Design of Fish Restocking Station for a Water Diversion Project in Guangdong

Deye Chen [1, 2, a] *, Kunlun Shen [1, 2, b], Shengzhe Wu [1, 2, c]

[1] China Water Resources Pearl River Planning Surveying & Designing Co. Ltd,Guangzhou 510610,China;

[2] Aquatic Ecological Engineering Center, Pearl River Water Resources Commission of the Ministry of Water Resources, Guangzhou 510610,China.

[a] 287176352@qq.com, [b] shenkl@prpsdc.com, [c] wusz@prpsdc.com

Abstract. According to 'Environmental Impact Report of the Water Diversion Project in Guangdong' and its reply of the Ministry of Ecology and Environment, a fish restocking station is required to be constructed. The fish restocking station locates in the vicinity of Xijiang River in Yunfu City, Guangdong Province. The primary species for breeding include Gan, Siniperca chuatsi, Channa maculata, Snakehead mullet and Spinibarbus with an annual scale of 450,000 tails. The station is equipped with parent fish pools, hatchery workshop, fry workshop, outdoor fish breeding pool, ancillary circulating water treatment rooms and wastewater treatment facilities. Recirculating aquaculture pattern is adopted. This paper gives a thorough introduction on technical design of fish restocking station, thus providing reference for similar projects.

Keywords: Fish restocking station; technical design; circulating aquaculture.

1. Engineering Background

The water diversion project is located in the southwest of Guangdong, involving four prefectural-level cities which are Zhanjiang, Maoming, Yangjiang and Yunfu. The water intake point locates on the right bank of the main stream of Xijiang River in Yunfu City, Guangdong Province. According to 'Environmental Impact Report of the Water Diversion Project in Guangdong' and its reply of the Ministry of Ecology and Environment, the reeling effect of water intake will cause the loss of fish resources after the operation of project. In order to mitigate negative impact, it is necessary to construct a fish restocking station and form the technical capacity of operation management and fish propagation.

2. Design Basis

2.1 Object and Scale of Fish Releasing

According to 'Environmental Impact Report of the Water Diversion Project in Guangdong', the project will have a certain impact on fish resources of the protected area. As required by 'Fisheries Law of the People's Republic of China' and other related laws and regulations, project owners need to take the fish artificial propagation as a compensation. This project's main releasing species are Guangdong dory, Gan, Mackerel, Grass carp, Spinibarbus, Silver carp, Bighead, Yellow catfish, Siniperca chuatsi, Channa maculata and Snakehead mullet. Among them, 6 types of seedlings are released by outsourcing which are Guangdong dory, Mackerel, Grass carp, Bighead carp, Bighead, Yellow catfish, while the rest by constructing fish restocking station. The quantities and sizes of fish breeding at restocking station are listed in table 1.

Table 1. Releasing Schedule of Fry (Breeding in Stocking Station)

Releasing species	Size（cm）	Quantity（10^4 tails）	Breeding pattern
Gan	12～15	5	Breeding in restocking station
Siniperca chuatsi	6～10	5	
Channa maculata	6～10	15	
Snakehead mullet	6～10	10	
Spinibarbus	6～10	10	
Summation		45	

2.2 Introduction of Fish Breeding at Restocking Station

2.1.1 Gan

Gan is the Asian endemic fish, belongs to the carp-shaped order, carp family, yarrow fish subfamily, Gan genus, commonly known as yellow cheek fish, pole fish and 'water tiger'. Gan is the upper middle layer of large ferocious carnivorous fish [1] which widely distributed in Yangtze river, pearl river, Heilongjiang and other basins. Gan grows large and fast that current-year fish can be up to 0.5 ~ 1.5kg, second-year fish can be up to 3 ~ 5kg, and the largest individual in natural water can be up to more than 50kg [2].

2.1.2 Siniperca chuatsi

Siniperca chuatsi, commonly known as Guihua fish and Bai Gui, belongs to the genus Siniperca of the order Perciformes, family Serpulidae. Siniperca chuatsi is an economically important and ferocious carnivorous fish which is endemic to China. This fish with large body and good taste is distributed in Yangtze River and its southern water system in China, preferring to inhabit flowing waters like rivers and lakes [3]. Siniperca chuatsi is short, with large eyes and a slightly curved dorsal surface. It's maxilla does not extend to the posterior border of eye [4].

