Research on Water Level Sensing Technology of Changjiang River

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Abstract: This paper firstly aims to survey the layout situation of water gauge in the jurisdiction of Changjiang River waterway maintenance management department, then, in terms of previous survey results, the research analyzes current problems of Changjiang water level sensing point layout and combines with the water level sensing technology development and application situation at home and abroad. This paper concentrates on the change rule of water surface profile of Changjiang River, mainly study the relationship between the sensing point layout density and capture the accuracy of water surface profile, and base on the research mention above to provides layout principles and schemes of different waterway reaches.

Introduction

Changjiang river waterway as the first essential factor of Changjiang river transportation, meanwhile, the water level information is also understood as the most important factors of Changjiang river waterway. The precise and efficient water level information is not only directly related to waterway navigation scale, but also as an important indicator of waterway dimensions maintenance. All in all, the water level information can be used as an useful method that ensures both safety and reasonable stowage of ships and security and smoothness of Changjiang river waterway.

Currently, Changjiang river lacks of relatively systematic measurement materials of water level data. Water level sensing measurement method has considerable limitation. Water conservancy administration department currently depends on existing water level observation stations, meanwhile, a large number of water level gauges were layout on both sides of natural escarpment for vessels safety demand. But, those water gauges' accuracy can not meet actual requirements. In terms of this key reason mentioned above, the relationship analysis between the water level sensing points layout density and the precision of water line were considered as first key element. Consequently, base on previous research and finally give a reasonable precept to solve the program of water level sensing points layout that could help Changjiang River waterway maintenance management department obtain useful and high precision data of water level to satisfy and promote the public service ability and maintenance level.

Lecture review

From 1970s, SM company of America cooperate with national weather bureau to develop a type of water level automatic monitoring equipment that help all users to obtain water level data on real-time. In 1980s, a large number type of water level automatic monitoring equipment have been developed and promoted by researchers[1-3]. According to those previous research results, water level automatic monitoring equipment were given a series of functions and could be connected different system data which were developed by different companies. In the developed countries, water level automatic monitoring research was studying by a lots of researchers and companies that results to some advanced equipment have been widely used in those countries[4]. What can not be ignored by researchers, such as Self-reported ultra-short

wave system, satellite platform and other advanced communication technology were firstly used in water level data monitoring research area.

In China, the relevant research of water level automatic monitoring was studying on 1980s. the infrastructure construction of hydrological monitoring system includes three stages: primary stage, developing stage and networked stage. In the late 1990s, a mounts of new technologies were widely researched and used in this area. Meanwhile, in order to satisfy actual demand of water and rainfall regime information automatic receiving, processing and analysis, and persistently perfect infrastructure construction, the state flood control and command system project aims to build 224 hydrologic information sub-center and 228 rainfall regime sub-center[5-6]. Base on those infrastructure construction, water level automatic monitoring system, and local rainfall regime monitoring system that was developed by local water authorities to achieve hydrological data real-time, rapid and accurate monitoring.

The current situation of water gauge layout along main channel of Changjiang River

At present, as the key points of this research are lack of systematic measurement of water level information that results to largely limitation of water level sensing research. Currently, the water gauge layout of water conservancy department depends on present water level and hydrological stations. Changjiang waterway bureau has arranged 105 water gauges along the Changjiang River and the average distance between 27 km[7-8]. Meanwhile, water conservancy department has arranged 35 water gauges and the average distance between 81 km. As mentioned above, the current obtain method of water level information always rely on artificially read and report. What can not be ignored by this artificial method that include main shortcomings of largely read period interval and low observation accuracy, according to those main reasons which results to fully unable reflect the water level change in real time. In the same, water conservancy department's water level information are also can not be satisfied by precision of water level dynamic monitoring and high-density measuring requirements, see Table 1.

Table 1 Water gauges layout of Changjiang River[9]

No.	River reaches	Number Of water gauges
1	Upper reaches of Changjiang River	53
2	Yichang to Cheng Lingji stream segment	33
3	Below Cheng Lingji stream segment	19

Water level sensing point layout research of main waterway in Changjiang River

Water surface profile change rule of Changjiang River in natural situation

Changjiang River main waterway usually be divided into three river reaches that include upper reaches, middle reaches and lower reaches of Changjiang River.

