# CHARACTERISTICS OF COASTAL EROSION AND DEPOSITION PROCESSES AT NANHUI FORELAND IN THE CHANGJIANG ESTUARY, CHINA

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**Abstract:** The Nanhui foreland located between the Changjiang Estuary and the Hangzhou Bay, is the prolongation in south of the Changjiang River Delta. It's the main passage of fresh water and sediment transportation into the Hangzhou Bay and southeast coast. Due to abundant sediment supply of the Changjiang River and with the extension of the Changjiang River Delta to the sea, the sea bed of this area was continually deposited before 1990. Because of the decrease of sediment flux from the Changjiang River after 1990's, the sea bed near the Nanhui foreland has been eroded instead of being deposited. On the other hand, the projects such as land using to accelerate the coastal deposit obstructed from sediment passing, so that the erosion process has been speeded. From now on, some big projects in the Changjiang estuary are under construction, the sediment flux into sea will keep at a low level in history, and the sea bed will be eroded sequentially. This phenomenon should be paid great attention to by the related marine engineering department.

**Key words**: Nanhui foreland, Changjiang estuary, Erosion, Deposition

## 1. INTRODUCTION

The Nanhui foreland, located in the south coast of the Changjiang estuary, faces the Qidong foreland on the north of the Changjiang Estuary (Fig. 1). As a part of the south submerge delta.

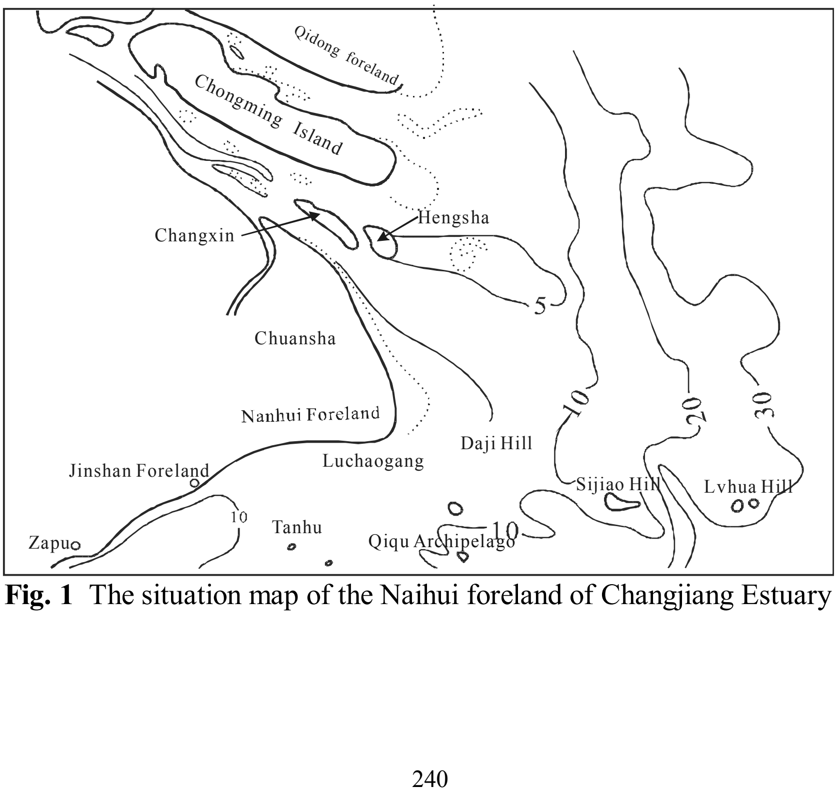



**Fig. 1** The situation map of the Naihui foreland of Changjiang Estuary

Its nearshore seabed is plainness. For example, the cross-section in the south-east direction, when the water depth is about 0 ~ -5m, the slope is 0.11%; between -5 to 10m， the slope is 0.02%. The silty clay and the clayey silt, coming from the Changjiang River, are major sediment of the bed surface. Historically, abundant sediment coming from the Changjiang River went into East China Sea as well as the Changjiang Delta constantly extended year by year[1,2]. The foreland of the Nanhui foreland went forward toward the sea at the same time. Since 1050, the quondam Han Seawall was built, to the 1995, the “Nine-five” Seawall formed, the coastline of the Nanhui foreland has extended seaward 12.8km within 900 years, in other words, it is 14.2m/a, and the biggest deposition rate was 21.5km (23.8m/a) during the same duration.

