The Study on Hydrodynamic Characteristics of Qianhai Bay in Shenzhen

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Abstract: Based on the fixed-point observation data in Qianhai Bay of Shenzhen in May 2020, the horizontal and vertical distribution characteristics of tidal current, wave in summer near Qianhai Bay of Shenzhen are analyzed. The results show that the correlation coefficient of high and low tide level between the Qianhai Bay and Chiwan hydrological station is 0.98. The former Bay is dominated by irregular semidiurnal tidal current, which basically rotates anticlockwise. Due to the special shape of Qianwan Bay, the average velocity in the bay is small, but the maximum velocity of flood tide is 0.48 m/s, the maximum velocity of ebb tide is 0.45 m/s, the possible maximum velocity is 0.64 m/s at the bay mouth. The average wave height is 0.07 m, the normal wave direction is southwest West (WSW), and the average period is 2.9 s.

1. Introduction

The study of Offshore Tidal Current and sediment is not only related to the law of marine water movement, but also closely related to the material transport and the evolution of coastal and seafloor sedimentary landforms [1]. Ocean current is one of the most important parameters in the study of marine environmental dynamics, and it is also an important factor to understand the process of marine dynamic deposition [2-3]. Through the quasi harmonic analysis, we can study the flow characteristics and velocity structure in Qianhai sea area [4]. The research on hydrodynamic characteristics of water area is of great significance for environmental protection, marine transportation, port engineering construction, Fishery Ecology in estuarine area and wave current research [5-7].

Due to the influence of runoff, tide and wave, the hydrodynamics of Shenzhen Qianhai is very complex. At present, there are few studies on the hydrology of Shenzhen Qianhai, and the observation data are very limited. Therefore, more comprehensive observation is very necessary to understand the hydrological condition of Qianhai in Shenzhen. In this study, spring, middle and neap tides were observed in the Qianhai bay. Based on the measured tidal level, tidal current and wave data in May 2020, the temporal and spatial distribution characteristics of tidal current and wave were analyzed, and the hydrodynamic characteristics of the area were preliminarily studied.

2. Study area

Shenzhen Qianhai area is located in the west of Nanshan Peninsula, the east of Lingdingyang and the East Bank of Pearl River Estuary, including the west of Nantou Peninsula and the central area of Bao’an. The annual average temperature is about 22 °C, the annual average rainfall is 1774.1 mm, and the wind direction frequency has seasonal variation. The tides in the Pearl River estuary are irregular...
half day mixed tides. There are two ups and downs in a lunar day (about 24 hours and 50 minutes),
and there are spring tide and neap tide in half a month, lasting for three days each. The average tidal
range of the Pearl River estuary is between 0.85 m and 1.62 m.

As shown in Table 1, the observation time is from May 1 to 30, 2020. The periods of high tide,
middle tide and neap tide are monitored respectively. The observation contents include tide level, tidal
current, wave, sediment, wind speed and direction. Each observation element is observed each hour.
The observation stations include: 1 short-term tide level station, 1 short-term wave weather station, 3
temporary wave stations and 4 hydrological station to measure tidal current, suspended sediment.

![Table 1. Station information](image)

3. Methods
The measured velocity and flow direction of each layer are decomposed into north component and
East component:

$$V_N = V \cos \theta, V_E = V \sin \theta$$  \hspace{1cm} (1)

The weighted average method is used to calculate the vertical average North component and East
component:

$$V_m = \sqrt{V_{Nm}^2 + V_{Em}^2}$$  \hspace{1cm} (2)

$$\theta_m = \arctan\left(\frac{V_{Em}}{V_{Nm}}\right)$$  \hspace{1cm} (3)

(if $V_{Nm} = 0$, when $V_{Em} > 0$, then $\theta_m = 90$; when $V_{Em} < 0$, $\theta_m = 270$)

According to the principle of quasi harmonic analysis, the harmonic constants of O1, K1, M2, S2,
M4 and MS4 are calculated by introducing the difference ratio. The possible maximum tidal current
and flow direction of the tidal current in the water area are calculated by the vector combination of six
main tidal currents:

$$S_{max} = 1.295W_{M2} + 1.245W_{S2} + W_{O1} + W_{K1} + W_{M4} + W_{MS4}$$  \hspace{1cm} (4)

The type of tidal current is determined by the ratio of the major diurnal component to the major
axis of the major semidiurnal component.

$$F' = \frac{(W_{K1} + W_{O1})}{W_{M2}}$$  \hspace{1cm} (5)

0<$F'$<0.50 Regular half day tide

0.50<$F'$<2.0 Irregular semidiurnal tide

4. Results
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same style to the title page. This paragraph follows a section title so it should not be indented[2-3].

4.1. Tidal level characteristics
During the survey period, the maximum and minimum tidal levels of the temporary tidal station are
1.94m and -1.07m, the maximum and minimum tidal levels of Chiwan station are 1.86M and -0.95m,
the maximum tidal range of the temporary tidal station and Chiwan station are 2.94M and 2.77M respectively. The tidal range of the temporary tidal station is slightly larger than that of Chiwan station, which conforms to the general rule that the tidal range of the upstream of Lingdingyang is larger than that of the downstream.

