# Target Analysis of Dredging Ship and Process Schemes of Inland River Main Channels in Jiangsu Province

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**ABSTRACT**

For the dredging projects of inland river main channels in Jiangsu Province, the demand research of suitable dredging ship and dredging process schemes was carried out. Firstly, the development situation and trend of dredging vessels and processes were analysed. Secondly, combined with the current dredging methods commonly adopted in Jiangsu Province, the main dredging problems in the dredging process were discussed. Finally, on the basis of extensive investigation on the dredging environment and characteristics of inland river waterways in Jiangsu Province, considering technology, using, environmental protection and safety the overall design objectives of dredging ship and process schemes of inland river main channels in Jiangsu Province were put forward, and the design scopes and performance requirements of each target were given. The research results provided references for relevant dredging ship and process schemes design.

***Keywords:*** *Inland river, Main channel, Dredger, Construction process, Design objective*

## 1. INTRODUCTION

Waterway refers to the waters where ships are navigable in coastal areas, rivers, lakes and canals. Waterway dredging is a project that concentrates a large amount of manpower, material resources and financial resources. The project has large quantities and complex engineering operation. Once improper operation, it will not only affect the normal construction and operation of the channel, but also affect the local economic and natural environment. Dredging is the engineering measure of using dredging ships or other tools and equipment to increase water depth or remove siltation. A reasonable dredging ship and dredging scheme should be selected for specific works, and the primary task of dredging scheme design is to carry out sufficient field research and analysis to form the technical requirements of the dredging engineering. Prejudging the problems existing in the dredging projects in the early stage and taking effective measures to deal with them can not only guarantee the quality and efficiency of the subsequent dredging projects, but also help to achieve good shipping economic benefits.

## 2. DEVELOPMENT AND TREND OF INLAND RIVER DREDGING VESSELS AND TECHNOLOGY

At present, the number of dredging ships in the United States, the Netherlands and China ranks among the top three in the world. With economic development and social progress, the application scope of dredging equipment is expanding. In order to adapt to the continuous changes of the global dredging market, dredging equipment must develop with the progress of modern science and technology. The trends are shown as follows [1]:

(1)Larger dredging equipment. With the increasingly large scale of the project, the construction period requirements are getting higher and higher which forces the dredger to constantly improve the productivity, so the trend of large-scale is inevitable.

(2)Automated dredging process. The safe and efficient construction of dredging vessels must rely on advanced control and automation technology. It also can help to reduce energy consumption, improve accuracy and achieve the maximum dredging benefits.


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(3)Multifunction. With less investment to achieve some additional features of dredgers which can improve the utilization, applicability and increase profits.

(4)Environmental dredging. Environmental protection requirements are getting higher and higher, and environmental protection dredger and related technologies are also paying more and more attention.

China is a strong country in dredging now, compared with western dredging countries there is no longer exist generation differences, but in some advanced frontier technologies and innovations there is a gap. Due to developed countries who earlier put forward environmental protection requirements and increasing attention to environmental protection dredging, the dredging companies and dredging technology research departments in Europe, America, Japan and other countries started early in the development and investment of environmental protection equipment, and accumulated and mastered the relatively advanced research technology of environmental protection dredging equipment. The development time of environmental protection dredging in China is relatively short, and the relevant research and application technology of environmental protection performance dredging equipment are still in the preliminary stage. Some technical means and methods still have certain defects and are still immature, and compared with developed countries there is still a large gap. In addition, the main technical performance parameters of small and medium-sized domestic inland river dredging vessels are still generally low, and the gap in power configuration is also very obvious [2].

In short, the development of dredging equipment is endless. With the progress of science and technology, more new technologies, new materials and new processes will be applied to the design, manufacturing and use of dredging equipment. The dredging industry will increasingly develop in the direction of high-tech industry.