The shoreline of the Nanhui located at the confluence area of the Changjiang Estuary and the Hangzhou Bay. It is the strait passageway for the Changjiang River sediment. The sediment exchanges frequently and complexly here, which directly affects the seabed evolution of the Nanhui foreland. The underwater bank vibrates and transposes to-and-fro at its both sides. This phenomena is so called “shaking head spit” by the local people. Although the large-scale polder project keeps the shallow area above 0m stabilized recently, the natural condition such as sediment discharge decrease from the Changjiang River will greatly affect the seabed scouring and silting near the Nanhui foreland.

This paper analyses the seabed landform cause and development tendency based on its scouring and accretion processes, combined with hydrodynamics, sediment deposition and geomorphology methods.

## 2. SEABED LANDFORM CHANGE NEAR THE NANHUI FORELAND

We examine sea-bed condition at different periods depending on topographic charts in 1959, 1979, 1989 and 1997 between the Luchao Harbor and the Qiqu Archipelago in the Nanhui foreland. The results are as following (Fig. 2):

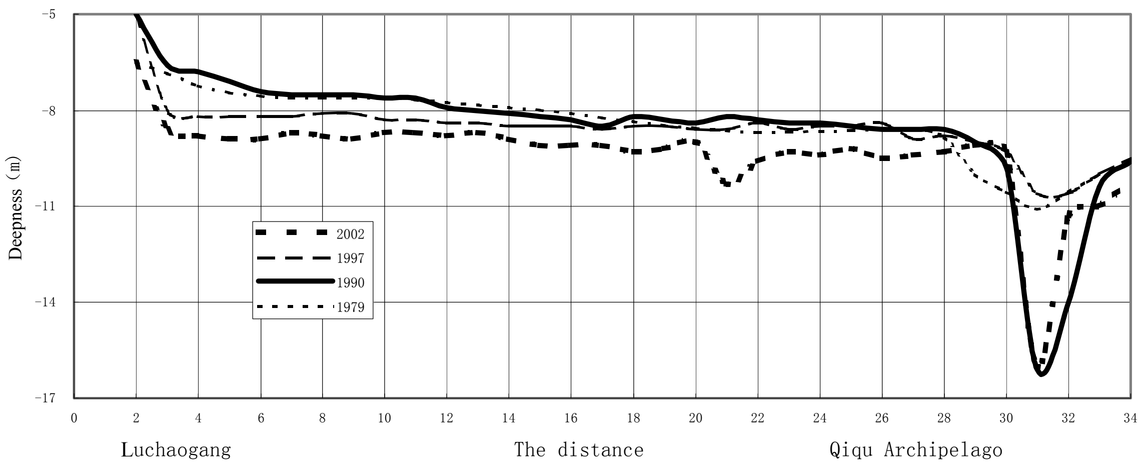



**Fig. 2** The seabed scouring and silting map between the Luchao Harbor and the Qiqu Archipelago

1. From 1959 to 1979, the seabed landform between the Nanhui foreland and the Qiqu Archipelago are silting up generally. At nearshore area, the maximal altitude could reach 2m, and at farther area silting reduced gradually. In 20km distance, the cross-section was silted by the speed of 0.8m and 0.04m/a. In the farther distance about 20~30km, it was scoured by mean of 0.4m and 0.02m/a.

2. From 1979 to 1989, the scouring and accretion intensity was obviously decreasing. Its amplitude generally varied from -0.2 to 0.2m in the most area where scouring alternated with

silting. The variety value for the whole section was averagely 0.1m, and 0.009m/a, less than 1cm per year. In fact, the whole profile was at its balance situation.

3. From 1989 to 1997, the whole bottom surface began to be scoured widely, and the scouring rate near land was stronger, averagely scoured 0.5m with 0.07m/a along the profile.

