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BACK-SILTATION IN DEEP WATERWAY OF THE CHANGJIANG ESTUARY

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Abstract: In describing sediment back-siltation in the Changjiang estuary, China, this paper reports the three steps of navigation channel project and two major reasons of sediment back-siltation during the first step of the project. Methods of minimum the back-siltation are discussed.

Key words: Changjiang estuary, Deep waterway, Back-siltation

1. INTRODUCTION

The navigation channel of the Changjiang estuary is the economic lifeline of Shanghai and the Changjiang delta. The shallow depth of the waterway restricts the local society and economy development. Based on the longtime research work and practice, some ideas have been set up such as to regulate the North passage first. The estuary regulation project and the waterways dredged project can stabilize the channel position, divert flow, block sediment and minimize the back-siltation. The overall project layout is showed on Fig. 1. Process of the project has three phases. First phase has completed and deepened the waterway from 7.0m to 8.5m (below the theoretical lowest-tidal level, the same to following). The second-phase project is processing to achieve 10m water depth and will not be finished until 2005. The third-phase project will reach the aim of 12.5m by the way of dredging .

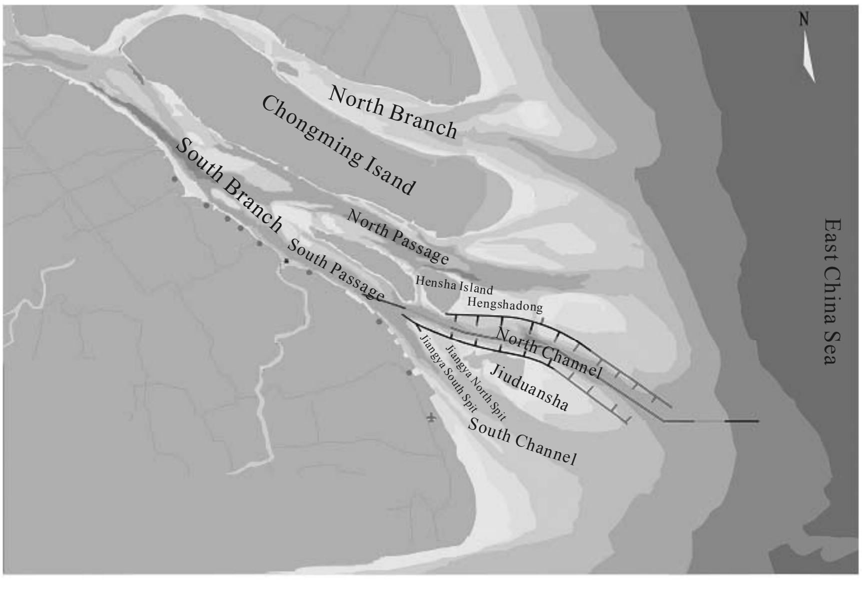

Fig. 1 Layout of the regulating deep waterways in the Changjiang estuary, China

The bck-siltation problem and minimizing deposition in the deep waterway are the critical problems. The first-phase project keeps the 8.5m-water deep steady on the budgetary maintenance dredging discharge. It is testified that most of the past work is credible with a lot of new experiences. It will be reported in this paper.

2. PRIMARY CAUSES OF BACK-SILTATION IN DEEP WATERWAYS

Key points of back-siltation are included two aspects. One is the river condition, the longtime evolution tendency of the Changjiang estuary, especially for the regulating channel, the North passage. Prediction and control of the tendency is basic guarantee to navigation's safety and stabilization. The influence of landforms and sediment movements to the waterway's scouring and accretion is the second key point for navigation channel back-siltation. Correct prediction of the amount and distribution of back-siltation in the waterways, is basis for the verification of the construction plans and the maintenance dredging plans.

Before the phase 1 project of regulating the deepwater channels in the Changjiang estuary, the lower stream from the Hengsha Island was on the nature conditions, and the stream vibrated largely. The effect of the river dynamic was weakened closing to the sea and the ocean dynamic became the dominating factor gradually.