## 3.PROBLEMS OF INLAND RIVER DREDGING SHIPS AND PROCESSES IN JIANGSU PROVINCE

Jiangsu Province is located in the eastern coastal area of China, it has many rivers and rich in water transport resources. The water area is about 17,300 km2, accounts for 17% of the total area of the province. It is one of the provinces with the most developed inland river shipping in China. The commonly used dredging methods of inland rivers in Jiangsu Province include grab dredger and cutter suction dredger. The main problems in the dredging process are as following [5-7]:

### *3.1.Insufficient ship positioning and excavation accuracy*

The excavation quality is not very good. The flatness of ship excavation is poor which will lead to the bottom ditches are uneven, the overexcavation and missing soil are serious, and affect the original soil and the self-purification ability of water bodies. In addition, with a little careless the dredging works near the banks, wharfs and other buildings will endanger the safety of the structures.

### *3.2. Old equipment and low work efficiency*

Most of the dredging equipment is old and seriously aging. Insufficient introduction of new ship technology and relatively backward technology level cause low dredging production efficiency, short construction life, decreased dredging capacity and increased construction cost. These cannot meet the needs of current shipping development, and dredging equipment needs to be added and updated [3].

### *3.3. Mismatch the environmental protection requirements*

The pollution caused by the dredging works mainly comes from the construction interference of the original soil layer and the returning sewage from the abandoned area. Common cutter suction dredger is to stir and break to promote the mixing of mud and water, and then inhale and discharge the mixing through the centrifugal pump. In the process of stirring, a large number of harmful substances are suspended in water, while the centrifugal pump cannot be fully absorbed them, which is easy to cause water pollution and damage the ecological environment of rivers and lakes. At the same time, limited by the location of the mud dump and drainage distance, the cutter suction dredger requires install and remove a large number of mud drainage pipelines with high investment. Due to the characteristics of the grab dredger, it cannot remove the most polluted liquid silt at the bottom of inland rivers and lakes, and it is also difficult to meet the environmental protection dredging requirements.

### *3.4. Contradiction between construction and navigation*

Many of the frequently used dredgers do not have independent navigation capacity, and although some dredgers have free navigation, the capacity level is limited, and they do not adapt to the actual engineering requirements. In waterway dredging projects, a related supporting fleet is often needed, including dredger, tug, mud barge, etc. The dredging of the large fleet causes navigation obstruction to narrow navigation areas, causes a decline in work efficiency, increasing relevant costs,

and brings inconvenience to work coordination. The dredging of the waterway is not concentrated, with a scattered distribution, and the frequent mobilization of a large fleet has become a headache. Therefore, it is necessary to reduce the fleet size, and make each ship has multiple functions with more efficiency and vitality than the existing fleet [4].

### *3.5. Dredged soil and tailwater discharge problems*

Dredged soil has pollution and strong mobility. The sites of inland river dredged soil are limited by the geographical location of the city, so it is increasingly difficult to find a suitable site. The disposal method of dredged soil is relatively extensive. The method adopted in the early stage has a high additional cost of land waste and environmental damage, which is inconsistent with China's national conditions, and needs to seek new and feasible methods to deal with the dredged soil.

The dredged tail water discharge has always been a difficulty in the dredging project. Due to the limited area of the drainage field, especially in the late stage of the drainage, the high concentration of mud water enters the surrounding river network from the water outlet, which has a great impact on the river water quality. In addition, there are emission standards control in the dredging technical specifications, but the standards are no longer adapted to the emission standards of various industries today. The differences between the standards of agriculture, industry, environmental protection and other departments cause frequent disputes.

### *3.6. Construction cost is higher*

Due to the aging of ship equipment, on the one hand, the maintenance cost of old equipment must be increased, on the other hand, the fuel and lubricating oil consumption of these equipment is also increasing. In addition, the current price of environmental protection dredging engineering is significantly higher than that of general engineering dredging.

