Bachelor Earth Sciences
Final exam of GEO3-4306 Coastal Morphodynamics

Date: January 28, 2015
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Please note the following:

- Before you start, carefully read the whole question.
- Answer each question on a separate piece of paper.
- Put your name and student number on each piece of paper.
- You may use the book by Masselink, Hughes & Knight, the readers by Hoekstra, and a calculator. The use of hand-outs, your own notes, papers used during the course, and answers to papers and exercises is not allowed.

Question 1: Currents and morphology in the nearshore zone

Coastal scientists deployed an extensive array of instruments to measure mean cross-shore and longshore currents in the nearshore zone. The sea-bed elevation on one particular day is shown in Fig. 1.1. In this figure, X stands for cross-shore direction and Y for longshore direction. The contours indicate the bed elevation with respect to mean sea level, with negative meaning below mean sea level. The thick black line is the 0-m contour; the dashed line is the location of the low-tide shoreline. Each black square is the location of an instrument that measured the mean cross-shore and longshore velocity.

Fig. 1.2 shows the mean velocity vectors during a high tide, when the tidal water level was about 1 m above mean sea level. The offshore root-mean-square wave height was about 1.5 m and the peak period was approximately 15 s. The waves were shore-normally incident. There was no wind.

a) Classify the bathymetry in Fig. 1.1 according to the Australian beach model of Wright-and-Short (1984). Motivate your answer.

b) Explain the surf-zone circulation seen in Fig. 1.2. Start your answer by calculating in what water depth you expect the incident waves to start breaking. Note: The answer "It is a rip current" is insufficient!

c) Explain whether the incident waves were sea waves or swell waves.

d) During the days after the measurements in Fig. 1.2, the scientists observed that the offshore peak period gradually reduced to 10 s. Outline the most likely cause for this reduction. There was still no wind.

e) Make a brief guess of the evolution of the bathymetry, assuming that the height of the incident waves remains rather low (but sufficiently high to suspend sediment) for at least another week.

