SFG2573

Han River Yakou Inland Waterway Navigation Complex Project

Environmental Impact Assessment Report

(Original Domestic EIA, Approved by MEP Febuary 2016)

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December, 2015

Preface

The middle and lower reaches of Han River, covering a populous and prosperous region with rapid social and economic development, is a pivotal shipping route boasting of abundant hydropower resources. The Yakou Shipping Hub Project is the sixth project of the hydro-development program of Han River within Hubei Province. Located at Yakou Village, Xiangbei Farm, 15.7 km downstream of Yicheng City, 52.67 km from Cuijiaying Dam Site in the top and 59.38 km from the Nianpanshan Dam Site in the bottom, the project is a shipping complex which will also facilitate irrigation, power generation, tourism development of the local region.

The project site covers a basin area of 133,087 km^2, with mean discharge at 1,100 m^3/s. The hub comprises of an earth-rockfill dam, sluices, low-head hydropower station, fish locks and fish ways. The normal water level of the reservoir is 52.22 m (capacity of 350.2 million m^3), which is adjustable on a daily basis; there are Grade III artificial waterways of 52.67 km, while the ship lock's designed capacity is 1000 tons, installed capacity of hydropower station 74.2MW, annual generating capacity 322 million kWh. The project is classified as a Class-II Large-scale (B) project. Total investment is 3.154 billion Yuan, of which 212.6912 million Yuan is used for environmental protection. The project plays an important role in the national energy development strategy and also is in line with the power sector development of Xiangyang City and Hubei Province; further, it constitutes an important part of the Han River Shipping Network and will promote the socio-economic development of Xiangyang City.

Water conservancy authorities have drafted multiple plans for development of Han River Basin since the 1950s. In 1954, Changjiang Water Resources Committee (namely, former Yangtze River Basin Planning Office, hereinafter referred as "CWRC") started study on Han River basin, and it issued *Report on Key Points of Han River Basin Planning* in 1956, and then revised it as *Summary of Report on Han River Basin Planning* in 1958. It defines the major water conservancy tasks, i.e., flood control, irrigation, power generation and shipping, and plans to divert Han River to Yellow River and Huai River for long-term benefits. It also recommends that Danjiangkou Hydro-juntion should be the first-phase project for comprehensive utilization of Han River. Danjiangkou Hydroproject was officially commenced on Sept. 1, 1958.

In 1993, CWRC issued *Comprehensive Utilization Planning Report for the Water Section of Han River Downstream from Jia River*, defining the development tasks of this river section as flood control, irrigation, power generation, shipping, water supply, water diversion for middle route project of South-to-North water diversion project, etc. It proposed a 9-section development program: Gushan (179.23m)- Danjiangkou (168.23m) - Wangfuzhou (86.23m)- Xinji (76.23m)- Cuijiaying (62.23m)- Yakou (55.22m)- Nianpanshan (49.23m)- Huajiawan (40.22m)- Xinglong (34.23m). In 2004, Hubei Provincial Water Resources and Hydropower Planning Survey and Design Institute worked out the *Pilot Planning Outline for Modernization Construction of Water Conservancy at Middle and Lower Reaches of Han River Basin in Hubei Province* (hereinafter referred to as *Planning Outline*), which proposed to build up a 7-section hydro-complex: Danjiangkou – Wangfuzhou – Xinji – Yakou – Nianpanshan – Xinglong by 2020. In Feb. 2005, In February 2005, the *Planning Outline* was approved by the Ministry of Water Resources and the People's Government of Hubei Province in SGJ Document [2005] 85. According to the reply of Hubei Provincial People's Government to *Request of Determination of PIU of Han River Yakou Shipping Hub Project* in Nov. 2011, Hubei Provincial Communications Planning and Design Institute completed the *Preliminary Feasibility Study Report of Han River Yakou Shipping Hub Project* in Mar. 2012, and completed the *Feasibility Study Report of Han River Yakou Shipping Hub Project* (Version for Review) in Jul. 2013, which was approved by the Comprehensive Planning Division of Ministry of Transport in Mar. 2014.

In May 2011, CCCC Second Harbor Consultants Co., Ltd. compiled the *EIA Report on the Plan of Building High-Grade Waterways in Han River and Jianghan Canal (2011-2015)*, which analyzed the importance of the construction plan, its environmental impact, resources availability and utilization, etc. and came up with detailed findings. In Jul. 2011, the plan passed the technical examination of the Ministry of Environmental Protection, which can provide reference for optimization of this project. Once completed, Yakou Shipping Hub will become an important part of the Yangtze River Economic Belt, and it will also contribute to the development strategy of Hubei Province which is fervently developing industrial belts and circles to promote the development of the Province and even central China.

In May 2012, Datang Xiangyang Hydropower Co., Ltd entrusted Hubei Academy of Environmental Sciences to conduct retrospective study on the environmental impact of the hydropower development in the middle and lower reaches of Han River. In Aug. 2012, Hubei Academy of Environmental Sciences completed the *Retrospective Report on the Environmental Impacts of Hydropower Development in the Middle and Lower Reaches of Han River*. In Nov. 2013, the retrospective report was reviewed and replied by MEP by *Opinions on the Retrospective Report on the Environmental Impacts of Hydropower Development in the Middle and Lower Reaches of Han River* (Document No. HBH [2013] 1273).

In Jun. 2012, Hubei Institute of Archaeology compiled the *Survey for Historical Relics of Han River Yakou Shipping Hub Project*, and no valuable relics and heritages were found within project site. The State Administration of Cultural Heritage therefore approved the commencement of the project (*Opinions from the Archaeological Survey concerning Han River Yakou Shipping Hub Project*, EWWH [2012] No. 27).

In Jun. 2012, Department of Land and Resources of Hubei Province clarified that there are no important mineral resources within project site covered land (*Letter on Mineral Resources below Han River Yakou Shipping Hub Project*, ETZYH [2012] No. 28).

In Jun. 2014, Hydrological Office, Yangtze Water Resources Committee compiled *Report on Flood Control of Hubei Han River Yakou Shipping Hub Report* (Version for Appraisal), *Report on the Water Resources of Hubei Han River Yakou Shipping Hub Project* (Version for Appraisal), which was approved by Changjiang Water Resources

Committee with Changjiang License [2015] No. 68.

Since the Environmental Impact Report is required during feasibility assessment stage according to Chinese laws, we, Zhongnan Engineering Corporation Limited, PowerChina, entrusted by the PIU (Administration of Shipping and Ports, Department of Transportation of Hubei Province), undertakes the EIA work (See Attachment 1).

We entrusted the Institute of Hydroecology, MWR & CAS to assess the project impact on aquatic ecology of Han River. The Institute of Hydroecology carried out two sampling survey during Jul. ~ Aug. 2012 and Apr. ~ Sept. 2014 and conducted extensive academic research, completing the *Special Report on the Impact of Aquatic Ecology of Han River Yakou Shipping Hub Project*. Since the Environmental Protection Office stated that “the hydro-development projects in Yakou and Nianpanshan will cause significant adverse impacts on the proliferation, migration and inhabitation of fishes, while more study is needed for the scope and seriousness of such impacts and the effectiveness of the mitigation measures” (HBH [1013] No. 1273). For this reason, the PIU entrusted the Institute of Hydroecology to design fish passes and fish breeding and releasing stations and asked for joint ecological operation; together with the Institute of Hydroecology, we carried out study on joint ecological operation for Han River sections below Danjiangkou and proposed *Plan for Joint Ecological Operation for Han River sections below Danjiangkou (Trial)* as well as its feasibility report.

We also entrusted Wuhan Imaginationnovo Co., Ltd to assess the project impact on terrestrial organisms and entrusted Shenzhen Centre Testing International (CTI) to carry out baseline survey on the water and soil quality of the related river sections and the air, noise and other environmental factors; CTI also conducted pollutant monitoring and toxic extraction test, and collected monitoring data on the water quality of river sections in the downstream of the built reservoirs in Han River; Report on project impacts on terrestrial organisms and report on environmental baseline study are completed.

In Dec. 2013, Hubei Provincial Water Resources and Hydropower Planning Survey and Design Institute completed the Plan on Water and Soil Conservation for Han River Yakou Shipping Hub Project, which was reviewed and approved by the Ministry of Water

Resources in Mar. 2015.

We have investigated the project site for multiple times to study the local landform, surface water, climate, soil, vegetation, socio-economic development and infrastructure, and conducted public consultation in various forms. Based on the FSR of the report, we have done massive work on the environmental baseline analysis, environmental impact analysis, recommended mitigation measures and environmental protection budgeting, and we completed the *EIA on Han River Yakou Shipping Hub Project* (draft version) in Aug. 2014, which passed the preliminary review of Transport Planning & Research Institute, Ministry of Transport, China in Dec. 2014 (JGHH [2015] No. 316). Later, we finished special reports on design of fish passes and fish breeding and releasing stations, and joint ecological operations based on the baseline survey on water quality of the project-involved river sections, and completed the latest version of *EIA on Han River Yakou Shipping Hub Project* in Nov. 2015.

We highly appreciate the support and assistance from Hubei Environmental Protection Bureau, Department of Transportation of Hubei Province, Xiangyang Municipal People's Government, Yicheng Municipal People's Government, Yicheng Water Supplies Bureau, Environmental Protection Bureau, Bureau of Land & Resources, as well as the dedicated work done by the Institute of Hydroecology, MWR & CAS, Wuhan Imaginationnovo Co., Ltd, Shenzhen Centre Testing International, Hubei Provincial Water Resources and Hydropower Planning Survey and Design Institute and Hubei CPDI for making this report!

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14 Reply to Yakou Shipping Hub Project Referendum, Wetland Protection Center, Forestry Department of Hubei Province, Clarification on the Impacts of Yakou Shipping Hub Project on Wanyangzhou National Wetland Park, Forestry Department of Yicheng City

15 Notice on the Consent to the Construction Plan of Han River Yakou Shipping Hub, Changjiang Water Resources Commission (CXK [2015] No. 55)

16 Opinions on Flood Control Assessment Report of Han River Yakou Shipping Hub, Changjiang Water Resources Commission (CXK [2015] No. 68)

17 Reply to the Water and Soil Conservation Plan of Han River Yakou Shipping Hub Report (SBH [2015] No. 132)

18 Preliminary Review on the EIA Report of Hubei Han River Yakou Shipping Hub Project, Transport Planning & Research Institute, Ministry of Transport (JGHH [2015] No. 316)

19 Letter of Commitment on Preparation and Implementation of Water Pollution Control Plan for Han River Basin (Xiangyang Section)

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1 Introduction

1.1 Objectives

Based on the project features, local environmental conditions and the conditions of the river basin, and according to the national laws and regulations, this EIR is prepared to:

a) Investigate and analyze the pollution sources, the environmental conditions (including water, atmospheric, acoustic, ecological and social environment), the sensitive receptors and the environmental problems in the project affected area, and get clear on local environmental functions, current environmental quality and future development trend.

b) Predict and evaluate the impacts of project construction & operation and resettlement activities on surrounding environment, analyze the location relations between the project site and surrounding sensitive receptors, and assess the compliance of the project with relevant standards and requirements.

c) Work out proper measures to mitigate the adverse environmental impacts of project construction & operation and resettlement activities, fully exert the economic, social and environmental benefits of the project, and promote benign and sustainable development of ecological environment in the project affected area.

d) Demonstrate the feasibility of the project from the perspective of environmental protection to provide a scientific basis for plan demonstration, environmental management and project decisions.

1.2 References

1.2.1 Laws and regulations

Law of the People's Republic of China on EIA (Sep. 1, 2003);

Environmental Protection Law of the People's Republic of China (January 1, 2015);

Water Law of the People's Republic of China (October 1, 2002);

Law of the People's Republic of China on Ports (January 1, 2004);

Water Pollution Prevention and Control Law of the People's Republic of China (June 1, 2008);

Law of the People's Republic of China on Prevention and Control of Atmospheric Pollution (September 1, 2000);

Law of the People's Republic of China on Prevention and Control of Pollution from Environmental Noise (March 1997);

Law of the People's Republic of China on the Prevention and Control of Environmental Pollution Caused by Solid Wastes (April 1, 2005);

Law of the People's Republic of China on Water and Soil Conservation (March 1, 2011);

Law of the People's Republic of China on Promoting Clean Production (January 1, 2003);

Land Administration Law of the People's Republic of China (the second amendment on August 28, 2004);

Cultural Relics Protection Law of the People's Republic of China (October 2002);

Mineral Resources Law of the People's Republic of China (January 1997);

Forestry Law of the People's Republic of China (April 29, 1998);

Law of the People's Republic of China on the Protection of Wildlife (April 1998);

Fisheries Law of the People's Republic of China (August 2004);

Law of the People's Republic of China on Flood Control (January 1, 1998);

Law of the People's Republic of China on the Prevention and Treatment of Infectious Diseases (December 2004);

Urban and Rural Planning Law of the People's Republic of China (January 1, 2008);

Regulations on the Administration of Construction Project Environmental Protection (Order No.253 of State Council, November 1998);

Regulation of the People's Republic of China on the Administration of River Courses (Order No.3 of State Council, June 1988);

Regulation of the People's Republic of China on the Administration of Navigable Waterways (G.F. [1998] No.31, October 1987);

Regulations of the People's Republic of China for the Administration of Water

Transport (Amended in December 1997);

Detailed Rules for the Implementation of the Water Pollution Prevention and Control Law of the People's Republic of China (Order No.284 of State Council, March 2000);

Regulation on the Implementation of the Land Administration Law of the People's Republic of China (Order No.256 of State Council);

Regulation for the Implementation of the Cultural Relics Protection Law of the People's Republic of China (Order No.377 of State Council);

Regulations of the People's Republic of China on Wild Plants Protection (Order No.204 of State Council);

Regulations of the People's Republic of China on the Prevention of Shipbreaking Pollution (June 1, 1988);

Regulations on Land Acquisition Compensation and Resettlement for Construction of Large and Medium-sized Water Conservancy and Hydropower Projects (Order No.471 of State Council);

Regulations of the People's Republic of China on Urban Water Supply (Order No.158 of State Council, July 19, 1994);

Regulations on the Safety Administration of Dangerous Chemicals (Order No.344 of State Council, March 15, 2002);

Decision of the State Council on Materializing Scientific Viewpoint of Development and Strengthening Environmental Protection (G.F. [2005] No.39);

Regulation on Land Reclamation (Order No.19 of State Council);

National Ecological Environment Construction Planning (January 1999);

National Major Function-Oriented Zone Planning (by the State Council in December 2010);

National Overall Plan for Emergency Response to Public Incidents (January 2006);

Regulations on the Protection of Basic Farmland (December 1998);

Other regulations issued by the People's Republic of China

1.2.2 Department regulations and regulatory documents

Provisions on the Administration of Port Construction (Order N0. 5 [2007]of the Ministry of Communications, effective date: June 1, 2007);

Provisions on the Administration of Navigable Channel Construction (Order N0. 3 [2007] of the Ministry of Communications, effective date: May 1, 2007);

Measures for the Administration of Environmental Protection of Transport Construction Projects (Order N0. 5 [2005] of the Ministry of Communications, effective date: June 1, 2003);

Provisions on Pollution Prevention and Control of Source Water Protection Areas (July 10, 1989);

National Plan for Environmental Protection of Urban Drinking Water Sources (2008-2020) (issued by five ministries and commissions including National Development and Reform Commission, Ministry of Environmental Protection and the Ministry Of Water Resources);

National Plan for Layout of Inland Waterway and Ports (2006-2020);

Notice on Enhancing Environmental Protection for Hydropower Construction (H.F. [2005] No. 13);

Catalogue for the Classified Administration of EIAs for Construction Projects (Ministry of Environmental Protection, June 1, 2015);

Notice on Strengthening the Ecological Environment Management for Natural Resources Development and Construction Projects (December 2004);

Regulation of the Peoples' Republic of China on the Protection of Terrestrial Wild Animals (Amended in January 2011);

Regulation of the Peoples' Republic of China on the Protection of Aquatic Wild Animals (Amended in February 2013);

Provisions of the People's Republic of China on the Prevention and Control of Vessel Pollution of the Inland Water Environment (Order N0. 11 [2005]of the Ministry of Communications);

Provisions of the People's Republic of China on the Administration of Navigation Safety for Above-Water and Underwater Construction Activities (Ministry of Communications, January 2000);

Notice on Issues Concerning the Land Used for Water Resources and Hydropower Projects (G.T.Z.F. [2001] No. 355);

Notice concerning Strengthening Management over Environmental Impact Evaluation and Preventing Environmental Risks (H.F.[2005] No. 152);

Notice on Further Promoting the Pilot Program of Environmental Supervision for Construction Projects (H.B. [2012] No. 5);

Opinions on Strengthening the Supervision over Ecological Environment Protection for Resource Development (H.F. [2004] No. 24);

Letter on Issuing the Technical Guidelines for EIA of Ecological-Use Water, Low Temperature Water and Fish Passage Facility in River Course for Water Resources and Hydropower Construction Project (for Trial Implementation) (H.P.H. [2006] No. 4);

Letter on Issuing the Meeting Minutes on Technology Policies for Soil and Water Conservation and Aquatic Ecology Protection for Water Resources and Hydropower Construction Project (H.B.H. [2006] No. 11);

Interim Measures for Public Participation in EIA (H.F. [2006] No. 28);

Notice on Further Enhancing Environmental Protection for Hydropower Construction (H.F. [2012] No. 4 of Ministry of Environmental Protection);

Notice on Further Strengthening Water Living Resources Protection and Tightening up EIA Administration (H.F. No. 86 [2013] of the Ministry of Environmental Protection and the Ministry of Agriculture);

Notice on Further Implementing the Ecological Environment Protection Measures for Hydropower Development (H.F. No. 65 [2014] of the Ministry of Environmental Protection and National Energy Administration);

Notice on Further Promoting the Pilot Program of Environmental Supervision for Construction Projects (H.B. No. 5 [2012] of the General Office of the Ministry of

Environmental Protection);

List of National Key Protected Wild Animals (January 14, 1989);

List of National Key Protected Wild Plants (the first batch) (August 4, 2001);

Announcement of Adjustment of the List of National Key Protected Wild Animals (No. 7 of State Forestry Administration);

Catalogue for Guiding Industry Restructuring (2011 Version) (2013 Amendment);

Measures for the Administration of National Wetland Park (for Trial Implementation) (L.S.F. No. 1 [2010] of State Forestry Administration)

1.2.3 Local rules and regulations

Regulations of Hubei Province on Water Pollution Prevention and Control (January 2014);

Environmental Protection Regulation of Hubei Province (December 1997);

Decision of the People's Government of Hubei Province on Materializing Scientific Viewpoint of Development and Strengthening Environmental Protection (E.Z.F. [2006] No.54);

Notice of the Department of Environmental Protection of Hubei Province on Further Strengthening Environmental Management for Construction Projects (E.H.F. [2005] No. 56);

Measures of Hubei Province for the Implementation of Water Pollution Prevention and Control Law of the People's Republic of China (December 1, 2000);

Regulations of Hubei Province on Atmospheric Pollution Prevention and Control (December 3, 1997);

Regulations of Hubei Province on the Administration of Urban Environmental Noise (September 20, 1986);

Technology Policies for Eutrophication Prevention and Control of Lakes and Reservoirs (H.F. [2004] No. 59);

Regulation of Hubei Province on Agricultural Ecological Environment Protection (September 2006);

Regulations of Hubei Province on Water Pollution Prevention and Control of Han River Basin (May 2000);

Environmental Function Categories of Surface Water in Hubei Province (Department of Environmental Protection of Hubei Province, January 2000);

Water Function Zoning of Hubei Province (Department of Water Resources of Hubei Province, July 20, 2003);

Notice of the General Office of the People's Government of Hubei Province on Strengthening and Regulating the Management of Newly-started Projects (E.Z.B.F. [2008] No. 9, February 2008);

Notice of the General Office of the People's Government of Hubei Province on Forwarding the "Notice of the Department of Environmental Protection on Environmental Function Categories of Surface Water" (E.Z.B.F. [2000] No. 10, January 2000);

Opinions of the General Office of the People's Government of Hubei Province on Further Strengthening Water Pollution Prevention and Control (E.Z.B.F. [2008] No. 49);

Announcement of the People's Government of Hubei Province on Delineating Key Areas for Prevention and Control of Soil and Water Loss (E.Z.F. [2000] No. 47);

Measures of Hubei Province for the Implementation of the Law of the People's Republic of China on the Protection of Wildlife (October 12, 1994);

Notice on Further Promoting Public Participation in EIA for Construction Projects (E.H.B. [2003] No. 67);

Notice of the People's Government of Hubei Province on Issuing the Outline of the 12th Five-Year Plan for Environmental Protection (E.Z.F. [2012] No. 13);

Notice of the General Office of the People's Government of Hubei Province on Forwarding the "Notice of the Department of Environmental Protection on Environmental Function Categories of Surface Water";

Plan for Delineating Urban Centralized Source Water Protection Areas (County or Higher Level) in Hubei Province;

Measures of Hubei Province for the Administration of Wetland Park (May 1, 2014)

1.2.4 Technical specifications and guidelines

Technical Guidelines for EIA – General Provisions (HJ2.1-2011);

Technical Guidelines for EIA – Surface Water Environment (HJ/T2.3-93);

Technical Guidelines for EIA – Atmospheric Environment (HJT2.2-2008);

Technical Guidelines for EIA – Acoustic Environment (HJ/T2.4-2009);

Technical Guidelines for EIA – Ecological Impact (HJ19—2011);

Technical Guidelines for EIA – Groundwater Environment (HJ610-2011);

Technical Guidelines for EIA – Water Resources and Hydropower Project (HJ/T88-2003);

Technical Guidelines for EIA for Construction Projects (HJ/T169-2004);

Norms of EIA for Inland Navigation Construction Projects (JTJ227-2001);

Norms of EIA for Port Construction Projects (JTS105-1-2001);

Technical Guideline for Delineating Source Water Protection Areas (HJ/T 338-2007);

Technical Guidelines for Biodiversity Monitoring - Inland Water Fishes (HJ 710.7-2014);

The Standards for Investigation of Natural Fishery Resources in Inland Water (for Trial Implementation);

Handbook for Investigation of Natural Fishery Resources in Inland Water;

Research Methods of Fresh Water Plankton;

Technical Specifications for Environmental Monitoring (Volumes II & III) (Ministry of Environmental Protection, 1986);

Technical Specifications for the Monitoring of Surface Water and Wastewater (HJ/T91-2002);

Technical Specifications for Medical Assessment of Environmental Impact of Water Resources and Hydropower Projects (GB/T16124-1995);

Technical Specifications for Comprehensive Control of Soil and Water Conservation (GB/T16453.1-16453.6-2008);

Standards for Classification and Gradation of Soil Erosion (SL190-2009);

Technical Code for Soil and Water Conservation for Development and Construction Projects (GB/T50433-2008);

Standards for Prevention and Control of Soil and Water Loss for Development and Construction Projects (GB50434-2008);

Notice on Issues Concerning the Land Used for Water Resources and Hydropower Projects (G.T.Z.F. [2001] No. 355);

Technical Specifications for CAD Drawing of Hydropower Projects (DL/T5127-2001)

1.2.5 Related technical documents

Brief Report on Comprehensive Utilization of the Yangtze River Basin (1990 amendment);

Report on the Plan for Comprehensive Utilization of the Han River Mainstream downstream from Jiahe River (Changjiang Water Resources Commission of the Ministry of Water Resources, January 1993);

Report on Planning of South-to-north Water Diversion Middle Route Project (2001 amendment);

Report on the Plan for Development of Major Waterways in Hubei Province (Hubei Provincial Department of Transportation, August 2003);

Report on Comprehensive Planning of the Han River Mainstream (Changjiang Water Resources Commission of the Ministry of Water Resources, June 2010);

Comprehensive Planning of the Yangtze River Basin (2011-2030) (Changjiang Water Resources Commission of the Ministry of Water Resources, 2012);

Plan for Water Pollution Prevention and Control at Middle and Lower Reaches of Han River in Hubei Province;

Construction Plan of High-grade Waterways along Han River and Jianghan Canal (2011-2015) (revised edition) (November 2010, Hubei Provincial Development and Reform Commission and Shaanxi Provincial Development and Reform Commission);

Environmental Impact Report for the Construction Plan of High-grade Waterways along Han River and Jianghan Canal (2011-2015) (May 2011, CCCC Second Harbor Consultants Co., Ltd.);

Feasibility Study Report of Han River Yakou Shipping Hub Project (draft for approval) (Hubei Provincial Communications Planning and Design Institute, August 2012);

Report on Soil and Water Conservation Plan for Han River Yakou Shipping Hub Project (May 2014, Hubei Provincial Water Resources and Hydropower Planning, Survey and Design Institute);

Cultural Relics and Historical Sites Investigation and Evaluation Report for Han River Yakou Shipping Hub Project (Hubei Provincial Institute of Cultural Relics and Archaeology, May 2012);

Water Resources Argumentation Report for Han River Yakou Shipping Hub Project (Changjiang Institute of Survey, Planning, Design and Research of Changjiang Water Resources Commission, August 2014);

Investigation and Evaluation Report of Mineral Resources below the Site of Han River Yakou Shipping Hub Project (Hubei Geological Survey Institute, June 2012);

Notice of the General Office of the People's Government of Hubei Province on Issuing the Plan for Delineating Urban Centralized Source Water Protection Areas (County or Higher Level) in Hubei Province (E.Z.B.F. [2011] No. 130);

Letter on Commissioned EIA for Han River Yakou Shipping Hub Project (Port and Waterway Administration of the Department of Transportation of Hubei Province);

Other technical reports and documents concerning flood control, mineral resources below project site and geological hazard assessment.

1.3 EIA standards

1.3.1 Environment quality standards

According to the reply of Hubei Provincial Department of Environmental Protection on the confirmation of EIA standards for this project (E.H.H. [2014] No. 393) (refer to Attachment 4) and relevant specifications and standards, in light of the environmental features of project site, the following EIA standards have been followed for this project:

a) Surface water quality standards

According to the *Environmental Function Categories of Surface Water in Hubei Province* (Department of Environmental Protection of Hubei Province, January 2000), this river section where the project locates is classified into "Xiangyang-Yicheng-Zhongxiang reserved area" and should meet the class-II standards specified in the *Environmental Quality Standards for Surface Water* (GB 3838-2002). The environmental function category of other tributaries in the reservoir area hasn’t been determined, but according to the reply, they should meet class-III standards.

Standard values for surface water in this project are shown in Table 1.3.1-1.

Table 1.3.1-1 Standard values for surface water

No.	Item	Unit	Class-II standard	Class-III standard
1	pH value	Dimensionless	6 ~ 9	6 ~ 9
2	SS		-	-
3	Dissolved oxygen	mg/L	≥6	≥5
4	CODmn	mg/L	≤4	≤6
5	CODcr	mg/L	≤15	≤20
6	BOD_5	mg/L	≤3	≤4
7	Ammonia nitrogen	mg/L	≤0.5	≤1.0
8	Total phosphorus	mg/L	≤0.1	≤0.2
9	Total nitrogen	mg/L	≤0.5	≤1.0
10	Copper	mg/L	≤1.0	≤1.0
11	Zinc	mg/L	≤1.0	≤1.0
12	Fluoride	mg/L	≤1.0	≤1.0
13	Selenium	mg/L	≤0.01	≤0.01
14	Arsenic	mg/L	≤0.05	≤0.05
15	Mercury	mg/L	≤0.00005	≤0.0001
16	Cadmium	mg/L	≤0.005	≤0.005
17	Hexavalent chromium	mg/L	≤0.05	≤0.05
18	Lead	mg/L	≤0.01	≤0.05
19	Cyanide	mg/L	≤0.05	≤0.2
20	Volatile phenol	mg/L	≤0.002	≤0.005
21	Petroleum	mg/L	≤0.05	≤0.05
22	LAS	mg/L	≤0.2	≤0.2
23	Sulfide	mg/L	≤0.1	≤0.2
24	Number of fecal coliform	In one liter	≤2000	≤10000

b) Groundwater quality standards

The groundwater at project site is mainly used as centralized drinking water and industrial and agricultural water, so the groundwater should meet the class-III standard specified in the *Quality Standards for Groundwater* (GB/T 14848-1993), as shown in Table 1.3.1-2.

Table 1.3.1-2 Standard values for groundwater

Item	Standard values	Item	Standard values
Chroma (dilution multiple)	≤15	Hexavalent chromium (mg/L)	≤0.05
Smell and taste	No	Copper (mg/L)	≤1.0
pH	6.5~8.5	Zinc (mg/L)	≤1.0

Item	Standard values	Item	Standard values
Permanganate index (mg/L)	≤3.0	Cadmium (mg/L)	≤0.01
Ammonia nitrogen (NH3-N) (mg/L)	≤0.2	Barium (mg/L)	≤1.0
Total coliforms (in one liter)	≤3.0	Beryllium (mg/L)	≤0.0002
Total bacteria (in one liter)	≤100	Selenium (mg/L)	≤0.01
Arsenic (mg/L)	≤0.05	Nickel (mg/L)	≤0.05
Lead (mg/L)	≤0.05	Cyanide (mg/L)	≤0.05
Mercury (mg/L)	≤0.001		

c) Ambient air quality standards

The project site (including the construction area and the area surrounding the reservoir), located at rural area, is defined as class-II function area of ambient air quality, and the ambient air quality at the project site should meet the class-II standard specified in the *Ambient Air Quality Standards* (GB3095-1996),as shown in Table 1.3.1-3.

Table 1.3.1-3 Standard values for ambient air

Pollutants	Type of value	Class-II standard values (maximum concentration, mg/m³)
Total suspended particles (TSP)	Daily mean value	0.30
Inhalable particles (PM10)	Daily mean value	0.15
Nitrogen dioxide (NO2)	Daily mean value	0.08
Sulfur dioxide (SO2)	Daily mean value	0.15

d) Acoustic environment quality standards

The construction area and the surrounding area sensitive to environmental noise should meet the class-II standard specified in the *Environmental Quality Standard for Noise* (GB3096-2008), i.e. not above 60dB(A) at daytime and not above 50dB(A) at nighttime.

The area within 50m from boundary line of trunk roads (provincial highway 218 and national highway 207) and the areas on both banks of navigable river course should meet the class-4a standard specified in *Environmental Quality Standard for Noise* (GB3096-2008), i.e. not above 70dB(A) at daytime and not above 55dB(A) at nighttime.

1.3.2 Pollutant discharge standards

a) Wastewater discharge standards

As mentioned, the river section where the dam locates should meet the class-II standard specified in the *Environmental Quality Standards for Surface Water*, so all kinds of wastewater and sewage produced during project construction and operation can't be discharged directly into the mainstream of Han River. The industrial wastewater should be recycled and reused for industrial production, with SS≤300mg/L and pH: 6~9; if domestic sewage is reused for washing vehicles and irrigating plants, the sewage must be treated first in accordance with the requirements of the *Reuse of Urban Recycling Water - Water Quality Standard for Urban Miscellaneous Water Consumption (GB/T18920-2002)*; if the domestic sewage is reused for farmland irrigation, the sewage must be treated first to meet the dry farming requirements specified in the *Water Quality Standard for Farmland Irrigation (GB 5084-2005).*

b) Air pollutant emission standards

Air pollutant emission concentration should not exceed the monitored maximum concentration of air pollutants discharged in an uncontrollable manner from new pollution sources as shown in Table 2 of the *Integrated Emission Standard of Air Pollutants (GB16297-96).*

c) Noise emission standards

During project construction, the noise at boundary of construction site should meet the requirements of the *Emission Standard of Environment Noise for Boundary of Construction Site (GB12523-2011)*; during project operation, the noise at boundary of hydropower station should meet the class-II standard specified in the *Emission Standard for Industrial Enterprises Noise at Boundary (GB12348-2008)*;

Details are provided in Table 1.3.2.

Table 1.3.2 Standard values for pollutant discharge

Pollutants	Discharge standard	Standard classification	Indicators and limits			
Domestic	If reused for washing	Limits	Indicators	Clean	Irrigate	Wash

<table>
<tr><th>Pollutants</th><th>Discharge standard</th><th>Standard classification</th><th>Indicators and limits</th></tr>
<tr><td rowspan="2">sewage</td><td>vehicles and irrigating plants, sewage should be treated in accordance with the requirements of the Reuse of Urban Recycling Water - Water Quality Standard for Urban Miscellaneous Water Consumption (GB/T18920-2002).</td><td></td><td><table>
<tr><td></td><td>roads</td><td>plants</td><td>vehicles</td></tr>
<tr><td>PH (dimensionless)</td><td colspan="3">6~9</td></tr>
<tr><td>Turbidity (≤)</td><td>10</td><td>10</td><td>5</td></tr>
<tr><td>BOD_5(≤mg/l)</td><td>15</td><td>20</td><td>10</td></tr>
<tr><td>NH_3-N(≤mg/l)</td><td>10</td><td>20</td><td>10</td></tr>
<tr><td>Total coliforms (in one liter)</td><td colspan="3">3</td></tr>
</table></td></tr>
<tr><td>If reused for farmland irrigation, the sewage shold be treated in accordance with the requirements of the Water Quality Standard for Farmland Irrigation (GB 5084-2005)</td><td>Limits</td><td><table>
<tr><td>Indicators</td><td>Dry farming</td></tr>
<tr><td>BOD_5(≤mg/l)</td><td>100</td></tr>
<tr><td>COD_{Cr}(≤mg/l)</td><td>200</td></tr>
<tr><td>SS(≤mg/l)</td><td>100</td></tr>
<tr><td>Petroleum (≤mg/l)</td><td>10</td></tr>
</table></td></tr>
<tr><td>Air pollutant</td><td>the monitored maximum concentration of air pollutants discharged in an uncontrollable manner as shown in Table 2 of the Integrated Emission Standard of Air Pollutants (GB16297-96).</td><td>Uncontrollable emission limits</td><td>Concentration:
TSP: 1.0mg/m³
NO_2: 0.12mg/m³</td></tr>
<tr><td rowspan="2">Noise</td><td>GB12523-2011 Emission Standard of Environment Noise for Boundary of Construction Site</td><td>Limits</td><td><table>
<tr><td rowspan="2">Location</td><td colspan="2">Limits</td></tr>
<tr><td>Daytime</td><td>Nighttime</td></tr>
<tr><td>Boundary of construction site</td><td>75</td><td>55</td></tr>
</table></td></tr>
<tr><td>GB12348-2008 Emission Standard for Industrial Enterprises Noise at Boundary</td><td>Class-II</td><td><table>
<tr><td>Boundary of hydropower station during project operation</td><td>60</td><td>50</td></tr>
</table></td></tr>
</table>

1.4 EIA grade and range

1.4.1 Water environment

1.4.1.1 Surface water

a) EIA grade

During project operation, only small amount of domestic sewage will be produced. So, EIA grade for surface water is determined based upon the sewage production during project construction, the environmental function of surface water, total area of surface water and the sensitivity of regional water environment. During project construction, the maximum sewage (wastewater) discharge is less than 5000m³/d; main pollutant in the sewage is SS; total area of surface water is large; the environmental function of surface water is rated as class-II. The reservoir is built in water course and regulated on daily basis. The capacity of the reservoir under normal water level is 350.2 million m³. When calculated based on the annual average flow rate of 1,100m³/s (equivalent to that of Danjiangkou reservoir in late stage), the water exchange period is 3.7 days, very short. In this section of Han River, there are only a small amount of pollutants and main pollutants come from the upstream water and the tributaries at reservoir tail. According to Article 5 of the *Technical Guidelines for EIA – Surface Water Environment (HJ/T2.3-93)*, the surface water EIA for this project is rated as grade-III. But, considering that future operation of the project will influence the hydrological conditions and water quality of the reservoir and the water downstream from the dam, this section has been classified into class-II function area, and there are water intakes in this section, the EIA grade is promoted from grade-III to grade-II.

b) EIA scope

During project operation, the surface water EIA scope is from Cuijiaying dam to the position 10km downstream from Yakou dam, with a length of 62.67km, including the mainstream of Han River, major tributaries such as Chunhe, Weihe, Yinghe and Manhe and the water receiving pollutants such as Laojianggou, Yidaodagou and Wangjiadagou.

During project construction, the surface water EIA scope is from the position 1km upstream from construction site to the position 5km downstream from the dam, with a total length of 6km.

1.4.1.2 Groundwater

a) EIA grade

According to the engineering analysis, the project impact on groundwater is mainly caused by reservoir inundation. During project operation, this project will bring no pollutants but will bring ecological impacts. After the reservoir is impounded, the groundwater level at surrounding area will be influenced by reservoir inundation and water leakage of the reservoir and dam foundation. The industrial wastewater and domestic sewage produced during project construction will be recycled and almost no wastewater is produced during project operation, so this project won't impair groundwater quality. In a word, during project construction and operation, this project only has influence on groundwater level, so this project is classified into class-II construction projects.

This hydropower project is built on riverbed and contains no underground works. So, project construction will have no influence on groundwater. During project operation, the reservoir impoundment may cause landslide, inundation and bank collapse, but the environmental hydrogeological disasters are not serious. According to the grading of groundwater environment sensitivity in the *Technical Guidelines for EIA – Groundwater Environment*, the project site is not a sensitive area.

According to the *Technical Guidelines for EIA – Groundwater Environment (HJ610-2011)* and based on the project features, the groundwater EIA for this project is finally rated as grade-III.

b) EIA scope

In accordance with the *Technical Guidelines for EIA – Groundwater Environment (HJ610-2011)*, the groundwater EIA scope should cover the area where groundwater is affected by the project during project construction & operation and after the expiration of service life. This project has impact on groundwater mainly during project construction and operation. During project construction, the groundwater at the dam area will be affected; during project operation, the reservoir inundation may influence groundwater level.

The groundwater EIA scope includes: the area to be inundated by the reservoir, including Zhangjiazui-Nanzhou section on left bank, Zhangjiazui-Lijiadian section on right bank and Ruanjiapo-Yakou dam section on both banks, and the dam site, mainly composed of the riverbed and the construction areas on both banks, with total area of about 4.0km^2.

1.4.2 Ecological environment

a) Grading

Project construction and inundation will exert adverse impact on vegetation and soil erosion in the area and will occupy land of about 90.6km^2. Length of backwater of the reservoir area (P=5%) is about 52.67km. There are no natural reserves, scenic spots, forest park and important wetland and other ecological sensitive areas in the project area. In accordance with *Technical Guidance for EIA—Ecological Impact* (HJ 19-2011), the ecological environment impact is evaluated as Grade II. However, the sluices and dam will exert bigger impact on hydrological regime and fish resources, so the ecological environment impact of this project is evaluated as Grade I (of which the terrestrial ecology assessment grading will be carried out with reference to Grade II).

b) Assessment scope

Scope of terrestrial ecology assessment: Cuijiaying hydro-junction to the downstream river section which is 5km away from Yakou Shipping Hub Project and the areas within 2km at both banks or the first watershed (when the distance between the river to the first watershed is shorter than 2km), including construction-occupied areas, inundation-affected areas and resettlement areas as well as the continent in the center of the river and the mudflats along the bank, such as Longmentan, Shuifomiao, Bajiazhou, Niulukou, Quejiatao and Guohaiying. The total area is about 211.07km^2. The inundation areas, construction-occupied areas and resettlement areas are the core.

The scope of soil erosion assessment is the construction site, rock and earth materials fields and farmland protection area.

The scope of aquatic ecology assessment is: Cuijiaying Dam Site to the downstream reaches 10km away from Yakou Dam Site, including the main stream and the main tributaries Ying River and Man River in-between. In consideration of the national level aquatic germplasm resources protection area of elopichthys bambus, ochetobius elongates and luciobrama microcephalus at Zhongxiang river section in the lower reaches, the investigation on larval fish resources in the main stream is extended to the river section from Nianpanshan to Rentan which is the core area of the national level protection area.

1.4.3 Atmospheric environment

a) Grading

There are no fixed air pollution sources during the project operation area and only the emission of vehicles on the crest access is taken into consideration. The pollution factors, CO and NO_x, are unorganized and unsteady. Therefore, we do not assess the ambient air in the project operation period.

The impact of this project on the ambient air mainly concentrates in the construction period. The atmospheric environmental impact mainlys tems from the explosion, excavation, operation of the construction machine and driving of the vehicles during the cosntruction period. Estimating on the basis of the project scale and consumption of fuels during the construction peirod, the air pollutants during the construction period are mainly TSP and the emitted gas $D_{10\%}<$ is nearest to boundary of the construction site. The gas is exhausted temporarily and in an unorganized manner and the emission mainly affects the construction site and both sides of the roads. The construction site is located in plain and the main environmentally sensitive points around the site are rural settlements and the project will exert impact of the ambient air mainly in the construction period. Therefore, according to the principles as specified in *Technical Guidance for EIA—Atmospheric Environment* (HJ/T2.2-2008), the atmospheric environmental impact is evaluated as Grading III.

b) Scope

In accordance with the supplementary provisions of HJ2.2-2008 and the emission characteristics of air pollutants during the construction period, the assessment scope is determined to be the areas within 200m of the construction site and the belt with 200m at both sides of the center line of the construction road.

1.4.4 Acoustic environment

a) Grading

The areas to be assessed are rural areas and usually functional zones of acoustic environment are not classified. According to needs of environmental management and upon confirmation of the Department of Environmental Protection of Hubei Province, the class 2 standard as specified in *Quality Standard for Acoustic Environment* (GB3096-2008) is followed in the assessment area. Yakou Shipping Hub Project is non-pollution construction project and basically no noise will be made in the operation period. But in the construction period, operation of the construction machine will make big noise and the noise level will reach to 3dB(A) to 5dB(A) and the frequency that people is affected by the noise will increase. According to the relevant provisions of *Technical Guidance for EIA—Acoustic Environment* (HJ2.4-2009), the acoustic environmental impact is evaluated as Grade II.

b) Scope

The assessment scope is the construction area of main works (the area within 500m of the boundary of land acquired for the construction) and the belt within 200m at both sides of the center line of the transportation road (including the passage within the construction site and the roads in earth and rock materials field)

1.4.5 Social environment

Brief assessment on the impact on the social environment is made and qualitative and analogue analysis of impact on major social environmental factors, such as, land resources, economic conditions and health of people, is made in accordance with the scope and degree of impact of this project construction on social environment. In consideration of the statistical standard of basic data and radiation effects of the impact, the scope of social environmental assessment is determined to be the construction areas, inundated areas and eight towns (sub-districts) and 36 villages in Xiangcheng District, Xiangyang District and Yicheng City which are under administration of Xiangfan City.

The grades and scope of EIA are shown in Table 1.4.5.

Table 1.4.5 Schedule of grades and scope of EIA

Factors	Grades	Scope
Surface water	Grade II	The river section of about 62.67km from Cuijiaying Dam site to downstream reaches which are 10km away from Yakou Dam site, including the main stream and main tributaries Ying River and Man River in-between. The assessment scope during the construction period is the river section of about 6km from the upstream reaches which are 1km away from the construction site and the downstream reaches which are 5km away from Yakou Dam.
Ground water	Grade III	The area may be inundated by the reservoir, including the areas within the embankment from Zhangjiazui to Nanzhou, the areas within the embankment from Zhangjiazui to Lijiadian and the areas within the embankment from Yuanjiapo to Yakou Dam site; as well as the dam site area, mainly are the riverbed and the construction areas at both bans. The total area is about 4.0km^2.
Ecological environment	Grade I	Aquatic ecosystem: main stream of Han River of 52.67km in the reservoir area and the downstream main stream of Han River which is 10km away from the dam site; the river sections under influence of backwater of tributaries of Han River in the reservoir area; the investigation of larval fish resources in the main stream is appropriately extended to the river section from Nianpanshan to Rentan which is the core area of the national level aquatic germplasm resources protection area of elopichthys bambus, ochetobius elongates and luciobrama microcephalus at Zhongxiang river section in the lower reaches.
		Terrestrial ecosystem: the scope within 2km of the boundary of the inundated areas of the main stream and tributaries in the reservoir area, construction-occupied areas, the inundation-affected areas and the resettlement areas.
Atmospheric environment	Grade III	The areas within 2.5km from the project, and the area is about 19.63km^2.
Acoustic environment	Grade III	The area within 200m of the boundary of the construction site as well as the belt within 100m at both sides of the center line of the road.
Social environment	-	Eight towns (sub-districts) and 36 villages in Xiangcheng District, Xiangyang District and Yicheng City which are under administration of Xiangfan City

1.5 Environmental protection object

1.5.1 Sensitive objects of environmental protection

Reservoir of Yakou Shipping Hub Project will inundate land of 8,538.87hm^2, of which the mudflat for crops planting is 2,804.34hm^2, the mudflat for fruit trees planting is 7.85 hm^2, the mudflat for forest is 1,611.89hm^2, the grassland is 16.99hm^2, the land for residence is 1.55 hm^2, the land for special use is 9.99 hm^2, the land for water conservancy facilities is 3,571.41hm^2 and other land is 514.86 hm^2. No valuable but rare wild plants are found in the assessment areas. There are natural spawning grounds in the project-located river sections. The main environmental protection objects in the project area are drinking water source protection area, spawning grounds, animals under key protection of the national and provincial governments, cultural relics and historical sites and villages around the project areas, etc. The villages near the construction site are Yakou Village, Maocao

Village, Nanzhou Village, Heluo Village and Haoji Village which should be protected. According to the project layout and characteristics of the surrounding environment, the environmental protection object of this project is shown in the following Table 1.5.1 and the specific location is shown in Attached Map 9.

Table 1.5.1 Schedule of sensitive objects of environmental protection of Yakou Shipping Hub Project

Environmental factors	Sensitive objects of environmental protection		Location	Scale and characteristics	Main causes	Possible impact	Requirement
Water environment	Drinking water source protection area in the reservoir area	Drinking water source protection area of Yicheng Water Plant	Right bank of the reservoir area and upstream reaches which are 20.0km away from the dam site	25,000t/d, combined water intake structure, pile framing water intake and 43 elevation for water intake	Inundation of the reservoir and changes of proliferation conditions of water sources	When the water at the water intake deepens, the flow slows and pollutants source load remains unchanged, the water quality may change.	Ensure that the water quality of the reservoir meets the requirements on function zoning of water environment, well clean the matters at the bottom of the reservoir, strengthen harness over the pollutant sources according to planning of pollution prevention and control, protect the water quality of the reservoir and formulate emergency plan for discharge accidents.
		Water intakes of Wangji Town, Xiangnan Prison Water Plant, Danjiangkou Resettlement Area Water Plant	Left bank of the reservoir area and 33.0km, 2.8km and 1.2km away from the dam site	5,000t/d, 2,000t/d and 5,000t/d respectively, separate, bell and floating water intake structure respectively and 38m to 42m elevation for water intake			
	Agricultural pump station in the reservoir area	Yingshan, Zhangzui and Nanying pump stations for irrigation	Left bank of main stream of Han River in the reservoir area	Tower and box water intake, the elevation for water intake is 55m to 57m and the irrigation area is about 110,000mu.			Ensure that the water can meet the irrigation demands and water quality meets the irrigation requirements.
		Ronghe pump station for irrigation	Right bank of main stream of Han River in the reservoir area	Tower and box water intake, elevation for water intake is 56m and the irrigation area is 50,000 mu.			
	Water intakes for industry use in the reservoir area	Water intake of Beijing Yanjing Brewery Co., Ltd.	Right bank of Han River in the reservoir area, upstream side of Han River Bridge in Yicheng city and 15.5km away from the dam site	Water for production use, floating water intake, elevation for water intake is 41m to 45m.	Rising of water level and deepening of the water of the reservoir	Better for taking water	-
		Water intake of	Right bank of main	Water for production			

Environmental factors	Sensitive objects of environmental protection		Location	Scale and characteristics	Main causes	Possible impact	Requirement
		Anneng Biomass Power Plant	stream of Han River in the reservoir area, downstream side of Han River Bridge in Yicheng City and 14.5km away from the dam site	use, floating water intake, elevation for water intake is 41m to 45m.			
	Water intakes under the dam	Water intake of Liushui Town Tap Water Plant	Left bank and 8.0km away from the dam	5,000t/d, separate water intake structure, Pile framing water intake and the elevation for water intake is 42m	Wastewater discharge in the construction period and operation of the reservoir during the operation period	Project construction brings adverse impact on water intake for domestic use in the lower reaches; water amount in the low flow season will be guaranteed.	Ensure the water amount at water intakes and the discharge volume meets the demands of different river sections for water. Ensure the water supply safety in the lower reaches and maintain the good water quality. Prohibit discharge of sewage (wastewater) into the river and formulate emergency plan for discharge accidents.
Atmospheric environment and acoustic environment	Right bank	Heluo Village	West side of the access road at right bank (the nearest location is 125m away)	About 190 households and 580 people	Wastes generated in the construction process and transportation	Make the quality of atmospheric environment in the region reduce and influence the acoustic environment of the sensitive points.	Ensure that the air quality meets the function zoning requirements. Watering and dust reduction vehicles must meet the environmental protection requirements. Explosion and transportation must be carried out at fixed time. Class II standard as specified in *Quality Standard for Ambient Air* (GB3095-1996) and class II standard as specified in *Quality Standard for Acoustic Environment* should be followed.
		Maocao Village	Near the concrete system in the construction area and around No. ① transfer site (the nearest location is 160m away)	About 320 and 958 people			
		Haoji Village	Around construction site of Yakou Shipping Hub Project (the nearest location is 170m away)	About 90 households and 255 people	Excavation of pit and transportation		
	Left bank	Yakou Village	In construction site of Yakou Shipping Hub Project and	About 120 households and 380 people			

Environmental factors	Sensitive objects of environmental protection		Location	Scale and characteristics	Main causes	Possible impact	Requirement
			around earth materials field (the nearest location is 100m away)				
		Nanzhou Village	Near the boundary of 3# waste dump and north of the waste dump (the nearest location is 140m away)	About 210 households and 760 people	Wastes generated in the construction process and exploitation of materials fields		

Table 1.5.1 (Continued)

Environmental factors	Sensitive objects of environmental protection		Location	Scale and characteristics	Main causes	Possible impact	Requirement
	Left bank	Shangwan Village	South of Matoushan block-stone field and aggregate processing system. The nearest location to Group Eight of Shangwan Village is 200m away.	About 58 households and 210 people	Exploitation of the materials filed and processing the rock materials		
Terrestrial ecosystem	Terrestrial plants	One pistacia chinensis bunge, an ancient famous tree	In Luojiahe and 500m away from the resettlement area, not affected by the project	-	-	-	-
		Camphor tree	Frequently-see tree and beside the residents areas around the reservoir	National grade-II key protected plants and typical synarthropic plant	Rising of the water level and land occupation by the project	None	Avoid them and ensure no reduction of the quantity
	Terrestrial animals	Five amphibian species, two reptile species, 18 bird species and one mammal species	Bushes and dense grass around the reservoir	Wild animal under key protection of Hubei provincial government	Inundation of the reservoir	Part of the habitats are inundated	Prohibit from hunting the wild animals, strengthen the monitoring and rescue them. Timely restore the damaged vegetation.

		Three bird species, i.e. common buzzard, black kite and kestrel	High attitude mountain around the reservoir area and the nearest location is about 1km away from the construction site	National Grade II key protected animals	Project construction	-	Protect the diversity of local terrestrial plants and ensure that they are not affected by the project.
Aquatic ecosystem	Spawning grounds		Yicheng spawning ground in the reservoir area, Guanjiashan and Dengjiatai spawning grounds for fishes laying pelagic eggs in downstream reaches of the dam	Yicheng spawning ground is 14.5km away from the dam site, Guanjiashan spawning ground is 13.5km away from the dam site and Dengjiatai spawning ground is 61.8km away from the dam site.	Rising of the water level and blocking of the dam	Spawning grounds of grass carp, black carp, silver carp and bighead will be affected	Protect the fish resources and make them not significantly reduce because of blocking of the dam and inundation of the reservoir. Take combined methods of enhancement and releasing, building of fish-way and joint scheduling of the hydro-junctions and the local fishery management departments should strengthen management on the reservoir and waterway.
	Valuable but rare fish species		Luciobrama microcephalus, ochetobius elongates, gracilicaudatus (varicorhinus macrolepis), leiocassis longirostris and eels, etc.	Five types of aquatic wild animals under protection of Hubei provincial government and migratory and semi-migratory fishes.	Blocking of the dam	-	
Wetland park	Cuijiaying Provincial Wetland Park in Xiangyang City		Backwater end of Yakou reservoir to Cuijiaying Hydro-junction.	Typical river wetland in basin of Han River, unique wetland type, good ecosystem and rich biodiversity. Total area is 5,100hm^2.	Inundation of the reservoir	Terrestrial vegetation in the wetland park will not be inundated	Basically not exert impact on ecological functions of the wetland park.
	Wanyangzhou National Wetland Park in Yicheng, Hubei Province		4.5km away from Yakou dam site and the water is all within the inundated area.	Permanent river wetland and flood plain, 69.53% of the land is wetland.	The reservoir inundates the land area	Increase of the water area and wetland area will have positive impact on the ecological functions	Adequately consider the impact of Yakou power station in the detailed planning of next stage and reasonably plan the five functional zones.
Social environment	Cultural relics and historical sites		12 ground cultural relics like Guanzhuang cemetery of Han dynasty, Wangjiagang cemetery, Tongmei cemetery, Heluo cemetery of six dynasties and Yakou cemetery in the reservoir	Wangjiagang cemetery is identified as cultural relics under protection of county government. The others have not yet been identified.	Inundation and immersion of the reservoir	Erosion effect of the inundation	Explore the cultural relics and implement archaeological excavation.

		area.				
	Residents to be resettled	Land occupied by inundation of the reservoir and the project construction	Production of 23,401 people needs to be arranged and 1,805 people have to move.	Inundation of the reservoir and land occupation by the project	Impact of project construction and inundation of the reservoir	Control the production and development in the reservoir area, protect the original vegetation in the reservoir area and compensate according the standard determined by the central government to avoid social conflicts.