## 4.ENVIRONMENTAL CHARACTERISTICS OF DREDGING OF INLAND RIVER TRUNK CHANNELS IN JIANGSU PROVINCE

### *4.1. Waterway planning of inland rivers in Jiangsu Province*

According to the Jiangsu Trunk Waterway Network Planning (2017-2035), by 2035, the trunk waterway network in Jiangsu province has a "two vertical and five horizontal" layout, forming Yangtze River trunk lines and Beijing-Hangzhou Canal as the core, level 3 and above waterway as the backbone, the thousand-ton trunk waterway network, and a total mileage of 4,010 kilometers. The schematic diagram of the planning and layout of the trunk waterway network in Jiangsu Province is shown in Figure 1. It is planned to form a total of 365 kilometers of level 1 channel, 643 kilometers of level 2 channel, 3,002 kilometers of level 3 channel, the thousand ton ships will reach more than 90% of the province's nodes including more than 80% of the major coastal port areas and all the major port areas along the Yangtze River. Some of the planned level 3 waterways that are difficult to implement can be implemented according to the level 4 standard in the near future, but the water depth is not less than the minimum standard of the level 3 waterway (3.2 meters).The net navigation height standard of bridges and buildings across Jiangsu Province trunk waterway network (except Yangtze River trunk lines) shall not be less than 7 meters [8]. The inland waterway grading and waterway clearance size in Jiangsu Province are shown in Table I.

**Table 1.** Inland waterway grading and waterway clearance size in Jiangsu Province

| Channel level | Ship ton (t) | Channel restrictions (m) | | Bridge clearance(m) | |
|---|---|---|---|---|---|
| | | Deep H | Bottom width $B_b$ | Net high $H_m$ | Net width $B_m$ |
| Ⅲ | 1000 | 3.2 | 45 | 7.0 | 70 |
| Ⅳ | 500 | 2.5 | 40 | 7.0 | 55 |

### *4.2. Transport ships*

The distribution of various types of inland river vessels (excluding Yangtze River) in Jiangsu Province in 2014 is shown in Table II. From the ship gross tonnage, grade 3 ships had the largest number of ships, accounting for 57.81% of the total, followed by grade 4 and grade 2 ships, accounting for 34.53% and 6.50% of the total [9]. In 2016, there were 39,922 registered inland river ships in Jiangsu Province, with a total net load tonnage of 32.37 million tons and an average ship load tonnage of 810 tons. .New ships on the trunk waterway (level 4 or above) generally exceed 500 tons, and 1,000 to 2,000 tons ships have navigated on the Beijing-Hangzhou Canal. The total number of ships is less, but the ships are more large, scale and modern.

**Table 2.** Statistics of inland river ships in Jiangsu Province in 2014

| Ship grade | Grade 1 | Grade 2 | Grade 3 | Grade 4 | Grade 5 |
|---|---|---|---|---|---|
| Gross tonnage | GT≥ 1600t | 1600>GT≥ 600t | 600t>GT≥ 200t | 200t>GT≥ 50t | 50t> GT |
| Proportion of ships | 0.58% | 6.50% | 57.81% | 34.53% | 0.58% |

### *4.3. Waterway bank protection structure*

In the river regulation, the use of hard bank protection or ecological bank protection is generally adopted. Through the statistics of various bank structures of representative rivers in Jiangsu Province, the results show that reinforced concrete retaining wall and ordinary concrete slope protection are the most commonly used hard bank revetment types. Danjinlicao River (Changzhou section) adopts the industrial prefabricated bank revetment wall which is transported to the site by water and installed by floating cranes. This kind of waterway bank protection structure is shown in Figure 1. In addition, the ecological bank protection in Jiangsu Province includes ecological self-embedded retaining wall, ecological stone cage slope protection and so on.

**Figure 1** Schematic diagram of the industrial prefabricated bank revetment wall

### *4.4. Cross-river bridges and pipelines*

Because most Jiangsu inland waterways directly pass through cities, towns, there are many the cross river bridges and pipelines. For the early built cross river bridges and pipelines on the trunk waterways (level 4 and above), most of the channel clearance and net width are not up to the standards. But in recent years bridges were all built in strict accordance with the standards, then there is no navigation situation again.

