Analysis on the characteristics of flow distribution of Jiaomen estuary in flood and dry season

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Abstract. Jiaomen estuary is the outlet of Jiaomen waterway, which undertakes the water and sediment of the West River and North River. It is mainly driven by runoff. The sediment transport capacity is only less than Modaomen estuary, and the flood discharge volume accounts for 16.8% of the eight major outlet of Pearl River. Jiaomen estuary has formed a main stream and a branch. The flow structure affected by shoreline, topography, bridge, riprap and other factors is particularly complex under the interaction of runoff and tide. The prototype observation of flow at Jiaomen estuary is an important means to master the hydrologic of Jiaomen estuary. It is helpful to understand velocity structure and flow distribution in order to study the evolution mechanism of erosion and deposition in Jiaomen estuary, and provide basic data for future regulation of Jiaomen estuary, which has important practical significance and scientific value.

1. Introduction

Jiaomen estuary is the second largest estuary in the middle runoff of the eight major outlet of the Pearl River Delta, with 16.8% of the total discharge[1]. At present, a stable pattern of one main stream and a branch has been formed. The main stream is the E-W trend and the branch is southeast trend. The diversion ratio of the two is related to the sediment transport and the evolution and trend of beach and channel in Jiaomen estuary. Xiaozhang Hu analyzed the size and cause of the change of Jiaomen estuary caused by high-intensity human activities[2]. Xiangxiang Xu and Shijun Wang studied the movement and development of water and sediment in Jiaomen estuary, and put forward the idea of regulating Jiaomen estuary[3,4]. Yu Yang used the mathematical model to study the natural diversion ratio of Jiaomen estuary during the flood ebb tide, and then worked out the regulation scheme of Jiaomen estuary[5]. The existing results are mainly based on macro analysis, with few prototype observation flow data. In recent years, with the rapid development of Nansha’s economy, a large number of beach reclamation and bridge construction have occurred, which have affected the cross-section area of water channel and changed the diversion ratio of Jiaomen estuary. Based on the observation data of Jiaomen estuary flow in March 2017 and July 2017, this paper analyzes the velocity distribution characteristics and diversion ratio of Jiaomen estuary, providing scientific basis for the future regulation.

2. Observations

2.1. location
The survey range is 113.566°E ~ 113.593°E, 22.698 °N ~ 22.741° n. There are three flow observation sections, which are respectively arranged in Jiaomen waterway, Fuzhou watery section and Nanzhi waterway. Simultaneously collect the upstream flow data and the tide level data of Nansha hydrological station.

![Fig. 1. Measuring section in Jiaomen estuary](image)

There are three sections in Jiaomen estuary, the first is Section A, which is located in Jiaomen watery. The second is Section B, which is located in Fuzhou waterway. The third is Section C, which is located in Nanzhi watery.

| Num | Name           |
|-----|----------------|
| A   | Jiaomen watery|
| B   | Fuzhou waterway|
| C   | Nanzhi watery |

2.2. Characteristics of the upstream and tidal

The tide of Lingding estuary belongs to the type of weak tide, the tide coefficient is between 0.89 and 1.92, which is an irregular irregular semidiurnal tide. During the observation period, the maximum ebb tide range of Nansha station in dry season is 2.17m, the ebb tide duration is about 9h. The maximum ebb tide range in flood season is 2.34M, and the ebb tide duration is about 8h. The daily average flow of the upstream from Sanshui and Makou in dry season is 1380m³/s and 4855m³/s respectively, while the daily average flow in flood season is 5384m³/s and 1906m³/s respectively. It can be seen that Jiaomen estuary has the characteristics of large amount of water, large tidal range and short duration in flood season.
Table 2 Characteristics of upstream flow unit: m³/s

| Hydrologic station | Dry season (March 10-11) | Flood season (July 10-11) |
|--------------------|--------------------------|---------------------------|
| Sanshui            | 1380                     | 5384                      |
| Makou              | 4855                     | 19067                     |

![Fig. 2. The process of tidal level](image)

3. Spatial distribution characteristics of velocity

It can be seen from Fig. 3.1-3a that in the dry season, the velocity in the middle of Jiaomen waterway is relatively small, and the velocity on both sides is relatively large. The ebb channel is concentrated on both sides of the river channel, while in the flood season, the velocity on the north side of the river channel is generally larger than that on the south side, and the ebb channel is concentrated on the north side. The velocity distribution law of the Fuzhou watery and Nanzhi watery is basically the same in the dry and flood seasons: The ebb current from Jiaomen watery flows to the Fuzhou channel and Nanzhi watery through the bifurcations, the maximum ebb and flow of the Fuzhou estuary is concentrated on the deep trough in the middle of the watery, the average ebb velocity of deep trough in the flood season reaches 0.66 m/s, and the deep trough and its north side are the main ebb and flow channels, from the deep trough to the left bank, the velocity presents a decreasing trend; The south side of the deep trough is affected by the water blocking and diversion of the riprap, and the fluctuating current speed is obviously smaller than the north side of the deep trough. The average velocity of ebb tide in flood season is only 0.34 m/s; The maximum ebb and flow of Nanzhi watery is concentrated in right side of the watery, with the average ebb current velocity of 0.50 m/s in flood season.

