Lb = 27.5 → 20 km
b/w = 2 → 1.1
W(x) = 2000 → 250 (land inward)
<h> = 5 → 7 → 9 m

Exam 2018 Morphodynamics of Tidal Systems (GEO4-4435)

Wednesday 24-01-2018: 9.00 – 12.00

33 p

Question 1 – Dynamics of the Loire Estuary

Have a look at Figures 1- 3. They show a map of the Loire estuary, historical changes in tidal range for several stations, and estimated changes in hydraulic drag (Chézy value (C), $C_d=g/C^2$) for different parts of the Loire estuary.

The Loire estuary has seen a main change in the first decade of the twentieth century. Large parts of the intertidal areas were reclaimed and the Loire estuary was canalized. The e-folding length scale for estuary width (Lb) changed from 25-30 km to about 20 km nowadays and the amount of intertidal areas changed (b/w in terms of Friedrichs paper) from about factor 2 to 1.1. The width of the estuary near saint Nazaire is nowadays max 3000 m, it is 2000 m at its narrowest point near the mouth, while it is about 250 m near Nantes.

Partly as a response to channeling of the estuary, and partly due to human interventions, the typical estuary depth changed. In 1900 it was about 5 m, in 1940 it was 7 m, and from 1970 onwards it is 9 m.

The average discharge of the Loire is 800 m^3/s, but peak discharges can be up to 5000 m^3/s. Q

Table 1 shows predicted times of high (PM) and low (BM) water level at Saint Nazaire and Nantes for January 22.

a) **3 pt.** Based on the given information, qualitatively explain why the tidal range changed at Nantes over the last 100 years. Discuss the role of deepening, funneling and changes in bed roughness.
b) **2 pt.** Explain how a loss in intertidal area can result in an increase in tidal range, even when Lb does not change.
c) **3 pt.** Figure 1 shows three cross-sections (1-3). The width at cross-section 1 is 2000 m, at nr 2 3000 m and nr 3 it is 1100 m. The distance between the cross-sections is 6.5 km. Based on empirical predictors, calculate the typical bar length, bar width and braiding index for cross-section 2.
d) **2 pt.** Upstream from Palmboeuf no bars are present nowadays. **Explain why.** Use the terms 'excess width' and 'ideal width' in your answer.
e) **2 pt.** Table 1 shows predicted HW and LW levels and their time of occurrence on 22nd January of 2018. The coeff in the second column is a value to indicate a relative strength of the tide, where 100 is the max value throughout the 18.6 year cycle and 50 is a typical neap tide value. Based on the data, calculate the propagation speed of the HW and LW wave.
f) **2 pt.** Based on Table 1 discuss the deformation of the wave and whether you expect ebb or flood dominance near Nantes based on tidal asymmetry.
g) **3 pt.** In the Loire estuary at least three sediment transport mechanisms are present: transport by river flow, transport by Stokes return flow and transport by tidal asymmetry. Make a sketch of these three transport mechanisms and indicate by the length and direction of the vector their

relative magnitude and direction. Draw vectors for Saint Nazaire, halfway Saint Nazaire and Nantes and for Nantes.

h) **3 pt.** Explain what will happen with the tides and with tidally averaged sediment transport during periods of high discharge (take 5000 m^3/s).

i) **3 pt.** In 1900 the estuary depth and shape was very different. Use **non-equilibrium theory** of Friedrichs to calculate the propagation speed of the wave around 1900. Hint: first calculate La, then use eq 3.40 to solve for c (do not start with an initial estimate for c, but directly solve the equation).

j) **2 pt.** Calculate the phase difference between water levels and flow velocities for 1900. Discuss how large the Stokes return flow used to be compared to values nowadays.

k) **3 pt.** Discuss the effect of the deeper channel (=two effects) and reduced intertidal area on tidal asymmetry near Nantes. Compare 1900 and 2005.

l) **3 pt.** Qualitatively discuss the changes in sediment transport patterns between 1900 and 2005. Discuss how the different sediment transport mechanisms of tidal asymmetry, Stokes return flow and river flow possibly have changed over time.

m) **2 pt.** Explain why the Chézy value has changed mainly between Cordemais and Nantes, and not so much in the more seaward part of the estuary.

