Researching on the Tidal Flooding Through the Coastal Simulation: Developing Potential Managed Realignment Areas of Humber Estuary in England

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Abstract: This paper combines the industrial background of Grimsby, the tidal flooding problem and geomorphology of the Humber Estuary, and an innovative approach to study the combination of aquaculture and managed realignment areas. Tidal simulation is used to study the effect of increasing the managed realignment areas on flood hazard. Based on the physical conditions of the Humber Estuary, shellfish species and aquaculture methods, the mapping of potential aquaculture areas in Grimsby are explored. We focused on the interaction between aquaculture and managed realignment areas. Via planning and designing the distribution mode of aquaculture farms, our objective was to find the optimal scheme which could have a positive impact on the managed realignment areas. At the same time, GIS software and CAESAR software are used together to simulate tidal flooding and extract information, such as water velocity, water direction, erosion and deposition process, and then import this information into GIS for processing to visualize the simulation information.

Keywords: Tidal flooding, managed realignment, simulations, aquaculture

1 Introduction

1.1 Background

Grimsby is a large town and seaport along the Humber Estuary in the east of England. In 19th century, Grimsby was one of the largest seaports in the world, hosting the largest fish fleet. The fishing industry declined dramatically after the Cod Wars, when Britain lost access to rich fishing areas in the North Atlantic. Today, Grimsby is recognized as the main centre of the UK fish processing industry, 70 % of the UK's fish processing industry is located there, with around 90 % of fish imported from Iceland and Norway. In 2018, plans for creating the National Aquaculture Centre in Grimsby were released by the city council and presented to industry, as the team behind the ambitious proposal moves in to a new phase.

1.2 Tidal Flooding

Grimsby was protected from ocean flooding by the marsh land around it. Nearly 90,000 hectares of land around the estuary lies below the level of the highest tides and, although it is protected by defences, this 'flood plain' is still vulnerable to flooding during extreme tidal events. The coast of the area of Humber Estuary is at high risk (BRYANT et al. 1995).

Within the Humber Estuary, the rising sea level will result in a relative increase in wave height and threaten to over-top existing flood defences, with significant losses of the intertidal habitats. This phenomenon, which is known as coastal squeeze (SHAOLONG 2011), also

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reduces the buffering protection afforded to the flood defences by the presence of the intertidal mudflats and marshes, and can result in erosion and undermining of defences.

1.3 Geomorphology

According to the development along the Humber Estuary from mid-18th century to the end of 20th century. The topography of the Estuary is gradually changing. It is estimated that every tide carries over 1,500 tonnes and up to 1.26 million tonnes of sediment may be present in the water in the estuary (OPEN UNIVERSITY 1999). The deposited sediments maintain estuary's important habitats such as mudflats, sandflats and saltmarshes. The estuary is fed by sediment from the adjacent Holderness coast as well as fluvial sediment. Several sand shoals exist in the entrance. These are mobile banks which undergo various stages of growth and erosion. The exchange of sediment between the bars is an important process occurring within the harbor entrance. The mobile sands add to the complexity of this estuarine system.

2 Find the Managed Realignment Areas for Aquaculture

2.1 Potential Area for Aquaculture

Two main factors influence where the Humber Estuary has the potential for aquaculture. Firstly, the intertidal zone is the area above water at low tide and underwater at high tide (i. e., the area between tide marks). This area includes many different types of habitats, with many types of animals, such as crustaceans, starfish, sea urchins, and numerous species of coral. Secondly, managed realignment of the floodable area is a coastal management policy that allows the shoreline to move more naturally. This movement is managed, usually by the construction of defences landward of a breached defence where they do not need to be as big as a new seawall built further seaward. Mudflats that develop as part of the realignment, help absorb wave energy and offer soft coastal protection, as well as create new habitats, which support wildlife and plant life.

2.2 Tidal Simulation

We research the tidal flooding through coastal simulations. The aim is to find out which places along the Humber Estuary can be influenced, and whether these managed realignment areas could reduce flooding. Two simulations are conducted: The first simulation is a original site without any human intervention. The second simulation adds the managed realignment areas.