2.1.3 Channa maculata

Channa maculata belongs to the order Perciformes, family Channaeidae, genus Channa, commonly known as 'Grass Li' and 'Li fish', which is mainly distributed in the south of Yangtze River basin such as Fujian, Guangdong, Hunan, Guangxi, Yunnan and other provinces. Channa maculata has a tender, fresh and nutritious taste with hematinic and stypsis effect in the field of medicine [5]. The hybrid of Channa maculata as mother and Channa argus can be fed with feed and is an excellent feeding varieties [6].

2.1.4 Snakehead mullet

The snakehead mullet belongs to the order Perciformes, suborder Climbing Perch, family Channaeidae, commonly known as seven-star fish, flower star fish, mountain spotted fish, octopus, etc. It is mainly distributed in swamps and streams in vast hills and mountains in the south of Yangtze River. Snakehead mullet has a small wild population and is less frequently found in the north of Yangtze River [7]. Its meat is tender and tasty, with many pharmacological effects such as nourishing yin and tonifying blood, removing silt and generating new blood, which is regarded as high-grade health care and nutritional food by the citizens of the two Cantons, the two lakes, Hong Kong, Macao and Southeast Asian countries [8].

2.1.5 Spinibarbus

Spinibarbus is commonly known as bamboo carp and green bamboo carp. It belongs to Carpiformes, Cyprinidae, and Barbel [9],and is a famous high-quality economic fish in Pearl River system. Spinibarbus is mainly distributed in Small North River and West River in Yangshan and Lianshan in Guangdong Province. But the population is decreasing year by year that the resources are on the verge of depletion. The fish has tender meat, delicious taste and high food value. Adult

fish has beautiful body shape, turquoise color and carmine-red gills, which also has high ornamental value [10].

3. Technical Design Process

3.1 Technological Process

Fry production can be mainly divided into six stages: parent fish collection, inspection and quarantine, parent fish domestication and cultivation, catalysis and fertilization, hatchery, and fry cultivation.

Parent fish refers to male or female fish with sexual maturity and the ability to reproduce. Most of the parent fish are selected and qualified in local seed farms or natural waters, and then sent to restocking station for further breeding by boats or live-fish trucks. As the seed fish for releasing, the quality of parent fish has a great influence on the qualification of releasing fry.

After being transported to the station, parent fish are first placed in quarantine pool for a comprehensive health check to further ensure their quality. This process is called inspection and quarantine.

The domestication and cultivation of parent fish are mainly done in the parent pools. Feedstuff and water currents stimulation are used to improve breeding environment and promote gonads maturation of parent fish.

Fertilization can be divided into natural fertilization and artificial fertilization. Fish catalyzing is done by injecting female fish with oxytocin and then placing them into catalyzing pool to wait for the birth. Stimulation of running water should be strengthened in this process.

Hatchery is mainly completed in incubation facilities by fertilized eggs. Depending on the characteristics of fertilized eggs, hatchery can be done in incubation buckets, hatchery tanks or Yushchenko incubators.

Fry cultivation can be divided into three stages according to the size of fry, that are splake fry, ursine fry and inchworm fry, and is completed in open-topped fry breeding pool, fry pool and seed pool respectively.

3.2 Breeding Pattern

Hydrostatic aquaculture, flow-through aquaculture and recirculating aquaculture are three common breeding patterns. Hydrostatic aquaculture is suitable for fish restocking stations with abundant land, convenient water access and fish breeding with hydrostatic aquaculture intention. Flow-through aquaculture is preferred for fish restocking stations with relatively abundant land, good water quality, abundant water resources and a certain height difference between the water source and the station. Recirculating aquaculture often applies to fish restocking stations where land and water conditions are restricted. The advantages and disadvantages of these breeding patterns are shown in the following table.