4. From1997 to 2002, even no large-scale survey data, the section survey showed that the whole cross-section was scoured continually to 0.7m deep and 0.14m per year. Compared with that before 1997, the erosion increased, and compared with that of 1980's, bed load occurred coarsening. (Table 1)

**Table 1** Sediment contrast between the 80's of the 20th century and the 21st century early

| Time of sample | Sand >0.063mm | Silt 0.063~0.004mm | Clay <0.004mm |
|---|---|---|---|
| 1980's(%) | 1−5 | <50 | >50 |
| 2002(%) | 5 | 60−70 | <20 |

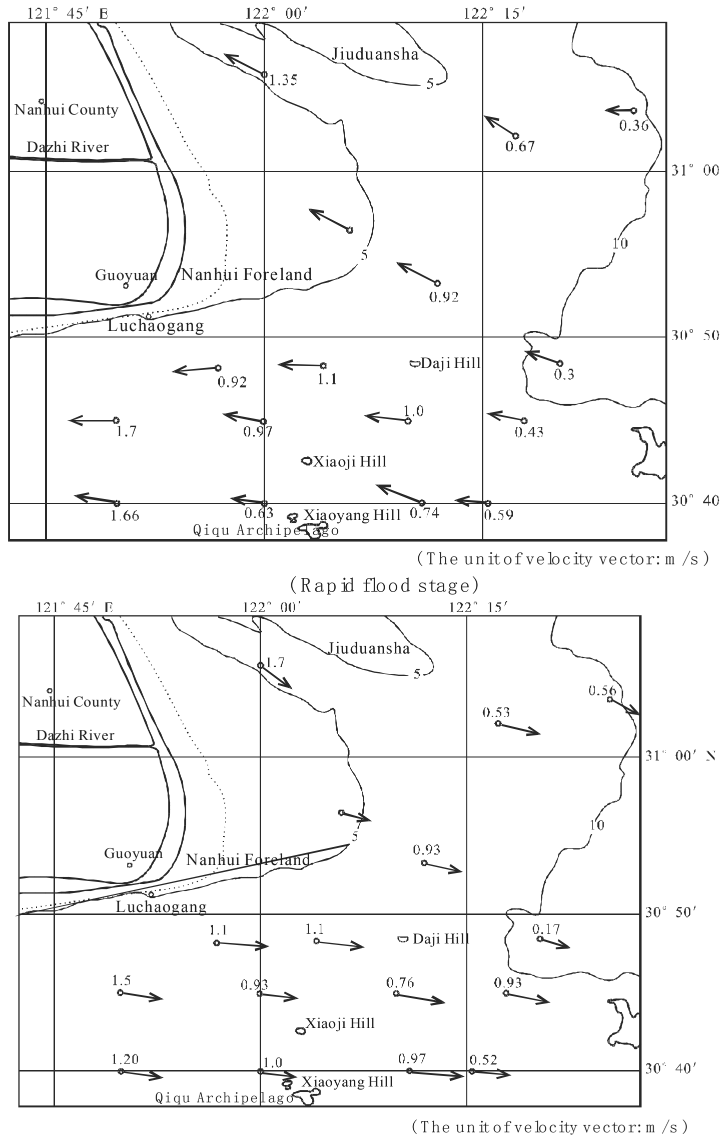
## 3. THE DYNAMIC AND SEDIMENT CONDITIONS IN THE NAIHUI FORELAND

The characters of dynamic and sediment in the Naihui foreland region are affected not only by the tidal waves of East China Sea but also the big discharge of fresh water and sediment from the Changjiang River. In the process of the north-branch tide from East Sea spreading simultaneity into the Changjiang Estuary and the north bank of the Hangzhou Bay, the tidal water flow diffluentence (flood) or flow concentration (ebb) at the Nanhui foreland area. The tide, which is the irregular semi-diurnal one, circumvolve clockwise. On the north side of the Nanhui foreland, near the Changjiang River, the tide is influenced by the South Passage of the Changjiang Estuary, and its major ellipse axis is on the SE − NW. The flood tide on NW direction flows up along the major channel of the South Passage, and the ebb tide on SE direction flows down to the sea. However, on the other side of the Nanhui foreland, closing to the Hangzhou Bay, as the ebb and flood tide is under the effect of the coastline tendency in the north bank of the Hangzhou Bay, the alongshore tide flows to and fro on SE direction, and the flood tide goes to west, the ebb tide flows to east. There is a mixing area of two streams of ebb tides, which come from the south Passage of the Changjiang Estuary and the north bank of the Hangzhou Bay, converging at the sea area between the Daji Hill out of the Nanhui foreland and the Qiqu Archipelago (Fig. 3). In the region between the Nanhui foreland and the Qiqu Archipelago, the tide is very strong. We can find that the mean velocity is above 1−1.5m/s at spring tide, the maximal mean velocity in vertical reaches 2.0−2.5m/s. The ebb is stronger than the flood tide and the velocity at spring tide is bigger than that at neap tide. Approximate 30km range from the shore seaward to the Qiqu Archipelago, the tide falls a reversing current on near EW direction, the rate of rotation, k, varies at 0.04−0.14. Closing to the Qiqu Archipelago, the velocity increases markedly with the flow direction turns to north during flood, to south during ebb period.