The first simulation is the one without any human intervention (Figure 1). It shows three different situations in a year, low tide, high tide and extreme flooding. The simulation shows the water movement in a natural way. From the result, there is less flooding during the low tidal period, even though there are certain areas which have a tidal flooding during the high tide of the day. The results are consistent with the historical flood warning zone, with most of the flooded areas dominated by agricultural land near mudflats in the intertidal zone. Some parts of these agricultural land are classified as Grade 4 and Grade 5 (LEINA 2007), which have great potential to be managed realignment areas.

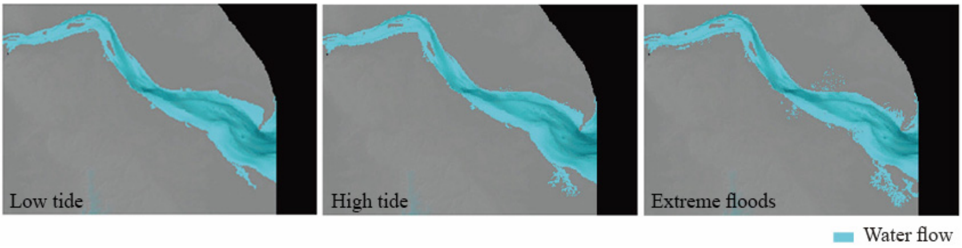

Fig. 1: Simulation 01: Original site

The second simulation studies the flood situation after increasing the managed realignment areas (Figure 2). The potential managed realignment areas are identified in the Investing in Natural Capital Plan as Natural Capital Opportunity Areas (NATURAL CAPITAL COMMITTEE 2018). Some of these areas overlap with existing flooded areas. We breached some parts of existing hard defences along the coast to let water flow into these managed realignment areas, and pushed the hard defense back to the places we do not want to be submerged. The results show that, in the case of extreme flooding, the flooded area is significantly reduced compared with the results of the first simulation. In the periods of low tide and high tide, the flooded area does not change significantly, and the basic flood occurs in the managed realignment areas which are designated. These phenomena indicate that the increase of managed realignment areas can effectively alleviate tidal flooding. In this way, the Humber Estuary can produce creeks, creating wetlands and new habitats, which provides a good opportunity to develop aquaculture.

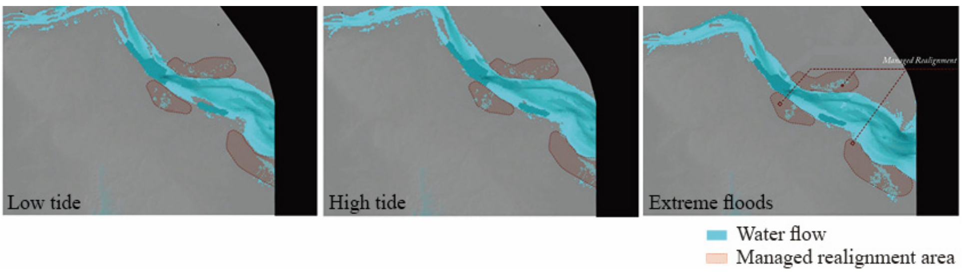

Fig. 2: Simulation 02: Managed realignment

2.3 Mapping the Aquaculture Area

Mapping the aquaculture areas is both exploratory and propositional, and thus crucial to the design process. Following Deleuze, we describe the propositional dimension of mapping as diagrammatic, as a shift from the representational to the productive, 'setting up so many points of emergence of creativity, of unexpected conjunctures, of improbable continuums' (DELEUZE 1988).

We choose five different types of shellfish commonly breed in England (Mussels Native flat oyster King scallop Clam and Cockles). The suitability of shellfish farms is based on three main physical conditions (seabed type, current speed, and water depth) (BENASSAI et al. 2011) (Table 1) and three different farming methods (containment, ranching, and suspended method). Current speed of all these three methods should be restricted between 1 to 2 knots. Almost all seabed conditions are suitable for containment and ranching, except for soft mud and rocky areas. The containment and ranching methods need to be 20 m below central water depth. The physical condition for the suspended method is different due to it requires suspended racks to be anchored to the seabed. In general, the construction of suspended need to greater than 3 m below central depth.