Xiangnan Prison Water Plant


Water intake of Xiangnan Prison Water Plant


Danjiangkou Resettlement Area Water Plant


Water intake of Danjiangkou Resettlement Area Water Plant


Wangji Town Water Plant


Water intake of Wangji Town Water Plant


Monument of Yicheng Drinking Water Source


Water intake of Yicheng Water Plant

Protection Area

Water intake of Beijing Yanjing Brewery Co., Ltd.

Water intake of Anneng Biomass Power Plant

Ronghe Pump Station

Zhangzui Electric Pump Station

Figure 1.5.1-1 Current conditions of water intakes for living, industry and irrigation in the reservoir area

Part of cemetery of Han dynasty in Guanzhuang

Close shot of Wangjiagang cemetery

Figure 1.5.1-2 Current conditions of part of cultural relics under the ground of the reservoir area

1.5.2 Quality objective of environmental protection

a) Water environment

In accordance with *Function Zoning of Surface Water Environment of Hubei Province* (Environmental Protection Bureau of Hubei Province, January 2000), Yakou dam site is located in the river section of Han River in Yicheng city and is identified as grade I centralized drinking water source protection area. The water environment function is subject to class II standard as specified in *Quality Standard for Surface Water Environment* (GB3838-2002).

In addition, in accordance with *Water Function Zoning of Hubei Province* (Hubei Provincial Department of Water Resources, July 20, 2003), altogether 259 grade I water functional zones and 116 grade II water functional zones are classified across Hubei Province. Zoning of grade water functional zones resolves the issue of water resource development, utilization and protection and coordinates the relations among areas. Grade I water functional zones consist of protection area, reserved area, development and utilization area and buffer area. The grade I water function zoning of main stream in middle reaches of Han River where Yakou Shipping Hub Project is located is shown in Table 1.5.2.

Table 1.5.2 Water function zoning of the river section to be assessed (grade I)

Basin	Type of the function zone	River section	Starting cross-section	Ending cross-section	Length km	Water quality goal	Classification basis
Main stream of Han River	The reserved area of Han River from Xiangyang to Yicheng to Zhongxiang	Xiangyang to Zhongxiang	Yujiahu Wangying in Xiangfan City	Chenjiatai in Zhongxiang City	125	II	Not very well developed and used

The water function zoning of project-located river section belongs to “the reserved area from Xiangyang to Yicheng to Zhongxiang” and the water environmental function follows class II standard. The project construction will not affect the drinking water source protection area and does not affect the water quality of four water intakes in the reservoir area. Hence, the protection objectives of water environment are as follows:

Construction period: to maintain the existing function of river section where the project is constructed, to meet the requirements on quality for domestic use, to prohibit the discharge of pollutants and to protect the water quality of the lower reaches.

Operation period: to guarantee the water quality not to be reduced due to construction and operation of this project, to make the water quality of the river section meet the functional requirements and requirements on quality of water for domestic use, to maintain the types of quality of the ground water and not affect the quality and quantity of ground water intake.

b) Ecological environment

Maintain the diversity and completeness of regional ecosystem, protect the diversity of terrestrial species in the construction area and the resettlement area and maintain the original ecological functions.

Combine with the aquatic ecosystem protection measures in main stream of Han River and the hub project itself, strengthen studies on artificial breeding, release fry and take other effective measures to protect the fish resources in the project-affected river sections and maintain the species and habitats of aquatic creatures in the reservoir area.

Reduce the adverse impact of the project on regional animals and plants as well as local land resources through reasonable layout of construction site, controlling the land occupied by construction and strengthening management on the construction, etc. Reclaim the cultivated land and forest land temporarily occupied by the construction and mitigate the pressure on local land resources imposed by the project construction. Gradually implement soil and water conservative works to control and manage the soil erosion in the project construction area and the resettlement area and realize the following goals: 95% of the disturbed soil has been harnessed, 97% of soil erosion has been controlled, the control ratio of soil erosion reaches to 1.0, 95% of the wastes have been intercepted, 99% of the forest and grass vegetation have been restored and the forest and grass coverage reaches to 17%.

Properly arrange the resettled people and mitigate the impact of resettlement on land resources and animals and plants resources.

c) Atmospheric environment

Maintain the air quality of the construction area and the surrounding areas and make the air quality of the living area of the construction personnel and the surrounding areas reaches to class II standard as specified in *Quality Standard for Ambient Air* (GB3095-1996).

d) Acoustic environment

Maintain the acoustic environment in the project-located areas and the surrounding areas. The acoustic environment during the construction period and operation period should comply with class II standard of *Quality Standard for Acoustic Environment* (GB3096-2008).

e) Social environment

Improve the environment for living and the sanitation conditions in the construction area and the resettlement area; control the morbidity of local diseases and infectious diseases under the current level; guarantee that the drinking water meets the standard as specified in *Sanitation Standard for Domestic and Drinking Water* (GB5749-2006); the construction personnel will be appropriately protected in respect of safety and hygiene during the construction period.

Try efforts to mitigate adverse impact of the project construction on local land resources, reclaim the cultivated land and forest land temporarily occupied by the construction and buffer the pressure on local land resources imposed by the project construction. Try efforts to reduce the number of people to be resettled, arrange them in nearby regions as possible as practical, guarantee the normal agricultural production and maintain the original production and living standard of the people to be resettled. Reduce impact on access of the residents and protect and treat the cultural relics according to the requirements on cultural relics and historical sites.

1.6 The year and key of assessment

We mainly assess the environmental impact of this project in the construction period and the operation period. According to the scheduling of the project construction and actual social conditions, the assessment year of current environmental conditions is 2013. The assessment year for the construction will be the peak period of construction (expected to be 2016). The assessment year for the operation will be the third year after formation of the project (expected to be around 2020).

The EIA will focus on impact on water environment and aquatic ecosystem, namely, predicting and analyzing the changes in water environment quality brought by the project construction and studying the corresponding water quality protection measures;

investigating and understanding the distribution of the valuable but rare fish species, autochthonous fish species and grass carp, black carp, silver carp and bighead in the project-located river sections and basin and studying the corresponding protection measures according to the impact degree.

1.7 Procedures

The procedures are shown in Figure 1.7.

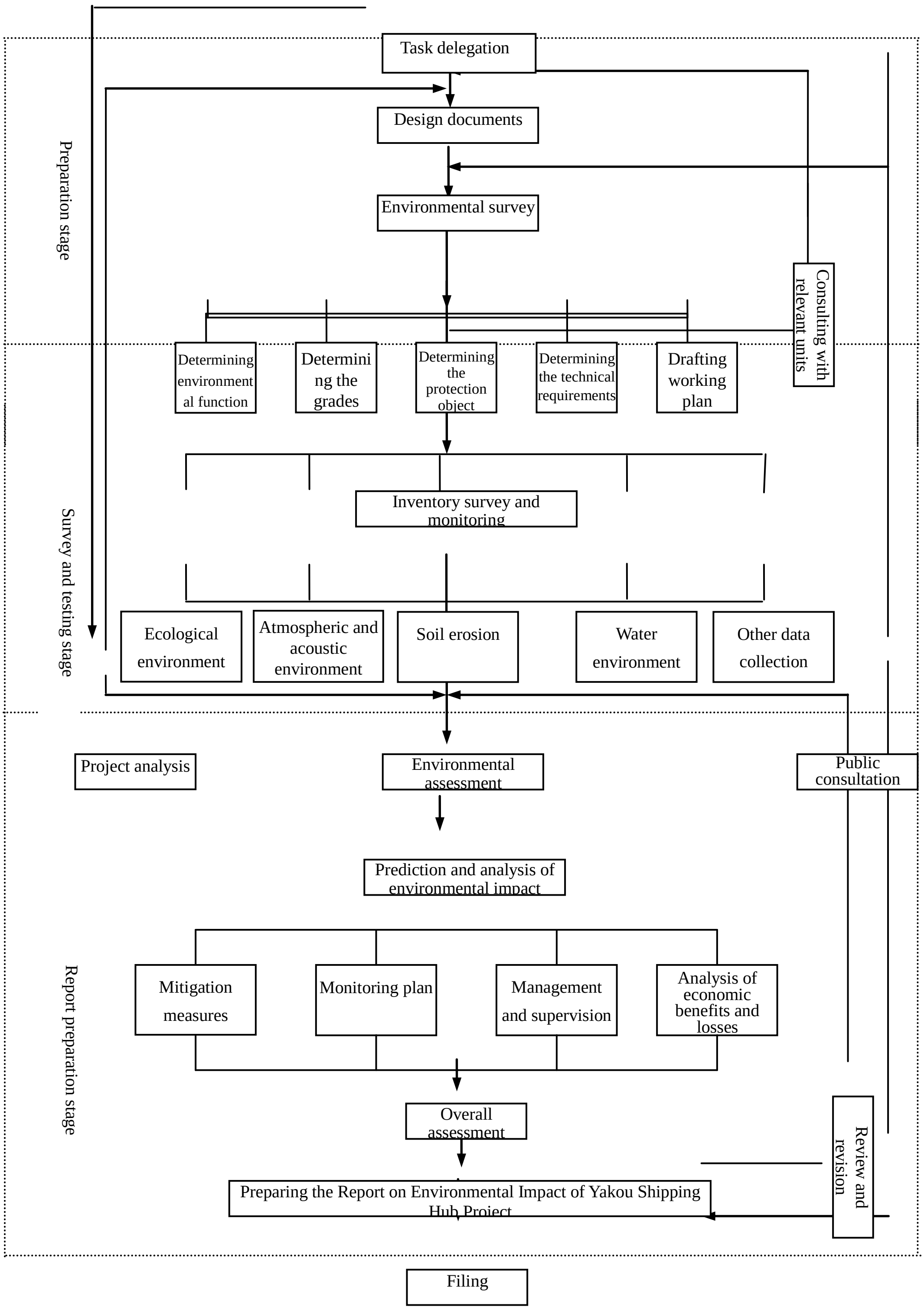


Figure 1.7 Procedures of EIA of Yakou Shipping Hub Project

2 Project Overview

2.1 Basin planning and the status of development and utilization

2.1.1 Basin introduction

Han River, one of the largest tributaries in the middle reach of the Yangtze River, originates from the south piedmont of Qinling Mountains in Shaanxi Province, passes through Shaanxi Province and Hubei Province, and falls into Yangtze River in Wuhan City. The total length is 1,567km, the fall of water level 1,964m, and the basin area 159 thousand km^2. Han River basin is located at East Longitude 106°12′ ~ 114°14′ and North Latitude 30°08′ ~ 34°11′, including the southern part of Shaanxi Province, the western part of Henan Province, the northern and middle parts of Hubei Province, the northeast part of Sichuan Province and the southeast part of Gansu Province. Han River is bounded by Qinling Mountains, Waifang Mountain, Funiu Mountain and Yellow River basin on the north, by Funiu Mountain, Tongbo Mountain and Huai River Basin on the northeast, and by Micang Mountain, Daba Mountain, Jing Mountain, Jialing River and Juzhang River on the southwest. To the southeast is Jianghan Plain with numerous and complicated river systems, and there is no distinct natural border with the main stream of Yangtze River.

The whole basin is divided into three typical reaches: above Danjiangkou is the upper reach. The total length is 918km and the controlled basin area is 95.2 thousand km^2. The reach is characterized by alternate gorges and basins with numerous beaches, turbulent water and large longitudinal gradient of river bed. The bed materials are mainly cobbles and locally stones, and the average gradient is more than 0.6‰. The main tributaries include Bao River, Xun River, Jia River and Dan River on the left bank, and Ren River and Du River on the right bank. In the topography, middle-low mountainous areas account for 79%, hills 18% and river valleys and basins only 3%.

From Danjiangkou to Zhongxiang is the middle reach. The total length is 270km, and the controlled basin area is 46.8 thousand km^2. In this section, the river passes through hilly land, and is wide and shallow wandering river section. The river width is 300m ~ 400m in low flow season and 2km ~ 3km in flood period. There are a number of sandy beaches and unsteady erosion and deposition at the river bed. The fall is 52.6m, and the average gradient is 0.19‰. The main tributaries include Xiaoqing River and Tangbai River on the left bank and Nan River, Man River and Bei River on the right bank. In the topography, plains account for 51.6%, mountainous land 25.4%, and hills 23%. The project is located at the middle reach.

From Zhongxiang to Hankou is the lower reach. The total length is 379km, and the catchment area 17 thousand km^2. In this section, the river passes through Jianghan Plain, and there are levees on both banks. The river bed is sandy bed, and the river narrows gradually, and is only 200m wide at the river mouth. This section is meandering river. The fall is 41.8m, and the average gradient is 0.06‰. Bei River falls into Han River on the left bank and Dongjing River on the right bank flows into Yangtze River. In the topography, plains account for 51%, mountainous land 22%, and hills 27%.

Han River basin is generally high in the northwest and low in the southeast. The landform in the upper reach is hilly and mountainous land alternating with valley plain, and the landform in the middle and lower reaches is plain protected by embankment. Among all landforms, mountainous land accounts for 55%, hills 21% and plain 23%. The basin area is in subtropical monsoon region with warm and wet climate. The average annual temperature is 12°C~16°C, and the average annual precipitation is 873mm, increasing gradually from the upper reach to the lower reach. The precipitation is mainly in flood season from May to October, accounting for 70% ~ 80% of the annual precipitation. The runoff is mainly recharged by precipitation, and the water flow is high. However, the runoff is distributed unevenly within the year, mainly from May to October. In the basin area, hydropower resources are abundant. According to the data from general survey of hydropower resources in 1980, the total theoretical reserves of hydraulic energy in the basin area are 10,930 thousand kW, developable installed capacity 6,140 thousand kW, annual generating capacity 25 billion kWh, and the theoretical reserves of hydraulic energy of the main stream are 3460 thousand kW, developable installed capacity 3,360 thousand kW, annual generating capacity 12.22 billion kWh. Han River is of high development and utilization value.

At the dam site of Yakou Shipping Hub, the average annual natural discharge is 1490m^3/s. After the dam of Danjiangkou Hydropower hub is heightened and 9.5 billion m^3/a of water transfer is completed in the first phase project of the middle route of South-to-North Water Transfer Project, the average annual discharge at the dam site is 1100m^3/s. There are 19 Grade-1 tributaries with catchment area more than 1,000km^2, among which, the catchment area of Dan River, Du River and Tangbai River exceeds 10,000km^2 respectively, as shown in Table 2.1.1.

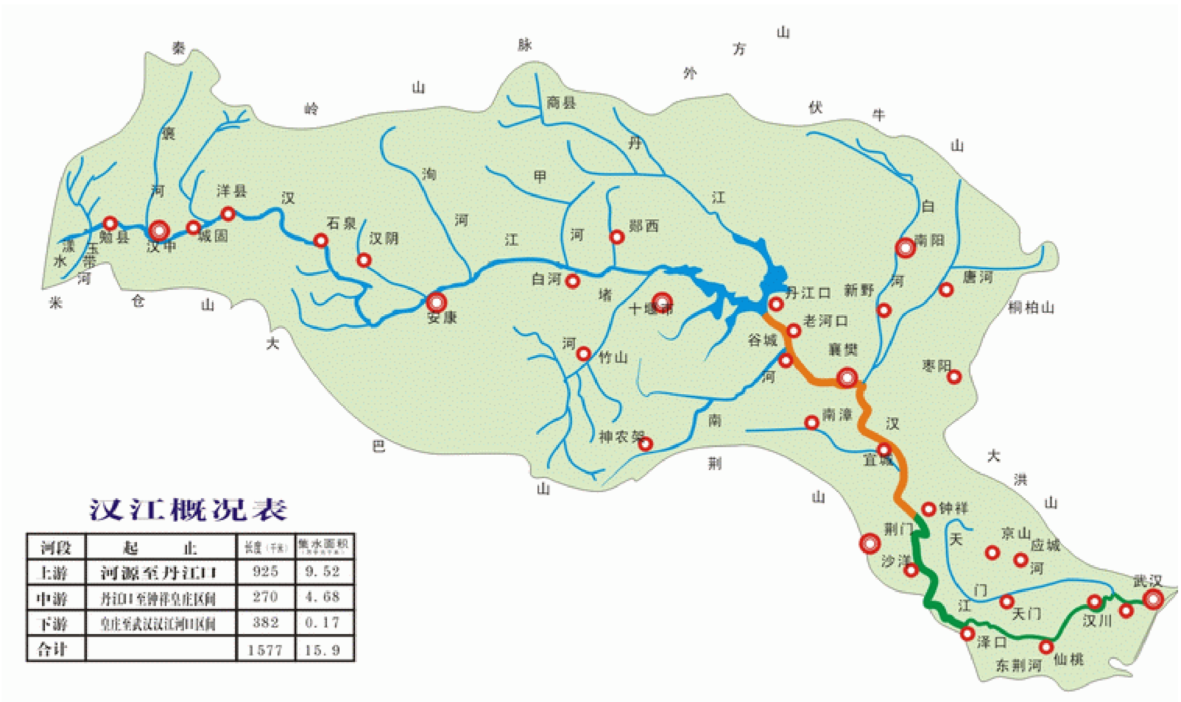


Figure 2.1.1 Sketch map of Han River basin

汉江概况表	Overview of Han River	河源至丹江口	From Heyuan To Danjiangkou
河段	River section	丹江口至钟祥皇庄区间	From Danjiangkou to Huanghuang in Zhongxiang
起止	From To	皇庄至武汉江汉河口区间	From Huangzhuang to the mouth of Han River in Wuhan
长度	Length	中游	Middle reach
千米	Km	下游	Lower reach
集水面积	Catchment area	合计	Total
上游	Upper reach		

Table 2.1.1 Basic information of main tributaries in the middle and lower reaches of Han

River

Name	Position	River source	River mouth	Catchment area (km^2)	Length (km)	Average gradient (‰)	Relationship between tributary and project
North River	Right	Nanjin Valley, Fang County	Xiaoping, Gucheng County	1194	103	2.96	Between Wangfuzhou Hydro-junction and Xinji Power Station
South River	Right	Tianjiashan Town, Shennongjia	Wangjiazui, Gucheng County	6481	253	25.10	
Xiaoqing River	Left	Hills in the south of Xichuan County, Henan Province	Qinghekou, Xiangyang City	1960	116	2.65	Between Xinji Power Station and Cuijiaying Hydro-junction
Tangbai River	Left	Laojun Mountain, Henan Province	Zhangwan, Xiangyang City	24500	352	49.37	
Man River	Right	Julong Mountain, Baokang County	Xiaohekou, Yicheng City	3276	184	14.58	Between Yakou Shipping Hub and Nianpanshan Hydro-junction
Zhupi River	Right	Zhaojiachong, Zilingpu Township, Jingmen City	Maliang Township, Jingmen City	72	58	0.88	Between Nianpanshan Hydro-junction and Xinglong Hydro-junction

Main tributaries in the river sections affected by Yakou reservoir area and at the lower reach include Chun River and Wei River (Wangjiadagou), and the main tributaries at the lower reach include Ying River and Man River. The length of the main stream of Chun River is 37.9km, and the total basin area is 100.8 km^2; the length of the main stream of Wei River is 32.6km, and the total basin area is 97 km^2.

(1) Ying River

Ying River, called Rushui River in the past, is a tributary of Han River. It originates from Qingfeng Hill in Zaoyang City, Hubei Province, and flows southwestwards into Yicheng County. There are six creeks flowing into Ying River in Zaoyang City. The total length is 63km, and the basin area is 403.9km^2. At the river mouth, the average annual discharge is 5.35m^3/s, the reserve of hydraulic energy 1,776kW, developed hydraulic energy 520 kW, and utilized area 302.6 km^2, accounting for 79.6% of the total basin area. The total capacity of Ying River reservoir #1 and reservoir #2 that have been built and completed is 119,500 thousand m^3 and 82,400 thousand m^3, respectively.

(2) Man River

Man River, also known as Xiaohe River, is a tributary at the right bank of the main stream in the lower section of the middle reach of Han River. It originates from the northeast slope of Jing Mountian, Mahuya in Longping Township, Baokang County, passes through Sandaohe Reservoir about 18km from west to east, and flows southeastwards and then westwards into Qingliang River and Hei River, and then it turns southeastward to Xiaohekou in Zhuandou Township, Zhongxiang City, and then flows into Han River via. Nanzhang County and Yicheng County. The total length is 184km, and the catchment area is 3,276km^2. The average annual discharge is 46m^3/s, the natural fall 1,080m, the gradient of the river way of the main stream 1.1‰, and the reserve of hydraulic energy 4,465 kW.

2.1.2 Basin planning and development

a) Comprehensive planning

Changjiang Water Resources Committee (namely, former Yangtze River Basin Planning Office, hereinafter referred as "CWRC") started planning study on of Han River basin in 1954, put forward *Report on Key Points of Han River Basin Planning* in 1956, and presented *Summary of Report on Han River Basin Planning* in 1958 after modification, which defined the water conservancy tasks of the basin, i.e., flood control, irrigation, power generation and shipping, considered diverting Han River to Yellow River and Huai River for long-term benefits, and recommended that Danjiangkou Hydro-juntion should be the first-phase project for comprehensive utilization of Han River.

In 1988, the former Beijing Survey Design Institute of Ministry of Water Conservancy and Electric Power completed *Development Planning Report for the Main Stream at the Upper Reach of Han River (Huangjin Valley ~ Jiangjun River)* (Shaanxi Section), which put forward the primary tasks of the main stream at the upper reach of Han River, i.e. power generation and shipping, and the seven-level development program of Huangjin Valley (normal water level 448.23m, Yellow Sea elevation, the same below) – Shiquan (408.23m) – Xi River (360.23m) – Ankang (328.23m) – Xunyang (238.23m) – Shu River (216.23m) – Jia River (194.23m), among which, the development has been completed except for Xunyang and Bai River (Jia River).

In October 1993, CWRC prepared *Comprehensive Utilization Planning Report for the Main Stream Section of Han River Downstream from Jia River*. According to the natural characteristics of Han River basin, actual socio-economic conditions and the needs of national economic development and in combination with the study results of previous development program, the report suggested the nine-level development program of Gushan (normal water level 179.23m, Yellow Sea elevation, the same below) - Danjiangkou (168.23m) – Wangfuzhou (86.23m) – Xinji (76.23m) – Cuijiaying (62.23m) –Yakou (55.22m) – Nianpanshan (49.22m) – Huajiawan (40.22m) – Xinglong (34.22m) as the representative program for treatment and development of this river section. Meanwhile, CWRC studied the development program of Xinji Power Station again, and suggested the development program of Danjiangkou (168.23m) – Wangfuzhou (86.23m) – Xinji (76.23m) – Cuijiaying (62.23m) as the representative program for the development of this river section. Due to some objections from related provinces and some major issues of the middle route of South-to-North Water Transfer Project still under study, the planning was not reviewed at that time.

In 2004, Hubei Provincial Water Resources and Hydropower Planning Survey and Design Institute worked out *Pilot Planning Outline for Modernization Construction of Water Conservancy at Middle and Lower Reaches of Han River Basin in Hubei Province* (hereinafter referred to as Planning Outline), which put forward the development tasks of the main stream of Han River at middle and lower reaches, i.e. flood control, water supply, water resources and water eco-environment protection, power generation, shipping, water and soil conservation etc. According to the Planning Outline, by 2020, a six-level hydro-junction of Wangfuzhou – Xinji – Cuijiaying – Yakou – Nianpanshan – Xinglong will be built below Danjiangkou Reservoir at the main stream of Han River at middle and lower reaches, the comprehensive development and utilization project of the main stream will be comprehensively completed, and the total planned installed capacity is 1542MW and the planned annual electricity generation capacity is 6.132 billion kWh. In February 2005, the

Planning Outline was approved by the Ministry of Water Resources and the People's Government of Hubei Province (SGJ [2005] No. 85).

In August 2007, CWRC worked out *Comprehensive Planning Report for the Main Stream of Han River (Draft for Comment)*, which was sent to Shaanxi Province and Hubei Province for comments in January 2009, and In June of the same year, after supplement and amendment *Comprehensive Planning Report for the Main Stream of Han River* was completed. In December 2010, China Renewable Energy Engineering Institute of the Ministry of Water Resources reviewed the report in Beijing, and after the review meeting CWRC modified and perfected the report based on the experts' comments and suggestions. In May 2011, CWRC put forward *Comprehensive Planning Report for the Main Stream of Han River (Revised Edition)* and submitted it to the State Council for approval. The planning report further defined the development tasks of Han River, including: flood control, water supply, water resources and aquatic ecological protection, water and soil conservation, power generation, shipping, channel improvement and bank line utilization, etc. Thereinto, due to Xinglong Hydro-junction in construction the normal water level of the river section from Nianpanshan to Xinglong was heightened by 2.0m compared with the original planned level. Through comprehensive comparison and selection, the report suggested cancelling Huajiawan Hub and proposed channel improvement measures to implement the planned development program. The development program for the main stream of Han River suggested in the report is: 15-level development program Huangjinxia (448.23m, Yellow Sea elevation, the same below) - Shiquan (408.23m) – Xi River (360.23m) – Ankang (328.23m) - Xunyang (238.23m) – Shu River (215.53m) - Bai River (194.23m) – Gushan (177.23m) – Danjiangkou (168.23m) – Wangfuzhou (86.23m) – Xinji (76.23m) – Cuijiaying (62.73m)- Yakou (55.22m) – Nianpanshan (49.22m) – Xinglong (36.22m). According to the planning, the hydro-junction development of Han River will be basically completed in 2020.

The shipping planning and hydro-junction development layout of Han River in Hubei Province is as shown in Attached Figure 2, and the hydro-junction development profile is as shown in Attached Figure 3.

b) Shipping planning

Han River, as a main line of water transportation in Hubei Province and Shaanxi Province, occupies an important position in the integrated transportation system of Hubei Province and Shaanxi Province. In the *Planning for Inland Waterways and Ports Layout in China* prepared in 2007, Han River is listed as “one line” in the layout scheme of “one transversal, one network and ten lines” for high-grade waterways in the water system of Yangtze River.

The transport authorities always attach importance to the shipping development of Han River. As early as 1958, the transport authorities worked out Shipping Planning Report for Han River Basin, which proposed different long-term and short-term measures for shipping treatment based on CWRC’s opinions on the layout of twenty shipping hubs at middle and lower reaches of Han River. In 1984, according to the arrangement of the State Council and guided by CWRC, thirteen provinces and cities and professional departments in Yangtze River Basin carried out Revision on Comprehensive Utilization Planning For Water Resources of Yangtze River Basin, and the Ministry of Communications also organized the preparation of shipping planning accordingly. The transport agencies of Shaanxi Province and Hubei Province jointly worked out Shipping Planning Report for Han River, which presented the principles for realizing canalization treatment through improvement and 18-level hydro-junction development of Han River. Depending on transport demands, the main stream of Han River is divided into three sections: below Danjiangkou, from Danjiangkou to Ankang and above Ankang. In the near term the three sections will reach Grade-IV, V and VI navigation standards, respectively, and in the long term they will reach Grade-III, IV and V navigation standard, respectively.

In 1992, the Department of Transportation of Hubei Province successively put forward a series of results including *Shipping Planning Report for the Water System of Yangtze River in Hubei Province* and *Shipping Planning Report for Han River in the Water System of Yangtze River*. Between 2003 and 2004 and in 10008, the department completed the supplement and amendment of *Shipping Development Report for Inland Rivers in Hubei Province* and

Shipping Planning Report for Han River in succession.

All of the abovementioned planning reports proposed to improve shipping conditions through engineering measures like regulation, in order to make Hankou ~ Danjiangkou, Danjiangkou ~ Xun County and Yun County ~ Bai River reach Grade-IV, V and VI navigation standard respectively, and to make Hankou ~ Danjiangkou, Danjiangkou ~ Ankang and Ankang ~ Yang County reach Grade-III, IV and V navigation standard respectively through the long-term hydro-junction canalization and the project of diverting Yangtze River to Han River. Since 1991, the number and positions of shipping development planning in Hubei Province have been consistent with the programs proposed by CWRC.

The abovementioned construction standard has been listed in the *Comprehensive Utilization Planning Report for Water Resources of Yangtze River Basin* approved by the State Council with No. 56 Document in 1996, and listed in the *Planning for Inland Waterways and Ports Layout in China* prepared in 2007. The Ministry of Communications, the Ministry of Water Resources and the State Economic and Trade Commission also gave an official reply to the short-term and long-term construction standards for Han River in [1998] No. 659 *Reply to Technical Grades of Inland Waterways*. According to *Planning for Inland Waterways and Ports Layout in China, Shipping Development Report for Inland Rivers in Hubei Province, Comprehensive Utilization Planning for the Main Stream of Han River* and *Comments of the People's Government of Hubei Province on Accelerating the Great-leap-forward Development of Water Transportation Industry in Hubei Province* (EZF [2011] No. 51), Han River shall complete the hydro-junction canalization construction and reaches the planned navigation standard by 2020, namely, Hanzhong ~ Yang County reaches Grade-VII navigation standard, Yang County ~ Ankang reaches Grade-V standard, Ankang ~ Danjiangkou reaches Grade-IV standard, and Danjiangkou ~ Hankou reaches Grade-III standard.

As for the hydro-junction planning program for the main stream of Han River in Hubei Province, the comments of the transport authorities are basically consistent with that of the water conservancy agency, that is, Gushan ~ Danjiangkou ~ Wangfuzhou ~ Xinji ~ Cuijiaying ~ Yakou ~ Nianpanshan ~ Xinglong.

In September 2012, the National Development and Reform Commission gave an official reply to the Construction Program for High-grade Waterways of Han River and Jianghan River Canals (2011-2015) submitted by the Development and Reform Commissions of Hubei Province and Shaanxi Province, and approved twelve construction projects of high-grade waterways of Han River and Jianghan River canals in the 12th five-year plan (2011-2015). Yakou Shipping Hub was listed as the newly-commenced project of the 12th five-year plan (2011-2015), and the construction contents include one 1,000t ship lock, hydropower station, earth dam, sluice, etc.

Dam of Danjiangkou Hydro-junction

Wangfuzhou Hydro-junction

Cuijiaying Hydro-junction

Xinglong Hydro-junction

Figure 2.1.2-1 Photos of built hydro-junction projects at the main stream of Han River at middle and lower reaches

Table 2.1.2 Property list for hydro-junction projects at the main stream of Han River at middle and lower reaches

Item	Uit	Danjiangkou (Initial stage)	Danjiangkou (follow-up)	Wangfuzhou	Xinji	Cuijiaying	Yakou	Nianpanshan	Xinglong
Drainage area	10^4 km^2	9.52	9.52	9.53	10.3	13.06	13.31	14.03	14.42
Average flow	m^3/s	1230	1230	1215	1282	1470	1520	1569	1569
Annual runoff	100 million m^3/s	387.8	387.8	383.1	404.3	463.6	479.3	494.8	494.8
Normal water level	m	157	170	86.23	76.23	62.73	55.72	50.72	36.23
Dead pool level	m	140	150	85.48	75.93	62.23	55.22	50.32	/
Drawdown depth	m	17	20	0.75	0.3	0.5	0.5	0.4	/
Normal water level Reservoir capacity	100 million m^3	174.5	290.5	1.495	3.012	2.45	6.08	8.77	2.73
Dead reservoir capacity	100 million m^3	76.5	126.9	1.207	2.806	2.05	5.41	7.94	/
Regulation reservoir capacity	100 million m^3	98	163.6	0.288	0.206	0.40	0.67	0.83	None
Regulation performance		Year	Incomplete many years	Danjiangkou anti-regulating reservoir	Day	Day	Day		None
Installed capacity	MW	900	900	109	120	96	80	200	37
Annual electricity generation capacity	100 million kWh	38.3	33.78	5.81	5.03	4.3	3.72	6.5	2.18
Development task		Flood control, power generation, irrigation and shipping	Flood control, water supply, power generation and shipping	Power generation, shipping, irrigation, aquatic breeding and	Power generation and shipping	Power generation and shipping	Power generation, shipping and irrigation	Power generation, shipping and irrigation	Power generation, shipping and irrigation
Implementation status		Completed	In construction	Completed	Feasibility study (preliminary preparation)	Completed	Feasibility study	Feasibility study	In construction

Time of completion		1973		2000 年		2010			
Location of construction site		Danjiangkou City	Danjiangkou City	Laohekou City	Xiangyang City	Xiangyang City	Yicheng City	Zhongxiang City	Qianjiang City
Construction unit or potential owner		Han River Water Conservancy and Hydropower (Group) Co., Ltd.	Han River Water Conservancy and Hydropower (Group) Co., Ltd.	Hubei Han River Wangfuzhou Hydropower Co., Ltd.	Datang Xiangyang Hydropower Co., Ltd.	Construction Management Office of Hubei Han River Cuijiaying Hydro-junction Project	Preparation Team of Yakou Shipping Hub Project	Hubei Han River Modern Water Conservancy Co., Ltd.	Construction Management Bureau of Hubei South-to-North Water Transfer Project

c) Engineering planning for the middle route of South-to-North Water Transfer Project

The South-to-North Water Transfer Project is a strategic infrastructure for optimizing the configuration of water resources and solving the water shortage in the north of China. On December 23, 2012, the State Council gave an official reply to the Overall Planning for South-to-North Water Transfer with GH [2002]117 Document, and the Ministry of Water Resources reviewed and passed the *General Report for the Feasibility Study on the 1st stage Project in the Middle route of South-to-North Water Transfer Project* and determined the construction program as below: implementing Danjiangkou dam heightening project and mainly adopting open channels to transfer water to Beijing, Tianjin and North China Plain. The average annual quantity of water transfer in the 1st stage project will be 9.5 billion m^3 and the total length of water transfer project is about 1,432km, mainly adopting open channels. Meanwhile, four treatment projects will be implemented at middle and lower reaches of Han River, i.e., diverting Yangtze River to Han River, Xinglong Hydro-junction, transformation of some sluice gate stations and regulation of some waterways.

At present, among the first-stage projects in the middle route, Danjiangkou dam heightening project and water transfer project have been commenced and in construction, and the water transfer along the whole line will be carried out by 2014. In accordance with the overall planning for South-to-North Water Transfer Project, the size of water transfer for Han River will be increased to 13 billion m^3 in the later-stage project in the middle route.

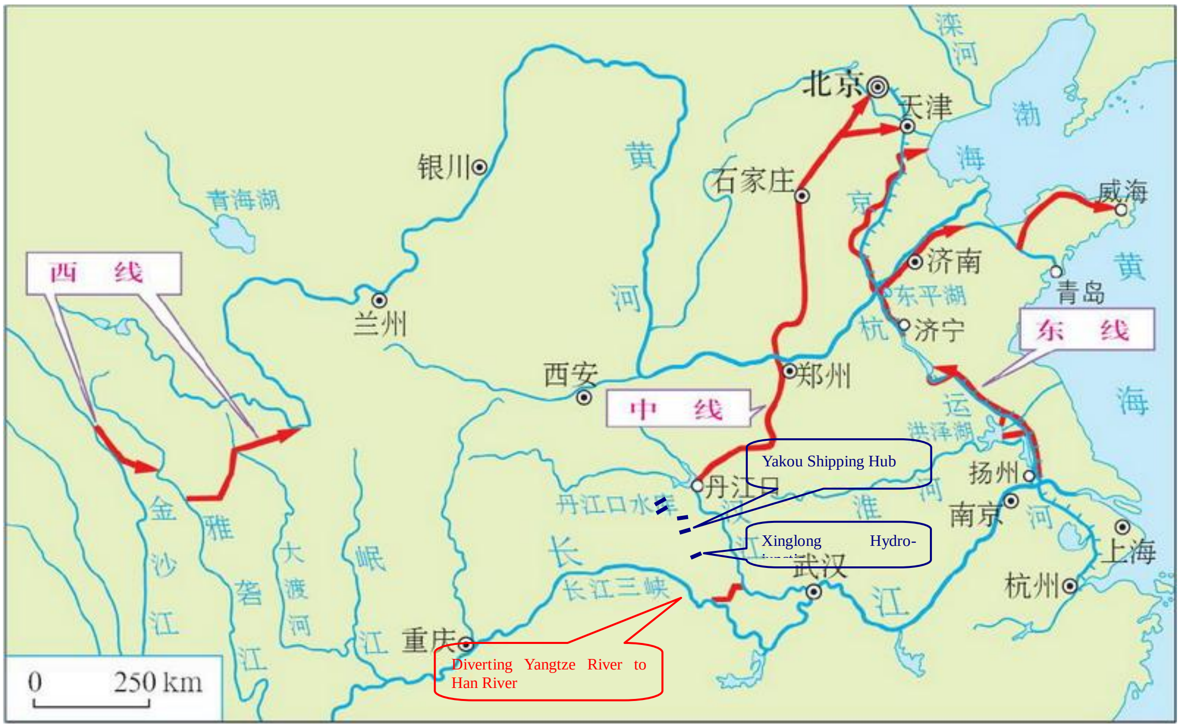


Figure 2.1.2-2 Sketch map for South-to-North Water Transfer Project

东线	East route
西线	West route
中线	Middle route

2.1.2.2 Status of drain development and construction

At present, there are 168 built and in-construction power stations in Han River Basin, and the total installed capacity is 3,674.9MW and annual electricity generation capacity 12.686 billion kWh. The initial-stage project of Danjiangkou dam was completed in 1973, and the follow-up project (Danjiangkou dam heightening) was commenced in September 2005 and is still in construction now; Wangfuzhou project was completed and put into production in 2000 and passed inspection and acceptance for individual items in 2003; Xinji project has been approved and still in preparation; the main works of Cuijiaying project was completed and put into operation in 2010; the earlier-stage design work for Yakou and Nianpanshan projects has been carried out; Xinglong project was commenced in 2009 and was completed and put into operation in 2014.

a) Danjiangkou Hydro-junction

Danjiangkou Hydro-junction is located at 800m downstream from the junction of Han

River and Dan River in Danjiang City, Hubei Province. The controlled drainage area is $9.52 \times 10^4 km^2$, and the average discharge at the dam site is $1230m^3/s$. It has integrated benefits such as flood control, power generation, irrigation, shipping and aquatic breeding. Danjiangkou Hydro-junction is the largest water conservancy project in the main stream of Han River. The initial-stage works was commenced in September 1958 and the initial scale was completed in 1973. The crest elevation is 162m, normal water level 157m, corresponding reservoir capacity 17.45 billion m^3, regulation reservoir capacity 9.8 billion m^3, and reservoir area $745km^2$. The length of backwater line along the riverway of Han River is 177km, and that of Dan River 80km. The total installed capacity is 900 thousand kW, and the annual electricity generation capacity is 3.83 billion kWh.

The follow-up works of Danjiangkou Hydro-junction is Danjiangkou dam heightening project, namely, the water source project of the 1st stage project in the middle route of South-to-North water Transfer Project. After Danjiangkou dam is heightened, the normal water level of the reservoir is increased to 170m from 157m and the corresponding reservoir capacity is increased to 29.05 billion m^3 from 17.45 billion m^3. The crest elevation of concrete dam is heightened to 176.6m from 162m, and the crest elevation of earth dam on both banks is heightened to 177.6m. For Danjiangkou dam heightening project, the check flood level is 174.35m, the dead pool level 150m, the extreme dead pool level 145m, the limit flood control level 160m ~ 163.5m, and total reservoir capacity 33.91 billion m^3. The reservoir area is $1050km^2$, and the length of backwater line of Han River is 194km, and that of Dan River is 93km. After Danjiangkou dam is heightened, Danjiangkou Hydro-junction can supply water of 9.5 billion m^3 to the intake area of South-to-North Water Transfer Project and irrigate 2,100 thousand mu of farmland in Tangbai River irrigated area, and the average annual electricity generation capacity is 3.378 billion kW·h. The project was commenced in September 2005, the crest of concrete dam was completed in June 2009, and all of 54 concrete crest sections were heightened to the top in March 2010. At present, Danjiangkou Hydro-junction is kept in operation at higher water level. Since the middle route project of South-to-North Water Transfer Project was switched on at the end of 2014, Danjiangkou reservoir has supplied water of 1.136 billion m^3 to the north by July 2015. In order to meet the water consumption demand of relevant departments at middle and lower reaches of Han River, in months when water supply guarantee rate is lower than 90%, the discharged flow of Danjiangkou Hydro-junction may not be less than 490m^3/s.

b) Wangfuzhou Hydro-junction

Wangfuzhou Hydro-junction is located at 3km downstream from Laohekou City, Hubei Province, and 30km away from Danjiangkou Hydro-junction. The controlled drainage area is 9.53×10^4 km^2 and the average flow at the dam site is 1,215 m^3/s. The main task of the junction is power generation and it also has functions of shipping, irrigation, aquatic breeding and tourism.

Wangfuzhou Hydro-junction is the first power generation and shipping hydro-junction at the lower reach of Han River that links with Danjiangkou Hydro-junction. The normal water level of the reservoir is 86.23m, and the corresponding reservoir capacity is 149.5 million m^3. After the project is completed, the benefit of power generation is added, and it may be also used as an anti-regulating reservoir of Danjiangkou Hydro-junction, which improves the navigation conditions upstream from the dam site to make the river section from Danjiangkou to Wangfuzhou reach Grade-V navigation standard and ensure that the net clearance under Laohekou Bridge in construction meets normal shipping requirements. The total installed capacity is 109MW. And the annual electricity generation capacity is 581 million kWh.

c) Xinji Hydropower Station

Xinji Hydropower Station is located in the territory of Xiangcheng District and Fancheng District, Xiangyang City, Hubei province at the middle reach of Han River. The dam is located at Baimadong, 47.5km away from Wangfuzhou Hydro-junction upwards, 63.6km away from Cuijiaying Hydro-junction downwards, and 28km away from the downtown of Xiangyang City. The controlled drainage area is 10.3×10^4 km^2, and the average flow at the dam site is 1,290m^3/s. In combination with the development conditions and the requirements of local socio-economic development, the development tasks of the hydropower station are mainly power generation and shipping.

Xinji Hydropower Station is the second-level junction downwards from Danjiangkou Hydro-junction at middle and lower reaches of Han River, and it is a water-retaining power plant with quite small self-regulating reservoir capacity. After the reservoir is completed, with the rising of water level, it may improve the irrigation water conditions on both banks, increase farmland irrigation area and increase probability of irrigation, creating favorable conditions for agricultural productions. The maximum dam height is 22.3m, the normal water level is 76.23m (Yellow Sea elevation), and the total reservoir capacity is 437.3 million m^3. The reservoir is a large (2) reservoir. The installed capacity is 120MW, and the project is a Class-3 project.

d) Cuijiaying Hydro-junction

Cuijiaying Hydro-junction is located at 17km downstream from Xiangyang City, and the controlled drainage area is $13.06\times10^4km^2$. The junction is 142km away from Danjiangkou Hydro-junction and 109km away from Wangfuzhou Hydro-junction upwards and 515km away from the river mouth downwards. The average flow at the dam site is $1470m^3/s$. The project is focused on shipping in combination with power generation, supporting shipping with power generation through integrated utilization.

Cuijiaying Hydro-junction is the third-level junction project downwards from Danjiangkou Hydro-junction at middle and lower reaches of Dan River. The normal water level of the reservoir is 62.73m, the corresponding reservoir capacity is 245 million m^3, and the installed capacity is 96MW. Cuijiaying Junction is a Class-II large (2) project. As the supporting facility of the junction, 1000t ship lock is constructed to improve the navigation conditions for about 30km of waterway.

(3) Nianpanshan Hydro-junction

Nianpanshan Hydro-junction is located in the territory of Zhongxiang City at middle and down reaches of Han River, and the dam is located at Yanshantou in Wenji Township. The controlled drainage area is $14.03\times10^4km^2$, and the average flow at the dam site is $1020m^3$ /s (result of Danjiangkou water transfer). Nianpanshan Hydro-junction is the fifth-level junction downwards from Danjiangkou Hydro-junction at middle and lower reaches of Han River. The normal water level is 50.72m (Yellow Sea elevation), the corresponding reservoir capacity is 877 million m^3, the check flow level is 50.81m, and the total corresponding reservoir capacity is 896 million m^3, and it is a Class-II project. The installed capacity is 200MW, and the annual electricity generation capacity is 650 million kWh. The junction mainly supplies power to Zhongxiang City and Jingmen City, and the power energy volume is incorporated into the power system of Hubei Province. The ship lock of this junction project is Grade-III, and the shipping grade is 1,000t.

The major development tasks of the project include power generation and shipping and also take irrigation and truism into account. It is the requirement of regional economic development to build Nianpanshan Hydro-junction, and it is also the primary task for meet the need of power system.

f) Xinglong Hydro-junction

Xinglong Hydro-junction is located at the junction between Xinglong, Qianjiang City and Baozui, Tianmen City, and it belongs to South-to-North Water Transfer Project together with Project of Diverting Yangtze River to Han River, Transformation Project of Some Sluice Gate Stations at middle and lower reaches of Han River and Regulation Project of Local Waterways at middle and lower reaches of Han River. Xinglong Hydro-junction is a Class-I project and a low-head runoff junction in plain area. The normal water level is 36.2m, the corresponding reservoir capacity is 273 million m^3, the total reservoir capacity is 485 million m^3, the irrigation area is 3,276 thousand mu, the backwater length of the reservoir area is 76.4m, the planning waterway level is Grade-III, the shipping tonnage is 1000t and the installed capacity of the power station is 40MW.

Xinglong Hydro-junction is the last hydro-junction in hydropower development plan on the main stream of Han River, and its primary tasks includes raising the water level of Xinglong reservoir in dry season, improving water diversion conditions of irrigated areas on both banks and shipping conditions of Han River as well as power generation. Xinglong Hydro-junction is mainly composed of release structures, navigation structures, hydropower stations, fishways and access bridges connecting two banks, and the total length of axis of the dam is 2835m.

2.1.2.3 Other hydro-projects in the middle and lower reaches of Han River

a) Situation of the 1st stage works in the middle route of South-to-North Water Transfer Project

The main water supply targets of the 1st stage works in the middle route of South-to-North Water Transfer Project are Beijing, Tianjin and North China. The water is diverted from Danjiangkou Hydro-junction and transferred northwards along the north edge of Tangbaihe Plain and the west edge of Huanhuaihai Plain, and it connects four large basins, i.e. Yangtze River Basin, Huai River Basin, Yellow River Basin and Hai River Basin. The water supply regions include Beijing, Tianjin, seventeen prefecture-level cities of Henan and Hebei provinces and more than one hundred counties (county-level cities) under their jurisdiction. The average annual water transfer quantity is 9.5 billion m^3, and the water distribution is as below: 3.77 billion m^3 in Henan Province (including 600 million m^3 of current water consumption in Diao River irrigated area), 3.47 billion m^3 in Hebei Province, 1.24 billion m^3 in Beijing and 1.02 billion m^3 in Tianjin. The basic tasks are urban domestic water and industrial water supply as well as ecological and agricultural water supply.

The 1st stage works in the middle route of South-to-North Water Transfer Project is located in Central China and North China to the north of the main stream of Yangtze River, involving Hubei Province, Shaanxi Province, Henan Province, Hebei Province, Beijing City, Tianjin City, etc. The project range may be divided into Danjiangkou Hydro-junction region, project region at middle and lower reaches of Han River and intake region.

The 1st stage works of South-to-North Water Transfer Project comprises three parts, namely, water source works, main channel works and regulation works at middle and lower reaches of Han River. The water source works include Danjiangkou Hydro-junction dam heightening project and Taocha Channel head sluice works. The regulation works at middle and lower reaches of Han River includes Xinglong Hydro-junction, Project of diverting Yangtze River to Han River, Transformation Project of Some Sluice Gate Stations and Regulation Project of Local Navigation Channels.

b) Project of Diverting Yangtze River to Han River

The Project of Diverting Yangtze River to Han River is a large-scale water transfer project diverting water from Jianghan River section of Yangtze River to Xinglong river section of Han River. It is one of four regulation projects at middle and lower reaches of Han River in the middle route of South-to-North Water Transfer Project, and the largest water resources optical allocation project in Hubei Province. The primary tasks of the project are to supplement the water loss of the river section of Han River below Xinglong caused by the water transfer in the 1st stage works in the middle route of South-to-North Water Transfer Project, as well as to improve the ecological, irrigation, water supply and shipping water conditions of the river section of Han River below Xinglong.

The Project of Diverting Yangtze River to Han River is divided into three parts, i.e., main channel for diverting Yangtze River to Han River, Dongjing River control works and highway and railway bridges rebuilding works. The project scale is large (I) type, and the project class is Class-I. The total length of main channel is 67.23km, channel bottom width 60m, design water depth 5.62~5.85m, and design inner slope 1:2~1:3.5; the design discharge of the channel is 350m^3/s, and the maximum water diversion flow is 500m^3/s. the recent scale of the pump station at channel head is 200m^3/s. Along the line, the project involves 83 various structures, including 14 sluice, 1 pump station, 2 ship locks, 3 rubber dams at Dongjing River, 30 inverted siphons, 32 highway bridges and 1 railway bridge. The project can be also open to shipping; it is a restricted level-III waterway, and the ship lock level is 1000t.

c) Project of Diverting Han River to Wei River

The Project of Diverting Han River to Wei River in Shaanxi Province is a key interbasin water transfer project in the territory of Shaanxi Province, and crosses Yellow River basin and Yangtze River basin. The project diverts water from Han River, passes through Qin Mountains and transfers water to Hei River, a tributary of Wei River, and finally sends the water to the water supply network of Guanzhong region for domestic water use of cities and towns. The project is a large-scale infrastructure construction project which can fundamentally solve the problem of water shortage in Guanzhong

Region. With the systematic coordination of five parts, the project diverts the water of Han River, a first-level tributary of Yangtze River with abundant water, into Wei River, a first-level tributary of Yellow River with severe water shortage, and may support the sustainable socio-economic development of Guanzhong Region with optical allocation of water resources.

With the systematic coordination of five parts, the Project of Diverting Han River to Wei River diverts the water of Han River (in North Shaanxi Region), a first-level tributary of Yangtze River with abundant water, into Wei River (in Guanzhong Region), a first-level tributary of Yellow River with severe water shortage. The project is a systematic project composed of five parts, i.e., Huangjinxia Reservoir, Huangjinxia Pump Station, Huangsan Tunnel, Sanhekou Hydro-junction, and Qin Mountains Tunnel Works. The project will be completed at a time, and the water allocation will be carried out in two stages. The water transfer quantity at the first stage (2025) will be 1003 million m^3, and the final water transfer scale (2030) is 1505 million m^3.

Figure 2.1.2-3 Sketch map for the 1st stage works in the middle route of South-to-North Water Transfer Project and the Project of Diverting Han River to Wei River

引江济汉工程	Project of Diverting Yangtze River to Han River
工程计划 2010 年开工，2015 年首期通水，首期调水规模为 10 亿立方米	The project was commenced in 2010 and was open to water transfer for the first phase in 2012, and the first-phase water transfer volume is 1 billion m³.
南水北调中线工程	Middle route of South-to-North Water Transfer Project
首期引水 95 亿立方米，2014 年汛期后通水	The first-phase water diversion volume is 9.5 billion m³, and the middle route was open to water transfer after the flood season in 2014.
计划中的引江补汉工程	Project of Diverting Yangtze River to Recharge Han River
预计引水量 60 亿立方米	Anticipated water diversion volume is 6 billion

	m^3.
引江济汉工程	Project of Diverting Yangtze River to Han River
总调水量为每年 30 亿立方米	Total water transfer volume is 3 billion m^3 every year.

2.1.3 Implementation of EIA

Because the law for EIA was not issued before and after the preparation of hydro-junction planning program for the middle and lower reaches of Han River, no requirement for EIA has been put forward and no EIA report for hydropower development plan on the main stream of Han River has been prepared. However, in accordance with relevant requirements, *Environmental Impact Report for High-grade Waterway Construction Program for Han River and Jianghan River Canals* (2011~2015), *Retrospective Report on the Environmental Impacts of Hydropower Development in the Upper Reach of Han River (Shaanxi Section)* and *Retrospective Report on the Environmental Impacts of Hydropower Development in the Middle and Lower Reaches of Han River* were put forward in different periods, and the description is as below:

2.1.3.1 Planning EIA for Han River (retrospective study)

a) Process of planning EIA for the main stream of Han River

Because the law for EIA was not issued before and after the preparation of hydro-junction planning program for the main stream at middle and lower reaches of Han River, no requirement for EIA has been put forward and no EIA report for hydropower development plan on the main stream of Han River has been prepared.