Table 2. Comparison of advantages and disadvantages of different breeding patterns

Breeding patterns	Advantages	Disadvantages
Hydrostatic aquaculture	Lower water demand,lower cost of construction	Relatively bigger footprint,suitable for projects with abundant land resources
Flow-through aquaculture	Lower cost of construction，more adaptable to adverse weather	Higher requirements for water quality, water quantity and a certain height difference between the water source and the station, larger amount of wastewater
Recirculating aquaculture	Smaller footprint,suitable for projects with limited land resources；lower water demand and smaller amount of wastewater	Relatively higher cost of construction and operation

This project locates beside Xijiang River, thus leading to convenient water resources along with land-use shortage. The water intake area of pumping station of main works is about to be designated as first-class drinking water source protection zone, which results in enormous pressure in sewage discharge for it is prohibited in protection zone. After thorough consideration, recirculating water aquaculture pattern is chosed as the main breeding pattern in the process of hatchery and fry culture. Whereas, the parent fish pond is relatively large and has a low density of fish culture, which leads to high breeding and operating cost. In this case, flow-through aquaculture pattern is adopted, and the daily water exchange rate of parent fish pool is taken as 15%.

4. Technical Design Content

4.1 Location and Land-use Condition of Fish Restocking Station

The fish restocking station has the nature of environmental protection and ecological compensation. Taking management, transportation and other factors into account, the location of fish restocking station should be coordinated with the main works. This project is built for water diversion, water pumping station and pumping station management area are constructed beside the water intake point. After thorough consideration, the fish restocking station is designed to locates in the south of pumping station management area, which occupies an area of about 36,000 square meters (including a drainage pumping station and some stacking area due to sloping area).This site is flat and vast that provides ideal condition for the layout of restocking station. Also, this site locates in the west side of Xijiang River and has the advantages of excellent water quality, convenient water intake, convenient transportation. A vast area of farmland nearby can be used as the receptor of outlet water after wastewater treatment and resource utilization. This site is close to pumping station management area that makes it handy for future management, operation and maintenance. Therefore, this site is relatively ideal.

The original field elevation is 15~19m. In order to meet the flood control requirements, designed field elevation is designated as 24.3m. The whole site level needs to be filled up about 5~ 9m.

4.2 Overall Layout

The general layout of the project is shown in the figure below. The land of fish restocking station is relatively regular, long from north to south and wide from east to west. The experimental building is on the left side of the entrance, with a reservoir on its north side which provides water for production and living as well as fire-fighting for the whole station. In the middle of the station lies the fish pool, with the largest area and is also used as a landscape pool. There are two workshops locating on the east side, that are hatchery workshop and fry workshop. The outdoor fry pool and auxiliary circulating water treatment room are arranged on the south side, while the production wastewater treatment facility on the southwest corner, the epidemic isolation pool and bait pool on the southeast corner.