Table 1: Physical condition of shellfish

Baseline lagoon condition	**Blue mussel/ Mytlus edulie**	**Native flat oyster/ Ostera edulis**	**King scallop/ Pecten maximus**	**European clam/ Ruditapes decussatus**	**Cockles/ Cerastoperma edulis**
Depth/ Bathymetry	Intertidal to 20 m	80 m below CD	5 to 110 m below CD	Lower intertidal	Mid to lower intertidal
Seabed/ Shore type	Stable sediment	Coarse/Stable sediment	Stable sediment	Sand & Silty mud	Sand/Muddy sand
Current speed	1-2knots	1-2knots	1-2knots	/	/

CD: Central depth

This map shows potential aquaculture areas in Grimsby (Figure 3), which overlaps partially with the managed realignment areas, thus we envision the possibility of developing aquaculture in the managed realignment areas. In this way, aquaculture could support the local fish processing industry in Grimsby while the flood problem could also be solved.

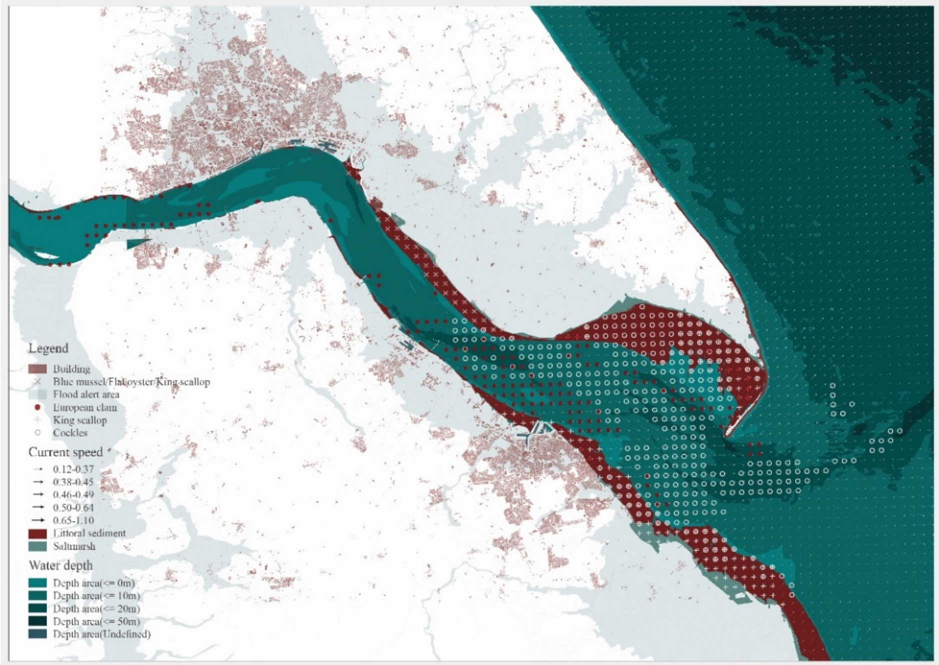

Fig. 3: Potential area for aquaculture in Humber Estuary

3 Impact of Aquaculture on Managed Realignment Areas

This paper chooses one part of the managed realignment areas to study in depth. Because the chosen mudflat is located in the intertidal zone near Grimsby, it has a good habitat for shellfish. In order to facilitate tidal flooding in the managed realignment area, we need to increase or maintain both number and flow of creeks in the original mudflats. We were trying to understand whether there is a positive impact between aquaculture and managed realignment areas, and how to select the most appropriate form of aquaculture racks distribution via planning and simulation.

DEM file is used as the basic carrier to import it into GIS for editing and processing, and then the data are exported to form CAESAR for simulation. Since the small site is located in the intertidal zone at the outer estuary, which is greatly affected by tides, only the Tidal mode (ZUKE 2005) is selected for the simulation of the small site. The test simulates the elevation, water flow, water depth, water volume, erosion and deposition information of the mudflat in a relative year. The results are imported into GIS for data visualization.

