Study on Influencing Factors of Flushing Time of Puyang River in the Upper Tributary of Qiantang River

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Keywords: Tidal river, Flushing time, Influencing factors, Hydrodynamic model

Abstract: Aiming at the prevention and control of the water environment of the Puyang River in the upper reaches of the Qiantang River, two-dimensional hydrodynamic model was established to study the influence factors of flushing time of Puyang River in the upper tributary of Qiantang River. The goal is to provide a new way to solve the problem of river water quality. The research results show that under the action of different influencing factors, the flushing time of the Xijiang and Dongjiang has a gradual increase trend from upstream to downstream. However, due to the supporting effect of the Fuchun River flow on the Puyang River outlet, the flushing time of area below Meichi increased first and then decreased from the upstream to the downstream. At the same time, the influence of discharge of Fuchun River on the flushing time roughly extends to the middle and lower reaches of the Xijiang and Dongjiang River. The discharge of Fengqiao River has little effect on the flushing time in the Xijiang River and area below Meichi, and the influence of the discharge of Fengqiao River on the flushing time of the Dongjiang River Basin is roughly 18km~25km away from the entrance of the Dongjiang River. The influence of the discharge of tidal intensity of Qiantang River on the flushing time of the area below Meichi is within 5km of downstream exit. The initial water level and the discharge of the Puyang River are the main factors affecting the flushing time of the river basin, and the discharges of the Fuchun River and the Fengqiao River also have a significant effect on the flushing time.The research results can provide technical support for the prevention and control of the water environment of tidal rivers.

1 INTRODUCTION

The Puyang River is a first-level tributary of the upper reaches of the Qiantang River. The quality of the water environment in the basin not only affects the production and life of the people along the river, but also affects the drinking water safety of millions of people in the lower reaches of the Qiantang River. With the rapid economic development, there are more and more industrial enterprises around the Puyang River, and industrial wastewater and domestic sewage are directly discharged into the river. At the same time, the Puyang River is a tidal channel, and its water environment is affected by both upstream runoff and the tidal effect of the Qiantang River, resulting in complex water quality issues (Wu et al., 2003). Although the Puyang River Basin has continuously increased its pollution control efforts in recent years, there are still water quality problems.

Since the end of the last century, the process of material transport has become an important issue in the water environment system. When the polluted water body is exchanged with a clean water body, the pollutant is diluted, its concentration is reduced, and the water quality of the water body is improved. Therefore, many scholars express the exchange capacity of water bodies inside and outside the system through the transmission time scale (Takeoka, 1984; Monsen et al, 2002; Sandery & Kämp, 2007). Among them, flushing time is a kind of transmission time scale. Dilute time can explore the law of material transport between the system and the external environment and the characteristics of the material exchange within the system itself (Takeoka, 1984; Monsen et al, 2002). In recent years, scholars have

Zhang, H., Lou, Y. and Wang, Z.
Study on Influencing Factors of Flushing Time of Puyang River in the Upper Tributary of Qiantang River.
In *Proceedings of the 7th International Conference on Water Resource and Environment (WRE 2021)*, pages 419-425
ISBN: 978-989-758-560-9; ISSN: 1755-1315

carried out a series of studies on the water environment using flushing time (Ding et al., 2003; Wang et al., 2004; Wan, 2009; Zhu, 2011) including using the flushing time to study the migration of pollutants in the estuary and assess the quality of the water environment. Therefore, carrying out relevant research on the flushing time of tidal rivers can provide guidance for the harmonious development of water conservancy projects and the water ecological environment of the river basin, the establishment of a long-term mechanism for river water environment improvement, and the management of sewage discharge along the river.

This paper takes Puyang River as the research object and establishes a two-dimensional hydrodynamic model to study the influence factors of flushing time of Puyang River in the upper tributary of Qiantang River, such as discharge of Puyang River , discharge of Fuchun River , discharge of Fengqiao River , tidal intensity of Qiantang River , and initial water level . The research results provide guidance for the prevention and control of water environment in tidal rivers.