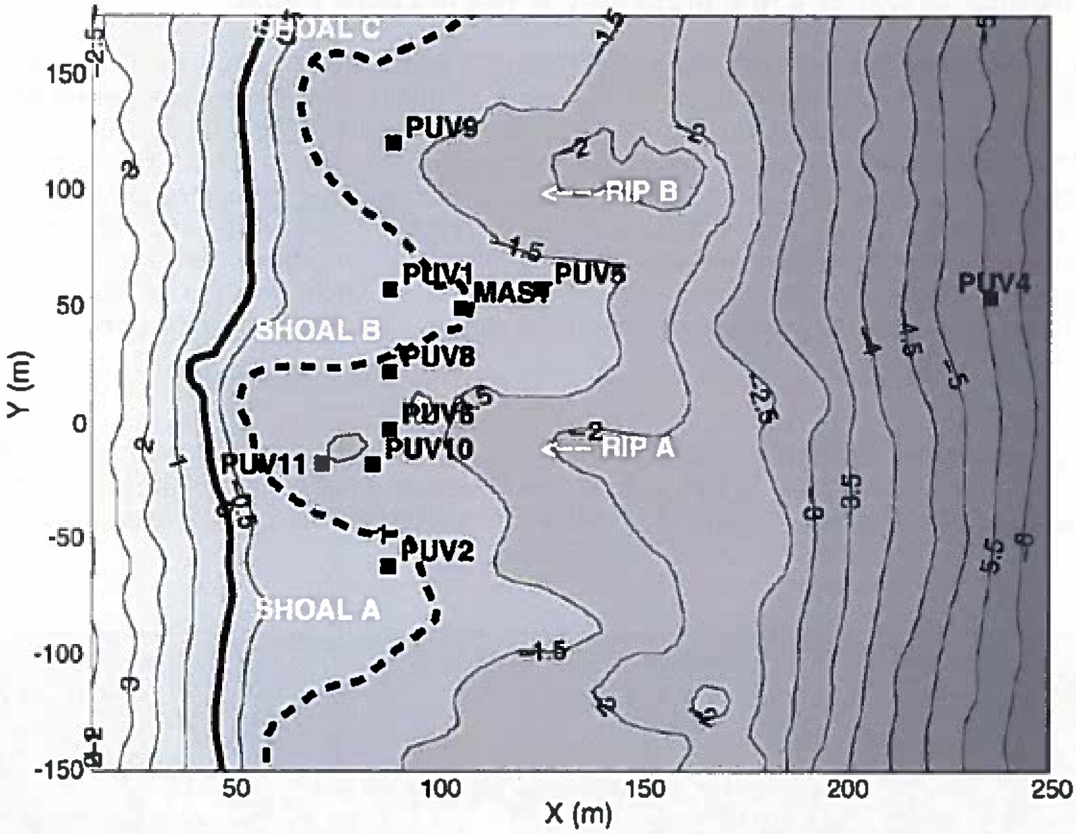

Fig. 1.1: Bathymetry (contours and colour shading) and instrument location (squares). X stands for cross-shore direction and Y for longshore direction.

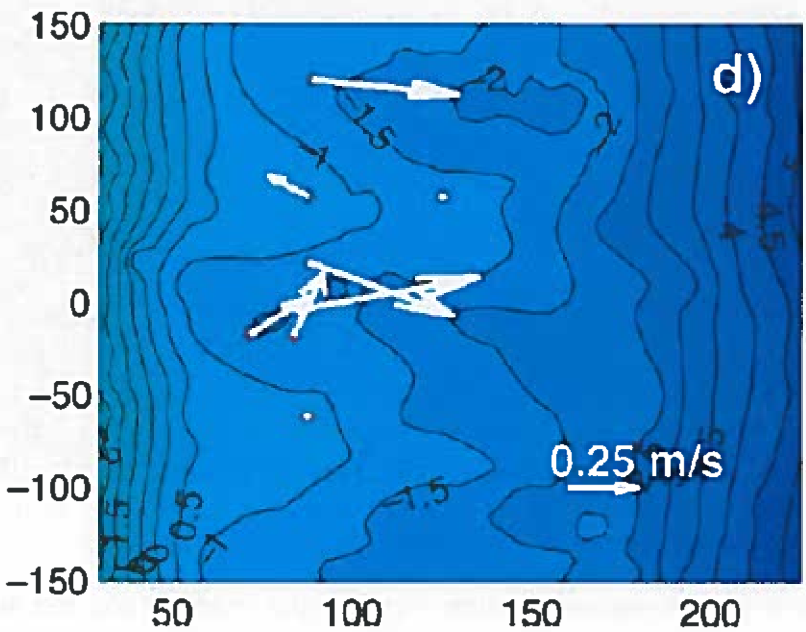

Fig. 1.2: Mean velocity vectors for a high tide during the measurement campaign. The arrows indicate both the magnitude and direction of the surf-zone circulation. The contours and colouring represent the bathymetry. The horizontal axis is the cross-shore direction, the vertical axis is the longshore direction.

Question 2: Waves and morphology in the nearshore zone

The photograph (Fig. 2.1) shows a picture of a beach during a storm. The waves, which have a root-mean-square wave height of about 2 m and a peak period of 8 s in deep water, break on the sandbar as indicated by the arrow. During the storm, nearshore scientists deployed instruments at the crest of the sandbar (indicated by A) and about 100 m seaward of the sandbar (indicated by B, mean water depth = 6 m). The instruments measured the cross-shore and alongshore near-bed velocity and sediment concentration 0.2 m above the sea bed. In addition, the scientists deployed an instrument at each location to determine whether the sea bed was flat or contained ripples. The median grain size at both A and B is 300 μm.

Fig. 2.2 shows two cross-shore profiles, one before the storm (solid line), the other one immediately after the storm (dashed line). The locations of the instruments are also indicated. The elevation is with respect to mean sea level.