The residual current reflects the net transport characteristics of the material group. In the dry season, the runoff is small. The residual current range of Jiaomen waterway section is 0.01-0.15 m/s, and that of Fuzhou waterway section is 0.03-0.10 m/s. Both of them show the distribution law of small residual current in deep channel and large residual current on both sides. It can be seen that the deep trough is also an important channel for flood tide, and the flood tide will offset most of the ebb tide, making the residual current relatively reduced. In the flood season, the residual current range of Jiaomen waterway is 0.20-0.50 m/s, and that of Fuzhou waterway is 0.25-0.54 m/s. As the runoff is dominant, the ebb current is strengthened and the flood current is relatively weakened. The material transport channels of each section are mainly concentrated in the deep channel, and gradually reduce to both sides.
4. Spatial distribution characteristics of flow

4.1. The discharge characteristics at Fuzhou Section

In the dry season, the discharge per unit width in the deep channel of Fuzhou waterway is largest, and the north side is gradually decreasing, the south side is decreasing first, and then increasing. Compared with the north side, the discharge per unit width in the south side of stone embankment is generally smaller. Fuzhou waterway is a wide and shallow waterway, so except for the discharge per unit of ebb tide at the deep channel which is greater than 5 m$^3$/s, the others are less than 3 m$^3$/s. The discharge per unit width of the ebb and flood at 6# is next to that of the deep channel, as the position of is facing the gap of the stone embankment. Influenced by the special flow pattern of the gap, the discharge per unit is relatively small at 7#, 8# and 9# are gradually far away from the gap, and the discharge per unit is increased.

In flood season, the discharge per unit width of ebb tide between -5m contour lines is the largest, which is 9.65 m$^3$/s, accounting for 27.8% of the total. The characteristics of ebb tide is basically the same as that in dry season. However, due to the increase of the flood tide power of the main trough, the ebb tide power is relatively weakened. The amount of ebb tide of the deep trough decreases from 27.1% to 15.1%. The flood tide of the south side of the stone embankment is relatively weak, the ebb tide is relatively increased, and the amount of ebb tide is increased from 19.7% to 30.4%.

The maximum discharge per unit width of ebb between 5m contours is 7.14 m$^3$/s, accounting for 26.6% of the total, which is mainly concentrated in the channel. The discharge per unit width between the contour lines on the south side of Fuzhou waterway is obviously smaller than that on the north side. The width between the contour lines of -4~ -1m on the south side is 646m, accounting for 37.2% of the measured section length. But the flow only accounts for 16% of the total flow. Although the river width accounts for a high proportion in the south side of the stone embankment, due to the influence of the stone embankment, the shoal is obviously silted up, and the flow capacity is significantly lower than that in the north side. Most of the water in Fuzhou waterway is discharged through the north side of stone embankment, in which the ebb tide accounts for 83.9% and the flood tide accounts for 81.4%.
Fig. 5. Discharge of unit width in dry season
Fig. 6. Discharge of unit width in flood season

Fig. 7. Flow distribution diagram in dry season

Fig. 8. Flow distribution diagram in flood season

Table 3: Distribution of discharge in Fuzhou watery

| Contour (m) | Wide (m) | Dry season | Flood season |
|-------------|----------|------------|--------------|
|              | Ebb amount ratio | Flood amount ratio | Ebb amount ratio | Flood amount ratio |
| -1~2        | 28       | 0.1%       | 0.7%         | 0.0%          | 0.7%          |
| -2~3        | 327      | 17.4%      | 15.8%        | 13.6%        | 19.8%        |
| -3~4        | 351      | 21.8%      | 20.4%        | 21.8%        | 22.0%        |
| -4~5        | 66       | 8.5%       | 6.3%         | 4.9%         | 3.3%         |
| -5~6        | 193      | 26.4%      | 27.1%        | 27.8%        | 15.1%        |
| -5~4        | 125      | 9.8%       | 10.0%        | 10.1%        | 8.7%         |
| -4~3        | 596      | 14.5%      | 17.6%        | 20.6%        | 27.9%        |
| -3~2        | 25       | 0.7%       | 1.1%         | 0.7%         | 1.2%         |
| -2~1        | 26       | 0.8%       | 1.1%         | 0.4%         | 1.3%         |
4.2. Analysis of flow diversion ratio

From the measured discharge hydrograph in April 2017, it can be seen that Jiaomen estuary is dominated by tidal power in the dry season, and the flow of Jiaomen estuary is greatly affected by the fluctuation of tide, and the diversion ratio of main stream and branch changes greatly at some times. With the increase of flow rate, the split ratio becomes stable. In the period of ebb tide that the flow of Fuzhou water is larger than 3400 m$^3$/s, the diversion ratio of Fuzhou waterway is relatively stable, basically at about 70%.

In the flood season, Jiaomen estuary is still dominated by tidal power. However, the runoff dynamic is obviously enhanced in than in dry season, relatively less affected by tidal fluctuation. When the flow of Fuzhou water is larger than 4800 m$^3$/s, the diversion ratio of Fuzhou waterway is relatively stable, basically at about 75%.

![Flow diversion ratio in dry season](image1)

![Flow diversion ratio in flood season](image2)

5. Conclusion

According to the above measurement data analysis, we can summarize the following characteristics:

The current of Jiaomen waterway is concentrated on the both side, and the current of Fuzhou waterway is concentrated on the deep trough at the middle of waterway, and the current of Nanzhi waterway is concentrated on the deep trough at the right side.

The north side of Fuzhou waterway is the main channel of fluctuation tide. Due to the influence of the stone embankment, the shoal on the south side is obviously silted up, and the flow capacity is significantly lower than that in the north side.

With the increase of discharge, the flow diversion ratio of Fuzhou waterway increases, and the flow diversion ratio of Nanzhi waterway decreases at the same time. Because of the increase of runoff in flood season, the flow diversion ratio of Fuzhou waterway in flood season is larger than in dry season, and the stable diversion ratio off flood and dry season is about 75% and 70% respectively.

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