

Modelling bed level change at Nhat Le estuary and structural impacts using Delft3D

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Abstract: In recent years, Nhat Le estuary has been accreted due to the development of a spit bar in the south bank, which obstructs the waterway navigation, the flood drainage and causes erosion in the north bank endangering the infrastructures of Dong Hoi city. This study shows the simulation of short-term and long-term bed level changes in 10, 50 and 100 years of the estuary and the impacts of applied structural solutions using Delft3D, a model developed by Delft Hydraulics.

1. Introduction

Nhat Le is an estuary of Kien Giang River in Quang Binh province. The accretion of the estuary has caused not only the obstruction of the waterway navigation and the flood discharging (see Figure 1) and but also the erosion of the north bank stranding fishermen on hundreds of ships as they bring their fish back to the mainland. Now all the ships must moor in the Gianh River about 40km far away or use smaller boats. The welfare and economic infrastructures on the left bank of Nhat Le estuary are now endangered.

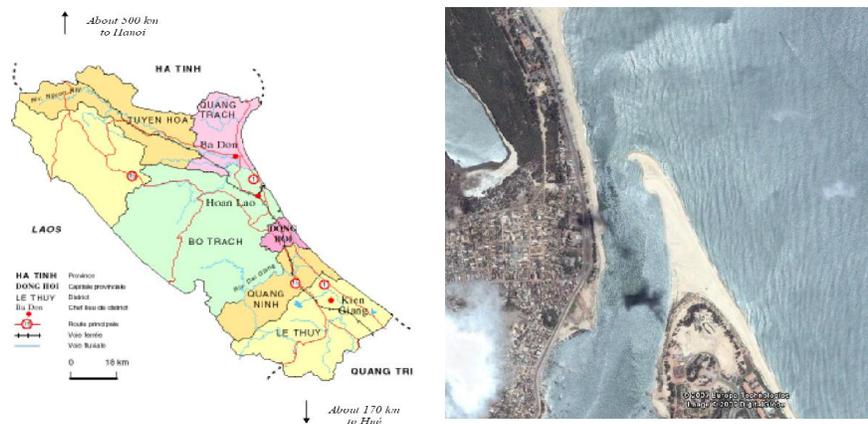


Figure 1. Map of Quang Binh and the topview of Nhat Le estuary

Studying the coastal and estuarine accretion-erosion as well as forecasting their evolution in Quang Binh coastal zone has a considerably urgent scientific and realistic significance. Knowing the accretion-erosion patterns, the forecast about the behaviour of the coastline and the flow channel at the estuary in the future and the proposals some counteractive measures to deal with the accretion-erosion problems can be made, which contributes to socio-economic development planning in coastal zone. With the help of Delft3D model, which provides a multi-disciplinary approach and numerical modelling for coastal, river and estuarine areas, the hydrodynamic factors relating to the accretion-erosion processes and the morphological changes in the study area will be simulated. Especially, with the application of the structural solutions, Delft3D can provide short-term and long-term simulation, which can be used to evaluate the impacts of the structures on the accretion-

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erosion of the estuary. This report includes the setup of simulation of short-term and long-term bed level changes in the estuary the application of the structures in the model. In addition, the results of these short-term and long-term simulations (with and without structures) are analysed in order to check their feasibility.

2. Model setup

2.1. Grids

In order to simulate the actual situation in the estuary, a curvilinear grid is set up and covers the modelling area. The grid is extended to -22m depth, which is about 11km offshore. It is extended about 21 km further upstream and about 20km in alongshore direction.

Considering the wave impacts on the study area, which means the interaction between the WAVE and FLOW modules, it is necessary to generate another grid for wave computation. This curvilinear grid is much larger and coarser than the FLOW grid. It is extended to -51m depth, which is 40km in cross shore directions, and about 45 km in alongshore directions. The lateral boundaries are far enough from the study area to ensure reliable computations.

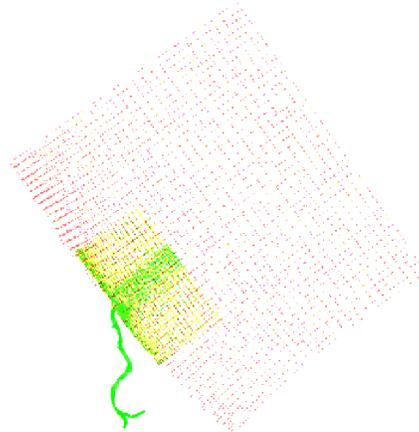


Fig 2 - *FLOW and WAVE Computational Grids*

The FLOW and WAVE computational grids are shown in Figure 2.