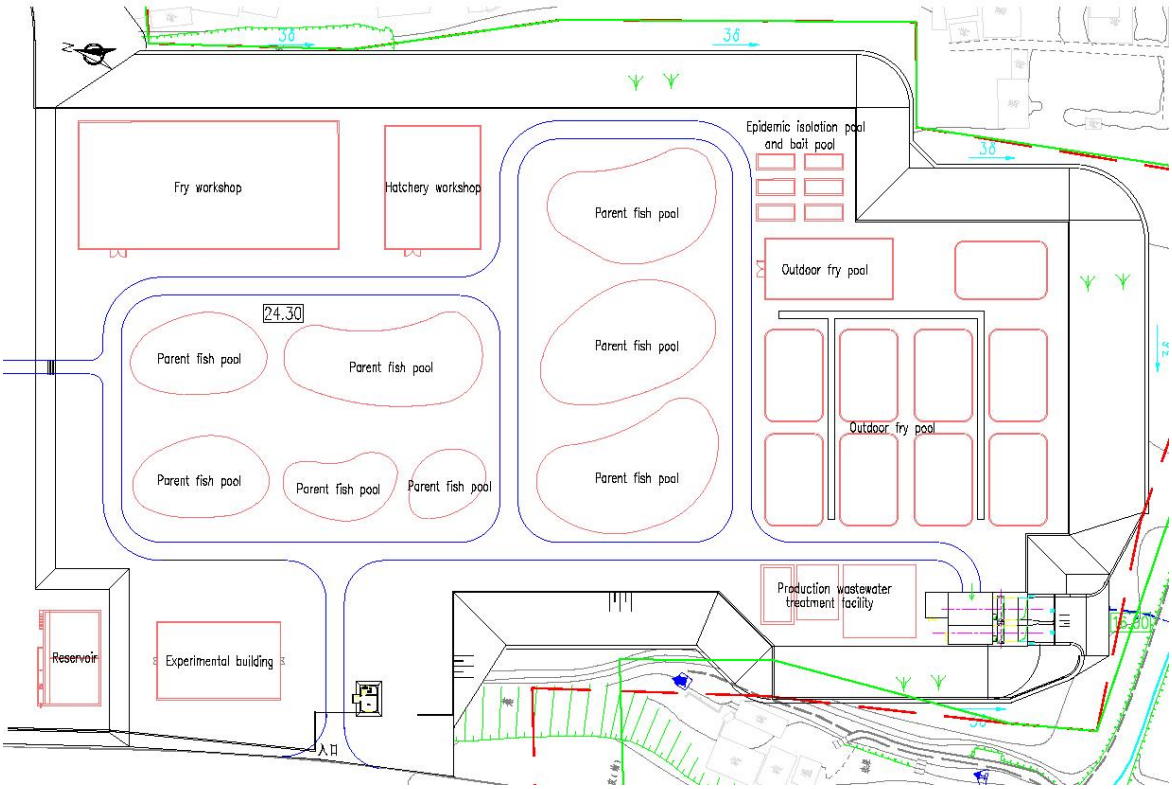

Fig. 1 Layout plan of fish restocking station

4.3 Design of Pump house and Reservoir

The water intake pumping house of the fish restocking station is located in the main pump house of main works. Due to the small amount of water consumption, water is taken from the suction pipe of main pump station, and then pressurized and lifted up to the reservoir.

Pump station management area is of 26.5 meters high while the fish restocking station is of 24.3 meters high. Therefore, the reservoir is arranged inside the pump station management area to make sure a certain height difference between the reservoir and the production pools that production water can flow by gravity. In addition, the reservoir is also used as the fire fighting pool and living pool of the whole management area and fish restocking station. The upper water serves for fish restocking station, the middle for living water and the lower for fire fighting pumps. The total volume of the reservoir is 864m³,being made up of two compartments which is of 432m³ volume individually.

A horizontal-flow grit chamber is set in the inlet of the reservoir to remove gravel and other solids. After the removal, water runs into the reservoir. Two steel gates with the specifications of DN300 is set in the outlet of the horizontal-flow grit chamber to serve as inlet control device for next compartments. Perforated aeration tubes are laid on the bottom of the reservoir. Roots blower is used for aeration to ensure the oxygen content of the inlet water. There are 3 water outlet pipes, which are fire-fighting water outlet pipe, domestic water outlet pipe and production water outlet pipe of the fish restocking station(from bottom to top).It should be ensured that domestic water and fire-fighting water will not be used for other purposes. Besides, overflow pipes are installed 0.2m above the designed water surface.

4.4 Design of Production Buildings

4.4.1 Parent fish pool

According to the ferocity of five different species of parent fish, the breeding density of the parent fish pool is designated as 0.15-0.30kg/㎡, water depth as 2m.There are 8 parent pools in total. One parent fish pool for Gan, with an area of 350m^2.One parent fish pool for Siniperca chuatsi, with

an area of 197m^2.Two parent fish pool for Channa maculata, with an area of 688m^2 and 689m^2 each. Two parent fish pool for snakehead mullet, with an area of 426m^2 and 852m^2 each. Two parent fish pool for Spinibarbus, with an area of 800m^2 and 770m^2 each. The total area of 8 parent fish pools is 4346m^2, the water volume is 8692m^3.The parent fish pools' shape is irregular, and are also used as landscape pools.

The parent fish pool is made of soil by excavating. The slope ratio is 1:1. In the bottom of the pool lays the waterproof membrane. Each single parent fish pool contains inlet and outlet pipes.

4.4.2 Bait pool and epidemic isolation pool

The total amounts of bait pools and epidemic isolation pools are six. The pool is rectangular and made from reinforced concrete structure. Each single pool is of 24 square meters, length of 8m, width of 3m, effective water depth of 1.5m, respectively. Intake pipes and vent pipes are set up at different ends of the pool.

4.4.3 Hatchery workshop

The hatchery workshop is equipped with hatchery equipment, spawning pool, parent fish holding pool, circulating water treatment equipment, blower, indoor pipe ditch and so on. The length of hatchery workshop is 26.90m and the width is 20.90m.

(1) Incubator

All of the fertilized fish eggs(5 types) bred in the fish restocking station are drifting fertilized eggs. There are 32 glass fiber reinforced plastic (FRP) hatchery tanks in total, with the diameter of 0.86m and the height of 1m for each single one.