After the polder projects, the sediment exchange between the major channel and the shore was blocked. Sediment concentration near shore decreased. While man-made shoreline led the 0m coastline moving seaward, accordingly the place of tide diffluentence or tide concentration on the Nanhui foreland sea area moved to the place between the Daji Hill out of the Nanhui foreland and the Qiqu Archipelago. It revealed that the sediment major transport channel would be changed by this.

## 4. THE CAUSATION AND TENDENCY OF THE SEABED SCOURING AND ACCRETION

The change about the seabed scouring and accretion near the Nanhui foreland include the effect of the nature-condition change and the local near-shore engineering projects.




(Rapid ebb stage)

**Fig. 3** Flow-field map in the Naihui foreland region

## 4.1. THE NATURE-CONDITION CHANGE

The change of sediment discharge from the Changjiang River will cause sediment erosion and deposition at the Nanhui foreland. During the 42 years from 1959 to 2001, the scouring and accretion discharge rate agreed well with the annual sediment discharge from the Changjiang River. Figure 4 shows the change of yearly water and sediment discharge at the Datong gauge station in the Lower Changjiang River. It shows that the sediment coming from the Changjiang River was abundance during the period of 1959−1979. The average sediment discharge was $4.63\times10^8$ tons, and at the corresponding period the most seabed area presented accretion, which was 0.04m per year. Between 1979−1989, the sediment discharge reduced slightly, the average sediment discharge was $4.32\times10^8$ tons, with the height of accretion 0.009m per year, which was close to the balance of sediment transport. From 1990 to 1997, the sediment discharge decreased obviously with $3.38\times10^8$ tons annually. It enhanced the scouring capability of the Changjiang Estuary. The seabed became to be scoured 0.07m/a. At the time of 1997−2001, the sediment discharge was still lack, only $3.26\times10^8$ tons. At 2001 year, it was no more than 2.76×10$^8$ billion tons, and the seabed was continued scouring, which achieved the maximum erosion rate of 0.14m. Figure.5 shows the relationship between the annual sediment discharge and the seabed scouring and accretion rate. The good relationship tells us that the sediment discharge is the major factor effecting the scouring and accretion evolvement of seabed near the Nanhui foreland.