3.1 Original Site and Shellfish Farm

In order to study whether the establishment of shellfish farms would significantly change the landscapes of the mudflat, the maximum density of aquaculture racks is constructed in the simulation. In the three aquaculture methods mentioned above, it is difficult to simulate the suspended method due to the limitations of the implementation. The simulations in this chapter are for only containment and ranching. The black squares in the figure represent aquaculture racks, which are 2 m by 2 m and distributed along both sides of the creeks with 1 m interval.

The simulation results show that in the natural tidal process (Test 1), erosion is most likely to occur on both sides of the creeks. The creek will be gradually filled with sediments while the number of creeks will be gradually reduced as time goes on. After simulating the maximum density of aquaculture racks (Test 2), we found that within the same period of time, the shellfish farms could catch more sediments, which greatly improved the duration of creeks and increase the depth of creeks in some river basin (Figure 4). These two tests demonstrate that the shellfish farm could have positive impact on the existence of creeks.

3.2 Shellfish Farm Density Simulation

Via this set of simulations, we were intended to change the distribution density of aquaculture farms to study the effect of density on the landscapes of this mudflat. The black squares still represent 2 m by 2 m aquaculture racks, which in turn increase the distribution distance between aquaculture racks in the following 4 tests (1 m, 2 m, 3 m, 4 m) (Figure 5).

The results shows that with the shortening of the distance between aquaculture racks, the longer the creeks existed, the more the number of tributaries increased. We believe that 1 meter is the best choice, which can not only increase the variability of the mudflat edge, but also shape the terrain. This means increased biodiversity in the mudflat and the ability to flood the managed realignment areas.

