the Red River delta will vary in time and space. Fig. 3.2 gives an overview of the delta and an example of one of the subdeltas, the Ba Lat delta (southwest). The delta near Haiphong is different from the Ba Lat delta.

- What are the morphological properties of both deltas and what are the main differences ?
- Explain the relative role of river outflow, waves and tides in both regions for delta development ?
- Where do you expect the presence and development of buoyant river plumes in front of the river mouth ?

In all cases: gives arguments to support your answers !

Fig. 3.2: The Red river delta with subdeltas: near Haiphong in the north and the Ba Lat in the southwest.



## Question 4 Sediment transport processes in estuaries

Hydrodynamic and suspended sediment transport measurements have been carried out in the Ems-Dollard estuary to analyse mud transport phenomena. The location and morphology of the Ems-Dollard estuary in the north of the Netherlands is illustrated in fig. 4.1. During one of these measurement campaigns data is collected of the particle size of suspended sediment ((fig. 4.2a), the flow velocities (Fig. 4.2b; the black lines represent lines of equal flow velocity in m/s and flood currents are positive and ebb currents are negative) and the concentration of suspended matter (Fig. 4.2c; indicated by grey tones and given in mg/l). The total data set represents a complete flood-ebb cycle and the measurements were carried out in the main channel of the estuary.

a) Analyse and explain the temporal and spatial (=vertical) distribution of suspended matter (SSC: suspended sediment concentration) in the water column as function of time in the tidal cycle. Based on the observations: how can one classify this Ems-Dollard estuary ?

b) Which factors are responsible for the change in floc size during the measurements? Explain their effect on floc sizes

c) Is the position of the measuring station located landward, seaward or within the turbidity maximum ?

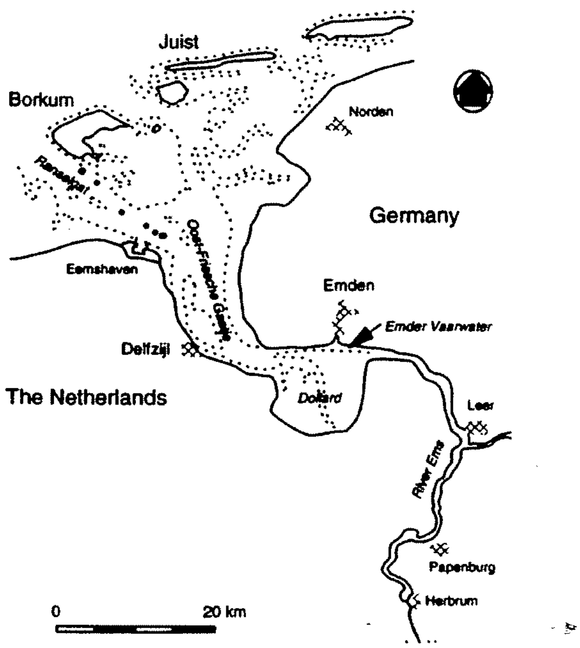



Fig. 4.1: The Ems-Dollard estuary at the boundary of the Netherlands and Germany.

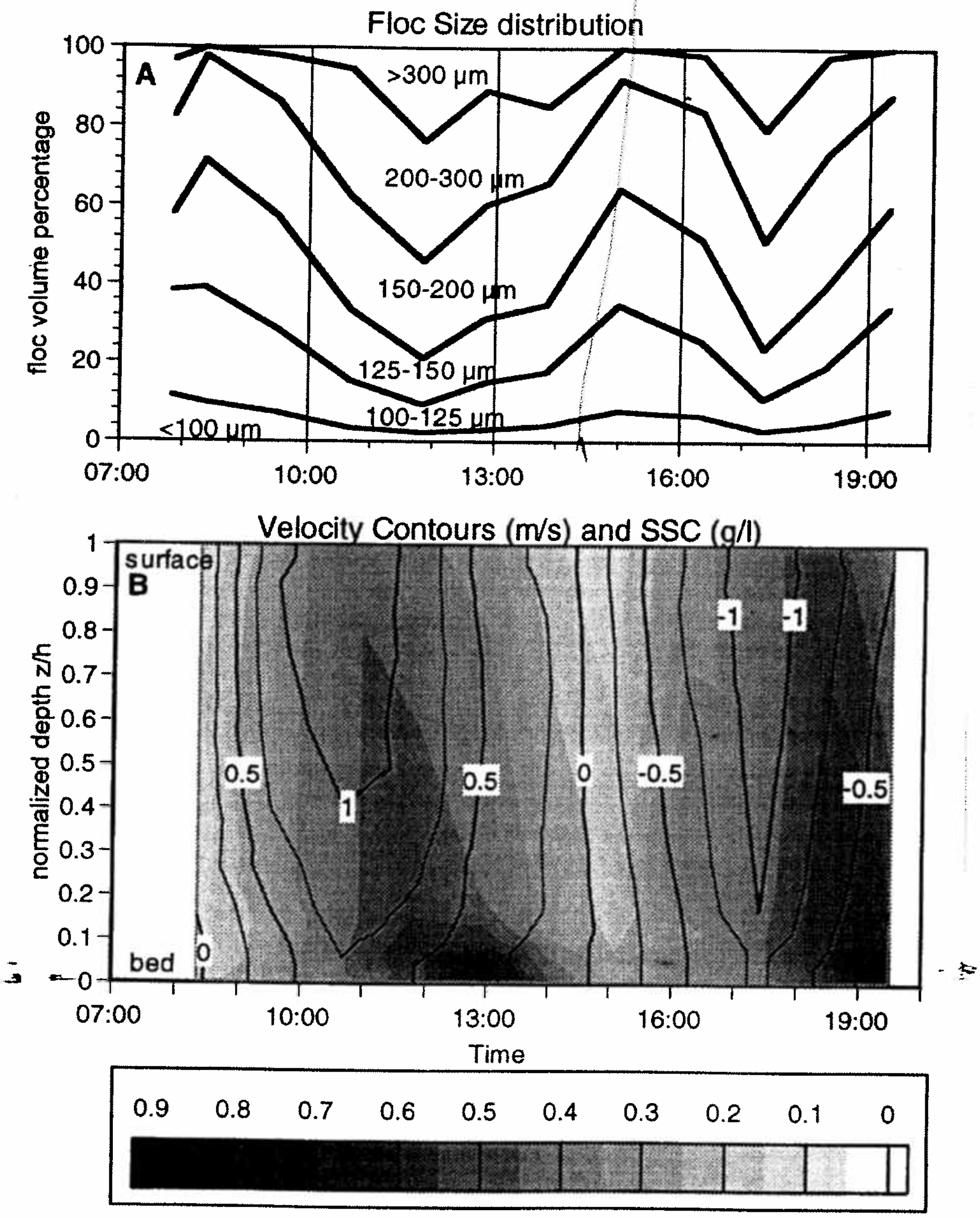



Fig. 4.2: Suspended sediment transport conditions: floc size (A), flow velocity and suspended sediment concentration (SSC; in C).