In August 2010, Shaanxi Coordination Leading Group Office for the Project of Diverting Han River to Wei River, Shaanxi Han River Investment and Development Co., Ltd. and CGNPC Han River Hydropower Development Co., Ltd. jointly entrusted Beijing Engineering Consultants Ltd. to carry out the retrospective study on EIA for the hydro-junction development of the main stream at the upper reach of Han River. In September 2010, Beijing Engineering Consultants Ltd. completed the Outline of *Retrospective Report on the Environmental Impacts of Hydropower Development in the Upper Reach of Han River (Shaanxi Section)*, and in October, Shaanxi Provincial Department of Environmental

Protection invited experts to consult the outline and issued SHH [2010] No. 807 Document to agree to carrying out EIA according to the outline. In October 2012, Beijing Engineering Consultants Ltd. put forward *Retrospective Report on the Environmental Impacts of Hydropower Development in the Upper Reach of Han River (Shaanxi Section),* and in April 2014, the Ministry of Environmental Protection issued its review comments in Letter from EPB [2013] No. 425.

In March 2012, Datang Xiangyang Hydropower Co., Ltd. called for bids for *Retrospective Report on the Environmental Impacts of Hydropower Development in the Middle and Lower Reaches of Han River* through open tendering, and Hubei Academy of Environmental Sciences won the bidding. In April 2012, Hubei Academy began the work of preliminary data collection and field survey, and in May 2012, Datang Xiangyang Hydropower Co., Ltd. formally entrusted Hubei Academy of Environmental Sciences to carry out the retrospective study on the environmental impacts of the hydro-junction development of the main stream at middle and lower reaches of Han River. Hubei Academy of Environmental Sciences completed *Retrospective Report on the Environmental Impacts of Hydropower Development in the Middle and Lower Reaches of Han River* in August 2012, and the Ministry of Environmental Protection issued its review comments in Letter from EPB [2013] No. 1273.

b) Main conclusions of retrospective assessment for the development of Han River

1) Main assessment conclusions

(1) The hydro-junction development of the main stream at middle and lower reaches of Han River conforms to the industrial policies of *Industrial Structure Adjustment Guidance Directory (2011 Version)* and *Notice on Accelerate the Restructuring of the Electric Power Industry to Promote the Healthy and Orderly Development* (FGN [2006] No. 661), is consistent with relevant regulations of *Water Law of the People's Republic of China, Flood Control Law of the People's Republic of China* and *Nature Reserve Management Regulations of the People's Republic of China*, and coordinates with relevant planning programs like *National Ecological Function Zoning, National Main Functional Area Planning, the Twelfth Five-year Plan for National Economic and Social Development, Outline of Sustainable*

Development, Water Conservancy Development Planning, Energy Planning and Environmental Protection Planning, as well as relevant local zoning and planning.

(2) The current hydro-junction construction at the lower reach of Han River takes positive role in facilitating regional economic development, improving power supply and increasing irrigation ability. However, the current hydro-junction development changes the original hydrological regime of Han River, and further impacts water environment and ecological environment to a certain extent. There is relatively significant impact on aquatic ecological environment, especially on the breeding of fish with pelagic eggs.

(3) After the planning hydro-junction development at middle and lower reaches of Han River is implemented completely, a seven-level development mode of Danjiangkou - Wangfuzhou - Xinji – Cuijiaying – Yakou – Nianpanshan – Xinglong is formed with Danjiangkou Hydro-junction as the first level. With the impact of South-to-North Water Transfer Project, the hydro-junction construction further changes the hydrological regime of the main stream at middle and lower reaches of Han River. As a result, the water environmental capacity reduces, the water quality of each section below Cuijiaying at middle and lower reaches of Hanjiang exceeds the standard to a certain extent, there is a mild eutrophication trend in each reservoir area, and the average water temperature of the river section above Xinji tends to reduce. The impact on aquatic ecological environment is mainly embodied in dam obstruction and decreasing flow rate as well as the adverse impact on the breeding of fish with pelagic eggs and the germplasm resources protection zones.

(4) In a word, the multi-level development of the main stream at middle and lower reaches of Han River may fully utilize hydropower resources and bring benefits for power generation and flood control at the lower reach. The original hydro-junction development program can be put into practice based on increasing the strength of water pollution control and fully implementing various mitigation measures, especially the aquatic ecological protection measures such as ecological regulation, artificial enhancement and releasing and fishway building.

2) Environmental protection requirements for this project

(1) Aquatic ecological protection measure suggestions

Building fish enhancement and releasing station: in order to maintain the balance of ecological system, fully utilize water ecological resources and compensate the loss of fish resources, fish enhancement and releasing station shall be built for the purpose of recover the fish resources of Han River. The fish species to be released mainly include: *Elopichthys bambusa*, *Ochetobius elongates*, *Long spikyhead carp*, black carp (*Mylopharyngodon piceus*), grass carp (*Ctenopharyngodon idellus*), silver carp (*Hypophthalmichthys molitrix*) and bighead carp (*Aristichthys nobilis*).

Fish passing measures: in order to guarantee the behavior channels of migratory fishes, fishway shall be built and the relevant design shall be carried out for special items.

There are a lot of central shoals and side shoals in the spawning areas of fish with pelagic eggs in Yicheng, so disorderedly and excessive sand milling is strictly forbidden.

Intensify fishery resources management and strengthen the breeding protection of fish resources. Strictly implement the regulations for closed fishing season and ground; restrict fishing gears and fishing methods. Netting gears of small size less than 6cm and some fishing methods like electric shocking, bombing and poisoning fish, shall be banned strictly. Carry out fishing license system and intensify fishery management.

(2) Terrestrial ecological protection measure suggestions

After the construction is completed, vegetation recovery shall be carried out at construction site and stock ground. Greatest efforts shall be made to protect the ecological environment of the original low hilly land in the construction area as well as to develop the terrestrial ecological system with broadleaved deciduous forest and brushwood and scrub-grassland vegetation as the main body.

(3) Social mitigation measures

Resettlement protection measures: implement resettlement plans and various policies; forbid the development of slope barren of more than 25°; supplement cultivated land through land development and adopt a series of agricultural and water conservancy measures to transform low-yield farmland. Drinking water purification and sterilization facilities shall be provided for the centralized water supply of resettlement area, and sewage treatment devices shall be provided for domestic wastewater discharge. Biogas digesters or hygienic toilets shall be built in resettlement area for harmless treatment of human and animal excreta. Water and soil erosion prevention measures shall be carried out in the construction process of resettlement area, and the greening work in residential district shall be intensified.

Drainage facility protection measures: the construction of Yakou Project will cause six drainage culvert sluice to loss self-drainage function, and water drainage, flood drainage and embankment facilities that may be impacted shall be transformed. Adopt the water logging drainage system combining open Ditches and concealed conduits in the farmland that may be inundated by the planned development, strengthen groundwater monitoring, and control groundwater depth in the farmland according to inundation and water logging drainage standards.

c) Review comments on planning EIA

The General Office of the Ministry of Environmental Protection gave an official reply to the report in Letter from EPB [2013] No. 1273: *Letter on Relevant Comments on Retrospective Report on the Environmental Impacts of Hydropower Development in the Middle and Lower Reaches of Han River*.

1) Overall evaluation on environmental reasonableness and feasibility

In general, the hydro-junction development program is conforming to the requirements of relevant planning such as economic and social development and water conservancy development planning, and is of great significance in promoting the basin and regional economic development, strengthening flood control ability, improving power supply and shipping conditions and increasing water supply and irrigation ability. Meanwhile, it may compensate the impact of South-to-North Water Transfer Project on the middle and lower reaches of Han River, and has significant economic and social benefits. Moreover, due to the hydro-junction development, the natural river channels change into a pattern the same as reservoir, hydrological regime changes significantly; the groundwater level in partial region rises and the original replenishment relationship changes; the spawning grounds of four major Chinese carps basically vanish in some river sections, which adversely impacts environmentally sensitive targets such as National Aquatic Germplasm Resources Protection Zone for *Elopichthys bambusa*, *Ochetobius elongates* and *Long ppikyhead carp* in Zhongxiang Section of Han River.

2) Comments on the process of optimized adjustment and implementation

(1) The hydro-junction construction of Yakou and Nianpanshan will cause obvious adverse impact on fish breeding, migration and important habitats. And in-depth study and demonstration shall be carried out for the property, range and extent of the impacts and the effectiveness of countermeasures for mitigating adverse impacts. It is suggested to further demonstrate the environmental feasibility of the hydro-junction development of Yakou and Nianpanshan on the premise of settling the major adverse impacts caused by the hydro-junction development.

(2) Strengthen the alternative habitat protection for aquatic organism. Build fish protection zone in the water area of Han River from Xinji dam site to Wangfuzhou dam site and in some river sections of Nan River and Bei River, and adopt effective measures to intensify the protection of aquatic organism in protection zone and its important habitats.

(3) Increase the connectivity of river channel. Fish passes shall be built in the follow-up hydro-junction development like Xinji. In combination with the layout of Wangfuzhou Junction, study the feasibility of increasing fishways or imitating natural channel. Carry out key technology study for fish gathering and guiding.

(4) Plan fish enhancement and releasing as a whole, and fully play the role in compensating fish resources in the basin. Consider the hydro-junction development of the basin as a whole and scientifically distribute fish stock enhancement stations. Accelerate long-term and middle-term study for releasing and artificial fish enhancement technology. Carry out in-depth study on the feasibility of building fish enhancement and releasing stations in combination with Danjiangkou and Wangfuzhou hydro-junction development.

(5) Build basin ecological regulation mechanism and guarantee ecological flow discharge. The breeding season of fish with pelagic eggs is from May to August. When the discharge flow of Danjiangkou Reservoir exceeds $800m^3/s$, the junctions at the lower reach involving fish spawning ground or aquatic germplasm resources protection zone shall

increase discharge flow, in order to make the hydrological conditions of relevant river sections meet the demand of breeding of four major Chinese carps and valuable and rare carps like *Elopichthys bambusa*, *Ochetobius elongates* and *Long spikyhead carp*.

(6) Carry out terrestrial ecological protection measures. Intensify the environmental management during construction, carry out water and soil conservation measures, and mitigate the impacts on wild animals, natural vegetation and landscape.

(7) Study and build hydro-junction ecological environmental protection organization. Carry out basin ecological basis survey and long-term tracking monitoring (including aquatic and terrestrial), and gradually build basic ecological monitoring system and basin ecological environment database.

2.1.3.2 EIA on high-grade waterway construction program for Han River

a) EIA process of high-grade waterway construction program

In November 2010, guided by Hubei Provincial Development and Reform Commission, with participation of Shaanxi Provincial Development and Reform Commission, and organized by Hubei Provincial Port and Shipping Administration and Shanxi Provincial Shipping Administration, Hubei Provincial Communications Planning and Design Institute worked out *High-grade Waterway Construction Program for Han River and Jianghan River* Canals (2011-2015). Between July 2010 ~ March 2011, in order to fully consider and prevent the environmental impacts caused by planning construction, mitigate the negative effects of waterway construction and operation on environment and ecology and coordinate the relationship between economic and social growth environmental protection, CCCC Second Port Consultants Co., Ltd., entrusted by Hubei Provincial Port and Shipping Administration, worked out *EIA Report for High-grade Waterway Construction Program for Han River and Jianghan River Canals (2011 ~2015),* in accordance with the relevant requirements of *Law of EIA of the People's Republic of China, Regulations for Planning EIA, Notice on Relevant Problems of Planning EIA Implemented in Communication Industry* (JHF [2004] No. 457) and related laws and regulations. In Jul 2011, the Ministry of Environmental Protection proposed review comments in HS [2011] No. 189 Document.

b) Main evaluation conclusions on the report

1) Main evaluation conclusions

It is planned to implement 17 waterway construction projects in Han River during Twelfth Five-year Plan (2011 – 2015), including 3 continued construction projects of the Eleventh Fiver-year Plan (2006 – 2010) and 13 new construction projects of the Twelfth Five-year Plan (2011 – 2015). Among the new construction projects, it is clearly proposed to build “Han River Yakou Hub Ship Lock Project”. Because there are problems in the shipping development of Han River such as slow waterway construction and low waterway standard, the construction program for building high-grade waterways may bring positive social and economic benefits. The planning is conforming to the upper-level planning of the basin, is basically compatible with other social development planning and basin planning, and may be linked up with the waterway planning of provinces along the river. The major environmental constraint factors in the implementation of this construction program are embodied in: effects of South-to-North Project on river regime and channel at the lower reaches as well as on water resources utilization; protection of aquatic ecological germplasm resources protection zone of Han River and protection of special habitats such as wintering ground, spawning ground and feeding ground of fishes; and the water quality requirements of drinking water source protection zone. The environmental constraint factors for the program implementation include: one aquatic germplasm resources protection zone, i.e., National Aquatic Germplasm Resources Protection Zone for *Elopichthys bambusa*, *Ochetobius elongates* and *Long spikyhead carp* in Zhongxiang Section of Han River, ten centralized water sources of cities and towns along the lien and Danjiangkou Reservoir water source of South-to-North Water Transfer Project, two important wetlands, i.e. Shaanxi Jianghan Wetland and Ankang Xun River Wetland, and eleven centralized fish spawning grounds.

Through distinguishing the coordination between construction program and relevant planning and the environmental rationality, relevant suggestions and mitigation measures are brought into the construction program, and ecological impact and environmental pollution may be controlled effectively. In the construction program, the total pollution discharge is small and makes limited contribution to the gross indicator of the basin. Prior to the implementation of the construction program, it is necessary to carry out sufficient demonstration and obtain the approval of related departments. It is required to avid centralized water source and other sensitive areas to the greatest extent, fully emphasize the shipping environmental risks of water sources of South-to-North Water Transfer Project, implement emergency plans and prevention work for ships and ports and improve ship pollutant receiving and treatment systems according to shipping characteristics of each province, in order to realize regional environmental objectives and mutual promotion between shipping development and regional development, and achieve the unification of social, economic and environmental benefits.

The overall layout of the construction program is reasonable, and is basically coordinated with other related planning. From the prospective of environmental protection, the planning is feasible in the premise of implementing relevant suggestions and environmental protection requirements proposed in the evaluation.

2) Requirements for EIA

In planning EIA, there is no definite key point and requirement for project EIA for Yakou Hub Ship Lock Project, but specific requirements are raised for Regulation Project for Unconnected Waterway Section between Cuijiaying Junction and Xinglong Hydro-junction of Han River which may be involved in this project: demonstrate the effect of the construction on the fishes in National Aquatic Germplasm Resources Protection Zone for *Elopichthys bambusa*, *Ochetobius elongates* and *Long spikyhead carp* in Zhongxiang Section of Han River and the change of protected fish habitats caused by project construction and analyze effect extent and aging in combination with project contents; put forward relevant ecological compensation measures according to the results of impact assessment, and analyze the risk impact on water taking safety of waterworks along the line during construction and operation of the waterway regulation project.

c) Review comments on EIA

In July 2011, the Ministry of Environmental Protection gave an office reply in Review

Comments on *EIA Report for High-grade Waterway Construction Program for Han River and Jianghan River Canals (2011 ~2015)* (HS [2011] No. 189):

1) Overall evaluation on environmental rationality and feasibility of the Planning

In general, there is certain environmental rationality in the waterway regulation part related to the Planning, but the effect of hydropower hub construction on aquatic ecological environment still has to be specified. Therefore, it is required to further optimize the planning implementation program, strengthen various mitigation measures and effectively prevent or mitigate the possible adverse environmental effects caused by the implementation of the Planning.

2) Comments on the optimized adjustment and implementation of the Program

(1) In the implementation process of the planning, consider as a whole the coordination with water resources utilization planning for the main stream of Han River and hydropower development planning.

(2) Further optimize the regulation project program for the waterway section of Hanjiang River from Ankang to Bai River, and avoid occupying or damaging Shaanxi Ankang Ying Lake Wetland, an important habitat of provincial nature reserve.

(3) Further optimize the regulation project program for the waterway section of Hanjiang River from Gu Mountain to Danjiangkou, and avoid occupying or damaging Hubei Provincial Danjiangkou Reservoir Area Wetland, an important habitat of provincial nature reserve.

(4) Optimize construction modes. Adopt ecological embankment, controlled damming and beach protection size, and avoid the core area of National Aquatic Germplasm Resources Protection Zone for *Elopichthys bambusa*, *Ochetobius elongates* and *Long spikyhead carp* in Zhongxiang Section of Han River; avoid the breeding seasons of *Leiocassis longirostris, Pelteobagrus vachelli, Elopichthys bambusa, Ochetobius elongates*, *Long spikyhead carp* and Spanish mackerel of Dan River; the waterway regulation project may not change the river regime and habitat conditions of tributaries and river mouths.

(5) Transport hazardous chemical materials strictly according to national laws and regulations; forbid transporting hazardous chemicals and pesticides and chemical fertilizers

in the waterway of Han River from Xi River to Danjiangkou.

(6) Plan fish passing facility construction as a whole and carry out remedial measures for the ecological impacts of South-to-North Water Transfer Project, and intensify the protection of drinking water sources such as Danjiangkou Reservoir.

(7) In the implementation process of the Planning, carry out follow-up EIA once every five years, and rework out the EIA report when amending the Planning.

3) Comments on EIA of recent construction projects included in the Planning

As for the recent construction projects included in the Planning, when carrying out EIA, the environmental impacts of the project implementation on water environment, water ecology and drinking water source shall be evaluated as an emphasis. In-depth evaluation shall be carried out on the impact mode, range and degree of the projects involving sensitive areas such as nature reserve, aquatic germplasm resources protection zone and important wetland, and the implementation of mitigation measures shall be intensified.

2.1.4 Implementation of the requirements raised in the reply to planning EIA

a) EIA on high-grade waterway construction program for Han River

There is no specific key point or requirement in Review Comments on *EIA Report for High-grade Waterway Construction Program for Han River and Jianghan River Canals (2011 ~2015)* and the reply to it for Yakou Hub Ship Lock Project. According to the reply, as for the recent construction projects, when carrying out EIA, the environmental impacts of the project implementation on water environment, water ecology and drinking water source shall be evaluated as an emphasis, in-depth evaluation shall be carried out on the impact mode, range and degree of the projects involving sensitive areas such as nature reserve, aquatic germplasm resources protection zone and important wetland, and the implementation of mitigation measures shall be intensified. Against the requirements in the reply, in the process of EIA, the environmental impacts on water resources, water ecology and drinking water sources have been taken as the emphasis, in-depth evaluation has been carried out on sensitive areas involved in this project such as Provincial Cuijiaying Wetland Park and Hubei Yicheng Wanyangzhou National Wetland Park, and multiple and diversified measures have been taken for water environment and aquatic ecological protection, which are conforming to the requirements of the high-grade waterway construction program for Han River

b) Retrospective evaluation of environmental impacts

In the process of preparing the report, detailed survey has been carried out item by item for the implementation of the requirements related to Yakou hydro-junction development, in *Review Comments on the Retrospective Report on the Environmental Impacts of Hydropower Development in the Middle and Lower Reaches of Han River* (HBH [2013] No. 1273) issued by the General Office of the Ministry of Environmental Protection. See Table 2.1.4 for details.

Table 2.1.4 Implementation of requirements related to Yakou hydro-junction development in the reply to planning EIA

Serial No.	Reply comments	Implementation status
1	The hydro-junction construction of Yakou and Nianpanshan will cause obvious adverse impact on fish breeding, migration and important habitats. And in-depth study and demonstration shall be carried out for the property, range and extent of the impacts as well as the effectiveness of countermeasures for mitigating adverse impacts. It is suggested to further demonstrate the environmental feasibility of the hydro-junction development of Yakou and Nianpanshan on the premise of settling the major adverse impacts caused by the hydro-junction development.	In the process of EIA, our company, cooperating with CAS Institute of Hydrology, carried out detailed survey and profound demonstration from multiple aspects including the impact of engineering construction on fish resources and important habitats and the effectiveness of fish protection measures, and conducted scientific and objective assessment on the environmental feasibility of Yakou hydro-junction development in terms of planning conformity, program rationality and environmental objective accessibility. For example, it is proposed to implement joint ecological regulation for open discharge of Cuijiaying, Yakou and Xinglong Hydro-junctions when Tangbai River floods so that the spawning grounds of fish with pelagic eggs below the reservoir and dam can still play ecological functions; in order to mitigate the obstruction impact in non-flood period, technological design of artificial fishway is carried out for the purpose of recovering the connectivity of rivers; technological design of fish stock enhancement and releasing station is carried out in terms of the impacts on fish resources. A series of such protection measures can effectively reduce the impact of the hydro-junction development at middle and lower reaches of Han River on fish resources and important habitats, and the project construction

Serial No.	Reply comments	Implementation status
		has environmental feasibility.
2	Strengthen the alternative habitat protection for aquatic organism. Build fish protection zone in the water area of Han River from Xinji dam site to Wangfuzhou dam site and in some river sections of Nan River and Bei River, and adopt effective measures to intensify the protection of aquatic organism in protection zone and its important habitats.	This project doesn't involve the water area of Han River from Xinji dam site to Wangfuzhou dam site, Nan River or Bei River. In the EIA, it is proposed to take Ying River, a tributary below the dam, as an important habitat of aquatic organism for habitat protection.
3	Increase the connectivity of river channel. Fish passes shall be built in the follow-up hydro-junction development like Xinji. In combination with the layout of Wangfuzhou Junction, study the feasibility of increasing fishways or imitating natural channel. Carry out key technology study for fish gathering and guiding.	The layout of Yakou hydropower hub includes fishway, and comparison study on fish passing schemes is carried out under entrustment. It is recommended to adopt the scheme of stimulating natural fishway on the left bank.
4	Plan fish enhancement and releasing as a whole, and fully play the role in compensating fish resources in the basin. Consider the hydro-junction development of the basin as a whole and scientifically distribute fish stock enhancement stations. Accelerate long-term and middle-term study for releasing and artificial fish enhancement technology. Carry out in-depth study on the feasibility of building fish enhancement and releasing stations in combination with Danjiangkou and Wangfuzhou hydro-junction development.	In order to plan fish stock enhancement and releasing and play the role in compensating fish resources in the basin, through comprehensive comparison and based on overall consideration, it is selected to build a new fish stock enhancement and releasing station at PIU's camp, so as to fully play its role and meet the requirements of project construction.

Table 2.1.4 (Cont.)

Serial No.	Reply comments	Implementation status
5	Build basin ecological regulation mechanism and guarantee ecological flow discharge. The breeding season of fish with pelagic eggs is from May to August. When the discharge flow of Danjiangkou Reservoir exceeds 800m^3/s, the junctions at the lower reach involving fish spawning	Raise the requirements for joint ecological regulation of the junctions of Han River below Danjiangkou: when the flow is greater than 8710m^3/s, after the water level of the reservoir reduces to the control water level of flood control operation, the water is discharged openly to flush sand and fish can swim upstream from the sluice. In order to ensure that fish can

Serial No.	Reply comments	Implementation status
	ground or aquatic germplasm resources protection zone shall increase discharge flow, in order to make the hydrological conditions of relevant river sections meet the demand of breeding of four major Chinese carps and valuable and rare carps like *Elopichthys bambusa*, *Ochetobius elongates* and *Long spikyhead carp*.	successfully swim upstream to the spawning ground. It is feasible to open the sluice to be fully open 24 hours in advance and keep open discharging according to water regime forecast. After spawning, roes will drift downward. In order to prevent the incubation process from being obstructed, it is suggested to close the sluice 48 hours after the flood peak.
6	Carry out terrestrial ecological protection measures. Intensify the environmental management during construction, carry out water and soil conservation measures, and mitigate the impacts on wild animals, natural vegetation and landscape.	In the period of feasibility study for Yakou hydro-junction development, EIA and subject demonstration for water and soil conservation are carried out. At next stage, relevant deepened design will be carried out according to the EIA and water and soil conservation assessment as approved, and will be implemented at construction stage.
7	Study and build hydro-junction ecological environmental protection organization. Carry out basin ecological basis survey and long-term tracking monitoring (including aquatic and terrestrial), and gradually build basic ecological monitoring system and basin ecological environment database.	In the period of preparing the report, aquatic and terrestrial ecological survey and earlier resources observation are carried out, and aquatic ecological monitoring plan and terrestrial monitoring plan are proposed including enhancement and releasing effect monitoring and fish passing effect monitoring. Meanwhile, it is recommended to build a basin environment management center and strengthen basin environment monitoring.

According to the table above, in the process of preparing project feasibility study and EIA reports, the construction unit, the design institute and our company all paid high attention to the requirements of Letter from EPB [2013]No. 1273. Especially in view of the first comment, namely, “the hydro-junction construction of Yakou and Nianpanshan will cause obvious adverse impact on fish breeding, migration and important habitat…… It is suggested to further demonstrate the environmental feasibility of the hydro-junction development of Yakou and Nianpanshan on the premise of settling the major adverse impacts caused by the hydro-junction development.” Our company, cooperating with CAS Institute of Hydrology, carried out a great deal of data collection and field survey and study, investigated the change of spawning grounds of fish with pelagic eggs in the main stream of Han River, analyzed and forecasted the impacts of Yakou hydro-junction construction on the spawning grounds of fish with pelagic eggs in the main stream of Han River, and carried out focused study and demonstration on the countermeasures for mitigating the adverse impacts on the breeding of fish with pelagic eggs in the main stream of Han River, in order to support the environmental feasibility of Yakou construction.

Seen from the accumulated impacts of the hydro-junction development at middle and lower reaches of Han River on fish resources, with the construction of Danjiangkou Reservoir, fish cannot swim upstream to Danjiangkou dam, and the fish spawning at the upper reach of Han River cannot swim to the middle and lower reaches of Han River and even Yangtze River. The original aquatic ecological functions are mainly undertaken by the middle and lower reaches of Han River, and the corresponding habitats shrink and functions ware weakened. Especially, the temperature of water discharged from Daniangou Reservoir is low and the fish breeding at middle and lower reaches of Han River is delayed for about one month. However, there are still many spawning grounds at middle and lower reaches of Han River, which are important places for fish spawning and breeding at middle and lower reaches of Yangtze River. With the construction of Wangfuzhou, Cuijiaying and Xinglong Hydro-junctions, some spawning grounds are inundated, fish migration channels are obstructed, spawning grounds shrink, breeding groups reduce, and spawning ground size significantly decreases. Especially, in dry year, due to low peak discharge and attenuation of multi-level junctions, the flood peak process is not obvious. At present, the spawning function of the remaining spawning grounds in Yicheng, Guanjiashan and Zhongxiang are weakened obviously. According to the survey results of spawning grounds in 2014, with low peak discharge of Han River in dry season, there was no early fish resources monitored in the spawning ground in Yicheng, and there was also no fish spawning or breeding monitoring in Zekou spawning ground below Xinglong dam; early resources were monitored only in the spawning grounds in Guanjiashan and Zhongxiang, with significant scale decreasing and spawning fish species reducing. With the operation of the 1st stage works of South-to-North Water Transfer Project, the water discharged from Danjiangkou dam will further reduce and the water temperature will also fall, which will further cause impacts on these spawning grounds. The spawning grounds at middle and lower reaches of Han River may recover some functions only when the flood peak discharge exceeds 8000m^3/s and the junctions discharge water openly for flood control in high flow year.

With the construction of Yakou Shipping Hub, the adverse impact on the fish with pelagic eggs at middle and lower reaches of Han River will further increase without ecological regulation. The spawning ground in Yicheng may recover some functions only when the flood peak discharge exceeds 8000m^3/s and the junctions discharge water openly for flood control; correspondingly, due to the attenuation of peak flood process caused by Yakou reservoir, adverse impacts may be caused to the spawning grounds in Guanshanjia and Zhongxiang below the dam when peak discharge is low. Therefore, even if Yakou Shipping Hub is not built at middle and lower reaches of Han River, due to the obstruction of built junctions, the early resources will continuously drift with water below Xinglong dam, mature parents at the lower reach of Han River and at middle and lower reaches of Yangtze River will swim upstream above Xinglong dam and be obstructed, the number of fish groups spawning drifting roes will continuously reduce, and the spawning and breeding functions of the current spawning grounds will also be weakened continuously.

However, according to the study on the hydraulic and hydrological conditions required for the breeding of fish with pelagic eggs at middle and lower reaches of Han River carried out between 2004 and 2007, the breeding of fish with pelagic eggs at middle and lower reaches of Han River mainly depends on the flood of Tangbai River and interval flood, especially Tangbai River flood, and the flood discharge of Danjiangkou reservoir only has the function of facilitation. Therefore, adopting the ecological regulation of open discharging for Cuijiaying, Yakou and Xinglong Hydro-junctions in due time according to the water regime of Tangbai River can recover the natural flow stats of main spawning river sections at middle and lower reaches of Han River and mitigate the adverse impacts of the change of water regime on the breeding of fish with pelagic eggs; moreover, opening sluice in proper time may smooth the connection between the project river section and the lower reach of Han River and the middle and lower reaches of Yangtze River and mitigate the obstruction impact on the breeding groups swimming upstream to spawning groundings. Such measures are of great significance in protecting and the spawning grounds of fish with pelagic eggs at middle and lower reaches of Han River and continuing to play the ecological functions of the spawning grounds of fish with pelagic eggs in

Yicheng in reservoir area and in Guanjiashan and Zhongxiang below the dam, which can not only effectively mitigate the adverse impacts of Yakou Hub on fish resources spawning drifting roes, but also mitigate the adverse impacts cased by the built junctions at middle and lower reaches of Han River to a great extent.

When adopting the schedule of open discharging, in order to mitigate the obstruction impact in non-flood period, it is suggested to build artificial fishway to keep the connectivity of the river, which can not only promote fish exchange above and below the dam, but also guarantee the smooth migration channels for migrating fish such as black carp, grass carp, silver carp and bighead cap and protect the integrity of fish life history. Furthermore, a habitat protection planning program is worked out, and auxiliary enhancement and releasing measures are taken against the impacts on fish resources. The impacts of the hydro-junction development at middle and lower reaches of Han River on fish resources may be effectively mitigated with a series of protection measures. The project construction has environmental feasibility.

2.2 Engineering properties

2.2.1 Geographical location

Yakou Shipping Hub is located in the middle reach of Han River between Xiangyang and Zhongxiang, and the dam is located in Yakou Village, Liushui Township, 15.7km downstream from Yicheng City and about 80km away from the downtown of Xiangyang City. This project is the sixth-level development project for the main stream of Han River in Hubei Province, 203km away from the Danjiangkou Hydro-junction and 446km from Hekou.

The sketch map for the geographical location of the project is shown in Attached Figure 1.

2.2.2 Development tasks

The development tasks of Yakou Shipping Hub are focused on shipping, and integrated utilization benefits like power generation, irrigation and tourism are also considered.

Shipping: the construction of the hub may be effectively linked with Cuijiaying

Hydro-junction upstream, and will inundate six beach groups including Longmen Beach, Shuifo Temple, Bajiazhou, Niulukou, Quejiatao and Guohaiying, upgrade the current grade III of waterway 52.67km long to Grade III, and be open to 1000t ships. In combination with other junctions built, in construction and to be built at middle and lower reaches of Han River and the construction of waterway regulation project, the high-level linking with the waterways of Yangtze River below Xiangyang may be realized.

Power generation: installed capacity of the power station is 74.2MW, and the average annual electricity generation capacity is 324 million kWh. The project is close to the load center of Xiangyang and Yicheng and may improve the power supply shortage in this area after being completed.

Irrigation: after the hub is completed, the normal water level of the reservoir will be heightened, and 80 thousand mu of farmland on both banks in Liushui Township, Zhengji Township, Yancheng and Nanying may be irrigated by gravity. Meanwhile, the probability of irrigation of Changshan Pump Station to be planned in Xiangyang may be increased (taking water from Yingshanzui, irrigation area 300.5 thousand mu), which may save water listing cost.

Tourism: after the hub is completed, the water surface width of the river channel in the reservoir area will reach 2km ~ 5km, and form a water surface of 12.7 thousand hectares, which will provide good development opportunities for tourism and facilitate Yicheng City to improve landscape, upgrade urban image and improve investment environment.

2.2.3 Project scale

The normal water level of Yakou Shipping Hub is 55.22m, the corresponding reservoir capacity is 541 million m^3, and the installed capacity is 74.2MW. In accordance with the regulations of General Design Code for Canalization Works Junction (JTS182-1-2009) and Flood Control Standard (GB50201-94), the grade of waterway is III, the design shipping tonnage is 1000t, the total reservoir capacity is 1000 million m^3 ~ 100 million m^3, the corresponding hub project grade is Grade-II, and the scale is large (2) type.

The main structures of this project include ship lock, hydropower station, sluice and water retaining dam and fishway is secondary structure. In accordance with junction grading standards, for permanent hydraulic structures, main structures are of Grade 2, secondary structures are of Grade 3, and temporary structures are of Grade 4.

The engineering properties of Yakou Shipping Hub are as shown in Table 2.2.3.

Table 2.2.3 Engineering characteristics of Yakou Shipping Hub

Serial No.	Item	Unit	Quantity	Remark
I.	Hydrology and sediment			
1	Total drainage area of Han River	km^2	159000	
2	Drainage area above the dam site	km^2	133087	
3	Average annual runoff	100 million m^3	348	Later scale of Danjiangkou
4	Representative flow			
	Average annual flow	m^3/s	1100	Later scale of Danjiangkou
	Maximum measured flow	m^3/s	29100	1958.7.19 (Huangzhuang Station)
	Minimum measured flow	m^3/s	180	1979.1.29 (Nianpanshan)
	Historical maximum flow	m^3/s	57900	July, 1535 (Nianpanshan)
	Design flood standard and flow	m^3/s	20200	P=2%, later scale of Danjiangkou
	Check flood standard and flow	m^3/s	27300	P=0.33%, later scale of Danjiangkou
5	Sediment			
	Average annual sediment load	10000t	0.19	Huangzhuang Station (after Danjiangkou reservoir is completed)
	Average annual suspended sediment	kg/m^3	0.371	Huangzhuang Station (after Danjiangkou reservoir is completed)
II.	Reservoir			
1	Reservoir water level			
	Check flood level (P=0.33%)	m	55.51	Later scale of Danjiangkou
	Design flood level (P=2%)	m	54.37	Later scale of Danjiangkou
	Normal water level	m	55.22	
	Dead pool level	m	54.72	
2	Reservoir area	km^2	85.38	At normal water level
3	Backwater length of reservoir	km	52.67	Main stream of Han River
4	Reservoir capacity			
	Total reservoir capacity	100 million m^3	4.073	
	Reservoir capacity below normal water level	100 million m^3	3.502	
	Regulation reservoir	100 million	0.415	Have daily regulation

Serial No.	Item	Unit	Quantity	Remark
	capacity	m^3		ability; not regulate peak
	Regulation reservoir capacity at shipping data	100 million m^3	0.324	
III.	Discharged flow and corresponding downstream water level			
1	Maximum discharged flow at design flood	m^3/s	20200	
	Corresponding downstream water level	m	54.14	
2	Maximum discharged flow at check flood level	m^3/s	27300	
	Corresponding downstream water level	m	55.13	
3	Regulated flow for shipping	m^3/s	450	Nianpanshan Junction is not built
	Corresponding downstream water level	m	45.53	Considering that the undercutting of river bed causes the water level reducing by 1.2m
IV.	Indicators of project benefits			
1	Shipping benefit			
	Raising shipping dimension standard	Grade	III	Original IV

Table 2.2.3 (Cont.)

Serial No.	Item	Unit	Quantity	Remark
	Mileage of canalized waterway	km	52.67	
	Design passing capacity of navigation structure	10,000 t/year	980	Maximum one-way passing capacity
2	Power generation benefit			
	Installed capacity	MW	74.2	
	Guaranteed output	MW	25.4/19.0	Before/after Nianpanshan hydro-junction is built
	Average annual electricity generation capacity	100 million kWh	3.22/2.53	Before/after Nianpanshan hydro-junction is built
	Annual operating hours	h	4343/3407	Before/after Nianpanshan hydro-junction is built
V.	Inundation loss and land occupation by project			
1	Reservoir inundation			
	Cultivated land	hm^2	2667.25	
	Forest land	hm^2	1432.76	
	Water area and land for water conservancy facilities	hm^2	3303.29	
2	Permanent /temporary land occupation by dam	hm^2	131.75/353.24	

3	Resettlement population	no.	1805	
4	Area of occupied houses	m^2	81332.4	Including enterprise buildings 10,991m^2
VI.	Hub structures			
1	Earth dam			
	Crest elevation	m	59.0	
	Crest length	m	1322.5	
	Maximum dam height	m	14.0	
2	Sluice			
	Sluice type			Open-type flat-bottom sluice
	Length of sluice	m	684	
	Types of sluice gate and hoist			Arc-shaped gate and hydraulic hoist
	Dimension and quantity of sluice gates	Hole, m×m	48, 14×14.1	
	Design flood discharge flow	m^3/s	20200	
	Check flood discharge flow	m^3/s	27300	
3	Navigation structure			
	Type			Single-line grade-I ship lock
	Maximum and minimum navigable water level at the upper reach	m	55.22, 52.77	
	Maximum and minimum navigable water level at the lower reach	m	53.21, 45.53	Nianpanshan Junction is not built
	Maximum/minimum navigation flow	m^3/s		
	Effective size of lock chamber	m	180×23×3.5	
	Maximum design ship type and fleet passing sluice			1000t one pushing boat and four barges
	Fleet dimension	m	167×21.6×2.0	Length × Width ×depth
4	Hydropower station			
	Type			Water-retaining type
	Dimension (L×W×H)	m	194.5×77.2×54.8	Length ×Width × Height
	Installation elevation of power generator	m	38.60	

Table 2.2.3 (Cont.)

Serial No.	Item	Unit	Quantity	Remark
	Length of power generator section	m	154.5	
	Number of installed generators		7	
	Rated flow	m^3/s	330.2	
	Rated head	m	3.8	

	Type of power generator			Bulb tubular
VII.	Main environmental protection works			
1	Fishway			
	Fishway type		Combining staggered stone-tyoe artificial channel with fishway	
	length	m	951.08	
	Bottom height of fish gathering tank	m	44.26\48.72	
	Elevation of fishway exit	m	55.0	
2	Fish stock enhancement and releasing station			
	Land occupation	mu	86.7	
	Releasing species		Grass carp, black carp, silver carp, bighead carp, Changchun bream, Xenocypris davidi, Bangana tungting and Leptobotia elongata	
	Releasing scale	10000/year	450	
VIII.	Construction			
1	Main quantities			
	Earth and rock excavation	10000 m^3	1413.75	Natural square, the same below
	Earth and rock backfilling	10000 m^3	685.38	
	Concrete and reinforced concrete	10000 m^3	73.54	
	Reinforced bar and metal structures	t	23822, 14915	
	Diaphragm wall	10000 m^2	6.82	
2	Types of River diversion during construction			Open channel diversion
3	Construction progress			
	Generation period of the first power generator	Month	46	
	Total construction period	Month	58	
IX.	Total project investment			
	Total investment of hub project	CNY 10 thousand	324571.1	
	Total static investment	CNY 10 thousand	319076.1	
	Apportionment of shipping project	CNY 10 thousand	173301	
	Apportionment of power generation project	CNY 10 thousand	142119	
	Installed investment per kilowatt	Yuan /kW	42624(19205)	In the brackets is apportionment of power generation
	Investment per KWH	Yuan/kWh	12.47(5.62)	

2.3 Project compositions

Yakou Shipping Hub Project comprises three parts, i.e., permanent works, temporary works, and resettlement works (including special works such as reservoir protection). Permanent works include sluices, water retaining structures, hydropower station, fish passes and navigation structures. Temporary works include diversion works and auxiliary works. See Table 2.3.1 for details.

Table 2.3.1 Compositions of Yakou Shipping Hub Project

Item			Compositions
Permanent works	Hub structures	Ship lock	It comprises upper and lower approach channels, upper and lower lock heads, lock chamber and navigation walls. The total length is 452.5m. The grade of ship lock is III, and the design representative fleet is 1000t double-row double-line one-roof 4-barge fleet. The effective side of lock chamber is 180×23×3.5m (Length × Width × water depth at threshold
		Sluice	Sluices are set on main river bed and beach land, and are connected with power station to the left and with ship lock to the right. There are 48 holes, and the net width of sluice hole is 14m. The total length of overflow edge in the direction of dam axis is 684m. Open-type lock chamber and wide-to-weir and flat-bottom program are adopted.
		Hydropower station	In hydropower station dam section, 7 bulb tubular power generators are installed. The unit capacity is 10.6MW, the total installed capacity 74.2MW, and the turbine runner diameter 7.06m. The structures in the plant area include hydropower station and booster station.
Permanent works	Hub structures	Earth dam	Water retaining structures adopt rolling-type earth dam structure. According to the arrangement plan of the hub, the water retaining structures are composed of earth dams on both left and right banks, and connection section. The total length is 1322.5m, including 510m of earth dam on the right bank, 149m of connection section (between ship lock and lock chamber) and 663.5m of earth dam on the left bank. The dams adopt anti-seepage body of non-earth materials. The crest elevation is 59.0m, the crest width is 8m, and the maximum dam height is 14.0m.
		Fishway	Adopt the combination of staggered stone-type artificial channel with fishway. The main entrance is built at the left side of the tail water channel of the hydropower station, and is connected to the fish collection system on the tail water platform. The total length of fishway is 814m, the length of artificial channel section is 492m, the slope is 1/100 and trapezoidal cross-section is adopted; the length of fishway section is 326m, and rectangular cross-section is adopted.
	Auxiliary works	Crest access bridge	Crest access bridge comprises sections crossing ship lock, sluice and power station. The total length of the bridge is 1087m, including 380m section crossing ship lock, 707m section crossing sluice and 707m section crossing power station. The main span of the bridge adopts a variable cross-section box girders, and side span adopts pre-stressed concrete hollow slab structure
		Navigation aid works	Class-I electrical navigating aids are set along the whole line. There are 78 new navigation aids, including 16 position-indicating navigation aids (including small beacons), 58 side aids, 2 whistle posts and 2 limit

Item			Compositions
			marks.
		Hub management district	The management district is set on the right bank of Han River, upstream from the dam axis and close to the hub. The floor area is 7.5hm^2, and the building area is 12500 m^2.
		Others	One berthing anchorage ground is set 1.7km upstream and downstream from the ship lock respectively. The mode of purchased wharf boat is temporarily adopted as anchorage ground.
Temporary works	Diversion works	Adopt three-stage diversion	At the first stage, build open diversion channel on the bank and longitudinal cofferdam, and the main river bed on the right side is used for diversion; at the second stage, cofferdam earth dam, ship lock, sluice and hydropower station on the right bank, and the open channel on the left bank is used for overflowing; at the third stage, carry out construction of earth dam on the left bank, and the sluice on the right bank that has been completed is used for discharging, and the ship lock on the right bank is open to navigation.
	Auxiliary works	Auxiliary enterprise for construction	Aggregate processing system, concrete production system, construction factory (metal structure assembly plant, integrated processing plant, automobile parking and maintenance plant), construction warehouse, power supply, water supply and communication systems, and others.
		Living and office areas	Living area and office area are distributed on the left and right banks. On the left bank is main camping ground, and some houses are used and some living and office rooms are also built.
		On-site access works	The length of approach road is 0.5km, the length of access roads is 8.55km, and there are two wharfs. Among the temporary access roads, 5.9m is taken into account for the land used for dam construction area and production and living areas. The length of new temporary access roads is 2.650km.
		Earth stock yard	One borrow area, Yakou borrow area

Table 2.3.1 (Cont.)

Item			Compositions
Temporary works	Auxiliary works	Waste dump	There are three waste dumps. The first is dumping area on the outer beach at the upper reach of the left levee along Han River; the second is dumping area on the outer beach at the upper reach of the right levee along Han River; and the third is the outer beach on the left bank of Ying River mouth.
Resettlement works	Resettlement	Production arrangement	The land inundated by reservoir area is overflow lands within the levees on both banks, which is the supplementary source of local resident incomes. The population involved in production arrangement due to land acquisition is 22,426, and according to the calculation the population will be 23,401 by the planning level year, including 23,307 persons in reservoir-affected area and 94 persons in hub project construction area.
		Relocation resettlement	The population involved in relocation resettlement due to land acquisition is 1729, and according to the calculation the population will be 1805 by 2018, the planning level year. All of the population is within the reservoir area of the hub

Item			Compositions
			project. Rural resettlement adopts two modes, i.e., centralized house building and dispersed house building.
	Reservoir inundation treatment		For inundation treatment, it is proposed to adopt open Ditch excavation. For the inundation-affected area on the right bank, it is proposed to excavate a transversal branch channel to connect to Yidao Ditch so as to discharge the groundwater below the dam. For the inundation-affected area, it is proposed to excavate a branch channel to connect to the existing drainage Ditch and to increase the scale of pump drainage station. The length of flood distribution channel is 30km, and the length of drain is 48km.
Environmental protection works			Fishway, fish stock enhancement and releasing station, water treatment facilities, atmospheric pollution prevention measures, noise prevention measures, water and soil conservation measures, ecological restoration, etc.

2.4 Hub layout and main structures

In accordance with the integrated utilization requirements of the hub, the main structures include ship lock, sluices, hydropower station, fishway and earth dams. The ship lock is distributed on the right bank (main river channel position), the hydropower station is distributed on the right bank, 48 sluices are distributed between them, and the position of second-line ship lock is reserved on the beach on the right bank. From right to left along the dam axis, the overall layout of the dam includes earth dam on the right bank, ship lock, connection section, fishway, water-retaining hydropower station, sluices and earth dam on the left bank. The length of the dam layout along the axis is 2,282m.

The layout plan of Yakou Shipping Hub Project of Han River is shown in Attached Figure 6.

2.4.1 Sluice

Sluice adopts reinforced concrete open-type flat-bottom sluice, with gravity-type sluice pier, empty-box-type quay wall, steel arch-gate and hydraulic hoist. The total width of the lock chamber on the left side is 615.6m, and there are 36 holes. The total length of the lock chamber on the right side is 205.2m, and there are 12 holes. The net width of single hole is 14m. The lock chamber is of sluice-pier parting type, and every two holes are linked together. The width of parting pier is 1.8m and the width of middle pier is 2.6m.

Waterstop structures are set in all vertical joints between upstream and downstream face and quay walls and upstream and downstream flange walls. The bottom sill elevation of the lock chamber of the sluice on the right side is 43.0m, and that on the left side is 45m. The sluice top elevation is 59.0m, and the length of bottom board in downstream direction is 31.0m. Steel arc-gate is set upstream from the lock chamber, and bulkhead gate channel is set at the pier head of each hole. The upper width of sluice wall is 35.5m, and from upstream to downstream gantry crane track beam, pipeline box girder, hoist room and crest highway bridge are distributed on the top of the sluice. Hoist room is built on the middle pier of each section, and hydraulic oil tanks, motors, electric equipment and centralized sluice control system of two gates are arranged in the machine room.

Seepage prevention of sluice foundation mainly adopts the horizontal ant-seepage body composed of upstream blanket and sluice floor board. The horizontal layout length of the upstream blanket is 30m, and the horizontal projected length of anti-seepage underground profile of sluice foundation is 60m. From the top down, stilling pool, apron and scouring prevention tank are arranged upstream from the lock chamber. The elevation of connection section is 59.00m, and quay wall is arranged between lock chamber and connection section.

2.4.2 Navigation structure

The ship lock axis is perpendicular to the dam axis, and the upper lock head is located at the dam axis and is a component of water-retaining structure of the hub. Ship lock-in and lock-out modes adopt the lockage mode of curve lock-in and straight lock-out. The ship lock comprises upstream and downstream approach channels, upper and lower lock heads and lock chamber, and the total length is about 1150.5m, among which, the length of upper lock head is 32m, that of lock chamber 180m, that lower lock head of 33.5m, and that of upstream approach channel about 452.5m and the width of upper approach channel is 75.6m. In order to guarantee the natural connection between approach channel and natural river channel, 202.5m navigation and regulation section and 250m berthing section are arranged at upstream approach channel. The length of downstream approach channel is 452.5m, including 202.5m navigation and regulation section and 250m berthing section. Crest access bridge crosses over the upper lock head at the lower reach, and connects the crest and the traffic on left and right banks.

The upper lock head is located at the dam axis and adopts reinforced entire-dock structure. The plane dimension is L×B＝32m ×44.0m (Length × Width), and the width of entrance is 23m. The foundation surface elevation is 34.50m, and the lock head top elevation is 59.00m. The lower lock head is located at the dam axis downstream and adopts reinforced entire-dock structure. The plane dimension is L×B＝33.5m ×44.0m (Length × Width), and the width of entrance is 23m. The foundation surface elevation is 35.00m, and the lock head top elevation is 58.20m. The dimension of lock chamber is 180m×23m×3.5m (Length ×Width× Water depth), and is divided into 11 sections. In order to facilitate the arrangement of the outlet of water delivery gallery of the upper lock head and energy dissipation facilities, the first section is 19.4m long, and the other sections are 16.06m long respectively. The lock chamber adopts entire-dock structures. Upstream and downstream navigation walls and breasting dolphins adopt gravity-type structure.

2.4.3 Hydropower station

The hydropower station is water-retaining type, and is also a water-retaining structure. The maximum head of the power station is 8.32m, the minimum head is 2.00m, and the rated head is 3.80m. Seven bulb tubular power generators are installed in the power station. Unit capacity is 10.60MW, installed capacity 74.2MW, turbine runner diameter 7.05m, and unit quotative discharge 327.30 m^3/s. The length of the dam section of the main hydropower station in the direction of flow is 81.20m, and trash rack, access door, upstream bulkhead, main engine room, tail water pipe, downstream bulkhead and tail water sluice pier are arranged successively. The bottom elevation of water inlet is 29.50m.

According to the general arrangement plan of the hub, the hydropower station is arranged on the water-facing side of low flood plain on the left bank, and the hydropower station dam section is one part of the water-retaining structure. The buildings in the plant area mainly include two parts, i.e., hydropower station and booster station. The total length of the hydropower station dam section along the dam axis is 219.70m, and the length of main engine is 155.00m. Erection bay and loading & unloading yard are arranged on the right side of the main engine room, and the length is 64.70m. The right end is connected to

38-hole sluice dam, and the left end is connected to 10-hole sluice dam with connection section. The crest elevation of the water inlet is 60.00m, and auxiliary hydropower station is arranged on the tail water pipe top plate on the downstream side of the main engine room. The elevation of tail water sluice pier is 57.50m. Booster station (main transformer, switching station and outgoing line platform) is arranged on the right side downstream from the erection bay and is open-type, and the elevation is 52.40m. The access highway leads to the turnaround downstream from the hydropower station via. connection section of earth dam on the right bank, and the elevation is 52.40m. The upstream access mode adopts crest highway leading to the turnaround on the left side of loading and unloading yard (installation and maintenance platform of sluice gate), and the elevation of the turnaround is 60.00m.

2.4.4 Earth dam and connection dam section

According to the arrangement plan of the hub, the hub comprises earth dams on the left and right banks and correction section. The length of dam axis is 2282m, including 1160m-long earth dams. The earth dams are composed of 380m connection section on the left bank, 180m connection section of power station sluice, 100m connection section of ship lock sluice and 500m connection section on the right bank.

The crest elevation is 59.0m, and the crest width is 10m. Access highway adopts asphalt concrete pavement 0.36m thick, including 0.3m-thick cement gravel stable layer and 0.06m-thick asphalt concrete surface layer. According to the dam site topography and the construction diversion arrangement plan, the largest cross section of earth dam is located at the connection section on the left bank, and the maximum dam height is about 14.0m. The dam body is filled with excavated silty-fine sand and gravels through layered rolling compaction.

The slope rate of upstream dam slope is 1:3.0. The slope surface adopts concrete hexagonal block embankment, and the thickness is 0.3m. The slope foot adopts riprap revetment, slope rate is 1:6, and the revetment top elevation is 51.50m. The downstream dam slope adopts press-immersion platform, the platform top elevation is 52.00m, the top width is 10m, and the slope surface adopts concrete hexagonal block revetment. The slope rate of dam slope above the platform is 1:2.5, and the slope surface adopts concrete hexagonal embankment 12cm thick, below which is 15cm sand cushion. The slope rate of dam slope below the platform is 1:3.0, and the slope surface adopts concrete hexagonal embankment 12cm thick, below which is 15cm sand cushion. A plastic concrete anti-seepage wall is built 2.5m upstream from the dam axis, and form dam foundation anti-seepage line together with ship lock and sluice anti-seepage walls at the same axis. The top elevation of anti-seepage wall of earth dam is 56.5m, the depth of anti-seepage wall of earth dam in main river channel section is 30m, and the depth of anti-seepage wall of earth dam of embankment slope section is 20m.

