ESTUARINE SAND DUNES AS NATURE-BASED SOLUTION AGAINST SALT INTRUSION

AN IDEALISED MORPHOSTATIC MODEL APPROACH

Saltwater intrusion in estuaries poses a critical issue with significant implications for both environmental sustainability and human activities. This phenomenon arises when saline water infiltrates the estuarine system, potentially leading to a shortage of freshwater, thus affecting industries, agriculture, and the accessibility of drinking water, and impacting ecology. This study investigates the impact of estuarine bed forms, which potentially increase the net vertical flux and, as such, reduce the salt intrusion length. We investigate the dynamics of estuarine salt transport and determine the potential of estuarine dunes as a nature-based solution against salt intrusion.

This is investigated using an idealised hydrostatic model with 2DV geometry, to specifically study the effect of vertical flow behaviour without possible interference of other system parameters. Our model is designed to be adaptable for the investigation of other estuarine systems that can be approximated as a single-channel estuary with relatively uniform geometry. Model results are presented with settings based on the Rotterdam Waterway (RWW), the Netherlands, during summertime conditions when salt intrusion is most detrimental. We determine the influence of dune characteristics (such as height, length and asymmetry) as well as dumping and dredging interventions on the salt intrusion length.

We show that the presence of estuarine sand dunes does not change the estuary or regime classification, although a different salt intrusion length may form by a changing balance of transport components. Changes in dune geometry and characteristics impact the salt intrusion length, which is most sensitive to a change in dune height (see left of Figure 1). An increase in dune height enhances vertical advective transport, brings more saline water upwards through the water column and reduces stratification. Similarly, a decrease in dune length increases the dune slope and enhances the vertical exchange. Dune asymmetry has a negligible influence on our model results.

Manipulation of an existing sand dune field changes the salt intrusion length. Dredging of sediment reduces the main outward-flowing river transport and decreases the amount of vertical mixing, both contributing to an increase in the salt intrusion length. The volume of sediment dredged is linearly related to the change in salt intrusion length. The influence of dumping depends on the strategy employed. When topography is preserved, dumping decreases the salt intrusion length proportionally to the volume of sediment dumped. However, when the bed is levelled by dumping of sediment, vertical mixing is reduced and this measure is only effective in mitigating salt intrusion when the volume used is sufficient to decrease the mean water depth significantly.

Dredging of artificial sand dunes in a flat bed can serve as a mitigation tool against salt intrusion. If dredged sufficiently deep, this dredged dune generates sufficient vertical mixing to counteract the adverse effects of deepening the channel, maintaining estuary navigability while enhancing vertical mixing with local topography (see right of Figure 1). This implies that estuarine sand dunes may serve as a nature-based solution against salt intrusion without changing accessibility to seaports.

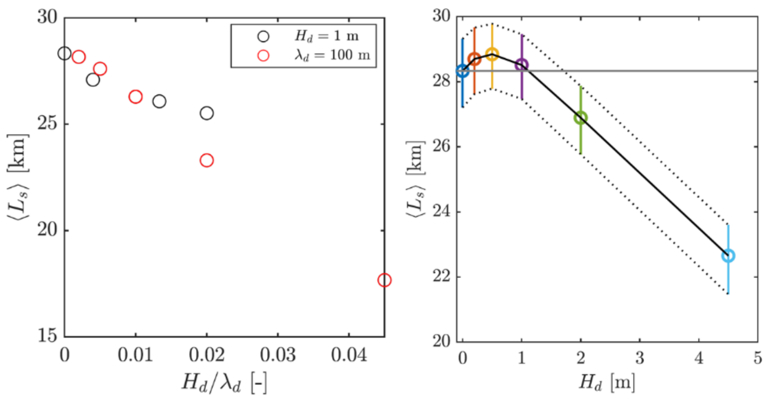

Figure 1: Left: influence of changing dune height H_d and dune length λ_d on tidally-averaged salt intrusion length $\langle L_s \rangle$ The mean bed level is equal between model runs, but navigability decreases with an increase in H_d. Right: Influence of changing dune height H_d on tidally-averaged salt intrusion length $\langle L_s \rangle$. The maximum bed level is retained between model runs and the mean bed level decreases (mean water depth increases) with an increase in H_d.

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