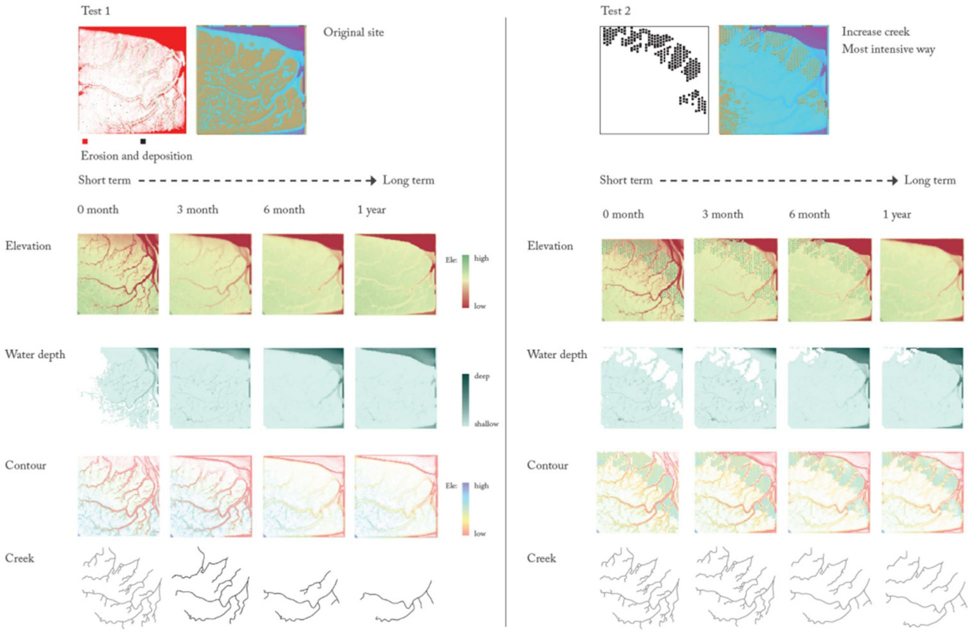

Fig. 4: Original site and intensive shellfish farm simulation

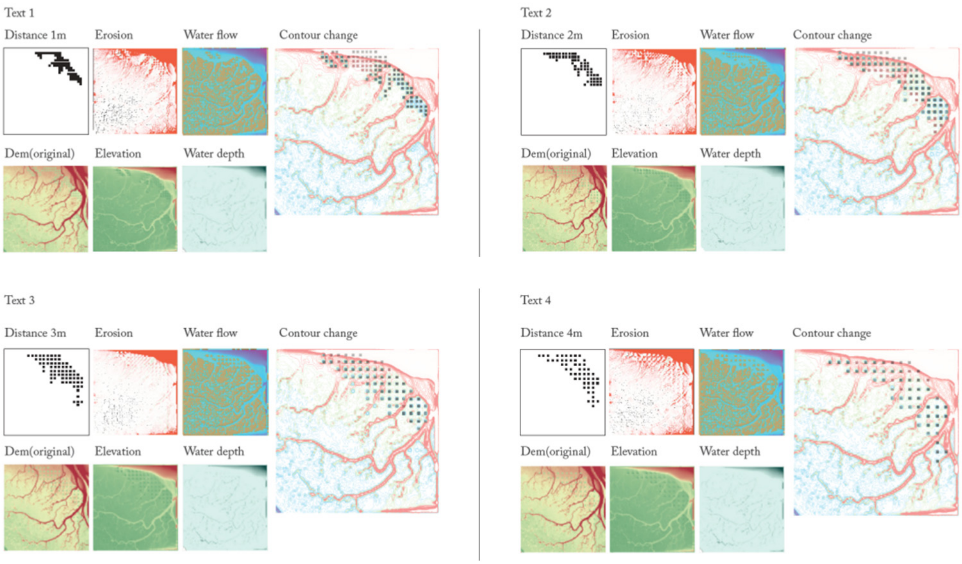

Fig. 5: Shellfish farm density simulation

3.3 Shellfish Farm Angle Simulation

We use the containment and ranching technologies to research how the placement angle between rectangular racks and tidal direction could impact the landscape of this mudflat. We change the 2 m by 2 m square racks to 2 m by 4 m rectangular racks. We simulate four different angles and distributions (0 degrees, 45 degrees, 90 degrees and angles parallel to the morphological changes of creeks) (Figure 6).

The results show that the creeks exist for a longer time when the distribution angle of the racks is parallel to the direction of the tide, while the creeks exist for the shortest time when the angle parallel to the morphological change of the creeks has a wide range of erosion phenomenon. When the distribution angle of the racks is parallel to the direction of the tide, it is better for managing the realignment areas in the flooded state.

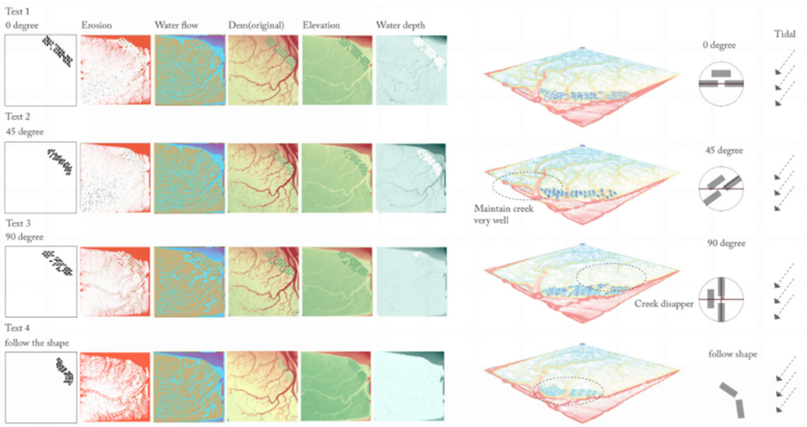

Fig. 6: Shellfish farm angle simulation

4 Conclusion

From the tidal simulation, we can see the positive interaction between aquaculture and the managed realignment areas. By changing the distribution mode of shellfish farms, the flooded state of the managed realignment areas can be maintained and the tidal flooding in the Humber Estuary can be alleviated. The implementation of the managed realignment areas also provides a good habitat for aquaculture to support the aquaculture industry in Grimsby.

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