Fig. 2.1: Snapshot (photograph) of a beach during a storm. The arrow points to the alongshore-uniform outer breaker zone above a sandbar (see Fig. 2.2). A and B are locations where cross-shore and alongshore velocities, and sand concentrations were measured at approximately 0.2 m above the sea bed.

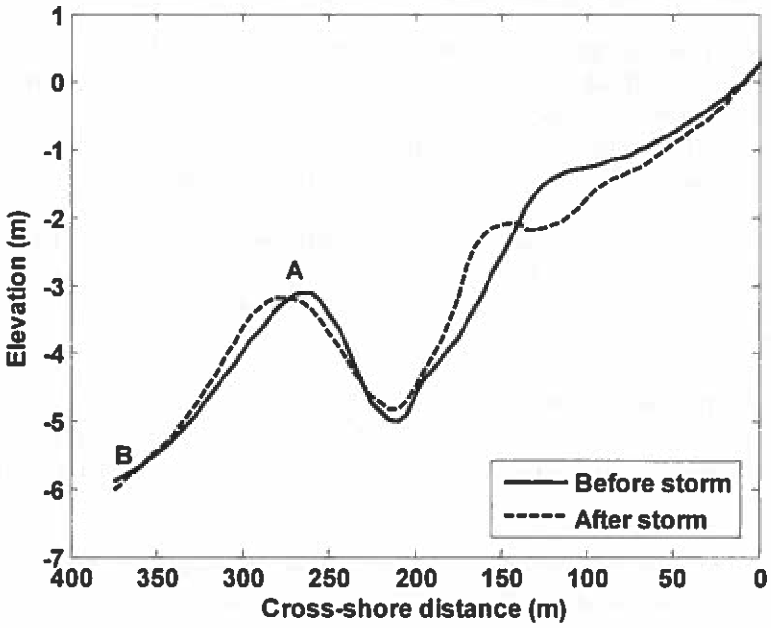

Fig. 2.2: Sea bed elevation (with respect to mean sea level) versus cross-shore distance before and after the storm shown in Fig. 2.1.

a) Use the *morphodynamic system approach* to explain why the sandbar migrated offshore (from approximately 265 to 275 m from the shoreline) during the storm. In your answer, use the photograph to reason about the dominant water motions during the storm.

b) The bed slope in the swash zone was approximately 1:50 during the peak of the storm. Provide an educated guess of the period of the swash motions at this time. Explain your answer briefly.

c) During the storm, the sea bed at location B was observed to be flat. The measurements showed the suspended sediment transport to be in the onshore direction. Describe the most logical cause for this onshore transport; clearly motivate your answer.

d) Several days after the storm, when the wave height had dropped to about 1 m, the suspended sediment transport was observed to be in the offshore direction. Describe the most logical cause for this offshore transport; clearly motivate your answer.

Question 3: Tidal conditions in the estuary of the Western Scheldt (NL)

Paleogeographic developments in the Western Scheldt estuary are illustrated in Fig. 3.1; it shows the effect of both natural and man-induced developments inside the estuary. Meanwhile and over the same period, tidal conditions in the Western Scheldt estuary also changed; the modification in tidal range is demonstrated in Fig. 3.2. This diagram is based on tidal observations since 1650.

a) What is the relation between the development of the tidal range (Fig. 3.2) and the morphological development of the estuary (Fig. 3.1)? Explain the longitudinal change in tidal conditions inside the estuary. Motivate your answer.

b) What has happened with the time lag between the moment of high water at Vlissingen (almost at the mouth of the estuary) and the moment of high water at Antwerpen (about 75 km upstream in the estuary) in the same period?

c) What has happened with the tidal prism of the Western Scheldt and what kind of morphological feedback can be expected?

d) What is the effect of an increase in tidal range for the erosional and depositional processes that operate in salt marshes? Discuss both wave- and current-driven processes.