2 METHODS

2.1 Model Establishment

In this paper, the two-dimensional hydrodynamic model of Puyang River Basin is constructed by using mike21hydrodynamic module developed by DHI. Maps of study area and model grid are shown in Figure 1. The research objects in the Zhuji section of the Puyang River are divided into Xijiang River, Dongjiang River and area below Meichi. Among them, from Wansha Brige to Caojiangkou to Meichi is called Dongjiang River. And Fengqiao River is the main tributary of Puyang River, which meet at Caojiangkou.

The entrance boundary of the mathematical model is located inWansha Bridge of Puyang River and Luojia Bridge of Fengqiao River. The exit boundary islocated in Sanjiangkou. Among them,Puyang Jiang-WanSha Bridge and Fengqiaojiang-Luojia Bridge are the flow import boundary, and the measured flow data of Zhuji Station and Fengqiao Station were adopted respectively. Sanjiangkou is the water level boundary, and the exit water level is calculated based on the one-dimensional model of the Qiantang River by coupling the flow of the Fuchun River and the tidal intensity of the Qiantang River.

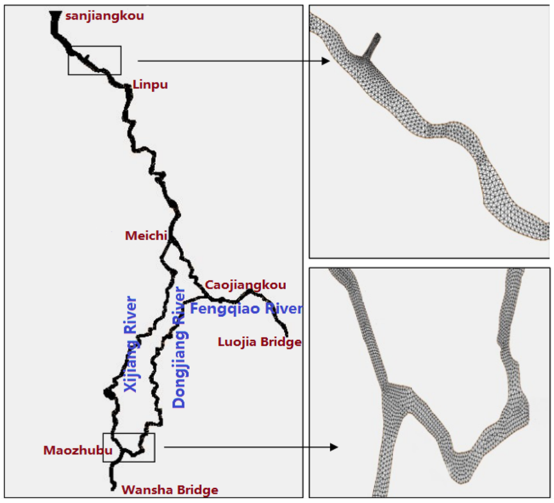


Figure 1: Map of study area and model grid.

2.2 Model Verification

The flood level verification was carried out on the model using the measured data of each boundary during the flood period from June 13 to June 21, 2011. During the model debugging process, the Manning coefficient has a certain influence on the model. Default value (0.020 m1/3/s.), the relative error interval between the calculated water level and the measured water level is -7.2%-10.2%. The final debug value of the manning coefficient in the model is 0.035 m1/3/s, and the verification results of Linpu, Meichi and Zhuji along the Puyang River are shown in Figures 3-5. It can be seen from the Figures 2-4 that: (1) The relative error interval between the calculated water level and the measured water level is -1.2%-3.2%, the highest flood level error is controlled within 4cm; (2) The calculated and measured flood level process changes are basically the same. The model’s rate parameter is basically reasonable and can be used for the analysis and study of the distribution of the flushing time of Puyang River.

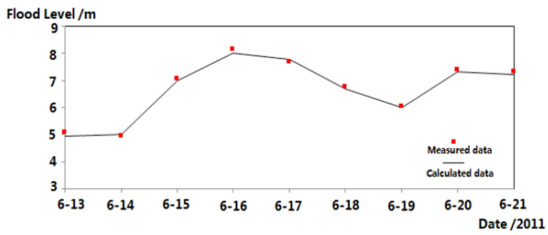


Figure 2: Comparison of measured and calculated data of Linpu station.

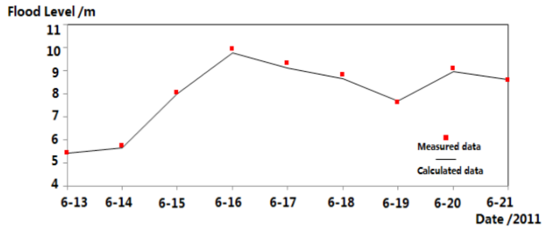


Figure 3: Comparison of measured and calculated data of Meichi station.