2.2. Time steps

In this model, the time step is 0.4 minutes or 24 seconds, which is sufficient enough for the accuracy and stability of the model.

2.3. Wave conditions

In winter, the dominant wave direction is North East with an average wave height of 0.8-0.9m and 1.1-1.2m in the first three months. The highest wave height is about 4.0-4.5m. In summer, the dominant wave direction is South West and South East with an average wave height of 0.6-0.7m. The highest wave height can reach 3.5-4.0m. In July and August, waves from West and South West directions are dominant with average height of 0.7m and maximum height of 4.0m. Especially in September and October with typhoons, the wave height can reach 6.0-7.0m or more. For this simulation, only the representative wave characteristics in each month are used. The most dominant wave directions are chosen, which based on the wave climates in each month.

2.4. Main scenarios

In order to simulate the estuarine evolution in short-term and long-term periods, three scenarios with the morphological periods of 10, 50 and 100 years are defined. For this simulation, the running time of the model is 1 year with a time step of 0.4 minutes (or 24

seconds) and the morphological factors of 10, 50 and 100 are applied corresponding to the main scenarios.

2.5. Model Calibration

In the modelling with Delft3D, the calibration parameter is the water level at the river mouth in August 2005 and November 2005 based on the availability of the data. For the calibration of the model, the bathymetry and other boundary conditions in August 2005 was used.

Firstly, the water level at the river mouth in August 2005 was compared (see Fig.3). The calculated water level and the measured water level match quite well, although sometimes differences exist between the two series.

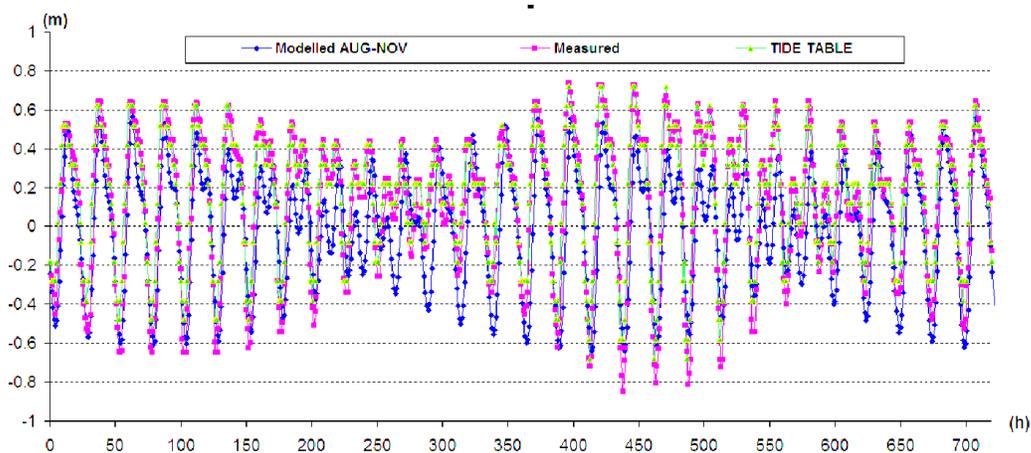


Figure 3. Water level calibration (August 2005)

The water level in November 2005 taken from the Tide Table was used in the calibration. The comparison between the water level from the Tide Table and the calculated water level is quite good as can be seen in Figure 4 below.