			ST NAZAIRE		NANTES	
Date	Coeff		Time	Level	Time	Level
22/01/2018		BM	1 h 59	1.60	4 h 20	1.35
Monday	72	PM	7 h 28	5.45	8 h 43	5.95
		BM	14 h 19	1.50	16 h 37	1.25
	69	PM	19 h 36	5.20	20 h 48	5.80

Table 1: HW (PM) and LW (BM) levels and times.

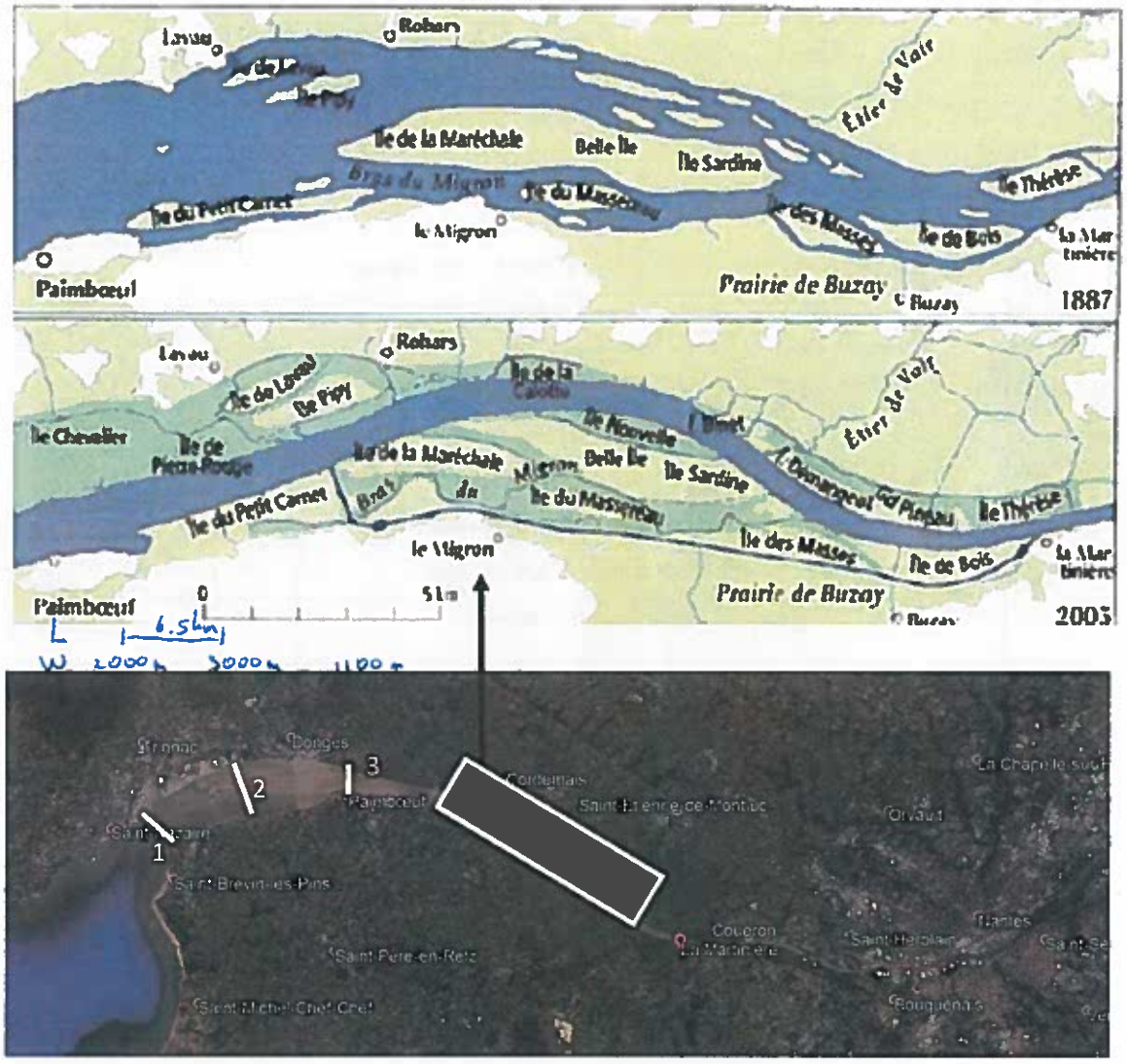


Figure 1: Loire Estuary, France. The lower panel shows the region from Saint-Nazaire to Nantes. The upper panel is an enlargement of the white area depicted in the lower panel. It shows the estuary in 1887 and 2003. The land was reclaimed in the first decade of the twentieth century. Similar land reclamations took place in the region between La Martiniere and Nantes, but there are no maps from that time period. The estuary is subdivided in four sections. Saint-Nazaire -> Palmboeuf = 13 km, Palmboeuf -> Cordemais =13 km, Cordemais -> La Martiniére = 11 km, ~~Cordemais~~ -> Nantes = 11 km.