According to the high and low tide data of temporary tide station and Chiwan station, the correlation analysis is carried out respectively, and the linear fitting is carried out. From the fitting results, the correlation between them is very good that the correlation coefficient of low tide level is 0.986, and the correlation coefficient of high tide level is 0.982. The specific fitting formula is as follows:

1) low tide level: \( y=1.040x-0.082 \);
2) high tide level: \( y=1.014x+0.003 \);

\( y \) is the temporary tide station, \( x \) is Chiwan station.

4.2. Tidal current characteristics

4.2.1. Property of tidal current

Tidal current refers to the comprehensive flow including tidal current component and non tidal current component. The average value after deducting tidal current from tidal current observation data is usually called residual current, which is a comprehensive reflection of wind current, density current and tidal residual current. The tidal current in Lingdingyang sea area is affected not only by tidal force, wind and uneven distribution of sea water density, but also by runoff, coastal current, topography and shoreline trend. It can be seen from table 5.1-1 that, except for some vertical water layers, \( f' \) value generally exceeds 0.5, with an average of 0.67, indicating that the irregular semidiurnal tidal current is dominant in this sea area.
Table 2. Flow type discrimination coefficient

| Station | Flow type discrimination coefficient | Average |
|---------|-------------------------------------|---------|
|         | Spring | Middle | Neap |         |
| 1#      | 0.50   | 0.60   | 0.70 | 0.60    |
| 2#      | 0.60   | 0.70   | 0.60 | 0.63    |
| 3#      | 0.40   | 1.20   | 0.50 | 0.70    |
| 4#      | 0.50   | 0.80   | 0.90 | 0.73    |
| Average | 0.50   | 0.83   | 0.68 | 0.67    |

4.2.2 Form of tidal movement
The sea area is dominated by semidiurnal tidal current, so the ellipticity value of M2 tidal current is used to judge the movement form of tidal current. If the $|k|$ is small, it indicates that the form of reciprocating flow is significant; otherwise, it indicates that the characteristics of rotating flow are strong. When $k$ is positive, the current rotates counter clockwise; when $k$ is negative, it rotates clockwise. After calculation, the $K$ value of M2 tidal current of each station is shown in table 5.2-1.

At 1# the values of $k$ are all positive, indicating that the direction of tidal current is counter clockwise, the magnitude of $k$ is relatively small, and the characteristics of reciprocating flow are obvious; at 4# the average value is negative, the direction of surface tidal current is clockwise, the magnitude of $K$ value is relatively large, and the characteristics of rotating flow are relatively strong.

4.2.3 Velocity of current
Spatially, the 1# at the mouth of the bay is the largest, and the velocity of 2 ~ 4# in the bay is small, which is basically less than 0.2m/s. The velocity of surface layer is larger than the bottom layer. From the time of distribution, the velocity of ebb tide is similar to that of flood tide, and the velocity of spring tide is the largest, and that of neap tide is the smallest. During spring tide, the maximum velocity of flood and ebb tide of 1# is 0.48m/s and 0.45m/s, and during neap tide, the maximum velocity of flood and ebb tide of 1# is reduced to 0.21m/s and 0.30m/s.

4.2.4 Residual current and probable maximum current
Residual current refers to the net flow velocity at a fixed space point after eliminating the periodic tidal current. Although its value is not large, it directly indicates the movement and exchange of water. The possible maximum current velocity is obtained by combining the possible maximum current velocity with the residual current vector. It can be seen from table 2 that the maximum possible current velocity of 1# is 0.64m/s, with the direction of 194° and that of 2# is 0.23m/s, with the direction of 195° respectively.

Figure 4. Velocity vector diagram of spring, middle, neap tide.
4.3. Wave characteristics
The correlation between wave height and tide is small. During the spring tide, the maximum wave height of 1# is 1.51m, and the maximum average wave height is 0.25m when during the neap tide, the maximum wave height of 1# is 1.84m, and the maximum average wave height is 0.82m. Wave height is mainly related to wind.

During observation, the wave direction range is 209-297°, the normal wave direction is WSW, the frequency of wave occurrence is 50.8%, the second normal wave direction is West (W), and the wave frequency is 40.6%. The mean wave period is 2.9s.

Table 3. The frequency of wave direction

| Station | (SSW) | (SW) | (WSW) | (W) | (WNW) |
|---------|-------|------|-------|-----|-------|
| 3#      | 0.3%  | 4.9% | 50.8% | 40.6% | 3.5% |

5. Conclusions
Based on the measured hydrological data of Qianhai Bay in May 2020, this paper analyzes the variation characteristics of tide level, tidal current and wave, the main conclusions are as follows:

(1) During the observation, the highest tide level and the lowest tide level are 1.94m and -1.07m, the correlation between the characteristic tide level of the survey area and the high tide level and low tide level of Chiwan station is strong, and the correlation coefficient is above 0.98.

(2) The irregular semidiurnal tidal current is dominant in this area, and the tidal current basically rotates anticlockwise. The maximum velocity of the flood tide at the bay mouth is 0.48 m/s, the maximum velocity of the ebb tide is 0.45 m/s, and the possible maximum velocity is 0.64 m/s.

(3) The mean wave height (H_s) is 0.07m, the mean maximum wave height (H_{max}) is 0.38m, the normal wave direction is southwest west (WSW), and the sub normal wave direction is West (W).

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