### *4.5. Navigational facilities*

There are more than 50 navigable locks in the Jiangsu inland waterway, among which nearly 30 locks are located on the main waterways, most of which are concentrated on the northern Jiangsu Canal. Over the years, the cargo turnover rate and cargo volume of the northern Jiangsu Canal have increased year after year. Taking Shiqiao Lock as an example, the maximum daily passage of the ship reaches 1.123 million tons, and the average daily passage exceeded more than 1,000 ships, and it is the highest one among the inland river locks in China [10]. As shown in Figure 2, the annual cargo volume of Shiqiao lock is almost twice that of Gezhouba lock in the same period, which shows the great potential of the northern Jiangsu canal locks and high comprehensive economic and social benefits. With the development of economy, cargo volume increases, ships are also in the direction of large, while locks in operation management expose some problems, such as in the northern section of Beijing-Hangzhou Canal the actual pass quantity of some multiple ladder locks has reach or exceed the design capacities of the locks, which will cause ship gate often crowded and form the limits of the transportation efficiency.

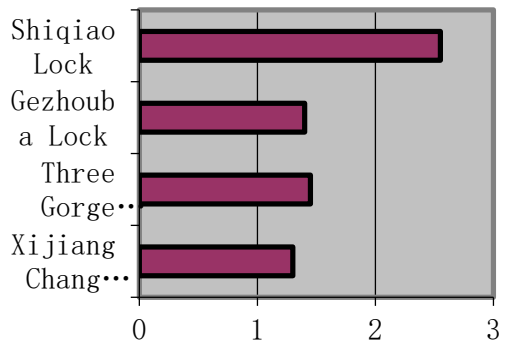


**Figure 2** Comparison diagram of the cargo volume of Shiqiao Lock and important domestic inland river locks in 2018(Unit:100 million tons)

### *4.6. Landscape construction*

Jiangsu adheres to the landscape construction and waterway culture, then gets the cultural achievements with waterway characteristics and The Times characteristics, such as the landscape project in Wangting Canal Park of Southern Jiangsu Canal. This landscape project is focusing on showing the canal town culture and experience, reproducing the ancient buildings, etc.

### *4.7. Comprehensive utilization of dredged soil*

The shoreline resources of Jiangsu Province are very tight, and there are few abandon soil areas along the coast.

The comprehensive utilization of earthwork is encouraged in the waterway renovation. For example, the renovation project of Changzhou section of Beijing-Hangzhou Canal applies the earthwork excavated from the new canal to the construction of new National Highway 321, subgrade filling of expressways and other municipal construction projects.

### *4.8. Low carbon construction*

Relying on the waterway renovation project in the province to carry out the construction of green channel, Jiangsu actively promotes the clean energy utilization and low-carbon construction of inland waterways. For example, in the construction process, Danjinlicao River (Changzhou Section) adopted a series of green cycle and low-carbon technologies such as the first multi-functional concrete special ship and the joint construction of water conservancy facilities shown in Figure 3.

**Figure** 3 Multi-functional concrete special ship

## 5. OBJECTIVES OF DREDGING SHIP AND PROCESS SCHEME OF INLAND RIVER TRUNK WATERWAY IN JIANGSU PROVINCE

Jiangsu Province has a high density of ships, ship locks, docks and other hydraulic structures. Along the river shores there are many towns, dwellings, scenic zones and factories. So the inland waterway dredging characteristics were remarkable in Jiangsu Province. According to the investigation and analysis, the objectives of the trunk waterway dredging ships and process scheme are as follows:

### *5.1. The width, height and draft of the dredgers shall meet the construction requirements and easily reach the construction area*

Thousand-ton ships are the mainstream ship type of inland river operation in Jiangsu Province. So dredgers should be designed according with thousand-ton level, which can dredge level 3 channels and take into account level 4 channels.