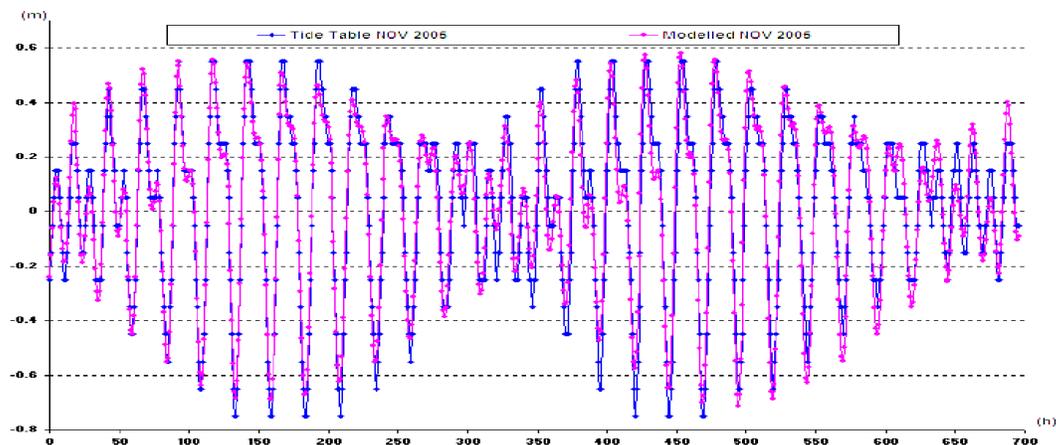


Figure 4. Water level calibration (November 2005)

It is difficult to achieve a better accuracy due to the lack of the data in different observational stations, and due to the unknown accuracy of the measured river discharges.

However, the calibration shows quite satisfactory results to describe the short-term and long-term simulation of bed level changes in the study area which will be presented in the next sections.

In general, the calibration of the model has shown the results which are just good enough to carry out simulation of the main scenarios.

2.6. Application of the structures

There are three T-head groin system on the left side (T1, T2, and T3) and two T-head groin system (T4 and T5) on the right side of the estuary. Two jetties (J1 and J2) are specified at the river mouth and a submerged breakwater (SB) is specified between the left jetty J1 and the third T-head groin T3 (see Fig.5). These structures are defined as thin dams, which are represented graphically in the model by means of the visualization area, with the crest freeboard of 2m in case of T-head groins and jetties, and -0.8m in case of the submerged breakwater. The representation of the applied structures might result in minor errors in the location, shape and size of the obstacles compared to the real situation; however these errors do not significantly affect the essence of the simulation.

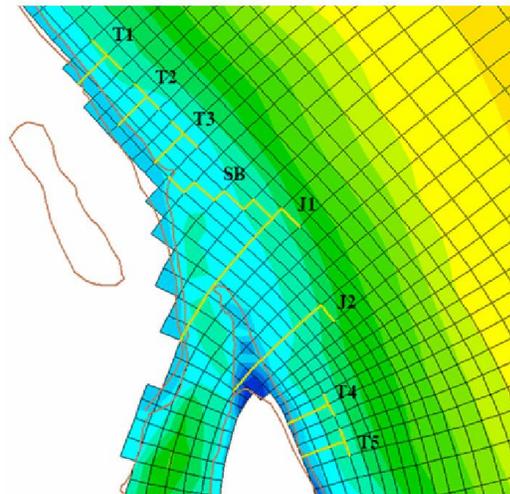


Fig 5. Structures specified in Delft3D

3. Result analysis

3.1. Short-term and long-term evolution of the estuary without structures

For short-term and long-term bed level changes, three scenarios have been simulated in Delft3D in order to consider the bathymetric changes or the evolution of the estuary after 10, 50 and 100 years. The results of these simulations are shown in Figure 6, Figure 8 and Figure 10. After 1 or 2 years, scattered accretion is found further offshore and erosion near the north bank of the estuary. However, after 10 years, the erosion at the river mouth tends to move to the other side. Besides, a long sand bar, which is accreted by 3-4m, will obstruct the river mouth and erosion on both sides of the estuary will occur (see Figure 6a).

The simulations of the estuarine evolution after 50 and 100 years show that the sand bar obstructing the river mouth will develop more drastically in both longshore and cross shore direction, and in both area and intensity (see Figure 8a and Figure 10a). More erosion with higher rate will occur along the north and south coastline sections near the river mouth, which will endanger the communication route and other welfare infrastructure of Dong Hoi city on the north bank, as well as the Sun Spa resort on the south bank of the estuary.