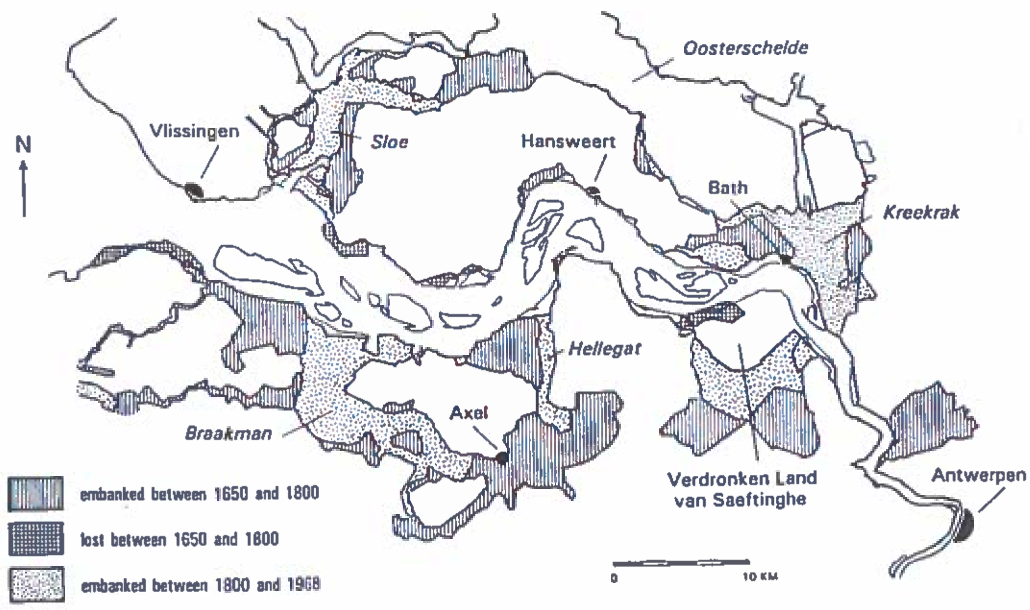

Fig. 3.1: Changes in intertidal morphology in the estuary of the Western Scheldt since 1650.