La Martiniere

22 + 26 = 48 km

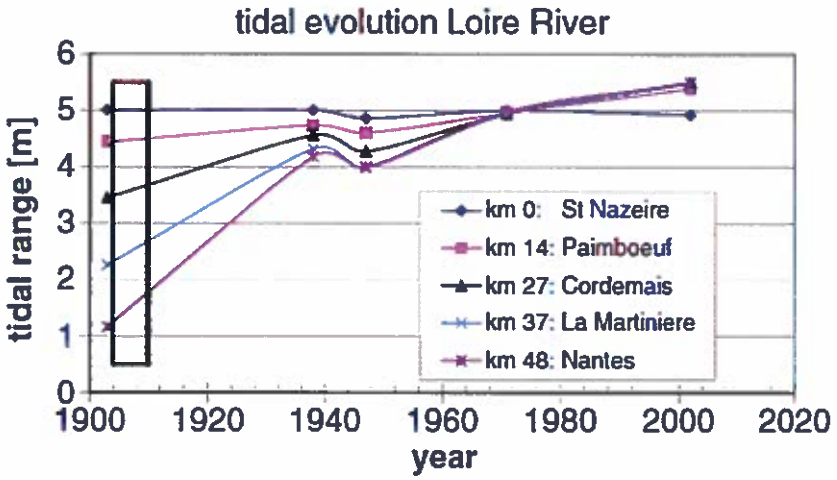


Figure 2: Tidal range as a function of time for five stations along the Loire estuary. The irregularities around 1940 is probably an error, you can assume a gradual rise in tidal range since 1940.

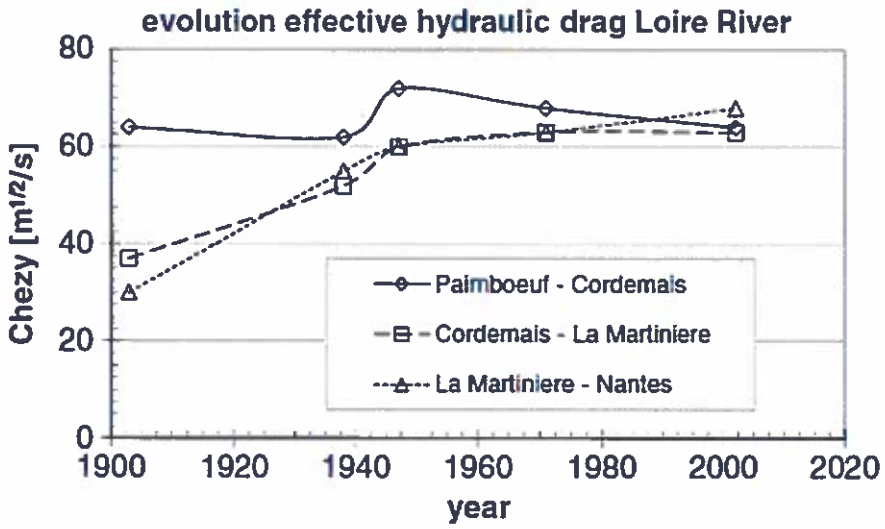


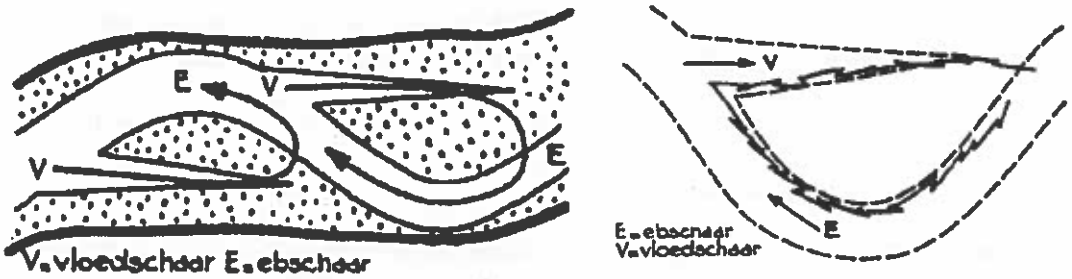
Figure 3: Chézy (C) value in the different parts of the estuary as a function of time. Note that $Cd=g/C^2$.