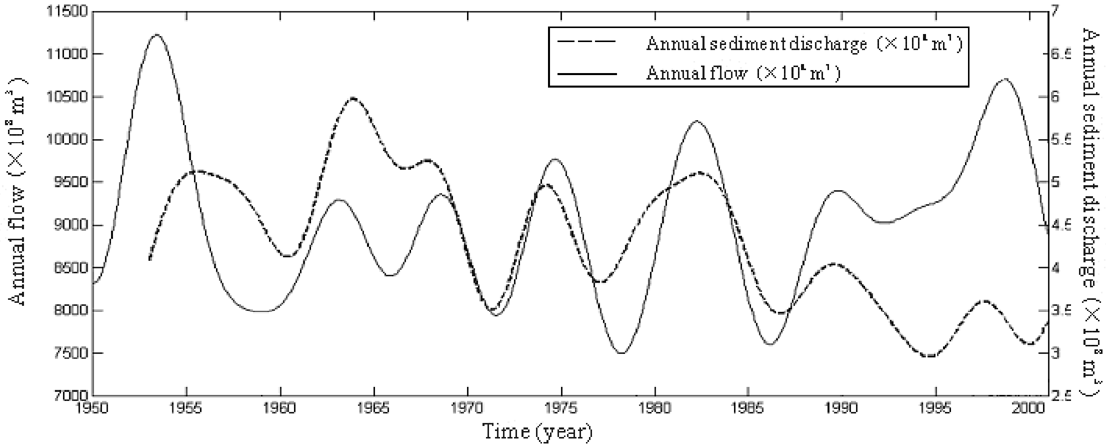



**Fig. 4** Time series of flow and sediment discharge at the Datong station in the Changjiang Estuary from 1950 to 2001

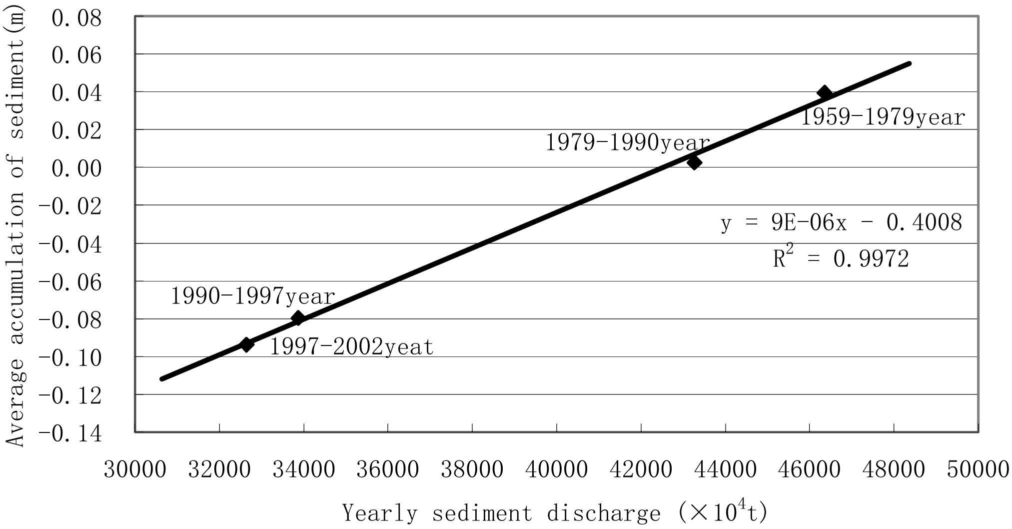



**Fig. 5** The relationship between the sediment discharge and the nearshore scouring/ silting rate

## 4.2 THE EFFECT OF THE LOCAL INNING PROJECTS

As the Changjiang River supply large amount of sediment, the coastlines of the Changjiang Estuary, including the Nanhui foreland, were outspread seaward constantly for quite a long time. Since the 1990's, the reclamation on coastal bottomland is getting faster with the demand of urban lands in Shngahai. Since 1994, the roughly statistics show that the large-scale inning engineering have been put in practice on the wide moderate and lower flat above 0m, where is about 45km from the east to the west coast of the Nanhui foreland. The engineering reclamation is carried out by two steps. Before the engineering reclamation, semi-submerged dikes are built to make the sediment from the Changjiang go over the dikes and fall down during the flood tide. When the flat altitude reached 1−2m, the engineering reclamation is carried out. A mass of sediment is retained by this way. Additionally, the silting dikes block sediment exchange between main channel and flat, especially decrease the sediment eroded from flat into the South Passage during storm season. Since 1994, both east and west flats of the Nanhui foreland's reclamation land reached 146km$^2$. Assuming the average deposition altitude is 1m, the held-up sediment has been $2\times10^2$−$3\times10^2$ million tons, 20−30 million tons per annum from 1994 to 2004. It is equal to 20−30% of the total discharge of the sediment passing the South Passage of the Changjiang estuary. The decreasing of the sediment discharge will increase the scouring at the Hanhui foreland.