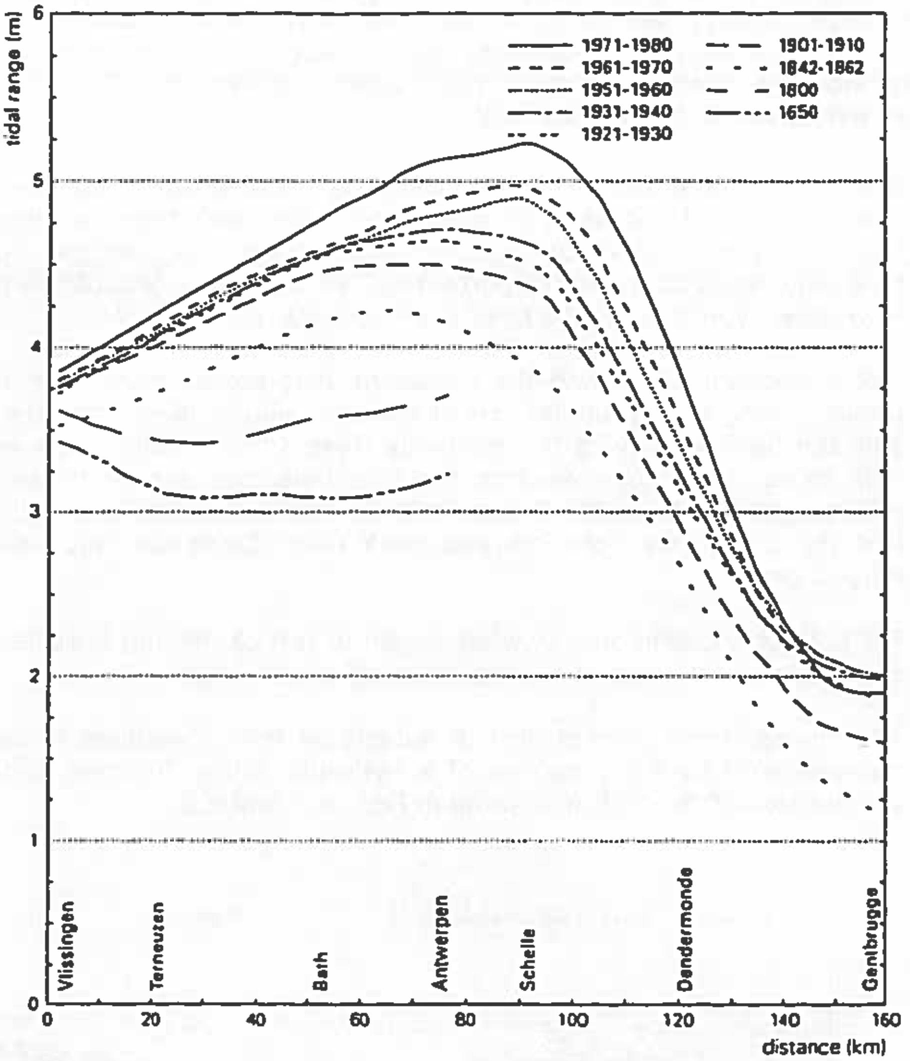

Fig. 3.2: Tidal range in the estuary of the Western Scheldt as function of time (developments since 1650) and location inside the estuary. The mouth of the estuary corresponds to km section 0 (close to Vlissingen).

Question 4: River outflow processes in the Mississippi Delta

Outflow processes in the South Pass of the Mississippi Delta are illustrated in Figs. 4.1 and 4.2. Conditions in Fig. 4.1 are related to phases with low river discharge; Fig. 4.2 relates to peak discharges. The figures include information on flow velocity, water density, the value of the densimetric Froude number (here: Fi). The lines of equal density (isopycnals) are expressed in terms of the deviation from the density of normal water (1000 kg/m^3; a density of 1022 kg/m^3 is therefore expressed by the number 22).

a) Explain the difference in outflow patterns (flow velocity, density and Fi-number) in and outside the river mouth for both flow conditions. Bed friction can be an important mechanism affecting river outflow. For which flow regime is bed friction important and what is the effect of this process? How would you classify the river outflow model in general?

b) Plot a diagram with along the horizontal axis the distance from the river mouth (along a longitudinal axis of the river plume) and along the vertical axis the flow velocity of the relatively fresh surface water masses. To be able to compare both systems the flow velocities should be normalized with respect to the mean flow velocity V_0 in the main river mouth (V/V_0). Plot the curves for both low and peak river discharges and explain the differences.

c) For both flow conditions: in what region is vertical mixing best developed? Explain your answer and outline criteria that you used.

d) The change from supercritical to subcritical flow conditions is commonly characterized by the presence of a hydraulic jump. Indicate and explain the position of the hydraulic jump in Figs. 4.1 and 4.2.