Upper reaches from Yibing to Chongqing is belong to mountain river and channel planform usually understood as a complex shape. Specific conditions of river reaches as follows（See Table 2）:

Middle reach from Yichang to Wuhan is belong to plain river and river bed evolution intensely results to waterway unstable. Middle reach commonly divided into two main reaches of Yichang to Cheng Lingji and Cheng Lingji to Wuhan, generally, water surface slope of upper reaches change greater than lower reaches. At the same situation, the water level varied intensely and waterway gradient have gradually slow down from upper reaches to lower reaches in middle reach of Changjiang River. Yichang to Cheng Lingji reach highly near to Three Gorges Dam and The Gezhou Dam, in terms of this reason, the waterway slope

change relatively large and the relationship between Changjiang River and Lakes are complex. Moreover, the curved reaches more than other area, the variation of erosion and deposition is highly and the water level mutation point in this waterway highly more than other reaches in this area. In according to those reasons as all mentioned above, it's hard for researchers to accurately forecast the water level change in short-time or long-time period.

Table 2 Yibing to Chongqing reach characteristics

No.	River reaches	characteristics
1	Yibing to Chongqing	① Typical mountainous rivers; ② River water surface slope is bigger; ③ Water flow relations remain stable of each gauging stations for a long time ;
2	Chongqing to Fuling	④ Varying backwater zone; ⑤ Reservoir and natural river flow conditions appear alternately; ⑥ Compared with the flood, flow velocity and slope are greatly slow down in dry season ;
3	Fuling to Yichang	⑦ The three gorges reservoir area of the river; ⑧ Navigation conditions have improved fundamentally and annual slope change slowly;

Lower reaches of Changjiang River from Wuhan to Liu Hekou is belong to branching reach and the water surface slope change relative slowly. The Changjiang main waterway surface slope is as follows（See Table 3）:

Table 3: The water line slope table of Changjiang river main waterway

Reaches	Segments	slope（10^{-4}）
Yibin to Chongqing reach	Yibin to Chongqing	2.68
Chongqing to Fuling reach	Chongqing to Changshou	1.1
	Changshou to Fuling	0.69
Fuling to Three Gorges Dam reach	Fuling to Fengdu	0.16
	Fengdu to Wanzhou	0.02
	Wanzhou to Dam	0.01
Yichang to Zhijiang reach	Yichang to Zhicheng	0.450
Zhicheng to Ou Chikou reach	Zhicheng to Chen Jiawan	0.579
	Chen Jiawan to Shashi	0.488
	Shashi to Haoxue	0.437
	Haoxue to Xinchang	0.563
	Xinchang to Shishou	0.523
Ou Chikou to Cheng Lingji reach	Shishou to Yao Qinao	0.466
	Tiao Qikou—Yao Qinao	0.413
	Tiao Qikou—Jianli	0.473
Cheng Lingji to Jiujiang reach	Luoshan to Longkou	0.243
	Longkou to Hankou	0.203
	Hankou to Huangshi	0.193
	Huangshi to Wuxue	0.205
	Wuxue to Jiujiang	0.232
No- tidal river reach	Jiujiang to Anqing	0.203
	Anqing to Datong	0.189
Tidal river reach	Datong to Wuhu	0.152
	Wuhu to Nanjing	0.144

In order to obtain accurate data of water level along the Changjiang River, this paper concentrates on lots of difficult analyzed reaches in main waterway to research water level

sensing points layout. Firstly, in the area of water surface slope change sharply and water level varied intensely, its hard for researchers to exactly analyze actual situation of water level change, therefore, the spacing of water level sensing points layout should be controlled in a smaller range. On the contrary, in the area of water surface slope change slowly, the spacing of layout program could be properly eased.

The relationship between the water level sensing points layout density and the precision of water line

On account of water slope change acutely, meanwhile, the waterway planform change and lateral inflow are also affecting on water surface change condition that easily results to sharply break. Facing to this situation, it's hard for researchers to use a common method of long linear interpolation to describe the changes along those reaches. Therefore, this paper study to work out the key problem of appropriately control spacing and location of water gauge. On the one hand, the researchers need to accurately understand and obtain abrupt change points of water surface along the Changjiang River. On the other hand, base on the water surface change characteristics to appropriately control distance between one and another water gauge, thereby, researchers could calculate and ensure interpolation precision of water level range.