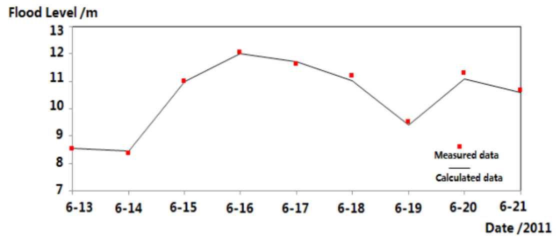


Figure 4: Comparison of measured and calculated data of Zhuji station.

2.3 Calculation Method of Flushing Time in the Model

Based on two-dimensional hydrodynamic model, the tracer is selected as the substance in the Puyang River, and the initial value of the tracer mass concentration is set to 1 kg/m^3, and the inlet and outlet boundary water bodies are assumed to be clear water, that is, the mass concentration of the tracer is 0. After setting the boundary conditions in the hydrodynamic model, the conservative tracer in the Puyang River gradually diffuses under the action of hydrodynamics, and the change function of regional material quality with time is obtained, see formula (1) for details. Then, substituting formula (1) into the flushing time definition expression, get the formula for calculating the water dilution time, see formula (2) for details. This section must be in one column.

$$\frac{M_3(t)}{M'} = (1+\frac{\beta_2}{\beta_1-\beta_2})\ e^{-\beta_2 t} + \frac{\beta_2}{\beta_2-\beta_1} e^{-\beta_1 t} = \frac{C_3(t)\cdot V}{C_3\cdot V} = C_3(t) \qquad (1)$$

$$F_t = \frac{1+\frac{\beta_2}{\beta_1-\beta_2}}{\beta_2} - \frac{\frac{\beta_2}{\beta_1-\beta_2}}{\beta_1} \qquad (2)$$

In the formula: $M_3(t)$ and $C_3(t)$ are the function of the tracer mass and mass concentration in the Puyang River, respectively; β_1 and β_2 are the exponential terms in the tracer concentration curve according to the double exponential law; V is the volume of water at any point in the Puyang River; M' is the initial amount of dissolved substances.

This article takes 16 equidistant calculation points along the central line of the main channel in the Xijiang River, the Dongjiang River and area below Meichi. According to the aforementioned calculation method, calculate the flushing time of each calculation point, and then discuss the distribution characteristics of the flushing time of the main channel in each region under the different factors.

2.4 Boundary Condition

The simulation conditions of this paper are based on the daily average flow of Zhuji Hydrological Station, the daily average discharge flow of Fuchun River, the daily average flow of Fengqiao River Hydrological Station, the daily average tidal range of Wenyan Station, and the daily average water depth of Zhuji Hydrological Station from 1991 to 2012. The range is determined, namely discharge of Puyang River condition, discharge of Fuchun River condition, discharge of Fengqiao River condition, tidal intensity of Qiantang River condition and initial water level conditions. Among them, the simulation of each factor includes 5 groups, and the other factors in each group are unchanged, which are shown in Table 1 below.