The connection between earth dam and concrete building adopts side-wall connection.

2.4.5 Fishway

Fish passes adopt the combination of staggered artificial channel and fishway. Fish passing season of fish passing channel is mainly from March to September every year. The maximum design water head difference is 9.46m, and flow rate of fish passing hole/vertical jint is 1.1m/s.

Fish passes are arranged on the left bank of the hydropower station on the left bank, and the entrances are located at the bottle edge of tail water, divided it high-water-level entrance (bottom elevation 48.72m) and low-water-level entrance (bottom elevation 44.26m). The low-water-level entrance joins the high-water-level entrance at confluence tank (bottom elevation 49.22m) after being folded once), and the length of confluence tank is 30m, and a gate is installed, adopting manual and electric dual-purpose screw hoist, which can open high or low water-level entrance according to the change of water level. After bypassing the booster station, the fish passing channel passes through above-dam structure and extends upstream into the upstream reservoir area about 330m away from the dam axis. Besides, special water replenishing channel is built, and the replenishing flow is 1.47m^3/s.

The total length of fish passes is 951.08m, including 560.58m-long stimulated ecological channel and 390.5m-long fishway. The stimulated ecological channel adopts trapezoidal cross-section with 2.0m of bottom width and 1:2.5 side slope. The water depth is 2.0m, the water surface width is 12.0m at normal operating water depth, and the longitudinal slope is 1%. There are 45 spacing sections (section length 10m, spaced with 200mm masonry clapboard and two rest sections (total length 60%). The side slope adopts masonry boulders and cobbles or gravels are laid on the bottom. Fishway adopts triangular cross-section, and the length of pool room is 3.6m and the water depth 3m. Fishway is equipped with seven rest pool sections, including four curve rest pools. The thickness of fishway partition is 200mm, and the minimum width of fish passing hole is 45cm. The baseboard and side walls of the fishway adopt cast0in-place concrete, the average longitudinal slope of the fishway bottom is 1/60, and the fall between pools is 0.06m. Cobbles or gravels are laid on the bottom of fishway

2.4.6 PIU’s camp

The PIU’s camp is set upstream from the earth dam on the right bank. The existing site is heightened through filling, and the design elevation is 59.0m. For future living and production needs, the camping ground may be combined with hub buildings to form a relatively closed management area, and the floor area of the ground is 7.50hm².

The construction of PIU’s camp includes construction of office building, ship lock management office, reception center, staff quarter, activity center, canteen, warehouse, substation, fire station and outdoor playground as well as greening measures.

For the PIU’s camp, the stock ground is excavated to the design elevation. The ground is close to construction production and living area upstream, close to the earth dam on the right bank downstream and next to the levee of Han River to the west and its eastern border near water is about 80 ~ 140m away from the steep coast of Han River. The PIU’s camp and the construction production and living area and ①waste dump belong to a filling entirety. The side near water adopts gabion box retaining wall, slope surface and foot adopt steel mesh gabion protection, and the design cross section is the same as the waste dump. Surrounding the PIU’s camp is drainage ditch, which adopts 30cm×30cm trapezoidal cross section, side slope 1:1 and 30cm-thick masonry, in order to discharge the water within the ground in time. After completion, greening measures are taken in the PIU’s camp, and the greening area is 2.63hm².

2.5 Ship type and operation organization

2.5.1 Water transportation quantity forecast

Han River Yakou Shipping Hub is a national large infrastructure construction project, and the cycle of earlier-stage demonstration, design and construction is longer than general projects. According to the current project progress, it is predicted to be completed in 2019. In accordance with the regulations of relevant specification, the first level year of the transportation quantity forecast takes Year 2020, and the second level year is 20 years after the ship lock is completed, i.e. Year 2040, and the long-term extending forecast is carried out by Year 2050.

a) Passenger traffic forecast

According to the development status of tourism in Danjiangkou, Wangfuzhou and Cuijiaying reservoir areas in recent years, it is forecasted that the passenger traffic volume of water tourism at middle and lower reaches of Han River will reach 200,000 persons-time, 400,000 persons-time and 500,000 persons-time by 2020, 2040 and 2050, respectively.

b) Freight volume forecast

According to the economic survey and the qualitative analysis on future integrated transportation structure, it is forecasted that the main cargo kinds in the future water transportation of the river section of Han River in Hubei Province will be still mineral building materials, coal, fuel oil, metallic ore, non-metallic ore, steel, cement, wood, grain, chemical fertilizer, chemical materials and products, and mechanical and electrical products. According to relevant planning data and in combination with the transportation development situation, all main cargo kinds are analyzed and predicted in the premise that the project will be completed before 2020 and the projects along Han River and other projects will be implemented successfully. Mineral resources, mineral building materials and chemical fertilizers are calculated with the method of proportional growth, and the other cargo kinds are analyzed as per market demand, sales direction and possible transportation modes in order to determine the transportation volumes in the river section of Han River in Hubei Province.

It is forecasted that the freight volumes in the river section of Han River in Hubei Province will be 33,080 thousand tons, 45,960 thousand tons and 51,720 thousand tons by 2020, 2040 and 2050, respectively; and at that time, the freight volumes of the ship lock of Yakou Shipping Hub will be 7,837 thousand tons (including 5,927 thousand tons downstream), 12,121 thousand tons (including 8877 thousand tons) and 15,474 thousand tons (including 10,822 thousand tons).

Table 2.5.1 Forecast of freight volumes passing the dam of Han River Yakou Shipping Hub

Item	Year 2020			Year 2040			2050year		
	Upstream	Downstream	Total	Upstream	Downstream	Total	Upstream	Downstream	Total
	(万 t)			(万 t)			(万 t)		
Total	191	592.7	783.7	324.4	887.7	1212.1	465.2	1082.2	1547.4
Coal		230	230		400	400		460	460
Fuel oil	20		20	40		40	50		50
Metallic ore		74.8	74.8		102	102		117	117
Non-metallic ore		60	60		75	75		80	80
Steel	56.2	5	61.2	78	7	85	98	8.5	106.5
Mineral building materials		115	115		142	142		215	215
Cement		35.5	35.5		42	42		50.6	50.6
Mechanical and electrical products	2.2	40.7	42.9	3	77	80	4	101	105
Others	69.8	24.1	93.9	119.9	34.7	154.6	207.7	38.4	246.1
Incl: container (10^4TEU)	1.5	1.5	3	3	3	6	6	6	12

2.5.2 Ship type and fleet planning

With the gradual realization of the targets of shipping construction planning of Han River, freight volume and ship quantity will certainly continue to increase. Port and shipping authorities should guide and actively develop the standard ship types conforming to natural and canalized waterways specified in *Navigation Standard of Inland Waterway* (GB 50139-2004), in combination with the construction standards for Han River waterways and hub navigation structures.

According to the feight volume forecast in this report, Han River will begain the bsiness of water transportation of containers in 2020. In order to better accomplish the starting work of water transportation container, in reference to the development experience of contrain transportation in Yangtze River, special contraining transportation ships with front cab is used for contrainer transportation.

Main ship types and fleets to be developed in Han River are as shown in Tables 2.5.2-1 and 2.5.2-2.

Table 2.5.2-1 Main ship types to be developed

Category	Ship name	Main dimension (m)			Main engine power (kW)
		Total length	Molded width	Draught	
Barge	1000t	67.5	10.8	1.8-2.0	
	500t	45	10.8	1.6-1.8	
	300t	35	9.2	1.3-1.5	
Push tug	1000KW	32	8	1.9	1000
	588KW	25	7.5	1.6	588
	368KW	21	7	1.5	368
	220KW	21	5.4	1.3	220
Cargo ship	1000t	85	10.8	1.8-2.0	460
	500t	67.5	10.8	1.6-1.8	220
	300t	55	8.6	1.3-1.5	150
Container ship	60 ~ 70TEU	70	12.8	2.0-2.6	300×2
	45 ~ 55TEU	64	10.8	2.0-2.4	230×2

Table 2.5.2-2 Main typical fleets to be developed

No.	Transportation section	Fleet type	Fleet composition	Fleet load capacity (t)	Fleet dimension (m)		
			Push tug power + number of barges × Barge tonnage		Total length	Total width	Draught

1	Danjiangkou ~ Hankou ~ Yangtze River	2×2pushing	1000+4×1000t	4000	167	21.6	2.0
2	Danjiangkou ~ Hankou ~ Yangtze River	1×2pushing	588+2×1000t	2000	160	10.8	2.0
3	Danjiangkou ~ Hankou ~ Yangtze River	2×2pushing	588+4×500t	2000	112	21.6	1.6
4	Danjiangkou ~ Hankou ~ Yangtze River	1×2pushing	368+2×500t	1000	111	10.8	1.6
5	Danjiangkou ~ Hankou ~ Yangtze River	2×2pushing	368+4×300t	1200	94	18.4	1.3
6	Danjiangkou ~ Hankou ~ Yangtze River	1×2pushing	220+2×300t	600	91	9.2	1.3

2.5.3 Operation organization mode

With the fast facilitation of the construction of Han River waterway, the transport ships in Han River shall have higher compatibility with the ships in the middle reach of Yangtze River. According to the distribution of transport ships in the backland or surrounding areas as well as the existing operation organization modes, it is predicted that cargo ship, pushing ship train and barge will still exist in the ship operation organization at middle and lower reaches of Han River, among which, 500~1,000t single cargo-ship transportation and fleet transportation will gradually develop into a primary operation mode.

See Table 2.5.3 for the future ship operation organization modes at middle and lower reaches of Han River.

Table 2.5.3 Future ship operation organization modes at middle and lower reaches of Han River

Ship type		Ship dimension (Length × Width × Draught)(m)	Remark
Cargo ship	300t cargo ship	(50 ~ 55)×8.6×(1.3 ~ 1.6)	
	500t cargo ship	(62 ~ 68)×10.8×(1.6 ~ 1.9)	
	1000t cargo ship	(80 ~ 86)×10.8×(2.0 ~ 2.4)	
Fleet	300t cargo ship+ barge	(80 ~ 90)×9.2×(1.3 ~ 1.5)	
	2×300t+ push tug	(81 ~ 91)×9.2×(1.3 ~ 1.5)	
	4×300t+ push tug	(82 ~ 94)×18.4×(1.3 ~ 1.5)	
	500t cargo ship+ barge	(102 ~ 112.5)×10.8×(1.6 ~ 1.8)	
	2×500t+ push tug	(101 ~ 111)×10.8×(1.6 ~ 1.8)	
	4×500t+ push tug	(102 ~ 112)×21.6×(1.6 ~ 1.8)	
	1000t cargo ship+ barge	(150 ~ 154)×10.8×(1.8 ~ 2.0)	
	2×1000t+ push tug	(152 ~ 160)×10.8×(1.8 ~ 2.0)	

	4×1000t+ push tug	(160 ~ 167)×21.6×(1.8 ~ 2.0)	

2.5.4 Main operation routes

According to freight volume forecast, the transportation of coal, metallic ores, non-metallic ores, yellow sand from Tangbai River, commodity automobiles and cement from Laohekou in Han River will have a certain volume scale, and the route is relatively long, which is easy to organize standard operation fleets for transportation and form relatively fixed routes (see Table 2.5.4).

Table 2.5.4 Bulk cargo operation routes and freight volume in the rivers sections of Han River above Yakou Section

No.	Route	Cargo kind	Average distance (km)	Freight volume of each route (10000 t)					
				2020		2040		2050	
				Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
1	Along the line from Yujiahu ~ lower reach of Han River	Coal	320		130		200		200
2	Ankang, Xunyang ~ Wuhan Iron& Steel	Metallic ore	960		75		102		117
3	Backland along the river ~ along Yangtze River and Han River	Non-metallic ore	380		60		80		87
4	Xiangyang ~ middle reach of Han River	Mineral building materials	80		100		200		250
5	Laohekou ~ middle and lower reaches of Yangtze River	Cement	800		38		45		48
6	Wuhan Iron & Steel ~ river section above Xiangyang	Steel	650	56	5	78	7	98	9
8	Danjiangkou, Xiangyang ~ middle and lower reaches of Yangtze River	Mechanical and electrical products	850		41		77		100
Total				56	449	78	711	98	811

2.6 Project construction planning

2.6.1 General construction layout

According to the characteristics of project building layout and river diversion during construction, and in combination with the topographical and geological conditions of the dam site, construction site is arranged on both left and right banks, mainly centralized on the right bank with high construction intensity. There is no bridge between the two banks, and temporary wharf were built in the diversion period at the first and second phases. After the third-phase cofferdam is completed, the built crest on the right bank may be connected to the cofferdam for traffic. Therefore, some temporary construction facilities, such as concrete system and integrated processing plant may use the site on the right bank in construction period. The construction materials on the left bank may pass hub structures and the cofferdam completed at the third phase. The layout in this program is relatively centralized, and is convenient for future production, management and operation.

2.6.2 Construction traffic conditions

a) External traffic

The highway traffic network in the downtown of Yacheng City extends in all directions, and may lead to Hubei, Henan and Sichuan provinces, Xiangjing Expressway (G55), 207 National Highway and 251 and 306 (Suinan Highway) Provincial Highways. It is 47km away from Xiangyang to the north, 53km away from Nanzhang to the west, 67km away from Jingmen to the south and 386km away from Wuhan to the southeast. There are highways on both banks of the dam site leading to Chengguan Township, Yicheng City. There are township roads on the left bank leading to S218, and 6~8m-wide highways on the levee on the right bank leading to Yipukong line and connecting to G207 to the west. According to the Twelfth Five-year Plan (2011- 2015), it was proposed to transform and expand Yipukong line in 2011-2012 with grade-II highway standard, and the roadbed width would be 12m and the pavement width 9m. As for railway, Jiaozhi Railway passes through Zhushi Township about 10km away from Yicheng City and connects to national railway trunks like Handan Railway and Xiangyu Railway; as for waterway, 300~500t ships in Han River may directly travel to Yicheng City from Wuhan City, and heavy and large members may be delivered to the construction site by ships.

Therefore, the traffic and transportation conditions of this project is great, and it is proposed to adopt highway transportation for outsourced materials, waterway transportation for heavy and large members and railway transportation for auxiliary transportation.

b) Construction roads within site

According to diversion program and characteristics of hub layout, on-site traffic is divided into left-bank traffic and right-bank traffic, and high-intensity construction area is mainly centralized on the right bank. The left bank of the hub is about 330m away from S218, and there is no centralized resident district. The approach highway on the left bank is considered to connect to S218; the traffic on the right bank may lead to Yicheng City northwards along the levee and lead to Yipukong line and connect to G207 westwards.

According to the dam topography, the characteristics of hub project layout and the program of river diversion during construction, in order to meet the requirements of personnel traffic on both banks and a small amount of cargo transportation, it is proposed to set one temporary wharf on the left and right bank respectively in the diversion period at the first and second phases, and both of them are slope wharfs. After the third-phase cofferdam is completed, the built crest on the right bank may be connected to the cofferdam for traffic.

Approach road is located on the slope land on the left bank, which needs excavation, filling and leveling, and other temporary access roads are located on flat land without need for excavation, filing and leveling. Therefore, for temporary access roads, only the amounts of topsoil stripping and hardened layer removal are included in earthwork balance.

The total length of on-site roads is 13.140km, of which, 5.900km is included in the land occupation for each zone. The length of new access roads is 7.240km, including 0.500km-long approach road which is permanent road, the length of new temporary access roads in the hub project zone is 2.650km, the length of access roads in reservoir area protection zone is 4.090km, and the total floor area is 6.17hm^2. The occupied land types include dry land, forest land, land for transportation, inland intertidal zone and bare land. Except for approach road, reclamation measures are taken for cultivated land and forest occupied by temporary access roads, including topsoil stripping and return, second ploughing of occupied cultivated land and vegetation recovery of occupied forest land.

See Table 2.6.2 for main roads on the site.

Table 2.6.2 Main characteristics of construction roads within site

Position		No.	Name	Length (km)	Highway grade	Pavement width (m)	Occupied land width (m)	Pavement structure	Property
Hub project zone	Right bank	①	Trunk road of ring line in the foundation pit on the right bank	3.80	II	9	12	Clay-bound macadam	Temporary road
		③	Road leading to waste dump on the right bank	0.40	II	9	12		
	Left bank	②	Approach highway on the left bank	0.50	II	9	14	Concrete	Permanent road
		④	Trunk road of ring line in the foundation pit on the left bank	1.40	III	7	9	Clay-bound macadam	Temporary road
		⑥	Road leading to ① waste dump on the left bank	0.30	III	7	9		
		⑧	Road leading to③ waste dump on the left bank	1.50	III	6	8	Clay-bound macadam	Temporary road
	Stock ground	⑦	Road in stock ground	0.80	III	7	9	Clay-bound macadam	Temporary road
			Others	0.35	III	6	8	Clay-bound macadam	Temporary road
	Communication between two banks			Two slope wharfs are built on the left and right banks.					
Reservoir area protection zone	Access roads for protection works			4.09	III	6	8		
Total	Included in each zone			5.60					
	New parts			7.24					
	Total			13.14					

2.6.3 Auxiliary enterprise for enterprise

a) Auxiliary enterprise for construction

The construction site and camps of this hub project adopt main works excavation and leveling. During construction, diversion channel is excavated firstly, and the excavated earth is directly used for leveling of construction site and camps on the left bank. The current elevation of the construction site and camps on the left bank is 47.0m~51.5m, and the elevation after leveling will be 56.0m. After the cofferdam intercepts the flow at the second phase, the excavated earth of the sluice is used for leveling of construction site and camps on the right bank. The current elevation of the construction site and camps on the right bank is 51.4m~5.8m, and the design elevation of the construction site and camps within the cofferdam after leveling is 59.0m and that outside of the cofferdam is 58.0m.

According to the demand of project construction, concrete system, sand processing system, metal structure assembly plant, automobile parking and maintenance plant, construction substation, integrated processing plant, integrated warehouse and construction camping ground are arranged.

1) Concrete system

Concrete system is placed on the flat ground to the south of the approach highway on the left bank. According to the general construction progress schedule, the peak-month concrete placement intensity in the hub project is 65 thousand m^3. Calculated on the basis of three shifts, the design production capacity of concrete system is $210m^3/h$. It is proposed to build a HL240-4F3,000L concrete blending building (rated production capacity $240m^3/h$) and a HL120-3F1500L concrete blending building (rated production capacity $120m^3/h$), which can meet the peak-month demand for concrete production, and the floor area is $2.50hm^2$.

2) Sand processing system

Sand processing system is placed in Matoushan quarry. According to the general construction progress schedule, the peak-month concrete placement intensity in the hub project is 65 thousand m^3. The system will be operated by two shifts. According to calculation, the processing capacity of sand processing system is 500t/h and the production capacity is 400t/h, and the floor area is $7.0hm^2$.

3) Automobile parking and maintenance plant

Construction machineries may be delivered to Yicheng City or adjacent counties for overhaul, and this plant mainly undertakes the tasks of equipment maintenance and minor repair. The floor area is $0.80hm^2$.

4) Construction camping ground

In view of the long distance between the major works area and the sand processing system, it is required to build two construction camping grounds, both of which are close to cities and townships. Most of construction works may live in construction camping grounds and a few personnel may rent local resident houses. The construction camping ground of the main works is arranged on the beach upstream on the left bank, and the floor area is 2.50hm².

The construction site and camp on the left bank is close to the earth dam on the left bank, and that on the right bank is adjacent to ① waste dump. The sides near water adopt gabion box retaining walls, slope surface and foot adopt steel mesh gabion protection, and the design cross section is the same as the waste dump. Surrounding the PIU’s camp is drainage ditch, which adopts 30cm×30cm trapezoidal cross section, side slope 1:1 and 30cm-thick masonry, in order to discharge the water within the ground in time. Reclamation measures shall be taken for cultivated land and forest occupied by temporary access roads, including topsoil stripping and return, second ploughing of occupied cultivated land and vegetation recovery of occupied forest land.

b) Layout of construction site and camps of reservoir area protection zone

In the construction process, the construction stock ground of the reservoir area protection zone may utilize protection works area and waste dump for layout. The living camping ground of construction workers may directly adopt the mode of renting, and it is only required to arrange a place near the protection works for a few concrete blending systems, cement warehouse and construction machineries, and the total floor area is 0.40hm². The construction site and camps of the reservoir are arranged on flat land without need for excavation, filing and leveling. Therefore, only the amounts of topsoil stripping and hardened layer removal are included in earthwork balance.

See Table 2.6.3 for the schedule of construction site and camp layout

Table 2.6.3 Schedule of construction site and camps

Position		No.	Item	Building area (10,000m²)	Floor area (hm²)	Land type	Elevation m	Remark
Hub	Rig	1	① concrete systen	0.20	17.90	Dry land	59.0	

Position		No.	Item	Building area (10,000m²)	Floor area (hm²)	Land type	Elevation m	Remark
project zone	ht bank	2	Metal structure assembly plant	0.05			(within cofferdam) 58.0 (outside of cofferdam)	
		3	Integrated processing plant	0.25				
		4	Integrated warehouse	0.20				
		5	Construction substation	0.04				
		6	Water works	0.02				
		7	① construction camping ground	1.00				A few may rent local resident houses.
		8	Automobile parking and maintenance plant	0.02				
	Left bank	9	Metal structure assembly plant	0.00	3.25	Forest land, inland intertidal zone, and bare land	56.0	
		10	Integrated warehouse	0.10				
Reservoir area protection zone	Other			0.05	0.40	Day land and inland intertidal zone		
Total				1.93	21.55			

2.6.4 Natural building materials and stock ground planning

According to the design data, the design demand for natural building materials is as below: earth materials of 203.1 thousand m^3, sand and gravels of $15m^3$ and rubbles of 277.8 thousand m^3. The survey data about the stock grounds for Yakou dam collected during pre-feasibility study is as shown in Table 2.6.4.

Table 2.6.4 Survey data about the stock grounds for Yakou dam collected during pre-feasibility study

Filler category	Stock ground name	Location	Transportation distance (km)	Reserve (10^4m^3)	Quality

Earth materials	Chihu borrow area	Area of Chihu, Zhengji on the right bank	4 ~ 5	>200	As homogeneous earth dam, it has high clay particle content; as anti-seepage earth materials, it is moderate. The natural moisture content of Yakou borrow area is relatively low.
	Yakou borrow area	Yakou, Liushui Township on the left bank	1 ~ 2	>500	
Sand	Tangbai River mouth sand stock ground	Tangbai River mouth in Xiangyang	80	>30	Capable of meeting the requirements
Gravel	Leihe - Kongwan gravel stock ground	Man River section beween Leihe and Kongwan	18 ~ 32	>20	Small grain size, and low sorting nature
	Gongnao gravel stock ground	Han River section at Gongnao	13	>10	Basically capable of meeting the requirements
	Longmentan gravel stock ground	Han River section in Liuji Township	50	>135	Poor grain composition, containing reactive aggregates
Rubble	Matoushan quarry site	Third Branch Field of Xiangbei Farm on the left bank	20	>30	Compact structure, high strength, high quality, suitable for rubbles and artificial aggregates.
	Jinniu mountain quarry site	West of Leihe Township on the right bank	35	>200	
	Dong Mountain quarry site	East of Leihe Township on the right bank	30	>50	

According to the survey on the stock grounds during feasibility study, Chihu borrow area and Yakou borrow area may be used at the borrow areas in this phase. However, the groundwater depth in Chihu borrow area is small and the groundwater level is within the range of exploitation depth, it is recommended to adopt Yakou borrow area. Tangbai River mouth sand stock ground has been in the reservoir area of Cuijiaing junction; Leihe – Kongwan gravel stock ground has been mined up; Gongnao gravel stock ground ad Longmentan gravel stock ground require underwater mining; and three quarries in Matoushan, Jinniu Mountain and Dong Mountian can be used as local quarries. Based on the survey results, preliminary investigation was carried out on borrow areas, sand stock grounds, gravel stock grounds and rubble quarries except for Lehe-Kongwan gravel stock ground. The location distribution of stock grounds is as shown in Figure 2.6.4.

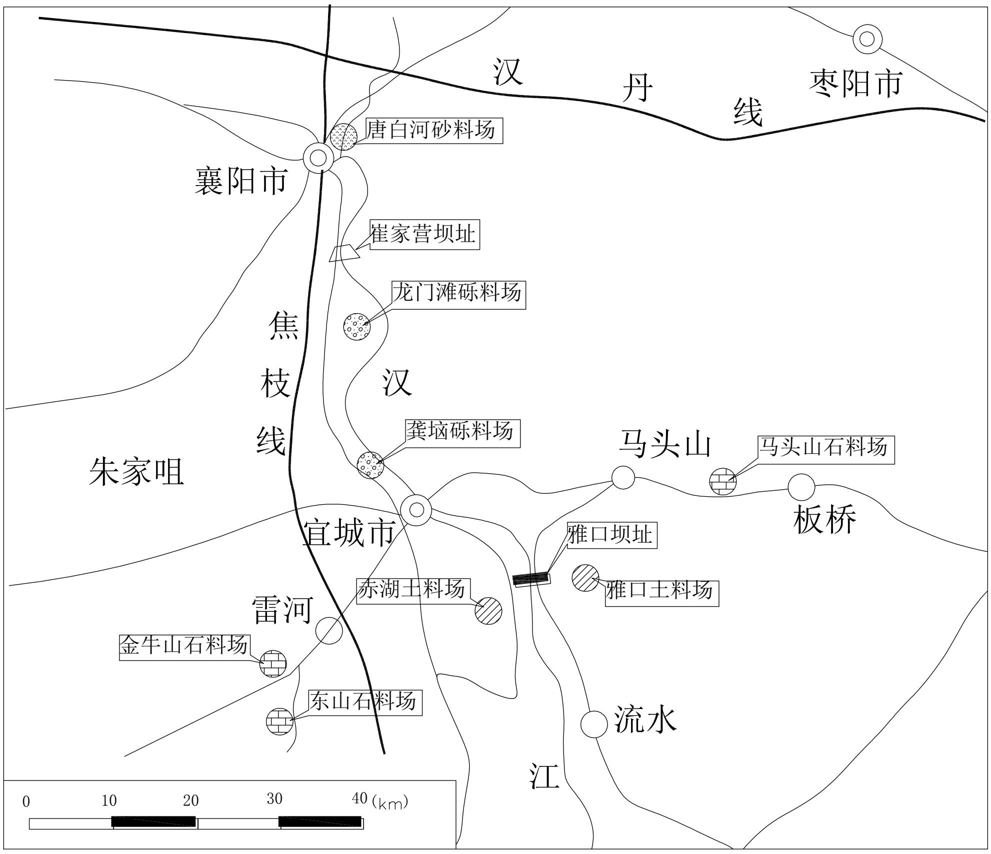


Figure 2.6.4 Sketch map for locations of natural building materials

襄阳市	Xiangyang City	焦枝线	Jiaozuo-Zhicheng Railway
枣阳市	Zaoyang City	龚垴砾料场	Gongnao Gravel Stock Ground
汉丹线	Wuhan-Danjiang Railway	朱家咀	Zhujiazui
唐白河砂料场	Tangbai River Sand Stock Ground	宜城市	Yicheng City
崔家营坝址	Cuijiaying Dam Site	马头山	Matoushan
龙门滩砾料场	Longmentan Gravel Stock Ground	马头山石料场	Matoushan quarry
金牛山石料场	Jinniu Mountain Quarry	雅口坝址	Yakou Dam Site
雷河	Lei River	板桥	Ban Qiao
赤湖土料场	Chihu Borrow Area	东山石料场	Dong Mountain Quarry
雅口土料场	Yakou Borrow Area	流水	Liushui

2.6.4.1 Borrow area

According to the design data, clay materials for filling cofferdam and earth materials used for earth dam and connection earth dam on the right bank shall be excavated from the borrow area, and the total demand for earth materials is 81 thousand m^3. The recommended

Yakou borrow area is located in Yujiawan, Yakou Village, Liushui Township on the left bank, about 2km away from Yakou dam site, and there is rural highways with good conditions and convenient traffic. The stock ground is distributed on the downland composed of Grade-III terrace of Han River. The top elevation is 62.3m, and the exploitable range is about 500m long and 100~200m wide, and the exploitable area is about 7.00hm². The surface is cultivated land, used for planting crops like watermelon and oilseed.

The useless layer on the surface of the stock ground is thin, and it is only required to strip arable layer about 0.3m thick with a quality small stripping amount. The reserve in the borrow area is about 560 thousand m³. The groundwater depth in the site is large, and the groundwater level is within the range of exploitation depth, easy to be exploited. According the project demand and the requirements for later recovery, the average excavation depth will be 1.5m (including 0.3m topsoil layer) for the sake of later cultivated land recovery. The total excavation volume is 89.3 thousand m³, including 20.3 thousand m³ of topsoil stripping, and the floor area of the stock ground is 6.75hm².

Borrowing earth from the top of gentle slope is adopted in the borrow area. The surface arable soil in cultivated land shall be striped before excavation and the stripping thickness is 30cm. In later period, the topsoil shall be returned to recover the cultivated land.

2.6.4.2 Outsourced sand and gravel materials

According to the main body design, the sand and gravel materials for this project shall be outsourced. Tangbai River mouth sand stock ground is about 80km away from the project by waterway, and is within the reservoir area of Cuijiaying junction. At present, the stock ground is in mining and underwater mining is required. The average grain side of sand materials is 0.42 mm, belonging to medium sand, and other indicators are basically up to standard or meet the requirements. According to relevant data of pre-feasibility study, the reserve of Tangbai River mouth sand stock ground exceeds 300 thousand m³. The sand materials to be used for this project may be outsourced from this stock ground, and artificial aggregates or other commodity sand materials may also be used.

2.6.4.3 Outsourced stone materials

The stone materials for this project will be outsourced from the quarries nearby. In overall consideration of the demand for sand and gravel materials and the reserves of stock grounds, Matoushan quarry is mainly used as the concrete aggregate ground, and Jinniu Mountain and Dong Mountain quarries are used as rubble quarry. At present, the quarries are in mining. The stone materials to be used for this project will be outsourced, and the materials from Matoushan will be directly delivered to sand and stone processing system for processing and production, and those from Jinniu Mountain and Dong Mountian will be delivered by the suppliers to the construction site for production and utilization. The specific conditions of the quarries are described as below:

a) Matoushan quarry site

Matoushan quarry is located in the third branch field of Xiangbei Farm, and there are many rubble quarries which are in private mining. According to traffic conditions, rubble quality and demand, Matoushan quarry is used as the quarry sitein this period. The quarry is close to Provincial Highway 306 and about 20km away from Yakou dam site, with convenient traffic.

The bottom elevation of the quarry is about 90m, the top elevation is 124m ~ 155m, and the relative height difference is 35m ~ 60m. Exposed bedrocks are Triassic thick-layer limestone of uniclinal structure, and the inclination of stratum is 335° and dip angle 30°. And there is no large-scale karst phenomenon observed. The top of the bedrocks is of quaternary system with different thickness. The thickness on the north side is 4m ~ 6m, and that on the west side is 8m ~ 15m. There is mainly slope residual soil, and some is formed by artificial piling.

According to the results of field survey and test analysis, this quarry is suitable for rubbles which can also be processed into coarse and fine concrete aggregates. At present, the quarry is in private mining, and the main mining surfaces are located on the north and west sides. The minable thickness of useful layer on the north side is about 30m, and the soil layer 4m~6m thick on the top shall be striped. The minable thickness of useful layer on the west side is about 40m, and the soil layer 8m~15m thick on the top shall be striped. The length of excavation section is about 200m, and the longitudinal excavation depth may exceed 100m, and the reserve exceeds 800 thousand m³, which can meet the requirements of the project for rubbles. The materials can be directly outsourced for the project.

b) Jinniu Mountain quarry site

The quarry is located in the southwest of Leihe Township, about 35km away from Yakou dam site and close to Provincial Highway 205, with convenient traffic.

The bottom elevation of the quarry is about 90m~114m, the top elevation is 160m ~ 244m, and the relative height difference is 70m ~ 100m. Exposed bedrocks are simian thick-layer dolomite and dolomite limestone of uniclinal structure, and the inclination of stratum is 80° and dip angle 25°. And there is no large-scale karst phenomenon observed. The top of the bedrocks is of quaternary system and is quite thin, about 1m~2m. There is mainly residual soil.

According to the situations of rubbles excavated in the quarry and compared with the characteristics of similar rock mass project, the rubble has compact structure and high strength and belongs to hard rock, suitable for rubbles. However, the rock mass is broken and the minability is relatively low. At present, the quarry is in private mining, and the height of artificial side slope formed by excavation is 40m ~ 60m and the height of natural side slope on the top of artificial side slope about 30m. The total thickness of minable useful layer is 70m ~ 90m, and the soil layer 2m thick on the top shall be striped. The length of excavation section is about 250m, and the longitudinal excavation depth may exceed 200m, and the reserve exceeds 4000 thousand m³, which can meet the requirements of the project for rubbles. The materials can be directly outsourced for the project.

c) Dong Mountain quarry site

The quarry is located in the southeast of Leihe Township, about 30km away from Yakou dam site and connecting to rurual highways, with convenient traffic.

The bottom elevation of the quarry is 85 ~ 92m, the top elevation is about 160m, and the relative height difference is about 70m. Exposed bedrocks are simian medium-thick-layer limestone of uniclinal structure, and the inclination of stratum is 280° and dip angle

30°. And there is no large-scale karst phenomenon observed. The top of the bedrocks is of quaternary system and is quite thin, about 1m~2m. There is mainly residual soil.

According to the results of field survey and test analysis, this quarry is suitable for rubbles which can also be processed into coarse and fine concrete aggregates. At present, the quarry is in private mining, and the height of artificial side slope formed by excavation is about 70m. The thickness of minable useful layer is about 65m, and the soil layer 2m thick on the top shall be striped. The length of excavation section is about 100m, and the longitudinal excavation depth may exceed 100m, and the reserve exceeds 650 thousand m^3, which can meet the requirements of the project for rubbles. The materials can be directly outsourced for the project.

2.6.4.4 Temporary soil storage site

A temporary soil storage site shall be arranged for excavation and utilization materials produced in the construction process. There is large-area mudflats on both left and right banks of the hub project zone, which may be used as temporary soil storage site and can completely meet the requirements of the works.

Temporary storage site is located on the mudflats downstream from the hub, and is mainly used for transferring and storing excavation and utilization materials in the main works on the right bank. The floor area of ① temporary storage site is 7.00hm^2, and the peak transfer and storage volume is 918 thousand m^3 (loose measure); the floor area of ② temporary storage site is 21.00hm^2, and the peak transfer and storage volume is 2350 thousand m^3 (loose measure). After the works is completed, ② temporary storage site located downstream from the sluice will be inundated.

The total floor area of temporary soil storage site is 28.00hm^2, and the occupied land is dry land and forest land. Reclamation measures will be taken for ① temporary storage site, including topsoil stripping, return and second ploughing. After the works is completed, ② temporary storage site will become a discharge channel, and there is no need for recovery.

See Table 2.6.4 for the schedule of floor area of temporary soil storage site and occupied land types.

Table 2.6.4 Schedule of temporary soil storage sites

No.	Item	Floor area (hm²)	Peak transfer and storage volume (10000 m³)	Average piling height at peak time (m)	Occupied land type	Remark
1	① temporary storage site	7.00	91.80	13	Dry land	On the right bank downstream, within the range of second-phase cofferdam
2	② temporary storage site	21.00	235.00	11	Forest land	On the left bank downstream, on the right side of diversion channel, outside of the range of second-phase cofferdam
Total		28.00	326.80			

2.6.5 Waste dump planning

2.6.5.1 Earthwork balance

In the construction process, the foundation excavation of each zone will involve earth excavation and backfilling. According to *Project Feasibility Study Report*, the excavated earth in each zone shall be deployed and utilized according to construction technologies and sequences.

The earthwork balance of the main works is divided into hub project zone and reservoir area protection zone. According to the statistics, the project involves excavation earthwork of 14,137.5 thousand m³ (natural square, the same below), and backfilling of 6,853.8 thousand m³, including utilized earth of 6618.8 thousand m³ and borrowed earth of 235 thousand m³ (among which, 69 thousand m³ is from borrow area, and 166 thousand m³ is outsourced sand and gravel materials). Waste earth of 7,518.7 thousand m³ is produced (including temporary waste earth of 1,096.8 thousand m³ and permanent waste earth of 6,421.9 thousand m³).

a) Hub project zone

According to the hub design, project excavation involves foundation excavation for permanent buildings, excavation for diversion channel and cofferdam removal. The foundation excavation materials are mainly sand and gravels.

The foundation excavation volume for permanent buildings (including hydropower station, sluice, ship lock, earth dam, PIU's camp, etc.) in the hub project zone is 4959.8 thousand m^3, the excavation volume for temporary works (including diversion channel, cofferdam removal, access roads, construction site and camps, etc.) is 6,461.3 thousand m^3, and the total excavation volume is 11,421.1 thousand m^3. The backfilling volume is 6,576.5 thousand m^3, and the volume of waste earth produced during construction is 5,079.6 thousand m^3. The waste earth is mainly produced by foundation excavation, diversion channel and cofferdam removal.

Except that the clay of 69 thousand m^3 required for cofferdam is from borrow area and the stone materials required for rubble masonry are outsourced, all of the other backfilling materials are from the excavated earth, and 96.4% of backfilling of the hub project utilizes excavated earth in the project.

According to the construction organization design of the main works, the excavated materials to be used for building foundations shall be piled in temporary storage site, and the spoil will be delivered to corresponding waste dump.

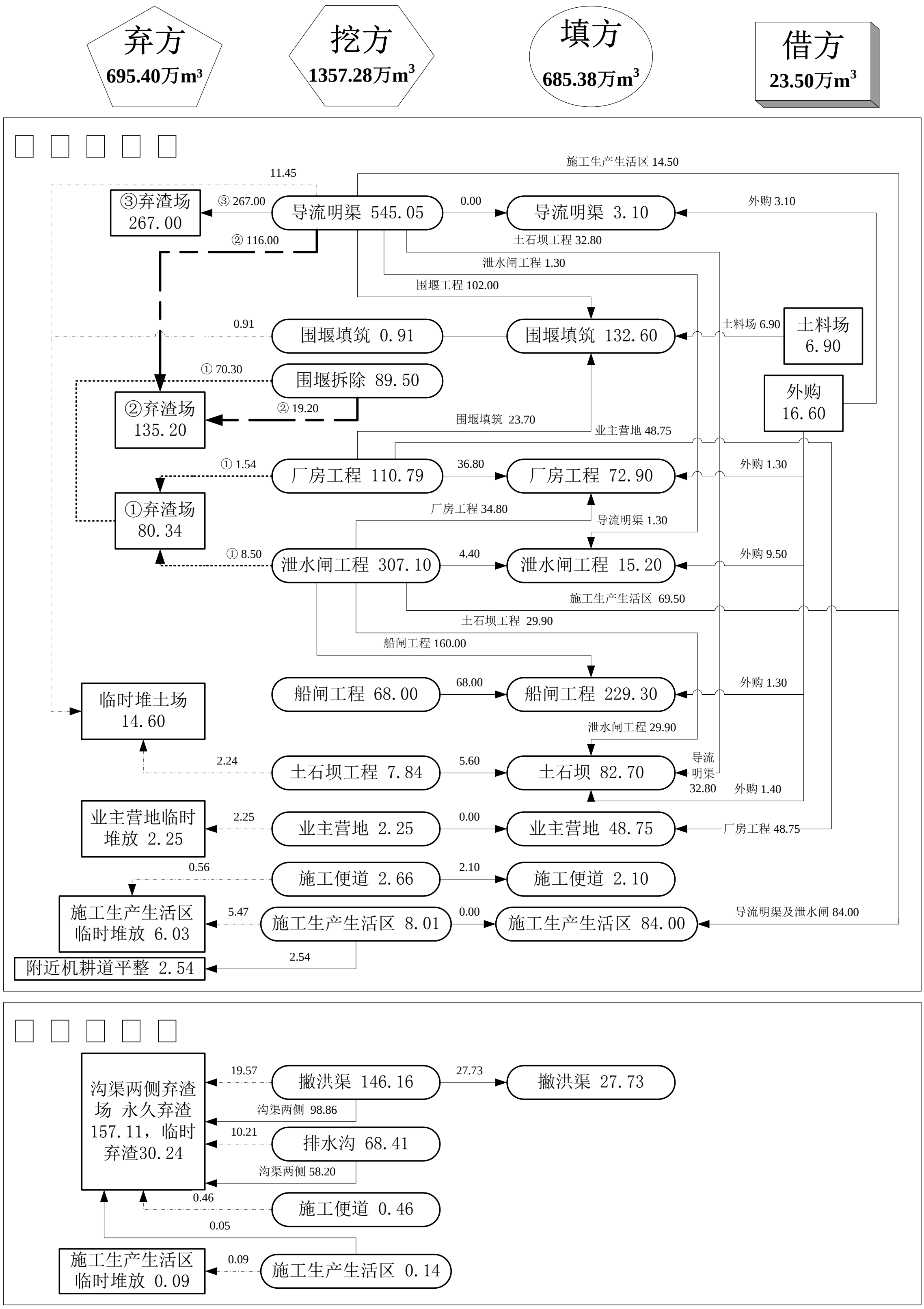


Figure 2.6.5 Sketch map for flow direction of earthwork balance of the main works Unit: 10000 m³

弃方	Waste	土石坝	Eaerth dam
挖方	Excavation	业主营地临时堆放	Temporary storage in

			PIU's site
填方	Filling	施工便道	Access road
借方	Borrow	施工生产生活区临时堆放	Temporary storage in construction site and camp
万	10 thousand	附近机耕道平整	Leveling of nearby farm machinery access
枢纽工程区	Hub project area	库区防护区	Reservoir protection area
弃渣场	Waste pump	沟渠两侧弃渣场	Waste dumps on both sides of channel
导流明渠	Diversion channel	永久弃渣	Permanent waste
施工生产生活区	Construction site and camp	临时弃渣	Temporary waste
外购	Outsourcing	撇洪渠	Flood diversion channel
土石坝工程	Earth dam works	沟渠两侧	On both sides of channel
泄水闸工程	Sluice works	排水沟	Drainage
围堰工程	Cofferdam works	业主营地	PIU's camp
围堰填筑	Cofferdam filling	厂房工程	Hydropower station works
土料场	Borrow area	船闸工程	Ship lock works
围堰拆除	Cofferdam removal	临时堆土场	Temporary storage site

b) Reservoir area protection zone

The reservoir area protection zone involves foundation excavation of floodway and drain.

According to the design data, the total excavation volume for reservoir protection works is 2,151.7 thousand m^3, the backfilling volume is 277.3 thousand m^3 and the waste earth volume is 1874.4 thousand m^3. The waste earth is mainly from excavation of floodway and drain. The waste dump is arranged on both sides of the reservoir area protection zone, which may meet the requirements of the project. Therefore no temporary soil storage site will be arranged in this program.

2.6.5.2 Spoil of hub project zone

a) Arrangement of waste dump

Waste dump in this project has good conditions. There is large-area mudflats on both left and right banks upstream from the dam site, and the waste capacity is high, which may completely meet the project demand. There is cultivated land with good irrigation conditions within the levees on both left and right banks, and there is large-area inland intertidal zone upstream from the dam site, which is used by local peasants for farming. After the hub is completed, the land will be inundated, and it is feasible to utilize the spoil of the project to heighten the mudflats outside of the levees for reducing inundations, so that the land can continue to be used for farming after land reclamation. The project is a runoff-type power station, and the waste dump is arranged on the mudflats upstream from the hub project zone, and the effective reservoir capacity occupied has little impact on the operation of power station. However, in this project, it is feasible to locate the waste dump of the hub project zone on the shoal land upstream from the dam site.

According to diversion program and the calculation results of earthwork balance, there are three waste dumps in the project. The waste dump on the left bank is mainly used for spoil caused by diversion channel and cofferdam removal, and the area on the right bank is mainly for waste caused by cofferdam removal, hydropower station and sluice. The area of each waste dump is as below: ① waste dump upstream on the right bank 20.09hm², ② waste dump upstream on the right bank 23.00hm² and ③waste dump 60.00hm². All the waste dumps are located in the reservoir area, among which, ① and ② waste dumps are close to the hub project zone, and ③ waste dump is located on the overflow lands within the inundated area about 3.5km upstream on the left bank, in order to reduce land occupation of waste, realize environmental protection and landscape and prevent waste from crossing the river for disposal. The elevation of every waste dump is lower than the normal water level.

See Table 2.6.5-1 for the specific conditions of the waste dumps in the hub project zone.

b) Protection of waste dump

The side of the waste dump near water adopts gabion box retaining wall, slope surface and foot adopt steel mesh gabion slope protection, and surrounding the waste dump is interception and drainage ditch. After the project is completed, second ploughing or vegetation recovery will be carried out according to the original landform.

1) Retaining protection

The foot of the waste dump in the hub project zone adopts gabion box retaining wall, and slope surface and foot adopt steel mesh gabion protection. The height of the section of retaining wall is 1.5m, the top width 1.0m, the bottom width 2.0m, and the buried depth 0.5m. The slope surface from the top of the retaining wall to the normal water level +0.5m adopts steel mesh gabion slope protection. The near-water sides of ① and ③ waste dumps adopt 2m-wide steel mesh gabion foot protection for preventing erosion. ② waste dump is close to the diversion channel, and the steel mesh gabion foot protection will provide protection up to the top of diversion channel and connect to the revetment of diversion channel, the width of which is 5m~10m.

After the project is used for normal impoundment, the normal water level is higher than the elevation of waste foot, and partial waste slope surface will still be inundated after the retaining wall is built. Besides, after water impoundment, the foot of retaining wall is easy to be impacted by flow scour, so corresponding slope protection measures are adopted. The slope surface of waste dump adopts steel mesh gabion slope protection, and the foot of retaining wall adopts steel mesh gabion protection pad, which has high anti-scour ability and anti-deformability as well as good durability and ecological effects. Such measure can prevent the waste from being damaged by flow and storm invasion and realize the natural exchange between water body and earth body below the slope so as to realize ecological balance. Vegetation on the slope may increase the effect of landscape and greening.

The dimension of steel wire slope protection and protection pad is 2.0m×1.0m×0.3m and adopts Galfan preservative treatment, and the clapboard is dual-clapboard. Except for cover plate, base board, clapboard, side board and end board are indivisible; the tolerance for length, width and thickness is ±3%, thickness tolerance is ±2.6cm, and the mesh dimension is 6mm×8mm. The tensile strength of steel wire is 350~550N/mm², and the elongation of unstretched steel wire may not be lower than 12% (the elongation of finished steel wire after being unstretched may not be lower than 7%). The diameter of steel wire on gabion surface is φ2.0mm, the tolerance is ±0.05mm, and the minimum cladding quantity is 215g/m². In order to increase the member stiffness, the end of steel wire panel adopts φ2.7mm end steel wire, the tolerance of clad steel wire is ±0.06mm and the minimum cladding quantity is 245g/m². The diameter of bound steel wire is φ2.2mm, the tolerance is ±0.06mm and the minimum cladding quantity is 230g/m².

Filling materials adopt cobbles, rubbles or rubbles, and the grain size shall be 100mm~300mm. The materials exceeding 5% of grain size ＜100mm are allowable, but may not be used on the exposed face of gabion mesh, and the void ratio may not exceed 30%. The stone materials shall be hard, with strength grade MU30 and specific gravity not less than 2.6t/m³. The materials are not easy to disintegrate or hydrolyze with water and are weather-resistant. Slice and strip materials may not be adopted, and decayed rocks and mud rocks may not be used as filling materials.

2) Drainage measures

Surrounding the waste dump is interception and drainage ditch. Because the terrain surrounding the ground is flat, the catchment area of ② and ③ waste dumps is mainly the floor area of the waste dumps. ① waste dump occupies the drainage ditch of the upstream sluice connecting to Han River, and the drainage design of the waste disposal group shall consider such requirement and increase the discharge capacity. The drainage ditch of the waste dump is designed according to 20-year flood control standard, and the design dimensions of interception and drainage ditches are as shown in Table 2.6.5-2.

Table 2.6.5- 2 Section dimension of interception and drainage ditch of each waste dump

Interception and drainage ditch	Unit	①waste dump	②waste dump	③waste dump
Upper bottom width	cm	270	170	170
Lower bottom wide	cm	90	50	50
Ditch depth	cm	90	60	60
Side slope ratio	-	1:1	1:1	1:1
Lining type	-	Masonry	Masonry	Masonry
Lining thickness	m	30	30	30

3) Reclamation of waste dump

For the ground occupying cultivated land and forest land, reclamation measures shall be taken. The works mainly involves topsoil stripping before commencement, and the topsoil shall be returned to the waste dump. Second ploughing shall be carried out occupied cultivated land, and vegetation recovery carried out for occupied forest land.

2.6.5.3 Spoil of reservoir area protection zone

The spoil of Reservoir area protection zone is mainly earth caused by excavation of flood diversion channel and drain, and it is proposed to adopt nearby waste disposal for such earth, which will be used on both sides of flood diversion channel and drainage ditch. In order to facilitate second ploughing and utilization by peasants, the side slope of waste piling shall be 1:2. The average piling height of waste dump for flood diversion channel is 1.5m, and the occupied land width on both sides is about 19m~27m. The average piling height of waste dump for drain is 1.0m, and the occupied land width on both sides is about 12m. The floor area of the waste dump is 125.31hm², and the occupied land types include paddy field, dry land, forest land and bare land. After the project is completed, second ploughing or vegetation recovery will be carried out according to the original landform.

See Table 2.6.5-1 for the layout of waste dumps.

Table 2.6.5- 1 Schedule of flow direction of spoil of Yakou Shipping Hub Project

Zone	Item	Floor area hm²	Waste quantity 10000 m³	Average piling height m	Occupied land type	Waste dump type	Waste top elevation m	Normal water level m	Waste bottom elevation on near-river side m	Design flood level (P=10%)	Check flood level (P=2%)	Remark
Hub project zone	①waste dump	20.09	80.34	4.0	Dry land	Reservoir area, flat land	58.0	55.22	51.1~53.8	53.30	54.31	Mudflats outside of the leve on the right bank
	②waste dump	23.00	135.20	6.0	Forest land, inland intertidal zone	Reservoir area, flat land	58.0	55.22	48.5~52.6	53.30	54.31	Mudflats on the left bank
	③waste dump	60.00	267.00	4.5	Dry land, forest land	Reservoir area, flat land	58.0	55.22	51.3~54.2	53.30	54.31	Mudflats outside of the leve on the left bank
	Subtotal	103.09	482.64									
Reservoir area protection zone	On both side of flood diversion channel	67.11	98.89	1.5	Paddy field, dry land, forest land and bare land	Flat land	Current ground elevation +1.5m					
	On both sides of drain	58.20	58.22	1.0			Current ground elevation +1.0m					
	Subtotal	125.31	157.11									

Total	228.40	639.65								

2.6.6 River diversion during construction

2.6.6.1 Grades of diversion structures

Han River Yakou Shipping Hub Project is a Class-II large (b) project, and the main structures are Grade-2. According to the regulations of *Design Specification for Construction Organization of Hydraulic and Hydroelectric Projects* SL303-2004, the grade of corresponding diversion structures is 4.

2.6.6.2 Diversion standards

According to the specification, the grade of diversion structures is 4. If adopting earth and rolfill structure, the design flood standard of diversion structures is 20~10 years; if adopting concrete and masonry structure, the design flood standard is 10~5 years.

This project adopts stage diversion, and the cofferdam at each stage adopts earth-rock cofferdam. At the first stage, the overflow lands on the left side is excavated to form open channel, which is excavated on the exiting flood land, and there is no need for cofferdam; at the second stage, the main riverbed on the right side is coffered and ship lock, 38-hole sluice and hydropower station are built on the right bank. The maximum cofferdam height is 13.5m, and the service life of 2nd stage cofferdam is two years; at the third stage, diversion channel is coffered, and 10-hole sluice and earth dam are built on the left bank. The maximum cofferdam height is 11m, and the service life of 3rd stage cofferdam is 1 year. At this stage, the cofferdam will be used to retain water for power generation in dry season, and the grade of 3rd stage cofferdam will not be increased.

According to topographic and geologic conditions, hydrological conditions, characteristics of stage diversion, cofferdam functions at each stage, protection objects and construction period, the following design standards are adopted:

a) The diversion standard at the first stage is five-year return period, and the flood peak discharge is 12000m^3/s;

b) The diversion standard at the second stage is ten-year return period, and the flood peak discharge is 13500m^3/s;

c) The diversion standard at the third stage is ten-year return period, and the flood peak discharge is 13500m^3/s;

At the third stage, the cofferdam shall be used to retain water for power generation, so the cofferdam height shall meet the requirements of dead pool level for power generation.