In order to carry out scientific research and prepare for subsequent releasing, additional hatchery grooves and Yushchenko incubators are set up for sticky fertilized eggs, sinking fertilized eggs and sticky fertilized eggs after de-sticking.

A total of 8 hatchery grooves are set up to incubate sticky fertilized eggs, made of FRP, with the dimensions of 2m×0.8m×0.6m. 3 Yushchenko incubators are set up to incubate sinking fertilised eggs and the sticky fertilized eggs after de-sticking, with the dimensions of 3.26m×0.85m×0.89m.

There are 6 types of pipelines being set up in incubation equipments, which are circulating water supply pipe, circulating water return pipe, fresh water replenishment pipe, aeration pipe, drainage pipe and overflow pipe.

(2) Parent fish holding pool and oxytocking pool

In hatchery workshop, there are two parent fish holding pools and two oxytocking pools. Both of which are reinforced concrete structures and circular with a diameter of 3m. The effective depth is 1.3m and the over-height is 0.3m.

Considering the large size of Gan [2], two specifications of the oxytocking pools are designed with the diameters of 3m and 4m respectively. The effective depth is 1.3m.

There are 6 types of pipelines being set up in parent fish holding pools and oxytocking pools that are the same as those in incubators.

(3) Roots blower

There are 4 Roots blowers in hatchery workshop,2 of which are for oxygen supply of the reservoir(1 with a standby),2 of which are for oxygen supply of incubators, the parent fish holding pools and oxytocking pools(1 with a standby).The parameters of the Roots blowers are Q=4.8m^3/min, P=40kPa, N=5.5kW and Q=4m^3/min, P=19kPa, N=3kW, respectively.

(4) Circulating water treatment equipment

The circulating water treatment equipment set in hatchery workshop mainly circulates the water in incubators, the parent fish holding pools and the oxytocking pools, with the designed treatment flow rate of 100m^3/h and the designed number of circulations of 24 times per day. The treatment process is physical treatment combining biological treatment. Circulating water should pass through microfilter, water-collecting pool, protein separator, biological filter and UV sterilizer in turn. Microfilter mainly removes large solid waste in circulating water. Protein separator mainly removes tiny suspended matter such as bioflocs, cellulose, proteins and other dissolved substances (or small

particles of organic impurities).Biofilter adopts biofilm method, removing pollutants such as organics, nitrogen, phosphorus, etc.. Ultraviolet sterilizer kills residual pathogenic bacteria. The effluent after circulating water treatment reaches the standard of circulating water reuse as stipulated in NB/T 35037-2014 'Design Code for Fish Breeding and Releasing Station of Hydropower Engineering'.

Circulating water flows into microfilter by gravity through circulating water return pipe firstly. The water pump of water-collecting pool pressurized the water and lifted it up to protein separator. Then the water passes through the biofilter and UV sterilizer by gravity. After all treatment processes, the water finally enters into every pool through circulating water supply pipe to complete one cycle.

(5) Pipe ditch

Pipe ditches are set up in hatchery workshop to lay circulating water supply pipes, circulating water return pipes, fresh water replenishment pipes, aeration pipes and sewage pipes. At the bottom of the ditch, a slope of i=0.01 is set to discharge overflow water from pools and residual water on the workshop ground. Main ditch and branch ditch are the two main ditch types being used.

One main pipe ditch is laid along the length of hatchery workshop, with the width of 1m and depth of 1.6m ~ 1.75m.In the ditch, pipes are arranged in two layers. The upper layer are circulating water supply pipe, fresh water replenishment pipe and aeration pipe, the lower layer are circulating water return pipe and sewage pipe. Four branch ditches is laid along the width of hatchery workshop, with the width of 0.6m and depth of 0.7m ~ 0.8m.The pipes in branch ditches are smaller in size so they are laid in one single layer.

4.4.4 Fry Workshop

Fry workshop is equipped with open-topped fry breeding pool, fry pool, circulating water treatment equipment, blower, indoor pipe trench, etc. The length of the fry workshop is 57.10m and the width is 27.90m.