In view of the waterways, stability of the branch channels is the main aspect of the channel positions. If the branch channels are unstable, the waterways would be difficult to keep steady longtime. It is so called stability that the channel cross-section is unchangeable or adaptive under the condition of the constant tidal discharge and the changeless diversion of flow and sediment.

MAIN CAUSES INFLUENCING THE BRANCH CHANNELS' STABILITY

(1)Equilibrium sediment transport in the branch channels

It is showed by statistical analysis that the annually averaged sediment discharge of the Changjiang estuary has reduced from 4.86×10^{8} t (1951−1990) to 3.37×10^{8} t (1991−2000) and the sediment particle size became finer (Table 1). This value maybe reduces gradually down to about 2×10^{8} t after the water storage of the Three Gorges Project. During the last ten years, water discharge increased a little. The sediment obviously decreases. This made the Changjiang estuary vary from deposition to erosion. It benefited the branch channel capacity's remainning and enlarging. Furthermore, it is a fine factor to the long-term maintenance of the deep waterway.

Table 1 the statistics of the yearly sediment discharge, runoff and sediment concentration of the Datong station of the Changjiang

Year	The yearly sediment discharge ($\times10^{8}$t)	The yearly flow discharge ($\times10^{8}$ m^3)	The yearly sediment concentration (kg/m^3)	The median diameter of the suspend sediment (mm)
1950-1960	4.652	9218.4	0.505	
1961-1970	5.132	8988.7	0.571	
1971-1980	4.262	8516.7	0.500	0.022
1981-1990	4.269	8897.0	0.480	0.021
1991-2000	3.371	9615.7	0.351	0.0095

(2) DISTRIBUTIONS OF THE FLOW AND SEDIMENT BETWEEN BRANCH CHANNELS

The statistical analysis showed that the branch channel will be relatively stable only if the ratio distribution of the flow and sediment (discharge ratio and sediment ratio) between both of branches is balance by and large enough. Through several decades evolvement, the north and south passages and the north and south channels are nearly stable, which have achieved the balance.

The phase1 project increased the resistance of the North passage, and changed the distributions of the flow and sediment. Its information is showed on Fig.2 and Fig.3. It is clearly that the distributions changed by the regulation. It is a long period that the effect can be seen, but the branches stability holds the essential significance to the navigations' safe and longtime work.

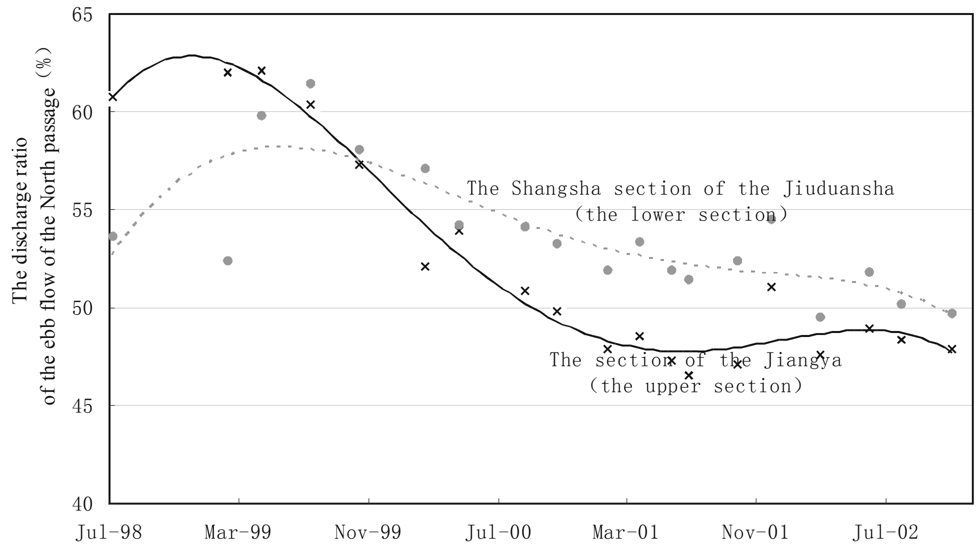

Fig. 2 The discharge ratio of the ebb flow of the North passage during the first phase project