2.6.6.3 Diversion program and procedures

At the axis of Yakou dam, the valley is about 2.3km wide, and on the left bank is Grade-III terrace, with high terrain; on the right bank is I-grade terrace, the levee is located on I-grade terrace and the levee crown elevation is 58.10m ~ 58.50m. The main channel of Han River is on the riverbed close to the right bank, and the water surface width is about 500m ~ 1000m, water depth usually 4.0m ~ 6.0m, maximum water depth about 8.0m, and river bottom elevation usually 43.5m ~ 45.4m. On the left side of the main channel is flat and broad low floodplain, and the width of floodplain surface is 680m ~ 1000m and ground elevation 49.0m ~ 52.6m. Close to the left bank is separate river channel, and the water depth is 3.0m ~ 5.0m, water surface width 80m ~ 150m and river bottom elevation usually 43.0m ~ 45.5m.

From left to right, hub structures include earth dam on the left bank, 10-hole sluice on the left bank, hydropower station, 38-hole sluice on the right bank, ship lock and earth dam on the right bank. According to the hydrologic characteristics of Han River and in combination with the topographic and geologic conditions of the dam site and the hub layout, the project adopts three- stage diversion. The diversion procedures are described as below:

a) 1st stage diversion: from December of the first year to October of the second year, build diversion channel and 2nd stage cofferdam on the left site and heighten river shoal to form temporary partitioning bank for water retaining. In the construction period of open channel, the main riverbed on the right bank is used for discharging and shipping. The open channel will be ready for discharging at the end of October of the second year;

b) 2nd stage diversion: in the middle November of the second year, intercept the main riverbed on the right side. From the middle November of the second year to September of the fourth year, ship lock on the right bank and 38-hole sluice and hydropower station are coffered, and the open channel on the left bank is open for discharging and shipping. The entrance of hydropower station and the tail water gate will be open at the end of September of the fourth year, before which, the hydropower station is a closed system and the construction may be carried out all year round.

c) 3rd stage diversion: in the middle November of the fourth year, intercept the open channel on the left side. From the middle November of the fourth year to January of the sixth year, carry out the construction of 10-hole sluice and earth dam on the left bank, and the built 38-hole sluice and ship lock on the right bank are open for shipping. From October of the fifth year to January of the sixth year, the 3rd stage cofferdam is used to retain water for power generation.

Table 2.6.6 Stages of river diversion during construction

Item	Diversion standard			Water retaining structure	Diversion and navigation structure	Enclosure foundation pit	Max. water level upstream (m)	Elevation of water retaining structure (m)
	Period	Frequency	Peak discharge (m³/s)					
Stage I	December of the first year – October of the second year	All year round 20%	12000	Temporary partitioning bank	Main riverbed on the right side	Open channel	53.25	54.5
Stage II	November of the second year – October of the fourth year	All year round 10%	13500	2nd stage longitudinal and transversal cofferdams	Open channel on the left side	Ship lock, 38-hole sluice and hydropower station on the right bank	54.41	56.00
Stage III	November of the fourth year – January of the sixth year	All year round 10%	13500	3rd stage longitudinal and transversal cofferdams	38-hole sluice + ship lock on the right bank	10-hole sluice and earth dam on the left bank	54.72	56.00

2.6.6.4 Diversion structure design

a) 1st stage diversion channel

The 1st stage diversion channel is located on the low floodplain on the left side of the hydropower station, with flat terrain. Along the diversion channel axis, the thickness of coverage layer is 20.3m ~ 22.1m, and the thickness of top silty-fine sand is 8.9m ~ 9.7m and that of lower silty-fine sand is 9.5m ~ 13.3m. The top elevation of bedrock is about 30.0m ~ 33.1m, and that at the upper reach is lower. Shallow bedrocks are mainly weak cementitious silty-fine sandstone, loose glutenite and clay rock with large lithological change, and spread in interlensing shape. In the construction period of open channel, temporary partitioning bank is used to retain water, and the open channel adopts double cross sections. The bottom elevation is 44.00m ~ 44.50m, and the width is 130m. There are

73.5m-wide platform on both sides, the elevation of which is 44.50m ~ 45.00m, and the side slopes on both sides are 1:3. Channel bottom and platforms adopt concrete hinged mattress protection, and the dimension of concrete block is 0.6m×0.6m×0.1m. Channel slope adopts high-tensile steel mesh gabion protection, and the dimension is 2.0m×1.0m×0.3m.

b) Upstream and downstream 2nd-stage transversal cofferdams

The upstream and downstream 2nd-stage transversal cofferdams are earth-rock cofferdams, crossing over the main riverbed, and connecting to the levee on the right bank. The thickness of coverage layer of cofferdam foundation is 11.5m ~ 24.7m, and the top elevation of bedrock is about 23.5m ~ 33.5m. The thickness of top silty-fine sand is 1.5m ~ 11.6m and that of lower silty-fine sand is 5.0m ~ 16.7m. The axial length of upstream transversal cofferdam is 1866.546m, the cofferdam crest elevation is 56.00m, the maximum cofferdam height is 13.5m, the cofferdam slope on near-water side is 1:3.0, and the cofferdam slope on land side is 1:2.6; the axial length of downstream transversal cofferdam is 1586.356m, the cofferdam crest elevation is 55.00m, the maximum cofferdam height is 12.0m, the cofferdam slope on near-water side is 1:3.0, and the cofferdam slope on land side is 1:2.6. The cofferdams adopt high pressure sprayed grouting + clay core wall seepage proofing.

c) 2nd-stage longitudinal cofferdam.

The 2nd-stage longitudinal cofferdam is earth-rock cofferdam, located between the hydropower station and the sluice on the left bank to connecting to earth dam. The ground elevation is 51.8m ~ 52.6m, and the terrain is flat. The thickness of coverage layer is 20.4m ~ 23.0m, and the top elevation of bedrock is about 23.5m ~ 33.5m. The thickness of top silty-fine sand is 8.7 ~ 11.6m and that of lower silty-fine sand is 9.7m ~ 15.2m. The axial length of the cofferdam is 506.800m, the cofferdam crest elevation is 56.00 ~ 55.00m, the maximum cofferdam height is 6.0m, and the cofferdam slopes on both sides are 1:3.0. The longitudinal cofferdams adopt high pressure sprayed grouting + clay core wall seepage proofing.

d) 3rd-stage transversal cofferdam

The upstream and downstream 3nd-stage transversal cofferdams are earth-rock cofferdams, located within diversion channel. The axial length of upstream transversal cofferdam is 416.500m, considering that the 3rd stage cofferdam can retain the food of 100-year return period and retain water for power generation, the cofferdam crest elevation is 56.00m, the maximum cofferdam height is 11.0m, the cofferdam slope on near-water side is 1:3.0, and the cofferdam slope on land side is 1:2.6; the axial length of downstream transversal cofferdam is 416.500m, the cofferdam crest elevation is 55.00m, the maximum cofferdam height is 11.0m, the cofferdam slope on near-water side is 1:3.0, and the cofferdam slope on land side is 1:2.6. The cofferdams adopt high pressure sprayed grouting + clay core wall seepage proofing.

e) 3rd-stage longitudinal cofferdam.

The 3rd stage longitudinal cofferdam is earth-rock cofferdam, located on the bank slope on the left bank of diversion channel. The axial length of the cofferdam is 426.685m, the cofferdam crest elevation is 56.00m, the maximum cofferdam height is 4.5m, and the cofferdam slopes on both sides are 1:3.0. The longitudinal cofferdams adopt high pressure sprayed grouting + clay core wall seepage proofing.

2.6.6.5 Channel interception

According to the general construction schedule, the interception period of 2nd stage main riverbed and 3rd stage open channel is in the middle November. According to the regulations of *Design Specification for Construction Organization of Hydraulic and Hydroelectric Projects* SL303-2004, the interception flow standard adopts the monthly or ten-day average flow of 5~10 year return period . In this period, the monthly average flow of ten-year return period in November is used as the design interception flow, and the design flow is 1790m^3/s. The berm elevation of 2nd stage and 3rd stage interception is 50.50m and 50.00m, respectively. Both 2nd stage and 3rd stage interception adopts unidirectional single-berm vertical-closure and advancing mode.

2.6.6.6 Initial impounding

According to the regulations of *Design Specification for Construction Organization of Hydraulic and Hydroelectric Projects*, the water impoundment standard for the reservoir construction is determined as per the requirements of power generation, irrigation, navigation factors as well as the factors such as free board of the dam, and the general guarantee rate is 75% ~ 85%. The design flow of the tail lock may take the average monthly or ten-day average flow of 5~10-year return period, or may be determined as per the measured upstream flow. According to the actual characteristics of the project, the design guarantee rate of initial water impoundment is 85%.

According to the general construction schedule, the reservoir will begin to lower the lock for water impounding from early October of the year, and the design flow of the tail lock takes the average monthly flow of 10-year return period in October, i.e. 4030m³/s. The design condition of the service gate of the lock dam is dynamic water hoisting. When the power generators are ready for power generation, the service gate of the sluice dam may start water impounding for power generation. The duration of water impounding is short, and it usually takes 6~7 days to reach the normal water level. Calculated at the design guarantee rate, 85%, of initial impounding, the minimum discharge volume of the controlled sluice is 450m^3/s, it takes 20.2d to reach the dead pool level 54.72m and takes 2.69da to reach the normal water level 55.22m from the dead pool level.

2.6.7 Project construction program

a) Sluice construction

The sluice works mainly includes earthwork excavation, concrete placement, foundation treatment, earthwork backfilling and metal structure installation. The main quantities include: 2,672.9 thousand m^3 of earthwork excavation, 72 thousand m^3 of earthwork backfilling, 274.7 thousand m^3 of concrete placement, 19.8 thousand m^3 of plastic concrete anti-seepage wall and 8293t of metal structure installation.

Sluice earthwork mainly involves silty-fine sand and sad gravels. Layered excavation is carried out from top to down, and 3 ~ 5m³ digger and 20t ~ 32t dump truck are adopted for earthwork. The average excavation intensity in peak month is 261.8 thousand m³. Some of excavated materials are used for filling of hydropower station channels, ship lock separation levee and earth dam on the right bank, and the rest is stored in ① waste dump.

For the 38-hole sluice on the right bank, the total concrete volume is 238.3 thousand m^3, and the average placement intensity in peak month is 24.2 thousand m^3. Two MQ540 gantry cranes and two 50t crawler cranes are adopted. For the 10-hole sluice on the left bank, the total concrete volume is 56.9 thousand m^3, and the average placement intensity in peak month is 9.2 thousand m^3. One MQ540 gantry crane and one 50t crawler crane are adopted.

b) Hydropower station construction

Hydropower station works mainly includes: earthwork excavation, concrete placement, foundation treatment, earthwork backfilling and metal structure installation. The main quantities include: 915.5 thousand m^3 of earthwork excavation, 339.1 thousand m^3 of concrete placement, 671.8 thousand m^3 of earthwork backfilling; foundation treatment mainly including consolidation grouting of about 17583m and curtain grouting of about 2381m; and 4.3 thousand m^3 of plastic concrete anti-seepage wall.

For the hydropower station, the average excavation intensity in the foundation pit month is 184.6 thousand m^3, and layered excavation is carried out from top to down. 3 ~ 5m^3 digger and 20t ~ 32t dump truck are adopted for earthwork excavation. Useful excavated materials will be used for cofferdam filling, earth dam filling and construction site leveling, and other useless materials will be delivered to the waste disposal site on the right bank.

Earthwork excavation is mainly centralized in the foundation pit of the hydropower station on the right bank. Earthwork excavation is carried out in two parts, and layered excavation is carried out above the protection layer. YQ-100 down-the-hole drill is used for drilling, deep-hole bench millisecond blasting is adopted, and the hole depth usually is 6 ~ 9m. Protection layer excavation is adopted within 1.5m of the foundation surface. Pneumatic drill and shallow-hole spark blasting are adopted. Excavated stone materials adopt 3 m^3 digger and 20t dump truck, some of which will be used for site leveling on the right bank, and the rest will be delivered to the waste dump on the right bank.

For the hydropower station, the total concrete volume is 349.2 thousand m^3, and the average placement intensity in peak month is 34.7 thousand m^3. Two MQ540 gantry cranes, one M900 tower crane and three 50t crawler cranes are adopted.

c) Ship lock construction

The ship lock works mainly includes earthwork excavation, concrete placement, foundation treatment, earthwork backfilling and metal structure installation. The main quantities include: 220.6 thousand m^3 of earthwork excavation, 948.6 thousand m^3 of earthwork backfilling, 116.5 thousand m^3 of concrete placement, 6.2 thousand m^3 of plastic concrete anti-seepage wall and 1,479t of metal structure installation.

For the ship lock, earthwork mainly involves silty-fine sand and sad gravels, and layered excavation is carried out from top to down. 3 ~ 5m^3 digger and 20t ~ 32t dump truck are adopted for earthwork. Some materials may be directly used for ship lock filling, and the others will be delivered to the waste dump (stock transfer).

For the ship lock, the total concrete volume is 115.6 thousand m^3, and the average placement intensity in peak month is 16.2 thousand m^3. One MQ540 gantry crane and two 50t crawler cranes are adopted.

d) Earth dam construction

The earth dam works on the left and right banks of the hub project mainly includes earthwork excavation, earthwork backfilling, concrete placement and foundation treatment. The main quantities include: 319.5 thousand m^3 of earthwork excavation, 792.4 thousand m^3 of earthwork backfilling, 271.4 thousand m^3 of rubble revetment, 34.9 thousand m^3concrete placement and foundation treatment mainly including 41.2 thousand m^3.

The earthwork mainly involves silty-fine sand, and the total volume is 64.6 thousand m. Layered excavation is adopted from top to down, and 3 ~ 5m^3 digger and 20t ~ 32t dump truck are adopted for earthwork. All of the excavated materials will be delivered to the waste dumps on the left and right banks. The concrete works on both banks mainly adopt prefabricated members, which are prefabricated by prefabrication plants on the left and right banks and delivered to the site by 5t or 8t dump trucks. Manual transfer and manual positioning and installation are adopted on the site.

2.6.8 Navigation during construction

a) Navigation during construction in the period of 1st stage river diversion during construction

According to the program of river diversion during construction, during the construction of the 1st stage works, the main riverbed on the left bank is used for discharging and navigation, and after maintenance, the existing waterway may meet the requirements of construction navigation of 500t ships.

b) Navigation during construction in the period of 2nd stage river diversion during construction

During the construction of the 2nd stage works, the main riverbed on the left bank is used for discharging and navigation, so the program for navigation during construction shall be carried out in combination with river diversion channel. After water of 9.5 billion m^3 is transferred in the 1st stage works of South-to-North Water Transfer Project, the design flow corresponding 97% navigation guarantee rate of the river section of the dam site is about $450m^3$, and the corresponding waterway level downstream is 47.05m. According to the design program for diversion structures, the bottom width of open channel is 290m, the baseplate elevation is 45.00m, and the navigation water depth is about 2m, reaching IV(2) navigation standard and meeting he requirements of navigation during construction.

c) Navigation during construction in the period of 3rd stage river diversion during construction

In the period of 3rd stage river diversion during construction, the ship lock is ready for navigation. The navigation during construction is this period can meet the requirements of navigation with reasonable scheduling of available sluice.

2.6.9 General construction progress

The total construction term is 4 years and 10 months, the preparation period is 11 months, the construction period for power generation is 35 months, and the completion period is 12 months. The construction period for ship lock to be ready for navigation is 34 months, and the construction period of the first power generator for power generation is 46 months (including 11 months of preparation period in the straight-line construction term).

According to the construction procedures and characteristics, the key line of the construction is as below: 1st stage channel excavation → second-cofferdam pre-advancing →2nd stage interception →foundation excavation for main hydropower station → foundation treatment and baseplate concrete placement → bottom concrete placement in main engine room→ upper concrete placement and bridge crane erection → installation of generator equipment →power generation of the first power generator → power generation of follow-up power generators. The total construction period of the key line is 58 months.

2.6.10 Land occupation

The land occupation in this project involves cultivated land (paddy field, irrigable land and dry land), park land, forest land, grass land, residential land, special land (land used for funeral and interment), land for transportation, water area and land for water conservancy facilities (river surface, pound surface and inland intertidal zone), and other land (bare land and agricultural land for facilities). The total floor area of the project is 9126.18hm^3, among which, the area of permanent land occupation is 8751.87hm^2, including dam construction area in the hub project zone (cofferdam area, diversion channel area and some land upstream from the dam site within the range of management), PIU's camp, approach road, and reservoir inundation area and protection works area in reservoir area protection zone, and the area of temporary land occupation is 374.31hm^2, including dam construction area (cofferdam area, diversion channel area and some land upstream from the dam site within the range of management), earth materials ground, temporary soil storage site, waste dump, construction site and camp and land for access road.

Statistics work is carried out for hub project zone and reservoir area protection zone respectively. The land occupied by hub project zone is 377.08hm^2, and the land occupied by reservoir area protection zone is 8,749.10hm^2. The area of land occupation within the territory of Yicheng City is 8,508.91hm^2, that within the territory of Xiangcheng District is 357.46hm^2, and that within the territory of Xiangzhou District is 259.81hm^2. See Table 2.6.10 for the details of land occupation of the project.

Table 2.6.10 Summary of land occupation of the project

Unit: hm²

Project zone			Land occupation type														Land occupation property	
			Cultivated land			Park land	Forest land	Grass land	Residential land	Special land	Land for transportation	Water area and land for water conservancy facilities			Other land		Subtotal	Permanent	Temporary
			Paddy field	Irrigable land	Dry land							River surface	Pond surface	Inland intertidal land	Bare land	Agricultural land for facilities			
Hub project zone	Dam construction area	Hub area										27.23		33.97			61.20	61.20	
		Earth dam area			3.18		3.20					1.08		7.37	5.34		20.17	20.17	
		Cofferdam area			2.21		1.66					11.12		4.91			19.90	10.08	9.82
		Diversion channel area					76.32							5.76			82.08	20.23	61.85
		Other land within the range of management			16.59		2.43					0.45		4.87			24.34	11.87	12.47
	PIU's camp				7.50												7.50	7.50	
	Earth materials ground				6.75												6.75		6.75
	Temporary soil storage site				7.00		21.00										28.00		28.00
	Waste dump				66.71		32.04							4.34			103.09		103.09
	Road works area	Approach road					0.57				0.13						0.70	0.70	
		Access road			1.15									0.28	0.77		2.20		2.20
	Construction site and				17.90		0.65							2.60			21.15		21.15

	camp																		
	Subtotal				128.99		137.87				0.13	39.88		64.10	6.11		377.08	131.75	245.33
Reservoir area protection zone	Reservoir inundation area			22.47	2763.07	7.85	1592.21	16.99	1.55	9.99		3567.57	5.76	423.12		83.54	8494.12	8494.12	
	protection works area	Flood diversion channel area	27.58		20.11		31.40								3.71		82.80	82.80	
		Anti-inundation area	14.39		10.49		16.38								1.94		43.20	43.20	
	Waste dump		41.74		30.44		47.52								5.61		125.31		125.31
	Access road				0.25		2.67								0.45		3.27		3.27
	Construction site and camp				0.12										0.28		0.40		0.40
	Subtotal		83.71	22.47	2824.48	7.85	1690.08	16.99	1.55	9.99		3567.57	5.76	423.12	11.99	83.54	8749.10	8620.12	128.98
Total			83.71	22.47	2953.47	7.85	1827.95	16.99	1.55	9.99	0.13	3607.45	5.76	487.22	18.10	83.54	9126.18	8751.87	374.31

Note: ① The construction of the dam zone is carried out by stages, the hub includes sluice, power station and ship lock, and there is overlapping between the land occupation of earth dam, diversion channel and cofferdam, which is not calculated or listed repeatedly;

② The permanent land occupation of cofferdam, diversion channel and other land within the range of management is some land upstream from the dam site, and the temporary land occupation is some land downstream from the dam site.

③ Somel land occupation of the hub project zone is located in the reservoir inundation area, which is deducted from the land occupation of reservoir inundation area and not calculated or listed repeatedly.

2.7 Land acquisition and resettlement

2.7.1 Land acquisition

2.7.1.1 Affected area of reservoir inundation

The total area of the land to be inundated by the reservoir of Yakou Shipping Hub is 79.51km^2, including land area of 46.54km^2 and water area of 32.97km^2. As per land natures, the affected area includes cultivated land of 2667.25hm^2, park land of 7.85 hm^2, forest land of 1432.76 hm^2, grass land of 16.99 hm^2, residential land of 1.55 hm^2, special land of 9.99 hm^2, 3303.29 hm^2 of water area and land for water conservancy facilities and other land of 511.54 hm^2. The affected population is 1378, including agricultural population 271 and non-agricultural population 1107. The area of affected houses is 81332.4m^2, including brick-concrete structures of 25441.3m^2, brick-wood structures of 47580.5m^2, wood structures of 311.7m^2, and miscellaneous houses of 7998.9m^2. There are two industrial enterprises and 27 private businesses to be affected by the inundation, and the special items mainly involve 2.2km-long farm machinery accesses, one port, two wharfs, two ferries, 2.6km-long optical cables, 3km-long power cables, three pump stations and nine drainage culvert sluices.

See Table 2.7.1-1 for the physical indicators to be affected by reservoir inundation of Yakou Shipping Hub.

Table 2.7.1- Physical indicators to be affected by reservoir inundation pf Yakou Shipping Hub

No.	Item	Unit	Total	Yicheng City	Xiangcheng District	Xiangyang District
I.	Rural area					
(一)	Land area	km^2	79.51	73.34	3.57	2.69
	Land	km^2	46.54	45.31	0.11	1.11
	Water area	km^2	32.97	28.03	3.46	1.48
1	Cultivated land	hm^2	2667.25	2667.25	0	0
	Dry land	hm^2	2644.79	2644.79	0	0
	Irrigable land	hm^2	22.47	22.47	0	0
2	Park land	hm^2	7.85	7.85	0	0
3	Forest land	hm^2	1432.76	1432.76	0	0

No.	Item	Unit	Total	Yicheng City	Xiangcheng District	Xiangyang District
	Woodland	hm^2	1267.23	1267.23	0	0
	Woodland (flood land)	hm^2	165.53	165.53	0	0
4	Grass land	hm^2	16.99	0	0	16.99
5	Residential land	hm^2	1.55	1.55	0	0
6	Special land	hm^2	9.99	9.99	0	0
	Land for funeral and interment	hm^2	9.99	9.99	0	0
7	Water area and land for water conservancy facilities	hm^2	3303.29	2808.66	346.24	148.39
	River surface	hm^2	3297.53	2802.90	346.24	148.39
	Pond surface	hm^2	5.76	5.76	0	0
8	Other land	hm^2	511.54	405.89	11.22	94.43

Table 2.7.1-1 (Cont.)

No.	Item	Unit	Total	Yicheng City	Xiangcheng District	Xiangyang District
	Sand land	hm^2	355.68	250.03	11.22	94.43
	Bare land	hm^2	72.32	72.32	0	0
	Agricultural land for facilities	hm^2	83.54	83.54	0	0
(II)	Population		1378	1378	0	0
	Agricultural population	person	271	271	0	0
	Non-agricultural population	person	1107	1107	0	0
(III)	House area		81332.4	81332.4	0	0
1	Brick-concrete structure	m^2	25441.3	25441.3	0	0
2	Brick-wood structure	m^2	47580.5	47580.5	0	0
II.	Professional facilities					
(I)	Traffic facilities					
	Farm machinery access	km	2.2	2.2	0	0
	Port	no.	1	1	0	0
	Wharf	no.	2	2	0	0
	Ferry	no.	2	2	0	0
(II)	Telecommunication facilities					
	Optical cable	km	2.6	2.6	0	0
	Power cable	km	3	3	0	0
(III)	Water conservancy facilities					
	Pump station	no.	3	3	0	0
	Drainage culvert and sluice	no.	9	9	0	0

2.7.1.2 Hub works construction area

The hub works construction area involves two villages, i.e., Yakou Village in Liushui Township and Maocao Village in Zhengji Township in Yicheng City. In the recommended program, main physical indicators in the hub works construction area is as below: the total involved area is 4.85km^2, including land area of 3.77km^2 and water area of 1.08 km^2. As land usage, the land area includes permanent land occupation of 131.75 hm^2 and temporary land occupation of 253.24 hm^2. The permanent land occupation involves cultivated land of 18.20 hm^2, forest land of 58.14 hm^2, road land of 0.13 hm^2, 49.93 hm^2 of water area and land for water conservancy facilities, and other land of 5.34 hm^2. The temporary land occupation involves 116.20 hm^2 of overflow lands for planting crops, 171.00 hm^2 of overflow lands for planting woods, 59.36hm^2 of water area and land for water conservancy facilities and other land of 6.68 hm^2. The special item involves 0.28km-long farm machinery access.

2.7.1.3 Other water conservancy works

Other water conservancy works construction area includes new levees in the reservoir area, pump station, culvert and sluice, flood diversion channel and drainage channel, and involves six townships, i.e., Liushui, Nanying, Wangji, Zhengji, Yancheng and Xiaohe in Yicheng City. The total involved land area is 124.07 hm^2, including permanent land occupation of 120.40 hm^2 and temporary land occupation of 3.67hm^2. The permanent land occupation involves cultivated land of 69.72 hm^2, forest land of 48.23 hm^2 and other land of 6.12hm^2. The population affected by land acquisition is 351, including agricultural population 301 and non-agricultural population 50. The area of houses affected by inundation is 20700m^2, including brick-concrete structures of 10800m^2, brick-wood structures of 5700m^2 and miscellaneous houses of 4200m^2.

2.7.2 Resettlement planning

2.7.2.1 Production arrangement planning

The cultivated land to be inundated by Yakou Shipping Hube Projet is located within the territory of Yicheng City. According to calculation, the production arrangement population affected by land acquisition for Yakou Shipping Hub in 2012 is 22,426. By the planning level year, the production arrangement population will be 23401, including 23,307 persons (2018) affected by reservoir area and 94 persons affected by hub project zone (2013). Because rural immigrants are mainly occupied in crop farming, and greatly depend on the local environment. Local resettlement within the village is primarily adopted, and according to the planning local resentment or cultivated land allocation within the local township will be adopted. According to the progress of local urbanization construction, efforts shall be made to actively develop the second and third industries, increase immigrants' employability, improve export of labor service and expand income increasing channels.

2.7.2.2 Relocation planning

According to the program that the normal water level of Yakou Shipping Hub Project reaches 55.22m, the total population affected by land acquisition and relocation is 1,729, and by the planning level year 2018, the relocation population is 1805, all being within the reservoir area of the hub project, including 1,439 persons in reservoir inundation area and 366 persons in other water conservancy works construction areas. Scattered resettlement is adopted for all of the population.

2.7.2.3 Preliminary program for follow-up support

The follow-up support to the immigrants affected by land acquisition for Yakou Shipping Hub Project construction involves rural immigrants within the land acquisition area, excluding the population newly added after resettlement and non-agricultural population. Follow-up support funds are proposed to be directly issued to individual immigrants. The immigrants within the range of follow-up support will be supported for twenty years since the completion date of moving, and the subsidy per capita every year is CNY 600.

2.7.3 Rehabilitation (reconstruction) planning for special items

The special items of Yakou Shipping Hub Projects include 2.2km-long farm machinery accesses, one port, two wharfs, two ferries, 2.6km-long optical cables, 3km-long power cables, three pump stations and nine drainage culvert sluices. Monetary compensation will be adopted for farm machinery accesses, optical cables and power cables. Nearby reconstruction will be carried out for three pump stations.

In order to solve the problems of water drainage, waterlog drainage and immersion area within the flood diversion areas in Xiangdong and Xiangxi, preliminary planning is worked out in this period.

2.7.3.1 Waterlog drainage design

Blocking and hole-expansion reconstruction will be adopted for nine culvert sluices to be affected by the reservoir inundation of Yakou Shipping Hub.

Culvert sluice reconstruction: for Baijiatao Sluice and Guhegou Sluice which are adversely affected, reconstruction at original location will be carried out, and the original culvert sluices will be removed or blocked.

Culvert sluice blocking: for Yejicheng Sluice, Nanhe Sluice, Huangjiagou Sluice, Gongnao Sluice, Annao Sluice, Guanzhuang Sluice and Nanzhou Sluice, because the ground elevation of the drainage outlet within the protection area is lower than the normal water level of the reservoir, and pumps shall be adopted for drainage. The original culvert sluices lose their functions, so blocking will be adopted.

2.7.3.2 Immersion treatment

It is proposed to build a immersion drainage ditch of a certain length along the inside of the levee from Jiang River levee in Yicheng City on the right bank of Han River to Yakou Hub, in order to drain the water seepage caused by immersion at the levee. The bottom width of drainage ditch is 2m, the height is 2m, the side slope on both sides is 1:1.5, and the length is 25km. It is proposed to build a immersion drainage ditch of a certain length along the inside of the levee from Xinzhou Village in Wangji Township on the left bank of Han River to Nanzhou Village under jurisdiction of Nanying Street Office , in order to drain the water seepage caused by immersion at the levee. The bottom width of drainage ditch is 2m, the height is 2m, the side slope on both sides is 1:1.5, and the length is 23km. The water seepage caused by immersion on both banks will be discharged to Han River via. original drainage culvert sluices or new drainage pump station.

2.7.3.3 Water intake works

After the reservoir of Yakou Shipping Hub begins water impoundment, the affected pump stations include Zhangju Irrigation Pump Station, Lift Pump Station of Thermal Power Plant, Nanying Irrigation Pump Station, Yicheng Water Supply Works and Water Supply Works of Xiangnan Chemical Plant, and the motor levels, pumps and water inlet maintenance of the pump stations are affected by inundation to different extent. When sediment deposition or corrosion causes failure, it is difficult to carry out maintenance and repair. It is required to reconstruct the water intakes.

2.8 Operation mode

Yakou Shipping Hub is located downstream from Danjiangkou Hydro-junction, and its runff is mainly from Danjiangkou scheduling discharge and water between Danjiangkou ~Yakou. At the dam site of Yakou Shipping Hub, the average annual discharge is 1490m^3/s. After the dam of Danjiangkou Hydropower hub is heightened and 9.5 billion m^3/a of water transfer is completed in the first phase project of the middle route of South-to-North Water Transfer Project, the average annual discharge at the dam site is 1100m^3/s. Since being built and combined to the grid for power generation in 1999, Wagfu Hydro-junction 30km downstream from Danjiangkou Hydro-junction has been in synchronous operation with Danjiangkou Junction, and after Danjiangkou Junction is heightened, Wangfuzhou Junction will plays the role of reverse regulation. Since Cuijiaying Junction was combined to the grid for power generation in 2009, the reservoir has carried out daily regulation of water level according to the demand for power generation.

2.8.1 Operation mode of Danjiangkou reservoir after being heightened

Danjiangkou reservoir include flood control and water supply, and the reservoir will create benefits of integrated utilization in combination of power generation and shipping.

b) Operating water level: normal water level is 170m (Wusong elevation, the same below), limit flood control level in flood season in summer (June 21 ~ August 20) is 160m and that in autumn (September 1 ~ September 30) is 163.5m, dead pool level is 150m, and extreme drawdown level is 145m.

c) Power supply scheduling: according to the water demand at middle and lower reaches of Han River, as per the incoming water level and reservoir water level of

Danjiangkou reservoir, and in combination with the demand for water transfer of intake area, scheduling will be carried out. Zoning scheduling shall be carried out as per reservoir water level.

d) When the reservoir water level is lower than 150m, water supply for middle and lower reaches of Han River and Qingquangou will be carried out as per 80% of water demand, and the discharged flow of Danjiangku reservoir is less than 490m^3/s; when the incoming water of Danjiangkou reservoir is less than 350m^3/s and the reservoir water level is lower than 150m, the discharged flow shall be controlled at 400m^3/s.

2.8.2 Operation modes of Wangfuzhou and Cuijiaying hyro-junctions

a) Wangfuzhou Hydro-junction

This project is a low-head runoff power station, and is a typical river-channel reservoir. Before being heightened, Danjiangkou Hydropower Station is basically in synchronous scheduling with Danjiagkou dam, and the reservoir is at the design pool level 88.0m all year round, with consistent water incoming and discharge volumes. After Danjiangkou Hydropower Station is heightened, the regulated flow of Danjiangkou Reservoir increases, and Wangfuzhou Hydro-junction carries out reverse regulation.

The typical daily discharged flow process of actual operation of Wangfuzhou Hydropower Project in wet, normal and dry seasons is as shown in Table 2.8.2-1. It is observed that the power station generates electricity as per incoming flow, there is no peaking operation within day, and interruption phenomenon will not occur downstream.

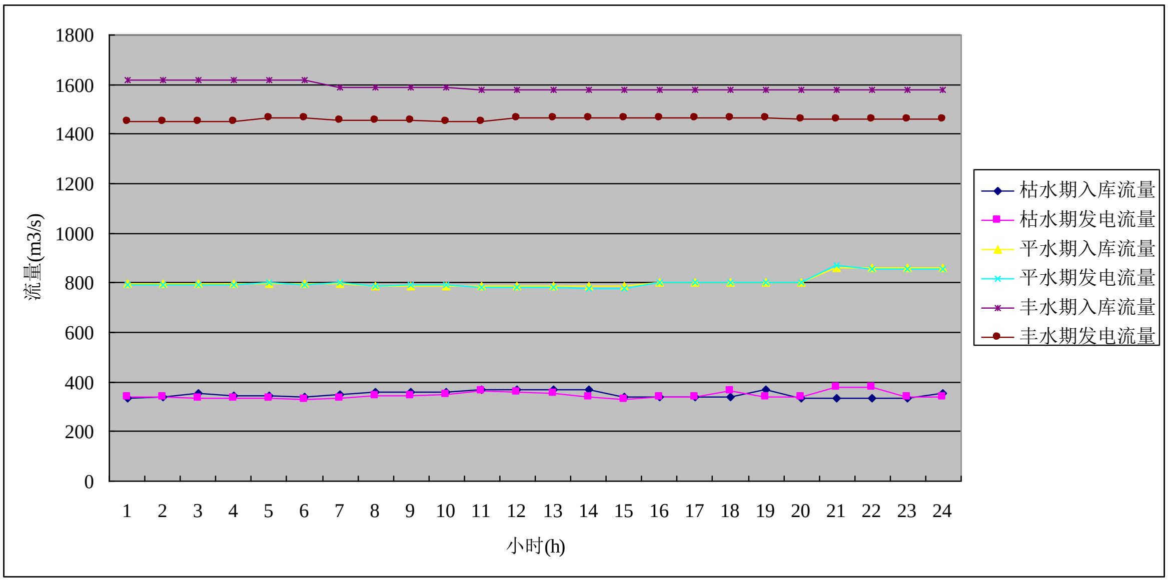


Figure 2.8.2-1 Typical daily flow process of Wangfuzhou Hydro-junction in wet, normal and dry seasons

枯水期入库流量	Inflow in low flow season
枯水期发电流量	Power generation flow in low flow season
平水期入库流量	Inflow in normal season
平水期发电流量	Power generation flow in normal season
丰水期入库流量	Inflow in high flow season
丰水期发电流量	Power generation flow in high flow season
小时	Hour
流量	Flow

b) Cuijiaying Hydro-junction

The normal water level of Cuijiaying reservoir is 62.73m, the dead pool level us 62.33m, the reservoir capacity corresponding to normal water level is 245 million m^3, the dead reservoir capacity is 205 million m^3, the effective reservoir capacity is 400 million m^3, and the working depth is 0.5m. The reservoir has the function of daily regulation. Cuijiaying Hydro-junction is a project combining navigation and hydropower and facilitating navigation with hydropower, focused on shipping and having functions of power generation, irrigation, water supply and tourism. In the premise of guaranteeing the safety of reservoir and dam hydropower station, best efforts shall be made to utilize water power, guarantee navigation and improve power generation benefits. According to the characteristics and tasks of the junction, the main principles of proposed scheduling are described as below:

①When the inflow is less than the minimum navigation flow $470m^3/s$, the regulated reservoir capacity shall be utilized to discharge the shipping base load flow, in order to ensure meeting the requirements of downstream navigation flow.

② When the inflow is greater than $470m^3/s$ and less than the maximum overflowing flow of hydraulic turbine set ($2200m^3/s$), the reservoir water level shall keep at the normal water level 62.73m, power station overflowing will be carried out, and the power station will generate electricity as per natural flow.

③ When the inflow is greater than $2200m^3/s$ and less than the shutdown flow of power generator $10000m^3/s$, sluice will be used to discharge the redundant water of the power station diversion, the hole number of sluice and the gatage shall be controlled, in order to make the discharged flow equal to the redundant water of power station diversion.

④ When the inflow is greater than $10000m^3/s$, the power generators will stop and all of the sluices will be open to discharge flood, in order to recover the natural flood status and reduce to the water level in front of the dam.

⑤ When the flood flow is greater than the maximum navigation flow $15820m^3/s$, the navigation will be closed, in order to guarantee the safety.

⑥ When the flood into reservoir is at the stage of recession and the inflow is less than equals to the shutdown flow, the gates on the dam will be gradually closed, and the principle of closing is to keep the reservoir water level at 62.73m, and the power station will recover power generation.

The typical daily discharged flow process of actual operation of Cuijiaying hydro-junction in wet, normal and dry seasons is as shown in Table 2.8.2-2. It is observed that the power station generates electricity as per incoming flow, there is no peaking operation within day, and interruption phenomenon will not occur downstream.

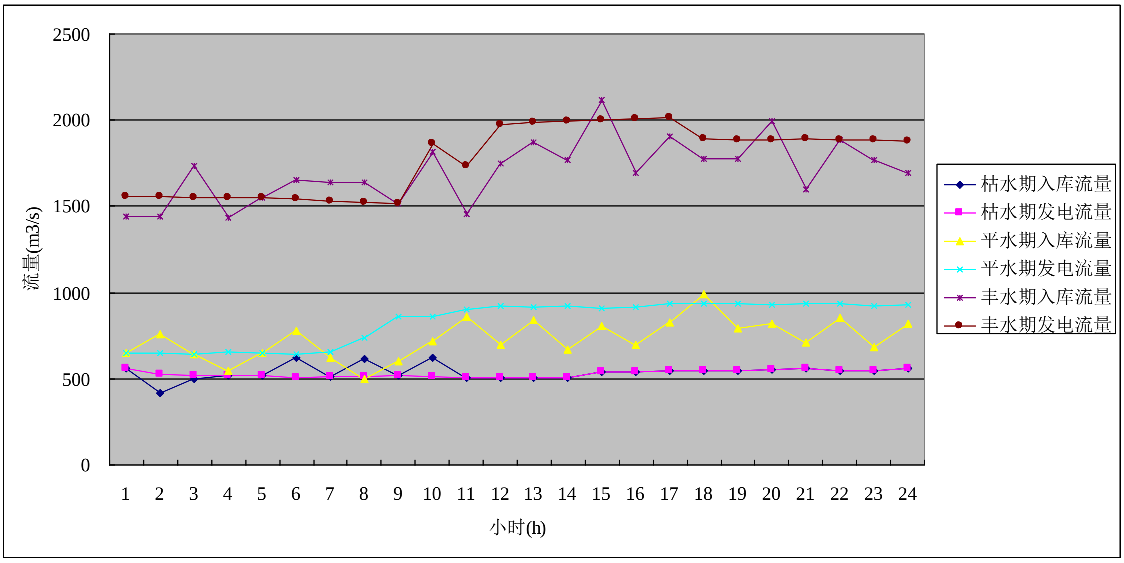


Figure 2.8.2-2 Typical daily flow process of Cuijiaying hydro-junction in wet, normal and dry seasons

枯水期入库流量	Inflow in low flow season
枯水期发电流量	Power generation flow in low flow season
平水期入库流量	Inflow in normal season
平水期发电流量	Power generation flow in normal season
丰水期入库流量	Inflow in high flow season
丰水期发电流量	Power generation flow in high flow season
小时	Hour
流量	Flow

2.8.3 Yakou operation mode

a) Reservoir operation mode

Yakou Shipping Hub is a low-head power station. The normal reservoir capacity is 350.2 million m^3, the dead reservoir capacity is 308.7 million m^3, the regulated reservoir capacity is 41.5 million m^3, and the working depth is 0.5m. The hub has the function of daily regulation, and it is a pivotal project focused on shipping and having integrated utilization benefits of power generation, irrigation and tourism. The hub doesn't undertake the risk of downstream flood control.

(1) When dam site discharge is less than 2,291m^3/s (the maximum flow passing through power generator), the sluice will be closed, the ship lock and the power station will start running. Besides meeting the water demand of the ship lock, all the incoming water

will pass through power generators for power generation. The downstream shipping base flow shall be kept at 450m^3/s during the operation of power station, and the reservoir runs at the water level of 55.22m. In this period, the ship lock is open to normal navigation. When the inflow is less than 450m^3/s, the minimum navigation flow, the regulated reservoir capacity shall be utilized to discharge the shipping base load flow 450m^3/s until it is exhausted, in order to meet the requirements of downstream navigation flow, and then the discharging will be carried out as per incoming flow.

(2) Between May and August every year, according to the requirements of EZH [2015]No. 235 Document *Reply to Joint Ecological Regulation Program (Tentative) for the Hydro-junctions at the Han River in Hubei Province below Danjiangkou,* when the flood discharge of Tangbai River reaches 600m^3/s or the flood discharge in low flow season reaches 300m^3/s, Yakou Hun will be open to discharge flood jointly with Cuijiaying and Xinglong Hydro-junctions, in order to provided the fish with conditions to swim upstream to spawning grounds and maintain the ecological functions of fish spawning grounds in Yicheng.

(3) Between March and May every year, according to the requirements of EZH [2015] No. 235, mature parent fish below the dams of Cuijiaying, Yakou and Xinglong Hydro-junctions may swim upstream through fishway, and there is no need for gate scheduling. When the fishway is not running, gate scheduling shall be carried out, and the gates of all the three junctions shall be open, in order to recover the natural river status at middle and lower reaches of Han River.

(4) When dam site discharge is greater than 2,291m^3/s but less than 5000 m^3/s and the net head of the power station is greater than 2m, ship lock, power station and sluice shall be open and run. Besides meeting the water demand of ship lock, the seven power generators shall start power generation, the reservoir shall run at 55.22m, and redundant water shall be discharged through gates. In this period, the ship lock is open to normal navigation.

(5) When dam site discharge is greater than and equals to 5000 m^3/s but less than 8710

m^3/s, the power station shall start power generation in due time as the circumstances may require, and the ship lock is in normal operation. In order to reduce the time of water re-impoundment, it is feasible to control sluice discharging and properly heighten the water level in front of the dam according to flood forecast, but it is unallowable to exceed the maximum operating water level as shown in Figure 2.2.4-1.

(6) When dam site discharge is greater than or equals to 8710m^3/s but less than 13500m^3/s, the peak flood flow of ten-year return period, the power station stops power generation, the ship lock is in normal operation, and the discharge shall be increased to lower the reservoir water level until recovering the natural status.

(7) When dam site discharge is greater than 13500m^3/s, the maximum navigation flow of the hub, the power station shall stop power generation, the ship lock shall be closed to guarantee the shipping safety, and the sluice shall be fully open to discharge flood.

(8) After the flood recedes, when dam site discharge is less than 13,500 m^3/s, the ship lock recovers navigation; when dam site discharge is less than 8,710 m^3/s, the reservoir begins water impoundment until reaching the normal water level 55.22m.

See Table 2.8.3-1 for characteristic water level of Yakou Shipping Hub Project

Table 2.8.3-1 Characteristic water level of Yakou Shipping Hub Project

Item	Unit	Upstream water level	Downstream water level	Remark
Normal water level	m	55.22		
Dead pool level	m	54.72		
Design flood level	m	54.31	54.14	P=2% Q=20200 m^3/s
Check flood level	m	55.40	55.12	P=0.33% Q=27300 m^3/s
Highest navigation water level	m	55.22	53.21	Normal water level/10-year return period, corresponding flow 13500m^3/s
Lowest navigation water level	m	52.38	45.30(50.32)	Water level corresponding to open discharge flow 8710 m^3/s /prior to construction of reservoir of Nianpanshan Junction (before the reservoir is built)
Maintenance water level	m	55.22	51.30	Normal water level/Nianpanshan Junction (after the reservoir is built) October ~February, 5-year return period

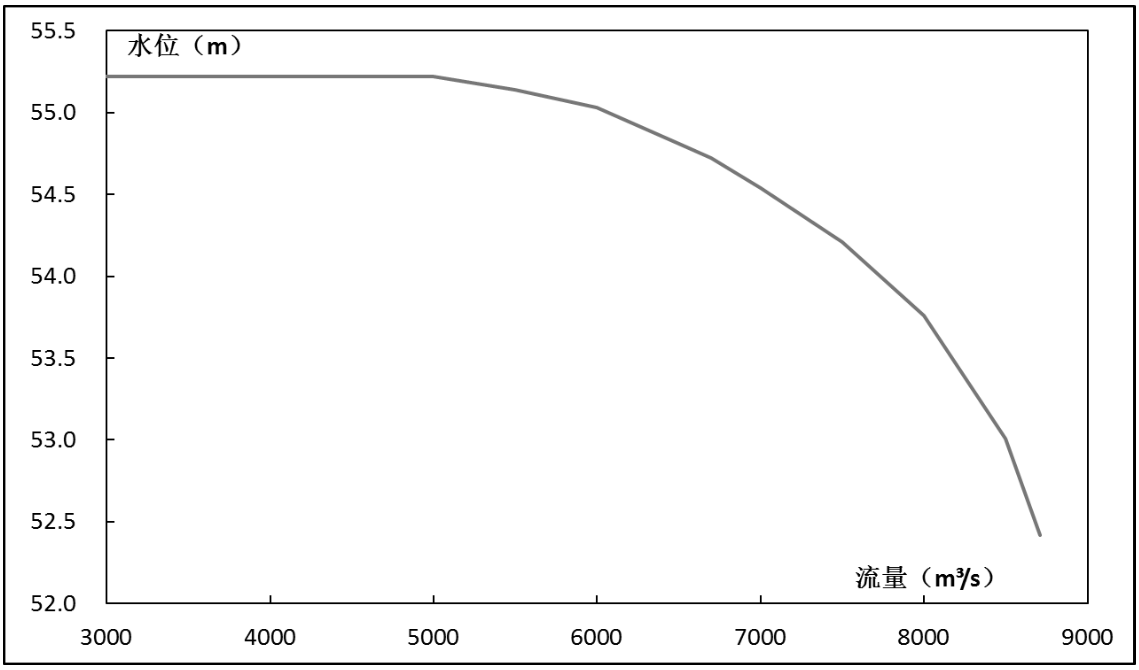


Figure 2.8.3-1 Curve of relation between incoming flow and water level in from of dam

水位	Water level
流量	Flow

b) Operation mode of power station

Because the scheduling principles and operation modes of Yakou Shipping Hub Project are basically consistent with that of Wangfuzhou Reservoir, although it has the function of daily regulation, the power station usually runs at the normal water level due to low head, and will not be involved in peak load operation.

The total installed capacity of the power station of Yakou Shipping Hub is small, only 74.2MW, and the electricity output of the reservoir has quite a small effect on local grid; Yakou Hub mainly bears base load in the system, and the shipping base load flow is 450m^3/s. When the inflow is greater than 5000m^3/s in flood season, the water level will be lowered gradually for operation, and the water level is lower than the dead pool level or the water head for power generation head less than is 2m, the power station stops. According to the results of preliminary design, the typical daily reservoir water level of Yakou Shipping Hub will be kept at the normal water level of 55.22m in dry, normal and wet seasons, and the flow process is shown in Tables 2.8.3-2 ~ 4.

Table 2.8.3-2 Calculation of typical daily regulation of Yakou Shipping Hub in low flow season

Hour(s)	Incoming flow (m^3/s)	Discharging flow (m^3/s)	Reservoir water level (m)	Average downstream water level (m)	Water head for power generation head
1	580.5	543.6	55.22	49.28	5.94
2	550.6	543.6	55.22	49.28	5.94
3	543.4	535.6	55.22	49.27	5.95
4	540.8	537.2	55.22	49.27	5.95
5	539.4	530.9	55.22	49.26	5.96
6	529.8	527.7	55.22	49.26	5.96
7	534.3	530.9	55.22	49.26	5.96
8	536.3	546.8	55.22	49.28	5.94
9	539.4	546.8	55.22	49.28	5.94
10	531.1	559.6	55.22	49.29	5.93
11	529.6	583.6	55.22	49.33	5.89
12	526.2	575.6	55.22	49.32	5.90
13	528.4	566.0	55.22	49.31	5.91
14	529.2	543.6	55.22	49.28	5.94
15	564.9	527.7	55.22	49.26	5.96
16	563.0	543.6	55.22	49.28	5.94
17	568.1	543.6	55.22	49.28	5.94
18	570.0	583.6	55.22	49.33	5.89
19	570.0	543.6	55.22	49.28	5.94
20	578.4	543.6	55.22	49.28	5.94
21	582.0	607.6	55.22	49.36	5.86
22	571.4	607.6	55.22	49.36	5.86
23	572.9	543.6	55.22	49.28	5.94
24	580.5	543.6	55.22	49.28	5.94

Note: the data is from *Preliminary Design Report for Yakou Shipping Hub Project*.

Table 2.8.3-3 Calculation of typical daily regulation of Yakou Shipping Hub in normal season

Hour(s)	Incoming flow (m^3/s)	Discharging flow (m^3/s)	Reservoir water level (m)	Average downstream water level (m)	Water head for power generation head
1	814.3	1032.21	55.22	49.39	5.83
2	813.6	1032.21	55.22	49.39	5.83
3	811.0	1032.21	55.22	49.39	5.83
4	823.5	1032.21	55.22	49.39	5.83
5	816.9	1043.93	55.22	49.40	5.82
6	810.4	1032.21	55.22	49.39	5.83
7	821.4	1041.32	55.22	49.40	5.82
8	927.3	1027.01	55.22	49.37	5.85
9	1084.2	1028.31	55.22	49.37	5.85
10	1080.9	1028.31	55.22	49.37	5.85
11	1133.5	1015.29	55.22	49.37	5.85
12	1160.0	1015.29	55.22	49.37	5.85
13	1154.2	1015.29	55.22	49.37	5.85
14	1159.4	1012.69	55.22	49.37	5.85

Table 2.8.3-3 (Cont.)

Hour(s)	Incoming flow (m^3/s)	Discharging flow (m^3/s)	Reservoir water level (m)	Average downstream water level (m)	Water head for power generation head
15	1142.5	1012.69	55.22	49.37	5.85
16	1154.6	1043.93	55.22	49.42	5.80
17	1179.0	1043.93	55.22	49.42	5.80
18	1177.3	1043.93	55.22	49.42	5.80
19	1177.2	1043.93	55.22	49.42	5.80
20	1172.1	1043.93	55.22	49.42	5.80
21	1175.9	1131.14	55.22	49.47	5.75
22	1178.0	1112.92	55.22	49.45	5.77
23	1159.8	1114.22	55.22	49.45	5.77

Hour(s)	Incoming flow (m^3/s)	Discharging flow (m^3/s)	Reservoir water level (m)	Average downstream water level (m)	Water head for power generation head
24	1165.1	1112.92	55.22	49.45	5.77

Note: the data is from *Preliminary Design Report for Yakou Shipping Hub Project*.

Table 2.8.3-4 Calculation of typical daily regulation of Yakou Shipping Hub in high flow season

Hour(s)	Incoming flow (m^3/s)	Discharging flow (m^3/s)	Reservoir water level (m)	Average downstream water level (m)	Water head for power generation head
1	2500.0	2836.20	55.22	50.29	4.93
2	2500.0	2836.20	55.22	50.29	4.93
3	2487.4	2836.20	55.22	50.29	4.93
4	2487.9	2836.20	55.22	50.29	4.93
5	2490.9	2871.40	55.22	50.31	4.91
6	2483.6	2871.40	55.22	50.31	4.91
7	2460.0	2845.98	55.22	50.29	4.93
8	2451.6	2847.93	55.22	50.30	4.92
9	2437.1	2851.84	55.22	50.29	4.93
10	2993.1	2836.20	55.22	50.29	4.93
11	2786.6	2836.20	55.22	50.30	4.92
12	3178.0	2871.40	55.22	50.29	4.93
13	3190.1	2871.40	55.22	50.29	4.93
14	3204.0	2871.40	55.22	50.29	4.93
15	3219.9	2871.40	55.22	50.29	4.93
16	3229.3	2871.40	55.22	50.29	4.93
17	3243.1	2871.40	55.22	50.29	4.93
18	3037.8	2871.40	55.22	50.29	4.93
19	3032.0	2871.40	55.22	50.29	4.93
20	3027.2	2855.76	55.22	50.29	4.93

Hour(s)	Incoming flow (m^3/s)	Discharging flow (m^3/s)	Reservoir water level (m)	Average downstream water level (m)	Water head for power generation head
21	3037.7	2855.76	55.22	50.29	4.93
22	3030.7	2855.76	55.22	50.29	4.93
23	3027.1	2855.76	55.22	50.30	4.92
24	3021.0	2855.76	55.22	50.29	4.93

Note: the data is from *Preliminary Design Report for Yakou Shipping Hub Project.*

c) Ecological regulation

According to the analysis on the flood peak process of the spawning processes of four major Chinese carps monitored by the Institute of Hydroecology over the years, the breeding scale of four major Chinese carps at middle and lower reaches of Han River can be facilitated by water discharging of Danjiangkou reservoir, but it is mainly depends on Tangbei River flood. When Tangbai River floods to a certain peak flow, the early resources of four major Chinese carps are monitored. Therefore, the ecological regulation is based on the flood of Tangbai River and combined with interval water incoming. Between May and August every year, joint ecological regulation for the hydro-junction at the main stream of Han River below Danjiangkou shall be carried out twice at least according to the flood process of Tangbai River. The details are as below: when the flood flow of Tangbai River reaches 600m^3/s from middle and late May to August in high flow and normal flow years, or when the flood flow reaches 300m^3/s in dry season, Danjiangkou will discharge ecological flow at 400m^3/s, in order to guarantee that the flow at Huangzhuang Hydrologic Station reaches 1200m^3/s (meeting the requirements for joint ecological regulation flow of hydro-junction proposed in retrospective evaluation). At this time, Wangfuzhou Junction will not impound water but discharge water as per the inflow. The gates of Cuijiaying, Yakou and Xinglong Hydro-junctions will be open ahead of schedule to discharge flood, in order to provide the fish with conditions for swimming upstream to spawning grounds. The open discharging will last 5~7 days until the flood peak finishes, so that the roes may drift downstream below the dam.