14 p.

Question 2- Efficiency of tidal movement of sediment in estuaries

This part of the exam considers the movement of sediment inside estuaries over **time scales of days to tens of years** - not longer. The movement of sediment as driven by the tidal flow regime, has intimate relations with the bathymetry and morphology of estuaries. In the paper by Van Veen sketch maps are shown describing the path that bed sediment takes (figures copied below). The paper makes the point that a grain of sand that is transported in an estuary, has a good chance to revisit the same position along the paths in the figures.

Sketch maps showing paths of sediment within the estuary
V = 'flood channel'; E = 'ebb channel'



From: Van Veen 1949/1950/2005:his figs. 12-13

4 pt QUESTION A.

Using qualitative keywords (no calculations), briefly describe ~~describe~~ the bathymetric/hydro-dynamic and transport/depositional conditions within which the sand grains reside, at each position in the scheme below.

Position	Bathymetry & Hydrodynamics	Transport/Depositional conditions
1 Entering V channel		
2 2nd part V channel		
3 Exiting V channel		
4 Entering E channel		
5 Mid part E channel		
6 Exiting E channel		

3 pt QUESTION B

At what of the six positions in the scheme above, is the bedform morphology and roughness variation (you discussed this in your essays), most sensitive to spring-tide neap tide variations? Mention the position and include a brief (three sentences max) explanation for your choice.

4 pt QUESTION C

It can take many, many tidal cycles for grains in the bed sediment to complete the entire sketched path. Consider a train of bedforms in the thalweg of the 'E channel' (ebb-channel, as in the Van Veen figure) over 2 kilometers length, with each individual bedforms 20 meter long, and with individual semi-diurnal tidal bundles in the foresets of these bedforms each 20 cm thick (on average, middling out spring-neap variation, quoted thickness measured in the horizontal direction).

1 pt C1: Make a sketch drawing of a single bedform, showing tidal bundles of the above dimensions.

Next, calculate the following quantities:

2 pt C2: Estimate the residence time of grains of sand in the dune, from the moment of being trapped in dune front avalanche, up to the moment they are remobilised because of dune migration. Show your calculation. *Hint: the foreset avalanche tidal bundles erode top down. The final part is eroded by the turbulence in front of the next 'wagon' in the bed form train.*

1 pt C3: Estimate the travel time of the typical grains of sand over the 2 km long E-channel segment. Show your calculation.

3 pt QUESTION D

The previous question was on travel time of sediment in the ebb channel part of the path shown in the starting figure. Now we switch to the flood channel part of the path, which we consider to be of about the same length (2 km again) as the ebb channel. Do you reckon the traveling time of sand along this part of the sketched path to be greater, equal or smaller than that through the ebb-channel? (qualitative arguments and/or simple demo calculations will do).

10 p

Question 3 - Wadden Sea forced by diurnal tides

Suppose the Wadden Sea was located in a region where diurnal tides are dominant. Furthermore, suppose that the barrier island shape, the distance between the islands and the distance to the mainland would be the same. In parts b-e you have to consider a typical Wadden Sea basin of 10-20 km length (from Barrier Island to main land) and 20-30 km width (from tidal divide to tidal divide). Typical average depth of Wadden sea basins is 3-4 meter.

a) **2 pt.** Explain whether the tidal prism for a Wadden Sea basin with diurnal tides will differ from a system with semidiurnal tides, assuming they have the same bathymetry.
b) **2 pt.** Argue whether the magnitude of the peak flood and peak ebb currents in a diurnal regime will differ from those in a semidiurnal regime, assuming that they have the same depth and width of the inlet and the tidal prism is the same.
c) **3 pt.** Assuming that the width of the inlet will be the same for both regimes, do you expect the depth of the inlet to be the same in the diurnal and semidiurnal regime? Give arguments based on (i) empirical relationships and (ii) peak ebb and flood flow.
d) **3 pt.** Assume that the wave climate of the Wadden Sea in the diurnal and semidiurnal regime are the same and that typical sediment concentrations and sediment size are the same as well. How will the equilibrium intertidal flat profiles in the diurnal regime Wadden Sea compare to the ones of the semidiurnal regime?