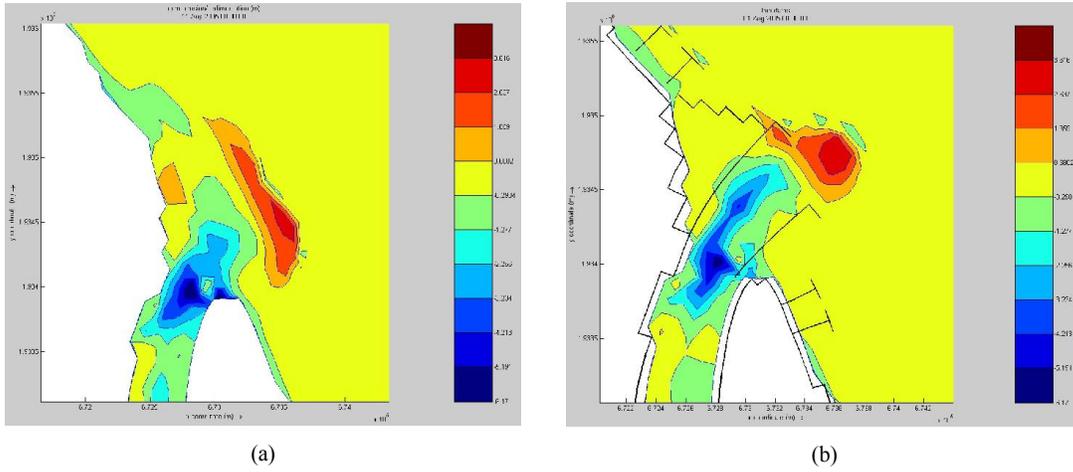


Figure 6. The bed level changes at the estuary after 10 years without (a) and with (b) applied structures

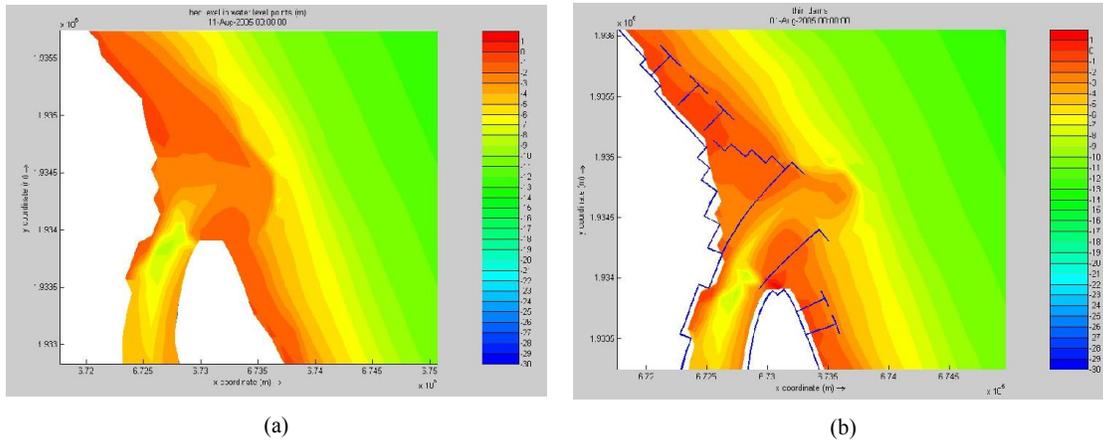


Figure 7. The bathymetries after 10 years without (a) and with (b) applied structures