2.9 List of items not included in project

2.9.1 Items excluded from projet scope

a) Reservoir levee

The reservoir levee of Han River Yakou Shipping Hub Project mainly includes levee of urban area of Yicheng City, Hedong levee of Yicheng City and revetments of Xiaoheying Village and Huijiazhou Village. For the levees to be affected by reservoir inundation and requiring reinforcement, the engineering measures include:

Heightening and thickening: in view of substandard crown height and pavement width of 8m-long levees in Xiaoheying Village and Huijiazhou Village protection zones as well as steep and thin side slopes, heightening and thickening treatment is proposed.

Levee anti-seepage treatment: in order to reduce the impact of reservoir inundation, it is planned to carry out anti-seepage treatment for 54.41km-long levee aong the river and adopt seepage-control concrete wall with water jetting.

Protection slope reinforcement: for 39km-long levee of Han River, there is no artificial concrete slope protection on the slope surface. In the period of water impoundment, the levee is used to retain water, and the levee foundation is under water throughout the year and is immersed and softened, and the slope surface is impacted by wave washing, erosion and abrasion, which will endanger the safety of the levee and provides low stability of reservoir bank. It is planned to adopt concrete precast blocks for slope protection on the near-water side of the levees on both banks.

b) Waterway regulation project

In order to basically eliminate the adverse impact of water transfer on the waterways at middle and lower reaches of Han River, it is planned to implement local waterway regulation project at middle and lower reaches of Han River during the 1st stage works in the middle route of South-to-North Water Transfer, so as to maintain the original 500t navigation waterway grade, and the regulation range is the river section 574km long from Danjiangkou to Hanchuan. As per the navigation grade and adopted standard ship types and fleet dimension as well as the existing waterway grade at middle and lower reaches of Han River, it is determined to design the local waterway regulation project at middle and lower reaches of Han River as per IV(2) waterway standard, and navigable fleet is one-pushing, four-barge, double-row and double-line 500t fleet, and the navigation guarantee rate is 97%. At present, the local waterway regulation project at middle and lower reaches of Han River is under construction, and is planned to be completed by the end of 2014.

The shipping function of Yakou Shipping Hub is to link Cuijiaying Hydro-junction and Nianpanshan Navigation and Hydropower Junction, canalize 52.67km-long waterway between Yakou and Cuijiaying, raise the existing Grade-IV waterway to Grade-III, and create necessary conditions for realizing the high-grade waterway planning target of Han River in 2020. After Yakou Shipping Hub is built and begins water impoundment, a 52.67km-long all-year-round reservoir will be formed, improving the waterway conditions of Fenghuang beach, Longmen beach, Shuifo Temple, Baijiazhou, Niulukou and Quejiatao. The water depth, width and bending radius of the waterway can meet the navigation dimension requirements of III (2) waterway.

c) Special rehabilitation (reconstruction) works of reservoir area

The special items of Yakou Shipping Hub Projects include 2.2km-long farm machinery accesses, one port, two wharfs, two ferries, 2.5km-long optical cables, 3km-long power cables, three pump stations and nine drainage culvert sluices. Monetary compensation will be adopted for farm machinery accesses, optical cables and power cables. Nearby reconstruction or rehabilitation will be carried out for ports and wharfs. In order to reduce the impact of reservoir water logging and immersion, two culvert sluices will be reconstructed, seven culvert sluices blocked, 31km-long flood diversion channel newly built, eight new pump stations built in the reservoir area protection zone, and about 48m-long anti-immersion channel newly built.

According to the provisions of *Agreement for Lump-sum Expenses of Reservoir Inundation Treatment and Permanent Land Occupation for Han River Yakou Shipping Hub Project*, the agreement is a “package” lump-sum agreement and adopts total lump-sum expenses, and the Preparation Team of Han River Yakou Shipping Hub Project of Hubei Province will pay to the People’s Government of Yicheng City a certain expense for a series of related work including necessary land acquisition and relocation and special item reconstruction (except for levee). Therefore, the report doesn’t include the special rehabilitation (reconstruction) works of the reservoir area in the project compositions.

d) Sand and gravel exploitation

According to the main body design, the sand and gravel materials of this project are outsourced from Tangbai River mouth sand stock ground and rubbles are outsourced from nearby quarries. In consideration of the demand for sand and gravel materials and the quarry reserves, Matoushan quarry is mainly used as concrete aggregate stock ground, and Jinniu Mountain and Dong Mountain quarries are used as rubble stock grounds. At present, all of the abovementioned quarries are in the process of exploitation. According to the division of responsibility subjects, environmental pollution treatment and ecological restoration of the stock grounds are undertaken by materials suppliers.

2.9.2 Environmental protection requirements

According to the principle of “whoever causes pollution is responsible of its treatment” and the division of responsibility subjects, in the implementation process of the abovementioned works which are not included in the project compositions, environmental protection shall be carried out:

a) Reservoir levee

The proposed levee works in the reservoir area shall strictly conform to the three-simultaneous system of environmental protection for construction projects, and each environmental protection measure shall be put into practice, and daily management and monitoring of environmental protection shall be intensified in the period of operation.

b) Waterway regulation works

Waterway regulation works mainly include slope protection, beach protection, damming and dredging. For the shoals to be regulated near water intake, it is required to increase underwater antifouling curtains, avoid construction during water intaking and take other measures to reduce the impact on water quality of Han River and water intaking. Usually, profundal zones near the regulated shoals are selected mud (slag) disposal, and barges are used to transport stones and manual riprapping is adopted. Suitable mud disposal zone shall be determined. It is forbidden to build mud disposal zone within water resource protection zone.

c) Special rehabilitation (reconstruction) works in reservoir area

In the reconstruction process of special facilities, attention shall be paid to environmental protection. The location of port and wharf reconstruction shall avoid local water intake, and highway reconstruction works shall occupy cultivated land as little as possible or not occupy cultivated land. Highway location and routing shall avoid the area vulnerable in water and soil erosion and the densely populated area as well as sensitive receptors. If underground cultural relic is discovered during construction, construction shall be stopped immediately and related department shall be informed, and corresponding protection measures shall be taken.

d) Sand and gravel mining

Tangbai River mouth sand stock ground now adopted underwater mining. It is required to avoid fish breading season, avid construction during water intaking and take other measures to reduce the impact on water quality of Han River and water intaking. Civilized construction and environmental protection shall be carried out, and construction site and living area shall be cleaned up. No hazardous substance may be close to water source or contaminate environment. Domestic garbage shall be disposed to avoid pollution. After the construction is completed, the materials shall be removed, the site shall be cleaned up and the road shall be clear and smooth.

3 Project analysis

3.1 Project consistency with laws and policies

3.1.1 Consistency with national policies

3.1.1.1 Consistency with national industrial policies

According to the Decision of the State Council on Promulgating the *Interim Provisions on Promoting Industrial Structure Adjustment* (2011) (revised in 2013) for Implementation, in Article 5 “Strengthening the construction of infrastructures such as energy, traffic, water conservancy and information network, etc., and enhancing their capacities of guaranteeing economic and social development”, it is stipulated that “We shall adhere to the principles of giving priority to conservation, and relying on domestic resources, focusing on developing coal resources, and developing diverse energy resources, and put in place a system that supplies stable, economical and clean energy. We shall optimize and develop coal electricity by stressing large-type high-efficiency sets, orderly developing hydro-electric power on the basis of ecological protection, actively develop nuclear power, strengthen electric power network construction, and optimize the structure of electric power network. We shall, by stressing network enlargement, form a convenient, expedite, high-efficiency, safe comprehensive traffic and transport system. We shall, by adhering to the overall planning and reasonable layout, realize mutual complement of advantages of the modes of transport by railway, by highway, by water, by civil aviation, and by pipeline, etc., and give play to the composite efficiency and overall advantages through mutual connection. We shall strengthen water conservancy construction, and optimize water resource allocation”. It is observed that Yakou Shipping Hub Project is an encouraged traffic and water conservancy project specified in *Industrial Structure Adjustment Guidance Directory (2011 Version)* (revised in 2013) issued by National Development and Reform Commission, and the construction of Han River Yakou Shipping Hub Project conform to national industry policy.

3.1.1.2 Consistency with national inland waterway and port layout planning

Inland water transportation is an important component of national integrated transportation system and integrated utilization of water resources, and it is featured by large transportation capacity, small land occupation, low energy consumption, small pollution and high safety and reliability. It is an important strategic resource for China to realize economic and social sustainable development. In the *Planning for Inland Waterways and Ports Layout in China* (issued by the Ministry of Communication on June 26, 2007), Han River is listed as a high-grade inland waterway, and the construction of this project will improve the waterway grade of the river section of Han River in an all-round way and upgrade the waterway water depth to Grade III from Grade V or VI, which is conforming to the layout specified in *Inland Waterways and Ports Layout in China* and meets the overall requirements of *Inland Waterways and Ports Layout in China* for accelerating the development of inland water transportation to conform to the scientific outlook on development and building a resource-saving and environment-friendly society.

3.1.1.3 Consistency with comprehensive planning of Yangtze River basin

According to the *Comprehensive Planning of Yangtze River Basin (2011 ~ 2030)* worked out by MWR Changjiang Water Resources Committee in 2012, the main tasks of regulation, development and protection of Han River include: flood control and waterlog prevention, water supply and irrigation, inter-basin water transfer, water resources and aquatic ecological environment protection, water and soil conservation, power generation, shipping, water conservancy schistosomiasis control, etc. In the planning, the planning of waterway development proposes that: after the whole line of Han River is canalized, 374km-long channel from Ankang to Danjiangkou is of IV waterway grade, and 649km-long channel from Danjiangkou to Hankou is of III waterway grade, and on a long view the downstream waterway will be gradually developed into high-grade waterway throughwaterway regulation project. It is proposed that: there are 15 levels at the main stream of Han River for hydropower development, and the construction of seven hydro-junctions at Huangjinxia, Xunyang, Baihe, Gushan, Xinji, Yakou and Nianpanshan will be continued. It is observed that the construction of Yakou Shipping Hub is consistent with the *Comprehensive Planning of Yangtze River Basin (2011 ~ 2030).*

In the implementation process of basin planning, certain mitigation measures shall be taken to mitigate the adverse impacts on ecological environment. According to the *Comprehensive Planning of Yangtze River Basin (2011 ~ 2030)*, it is required to: strengthen aquatic organism protection; implement aquatic ecological environmental protection and biological resources conservation, habitat protection and restoration to protect aquatic organism species, habitats and ecological system; build aquatic organism protection zone, protect the valuable and rare fish resources in Yangtze River basin, comprehensively consider the biological characteristics of valuable ad rare fish and the current situation of fish resources in Yangtze River, and unify the planning and construction of artificial fish enhancement and releasing stations; adopt suitable fish passes in the process of hydraulic project development at the main stream and important tributary where migratory fishes exist, and guarantee the connectivity of aquatic organism habitats; enhance fishery resources management, takes such measures as closing fishing in Yangtze River, adopting fish enhancement and releasing, sowing shellfishes on the bottom, planting aquatic vegetation, building artificial fish nests and intensify the management of aquatic germplasm resources protection zone, and strengthen the protection of fish resources breeding. In the development process of Yakou Shipping Hub, corresponding protection measures are taken, such as mainstream and tributary habitat protection, building fish passes and artificial enhancement and releasing station and carrying out ecological regulation and fishery management. It is consistent with the *Comprehensive Planning of Yangtze River Basin (2011 ~ 2030.*

3.1.1.4 Consistency with shipping planning of Yangtze River system

According to the *Shipping Planning Report for Yangtze River System* worked out by Yangtze River Shipping Planning Research Center and the Planning Office of Yangtze River Shipping Affairs Administration, the waterway planning mainly is to take thirteen high-grade key waterways as the framework, i.e., the main stream of Yangtze River, Jialing River, Han River, Yuan River, Han River, Sha-Sha (Shayang – Shashi) Canal, Gan River, Xin River, Jianghuai Canal, Jinghang Beijing-Hangzhou Canal, Changhushen Canal, Suzhou-Shanghai Outer Port Line and Hangyong (Hangzhou – Ningbo) Canal, take the main navigation rivers in the water system as the support, and take cross-water-system works as the bridge to build a modern waterway network in Yangtze River system.

The contents related to the shipping development planning in the Planning are basically consistent with the *Comprehensive Planning Report for the Main Stream of Han River* prepared by CWRC in June 2010, and the recommended hydro-junction development program at the main stream of Han River below Jia River is a eight-level program i.e. Gushan – Danjiangkou – Wangfuzhou – Xinji – Cuijiaying – Yakou – Nianpanshan – Xinglong.

Han River is a high-grade national waterway, and water resources and communications departments have determined the development and regulation guidelines in successive planning of Han River for upgrading the navigation grade, improving waterway conditions and implementing hydro-junction canalization. The waterway planning standard of Han River is as follows: Yangxian ~ Ankang is Grade-V waterway, Ankang ~ Danjiangkou is Grade-IV waterway, and Danjiangkou ~ Hankou is Grade-III waterway. The abovementioned construction standard has been listed in *Brief Report for Integrated Utilization Planning of Water Resources of Yangtze River Basin* and *Planning for Inland Waterways and Ports Layout in China approved by the State Council in 2007.*

Therefore, Yakou Shipping Hub is the sixth level of the hydropower development of Han River within the territory of Hubei Province, and is an essential link in the comprehensive development of Han River, and its construction is consistent with the integrated utilization planning of Yangtze River basin and the shipping planning of Han River and is an important component to realize the waterway planning target of Han River. The implementation of this project is conforming to the *Shipping Planning of Yangtze River System*.

3.1.2 Analysis of the coordination between project program and related planning

3.1.2.1 Consistency with related basin development plans

In combination with the study results of previous hydro-junction development programs, in the *Planning Report for the Integrated Utilization of the River Section of Han River above Jia River* worked out by CWRC in 1993, it is defined that the development tasks of this river section include flood control at middle and lower reaches of Han River, Irrigation, urban and rural water supply and water diversion in the middle route of South-to-North Water Transfer Project, power generation, shipping, waterlog control and snail control, water and soil conservation, river regime control and water source protection, and a nine-level development program of Gushan (181m, Wusong elevation) – Danjiangkou (170m) – Wangfuzhou (88m) – Xinji (78m) - Cuijiaying (64m) – Yakou (57m) – Nianpanshan (51m) – Huajiawan (42m) – Xinglong (36m) is recommend through comprehensive comparison.

In 2004, Hubei Provincial Water Resources and Hydropower Planning Survey and Design Institute worked out *Planning Outline for Water Conservancy Modernization at Middle and Lower Reaches of Han River Basin in Hubei Province*, and proposed the development tasks of the main stream at middle and lower reaches of Han River as flood control, water supply, water and resources and aquatic ecological environmental protection, power generation, shipping and water and soil conservation. According to the Planning Outline, six-level hydro-junctions including Wangfuzhou – Xinji – Cuijiaying – Yakou – Nianpanshan – Xinglong will be built below Danjiangkou reservoir at the main stream of Han River by 2020. In February 2005, the Ministry of Water Resources and the People's Government of Hubei Province gave an official reply to the Planning Outline in SGJ [2005]No. 85 Document.

In August 2009, according to the economic development situation of Han River basin and the new requirements for river development, CWRC worked out *Comprehensive Planning Report for the Main Stream of Han River*. In accordance with the natural characteristics of Han River basin, actual social and economic situation, the demand of national economic development of each department and the relationship between economic development of nearby basin and the development of Han River basin, and on basis of comprehensive study and analysis, in the report the water conservancy tasks of Han River basin are defined as below: first, reducing and eliminating the flood threat at middle and lower reaches of Han River and in Pingchuan Section at the upper reaches; meeting the water demand of living, production and ecology in the basin; on this premise, utilizing the characteristics of natural geographical location and water quality advantages, and implementing inter-basin water transfer; strengthening water resources and ecological environmental protection in water source areas; cultivating water sources, preventing water and soil erosion, and intensifying water and soil conservation; fully utilizing water resources and energetically developing hydropower; improving shipping conditions; regulating river channels, stabilizing river regime and strengthening waterfront utilization management; and developing tourism; in short words, the development tasks include flood control, water supply, water resources and aquatic ecological environmental protection, water and soil conservation, power generation, shipping, river channel regulation and waterfront utilization. It is recommended that the eight-level hydro-junction development program from Jiahe to Hekou including Gushan (177.23m) –Danjiangkou (168.23m)- Wangfuzhou (86.23m)- Xinji (76.23m)- Cuijiaying (62.73m)- Yakou (55.22m)- Nianpanshan (49.23m)- Xinglong (36.2m) shall be the typical program for the regulation and development of this river section.

In October 2012, the People’s Government of Hubei Province printed the *Overall Planning for the Comprehensive Development of Han River Basin of Hubei Province* (2011-2020) in EZF [2012]No. 83Document, and raised the requirement of actively implementing hydro-junction development of the main stream, realizing the integrated utilization of water resources at the main stream and vigorously promoting the continued construction of Fushan Junction and three proposed hydro-junction projects at Xinji, Yakou and Nianpanshan. It is observed that the construction of Yakou Shipping Hub is consistent with all previous related planning programs for the basin development.

3.1.2.2 Consistency with the high-grade waterway construction plan for Han River and Jianghan Canal

The 12th five-year Plan period (2011- 2015) is an important period of strategic opportunities for facilitating the rapid development, harmonious development, safety development and green development of inland shipping and promoting the comprehensive construction of high-grade waterways. This is a breakthrough period for realizing the planning objectives of Han River and Jianghan Canal and is also a good opportunity for Hubei Province and Shaanxi Province to "vigorously develop water transportation and develop large-scale water transportation". Therefore, according to the requirements of *Notice of the General Office of National Development and Reform Commission on Related Work of High-grade Inland Waterway Construction Planning in the Twelfth Five-year Plan* (FGBJ [2010] No. 582), the *Construction Program for High-grade Waterways of Han River and Jianghan River Canals (2011-2015)* was prepared, led by the Development and Reform Commission of Hubei Province and with participation of the Development and Reform Commission of Shaanxi Province. In The 12th five-year Plan period, it is planned to implement 17 waterway construction projects of Han River, including 3 continued construction projects of the Eleventh Five-year Plan (2006 -2010) and 14 new construction projects of the Twelfth Five-year Plan, including Han River Ankang ~ Baihe Section Waterway Regulation Project, Ship Lift Upgrading and Transformation Project of Han River Xunyang Hydro-junction, Ship Lift Upgrading and Transformation Project of Han River Shuhe Hydro-junction, Ship Lift Upgrading and Transformation Project of Han River Baihe Hydro-junction, Ship Lock Project of Han River Gushan Junction, Ship Lock Project of Han River Xinji Junction, Ship Lock Project of Han River Yakou Junction and Ship Lock Project of Han River Nianpanshan Junction. It is observed that the construction of Yakou Shipping Junction is consistent with the high-grade waterway construction planning of Han River and Jianhan Canal.

3.1.2.3 Consistency with the shipping development planning of Hubei Province

In the *Strategic Planning of Highway and Waterway Transportation Development of Hubei Province (2002 ~ 2020)*, it is proposed to: comprehensively perfect the highway and waterway transportation infrastructure networks, comprehensively improve waterway conditions, build Xinji, Yakou, Nianpanshan, Huajiawan and Gushan integrated junctions at Han River, expand the navigation facilities of Wangfuzhou Junction and make the main water transportation channels meet the planning standard."

In the *Strategic Planning of Highway and Waterway Transportation Development of Hubei Province (2002 ~ 2020)*, it is pointed out that: "the main water transportation channels are important components of large national comprehensive transportation channel and the backbone of national waterway system and Yangtze River, Han River and Sha-Sha Canal have been brought into the main channel layout planning for national inland water transportation"; "the construction of two main river channels, i.e. Han River and Sha-Sha Canal was arranged before 2010; from 2010 to 2020, hydro-junction canzlization will be gradually implemented at Han River …"; and 1. Xinji, Yakou, Nianpanshan, Huajiawan and Gushan hydro-junction; 2. Wangfuzhou ship passing facilities expansion works; and 3. Regulations works of backwater terminal and unconnected section of each junction have been brought into the comment table for engineering measures and stage implementation of waterways in Hubei Province between 2010 and 2020.

In summary, the construction of Yakou Shipping Hub is completely consistent with the requirements of the inland shipping development planning of Hubei Province.

3.1.2.4 Consistency with the port layout planning of Hubei Province

In the Port Layout Planning of Hubei Province, the planning objective is to "build a modernized port system with reasonable structure, distinct gradation, perfect functions, smooth information, high and safe quality, high convenience and efficiency and good environmental protection." In the planning, the ports are divided into three types, i.e., primary port, important port and ordinary port. The port layout planning program of Hubei Province is intended to form a reasonable, well-structured, clearly-functioned port system conforming to the regional economic development level, with Wuhan Port, Yichang Port, Huangshi Port and Jingzhou Port as the core, with eleven ports along the main stream of Yangtze River including Badong Port and Zigui Port and eight local important ports including Xiangfan Port and Zhongxiang Port as the foundation, and with other ordinary ports as the supplement. Ordinary ports include 28 ports such as Gucheng, Yicheng, Xingshan, etc. , which are important components of the inland port system of Hubei Province.

After the proposed Yakou Shipping Hube is completed, 52.67km-long 100t waterways will be canalized, and the conditions for port construction are quite good; national highways, railways and in-construtcion expressways pass through the territory of Yicheng City, and the traffic infrastructures are complete. Relying on Yicheng Port, the waterway will mainly undertake the risks of energy, building materials and foreign trade materials transportation of Yicheng City and other surrounding cities and counties, and will play an important role in regional economic development and the construction of Yicheng City. Therefore, the construction of this project is conductive to the implementation of the *Port Layout Planning of Hubei Province* and is consistent with the planning.

3.1.2.5 Consistency with national economic and social development of Hubei Province

a) Consistency with the objective of social and economic development

In the *Planning Outline of the Twelfth Five-year Plan of National Economic and Social Development of Hubei Province*, the main objective of economic and social development of Hubei Province is demonstrated from seven aspects, i.e. social development, industrial structure upgrading, urban and rural regional development, construction of two-oriented society, security and livelihood improvement, system innovation and promotion to the rise of Central China. In the Planning Outline, for accelerating the construction of two-oriented society, it is clearly proposed to vigorously develop cyclic economy and low-carbon industry, strengthen environmental protection and promote ecological restoration. Compared to the indicators at the end of the Eleventh Five-year Plan, the energy consumption per unit of gross domestic product (GDP) in Hubei Province is reduced by 16%, the total emission of key pollutants is significantly reduced by 16%, the carbon emission per unit of GDP is reduced, and the water quality of key water areas is further improved.

The water transportation of Han River is an important component of the comprehensive transportation system of Hubei Province, and has been important support of the sustainable rapid economic development along Han River. The freight volume of Han River within the territory of Hubei Province every year reaches 1700 tons, 1.34 times of Handan Railway. The water transportation of Han River plays an important role in facilitating the development and utilization of mineral resources along the river, reasonably planning and developing the industrial zones along the river and promoting the water resource development of Han River and the container transportation of Hubei Province. The implementation of this project is targeted at facilitating the reasonable utilization of water resources and Han River, promoting the transformation of energy consumption structure of Hubei Province and guaranteeing the water supply of the cities along Han River. Therefore, the project is consistently with the objective of social and economic development of Hubei Province.

b) Consistency with transportation development planning

In the *Planning Outline of the Twelfth Five-year Plan of National Economic and Social Development of Hubei Province,* Chapter 6, A New Round of Opening and Development of Yangtze River Economic Zone of Hubei Provice, clearly brings out the tasks of facilitating the comprehensive development of Han River basin in Hubei Province, namely, accelerating the construction of moderan water conservancy projects and shipping, focusing on the construction of comprehensive development projects of water resources; accelerating the implementation of four regulation project at middle and lower reaches of Han River, i.e., Xinglong Hydro-junction of South-to-North Water Transfer Project, project of diverting Yangtze River to Han River, transformation of some sluice gate stations and regulation of some waterways; building a modern shipping system, facilitating the construction of Han River shipping hub, form a 810km-long high-grade waterway circle of Yangtz River – Jianghan Canal and Han River encircling Jianghan Plain, and build a well-functioned, processional and high-efficiency port system of Han River. In Chapter 21, Comprehensive Transportation, it is clearly proposed to build a convenient, rapid, smooth, high-efficiency and safe comprehensive transportation system and make all efforts, build a shipping hub at the middle reach of Yangtze River in Wuhan City, intensify the high-grade waterway regulation of Yangtze River and Han River, improve water traffic capacity, and focus on smoothening the middle reach of Yangtze River, canalizing the regulation of Han River and getting through Jianghan Canal

Yakou Shipping Hub will play an active role in upgrading the waterway level of Han River, strengthening waterway regulation, expanding river and ocean combined transportation and building professional transportation of Han River, it is consistent with the transportation development planning of Hubei Province.

c) Consistency with energy development planning

In the *Planning Outline of the Twelfth Five-year Plan of National Economic and Social Development of Hubei Province*, Chapter 24, Energy Industry, proposes the tasks of insisting on energy saving priority, optimizing energy structure, vigorously developing nuclear power, optimizing thermal power development, developing hydropower in an orderly way, accelerating the development of new energy, reasonably consuming coal, actively importing energy from other provinces, enhancing the capacity of energy reserves, and building a safe, economical, and clean modern energy industry system. In Chapther 24, it is further proposed to integrate the utilization of hydroelectric resources and focus on the hydro-junction development of Han River as well as the construction of hydropower projects such as Pankou, Jiangping River, Linxi River, Longbeiwan, Yaojiaping, Gushan, etc.

Han River has abundant water resources, and the construction of this project will promote the utilization of water resources of Han River and reduce the energy consumption per ten thousand yuan GDP of Hubei Province, which is consistent with the energy industry planning in the Planning Outline.

d) Consistency with resources and environmental development planning

In the *Planning Outline of the Twelfth Five-year Plan of National Economic and Social Development of Hubei Province*, Chapter 32, Resources Saving, proposes the tasks of insisting on resources saving priority, intensively and economically utilize land resources, comprehensively implementing total quantity control of resources utilization, supply-demand two-ways regulation and differentiated management, and enhancing the saving consciousness of the whole society. In Chapter 36, Environmental Protection, it is proposed to focus on solving the prominent environment problems that will harm human health and impact sustainable development, strictly carrying out pollutant emission and total quantity control, intensifying comprehensive treatment and obviously improving environmental quality.

The construction of Yakou Shipping Hub will take full advantage of water resources of Han River, realize the utilization of clean energy, reduce thermal power projects to a certain extent, change the modes of traditional coal energy consumption, decrease SO2 emission, and mitigate environmental problems of acid rain pollution caused by economic and social development. Therefore, the project is consistent with the resources and environmental development planning of Hubei Province.

3.1.2.6 Consistency with the overall opening and development planning for Han River Ecological Economic Belt of Hubei Province

The *Overall Opening and Development Planning for Han River Ecological Economic Belt of Hubei Province (2014~2025)* (EZF (2015) 26 Document) is a strategic measure for accelerating the opening and development of Han River ecological economic belt of Hubei Province and improving the overall development pattern of "two circles and two belts, it is of great significance in promoting the rise of Central China, speeding up realizing the grand objective of building a pivot and going ahead, and cultivating the new economic growth of Hubei Province. The planning is intended to implement the strictest comprehensive management of water resources, strengthen the comprehensive defense capability for flood and drought, ability of reasonable allocation and high-efficiency utilization of water resources, ability of aquatic ecological environmental protection and restoration and ability of scientific river regulation and lawful water control, and build a modernized demonstration belt of basin water conservancy in China. By 2015, Han River ecological economic belt of Hubei Province will be built into "Green Han River", "Rich Han River", "Calm Han River", "Smooth Han River" and "Happy Han River". In the planning, it is proposed to accelerate the construction of hydro-junction projects of Han River, complete the construction of hydro-junctions of Nianpanshan, Yakou, Xinji, Gushan and Jiahe at middle and lower reaches of Han River, guarantee the water supply demand for ecology, irrigation, power generation, shipping and production and living along Han River, realize the reasonable utilization of water resources and give full play to its comprehensive benefits. Obviously, the project is consistent with the overall opening and development planning for Han River Ecological Economic Belt of Hubei Province

3.1.3 Coordination between project program and related eco-environmental protection planning

3.1.3.1 Consistency with national ecological function zoning

In 2008, the Ministry of Environmental Protection issued National Ecological Function Zoning, aiming at coordinating the relationship between human being and nature, coordinating the relationship between ecological protection and economic and social development and facilitating the sustainable economic and social development. There are 31 first-grade ecological function zones in three categories, 67 second-grade function zones in nine categories (including the function of ecological regulation such as water conservation, soil conservation, wind prevention and sax fixation, biodiversity protection and flood water storage, the function of providing agricultural products and forest products, and the habitation security function in metropolis cluster and key town cluster), and 216 third-grade function zones.

According to ecological function zoning, the assessment area belongs to ecological regulation zone - water conservation zone – third-grade water-conservation function zone with evergreen broad-leaf forest and hilly downland in central Hubei Province. The area is located in north subtropical area, and the vegetation mainly includes evergreen broad-leaf and deciduous broad-leaf mixed forest. The main landform in the assessment area is downland, with low and flat terrain and small surface relief. Soil types mainly include yellow dead clay, yellow brown soil and damp sandy soil along Han River, and soil fertility is high. Cultivated land is extensively distributed, with good conditions for agricultural development. The primary ecological service function of the area is agricultural ecology. However, this area is located in the driest district in Hubei Province, with frequent drought and severe water and soil erosion. The main existing ecological problems include severe vegetation deterioration, low soil conservation capacity of forest ecosystem and severe soil erosion. The key point of ecological protection and construction is continuing to intensifying water conservancy construction, increasing waterlog drainage capacity, increasing and applying organic fertilizers, avoiding soil hardening and salt return, and increasing land productivity; vigorously developing industrial crops and improving the management level and economic benefits of crop farming; building modern ecological agricultural demonstration zone and the ecological demonstration zone orienting the development of high-tech agriculture, high-quality safe agricultural products and competitive industries.

According to verification, the project is not among 216 function zones specified in *National Ecological Function Zoning*, and the project construction is not in conflict with national ecological safety and is consistent with the requirements of national ecological function zone.

3.1.3.2 Consistency with ecological function zoning of Hubei Province

The guideline of the ecological function zoning in Hubei Province is: building scientific zoning indicators and methods with the goal of implementing sustainable development strategy and guaranteeing the sustainable social and economic development, according to the current situation and characteristics of natural ecological environment of Hubei Province and centered on main ecological environmental problems, defining the service functions and the importance of each ecological system, determining the ecological function zones in Hubei Province, and providing a scientific foundation for improving the regional ecological environment quality and maintaining regional ecological environment safety of Hubei Province, restraining ecological environmental degradation and promoting the virtuous cycle of natural ecological system and the health social and economic development.

According to the *Study on Ecological Function Zoning of Hubei Province*, the assessment area belongs to agricultural and forestry ecological zone on hilly downland in central and north Hubei Province - agricultural and forestry ecological subzone on hilly downland in central Hubei Province- ecological function zone of biodiversity and landscape protection in Dahong Mountain. The primary service functions include biodiversity protection and landscape protection. Ecological environmental sensitivity is high sensitivity to soil erosion, high drought sensitivity and medium sensitivity of water environment. Main ecological problems include biodiversity threat and landscape destruction caused by excessive human activities. Protection measures and development directions include: intensifying the management of natural reserves, forest parks and scenic spots to effectively protect forest biodiversity; developing diversified economy in mountainous areas and increasing comprehensive agricultural benefits; reasonably guiding and developing ecological tourism; strengthening the management of mining and quarrying and ecological restoration after mining, and intensifying landscape protection. With respect to environmental protection planning, in this project, a series of mitigation measures are put forward, including: measures for prevention and mitigation of water quality and aquatic ecological environmental pollution, measures for preventing air pollution and mitigating its impact; noise pollution prevention measures, solid waste control measures, measures for stabilizing levees and bank slopes , agricultural production impact control measures, and measures for environmental management and monitoring during construction, in order to prevent environmental problems. The objectives of such measures are consistence with the guideline of ecological function zoning of Hubei Province.

Therefore, the project program is consistent with the ecological function zoning of Hubei Province.

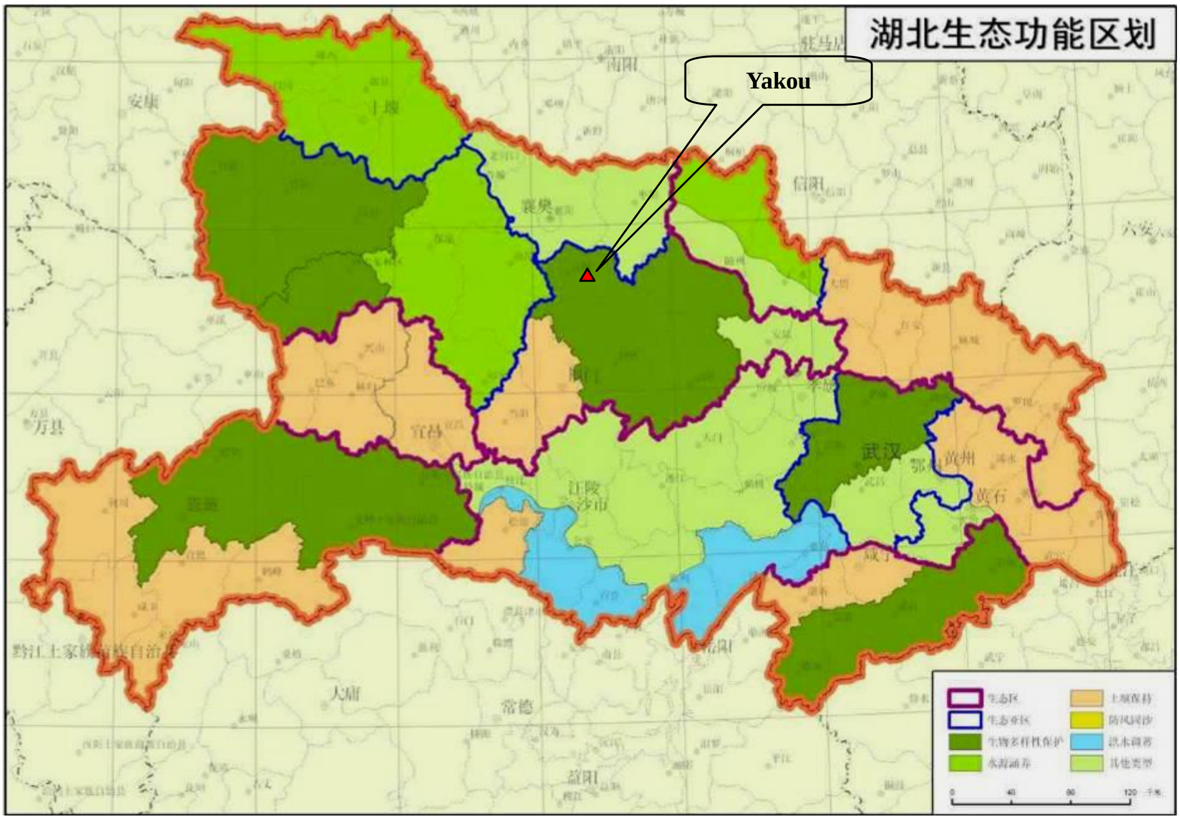


Figure 3.1.3 Ecological Function Zoning Map of Hubei Province

湖北省生态功能区划	Ecological function zoning of Hubei Province

3.1.3.3 Consistency with environmental protection planning in the Twelfth Five-year Plan of Hubei Province

In the *Environmental Protection Planning Outline in the Twlefth Five-year Plan of Hubei Province*, it is proposed that, “we shall put into practice the development strategy of two circles and one belt and comprehensively strengthen the water pollution prevention of Three Gorges reservoir area and Danjiangkou reservoir area on the basis on regional resources environment carrying capacity”; “we will adjust and optimize the industrial layout along the river according to water environmental capacity and carrying capacity. We shall strictly control environmental admittance and reduce the total amount of pollutants entering river. We shall strengthen water pollution prevention, continuously improve water environment quality and guarantee the safety of drinking water"; "we shall fully consider the environmental impacts of South-to-North Water Transfer Project and hydro-junction development of Han River relying on the comprehensively development of Han River, and shall optimize the industrial layout along the river and reasonably allocate the scale of industrial development along the river according to impaired environmental capacity. We shall focus on pollution prevention of the river section from Xiangyang to Qianjiang, intensifying the water environmental pollution treatment of main tributaries including Tangbai River, Zhupi River, Man River, Hanbei River, etc., and ensure meeting the requirements of water environment function zoning at middle and lower reaches of Han River. We shall plan water resources development and protection as a whole, scientifically demonstrate water resources scheduling mode, and guarantee ecological water supply and reduce the frequency of algal bloom. We shall build a risk assessment system for water pollution emergency, optimize the three-level water quality monitoring network of province, city and county, and improve the automatic quality monitoring system for cross-section water environment quality and the algal bloom pre-alarming system. We shall build urban and rural greening networks and green corridors along the river, control water and soil erosion in an all-round way, and guarantee that the main steam and tributaries of Han River can meet the standards".

The implementation of environmental protection planning will improve the environmental quality along the river, distinctly improve the water quality of Han River, and reduce the adverse impact caused by the construction of Yakou Shipping Hub and shipping works, which is conductive to the construction of the project. On the other hand, a series of mitigation measures are put forward, including aquatic and terrestrial ecological protection measures, water pollution prevention measures, noise and air pollution mitigation measures and various environmental management measures. Such measures are consistent with related guarantee measures proposed in the environmental protection planning in the Twelfth Five-year Planning of Hubei Province. After the abovementioned measures are put into practice, the indirect and long-term accumulated impacts of the project on the environment will be reduced to the minimum. Therefore, the construction program is consistent with Environmental *Protection Planning Outline in the Twelfth Five-year Plan of Hubei Province.*

3.1.3.4 Consistency with water pollution prevention planning for the middle and lower reaches of Han River

The Water Pollution Prevention Planning for the Middle and Lower Reaches of Han River is aimed at meeting the requirements for water quality protection of water function zones in the middle and lower reaches of Han River in Hubei Province. In the planning, it is proposed to enhance the construction of urban infrastructures, increase the treatment rate of domestic sewage and household garbage, improve the treatment rate of water and soil erosion, and ensure that each water body in Han River basin may stably meet the standard for a long term. The planning range is Han River basin below Danjiangkou reservoir dam, and the main river water bodies include the river section of Han River from Danjiangkou reservoir dam to Wuhan; first-grade tributaries of Han River including Nan River, Bei River Xiaoqing River, Tangbai River, Man River, Zhupi River, Tianmen River and Hanbei River; and secondgrade tributaries of Han River including Gun River, Qingxi River, Dafu River, etc.

Special Planning for Water Pollution Prevention and Ecological Protection of Xiangfan Section of Han River Section (November 2010) takes Year 2009 as the reference year, and the planning period is from 2011 to 2015, extending to 2020. The Special Planning takes the improvement of water environment quality and the maintenance of ecological balance as the fundamental starting point, highlights the protection of drinking water sources, and puts forward water pollution prevention measures and ecological environment protection program according to the actual requirements of sustainable social and economic development and ecological and environmental protection.

The water pollution sources of the construction of Yakou Shipping Hub mainly include industrial wastewater and worker domestic wastewater during construction, domestic wastewater of management area during operation, and oil contamination of ship lock. Recycling is considered in the engineering design, which is conforming to the pollution source treatment planning. The project construction may not increase water quality pollution of Han River, increase pollution load, distinctly change water environment quality of Han River, or conflict with the objective of environmental quality protection planning. With the change of hydrological conditions and the change of migration and diffusion conditions of pollution sources in reservoir area, the water quality of local water areas at the drain outlet may change, which requires scientific calculation and analysis. In a word, the project construction is not in conflict with related environmental protection planning for Han River.

3.1.4 Consistency with related local planning

3.1.4.1 Consistency with environmental protection planning of Xiangyang City

In the Environmental Protection Development Planning in the Twelfth Five-year Plan of Xiangyang City in Hubei Province, in The 12th five-year Plan period, key basins and districts of environmental protection of Xiangyang City are one great river, five rivers, four cities and one county. One great river is Han River; and five rivers include Bei River, Nan River (including Qingxi River), etc. The water environment control zones are divided as below. (1) Key protection zones, mainly including drinking water source protection zones of surface water in urban area. In such ones, it is required to strictly conform to control requirements and select industrial development types. In view of the hydro-junction development of Han River, the abovementioned zones will gradually become closed or semi-closed water bodies, and the risk of water eutrophication increases. It is required to accelerate the construction of urban sewage plants, vigorously develop ecological agriculture that can reduce the input of nutrient substances, and forbid new industrial projects with heavy pollution and high environmental risk. The existing heavy-pollution enterprises in the urban area of Xiangyang City shall move out or locally carry out adjustment. (2) Restricted development zones, mainly including the basins of Nan River, Bei River, Man River, Tangbai River and Xiaoqing River and all reservoirs. Based on the reality that the abovementioned zones are generally lack of water environment capacity and the water quality is low, it is required to restrain the trend of water environment degradation and improve the water environment quality of some water bodies through actively adjust industrial structure and intensifying the treatment of water pollutants. It is forbidden to build industrial projects with high water consumption and heavy pollution, and the existing heavy-enterprises shall realize up-to-standard emission and strictly control the newly-increased scale. Meanwhile, it is required to strictly control the development scale of intensive-culture and semi-intensive-culture fishery in the reservoir area. (3) Optimized development zones, mainly including the main stream of Han River. Heavy-pollution industries shall be strictly restricted. It is required to optimize industrial structure when meeting the requirements of up-to-standard emission and regional environmental capacity, and take the lead in accomplish the task of reducing totao pollution discharge. It is required to make good preparations for disadvantageous situation such as water flow reduction due to South-to-North Water Transfer Project, vigorously strengthen the sewage treatment of main cities along the river, and accelerate the construction of second-grade sewage treatment plants with ability of nitrogen and phosphorous removal; in consideration of that after Wangfuzhou, Xinji and Cuijiaying hydro-junctions are completed the river section in Xiangyang City will become a semi-closed water body and the possibility of eutrophication will increase. Besides strengthening urban sewage treatment, enterprises discharging massive nutrient substances may not be newly built or expanded, such as nitrogen fertilizer plant, phosphorous chemical plant and some food and beverage enterprises

Yakou Shipping Hub Project itself may not product pollutants, and is no in conflict with the objective of environmental protection. The construction of the hub may change the hydrological regime of Han River, and potential water environmental risks may be reduced with corresponding measures; the project design gives full consideration to discharge flow, which can meet the water demand of urban residents for production and living at the middle reach; in the project construction, it is required to carry out zero emission of wastewater and sewage. Early investigation and study may further make the status of pollution sources of Yicheng Section clear, and promote the treatment of existing industrial pollution sources. The project implementation will accelerate the implementation of environmental protection planning, which is also beneficial to the project implementation. Therefore, the project is in harmony with the environmental protection planning.

3.1.4.2 Consistency with overall planning of Yicheng City

In the *Overall Urban Planning of Yicheng City*, for the long-term planning, the area of construction land in the urban area is $38km^2$, and the population is 380 thousand. The objective is to make the best of the exiting mountain and water resources advantages and the good climate and soil conditions of Yicheng City, optimize the spatial structure of the urban mountain and water ecological green space system and the regional ecosphere based on the existing urban planning framework, and build Yicheng into a ecological park city suitable for entrepreneurship, development and habitation. The main planning indicators of the urban green space system construction of Yicheng City are defined as below: by 2020, the greening rate of the built area shall reach 14%, the greening coverage ratio reach 45%, and the per capita area of park green space reach 15.7 m^2/person.

In Chapter 9, Biodiversity Protection and Construction Planning, it is proposed to reserve the original ecological system in the central urban area and suburb of Yicheng City, which shall be strictly classified as protection zone, development efficient management, give play to various functions like urban landscape composition and urban climate regulation. Obviously, the construction of Yakou Shipping Hub will heighten the water level of the reservoir, expand the water surface, and plays an active role in improving the landscape quality of Yicheng City and local microclimate.

3.1.4.3 Consistency with forestry planning of Yicheng City

In the Forestry Development Planning of Yicheng City, it is proposed that The 12th five-year Plan period is key five years for forestry construction, and is a rapid development stage of ecological problem solving and industry acceleration. It is required to tightly seize the strategic opportunity to realize the rapid growth of forest resources and the strengthening of forestry industry guided by key projects. By 2015, the forest coverage ratio of the whole city will reach 31.9%, forest area reach 811 thousand mu, and the living wood growing stock reach 1800 thousand m^3. The forestry industrial system is further developing, and the industrial structure tends to be reasonable. The main construction tasks of the Twelfth Five-year Plan include returning the grain plots to forestry, and the area of forest plantation will be 270 thousand mu, which is mainly distributed on two banks of the river, surrounding the lake and reservoir, along the traffic line and on barren mountain and land in ecological vulnerable areas. The area of forest plantation of on both banks of Han River is 8000mu, and the area of afforestation in closed hillsides is 10 thousand mu.

In the construction area of Yakou Shipping Hub Project, vegetation recovery will be carried out through grass planting and economic forest planting and the planting of protection forest on the banks of the reservoir will be intensified, which is abiding by the planning principle of forest ecological construction and protection of Yicheng City.

3.1.5 Consistency with the classification of drinking water source protection zone and wetland park

3.1.5.1 Consistency with centralized drinking water source protection zone in Hubei Province

As for the drinking water source protection zone in Yicheng City involved in the river section of Yakou Shipping Hub reservoir, according to the *Zoning Program for Centralized Drinking Water Source Protection Zone above County Level in Hubei Province*, the scope of the water source protection zone of Yicheng Water Plant is shown in Table 3.1.5, and the relationship between protection zone scope and the project location is shown in Figure 3.1.5.

The water source of Yicheng Water Plant is located in the reservoir area of Yakou Shipping Hub Project, and the water intake is 20.0km away from the dam site; there is no waterway regulation project involving dredging and mud disposal downstream or upstream from the drinking water source protection zone. Therefore, the project doesn’t conflict with the zoning of centralized drinking water source protection zone in Hubei Province.

Table 3.1.5 Zoning of water source protection zone of Yicheng Water Plant

Water source	Grade	Protection zone scope		Remark
		Water area	Land area	

Water source of Yicheng Water Plant	I	Length: 1,000m upstream from the water intake to 100m downstream Width: water area from the stream central line to the right bank of Han River	Length: length of water area of grade-I protection zone Width: land area within the levee on the right bank	No standby water source
	II	Length: 3,000m upstream from the water intake to 300m downstream Width: water area outside of grade-I protection zone within the levee along the river channel	Length: length of water area of grade-II protection zone Width: land area outside of the land area of grade-I protection zone and within the levee	

According to the Management Regulations for Pollution Prevention of Drinking Water Protection Zone, in the Grade-I protection zone, no wharf unrelated to water supply may be built, and ship berthing is forbidden. In the Grade-II protection zone, it is forbidden to newly build or expand the project discharging pollutants into water and build wharfs loading and unloading garbage, excrement, oils and toxic substances. In the protection zone, the project doesn't involve related wharfs or pollution projects. After the project is completed, the management of sewage from ships in the waterway will be intensified, and there will be no pollution impact on the water environment in the waterway. Therefore, the construction of Yakou Shipping Hub Project is in harmony with the centralized drinking water source protection zone in Hubei Province.

Figure 3.1.5 Relationship between Yakou Shipping Hub and the water source protection zone of Yicheng City

图例	Legend
雅口航运枢纽	Yakou Shipping Hub
饮用水源一级保护区	Grade-I drinking water source protection zone
饮用水源一级保护区	Grade-I drinking water source protection zone

3.1.5.2 Consistency with Cuijiaying Provincial Wetland Park

On December 29, 2010, the Forestry Department of Hubei Province (ELHH [2010]No. 547) approved the building of Xiangyang Cuijiaying Provincial Wetland Park. The park is located between Xiangyang Cuijiaying Dam and First Han River Bridge at middle and lower reaches of Han River, and the total area is 3428 hm^2. It is a typical riverine wetland in Han River basin, and is of great significant in protecting the water sources at the middle reach of Han River, restoring the ecological system and facilitating the economic development of Xiangzhou District and the construction of ecological cultural tourism cycle in west Hubei.

As per function zoning, Cuijiaying Wetland Park is divided into four zones, i.e., ecological conservation zone, water recreation zone, Yuliangzhou ecological city and dam sightseeing zone. The construction of the dam of Yakou Shipping Hub has no impact on the wetland park. After the dam is constructed, the area from the backwater end of the reserve to Cuijiaying Shipping Hub involves the dam sightsee zone of Cuijiaying Provincial Wetland Park (300m below the dam). However, because the dam sightseeing zone, the boundary of the wetland park, is the backwater end of the project, the water level will not change significantly, and cause no impact on the integrity of the wetland park. Besides, for the area 300m below the dam, the left bank elevation is higher than 60m, and the right bank elevation is higher than 56m, both of which is higher than 55.2m, the normal water level of the project. Therefore, the project will mainly increase the water level of the wetland park below the dam, and will not inundate the terrestrial vegetation. The ecological conservation zone of the wetland park is located in the south of Yuliangzhou, and will not be disturbed by the project. Therefore, the project will not impact the ecological functions of the wetland.

3.1.5.3 Consistency with Yicheng Wanyangzhou National Wetland Park in Hubei Province

On December 31, 2013, State Forestry Administration (LSF [2013]No. 243) approved the building of Yicheng Wanyangzhou National Wetland Park. The wetland park takes Han River (Yicheng Section) as the main body, and the total area is 2466.03 hectares. Wetland types include permanent riverine wetland and flood plain wetland, and the wetland ratio is 69.53%. In the wetland park, there are 74 families, 185 genera and 229 species of vascular plants and 27 orders, 52 families and 119 species of vertebrates. The wetland park is divided into five function zones, i.e., wetland conservation zone, restoration and reconstruction zone, propaganda and education demonstration zone, reasonable utilization zone and management service zone. Wanyangzhou has beautiful natural landscapes and diversified biological species, and the building of national wetland park has great significance in protecting the existing wetland resources of Han River, maintaining ecology and improving the image of Yicheng City.

Yakou Shipping Hub Project is located 4.5km downstream from the wetland park, and the construction of the project will have no impact on the park. After the reservoir is built and begins water impoundment, there may be some adverse impacts such as inundating some shrubs and forests and reducing the habitats of some wetland animals and plants, but with the rising of water level in the wetland park, the water area will be expanded and the wetland rate increase, which is beneficial to the protection of wetland resources. The project construction has certain impacts on the ecological functions of the wetland park, and it is suggested that the Management Bureau of Wangyangzhou National Wetland Park take the impacts of the project into full consideration in future detailed planning.

3.2 Necessity of project construction

a) The construction of Yakou Shipping Hub is conforming to the integrated utilization planning of Han River basin and is an important component for realizing the objective of waterway planning of Han River.