Considering that the inland water transportation in Jiangsu Province is relatively developed, the ships can be transported from the waterway to each construction site. The inland waterway is narrow and long, suitable for small dredgers. In Jiangsu Province the bottom width of level 4 channel is 40m, the water depth is 2.5m. In Yangzhou city Yunxi lock is 230m long and less than 10m wide. Several small bridges span across the rivers and their net height is less than 5m.

### *5.2. Advanced equipment technology, accuracy and efficiency meet the dredging requirements to ensure the project quality*

Advanced methods should be actively introduced, aging and outdated construction equipment should be replaced, and advanced technology including the new concentration tester, environmental protection cutter, quality monitoring system also should be introduced. Carrying out the overall technical optimization of inland river dredging equipment that is ensure the high practicability and technology in the construction process. Accurate construction should be implemented, for ecological dredging generally requires excavation accuracy is less than 10cm.

### *5.3. With a certain self-navigation ability*

Self-propelled dredger has the advantages of rapid entering and retreat, fast and easy construction positioning, easy response to emergencies, easy handling, safety and reliability.

### *5.4. The dredger has its own function of dredged soil dehydration and tail water treatment*

The dredging, sorting, dehydration and tail water treatment are all completed at one time on the ship. The coarse materials selected are sorted, recycled and reused. The tail water in the dehydration process is selected in an appropriate area for discharge after treatment on the ship. After dehydration, the dredged soil is transported to the factory by the barges as production raw materials. This disposal method can save land resources, also reduce transportation costs for operating enterprises, will not cause secondary pollution to the environment, and provide high-quality construction materials for national construction.

### *5.5. Developing a multi-purpose dredger to reduce construction costs*

The inland river dredging project is small. From an economic perspective the smaller dredgers should be used. The ship should be self-navigation and mechanical modern, self-loading, self-navigation, and self-unloading. It will not affect the navigation, and realize the construction while navigation. A multi-functional ship

can also save investment, reduce personnel, greatly improve the utilization rate of equipment, to avoid low-level equipment repeated investment and construction.

### *5.6. Maintaining the original navigation capacity during the construction period*

While improving the construction efficiency of dredging, the contradiction between construction and navigation should be reduced. Considering the impact of regional navigation, construction while navigation is usually carried out or one-way control construction is adopted for channel dredging.

### *5.7. Environmental protection dredging*

In addition to affecting the water quality, the dredging pollution also includes the deterioration in air quality, noise, vibration caused by underwater blasting, soil quality and natural terrain. In order to control dredging pollution, advanced dredging equipment and dredging technology should be adopted to ensure high concentration inhalation and control the concentration of suspended objects. The advanced equipment also can lower noise, recover waste water and waste oil. With paying attention to the time and place of construction, reasonable measures also should be adopted to minimize the impact of pollutants on ecological.

### *5.8. Reasonable treatment and reuse of the dredged soil*

Dredged soil is a kind of resource that should be rationally reused and should not be discharged to natural rivers which will affect the ecological environment. Dredged soil has complex composition and different characteristics, which requires scientific treatment to reduce the ecological impact, and should be realized the reuse as far as possible.

### *5.9. Ensure the stability of the bank slopes*

Appropriate dredging equipment should be selected during construction, and reasonable construction methods should be formulated, and strengthen dynamic monitoring during construction to ensure the quality of excavation of the slope.

## 6. CONCLUSION

Jiangsu Province is a major water transportation province in China. With the gradual completion of the main framework of inland river trunk waterway in Jiangsu Province, the waterway development has gradually changed from large-scale construction stage to management and maintenance stage. However, the dredging ship and process scheme adopted are relatively backward, which cannot meet the dredging needs of waterway maintenance in Jiangsu Province, and need to be improved. The paper investigates the development status of inland river dredging vessels and technology at home and abroad, analyzes the problems of dredging methods and dredging characteristics of inland river trunk channels in Jiangsu Province. Then the overall design goals of dredging vessels and process scheme in Jiangsu Province are obtained, which provide the direction for the future design of dredging vessels and processes.

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