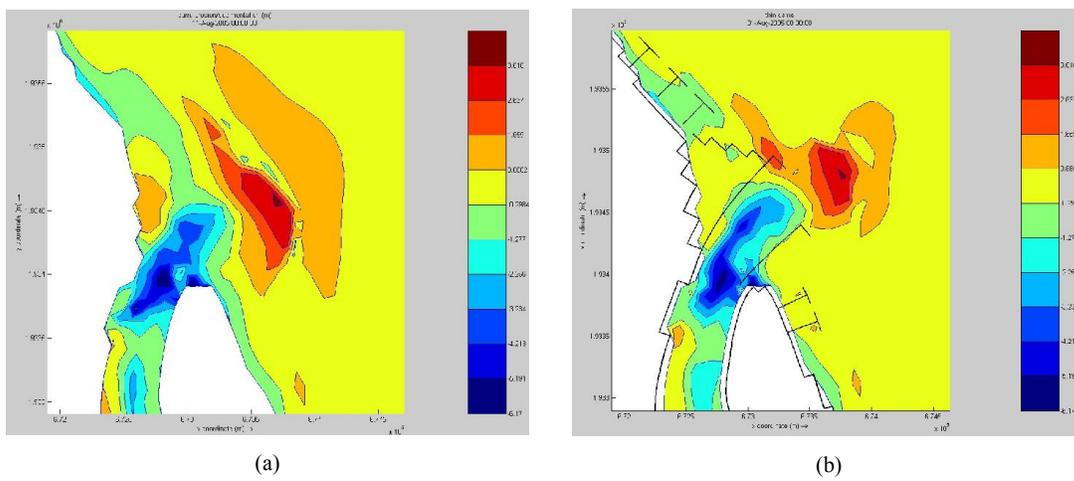


Figure 8. The bed level changes at the estuary after 50 years without (a) and with (b) applied structures

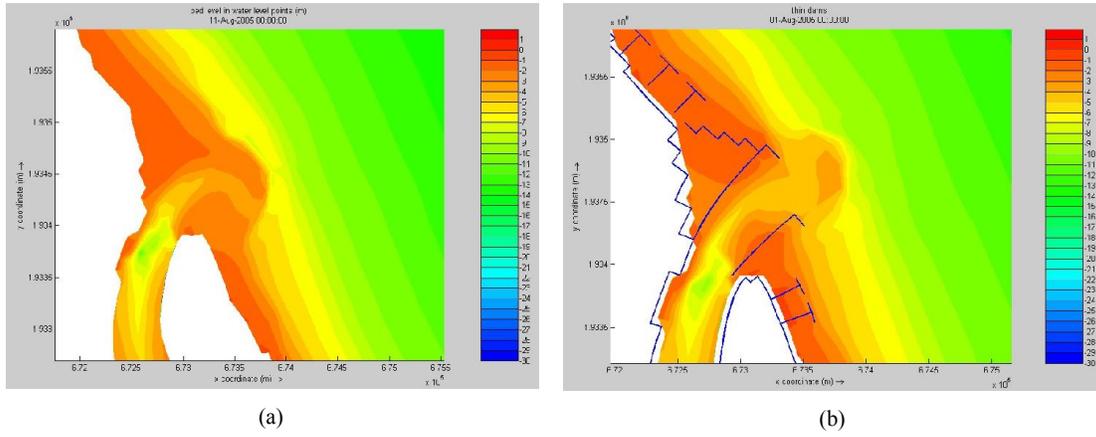


Figure 9. The bathymetries after 50 years without (a) and with (b) applied structures

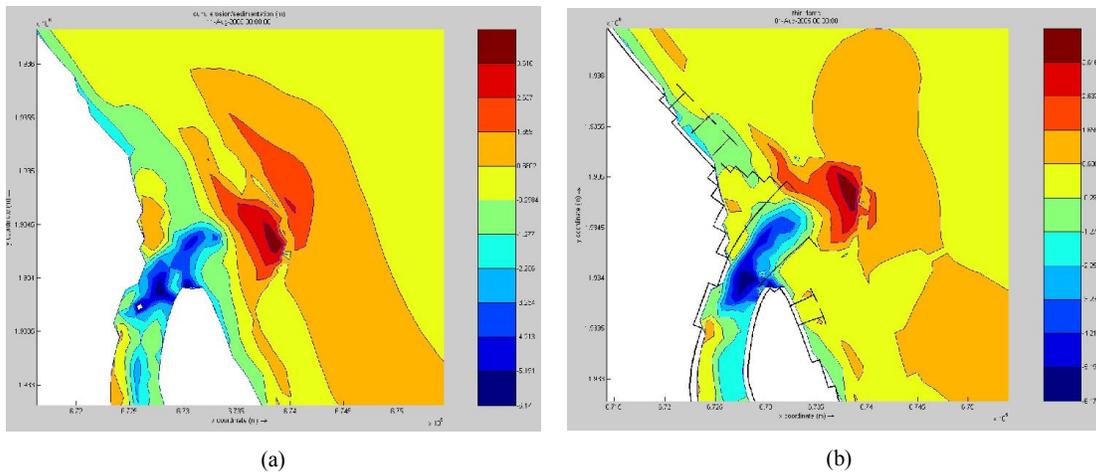


Figure 10. The bed level changes at the estuary after 100 years without (a) and with (b) applied structures