Han River is a national high-grade waterway, and water conservancy and transportation departments have defined the development and regulations guidelines in previous planning for raising the navigation grade of Han River, improving waterway conditions and realizing hydro-junction canalization. The waterway planning standards of Han River is described as below: Yang County ~ Ankang reaches Grade-V standard, Ankang ~ Danjiangkou reaches Grade-IV standard, and Danjiangkou ~ Hankou reaches Grade-III standard, which have been listed in the *Brief Report for the Integrated Utilization Planning for Water Resources in Yangtze River Basin* and the *Planning for Inland Waterways and Ports Layout in China* approved by the State Council in 20007. Yakou Shipping Hub is the sixth-level project in the hydro-junction development of Han River within the territory of Hubei Province and is an essential lick in the overall comprehensive development of Han River. The project construction is conforming to the integrated utilization planning of Yangtze River basin and the shiping planning of Han River, and is an important component for realizing the objective of waterway planning of Han River. The construction of Yakou Shipping Hub may be effectively linked with Cuijiaying Hydro-junction upstream, and will inundate six beach groupes, i.e., Longmen Beach, Shuifo Temple, Bajiazhou, Niulukou, Quejiatao and Guohaiying. The project will make the navigation standard of the 52.67km-long river section upstream from the dam site reach 1000t waterway standard and lays foundation for realizing the objective of waterway planning of Han River.

b) Yakou Shipping Hub is a key project for fully realizing the objective of 2020 waterway planning of Han River, and the construction is beneficial to realizing the benefits of built projects and is quite necessary and urgent.

At present, the up-to-standard waterway construction of Han River is moving quickly. With respect to canalized hydro-junction construction, among the eight-level hydro-junction canalization junctions planned from upstream to downstream of Han River within the territory of Hubei Province, Danjiangkou, Wangfuzhou and Cuijiaying junctions have been built, the heightening works of Danjiangkou dam has been completed, and Xinglong Hydro-junction is in full construction. According to the *Planning for Inland Waterways and Ports Layout in China* that has been approved, the main stream of Han River shall reach the waterway planning standard by 2020, and it is necessary to accelerate the construction of Gushan, Xinji, Yakou and Nianpanshan junctions . At present, the feasibility study for Gushan Junction and Xinji Junction has been at the stage of review and will be approved soon, the preliminary work of Nianpanshan Junction was started in 2004, and the project proposal was approved in 2005. In view of the 2020 waterway planning objective of Han River, Yakou Shipping Hub has been a bottleneck and key project for the up-to-standard waterway construction of Han River, and it is necessary and urgent to commence the construction of Yakou Shipping Hub, which is conductive to realizing the comprehensive benefits of built junctions and the waterway regulation works below Xinglong.

Han River is an important tributary of Yangze River, and numerous industrial towns in eight cities are distributed along the river. The early construction of 1000t high-grade waterway bellow Danjiangkou, especially below Xiangyang, will give full play to the polling function of water transportation in regional economy, bring the economic development along Han River into a new period.

c) The construction of Yakou Shipping Hub is the need for improving the comprehensive transportation structure of Han River basin and building comprehensive transportation system.

Han River is a high-grade waterway in Hubei Province and Shaanxi Province, is the major tributary among high-grade waterways in the water system of Yangtze River, and is an important component of inland comprehensive transportation system. Accelerating the development of high-grade waterway of Han River and increasing competitive capacity is the objective demand for building a high-efficiency, rapid, mutually-coordinating modern comprehensive transportation system.

Yakou Shipping Hub is one of up-to-standard projects for hydro-junction canalization construction in the river section from Danjiangkou to Xinglong, and has been listed in the *Construction Plan of High-grade Waterways for Han River and Jianghan Canal (2011-2015)*. The construction of the hub will upgrade the current grade III of waterway 52.67km long to Grade III. In combination with built Cuijiaying Hydro-junction, in-construction Xinglong Hydro-junction and Nianpanshan Hydro-junction at the stage of preliminary work as well as the waterway regulations works in progress below Xinglong Hydro-junction, the sound connection with the waterways of Yangtze River below Xiangyang may be realized, which may significantly improve the water transportation conditions at middle and lower reaches of Han River, take full advantages of low cost, small land occupation, large freight volume and low energy consumption, attract cargos of large lot size and low time requirement, reinforce and upgrade the position of inland water transportation in the comprehensive transportation system of Hubei Province and Shaanxi Province, and form a comprehensive transportation system in combination with highway, railway, civil aviation and pipes. The project will help optimize and improve the inland comprehensive transportation structure, play the leading role when Hubei Province builds comprehensive transportation overpass in China, and will accelerate the scientific and leap-type development of water transportation industry.

d) The construction of Yakou Shipping Hub is an important extension of the special channel for North-to-South coal transportation, and is the need for guaranteeing the safety of energy supply in Hunan, Hubei, Jiangxi provinces and the rapid economic and social development.

Coal resources in China are mainly distributed in Shanxi Province, Shaanxi Province and the west of Neimenggu (“three-west regions” for short), but the organizations with high consumption of coal are concentrated in east coastal region, South China and Middle China. The reverse distribution of coal resources and demand in China results in that a great deal of transportation capacity is required to complete the resource allocation in the coal demand and supply relation. In general, the coal demand in eastern coastal region of South China may be solved through West-to-East coal transproitation channel that has been built for years and port transfer as well as through import from Australia and other countries. But the Middle China is in the embarrassing situation of severely insufficient coal transportation capacity.

According to the preliminary program for the dedicated coal transportation railway channel the west of Neimenggu to Middle China, in the future, Xiangyang will become an important logistics hub and coal trade market for transferring the coal from three-west regions to Hunan, Hubei and Jiangxi Province. Yujia Lake Port Zone of Xiangyang Port is one of the coal launching port in the earliest planning of the country, and is also a dedicated port for coal transfer with the largest scale, most advanced equipment and highest modernization degree in Han River. However, due to a lot of reasons, Yujiahu Port has not been put into operation since being built. With the construction of the dedicated coal transportation railway channel the west of Neimenggu to Middle China, Xiangyang Port is paid attention to again and has the potential to develop into inland “Qinghuadao Port” , and the development and construction of Han River will become an important link.

As the important extension of the dedicated channel for North-to-South coal transportation, Han River relies on the coal launch port in Yujia Lake, leads to Han Kou through the development and construction of Yakou, Nianpanshan and Xinglong Hydro-junctions as well as the in-progress 1000t waterway regulation works of Jianghan Cannal and Xinglong-Hanchuan Section, then is connected to Han River in Jiujiang City along Yangtze River, and traces in-progress Jianghan Canal and smoothes the connection between Dongting Lake and Han River and Yuan River, forming a 1000t waterway network at the middle reach of Yangtze River. This will be convenient for connecting the water transportation network in Hubei and Jiangxi provinces, service the whole region of Hunan, Hubei and Jiangxi provinces, and guarantee the safety of energy supply in Hunan, Hubei, Jiangxi provinces and the rapid economic and social development.

e) The construction of Yakou Shipping Hub is the need of regional economic development and will greatly pull the economic development of economic belts of Hubei Province and Shaanxi Province along the river.

The cities and towns in Hubei Province and Shaanxi Province are featured by numerous great rivers and rivers. A number of cities including Ankang, Shiyan, Xiangyang, Jingmen, Qianjiang, Tianmen, Xiantao and Hanchuan are distributed along Han River, and Wuhan City, the capital of Hubei Province, is located at the intersection between Han River and Yangtze River. Corresponding to the urban layout, along the river is also an important area for industrial layout. Along Han River, a complete industrial and agricultural production system has been formed with advantageous sectors such as automobile, iron & steel, electric power, building materials, textile ad garments and high and new technologies as the representative, and shipping is always one of the primary transportation modes.

On the two banks at middle and lower reaches of Han River are grain, cotton and oil production bases. After Yakou Shipp Hub is completed, the perennial water level of the river section where the reservoir is located will be increased, and 80 thousand mu of farmland in Liushui Township, Zhengji Township, Yancheng and Nanying in Yicheng City will be irrigated by gravity. This will increase irrigation probability, reduce water lifting expenses and create conditions for developing high-efficient and economic agriculture.

f) The construction of Yakou Shipping Hub is the demand of Xiangyang City, especially Yicheng City, for national economic and social development, and may reduce the tension in power supply in this area.

Under the control of Xiangyang power grid, there are Xiangyang urban grid and seven county-level grids of Xiangzhou, Laohekou, Yicheng, Nanzhang, Gucheng and Baokang, and it is the hub for West-to-East power transmission and South-North mutual power supply in the power grid of Hubei Province. Xiangyang City is the political, economic and cultural center in the northwest of Hubei Province, and has built an industry system with relatively complete categories. Its industrial and economic scale ranks only second to Wuhan City in Hubei Province, with the rapid economic growth, the power consumption increases quickly. In 2010, the total electricity consumption was 9740 million kWh, and the maximum power load is 1840 thousand kW. Yicheng City is close to the downtown of Xiangyang City to the north. In The 12th five-year Plan period, Yicheng Economic Development Zone will be developed as a key task, with large power demand and load. According to forecast, the total electricity consumption and the maximum power load will be 25200 million kWh and 396 thousand kW, respectively. Because there is no large power supply installed in Yicheng power grid and power is in great shortage, 220KW Yuling Substation lower grid is mainly depended on to meet the power demand of Yicheng power grid.

Yakou Shipping Hub is more than 80km away from Xiangyang City and 15.7km away from Yicheng City. The installed capacity is 74.2MW, the guaranteed output is 25.40MW, and the average annual electricity generation capacity is 322 million kWh. The hub is close to the load center of Xiangyang and Yicheng, and will reduce the tension in power supply and facilitate the national economic and social development of Xiangyang City and Yicheng City.

g) The construction of Yakou Shipping Hub is conforming to the cleaning energy development planning, is beneficial to the development of low-carbon economy, and is the need of building resources-saving society.

The installed capacity of Yakou Shipping Hub is 74.2MW, and the annual electricity generation capacity is 322 million kWh. Calculated as per standard coal consumption of 320g/kWh, the power station project will reduce the coal consumption by 103.7 thousand tons of standard coal every year, equaling to reducing CO_2 emission by 311.1 thousand tons every year (equaling to reducing carbon emission by 84.8 thousand tons every year); meanwhile, the project may reduce SO_2 emission by 1 thousand tons at least every year.

After Yakou Shipping Hub is completed, 52.67km-long waterway will be canalized, and the waterway grade will be raised to 1000t grade from 500t grade, the waterway navigation capacity and the operating benefits of the ships will be increased, the shipping will develop towards large size, standardization and serialization, and the oil consumption will be dramatically reduced. According to shipping status survey, the comprehensive oil consumption of existing ships at middle and lower reaches of Han River is 8kg/1000t.km, and the oil consumption will be reduced by 30% ~ 40% after canalization. Calculated as per 4,000 thousand tons of average freight volume of the river section from Cuijiaying Junction to Yakou in 2020, the annual freight turnover is 210,680 thousand t.km, and 590 tons of fuel oil will be saved every year. By parity of reasoning, by 2030, 725 tons of fuel oil will saved, and by 2050, 1080 tons of fuel oil will be saved, which may reduce the consumption of non-renewable resources such as petroleum and coal.

Obviously, as a hydropower project, the project meets the requirements for giving priority to developing clean energy, has obvious effects on reducing environmental pollution and protecting ecological environment, and plays an significant role in energy conservation and emission reduction.

3.3 Environmental rationality of project program

3.3. Environmental rationality of project program

3.3.1.1 Rationality of dam site selection

a) Dam site selection

Yakou Shipping Hub is the sixth level in the hydro-junction development planning for the main stream of Han River within the territory of Hubei Province. When selecting the dam site, the following landform control factors shall be taken into account: ① riverway width: the project is located in the middle and lower reaches of Han River, where the riverway is wide and the beaches are developed. When avoiding too long dam line, it is required to take full advantage of the river regime and landform for hub layout in order to avoid large-volume excavation. ② Yicheng Han River Bridgeis located in the selection range, and ships shall be able to successfully pass through the main navigation hole of the crossing-river bridge. In full consideration of the factors like landform and river regime, the principles for dam site selection are described as below:

(1) The dam site selection shall conform to the comprehensive planning for the main stream and shall guarantee the mutual linking between upstream and downstream hydro-junction to the best extent, raising the ship grade and fully utilizing water head for power generation.

(2) The dam site selection shall give priority to shipping, and shall be favorable to the smooth connection between ship lock arrangement and waterway. The comparison and selection range includes Yicheng Han River Bridge and planned Yicheng Second Han River Bridge and the navigation safety shall be taken into account.

(3) The dam site selection shall consider reducing reservoir inundation and immersion. There is a lot of overflow lands outside of the levees, and the terrain within the levees is low-lying. Farmland, residents and industrial and mining enterprises affected by reservoir inundation shall be as few as possible, and the impact range of immersion area shall be as small as possible.

(4) The dam site selection shall give due consideration to the requirements for the improvement of urban landscape and water environment, in order to strive for more social benefits.

(5) The dam site selection shall be carried out through comprehensive technical and economical comparison, and the dam site with better economic benefits shall be selected.

In accordance with the regime characteristics of the river section and the selection principles and in combination with the comprehensive planning for the main stream of Han River, the available river sections for dam site include: river section above Hongshantou, river section from Hongshantou to Yicheng Bridge, river section from Yicheng Bridge to Guanzhuang, river section from Guanzhuang to Yakou and river section below Yakou.

If the dam site is in the river section below Yakou, there is no systematical levee on the left bank of Ying River, the terrain within the area is low, there are numerous resident points, and the impact scope of inundation is large. Besides, the river surface is wider downstream, and the hub axis is too long, which may cause more construction quantities and inundation loss. At the same time, the jacking of Nianpanshan Junction downstream is larger, the water head for power generation doesn’t increase obviously, and the power generation benefits increase little.

If the dam site is in the river section above Hongtoushan, it will be 30km below Cuijiaba, and the loss caused by reservoir inundation is small. However, the length of the unconnected section of Grade-III waterway between Yakou and Nianpanshan Junction is about 8km, the water utilization indicators of water energy are poor, and the improvement of urban landscape and water environment of Yicheng City will be small.

Figure 3.3.1 Sketch map of dam site riverway

红头山坝址	Hongtoushan dam site
国道	National highway
宜城市	Yicheng City
二广高速	Erenhot-Guangzhou Expressway
宜城汉江大桥	Yicheng Han River Bridge
大堤	Levee
莺河	Ying River
南洲坝址	Nanzhou dam site
李家山头坝址	Lijiashantou dam site
雅口坝址	Yakou dam site
省道	Provincial highway
官庄坝址	Guanzhuang dam site
宜城坝址	Yicheng dam site

If the dam site is in the river section from Hongtoushan to Yicheng Bridge, it will be about 40km below Cuijiaba, and the loss caused by reservoir inundation will be small. However, the water utilization indicators of water energy are poor, and the improvement of urban landscape and water environment of Yicheng City will be small. Meanwhile, according to the planning of Yicheng City, Second Han River Bridge will be built 3km upstream from Yicheng Han River Bridge, and then Yicheng dam site will be between two Han River Bridges, and the distance between the dam site and bridge is less than 1.5km, which will greatly impact the ship navigation.

If the dam site is in the rive section from Yicheng Bridge to Guanzhuang, it will be about 45km below Cuijiaba, and the loss caused by reservoir inundation will be small. the water utilization indicators of water energy are poor, and the improvement of urban landscape and water environment of Yicheng City will be large. However, the riverbed in this section extends in S-shape, the main river channel transits from the right bank to the left bank, the river surface is about 4km wide and the shipping track is in the center. It will be difficult to connect the reservoir waterway to the natural waterways upstream and downstream, the required excavation volume is large, and there is no advantage compared with the inundation loss to be reduced.

Comparatively speaking, it will be more advantageous to locate the dam in the river section from Guanzhuang to Yakou. According to the hub layout and the requirements for flood discharge, navigation (second line) and power generation, the length of main hub structure shall be 1.3km. In the river section from Guanzhuang to Yakou, the width of river surface is mostly greater than 3km, and the layout of situation will not be problem. With impacting navigation, the shorter dam axis will save engineering quantities and reduce investment. In comprehensive consideration of landform, navigation safety, main structure layout and reservoir inundation, at this stage, Yakou dam site about 250m at the upper reach of Ying River, Lijiashantou dam site (2.86km upstream from Yakou) and Nanzhou dam site (6.67km upstream from Yakou) are selected as comparable dam sites.

b) Recommended dam site of main works

The abovementioned three dam sites are compared in details in terms of comprehensive project cost, navigation conditions, land acquisition expenses and power generation benefits, and the comprehensive comparison is shown in Table 3.3.1-1. As shown in the table below, the topographic and geological conditions and the construction conditions of the three dam sites are good, and there is no problem restricting the building of the dam. There is no big difference between indictors of reservoir inundation.

Table 3.3.1-1 Comparison and selection of dam sites

Item	Yakou dam site	Lijiashantou dam site	Nanzhou dam site
Topographic ad geological condition	Left bank and right levee; for ship lock, thickness of silty-fine sand 1.5m ~ 5.9m, and thickness of sand, cobbles and gravels 7.9m ~ 13.1m; for hydropower station, thickness of silty-fine sand, cobbles and gravels 20.4m ~ 23.0m, bedrocks include loose glutenite and clay rock; for sluice, thickness of upper silty-fine sand 1.7m ~ 9.5m, and thickness of lower cobbles and gravels 6.5m ~ 16.7m.	Left bank and right levee; for ship lock, thickness of silty-fine sand 6.0m ~ 10.0m, and thickness of sand, cobbles and gravels 2.0m ~ 8.5m; for hydropower station, thickness of silty-fine sand, cobbles and gravels 20.5m ~ 23.2m, bedrocks include loose clay rock and marlstone; for sluice, thickness of upper silty-fine sand 2.0m ~ 9.9m, and thickness of lower cobbles and gravels 5.8m ~ 15.8m.	Left bank and right levee; for ship lock, thickness of silty-fine sand 0.7m ~ 1.4m, and thickness of sand, cobbles and gravels 9.6m ~ 11.7m; for hydropower station, thickness of silty-fine sand, cobbles and gravels 13.8 ~ 16.8m, bedrocks include loose clay rock and marlstone; for sluice, thickness of upper silty-fine sand 1.7m ~ 7.1m, and thickness of lower cobbles and gravels 5.4m ~ 11.2m.
Hub layout	Dam axis 2282m long; ship lock on the right bank + right-channel 36-hole sluice + hydropower station on the left bank + left-channel 12-hole sluice	Dam axis 3220m long; ship lock on the right bank + left-channel 34-hole sluice + hydropower station on the left bank + right-channel 14-hole sluice	Dam axis 3734m long; ship lock on the right bank + left-channel 34-hole sluice + hydropower station on the left bank + right-channel 14-hole sluice
Navigation condition	Ship lock is located in the main river channel; the shipping route upstream is smoothly connected to the main river channel through local dredging, and the shipping route is smoothly connected to the main river channel downstream. At discharge flow of different grades, ships can pass through the entrance successfully.	Ship lock is located in the main river channel; the shipping route upstream is connected to the main river channel, and ships can pass through the entrance successfully. The shipping route downstream is connected to S-shape bank of the main river channel, and the entrance area and the connection-section waterway slant through the discharge area of the hub. When the sluice opens discharge (Q>2300m^3/s), it is difficult to handle the ship.	Ship lock is located in the main river channel; the shipping routes upstream and downstream are smoothly connected to the main river channel and at discharge flow of different grades, ships can pass through the entrance successfully.

Table 3.3.1-1 (Cont.)

Item	Yakou dam site	Lijiashantou dam site	Nanzhou dam site
Flood discharg	The sluices are distributed dispersedly, and there is side	The sluices are distributed dispersedly, and the side	The sluices are distributed dispersedly, and the side

Item	Yakou dam site	Lijiashantou dam site	Nanzhou dam site
e condition	shrinkage of water flow in front of the dam. In the model test, the maximum height of backwater in front of the dam is 0.28m.	shrinkage of the water flow in front of the dam is severe. In the model test, the maximum height of backwater in front of the dam is 0.38m.	shrinkage of the water flow in front of the dam is severe. According to theoretical calculation, the maximum height of backwater in front of the dam is 0.42m.
Reservoir inundation	Area of inundated overflow lands 74511.9mu, area of demolished houses 81332.4m^2, relocated population 1378	Area of inundated overflow lands 70168.9mu, area of demolished houses 81332.4m^2, relocated population 1378	Area of inundated overflow lands 66569.9mu, area of demolished houses 81332.4m^2, relocated population 1378
Hydro-energy utilization	Installed capacity 74.2MW, and average annual electricity generation capacity 263 million kWh.	Installed capacity 71.1MW, and average annual electricity generation capacity 260 million kWh.	Installed capacity 70MW, and average annual electricity generation capacity 247million kWh.
Construction condition	3rd stage diversion, and all-year-round cofferdam	3rd stage diversion, and all-year-round cofferdam	3rd stage diversion, and all-year-round cofferdam
Total static investment	3154.20 million Yuan	3128.85 million Yuan	3182.27 million Yuan

Note: the data is from the consultation draft of *Feasibility Study Report for Han River Yakou Shipping Hub Project*.

The waterway conditions of Nanzhou dam site and Yakou dam site can meet the navigation requirements, the shipping route downstream from Lijiashantou dam site is connected to the S-shape bank of the main river channel and the entrance area and the connection-section waterway slant through the discharge area of the hub. When the sluice opens discharge (Q>2300m^3/s), it is difficult to handle the ship. Comparatively speaking, the waterway conditions of Yakou dam site are better. As for flood discharge conditions, because the axis of Danzhou dam is too long, the side shrinkage of water flow in front of the dam is the most severe, and the maximum height of backwater in front of the dam is the largest. Lijiashantou dam site takes the second place, and Yaokou dam site is the lowest.

With respect to economic indicators, the electricity output of Nanzhou dam site is less than that of Lijiashantou dam site, the project investment of Nanzhou dam site is more than that of Lijiashantou dam site. Obviously, the economic indicators of Lijiashantou dam site are better; compared with Lijisahantou dam site, the supplementary unit kW investment of Yakou dam site is CNY 12,071, far less than the unit kW investment of Lijiashantou dam site, CNY42,509, indicating that the earnings of the supplementary investment are better. The supplementary unit kWh investment is CNY 8.45, less than the unit kWh investment of Lijiashantou dam site, CNY 12.48, indicating that the earnings of supplementary investment are better.

Based on the comprehensive analysis of the abovementioned factors, especially waterway conditions, Yakou dam site is selected as recommended dam site.

c) Analysis of environmental rationality of dam site selection

The factors related to environmental impacts are selected for comparison and analysis, such as geological environment, reservoir inundation, land occupation for construction, settlement, construction conditions, engineering quantities, etc. The comparison and selection details of dam site are shown in Table 3.3.1-2.

Table 3.3.1-2 Comparison and selection of dam site programs

Item	Yakou dam site	Lijiashantou dam site	Nanzhou dam site	Recommendation
Landform	Landform is relatively flat, river valley is open, and the dam axis is 2282m long. On the left bank is bedrock bank slope, and on the right bank is levee, there is shoal in the middle. The main riverway is on the right side, the width is 550m ~ 580m, and the water depth usually is 4.0m ~ 6.0m.	Landform is relatively flat, river valley is open, and the dam axis is 3240m long. On the left bank is bedrock bank slope, and on the right bank is levee. The main riverway is on the left side, the width is 570m ~ 620m, and the water depth usually is 4.5m ~ 7.1m.	Landform is relatively flat, river valley is open, and the dam axis is 3734m long. On both banks are levees, and the riverway parts. The main riverway is on the left side, the width is 380m ~ 420m, and the water depth usually is 3.6m ~ 5.8m.	Each dam site has geological conditions for building low-head gate dam.

Table 3.3.1-2 (Cont.)

Item	Yakou dam site	Lijiashantou dam site	Nanzhou dam site	Recommendation
Hydrological and geological conditions	The corrosivity of surface and underground water is weak; a few drilling holes reveal that the buried depth of bedrock confined water is great, so there will not be obvious adverse impact on buildings and foundations the water permeability of silty-fine sand and cobbles is high, and allowable gradient is small. The water permeability of clay rock, marlstone, silty-fine sandstone and medium-coarse sandstone is lower than		Similar to Yakou dam site, but there is confined water observed.	All dam sites have equivalent conditions

Item	Yakou dam site	Lijiashantou dam site	Nanzhou dam site	Recommendation
	10Lu, the water permeability of glutenite and weak-cement silty-fine sandstone is slightly higher than 10Lu, and the water permeability of loose glutenite usually is higher than 20Lu.			
Water environment	The downstream waterway of Yakou Hub can be connected to the dead pool level of Nianpanshan reservoir only after dredging.	The downstream waterway of Yakou Hub can be connected to the dead pool level of Nianpanshan reservoir only after a little dredging.	The downstream waterway of Yakou Hub can be connected to the dead pool level of Nianpanshan reservoir only after a little dredging.	The adverse impacts of dredging on water environment are equivalent.
	Concrete quantity: 803.9 thousand m^3	Concrete quantity: 809.3 thousand m^3	Concrete quantity: 810.9 thousand m^3	The concrete quantity of Nanzhou dam site is larger, and the wastewater volume is larger
	The drainage outlets of urban sewage of Yicheng City, Laojiang Ditch and Yidao Ditch are below the dam, causing on impact on urban sewage discharge. The water intake of Yicheng Water Plant is located in the reservoir, where the water flow is slow and the self-cleaning capacity is weak, so the probability of water quality risk for water intake increases.			All dam sites have equivalent conditions
	The sluices are distributed dispersedly, and there is side shrinkage of water flow in front of the dam. The maximum height of backwater in front of the dam is 0.28m, favorable to flood discharge, and the water pollution risk in high flow season is low.	The sluices are distributed dispersedly, and there is severe side shrinkage of water flow in front of the dam. The maximum height of backwater in front of the dam is 0.38m, and the water pollution risk in high flow season increases.	The sluices are distributed dispersedly, and there is severe side shrinkage of water flow in front of the dam. The maximum height of backwater in front of the dam is 0.42m, and the water pollution risk in high flow season increases.	Yakou dam site is better
Atmospheric and acoustic environment	Both banks are open, with few resident points. Carry out reasonable construction layout in combination with the main works.	Resident points are dense, and construction cause great impact on residents.	Resident points are dense, and construction cause great impact on residents.	Yakou dam site is better
Terrestrial ecology	Area of inundated overflow lands is 74,512 mu, area of demolished houses is 81,332.4m^2, relocated population is 1,378. The area of land inundated by reservoir is large, increasing surface disturbance.	Area of inundated overflow lands is 69,769 mu, area of demolished houses is 81332.4m^2, relocated population is 1,378. The area of land inundated by reservoir is large, increasing surface disturbance.	Area of inundated overflow lands is 66,170 mu, area of demolished houses is 81,332.4m^2, relocated population is 1,378. The advantages of reservoir inundation are obvious, and the surface disturbance is small.	Nanzhou dam site is better
Water and soil conservation	Earth excavation volume is 10,250 thousand m^3, area of construction disturbance is small, and area of water conservation facilities occupying vegetation is small, causing relatively small volume of water and soil erosion, and favorable to water and soil conservation.	Earth excavation volume is 10,780 thousand m^3, area of construction disturbance is large, and area of water conservation facilities occupying vegetation is large, causing relatively large volume of water and soil erosion, and not favorable to water and soil conservation.	Earth excavation volume is 12,850 thousand m^3, area of construction disturbance is relatively large, and area of water conservation facilities occupying vegetation is relatively large, causing relatively large volume of water and soil erosion, and not favorable to water and soil conservation.	Yakou dam site is better
Aquatic ecology	The spawning grounds of fishes spawning drifting roes are all below the dam. Guanjiashan spawning ground and Dengjiatai spawning ground are 13.5km and 61.8km away from Yakou dam site, respectively, obstructing the migration and spawning channels of fishes spawning drifting roes like four major Chinese carps.			The obstruction effects of dam sites on fish are equivalent

Item	Yakou dam site	Lijiashantou dam site	Nanzhou dam site	Recommendation
Environmental risks	The layout of ship lock is smooth and straight, the waterway vision is wide, and the probability of risks and accidents is relatively low.	The river section leading to ship lock is curved, the waterway vision is narrow, and the probability of risks and accidents is relatively high.	The river section leading to ship lock is curved, the waterway vision is narrow, and the probability of risks and accidents is relatively high.	Yakou dam site is better
Waterfront landscape	All dam sites are located downstream from Yicheng City, and the county seat is located within the scope of reservoir area, with beautiful waterfront landscape, which is conductive to beautifying the environment and promoting the development of the county. Each dam site can further improve the waterfront landscape environment of Yicheng City.			All dam sites have equivalent conditions
Comprehensive comparison and selection	Based on the analysis and comparison from the prospective of environmental protection, the program of Yakou dam site is better.			

3.3.1.2 Selection rationality of normal water level

a) Selection of normal water level

At this stage, in-depth analysis is carried out for the major factors related to the section of normal water level, and in combination of the review comments on the comprehensive planning of Han River and the pre-feasibility study report for Yakou Shipping Hub, shipping requirements of Yakou reservoir area, hydro-junction linking, reservoir inundation, bridge freeboard and other comprehensive factors, three programs of normal water level of 54.72m, 55.22m and 55.72m are proposed for comparison.

1) Shipping condition: from the prospective of navigation conditions, each normal water level program can meet the shipping requirements for Grade-III waterway width and water depth, and with the rising of normal water level, the navigation conditions get better. From the prospective of hydro-junction linking, each normal water level program is linked with upstream Cuijiaying Hydro-junction, and the water level can meeting the requirements of navigation linking. However, the program of 54.72m has no regulation performance and the operation flexibility of power station is relatively low.

2) Energy indicators: in the program of normal water level of 54.72m ~ 55.72m of Yakou hub, the corresponding average annual electricity generation capacity is 360,720 thousand kWh ~ 428,220 thousand kWh, and the energy effect on upstream Cuijiaying is 23,720 thousand kWh ~ 48,840 thousand kWh; for every 0.5m rising from 54.72m of the normal water level, the annual electricity generation capacity of Yakou Shipping Hub

increases by 34,170 thousand kWh and 3,333 thousand kWh respectively, the jacking effect on Cuijiaying increases by 11,220 thousand kWh and 13,900 thousand kWh, respectively, and the total increment of annual electricity generation capacity of two hydro-junction is 22,950 thousand kWh and 19,430 thousand kWh respectively. Obviously, with the rising of normal water level of Yakou hub, the power generation benefits of hydro-junctions increase, and the program of higher normal water level is better.

3) Inundation and immersion analysis: for each normal water level program, there is no substantial difference in resettlement difficulties. However, for every 0.5m rising from 54.72m of normal water level, the occupied cultivated food land will increase by 4,997mu and 4,423mu respectively, and the immersion area increase by 21.5km^2 and 10.5km^2. The program of higher normal water level has relatively greater inundation and immersion impacts.

4) Project investment: the number of generators in each program is 7. With the rising of normal water level, various indicators of project investment for reservoir inundation and protection increase, the compensation investment for reservoir inundation increases by CNY 139,580 thousand and CNY 124,480 thousand, and the total static project investment increases by CNY 101,870 thousand and CNY 109,380 thousand. The investment for the program of higher normal water level is greater.

5) Economic indicators: in terms of annual cost, the annual cost of each normal water level program of Yakou hub is 30662, 30575 and 30562, and for normal water level of 55.22m and 55.72m, the annual cost is equivalent and relatively low. For every 0.5m rising from 54.72m of normal water level, the supplementary unit kW investment is 10,187yuan/kW and 10,938 Yuan/kW respectively, and the supplementary unit kWh investment is 2.98/3.19yuan/ kWh (before / after Nianpanshan is constructed, the same below), and 3.28/3.45 Yuan/kWh, far less than the own indicators of the project. Obviously, the economic indicators of the program of higher normal water level are better.

From the prospective of the impact of Yakou project on other relevant departments, each program has no impact of navigation of Han River Bridge and flood control of Cuijiaying; according to each program, the reservoir levees shall be reinforced as per corresponding standards, and in terms of the safety of reservoir flood control, there is little difference among the programs; from the prospective of urban flood control, the warning water level of Yicheng City is 55.47m, and although adjustment is possible, a lot of factors will be involved. At present, the water level of Yakou hub may not exceed the current warning water level.

To sum up, the waterway in each program can be well linked with upstream Cuijiaying; after rising the water level, the power generation benefits of hydropower station get better; the total static project investment gradually increases, while annual cost reduces gradually and supplementary unit kW investment and supplementary unit kWh are far less than the basic program. Obviously, the program of higher normal water level is more advantageous. However, from the prospective of the urban flood control, at present the water level of Yakou hub may not exceed the warning water level of Yicheng City, 55.47m.

Based on comprehensive comparison and selection, the normal water level of Yakou hub is recommended to be 55.22m.

b) Analysis of environmental rationality

At the stage of feasibility study and design, the comparison and analysis was carried out for three schemes for normal water level of Yakou Hydropower Station, i.e., 54.72m, 55.22m and 55.72m, and the main environmental elements are shown in Table 3.3.1-3.

Table 3.3.1-3 Schedule of comparison and selection of main environment elements of normal water level scheme

Elemental element	Item	Unit	Normal water level program		
			54.72m	55.22m	55.72 m
Hydrological regime	Rising of water level in front of dam	m	7.04	7.54	8.04
	Length of backwater of main stream	m	51.46	52.67	53.65
	Reservoir capacity below normal water	100 million	2.717	3.097	3.097

	level	m^3			
	Regulation capacity	100 million m^3	0.378	0.415	0.440
Water temperature	A value (α-β) method		127.7	112.0	112.0
Water quality	Tributary backwater		Little difference		
	Overall water quality		Little difference		
Fish			Each scheme has the same inundation impact on the spawning grounds in the river section		
Human health			Little difference		
Reservoir inundation and relocation	Inundated land	mu	67166	74598	83280
	Including: basic farmland	mu	3975	4054	4232
	Immersion area	km^2	95	116.5	127
	Production arrangement population	Person	18201	18333	18465
	Relocation resettlement population	Person	1378	1378	1378
	Major rebuilding projects		Little difference		
	Cultural relics and historic sites		No difference		
	Sensitive area		Reservoir inundation involves drinking water source protection zone, and there is little difference.		
Construction quantities	Earth excavation	10 thousand m^3	1032	1025	1022
	Concrete earthwork volume	10 thousand m^3	81.91	80.39	79.80

Note: the data is from the chapter for comparison and selection of normal water level in the *Feasibility Study Report for Han River Yakou Shipping Hub Project*.

According to the table, there is little difference among normal water level schemes in terms of hydrological regime, water temperature, water quality, inundation and relocation and fine. The lower the normal water level, the less the ecological environmental impact, and the less the impact of relocation resettlement on social economy. Each scheme doesn't involve natural reserves, scenic spots or other sensitive areas, and the dam doesn't involve drinking water source protection zone. There is no obvious difference in environmental impact, which is not the factor restricting the selection of normal water level.

Therefore, based on the comprehensive analysis of reservoir inundation reduction and economical efficiency, the normal water level of Yakou Shipping Hub Reservoir is recommended to be 55.22m, which may meet the shipping demand (linking with the minimum navigation water level of upstream Wangfuzhou Hydro-junction) as well as realize the reasonable utilization of water resources in the river section.

3.3.1.3 Environmental rationality of hub arrangement plan

At the preliminary stage of program design, for the overall layout of the hub, the separate layout of ship lock and power station and the combined layout are taken into account. At this stage, three schemes are considered: Scheme I (right ship lock + sluice + hydropower station + sluice), Scheme II (right ship lock + sluice + left ship lock), and Scheme III (right ship lock + hydropower station + sluice).

The abovementioned schemes have several common points, such as successive parallel arrangement of main structures along the dam axis, using highway bridge to connecting the traffic between dam crest and left and right banks and open channel diversion. The difference relies on the difference of locations of hydropower station, sluice and ship lock as well as the resulting position change between structures. Analysis and comparison is carried out for environmental elements, as shown in Table 3.3.1-4.

Table 3.3.1-4 Comparison of hub arrangement plan

Item	Scheme		
	Scheme I	Scheme II	Scheme III
Arrangement plan	Ship lock on the right bank + right-channel 36-hole sluice + hydropower station + on the left bank + left-channel 12-hole sluice	Hydropower station on the right bank + 48-hole sluice + ship lock + on the left bank	Ship lock on the right bank + hydropower station in the middle + 48-hole sluice on the left bank

Navigation condition	Ship lock is located n the deep channel of the river bed on the right bank, upstream approach channel is smoothly connected to the main waterway through local dredging, and the central line of downstream approach channel is basically parallel to the main flow direction of waterway and is smoothly connected. The probability of collision risk is quite low.	Ship lock is located on the mudflats on the right bank, and the mudflats shall be excavated to build ship lock. Downstream approach channel is connected to the main waterway via. S-shape curve, and the connection section slants through the discharge area of the hub. The probability of collision risk is quite high.	Ship lock is located n the deep channel of the river bed on the right bank, power station is close to sluice, and the water diversion at the inlet and the effluent of tail water channel may disturb the navigation water flow of the ship lock to a certain extent.
Flood discharge condition	Sluices are distributed dispersedly, basically conforming to the conditions of natural flood discharge, changing river regime slightly and favorable to ecological regulation.	Sluices are distributed centrally with long span, and there is severe side shrinkage of the water flow in front of dam, which is disadvantageous to fish breeding in flood discharge period.	The same as Scheme II
Operation condition	Hydropower station is located on the mudflats on the left bank, and the outgoing line shall cross cover ship lock and sluices, flow conditions of the outlet are bad, and fish luring effect of fishway is unsatisfactory.	Hydropower station is located in the main river channel on the left bank, it is convenient for line outgoing, flow conditions of the inlet and the outlet are good, and fish luring effect of fishway is good.	Hydropower station is located in the main river channel on the left bank, the outgoing line shall cross cover ship lock, flow conditions of the inlet and the outlet are good, and fish luring effect of fishway is good.
Construction condition	Adopt three-stage diversion mode. At the first stage, utilize the original riverbed for discharge and navigation; at the second stage, utilize open channel excavation for discharge and navigation; at the third stage, ship lock is open to navigation and 36-hole sluices are used for discharge; mixing systems shall be installed on both banks; time limit for power generation is 46 months.	Adopt three-stage diversion mode. At the first stage, utilize the original riverbed for discharge and navigation; at the second stage, narrowing the river bed through dredging; at the third stage, ship lock is open to navigation and 24-hole sluices are used for discharge; mixing systems shall be installed on both banks; time limit for power generation is 54 months.	Adopt three-stage diversion mode. At the first stage, utilize the original riverbed for discharge and navigation; at the second stage, utilize open channel excavation for discharge and navigation; at the third stage, ship lock is open to navigation and 48-hole sluices are used for discharge; time limit for power generation is 46 months; ship lock and hydropower station are arranged together and construction may cause certain disturbance.
Geological condition	Because the geological conditions along the dam axis are simple and single, and the composition structures are basically the same. The difference is only relying on the fluctuation of landform conditions and the difference of overage thickness, and there is no condition restricting dam construction. However, in all Schemes, there are problems such as insufficient bedrock strength, differential settlement and effect of confined water on foundation.		

According to comprehensive analysis, the above-mentioned three schemes have merits and demerits respectively in terms of navigation condition, operation condition, flood discharge condition, construction condition, and geological condition, while the three schemes have equivalent quantities and equivalent environmental impact extent. Scheme I with better navigation condition as recommended for the main works is approved, namely, adopting “right ship lock +sluice + hydropower station + sluice”. Moreover, the project will be equipped with two berthing anchorage grounds, 1.7km upstream and downstream from the ship lock respectively, both of which don’t involve drinking water source or domestic water intake, and purchased barges are used as anchorage grounds, which may reduce riverbed disturbance and is favorable to water environmental protection. Therefore the scheme of anchorage ground is of environmental feasibility.

3.3.1.4 Environmental rationality of river diversion during construction and initial impounding program

Against large flow and wide river channel at the dam site of Yakou hub and according to navigation requirements, stage diversion shall be adopted for Yakou hub. Based on the analysis of the layout of Yakou hub and with reference to similar projects, two schemes are put forward for stage diversion: Scheme ①: adopting the mudflats on the left side and combine with 12-hole sluice on the left bank to excavate open channel, coffer ship lock on the right bank, 26-hole sluice on the right bank and the large foundation pit of the hydropower station; Scheme ②: narrow riverbed, and coffer ship lock on the right bank, hydropower station on the left bank and some sluices.

The diversion procedure in Scheme ① is simple, but the quantity of dredging and excavation is large; as per Scheme ②, longitudinal concrete cofferdam shall be built for narrowing the riverbed, but the coverage of the riverbed at the dam site is thick and it is difficult to build longitudinal concrete cofferdam. Therefore, at this stage, the stage diversion scheme of open channel excavation is selected, namely, at the first stage, excavating the mudflats on the left side to form open channel; at the second stage, coffering the main riverbed on the right side and building ship lock on the right bank, 36-

hole sluice on the right bank and hydropower station; at the third stage, coffering diversion channel, and building 12-hole sluice on the left bank and earth dam. In this period, 3rd stage cofferdam is used for power generation in dry season.

In Scheme I, the 1st stage diversion standard is 5-year return period, and the 2nd stage and 3rd stage diversion standard is 5-year return period. In case of the flood of 10-year return period, the water surface profile at the dam site is heightened by 1.72m at most compared with natural water surface profile, and the maximum water level at the dam site reaches 54.72m, 1.15m lower than the actual flood water level in 1964, 55.87m, which cause no impact on flood discharge safety. During construction the water level in front of cofferdam upstream shall be controlled within 54.72m, which may minimize temporary inundation loss. Therefore, the diversion scheme recommended at this stage has the minimum adverse environmental impact.

It is observed that there is no water impoundment at the first and second stage of diversion and water will be discharged as per natural inflow water; at the end of 3rd stage diversion, i.e., in initial impounding period, the reservoir begins water impounding in early October of the fifth year. When the inflow of Yakou dam site is not greater than 450m^3/s, water will be discharged as per inflow; when the inflow is greater than 450m^3/s, water will be discharged at 450m^3/s, and the redundant water will be stored in the reservoir. At 85% of the inflow, it will take 22.89 days to impound water from the reservoir bottom to normal water level 55.22m. The water impoundment time is not long, and the minimum discharge volume when impounding water is 450m^3/s, which has no impact on downstream shipping and ecological water demand in the riverway. Therefore, the initial impounding scheme is of environmental rationality.

3.3.1.5 Environmental rationality of project operation scheduling program

According to the reservoir operation scheduling program, when dam site discharge is greater than or equals to 8,710m^3/s, the power station stops power generation, and the discharge flow of sluices increases to reduce the reservoir water level until recovering natural status. When the hub is open to discharge, the flow rate at the sluice gate is 0.55 ~ 2.41m/s, and some fishes can swim upstream above the dam and the river above the dam may partially recover natural status and meet corresponding breeding conditions. However, after South-to-North Water Transfer Project is put into operation, there is quite low probability of reaching open-discharge flow. In order to mitigate the adverse impacts of the project construction on fish breeding, migration and important habitats, on the basis of the existing reservoir operation scheduling mode, Yakou Shipping Hub Project increases ecological regulation, that is, in fish breeding season from May to August every year, joint ecological regulation of hydro-junctions at the main stream of Han River above Danjiangkou will be carried out at least twice in combination with the flood process of Tangbai River. In high and normal flow years and in low flow year, when the flood flow of Tangbai River reaches $600m^3/s$ and $300m^3/s$ respectively, Cuijiaying, Yakou and Xinglong Hydro-junctions will be open ahead of schedule to discharge flood, in order to provide the fish with conditions for swimming upstream to spawning grounds. The open discharging will last 5~7 days until the flood peak finishes, so that the roes may drift downstream below the dam. This scheduling program has little impact on peak flood process, will not change water level amplitude within day, and may minimize the impact on spawning ad breeding of fishes spawning drifting roes. Therefore, the project operation scheduling program is reasonable.

3.3.2 Analysis of environmental rationality of construction planning

3.3.2.1 General construction layout

In the main works design, the basic state policy of treasuring and reasonably utilizing each inch of land and effectively protecting cultivated land has been carefully implemented, in order to minimize permanent land acquisition and protect local land resources to the maximum. According to the characteristics of project structure layout and river diversion during construction, and in combination with topographic and geological conditions of the dam site, construction sites are arranged on both banks, focusing on the right bank with higher construction intensity. There is no bridge between banks. At the first and second stages of diversion, temporary wharfs are built. After the third-stage cofferdam is built, the dam crest on the right bank that has been completed will be connected to the third-stage cofferdam. Therefore, during construction, temporary facilities such as concrete system and integrated process plant can be arranged on the site on the right bank, and the materials transportation on the left bank may be carried out hub structures and third-stage cofferdam. In this program, the layout is relatively concentrated, which is convenient for future production and management, reduces land occupation, dramatically reduces surface disturbance and is favorable to land resources protection and water and soil conversation. Besides, in combination with construction sequence, excavation and backfilling balance shall be realized and waste soil shall be reduced to the great extent. For the construction of Han River Yakou Shipping Hub Project, there is no significant factor restricting environment, and local impact may be mitigated with corresponding measures.

3.3.2.2 Environmental rationality of stock grounds

a) Quarries

In the project, the demand for concrete is 8.3.9 thousand m^3, and the demand for aggregates is 1,692 thousand tons. According to field investigation, in the main works design, it is proposed to outsource stone materials and sand-gravel materials, and the surrounding material sources are sufficient. Matoushan Quarry is selected preliminarily, which may avoid a series of adverse environmental impacts caused by new quarries, and this quarry is of certain mining scale, the reserve and quality of which can meet the requirements of the project. There are built highways between the dam site and the quarry, with convenient traffic, and it is an ideal project quarry.

The construction unit shall well cooperate with the seller or the supplier, pay attention to solving the conflicts between stone and gravel mining and environmental destruction, plan the work as a whole, and minimize the environmental destruction such as vegetation deterioration in the mining area. As for outsourced stone materials and gravel materials, on the principle of whoever causes destruction, whoever provides protection; whoever causes water and soil erosion, whoever is responsible for restoration”, the responsibility of prevention and treatment shall be borne by the seller. When entering into purchasing contract with the mining party, the construction unit shall make clear that the mining party shall be responsible for environmental protection and water and soil conservation in the quarry, and define the mining party as the party responsible for prevention and protection. The mode of materials outsourcing may avoid vegetation deterioration and water and soil erosion increasing caused by mining, cultivated land and park land occupation and resettlement. Therefore, the mode of outsourcing sand and gravel materials may effectively reduce the adverse environmental impacts of the project.

b) Borrow area

Most of backfilling materials required by the project may use excavated materials, and both the quality and the quantity can meet the project demand. Therefore, the borrowed earth materials are mainly clay, used for cofferdam filling, and the volume is 81 thousand m^3. According to the geological investigation, a gentle slope at Yujiawan in Yakou Village, Liushui Township on the left bank, about 2km away from Yakou dam site, may meet the clay demand. One borrow area is set, and it is connected to rural highway, with convenient traffic.

Earth will be borrowed from the top of the gentle slope, and cultivated land will be occupied. Prior to excavation, the surface arable soil shall be stripped, and the stripping thickness is 30cm. the average excavation depth is 1.5m, and the borrow area shall be excavated as needed. After completion, the topsoil shall be returned for second plough. In the program, the preventive measures for stripping topsoil shall be supplemented.

The proposed borrow area is not in collapse and landslide danger area or high-happening area of debris flow, and both the quality and the reserve may meet the project demand. According to the analysis in terms of water and soil conservation, second ploughing will be carried out in the borrow area after temporary land occupation, conforming to the requirements of technical specification for water and soil conservation. For the borrow area, drainage measures shall be added, and temporary earth piling shall be protected by corresponding retaining structures, in order to reduce water and soil erosion. According to the survey, there is basically no vegetation in the borrow area and the area with local residual soil layer has been cultivated and becomes dry land, so the impact of the excavation on biodiversity is quite small. However, the borrow area is only 80m away from the nearest resident point, excavation area shall be marked off and shall be as far away from the resident point as possible, so as to reduce the impact on sensitive spot.

To sum up, the stock ground selection is of environmental rationality, and it is suggested to further strengthen detailed geological survey, optimize the stock grounds, and utilize the excavation materials and reduce waste materials to the greatest extent at the next stage of design.

3.3.2.3 Environmental rationality of construction road planning

Because the transportation volume of earth work is large and the construction intensity is high, the traffic on sit site mainly adopts highway transportation, and highways will be built to working area on both banks upstream and downstream from the dam site. In the area, there is no environmentally sensitive objective such as nature reserve and scenic spot, and no national protected animal and plant; after relevant prevention measures are taken, the adverse environmental impact of road construction on the resident point may be mitigated to the greatest extent; the vegetation in the affected area mainly involves secondary vegetation, mainly shrub wood, and the geological condition is relatively stable. In the design, excavated materials produced during highway construction will be used for unified backfilling, effectively reducing the impact on landform, soil and vegetation.

Therefore, from the prospective of environmental protection, corresponding protective measures shall be taken for the resident points along the highway. After the measures for vegetation protection and water and soil erosion prevention during construction are adopted, the planning program for in-site traffic roads will be reasonable.

3.3.2.4 Environmental rationality of waste dump

In the hub project zone, the waste is mainly produced by diversion channel excavation, sluice works, cofferdam removal and hydropower station works. According to construction procedures, Waste dumps are distributed on the mudflats on both banks near the hub project zone. After excavation, spoil may be directly transported to the corresponding water disposal grounds, and there is no need for transfer or crossing-river disposal. In combination with the construction procedures, excavation and backfilling balance shall be realized to the greatest extent, and greatest efforts shall be made to reduce land occupation by waste. In the project, three waste dumps are proposed, in order to avoid randomly storage of spoil, which is favorable to water and soil conservation. The waste dumps are located on both banks, which may reduce transportation distance and decrease noise and dust pollution.

① Waste dump is located on the right bank upstream from the hub project zone. The area of occupied land is 20.09hm², and the occupied land is dry land. The volume of waste piling is 803.4 thousand m³ (natural square, the same below), the average piling height is 4.0m, and the side slope is 1:3. It is a reservoir-type and flat-type ground, and mainly used for storing waste produced by sluice works, hydropower station works and cofferdam removal. The waste top elevation is 58.0m.

② Waste dump is located on the left bank upstream from the hub project zone. The area of occupied land is 23.00hm², and the occupied land is inland intertidal zone and forest land. The volume of waste piling is 1,352 thousand m³, the average piling height is 6.0m, and the side slope is 1:3. It is a reservoir-type and flat-type ground, and mainly used for storing spoil produced by diversion channel excavation and cofferdam removal. The waste top elevation is 58.0m.

③ Waste dump is located on the overflow lands on the right bank 3.5km upstream from the hub project zone. The area of occupied land is 60.00hm², and the occupied land is dry land and forest land. The volume of waste piling is 2,670 thousand m³, the average piling height is 4.5m, and the side slope is 1:3. It is a reservoir-type and flat-type ground, and mainly used for storing waste produced by diversion channel excavation. The waste top elevation is 58.0m.

In addition, according to the construction procedures, after the construction site and camps are completed, second plough or vegetation restoration has been carried out for the waste dumps. The spoil of 26.4 m³ produced by removal of hardened layer is used for leveling nearby farm machinery accesses.

The waste dumps of the project occupy the land outside of the levee upstream from the dam site, and they are reservoir-type and flat-type waste dumps. The current state mainly is cultivated and forest land, and now the land used by local peasants for farming and will be inundated after the hub is completed. The spoil of the project may heighten the mudflats within the range of land occupation and reduce inundation, and the land may be used for farming after land reclamation. The project is a runoff-type power station, and the effective reservoir capacity occupied by the waste dump on the mudflats upstream from the project hub zone has quite little impact on power station. According to the main works design, such measures as retaining, drainage and second ploughing of occupied cultivated land and forest land will be taken, conforming to the requirements of technical specifications for water and soil conservation.

Partial area of the waste dumps on both banks may be used as construction layout area after waste dumping, in order to reduce land occupation and adverse impact on ecological environment in the assessment area. In the waste dump, natural geological disaster doesn’t develop, geological conditions are good, and slope is gentle. Therefore, as long as waste piling planning is done well and necessary prevention measures are taken, no ecological environmental damage such as water and soil erosion will be caused. From the prospective of environmental protection, the selection of waste dumps is reasonable.

3.3.2.5 Environmental rationality of resettlement plan

Because the affected immigrants have form their unique living habits and social relation networks in the long-term process of life, in order to cause no impact on their living habits, not damage their social relation network and not increase original cultivated radius, the immigrants of the affected villages shall be resettled nearby based on the resettlement planning, so as to maintain their original living and production styles, habits and social relationship and enhance their positivity and adaptability in production and living. Rural immigrants will still focus on crop farming and breeding industry, and the driver for agricultural development will be enhanced through improving farmland infrastructures and adjusting agricultural structures.

The resettlement plan fully considers local resources and environmental conditions, and unified planning is carried out for infrastructures in resettlement area, which will improve house, road and water resources conditions for immigrants. Meanwhile, follow-up support is considered in order to improve production and living level of immigrants and promote harmonious and sustainable development. On the premise of carrying out various measures, the resettlement plan is conforming to the requirements of environmental protection. However, it is required to strengthen ecological impact control and water and soil erosion regulation during construction and promote the construction of environmental protection projects such as sewage and domestic waste treatment.