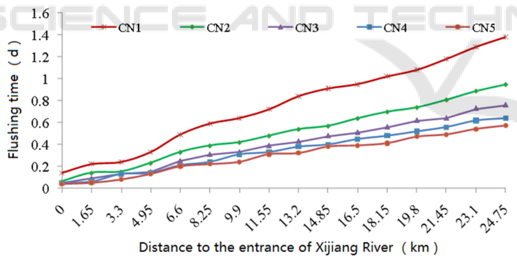
3 RESULTS AND ANALYSIS

3.1 The Influence of Discharge of Puyang River on the Flushing Time

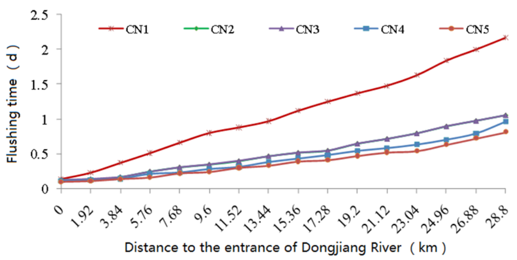
The distribution of the flushing time under different discharge of the Puyang River conditions are shown Figure 5. It can be seen that the flushing time of the Xijiang and Dongjiang has a gradual increase trend from upstream to downstream. However, due to the supporting effect of the Fuchun River flow on the Puyang River outlet, the flushing time of area below Meichi increased first and then decreased from the upstream to the downstream. From the perspective of the distribution curve spacing of the flushing time under the different discharge of Puyang River conditions, when the discharge of Puyang River increases from 150 m^3/s to 300 m^3/s, The impact of the Puyang River flow on the flushing time of the Xijiang River, the middle and lower reaches of the Dongjiang River and area below Meichi is more significant than when the discharge of Puyang River increases from 300m^3/s to 750m^3/s.In general, the flushing time of the Xijiang River, Dongjiang River and area below Meichi decreases with the increase of discharge of Puyang River .

Table 1: The simulation conditions.

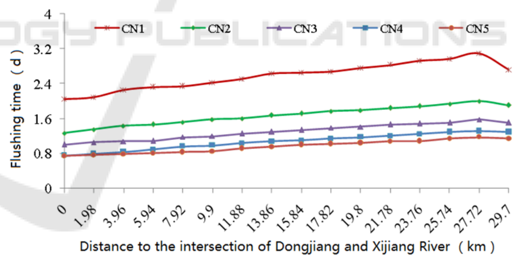
Impact factor	Condition No.	Discharge of Puyang River(m^3/s)	Initial water level (m)	Discharge of Fuchun River(m^3/s)	Discharge of Fengqiao River(m^3/s)	Tidal range (%)
Discharge of Puyang River	CN1	150	9.3	1600	15	50
	CN2	300	9.3	1600	15	50
	CN3	450	9.3	1600	15	50
	CN4	600	9.3	1600	15	50
	CN5	750	9.3	1600	15	50
Discharge of Fuchun River	CN6	300	8.8	1600	20	50
	CN7	300	8.8	3200	20	50
	CN8	300	8.8	4800	20	50
	CN9	300	8.8	6400	20	50
	CN10	300	8.8	8000	20	50
Discharge of Fengqiao River	CN11	150	7.35	1600	10	50
	CN12	150	7.35	1600	20	50
	CN13	150	7.35	1600	30	50
	CN14	150	7.35	1600	40	50
	CN15	150	7.35	1600	50	50
Qiantang River tidal intensity	CN16	300	8.8	4050	20	10
	CN17	300	8.8	4050	20	30
	CN18	300	8.8	4050	20	50
	CN19	300	8.8	4050	20	70
	CN20	300	8.8	4050	20	90
Initial water level	CN21	300	7.3	1600	20	50
	CN22	300	8.8	1600	20	50
	CN23	300	10	1600	20	50
	CN24	300	10.5	1600	20	50
	CN25	300	11	1600	20	50



(1) Xijiang River



(2) Dongjiang River



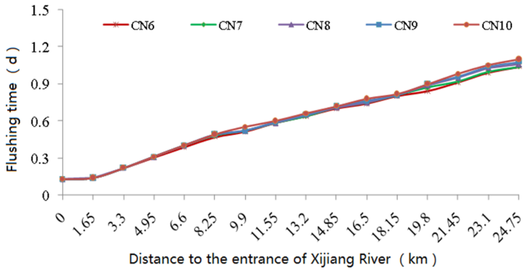
(3) Area below Meichi

Figure 5: The distribution of the flushing time under different discharge of the Puyang River conditions.