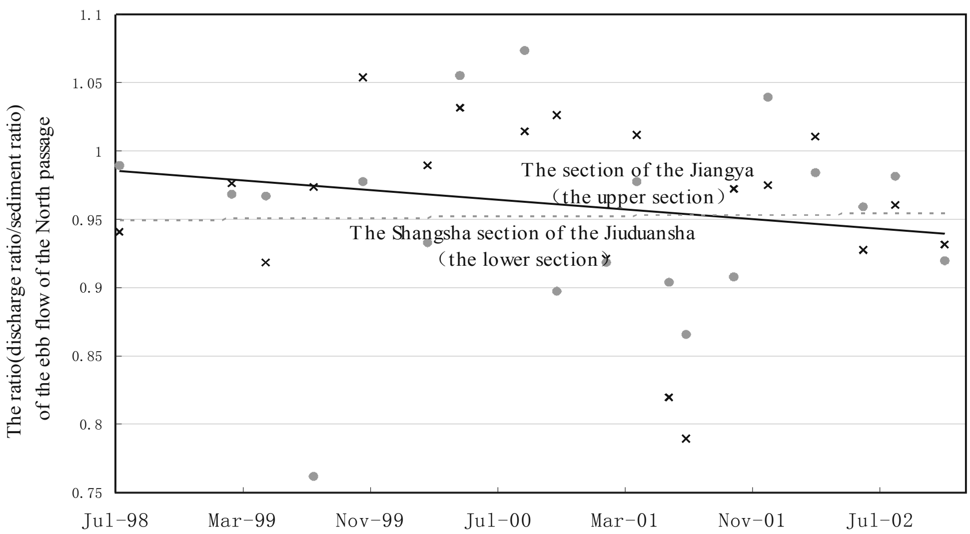

Fig. 3 Ratio (discharge ratio/sediment ratio) distribution of the ebb flow in the North passage during the project phase one

(3) EXCHANGE OF SEDIMENT BETWEEN SHORE AND CHANNEL, ESPECIALLY THROUGH THE CLUSTER DITCHES.

The transversal water surface gradient increases the cross flow and makes the cluster ditches forming, which is one of the main passage for flow and sediment exchange between branches . The flow and sediment movement in the cluster ditches adjusts their distributions in the branch channels, keeps the major branch stable at the same time. For example, the cluster ditch blocked on the east beach of the Hengsha leaded the Hengsha passage extended, therefore the south and north passages were stable (Table 2).

Table 2 Changes of the channel capacity and the mean water depth of the Hengsha passage below 5m

year	the channel capacity (10^7 m^3)	the mean water depth (m)	year	the channel capacity (10^7 m^3)	the mean water depth (m)
1997.5	2.64	7.90	2001.2	3.67	10.15
2000.2-3	3.04	9.40	2001.5	3.58	10.14
2000.5	3.44	10.02	2001.8	3.51	10.07
2000.8	3.41	10.10	2001.11	3.60	10.27
2000.11	3.65	10.28	2002.2	3.60	10.24

The frequent vibration of the main channel and the nature thalweg is one of the major causes for the high back-siltation of the normal 7.0m waterway. The quondam 7.0m waterway has changed its location several times (from the south passage to the north passage). The back-siltation discharge is about $1.2 \times 10^7 m^3$, and if calculated by the waterways' scale and the actual maintenance water depth (the height difference of flat and trough), it is 2−2.4m high, viz. 3−4 folds of the mean maintenance water depth. The maintenance should be done all of the year, dredging with silting and without the surplus water depth. So the actual waterway depth is less than 7.0m. Stabling main flow, especially the main ebb flow, is a very important point for the regulation of the Changjiang estuary.