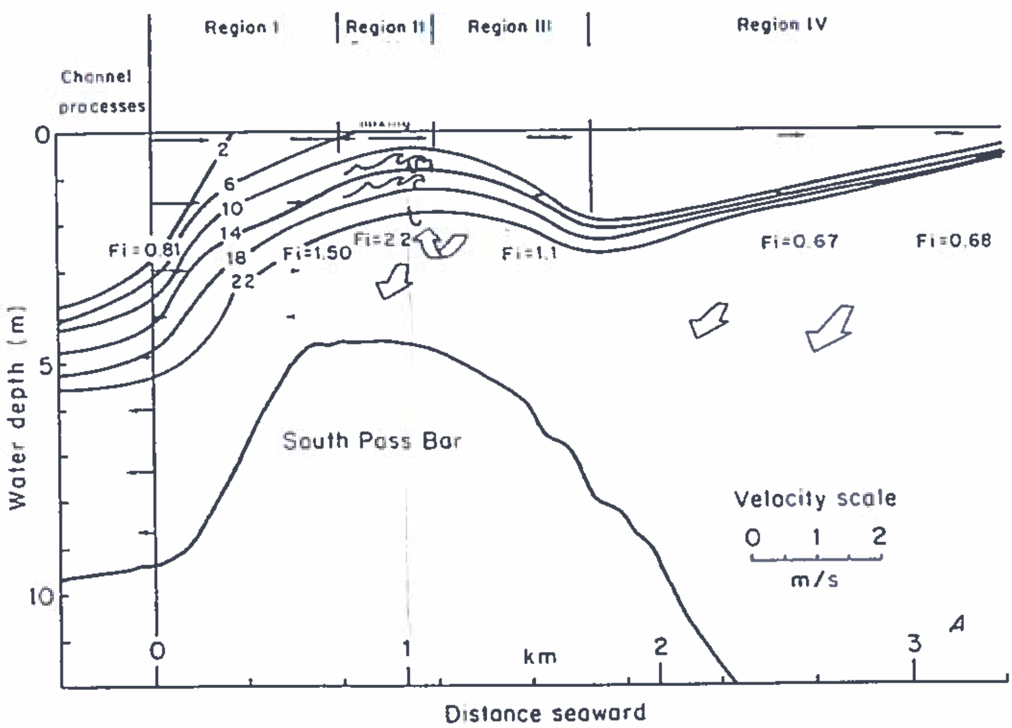

Fig. 4.1: River outflow in the South Pass, Mississippi delta; low river discharge.

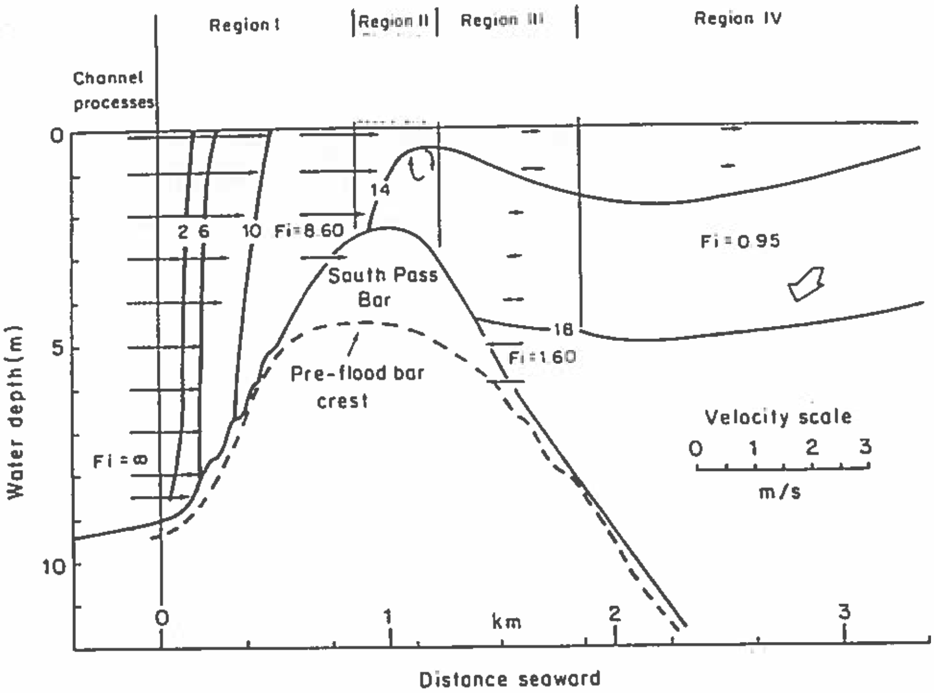

Fig. 4.2: River outflow in South pass, Mississippi delta; peak discharge.