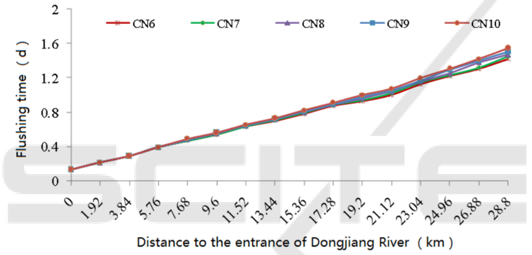
3.2 The Influence of Discharge of Fuchun River on the Flushing Time

The distribution of the flushing time under different discharge of the Fuchun River conditions are shown Figure 6. It can be seen that the variation law of the flushing time along the three regions is the same as the aforementioned discharge of Puyang River factor. In general, the flushing time of the Xijiang River, Dongjiang River and area below Meichi increases with the increase of discharge of Fuchun River.

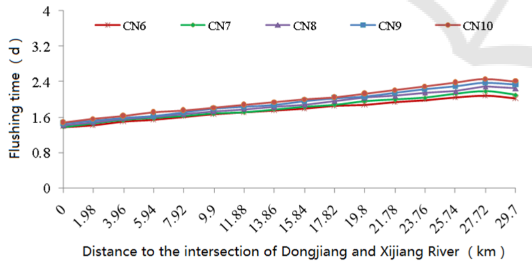
From the perspective of the distribution curve spacing of the flushing time under the different discharge of Fuchun River conditions, the influence of discharge of Fuchun River on the flushing time roughly extends to the middle and lower reaches of the Xijiang and Dongjiang River. At the same time, the discharge of Fuchun River has a smaller impact on the flushing time of the Puyang River than the discharge of Puyang River.



(1)Xijiang River



(2) Dongjiang River



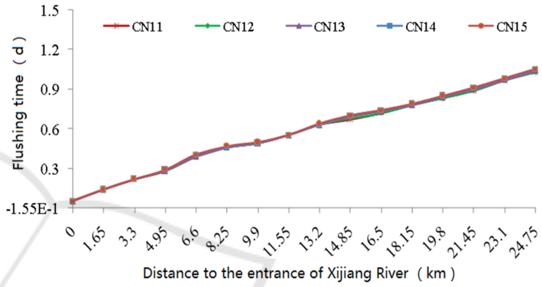
(3) Area below Meichi

Figure 6: The distribution of the flushing time under different discharge of the Fuchun River conditions.

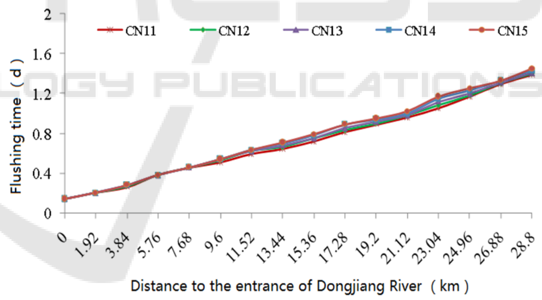
3.3 The Influence of Discharge of Fengqiao River on the Flushing Time

The distribution of the flushing time under different discharge of the Fengqiao River conditions are shown Figure 7. It can be seen that the variation law of the flushing time along the three regions is the same as the aforementioned discharge of Puyang River factor, also. In general, the flushing time of the Xijiang River, Dongjiang River and area below Meichi increases with the increase of discharge of Fengqiao River.

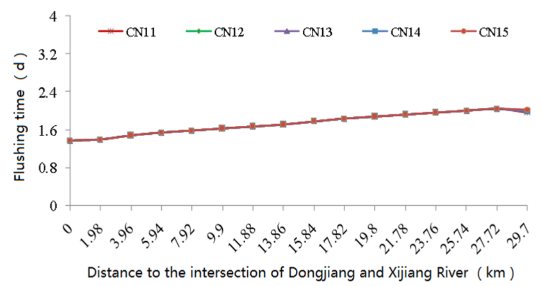
From the perspective of the distribution curve spacing of the flushing time under the different discharge of Fengqiao River conditions, the distribution curves of the flushing time along the Xijiang River and area below Meichi under different conditions basically coincide, that is, the discharge of Fengqiao River has little effect on the flushing time in these two regions. And the influence of the discharge of Fengqiao River on the flushing time of the Dongjiang River Basin is roughly 18km~25km away from the entrance of the Dongjiang River.