In principle, this paper assumes the length of reach was fixed by research demand, if researchers arrange a larger number of water gauges in this hypothetical reach that bring an useful result of the distance among water level sensing points became more and more small, the precision of water surface profile would become increasingly higher.

In order to obtain correlation data, this paper bases on the historical measurement data of 33 water gauges from Yichang to Cheng Lingji reach (400km), at the same time, the researchers select a certain number of water level sensing points to calculate water level by linear interpolation method. Compare historical measurement data with those calculate results, it's a good study method for researchers to analyze the relationship among the number of water level sensing points, the spacing of water level sensing points and precision of water surface profile（See Table 4 , Fig.1 and Fig.2 ）.

Table 4 Number of water level sensing points, the spacing of water level sensing points and precision table of water surface profile of Yichang to Cheng Lingji reach

Number of water level sensing points	Maximum spacing of water level sensing points	Average spacing of water level sensing points	Maximum deviation of water level （Absolute value）
2	396.00	396.00	2.11
3	202.20	198.00	2.00
4	135.00	132.00	1.96
5	107.00	99.00	1.90
6	91.00	79.20	1.37
7	82.00	66.00	0.99
8	72.00	56.57	0.96
9	67.00	49.50	0.95
10	67.00	44.00	0.85
11	51.00	39.60	0.85
14	42.00	30.46	0.76
16	40.00	26.40	0.52
20	40.00	20.84	0.44

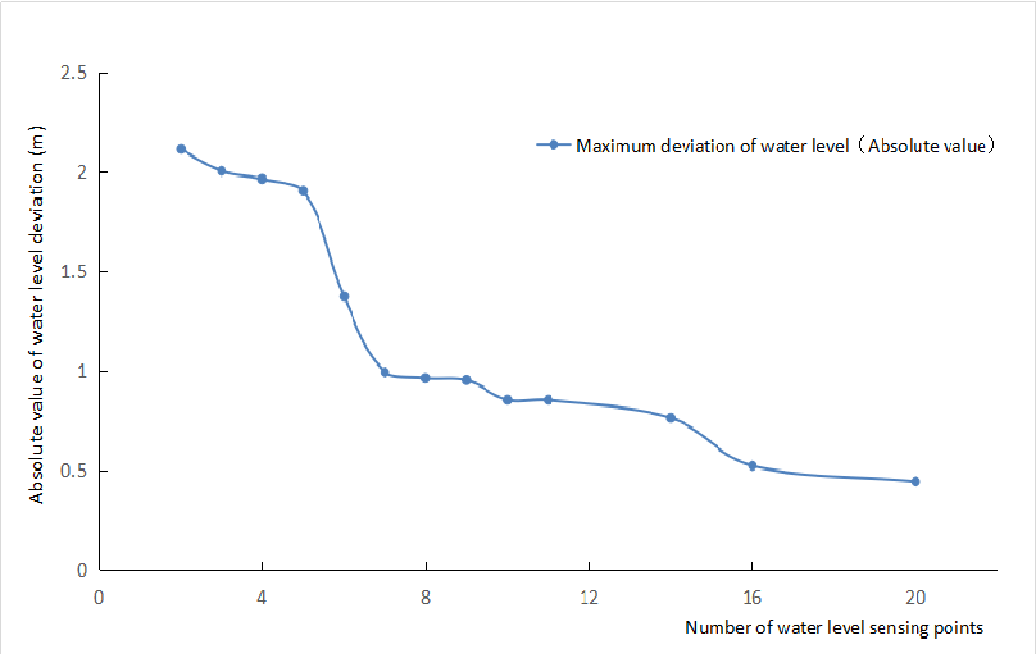

Fig.1 The relationship between the number of water level sensing points and water surface profile deviation of Yichang to Cheng Lingji reach

