Shoal margin collapses in the Western Scheldt Estuary

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Channel bank failure and collapses of shoal margins (flow slides) have been recorded systematically in Dutch estuaries for the past 200 years. Between 1800 and 1978 more than 1000 large failures with sediment volumes up to a million cubic meters were documented in soundings of the Eastern and Western Scheldt estuaries (Wilderom, 1979). In many locations collapses reoccur at intervals of several years to decades. Flow slides are subdivided theoretically into two different types of underwater failure processes: rapid flow slides due to liquefaction and slow due to retrogressive breaching. The objective of this study is to investigate where shoal margin collapses occur, what shoal margin collapses volume are, and predict shoal margin collapse locations in the Western Scheldt.

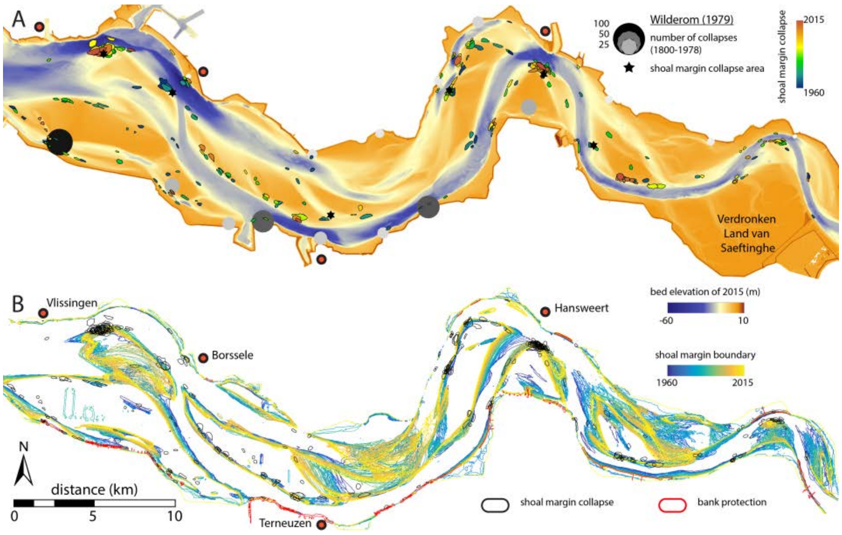
We identified shoal margin collapses from existing Digital Elevation Models (DEMs) by analysing DEMs of Difference (DoD) of the Western Scheldt for the period 1959-2015. We determined the area, volume and geometries of the shoal margin collapses, and analysed the location of the shoal margin collapses with a bar-to-excess width ratio. Furthermore, we analysed the shoal margin locations to a probability of occurrence formula $P(FS) = 1 - e^{-F(FS)}$. The frequency (*F(FS)*) used for bank safety assessment in the Netherlands (WBI, 2017) reads as follows

$$F(FS) = \left(\frac{5}{cot\alpha_r}\right)^5 \cdot \left(0.5 \cdot \left(\frac{H_R}{24}\right)^{2.5} \cdot \left(\frac{1}{10}\right)^{-10\,(0.05+\psi)} + 0.5 \cdot \left(\frac{H_C}{24}\right)^5 \cdot Fr_{mud}\right) \cdot \frac{\#SM}{L_{SM}} per\ km, yr$$

where α_r = relative slope gradient, H_R = relative slope height, ψ = state parameter, H_C = channel depth, Fr_{mud} = mud layers fraction, #SM = number of shoal margin collapses per year, and L_{SM} = shoal margin boundary length. Afterwards, we identified the accuracy of the prediction by plotting the true positive rate against the false positive rate.

We identified 292 shoal margin collapses along a 300 km long shoal margin boundary. Shoal margin collapses occur at locations where the bar-to-excess width ratio is greater than 1 and where shoal margin migration is low (in the Netherlands often defined by bank protection works, Wilderom 1961-1973), whereas no collapses occur at locations where shoal margin migration is high (see Figure). The average shoal margin collapse area is about 34,000 m^2 and has an average volume of 100,000 m^3, meaning that the average thickness is about 3 m. The shoal margin collapse geometry is best represented by a ¼ ellipsoid. The probability of occurrence formula identified low probabilities for the shoal margin collapses as the average relative slope height was only 11 m and the average relative slope gradient only 6^o for the collapsed shoal margins. Nonetheless, by applying various threshold values for the probability of occurrence, we found that the true positive rate was 2.5 times higher than the false positive rate when 50% of all the shoal margin collapse locations were predicted. So, we assume that a flow slide is predicted, if the calculated probability is 10^{-7}%.

We conclude that on average 5.3 shoal margin collapses per year occur in the Western Scheldt, and that the location of the shoal margin collapse can be predicted by mainly the variation in relative slope height and gradient within the Western Scheldt Estuary.



***A**. DEM of the Western Scheldt Estuary of 2015 with channel/ shoal margin collapses according to Wilderom (1800-1978) and new identified shoal margin collapses from 1959-2015. **B**. Shoal margin boundaries over time showing locations of high and low migration, where collapses mainly occur around low/no migration of the shoal.*