3. THE MEASURES AND EFFECTS OF MINIMIZING BACK-SILTATION

The measures to minimize the back-siltation in the deep waterways can be basically categorized into two major aspects. One is building the regulating construction to stabilize the river and to regulate and stabilize the current field and the bed configuration in the north passage as well as to fend off the sand coming into the waterway. The other one is correctly determining the location of the navigation channels and establishing scientific and rational criteria for navigation and technology for waterway construction, thus improving the management level of maintenance dredging.

The key phase of science and technology has finished the task of choosing the North passage to regulate. Then the following step is to make a regulating scheme. Its main content includes achieving the river conditions stability, adjusting the current field and landform, improving the maintenance conditions of the deep waterways.

(1) On the diversion putting the spit project in practice is to prevent the foreland (the south foreland of the Jiangya) scoured and migrated down for stabilizing the flow and sediment of the North passage （The -5m foreland line of the Jiangya south foreland migrated down 1800m at 1992−1995, and 500m at 1995−1997.）. Constructing the south and north jetty project is to steady the North passage boundaries, to hold up the sediment exchange in the shallow channels between the South channel and the North passage and between the North passage and the South passage, and to stop the sediment blew into the North passage for stabilizing the North passage.

(2) The conjunct action of the jetties and the groins adjusts the current field of the North passage, turning rotary current into reversing current, plugging the transverse current in the channel and altering the strait trend of ebb flow according with that of the navigation. To adjust the current field is to adjust the North passage's landform, to shape an invariable thalweg trend, to decline the river bottom depth in the regulating range and to minimize the height difference between the dredge trough and the shallow flat (the water depth radio).

(3) The regulating construct shouldn't add the bottom resistance too much and scour too much, and in addition it should be attended the sail condition's change causing by the flow velocity's change.

The first phase project obviously regulated the current field and the landform of the North passage and enhanced the effect of block sediment. The new conditions of deep waterways are showed as follow:

(1) Except around the mouth of the North passage, there are general the reversing currents, whose trends agree with the North passage.

(2) The transverse flow and the oblique flow on the flat and the channel have been eliminated. The trend of the strait ebb flow is consistent with the waterway of the North passage and the flow velocity increases a little on the waterway's middle portion and both sides.

(3) It has been shaped the good-wide and steady thalweg covering all of the waterway, which has 8m water deep and at both sides the flat depth is clearly declined. The height difference also has minimized between the waterway and the flat. Otherwise, the channel capital has been changeless.

(4) The groins 'effect of blocked sediment is very distinct and the sharp deposition by typhoons is commonly limited out of the jetty mouth. The effect of the current field adjusted by jetties is mainly as the regulating training line being.

Of course, it is right that to increase the unit discharge and decrease the silting in waterways about the back-siltation effect of regulation constructions. But there are two points should been attended. One is that the increasing flow resistance will decrease the tidal discharge. To a certain extend, the unit discharge will not increase any more as well as the case of the Longkou. In long views, the less tidal discharge (discharge ratio) will endanger the channels. The other is that at the period of the jetties building the upper or lower riversides maybe will fall under damage because building jetties will decrease the velocity and come up silting at the upper river.

4. CONCLUSIONS

Correct prediction of the amount and distribution of back-siltation in the waterways is an important basis for the the construction plans and the maintenance dredging plans. Experience has been gained in the dredging and maintenance of the 8.5 m deep waterway. It can be basically categorized into two major aspects. One is to build the regulating construction in order to stabilize the river evolvement, to regulate and stabilize the current field and the bed configuration in the north passage as well as to fend off the sand coming into the waterway. The other one is correctly determining the location of the navigation channels and establishing scientific and rational criteria for navigation and technology for waterway construction, thus improving the management level of maintenance dredging.