(1) Open-topped fry breeding pool

The open-topped fry breeding pool is used to breed splake fry. The breeding density is taken as 10,000 tails/m³.The time of open fry stage is short so staggered production can be carried out [11].In order to save investment and improve the equipment utilization efficiency, open-topped fry breeding pool is designed to be used two times per year. A total of 36 open-topped fry breeding pools are set with reinforced concrete structure, circular and diameter of 2m. The effective water depth is 0.9m and the super high takes 0.3m.

There are 6 types of pipelines being set up in open-topped fry breeding pools, which are circulating water supply pipe, circulating water return pipe, fresh water replenishment pipe, aeration pipe, drainage pipe and overflow pipe.

(2) Fry pool

The fry pool is used to cultivate Grey mullet fry. The breeding density is taken as 2,500 tails/m³.9 rectangular fry pools with reinforced concrete structure are set up in total, with the length of 12m and width of 3m. The effective water depth is 1m and the super high takes 0.3m.

There are 6 types of pipelines being set up in fry pools that are the same as those in open-topped fry breeding pools.

(3) Roots blower

There are 2 Roots blowers in fry workshop to supply oxygen for open-topped fry breeding pools and fry pools, with 1 set for use and 1 set for backup. The parameters of the Roots blowers are Q=8m³/min, P=19kPa, N=5.5kW.

(4) Circulating water treatment equipment

The circulating water treatment equipment in fry workshop is mainly used to circulate the water in production pools. The designed treatment flow rate is 200m³/h and the designed number of cycles is 12 times per day. The treatment process, treatment flow and effluent standard are the same as the circulating water treatment equipment of hatchery workshop.

(5) Pipe ditch

Pipe ditches set up in fry workshop work the same as in hatchery workshop. There are mainly two types of pipe ditches: the main pipe ditch and the branch pipe ditch.

One main pipe ditch is laid along the length of fry workshop, with the width of 1m and depth of 1.6m~1.9m. In the ditch, pipes are arranged in two layers. The upper layer are circulating water supply pipe, fresh water replenishment pipe and aeration pipe, the lower layer are circulating water return pipe and sewage pipe. Six branch ditches is laid along the width of fry workshop, with the width of 0.8m and depth of 0.9m~1.0m.Pipes are arranged in two layers in branch ditches, the same as in main pipe ditch.

4.4.5 Outdoor fish breeding pool and ancillary structures

(1) Outdoor fingerling pool

The outdoor fingerling pool is set to cultivate inch-size fry in the south side of the station. The breeding density is taken as 280 tails/m³.9 rectangular fry pools with reinforced concrete structure are set up, with the length of 20m and width of 12.5m. The effective water depth is 1m and the super high takes 0.3m.

There are 6 types of pipelines being set up in outdoor fingerling pools that are the same as those in open-topped fry breeding pools.

(2) Circulating water treatment room

The circulating water treatment room mainly treats the water in outdoor fingerling pools. The designed treatment flow rate is 600m³/h and the designed number of cycles is 6 times per day. The treatment process, treatment flow and effluent standard are the same as the circulating water treatment equipment of hatchery workshop.

There are 2 Roots blowers to supply oxygen for outdoor fingerling pools, with 1 set for use and 1 set for backup. The parameters of the Roots blowers are Q=11m³/min, P=19kPa, N=7.5kW.

(3) Outdoor pipe ditch

The supporting pipes of outdoor fingerling pools lays in outdoor pipe ditch, including circulating water supply pipe, circulating water return pipe, fresh water replenishment pipe, aeration pipe and sewage pipe. There are 1 main ditch and 2 branch ditches and both are arranged in 2 layers. The upper layer is laid with circulating water supply pipe, fresh water replenishment pipe and aeration pipe, the lower layer is laid with circulating water return pipe and sewage pipe. The width of main ditch is 1.5m and the depth is 1.8m~2.1m. The width of branch ditch is 1.5m and the depth is 1.5m~1.8m.

4.5 Design of Production Wastewater Treatment

Wastewater from each production pool is discharged regularly to production wastewater treatment facility. The treatment facility consists of a regulating pool, an integrated treatment equipment and an ecological reuse pool.

4.5.1 Regulating pool

Regulating pool is used to adjust the amount and quality of wastewater.The pool's length is 12m, width is 6m,and effective depth is 2.5m. A tooth rake-type rotary grille is installed in the front to intercept large solid pollutants in suspended or floating state. In the end are 4 pumps, including 2 sets of 1# submersible sewage pump and 2 sets of 2# submersible sewage pump (all are one with a spare). 1# submersible sewage pump is used to lift regular water to integrated treatment equipment. 2# submersible sewage pump is used to lift excessive water to ecological reuse pool.