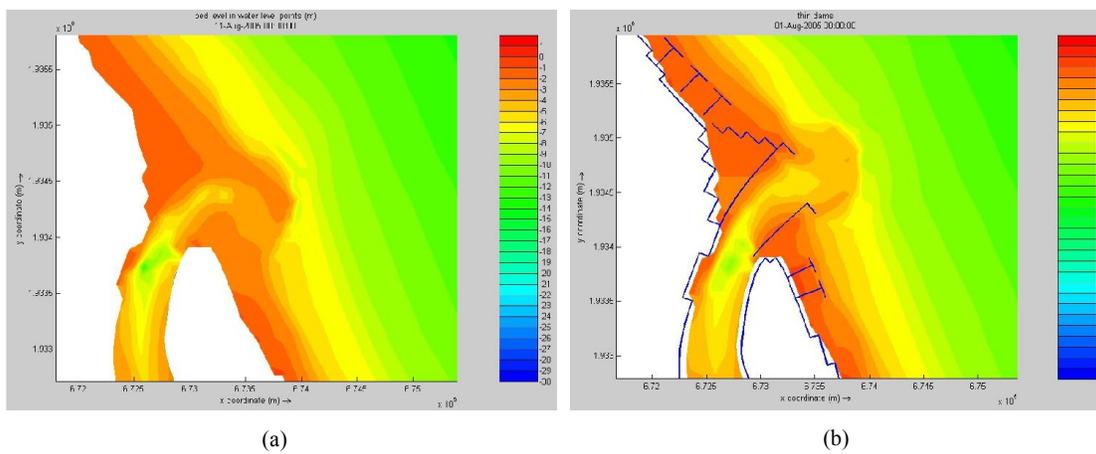


Figure 11. The bathymetries after 100 years without (a) and with (b) applied structures

The bathymetries after 10, 50 and 100 years are shown in Figures 7a, 9a and 11a. It can be seen that the bed level at the deepest area of the estuary is about -10m, which is near the river mouth and the bed level in front of the river mouth is in the range 2.0 - 5.0m. The flow channel is deepened further seawards through the river mouth.

Therefore, if the do-nothing solution is applied in the study area, the estuarine evolution will have negative impacts on the coastal erosion and estuarine accretion, and as a result these changes will have negative impacts on the socio-economic development of the study area.

3.2. Impacts of the structural solutions

As the short-term and long-term simulations show the adverse evolution of the estuary, the structures which are considered the most feasible solutions were also simulated in Delft3D (see also Figures 6b, 8b and 10b above). It can be seen in each simulation that the structures will push away the accreted sand bar further offshore and deepen the flow channel at the river mouth by 5-6m. They also have effect on straightening the flow channel, which is favorable for the navigation. The erosion on both side of the river mouth is reduced considerably, especially the area between the T-head groin system. The results also show the effect of the submerged breakwater as a sand trap. In long-term development, this can help to prevent erosion of the coastline sections and also to provide the land reclamation for socio-economic development planning.

From the bathymetries after 10, 50 and 100 years, it can be seen that the accretion in front of the estuary is pushed away further seawards, which make the offshore area shallower with the bed levels in the range of 2.0 - 5.0m. The flow channel is deepened with more intensity, especially after 100 years the bed level of about 6.0 -7.0m can be found at the entrance of the river mouth (with jetties) (see Figures 10b, 12b and 14b).

4. Conclusion

Study on the coastal and estuarine accretion-erosion law, as well as the forecast of coastline development in coastal zone of Nhat Le estuary have significantly scientific and realistic meanings. Having a thorough grasp of the accretion-erosion law, the behaviour of the coastline and the river channels at the estuary in the future can be forecasted, which makes a contribution to the socio-economic development planning of the coastal zones. Based on that understanding, better technical and scientific solutions for the prevention of the coastal erosion and estuarine accretion, which serve the purpose of flood relief and navigation, can be proposed and applied in this area.

In short-term and long-term evolution, there will be more and more erosion along the coast as well as accretion at the estuary if nothing is done. The applied structural solutions show positive impacts on the prevention of the estuarine accretion, as well as the coastal erosion. The jetties deepen and straighten the flow channel at the estuary, the T-head groin systems reduce the erosion in the protected areas and the submerged breakwater functions as a effective sand trap.

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