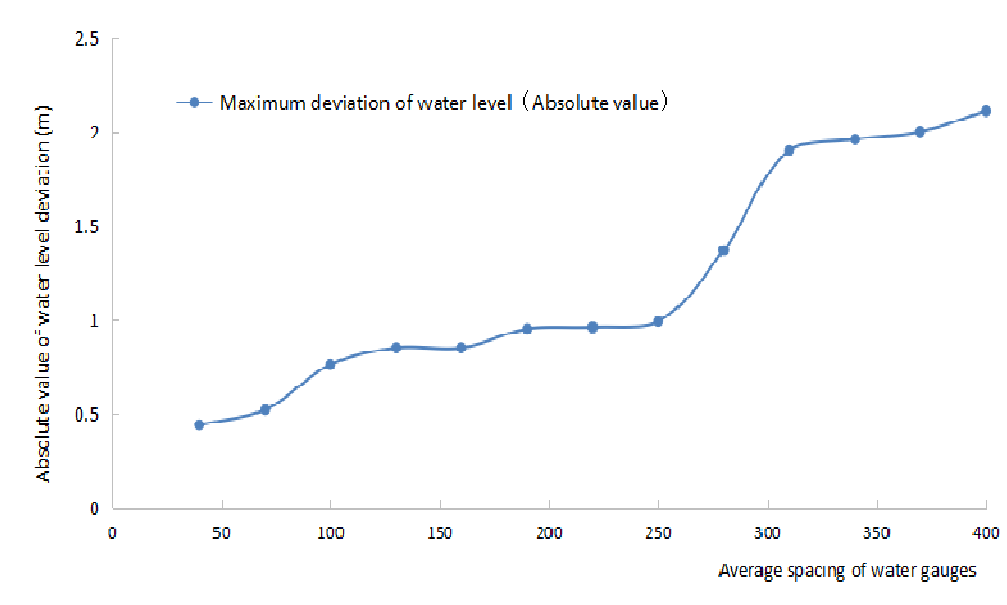

Fig. 2 The relationship between the average spacing of water level sensing points and water surface profile deviation of Yichang to Cheng Lingji reach

On the basis of analysis data of table 4-3, Chart 4-1 and chart 4-2 display above, it's clearly understand the relationship between water surface profile deviation and the number of water level sensing points. When the length of reach was be fixed by research demand, researchers increasingly arrange the number of water level sensing points in this reach as well as the precision of water surface profile will similarly increasing at the same time. As table 4-3 mentioned above, researchers select the reach of Yichang to Cheng Lingji as study sample and arrange 2 water level sensing points on both sides of this reach, then, the maximum deviation of water surface profile highly up to 2.11m. With the number of water level sensing points increasing more than 20, the deviation of water surface profile can be controlled within

0.5m. Similarly, if researchers decrease the spacing of water level sensing points, the deviation of water surface profile difference value could effectively reduce.

In accord with those analysis results mentioned above, the water level sensing points deviation is inversely proportional to the number of water level sensing points and change rate of spacing. Especially, the research results display an obvious conclusion for researchers.If the number of water level sensing points is relatively small in a fix distance reach, it's a simply method could increasingly arrange the number of water level sensing points that results to decrease spacing of any two sensing points and sharply decrease water level deviation. This study indicates that the spacing of 20km between any two sensing points is a critical leverage points for ordinary waterway. If the spacing of water level sensing points steadily decrease into 20km and continue increase the number of water level sensing points, the precision of water surface profile slightly improve not as much as previous study data.

The principle of water level sensing points layout

In the light of Changjiang River water surface profile variation characteristics of natural environment, the research results of relationship among the number and spacing of water level sensing points with the deviation of water level sensing system. This paper concludes a series of water level sensing points layout principle of Changjiang River as follow:

Concentrating on analyze the water surface profile change condition of key reach in Changjiang River, meanwhile, for layout project demand that deciders should selectively and persistently analyze the abrupt change area of waterway planform, the reach of thalweg sharply change and lateral inflow. Moreover, the areas of shoal, rapids and dangerous shoal are also considered as research key points by actual demand of water level data collection.

The layout project of water gauges should guarantee the gauging station can be observed effectively for a long-term period. Furthermore, the problems of water gauges installation and maintenance are also reasonably considered by deciders.

The setting of water gauges should satisfy domestic relevant standards that include "Inland waterway and port water flow and sediment simulation standard", "Inland waterway and port hydrology specification" and so on.

Conclusion

This paper firstly and systematically concentrates on Changjiang river water surface line change rule, meanwhile, and analyzes the relationship between the water level sensing points layout density and the precision of water line. Base on previous research results display in those chapters, this paper provides water level sensing points layout principle and layout method. At last, an actual layout program was given by researcher that include 168 water level sensing points in Changjiang river main reaches and covers the areas of water level change dramatically, critical control node, key rapids reach and other relevant reaches.

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