(1)Xijiang River



(2) Dongjiang River

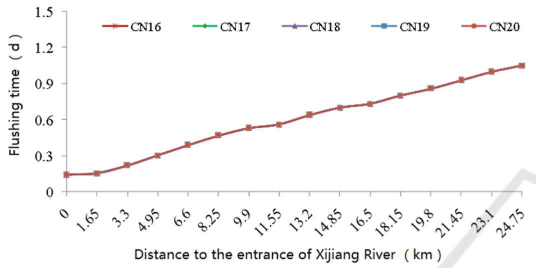


(3) Area below Meichi

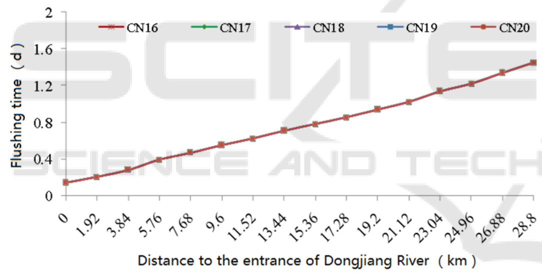
Figure 7: The distribution of the flushing time under different discharge of the Fengqiao River conditions.

3.4 The Influence of Discharge of Tidal Intensity of Qiantang River on the Flushing Time

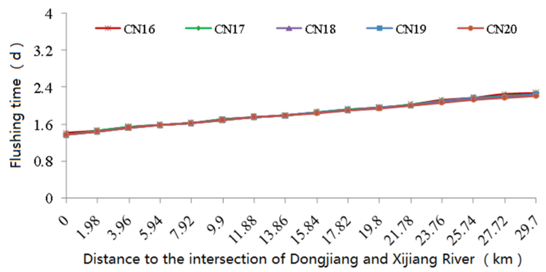
The distribution of the flushing time under different tidal intensity of Qiantang River conditions are shown Figure 8. It can be seen that the variation law of the flushing time along the three regions is the same as the aforementioned discharge of Puyang River factor, also. In general, the flushing time of the Xijiang River, Dongjiang River and area below Meichi increases with the increase of discharge of tidal intensity of Qiantang River.



(1) Xijiang River



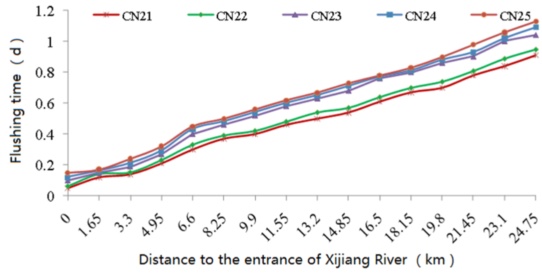
(2) Dongjiang River



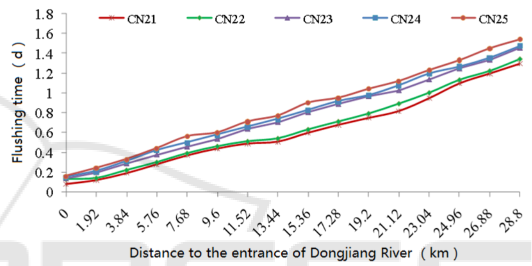
(3) Area below Meichi

Figure 8: The distribution of the flushing time under different tidal intensity of Qiantang River conditions