4.5.2 Integrated treatment equipment

The treatment scale of integrated treatment equipment is 500m³/d. Biological method is used and the effluent standard reaches the stricter value of primary standard in second stage of 'Limit Standard of Water Pollutant Discharge in Guangdong'(DB4426-2001) and 'Municipal Sewage Recycling-Urban Miscellaneous Water Standard'(GB/T18920-2020).

4.5.3 Ecological Reuse Pool

The ecological reuse pool is of 400 square meters and the effective water depth is 2m. Above the water is biological floating islands, under the water is hydrophytes. In addition to degrade pollutants, the pool is also capable of ecological landscape demonstration.2 reuse pumps are set up in the pool with one and a spare. The effluent is preferred to be used for green watering and road cleaning in station, while excessive effluent is partially discharged to agricultural irrigation canal outside the station for resource utilization.

5. Conclusions

The fish restocking station construction is one of the primary ecological protection measures of water intake of the water diversion project in Guangdong. Its implementation can effectively mitigate negative impact of engineering construction on fish resources. This paper gives a thorough introduction on technical design of fish restocking station. Under the realistic conditions of limited land at water intake and high pressure of sewage discharge in adjacent water protection zone, recirculating aquaculture pattern is preferable. This is of positive significance to ecological environment protection of Xijiang River, and also provides a reference for the design of fish restocking stations in water conservancy projects.

References

[1] SHEN Zhigang, GUAN Hehe, DING Yunmin, et al. Gan artificial propagation and seedling breeding research progress[J/OL]. Journal of Aquatic Biology:1-9[2024-04-15].https://sso.gzlib.org.cn/interlibSSO/goto/75/+jmr9bmjh9mds/kcms/detail/42.1230.q.20231108.0933.006.html.

[2] WAN Songliang, WANG Liang, LI Jianbin, et al. Gan Gan artificial reproduction technology preliminary research[J]. Journal of Aquaculture, 2008, 21(1):6.DOI:10.3969/j.issn.1005-3832.2008.01.003.u

[3] Morphological differences among three wild populations of Siniperca chuatsi in the Pearl River Basin[J]. Chinese Aquatic Sciences, 2016, 23(2):11.DOI:CNKI:SUN:ZSCK.0.2016-02-019.

[4] ZHU Shuqin,ZHAO Jinliang,ZHOU Yunhong,et al. Morphological differences between Siniperca chuatsi, Siniperca chuatsi and its ‘intermediate types’ in the middle reaches of the Yangtze River[J]. Aquatic Sciences, 2021, 40(4):7.DOI:10.16378/j.cnki.1003-1111.19298.

[5] Chen Fen-Shen. Research on artificial propagation and nursery technology of snakehead mullet[J]. Fisheries Research, 2004, 000(003):68-69.

[6] YE Zhongping,ZHONG Qiang,LIN Gang. Reproductive biology of Zuojiang snakehead[J]. Aquatic Science and Technology Intelligence, 2015, 42(3):5.DOI:10.16446/j.cnki.1001-1994.2015.03.009.

[7] LIN Dongnian. Experiments on total artificial propagation of snakehead mullet[J]. Water conservancy and fishery, 2005(003):025.

[8] LI Xingxian, FENG Yaoquan, YU Xiakui. Research on artificial breeding technology of snakehead mullet[J]. Freshwater Fisheries, 2004.DOI:CNKI:SUN:DSYY.0.2004-06-020.

[9] Chen Ting. Experiment on cultivation of barbs[J]. Fishing Guide to Riches, 2016(16):3.DOI:CNKI:SUN:YYZF.0.2016-16-021.

[10] LIN Wei-Qiang,CHEN Ting,LIAO Xian-Ping,et al. Research on the key technology of large-scale nursery of barbel[J]. Anhui Agronomy Bulletin, 2016, 22(9):3.DOI:10.3969/j.issn.1007-7731.2016.09.061.

[11] YANG Zhenbing LI Yaohui ZHANG Yang. Research on process design of fish propagation station in Fengshan Reservoir[J]. Water conservancy and hydropower engineering design, 2022, 41(1):22-25.