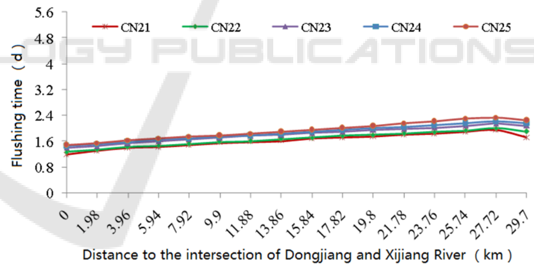
From the perspective of the distribution curve spacing of the flushing time under the different tidal intensity of Qiantang River conditions, the distribution curves of the flushing time along the Xijiang and Dongjiang River under different conditions basically coincide, that is, the tidal intensity of Qiantang River has little effect on the flushing time in these two regions. And the influence of the discharge of tidal intensity of Qiantang River on the flushing time of the area below Meichi is within 5km of downstream exit.



(1) Xijiang River



(2) Dongjiang River



(3) Area below Meichi

Figure 9: The distribution of the flushing time under different initial water level conditions.

3.5 The Influence of Discharge of Initial Water Level on the Flushing Time

The distribution of the flushing time under different initial water level conditions are shown Figure 9. It can be seen that the variation law of the flushing time along the three regions is the same as the aforementioned discharge of Puyang River factor, also. In general, the flushing time of the Xijiang River, Dongjiang River and area below Meichi increases with the increase of initial water level.

From the perspective of the distribution curve spacing of the flushing time under the different initial water level conditions, when the initial water level increased from 7.3m to 8m, the impact of the flushing time in the three regions was small; When the initial water level increased from 8.8m to 10m, the impact of the flushing time in the three regions increased significantly. Among them, the Xijiang River and Dongjiang River have a relatively large range of changes, and area below Meichi is relatively small. The reason is related to the topography of the cross-section of the river bed in each region. The bottom slopes of the Xijiang River and Dongjiang River are steeper and the upper parts of the Xijiang River and Dongjiang River are gentler, while the riverbed of area below Meichi is wider, and the slope changes at the bottom and upper part of both banks are smaller than those of the Dongjiang River and Xijiang River. When the initial water level increased from 10m to 10.5m and then increased to 11m, the flushing time curves of the three regions also changed evenly.

4 CONCLUSIONS

This paper takes Puyang River as the research object and establishes a two-dimensional hydrodynamic model to study the influence factors of flushing time of Puyang River in the upper tributary of Qiantang River. The research results provide guidance for the prevention and control of water environment in tidal rivers, got the following conclusions:

(1) Under the action of different influencing factors, the flushing time of the Xijiang and Dongjiang has a gradual increase trend from upstream to downstream. However, due to the supporting effect of the Fuchun River flow on the Puyang River outlet, the flushing time of area below Meichi increased first and then decreased from the upstream to the downstream. At the same time, the influence of discharge of Fuchun River on the flushing time roughly extends to the middle and lower reaches of the Xijiang and Dongjiang River. The discharge of Fengqiao River has little effect on the flushing time in the Xijiang River and area below Meichi, and the influence of the discharge of Fengqiao River on the flushing time of the Dongjiang River Basin is roughly 18km~25km away from the entrance of the Dongjiang River. The influence of the discharge of tidal intensity of Qiantang River on the flushing time of the area below Meichi is within 5km of downstream exit.

(2) Except for the negative correlation between the discharge of Puyang River and the flushing time of Puyang River Basin, and between the discharge of Fengqiao River and the flushing time of the Fengqiao River, each factor has a positive correlation with the flushing time of the Puyang River Basin.

(3) The initial water level and the discharge of the Puyang River are the main factors affecting the flushing time of the river basin, and the discharges of the Fuchun River and the Fengqiao River also have a significant effect on the flushing time.

The results of this research can provide the basis for the prevention and control of the water environment of tidal rivers, and also provide technical support for the ecological regulation of tidal rivers.

ACKNOWLEDGEMENTS

This experiment was supported by the Dean's Fund of Zhejiang Institute of Hydraulics & Estuary. Thank you here.

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