3.4 Project impact sources

3.4.1 Construction impact sources

3.4.1.1 Construction wastewater (sewage)

a) Drainage of foundation pit

a) Drainage of foundation pit

Drainage of foundation pit is divided into initial drainage and routine drainage. Initial drainage comprises water accumulating volume in foundation pit after water tight treatment of cofferdam, water seeping volume of cofferdam and foundation during pumping, water seeping volume surrounding the cofferdam, water content of cofferdam and foundation pit coverage and precipitation. Routine drainage is mainly composed of water seepage of cofferdam and foundation, water seepage surrounding the cofferdam, construction wastewater and precipitation. According to the survey on in-construction and built power stations, the routine drainage of foundation pit is mainly precipitation and water seepage, the volume of concrete curing water and flushing water is quite small, and the increment of suspended substances and pH value is also quite small. According to the monitoring data about built-up projects, alkaline water produced by concrete placement and curing makes pH value of the waste water in local water area of foundation pit rise by 11 ~ 12 to the maximum and the concentration of suspended substances reach 2000mg/L. Direct drainage may cause adverse impact on the water quality upstream from the dam site.

The longitudinal and transversal cofferdam foundation pits at the second stage are proposed to be drained within five days, and the longitudinal and transversal cofferdam foundation pits at the third stage are proposed to be drained within five days. Five pumps will be used at each stage (lift 33m; pump discharge 800m^3/h). In this period, the intensity of routine drainage is 200m^3/h, and the equipment for initial drainage will be used.

Flocculating agents shall be added into the foundation pit prior to drainage, and the water shall be left standing still for two houses and then be drained. According to the experiences of other hydropower projects in foundation pit wastewater treatment, the above-mentioned method is reasonable, effective and cost-saving. SS of pumping drainage of the upper layer of foundation pit usually is ≤70mg/L, meeting the requirements.

b) Wastewater of sand and gravel processing system

The total concrete quantity in the project (including diversion works) is 803.9 thousand m^3, and the demand for sand and gravel materials is 2,163 thousand tons. The sand and gravel processing system is placed in Matoushan quarry, and the processing capability is 500t/h, production capacity 400t/h, and water consumption in peak hours $400m^3/h$. In consideration of 10% loss of water volume caused by surface water content, evaporation and seepage, the other 90% will become production wastewater. Calculated on this basis, the wastewater output of sand and gravel processing system in Matoushan quarry is $360m^3/h$ in peak hours, and the converted discharge is $0.10m^3/s$.

The wastewater of sand and gravel processing system is featured by large volume and high SS concentration. According to the characteristics of sand and gravel source and processing and production methods, and with reference to field sampling measurement data about some in-construction and built power stations, it is determined that SS concentration of wastewater of sand and gravel processing system is about 25000mg/L, sand with grain size of 0.15mm ~ 5mm in wastewater accounts for about 15%, sand with grain size of about 0.1mm accounts for 79%, and sand with gain size less than 0.1mm accounts for 6%.

c) Waste of concrete mixing system

Concrete system is placed on the flat ground to the south of approach highway on the left bank of the hub. The peak-month concrete placement intensity is 65,000 m^3, and the design production capacity is 210 m^3/h. It is proposed to build a HL240-4F3000L concrete blending building (rated production capacity $240m^3/h$) and a HL120-3F1500L concrete blending building (rated production capacity $120m^3/h$). The wastewater of concrete mixing building is mainly flushing wastewater and is produced only when flushing the mixing building at shifting of duty, which will be finished with several minutes and is intermittent and instantaneous. Calculated at flushing once every shift, the flushing volume for one time is about $6m^3$, and three shifts are arranged every day, so the daily wastewater output of each system is about 30 m^3. Although the flushing wastewater volume is small, the wastewater is alkaline with high pH value at 11 ~ 12, and the concentration of suspended substances is about 2,000 mg/L.

d) Oily wastewater produced by machine maintenance

The oil contamination of the river section of the construction area is mainly caused by oil leakage of fuel machinery and transport vehicles in construction area and fuel leakage of construction machinery during operation and maintenance, and the oil will delivered by rainwater or artificial drainage into the river section of the construction area.

As per the quantities of construction machinery and vehicles, the output of oily wastewater caused by comprehensive processing plant and machine repair workshop in the construction area is about $20m^3/d$, and the maximum hourly drainage volume is about $2.0m^3/h$. The volume of wastewater is small, and the pollutants mainly include SS and petroleum, with concentration of 3000mg/L and 20mg/L respectively. If oily wastewater is directly drained into water body, oil slick will be formed on the water surface, and as a result the dissolved oxygen in the water cannot be recovered, which will impact water quality. Therefore, necessary treatment measures shall be taken and recycling and integrated utilization shall be carried out to the greatest extent.

e) Domestic sewage

The total construction term of the project is 58 months, and the number of construction workers in peak time is 1500. For the convenient of construction, the construction site and camps are arranged compactly. Calculated as per 80% of the water consumption indicator per capita (250L/person·d), the daily sewage volume per capita is 200L, and total daily domestic sewage volume in construction site and camps will be $300m^3$.

For hydropower works, the workers during construction mainly have meals in large canteen, and the domestic sewage is mainly from washing, and bathroom and canteen drainage. Domestic water consumption is large, and the main pollutants in the domestic sewage mainly include COD_{Cr}, BOD_5, TP, etc. Various indicators of the sewage are lower than those of urban domestic sewage. In analogy with built Cuiiaying Navigation and Hydropower Junction, the measured indicator values of domestic sewage in this project are shown in Table 3.4.1-1.

Table 3.4.1 Comparison between project domestic sewage and urban domestic sewage

Item	Cuijiaying domestic sewage	Urban domestic sewage
COD_{Cr}(mg/L)	120	300
BOD_5(mg/L)	55	150
TP (mg/L)	1.5	4

To sum up, the maximum output of regular production wastewater in construction peak time is about 4,700m^3/d. The wastewater is mainly produced by the production of sand processing system, but the pollutant composition is simple and mainly is SS carried by flushing wastewater, and it doesn't include toxic pollutant.

Characteristics of production wastewater and domestic sewage are as shown in Table 3.4.1-2.

Table 3.4.1-2 Characteristics of wastewater discharge during construction of Yakou Shipping Hub Project

Item		Discharge in peak time	Production position	Discharge period	Main pollutants and concentration
Production waste water	Wastewater of sand processing system	360m^3/h	Matoushan quarry	January in the 2nd year ~ May in the 3rd year	SS:25000mg/L
	Wastewater of concrete mixing system	60m^3/d	Mixing building on the left bank	January in the 2nd year ~ May in the 3rd year	SS: 2000mg/L pH: 12
	Oily wastewater	20m^3/d	Processing plant on the left bank	August in the 1st year ~ February in the 4th year	SS: 1000mg/L Petroleum: 20mg/L
Domestic sewage	Domestic sewage of living camps	300m^3/d	August in the 1st year ~ February in the 4th year	August in the 1st year ~ February in the 4th year	BOD5: 150 mg/L CODCr: 300 mg/L

3.4.1.2 Ecological impact sources

a) Vegetation occupied and damaged by project

During construction, hub building, construction site arrangement and quarry mining will occupy land and damage vegetation. The area of permanent and temporary occupied vegetation is 403.64hm^2, accounting for 1.30% of the assessment area of ecological environment, 211.07km^2. After the project is completed, except for some vegetation occupied by permanent building and unrecoverable, the other damaged vegetation may be recovered, and artificial greening measures such as planting grass, flowers and trees shall be taken to increase the vegetation coverage in the affected area, eliminate bare ground, and further reduce water and soil erosion. Therefore, the impact of the construction on vegetation is temporary and the vegetation is recoverable.

b) Water and soil erosion caused by project excavation

In the main works, project construction such as cofferdam construction, foundation pit excavation, quarry excavation and blasting and waste storage may change, damage or occupy original landform and vegetation to different extent as well as change original surface configuration and confluence conditions on the slope. In case that drainage and protection facilities are not arranged in time, it will easily cause surface erosion, gully erosion, collapse and debris flow and form new water and soil erosion. If spoil is stored randomly without necessary protection measures, water and soil erosion will is easy to occur, which may cause adverse impact on surrounding ecological environmental and also block riverway and impact flood drainage.

c) Fish habitats damaged by underwater construction

There will be a lot of construction workers during construction, various machineries will work under water. Physical factors like sound, light and electricity may cause adverse impacts on fish inhabiting, growth, breeding and immigration in the construction river section; during construction, washing of building materials and drainage of foundation pit may make the water in local river section muddy, reducing transparency and water quality, which is unfavorable to fish inhabiting, especially juvenile fish inhabiting. After the 1_{st}-stage cofferdam is built and the riverbed is narrowed, the water level will rise and the fall and the flow rate will increase, which may hinder downstream fishes from swimming upstream. In the period of initial impounding, the flow of the river section below the site may be reduced with certain time, and the breeding of downstream fishes may be affected.

3.4.1.3 Air pollutants

During construction, the air pollution sources are divided into two types. The first is dust caused by foundation excavation, filling, construction road excavation, concrete construction and vehicle transportation, and the main pollutant is TSP; the other is exhaust gas of fuel machinery and the main pollutant is NO_x. According to analysis, the main impacts of the project on atmospheric environment are caused by excavation, sand processing, concrete mixing, fuel oil and transportation.

a) Stock ground

The sand processing system in the program mainly undertakes the processing of 2,163 thousand tons of construction aggregates, including crushing, screening and transportation. According to *Guideline for EIA* (prepared by Xianyang Environmental Sciences Society and Xianyang Qindu District Urban and Rural Construction and Environmental Protection Bureau, published by Tianze Press), the dust emission coefficient of sand processing usually is 0.77kg/t of aggregates (including crushing, screening and transportation) without emission control, so the total calculated dust emission is 1,666.6t.

In the project, in the process of sand processing, spraying is adopted for dust suppression, and wet powder recovery devise is equipped. According to *Technical Manual for Three Wastes Treatment Works* (Exhaust Gas Volume), and in analogy with the monitoring data about other hydropower projects such as Three Gorges, the output of dust will be reduced by more than 99.0% after dust suppression measure is taken. Calculated on this basis, the dust emission coefficient of this system is 0.0077kg/t of aggregates and the total dust emission is 16.7t.

b) Construction area of main works

In the construction area of main works, the dust is mainly produced by earth-rock excavation, concrete mixing and highway transportation.

In the project, the total earth-rock excavation volume 14,137.5 thousand m^3, the filling volume is 6,853.8 thousand m^3, and the waste volume is 7,518.7 thousand m^3. The dust produced by open earth-rock excavation causes obvious impact on atmospheric environment. In analogy with the dust emission caused by earth-rock excavation in the Three Gorges Project, the dust emission coefficient will be 12t/10,000 m^3 (excavation volume) without prevention measures. Considering that the main works mainly involves excavation of sand and gravel coverage on the riverbed, the blasting volume is small and the excavation is carried out in humid environment, the dust volume will be far smaller than other projects. The dust emission coefficient of dam foundation excavation is defined as 0.06t/10,000 m^3, and the dust emission volume caused by earth-rock excavation is 58.1t.

In the project, the total concrete placement volume is 803.9 thousand m^3, and the converted quantity is 2,160 thousand tons. The primary pollutant is dust, mainly producing during cement transportation, loading & unloading and materials feeding. According to *Guideline for EIA*, the dust emission coefficient is 0.91kg/t without prevention measures and the calculated dust emission of this system is 1,965.6t. In this project, concrete mixing system adopts fully-enclosed mixing building and is equipped with bag filter. As per the parameters specified in *Technical Manual for Three Wastes Treatment Works* (Exhaust Gas Volume), the efficiency of bag filter can reach 99.0%, so the dust emission coefficient of the concrete mixing system in the project is 0.009kg/t, and the total dust emission is 19.7t.

c) Transportation system

In the project, the outsourced materials are mainly delivered through highway transportation. In addition, stone materials, concrete and waste during construction are also delivered through highway transportation, and thus a large number of vehicles will be used as transportation facilities. Vehicle fuel will produce exhaust gas like NO_2, and vehicles will produce dust during running. Therefore, highway transportation will cause certain impacts on the quality of atmospheric environment.

To sum up, during construction, concrete mixing, vehicle transportation, earth-rock loading & unload, blasting and mining of stock grounds, earth-rock excavation of foundation pit will produce a great deal of dust (especially in dry season), which may increase the concentration of TSP in air, cause certain impacts on atmospheric environment and inconvenience surrounding residents. Therefore, strict prevention measures shall be taken during construction, such as hardening roads within site, covering transport vehicles, using watering cart for regular watering, using dust removing equipment, locating the equipment and structures that may produce dust at the downwind area or far away from residential areas, etc.

3.4.1.4 Construction noise

Noise is mainly caused by construction excavation, drilling, blasting, sand crushing, transportation and machinery operation. According to the acoustic environment monitoring results about built projects, most of machinery noise is above 75dB(A).

a) Excavation noise

In the project, both foundation pit excavation and stone mining may produce nose and cause certain impacts on surrounding environment. 17 drilling machines will be used in the project. According to the measured results of noise produced by dam foundation pit excavation during the construction of Cuijiaying Hydro-junction, the average superimposed noise level within the range of 10m ~ 100m away from the dam is 95.7dB(A). If the noise produced by excavation and loading of large machinery and vehicle transportation is taken into account, the estimated superimposed noise level is about 96 dB(A) ~ 110dB(A). In analogy with Cuijiaying Hydro-junction, the superimposed noise level of this project is defined as 100dB(A).

b) Blasting noise

In the project, for foundation pit excavation, blasting operation is required, and blasting noise will cause impact on surrounding environment. According to the blasting test and monitoring results of Xiangjiaba Power Station, the average noise level within the range of 100m ~ 450m away from the blasting center is 128dB(A), and in analogy, the blasting noise level of this project is defined as 125dB(A).

c) Concrete mixing noise

In the project, concrete mixing system is placed on the right bank in the construction area. The noise of concrete mixing system is mainly produced during mixing operation of concrete mixing station, and will cause certain impacts on surrounding environment.

According to the noise monitoring results of the mixing building of Cuijiaying Hydro-junction during construction, when no sound insulation or noising reduction measures are taken, the measured noise values of stirring layer and discharge hole are greater than 90dB(A), and the measured value of discharge hole without discharging is 77dB(A). Based on calculation, the superimposed noise level when mixing building is working is 96 dB(A) ~ 99dB(A). When sound insulation measures are taken, the noise level of ancillary equipment like circular vibrating screen, air compressor and spiral lobe refrigeration compressor is 95dB(A), 90dB(A) and 95dB(A), respectively. If the production system is treated as a point acoustic source, the superimposed noise level of concrete system is 100dB(A).

d) Noise of sanding processing system

Sand processing system is placed in Matoushan quarry, and is equipped with four circular vibrating screens and two impact crushers. According to the noise monitoring results of sand processing system of Cuijiaying Hydro-junction during construction, the noise may reach 94 dB(A) ~ 106dB(A). In analogy, the noise level of sand processing system in this project is defined as 100dB(A).

e) Noise of transportation system

The external traffic of Yakou Shipping Hub Project is developed, and there are highways and waterways directly leading to the dam site. The transportation system includes highway and waterway transportation. The primary outsourced materials are transported to the dam site by waterway, and the water transportation only has little impact on surrounding acoustic environment. There are highways on both banks. In the project, the superimposed noise impact caused by highway transportation within site on the environment is predicted.

The highway traffic noise is related to traffic flow. According to the noise monitoring data of vehicle transportation of Cuijiaying Hydro-junction, the noise of single transport vehicle is 89 dB(A) ~ 92dB(A), and the noise of single transport vehicle in this project is defined as 90dB(A).

3.4.1.5 Solid waste

a) Domestic garbage

Compositions and characteristics of domestic garbage: the compositions of domestic garbage are affected by various factors such as living standard, living habits and energy structure. The domestic garbage in the construction site of the hydropower station has its own characteristics and mainly is organic kitchen waste. In addition, the relative contents of vegetation, plastic packaging bag, paper and brick slag are relatively high.

Domestic garbage output: according to the survey results of domestic garbage output in the construction area of Cuijiaying Hydro-junction, the domestic garbage output of construction workers in this project will be calculated as per 0.6 kg/person·day, and the domestic garbage output of office staff in PIU camps will be calculated as per 1.0 kg/person·day. According to the construction planning, the number of workers in peak time is about 1500, the number of office staff in PIU's camps in peak time is about 50, and the total construction term is about 58 months. Therefore, the estimated daily garbage output during construction is 1.5t, and total estimated garbage output during construction is 21,90t.

b) Wastes in construction area

There will be some wastes in the construction area, such as scrapped construction machinery and vehicle, worn steel materials, steel pipes, oil drums, packaging bags, wood and accumulators. If not disposed properly, these wastes may cause environmental pollution.

c) Spoil

In the project, earth-rock excavation and filling and spoil sources mainly include dam works, hydropower station, diversion works, ship lock works, temporary construction facilities, roads within site, stock grounds and cofferdams. The total spoil volume in this project is 7,518.7 thousand m³, including temporary waste of 1096.8 thousand m³ and permanent waste of 6,421.9 thousand m³. If not disposed properly, the waste may cause water and soil erosion and damage local landscape.

3.4.1.6 Other impact sources

In the project, the number of construction workers in peak time is about 1500, and the construction term is four years and ten months. The population density in the construction area increases sharply. If basic environmental sanitation facilities are insufficient, certain impacts may be caused on regional environmental sanitation, human health and social environment.

The project construction requires a great number of labors and building materials, and large scale of social logistics services are required for the living of construction workers and management staff, which may significantly increase local employment opportunity, increase peasant income and promote local economic development. The external traffic roads for the project construction will improve local traffic conditions and improve communication facilities.

3.4.1.7 Summary of pollution sources

The pollution sources, primary pollutants, pollution source strength, pollution source positions and discharge rules are summarized in Table 3.4.1-3.

Table 3.4.1-3 Summary of pollution sources of Yakou Shipping Hub during construction

Type	Pollution source	Main pollutant	Source strength	Total amount	Total discharge amount	Discharge rule
Water pollution source	Flushing wastewater of sand processing system	SS, 25000mg/L	$360m^3/h$	1950 thousand m^3	0	Point source, continuous discharge
	Flushing wastewater of concrete mixing system	SS, 5000mg/L;pH>10	$60m^3/d$	54 thousand m^3	0	Point source, discontinuous discharge
	Wastewater of machinery repair system	SS500-1000mg/L Petroleum 20mg/L~40mg/L	$20m^3/d$	22 thousand m^3	0	Point source, discontinuous discharge
	Domestic sewage of living and office areas	BOD, 200mg/L; COD, 400mg/L	$300m^3/d$	488 thousand m^3	0	Point source, continuous discharge
	Other scattered production wastewater	SS: 200-1000	Little	Little	0	Disorganized discharge
Air pollution	Dust of sand processing system	Dust	0.01-0.19kg/t (product)	118.2t	-	Disorganized discharge, surface

Type	Pollution source	Main pollutant	Source strength	Total amount	Total discharge amount	Discharge rule
						source
	Transport exhaust gas within site	CO	4.48g/km per vehicle	3.31-4.59 t/a	The same as the left	Disorganized discharge linear source
		THC	1.79g/km per vehicle	1.52-2.03t/a		
		NO_x	10.48g/km per vehicle	7.76-8.75t/a		
Air pollution	Blasting and excavation	TSP	47.49g/kg emulsion explosive	47.82t	The same as the left	Disorganized discharge, surface source
		NO_x	3.508 g/kg emulsion explosive	3.27t		
Noise pollution	Sand processing system	L_{eq}	115 dB	-	-	Fixed sound source
Noise pollution	Other construction faces	L_{eq}	85 dB -100 dB			Fixed sound source
	Traffic noise	L_{eq}	80dB~85dB	-	-	Linear source
	Blasting operation	L_{eq}	110dB~130dB	-	-	Intermittent and instantaneous point source
Solid wastes	Living and office areas	Domestic garbage	1kg/person. day	2190t	2190t	
	Main works	Spoil	--	1413.75 万 m^3		

3.4.2 Impact sources during project operation

3.4.2.1 Dam obstruction

The shipping hub dam obstructs fishes in the upper and lower reaches of Han River from swimming upstream and the catadeomous migration natural channels, and obstructs the gene exchange of fishes upstream and downstream.

According to the survey, although the built hub projects upstream and downstream from Yakou obstruct fish migration and reduce migratory fishes, at present, Yakou reservoir area is till the major spawning ground of four major Chinese carps and other migratory fishes. The construction of Yakou Shipping Hub will further change the original natural conditions of Han River and may cause various impacts on aquatic organisms including fish. For example, large change of hydrological conditions may change fish habitats; the change of original natural river status of Yicheng section of Han River may further polarize or shrink fish spawning grounds; dam construction may further obstruct the migration channels of parent fishes.

3.4.2.2 Initial impounding of reservoir

According to the general construction progress scheduling, the reservoir will begin water impounding in early October in the fifth year. Calculated as per 85% of the design guarantee rate of initial impounding, the minimum discharge volume of controlled sluice is $450m^3/s$, and it will take 20.2 days to impound water to the dead pool level 54.72m and take 2.69 days from the dead pool level to the normal water level 55.22m. As per the water demand of power generation of downstream water station, river navigation and downstream industry and agriculture, the water will be discharged to the downstream at $450m^3/s$ in the period of impounding. From October in the fifth year to January in the sixth year, the 3rd- cofferdam is utilized for water retaining and power generation.

Since the main riverbed is blocked until the water impounding meet the navigation requirements of ship lock, the navigation shall be suspended. The navigation suspension period is from 3rd-stage interception to the time when water impounding meets navigation requirements, and is about 1.5 moths, namely, from early October in the fourth year to middle November. In the navigation suspension period, freight transportation is all changed to highway transportation because the highways on both banks are smooth.

3.4.2.3 Reservoir operation control

The normal water level of Yakou hub is 55.22m, the corresponding reservoir capacity is 350 million m^3, and the dead pool level is 54.72m. The reservoir has daily regulation capacity, and the regulation reservoir capacity is 41.5 million m^3. Due to low head, in order to gain the maximum power generation benefits, the reservoir usually operates at normal water level and doesn’t involve system peaking operation. Yakou hub mainly bear base load in the system, and the shipping base load flow is $450m^3/s$; when the inflow in flood season is greater than $5000m^3/s$, the water level will be reduced gradually, and when the water level in front of dam is lower than the dead pool level or the power generation head is lower than 2m, the power station is shut down; if required in low flow season daily regulation may be carried out in combination with the system's capability and demand.

Due to water impounding in the reservoir, some original land in the reservoir area changes into water area, the original natural riverway changes into reservoir, hydrological regime of the river section changes to some extent, the flow of original natural riverway slows, the self-purification and degradation capability of water body reduces. In dry season, after pollutants enter the water body in the reservoir, the ability of water body diffusing pollutants reduces due to flow rate reducing, which may increase the resident time of pollutants in the reservoir and may affect oxygen and chemical substances in the water.

After the reservoir begins water impounding, a water area with suitable depth, slow flow and steady water level is formed in the reservoir area, the area of water surface and the water volume increases, which is favorable to the growth of aquatic organisms like algae and mollusks as well as to the natural breeding and growth of some fishes. After the project is put into operation, some organisms adapted to living in torrent may be instead of those living in slow flow. Fish population structure in the reservoir may change compared with that before the reservoir is built. Fishes preferring living in flowing water will reduce and those preferring living in static water may gradually increase.

After the reservoir begins water impounding, the water level rises and the area of water surface and the water volume increase. Some mudflats will be inundated, and water area with high thermal capacity replaces land with low thermal capacity. According to the analysis of similar projects, water conservancy projects are conductive to the regulation of local air temperature, increasing air temperature in winter and reducing air temperature in summer, and they will intensify the ecological functions such as air purification, mitigating urban heat island effect, regulating air humidity and improve microclimate environment. Meanwhile, the expanding of water surface may cause wind speed on the water surface to increase, and lake-land breeze may occur on both banks.

After the reservoir begins water impounding, the flow rate of the water body reduces and the water surface expands, providing conditions for vector breeding like mosquito. Meanwhile, rats move backwards due to reservoir inundation and immersion effects, which may increase the rat density surrounding the reservoir and the probability of insect-borne infectious disease. Based on the analysis of similar reservoirs in Hubei Provinces that have been put into operation, the insect-borne infectious disease may be controlled as long as the residents surrounding the reservoir can pay attention to food and drinking water hygiene, take periodic physical examinations, and regularly eradicate mosquito and rats.

3.4.2.4 Flood regulation

Yakou Shipping Hub doesn't undertake the flood control task downstream, and the flood control shall conform to the principle of not deteriorating the flood control conditions downstream. As per the flood carrying capacity of flood discharging structures, on the premise of the discharge volume not greater than the design flood discharge of the dam site, the flood shall be discharged as much as possible in order to guarantee the dam safety. The flood regulation principles of Yakou Shipping Hub are described as below:

①Regulation starting water level is normal water level;

②When the flood discharge at the dam site is less than or equals to the flood carrying capacity at corresponding water level, the flood will be discharged as per inflow; when the flood discharge at the dam site is greater than the flood carrying capacity at corresponding water level, the flood will be discharged as per the discharge capacity of the hub.

According to the survey, there may be spawning grounds of four major Chinese carps near Yakou dam site and in the reservoir area. Four Major Chinese carps, i.e., grass carp, black carp, sliver carp and bighead carp are migratory pleustonic fishes. After the hub is built, the channels of fish migration, foraging and spawning may be obstructed, causing adverse impacts on the natural growth and breeding of fishes. In Yicheng river section of Han River, an environmental suitable for Chinese carp spawning is formed due to geographical position and natural river characteristics, and a great number of parent fishes will swimming upstream along Yangtze River to this river section for spawning at the end of spring and the beginning of summer, i.e., from April to June. The impacts of the project construction on four major Chinese carps are mainly embodied in the period of operation. The hub construction changes water level and flow rate and may vanish some spawning grounds and obstruct the migration channels of parent fishes.

3.4.2.5 Waster discharge of power station

a) Power generation flow

The reservoir of Yakou Shipping Hub has daily regulation capability. The full-load flow of upstream Cuijiaying Hydropower Station is 2232m^3/s, and the rated flow in the program of 74.2MW installed capacity of Yakou Shipping Hub is 2291m^3/s. The full-load flow of Yakou power station basically equal to that of Cuijiaying Hydropower Station after interval inflow is considered. Because the riverway from Cuijiaying to Yakou is short, there is no large tributary inflow, both junctions are low-head power stations, the primary task of two junctions is shipping, and the power supply scope is Xiangyang power grid, the operation modes of both power stations are basically in synchronization.

For example, in low flow season(corresponding guarantee rate is 90%), the daily inflow of Yakou Shipping Hub is 640m^3/s, and the power station works in two control time frames. For eleven hours, the power station work according to the requirements of ship baseload, the reservoir discharges shipping base flow at 450 m^3/s and the corresponding output is 25.4MW; the power station work for thirteen hours at shoulder load, the discharge volume is 615m^3/s, and the corresponding output is 45.8MW. In dry season, the daily inflow of Yakou Shipping Hub is 870m^3/s, and on the premise of meeting the shipping base flow downstream the power station works in three control time frames. On the basis of meeting the shipping load of 25.4MW, the surplus energy storage output bears system shoulder load and peak load. When bearing shoulder and peak load, the discharge volume is 830m^3/s, and the corresponding output is 48.2MW; when bearing peak load, the power station works for two hours at installed capacity of 74.2MW.When the power station is fully loaded, the power generation flow is 2291m^3/s

b) Electricity output

When the power station is at normal water level 55.22m and at installed capacity 74.2MW, the dynamic indicators of Yakou Shipping Hub are as below: guaranteed output is 25.4/19.0MW (before /after Nianpanshan is built), the average annual electricity generation capacity is 322/253 million kWh (before /after Nianpanshan is built), and the time of utilization of installed capacity is 4,343/3,407h (before /after Nianpanshan is built).

3.4.2.6 Ship lock navigation

In comprehensive consideration of the building size of ship locks of Cuijiaying Hydro-junction upstream and Xinglong Hydro-junction downstream that have been built and Nianpanshan Junction that is to be built as well as the waterway construction standards of the river section below Xinglong and according to the waterway planning objectives at middle and lower reaches of Han River, Yakou Shipping Hub shall be built as per III (2) grade standard. Navigation guarantee rate: 8%; design ship type dimension: 67.5m×10.8m×2.0m (Length ×Molded width× Design draught); design fleet dimension: 167m×21.6m×2.0m (Length ×Width× Design draught); design fleet type: one pushing, four barges, double rows and double lines; design waterway dimension： 2.4m×90m×500m (Water depth × Width of double-route waterway ×Bending radius).

a) Domestic sewage of ships

According to Regulations for Minimum Safe Manning of Vessels of the People's Republic of China, the safe navigation speed of 1000t ship is 12 knots, and the fixed number of staff members on board is about 10. If it is assumed that the water consumption every person every day is 150L/(person·day) and the domestic sewage discharge coefficient is 0.8, the domestic sewage output of the ship can be estimated, and the concentration of main pollution factors, namely COD, BOD_5 and NH_3-N, is defined as 150mg/L, 50mg/L and 15mg/L.

According to the forecasting results of freight volume in different level years, and with estimating the number of sailing shipping and the duration of voyage as per typical ship type, the domestic sewage output of ships in different level years is shown in Table 3.4.1-1.

Table 3.4.2-1 Forecasting of domestic sewage output of ships

Level year	2020	2040	2050

	Upstream	Downstream	Total	Upstream	Downstream	Total	Upstream	Downstream	Total
Freight volume (10 thousand tons)	191	592.7	783.7	324.4	887.7	1212.1	465.2	1082.2	1547.4
Duration of voyage (h)	2.37	2.67	-	2.37	2.67	-	2.37	2.67	-
Sewage output (t/a)	226.34	791.25	1017.59	384.41	1185.08	1569.49	551.26	1444.74	1996.00
COD(kg/a)	33.95	118.69	152.64	57.66	177.76	235.42	82.69	216.71	299.40
BOD_5(kg/a)	11.32	39.56	50.88	19.22	59.25	78.47	27.56	72.24	99.80
NH_3-N(kg/a)	3.40	11.87	15.26	5.77	17.78	23.54	8.27	21.67	29.94

According to the forecasting results of domestic sewage output of ships, the domestic sewage output of ships in 2020, 2040 and 2050 is 1,017.59 t/a, 1,569.49 t/a , and 1,996.00 t/a, respectively.

b) Analysis of bilge water impact in waterways in the reservoir area

According to the distribution and the existing operation and organization modes of transport ships in the reservoir area, it is predicted that several ship types will still exist in the ship operation organization at middle and lower reaches of Han River in future, including cargo ship, push fleet, and barge pushed by cargo ship, and 500~1000t single cargo ship transportation and fleet transportation will gradually develop into the major operation modes. The design navigation ship tonnage of the ship lock is 1,000t, and the sewage discharge amount of ship during operation is estimated with 1,000t ship as a typical ship type.

According to the *Design Code of Environmental protection for Port Engineering* (JTS149-1-2007), the statistical data about the bilge oily wastewater output of ships of different tonnage is shown in Table 3.4.2-2, and the average oil concentration is 5000mg/L. In this project, 1000t ship is taken as the typical ship type, and the bilge oily wastewater output is 0.27t/d·ship.

Table 3.4.2-2 Output of bilge oily wastewater in ship of different tonnage

No.	Ship tonnage DWT(t)	Output of bilge oily wastewater (t/d·ship)
1	500	0.14
2	500 ~ 1000	0.14 ~ 0.27
3	1000 ~ 3000	0.27 ~ 0.81

No.	Ship tonnage DWT(t)	Output of bilge oily wastewater (t/d·ship)
4	3000 ~ 7000	0.81 ~ 1.96
5	7000 ~ 15000	1.96 ~ 4.20
6	15000 ~ 25000	4.20 ~ 7.00
7	25000 ~ 50000	7.00 ~ 8.33

According to the forecast results of freight volume in different level years, and with estimating the number of sailing shipping and the duration of voyage as per typical ship type, the safety navigation speed of 1000t ship is 12 knots, and the bilge oily wastewater output of ships in different level years is shown in Table 3.4.2-3.

Table 3.4.2-3 Forecasting of bilge oily wastewater output of ships

Level year	2020			2040			2050		
	Upstream	Downstream	Total	Upstream	Downstream	Total	Upstream	Downstream	Total
Freight volume (10 thousand tons)	191	592.7	783.7	324.4	887.7	1212.1	465.2	1082.2	1547.4
Duration of voyage (h)	2.37	2.67	-	2.37	2.67	-	2.37	2.67	-
Oily wastewater output (t/a)	50.93	178.03	228.96	86.49	266.64	353.14	124.03	325.07	449.10
Oil content (t/a)	0.25	0.89	1.14	0.43	1.33	1.77	0.62	1.63	2.25

According to the forecasting results of bilge oily wastewater output of ships, the bilge oily wastewater output of ships in 2020, 2040 and 2050 is 228.96t/a, 353.14t/a, and 449.10 t/a, respectively.

c) Exhaust gas and noise

During ship operation, the exhaust gas pollutants produced by the operation of marine power devices mainly include SO_2 and NO_2. However, because the time of ship passing through the ship lock is quite short, the impact of air pollutants emitted by the ship is quite small.

With the improvement of navigation capacity of the reservoir area, traffic noise produced by ships in the reservoir area and passing through the ship lock will increase to some extent. However, the ship noise is produced within the limited range and can be controlled with the measure of whistling restriction, and the value of noise contribution of ship traffic to the banks is very small, only about 1.0dB. Thus the impact on regional acoustic environment quality is limited.

3.4.3 Analysis of resettlement environmental impacts

3.4.3.1 Preliminary analysis of resettlement environmental capacity

The land acquisition for the construction of Yakou Shipping Hub Project affects 21 administrative villages involving cultivated land, all of which are located within the territory of Yicheng City. Environmental capacity analysis is carried out for the affected villages with the indicator of per capita cultivated land. After reclamation and regulation, if the per capita cultivated land in affected villages reaches the production arrangement standard of 2mu, it is considered that the environmental capacity of this village is sufficient, and the resettlement population can be resettled within the territory of such village. Otherwise, the resettlement population shall be resettled outside of the village. According to survey, the production arrangement of Yakou reservoir area involves agricultural population of 23,401persons in 24 villages and 6 townships, the area of existing cultivated land is 145,543.9mu, the area of per capita cultivated land is 2.39mu, the area of cultivated land inundated by reservoir is 4,008.82mu and the area of remaining cultivated land is 105,535.1mu. After regulation of cultivated land of 5530mu, the area of per capita cultivated after project construction is 1.75mu, slightly lower than the average level of Yicheng City, 2.39mu. On the whole, the environmental capacity in the reservoir area is relatively sufficient, and resettlement can be realized through regulating cultivated land. According to analysis, all of the cultivated land inundated by the reservoir is distributed in rural area, the inundated cultivated land of each village is small and decentralized, and the remaining cultivated land resources of each village are still abundant. The villages affected by reservoir inundation can improve the yield and the benefits per unit area of remaining cultivated land and make up for the loss caused by inundated cultivated land through various approaches such as agricultural structure adjustment, crop variety transformation and increasing science and technology input. Most of the affected people can be resettled within the territory of the original village through cultivated land regulation, and there is no need for emigration resettlement.

3.4.3.2 Preliminary EIA of resettlement work

By the level year in the planning of Yakou Shipping Hub Project, the production resettlement population in the reservoir area will be 23307 and that in the construction area of hub works will be 94; totally 5530mu of cultivated land shall be regulated; the total relocation population is 1805, and all are in the reservoir area of the hub works, including 1378 persons in reservoir inundation area and 351 persons in construction areas of other water conservancy works. According to the preliminary planning, the mode of decentralized and backward resettlement within the territory of original village will be adopted, and the resettlement standard is 80 m^2 of homestead per household. Production arrangement for migrants is mainly agricultural arrangement. It is required to reasonably utilize the exploitable resources in reservoir area and resettlement area, support and encourage some conditional migrants to go into business and adopt multi-channel and multi-type resettlement. Considering the living habitats in the project area, the backward resettlement shall be adopted. Besides old-age security, seeking refuge with relatives and friends and seeking self-employment, the combination of cultivated land adjustment with developing and transforming land for centralized house building shall be adopted. In the reservoir and the resettlement area, there is no ground cultural relic or historic site to be directly inundated. The above-mentioned measures such as house building, land development and transformation and centralized infrastructure arrangement may results in water and soil erosion and cause some impacts on land utilization and agricultural economy.

3.5 Screening of assessment factors

3.5.1 Identification of environmental impact

Based on project analysis and environmental overview, according to engineering development tasks and project compositions, and in combination with project features and environment characteristics as well as the property and extent of possible impacts on environment, the environmental impact factors of this project are screened, so as to make preparation for determining major assessment factors. The identification of environmental impact factors of the project are shown in Table 3.5.1.

Table 3.5.1 Identification of the characteristics of environmental impacts of the hub project

Subject		Environmental protection objective	Contents and characteristics of environmental impact		Relationship between project and environmental impact
			Construction period	Operation period	
Environment	Water environment	Water quality of water body of Han River	a. Hydrological regime: direct impact, short-term/irreversible impact, with significance and sensibility; b. Water quality of riverway – direct impact, short-term/reversible impact, with significance and sensibility;	a. Hydrological regime: direct impact, long-term/irreversible impact, with significance and sensibility; b. Water quality of riverway – direct impact, long-term/irreversible impact, with significance, sensibility, cumulativity;	The project implementation changes hydrological regime, and accordingly change the impact of hydrological regime on pollutant transfer as well as the contribution rate of pollution source to water quality
	Ecological environment	Aquatic organisms of Han River, fish spawning ground, and waterfront landscape of Han River	a. Terrestrial ecology : direct impact, short-term/reversible impact, with significance; b. Aquatic ecology – direct impact, short-term/reversible impact.	a. Terrestrial ecology : direct impact, long-term/irreversible impact, with significance; b. Aquatic ecology – direct impact, long-term/irreversible impact, with significance and sensibility;	The project implementation will inundate some land and eyots and change the original terrestrial ecology into aquatic ecology. Meanwhile, the change of hydrological regime causes impact on fish migration; the vanishing of eyots will affect fish spawning and breeding as well as the species and quantity of fish.

Table 3.5.1 (Cont.)

Subject		Environmental protection objective	Contents and characteristics of environmental impact		Relationship between project and environmental impact
			Construction period	Operation period	
Environment	Ecological environment	(the same as above)	c. Water and soil erosion : direct impact, short-term/reversible impact, with significance; d. Landscape– direct impact, short-term/reversible impact, with significance;	c. Water and soil erosion : indirect impact, long-term/reversible impact; d. Landscape– direct impact, long-term/irreversible impact	(the same as above)
	Ambie	Air	a. Ambient air quality:	-	The hub project doesn't

Subject		Environmental protection objective	Contents and characteristics of environmental impact		Relationship between project and environmental impact
			Construction period	Operation period	
Environment	Ecological environment	(the same as above)	c. Water and soil erosion : direct impact, short-term/reversible impact, with significance; d. Landscape– direct impact, short-term/reversible impact, with significance;	c. Water and soil erosion : indirect impact, long-term/reversible impact; d. Landscape– direct impact, long-term/irreversible impact	(the same as above)
	nt air	environment quality in construction area	direct impact, short-term/reversible impact, with sensitivity		produce air pollutant by itself, and the atmospheric environmental impact is mainly embodied in dust pollution during construction
	Acoustic environment	Acoustic environment quality in construction area	a. Acoustic environment quality: direct impact, short-term/reversible impact, with sensitivity	-	The noise during operation mainly is nose produced by hydropower station, which basically have no impact on regional acoustic environment quality
	Solid wastes	Project waste and domestic garbage	a. Solid waste output: direct impact, short-term/reversible impact, b. Domestic garbage output: direct impact, short-term/reversible impact, without significance and sensitivity	a. Domestic garbage output: direct impact, long-term/reversible impact, not with significance or sensitivity	Construction waste and domestic garbage of construction workers may cause adverse impact on surrounding environment if not disposed properly
Environment	Social economy	Socio-economic development in project area	a. Economic development : indirect impact, short-term/reversible impact, with significance; d. Flood control situation– direct impact, short-term/irreversible impact	a. Economic development : indirect impact, long-term/irreversible impact, with significance and cumulative effect ; d. Drainage– direct impact, long-term/irreversible impact, with sensitivity and significance	The project implementation may change the industrial layout, traffic structure and regional power supply structure along the waterway of Han River. The rising of water level may cause inundation of some drainage outlets and cause drainage difficulty; narrowing riverbed during construction may cause certain impact on flood discharge.
Resourc	Land	Land use type	a. Land occupation by construction: direct impact, short-term/irreversible impact,	a. Land inundation: direct impact, long-term/irreversible impact, with significance	The project construction changes the land use types in the construction area and surrounding the reservoir

Subject		Environmental protection objective	Contents and characteristics of environmental impact		Relationship between project and environmental impact
			Construction period	Operation period	
Environment	Ecological environment	(the same as above)	c. Water and soil erosion : direct impact, short-term/reversible impact, with significance; d. Landscape– direct impact, short-term/reversible impact, with significance;	c. Water and soil erosion : indirect impact, long-term/reversible impact; d. Landscape– direct impact, long-term/irreversible impact	(the same as above)
es			with sensitivity		area
	Tourism	Scenic spot along Han River	-	a. Scenic spot: direct impact, long-term/irreversible impact, with significance	The project implementation may create new landscapes and increase scenic spots
	Minerals	Transportation of mineral resources below construction project	-	a. Mineral resources below construction project: direct impact, long-term/irreversible impact, without significance and sensitivity	There is no valuable mineral resources in reservoir inundation area
	Water resources	Water demand for resident production and living, ecological and environmental water demand and navigation water demand	-	a. Water resources regulation and utilization: indirect impact, long-term/irreversible impact, with significance	water resources regulation by the hub project may affect production and living water utilization, environmental water use and ecological water use along the banks upstream and downstream from the hub

According to Table 3.5.1, the environmental impacts during construction are mainly short-term and various impacts and those during operation are mainly long-term impacts.

Environmental impacts during construction include: vegetation deterioration near the dam site caused by earth borrowing and wasting and earth-rock excavation, which intensifies water and soil erosion; impact of nose of construction machinery on acoustic environment; air pollution caused by materials transportation and concrete mixing;

pollution of Han River caused by production wastewater and domestic sewage in construction area.

Environmental impacts during operation include: the reservoir changes original hydrological regime and is unfavorable to longitudinal diffusion of water pollutants. Meanwhile, the dam obstructs fish migration channels and the reservoir will inundate a great deal of land along the banks; the operation of highway bridge below dam may aggravate regional noise pollution, and the pollution of vehicle exhaust gas may be increased. However, the operation of reservoir will promote the development of regional water transportation, and hydroelectric generation, shipping convenience and highway bridge operation below dam will improve the traffic on both banks, facilitate regional economic development and be favorable to employment. Vegetation recovery is quite important, and it is beneficial to social environment, material resources, ecological environment and landscape quality.

3.5.2 Screening of assessment factors

The screening of EIA factors is shown in Table 3.5.2.

Table 3.5.2 Screening of assessment factors

environmental element	Impact factor	During construction	During operation
Social environment	Socio-economic development	●	●
	Land utilization	●	■
Ecological environment	Aquatic organism	■	●
	Vegetation	●	■
	Water and soil erosion	●	
Water environment	Hydrology	■	●
	Water quality	●	■
Acoustic environment	Noise of construction machinery	●	
Air environment	TSP	●	
	Vehicle exhaust		■
Remark	●-significant impact; ■-ordinary impact; blank-no significant impact		

Based on engineering analysis and environmental status survey as well as screening of assessment factors, we may preliminarily determine that the key work of the assessment is divided into three parts: ① Placing emphasis on predicting the impact of the project on regional hydrological regime and water quality change during operation; □② placing emphasis on predicting on the impact of ecological environment, including impact on vegetation and land use pattern change during construction as well as impact on aquatic organisms during operation; and ③ putting forward adverse impact prevention measures, so as to minimize the adverse impact of the project on environment.

3.6 Preliminary analysis conclusion

According to the analysis for the impact of the project on surrounding environment in the periods of construction, operation, reservoir inundation and resettlement, the impacts of the project building on the environment are mainly caused by engineering activities like project construction, reservoir inundation, resettlement and project operation, and the main conclusions of the project impact analysis are shown in Table 3.6 in details.

4 Environmental baseline

4.1 Natural environment

4.1.1 Climate

Han River basin is in the subtropical monsoon climate zone in East Asia, with mild weather and abundant rainfall. It is affected by high cold pressure of Eurasian continent in winter and is affected by western pacific subtropical high pressure. The climate has significant seasonal differences. It is severely cold in winner and extremely hot in summer.

a) Air temperature

Annual average temperature of Han River basin is 12°C ~ 16°C, and the air temperature to the south of Hanzhong is lower and increases from upstream to downstream. The maximum monthly average temperature is in July, usually 24°C ~ 29°C and the minimum monthly average temperature is in January, usually 0°C ~ 3°C. The maximum extreme temperature is 42.7°C in Yunxian County (July 19, 1966), and the minimum extreme temperature is － 17.6°C in Fangxian County (January 30, 1977).

Perennial mean temperature near Yakou dam site is 16°C. The maximum monthly average temperature is in July, usually 28°C and the minimum monthly average temperature is in December, usually 3°C. The maximum extreme temperature is 37.9°C and occurs on July 19, 1971, and the minimum extreme temperature is -16.5°C in and occurs on January 30, 1977).

b) Precipitation

The average annual precipitation in Han River basin is 700 mm ~ 1,800 mm, and the annual precipitation on the south bank is greater than that on the north bank, and the annual precipitation upstream is greater than annual precipitation downstream. The annual precipitation at the middle reach is distributed regularly. In the area, the annual precipitation distribution is uneven, and 60% is mainly centralized between May and October. The annual precipitation shows a decreasing trend from south to north. The annual average evaporation from water surface in Han River basin is 893 mm, and that from land surface is 513mm. The maximum evaporation is in June and July, and the minimum evaporation is in January.

According to the statistics of measured data from Xiangyang Weather Station upstream from Yakou dam site, the annual average precipitation is 813.8mm, the annual maximum precipitation is 1700mm (1963) and the annual minimum precipitation is 574.4mm (1966). Rainstorm usually occurs in July, August and September, and the precipitation in summer may reach 400~450mm. The number of annual precipitation days is 107~135.

According to the statistics of precipitation data for many years from Shayang (Third) Hydrological Station downstream from Yakou dam site, the annual average precipitation is 1,037mm, the annual maximum precipitation over the years is 1,530mm (1954) and the annual minimum precipitation over the years is 659mm (1966).The precipitation is mainly distributed between April and August.

c) Wind regime

The annual average wind speed in Han River basin is 1.0 ~ 3.0m/s, and the seasonally average wide speed doesn’t change obviously and is approximate to the annual average wind speed. The wind direction is of obvious monsoon characteristics. It is mainly NE wind in winter and SE wind in summer. The number of gale days is about 2 ~ 13, and the maximum average wind speed for ten minutes at each station is 17 ~ 24m/s. The maximum wind speed occurs in Ankang, 24.3m/s(SSW), and Zaoyang, 24.0m/s(S).

The annual average wind speed near Yakou dam site 2.3m/s, the annual maximum average wind speed is 11.5m/s, and the maximum wind speed over the years is 15.7m/s, occurring on May 14, 1983.

d) Fog regime

There is more fog in winter and spring, and the average number of fog days is 20 ~ 40, but the duration of fog within the day is not long.

e) Relative humidity

The annual average relative humidity of Yicheng City is 76%.

4.1.2 Hydrological sediment

4.1.2.1 Runoff

Yakou Shipping Hub is located at downstream from Danjiangkou Hydropower Junction, and the runoff is manly composed of regulation discharge of Danjiangkou and interval inflow between Danjiangkou and Yakou. The inflow runoff of Danjiangkou is regulated according to the regulation specification for Danjiangkou Reservoir and then is discharged, and the discharge volume of Danjiangkou is superimposed with the corresponding interval runoff, and the superimposed result is the inflow runoff of Yakou.

Considering the reduction of reservoir and industrial, agricultural and domestic water above Han River, the natural inflow runoff of Danjiangkou Reservoir is 38.1 billion m^3, the annual average natural reduction runoff between Danjiangkou and Yakou is 9 billion m3, the annual average natural inflow runoff of the dam site of Yakou Shipping Hub is about 47.1 billion m3, and the annual average discharge is 1,490 m^3/s.

In order to be consistent with the transferrable water volume series in the middle route of South-to-North Water Transfer Project, the inflow runoff series of Yakou Shipping Hub adopts 42-year runoff series from May in 1956 to April in 198, and the regulation calculation period is a period of ten days.

After the first-phase water transfer in the middle route of South-to-North Water Transfer Project in level year 2010, the annual average discharge volume of Danjiangkou Reservoir is 25.8 billion m^3, and the annual average runoff between Danjiangkou and Yakou dam is 9 billion m^3. Then, after water transfer, the annual average inflow runoff of Yakou Shipping Hub is about 34.8 billion m3, and the annual average discharge is 1,100m3/s.

The annual average runoff of the dam site of Yakou Shipping Hub is shown in Table 4.1.2-1.

Table 4.1.2-1 Annual average runoff of the dam site of Yakou Shipping Hub

Month	5	6	7	8	9	10	11	12	1	2	3	4	Year
Runoff (100 million m^3)	30.99	40.42	55.19	46.33	49.13	26.57	18.67	16.61	15.68	14.22	16.51	17.63	348

Annual averaag e discharg e (m^3/s)	115 7.0	155 9.4	206 0.6	172 9.8	189 5.4	992. 0	720. 3	620. 1	585. 4	587. 8	616. 4	680. 2	110 0.0

4.1.2.2 Sediment

The sediment at the dam site of Yakou Shipping Hub is from two sources, discahrge of Danjiangkou Reservoir and influx of Tangbai River and Nan River between Danjiangkou and Yakou. Due to the successive completion of a large number of reservoirs above Yakou, the annual sediment discharge at the dam side declines sharply.

The catchment area of Yakou Shipping Hub accouts for 94.8% of the control area of Nianpanshan Station, and there is no large tributary influx between them. The sediment at the dam site of Yakou Shipping hub may directly adopts the statistical results of sediment system of Nianpanshan Station (Huangzhuang).

Before Danjiangkou Reservoir was built (1956 ~ 1967), the annual sediment discharge of Huangzhuang Station is 119 million tons; after Danjiangkou Reservoir was built (1968 ~ 2010), incoming sediment upstream from Danjiangkou was mostly retained and stored in Danjiangkou Reservoir, and the annual sediment discharge didn’t reach 19 million tons, less than 15% of that before Danjiangkou Reservoir was built.

Before Danjiagkou Reservoir was built (1957 ~ 1967), the sediment was mostly from upstream. Before the reservoir was built, the annual sediment discharge of Huangjiagang Station was 77.3% of that of Huangzhuang Station, and the incoming sediment of Nan River and Tangbai River was 3.35% and 9.45% of that of Huangzhuang Station, respectively. After Danjiangkou Reservoir was built (1968 ~ 1990), the incoming sediment of downstream riverway was mainly from riverbed scouring, bank collapse and tributary supply. At the same time, the incoming sediment of Huangjiagang Station was only 4.01% of that of Huangzhuang Station, and the incoming sediment of Nan River and Tangbai River was 9.69% and 22.8% of that of Huangzhuang Station, respectively. Huangzhuang Station downstream from Yakoudam site keeps observation data about suspended sediment grading. In this project, the caculation is based on the measured data about suspended sediment grading between 1996 and 2010, and the median grain size is 0.04m, the average grain size is 0.09mm, and the maximum grain size is 0.78mm. The annual average suspended sediment grading of Huangzhuang Station is shown in Table 4.1.2-1.

Table 4.1.2-2 Suspended sediment grading of Huangzhuang Station

Grain size (mm)	0.002	0.004	0.008	0.016	0.031	0.062	0.125	0.25	0.5	1.0	Median grain size (mm)	Verage grain size (mm)	Maximum grain size (mm)
Percentage less than some grain-size sediment weight (%)	0.7	25.1	33.4	42.7	51.4	57.8	65.4	90.7	100	100	0.04	0.09	0.78

4.1.2.3 Relationship between water level and discharge at the dam site

Yicheng Gauging Station, built in 1929, is located about 15km upstream from Yakou dam site; Zhuandouwan Gauging Station, built in May, 1981, is located about 22km downstream for Yakou dam site. Yujiahu Hydrological Station is located bout 35m upstream from Yicheng, and began flow gauging in 2011. In this project, the measured water level and the discharge data of Yujiahu, Yicheng, Zhuandouwan and Huangzhuang stations are analyzed to propose the relationship between water level and discharge of Yakou dam site.

Based on the measured discharge data of Huangzhuang Station and Yujiahu Station in 1983, 2010, 2011 and 2012, Yicheng water level and Zhuangdouwan Water level in corresponding time frame are obtained through interpolation calculation, and hereby the corresponding water level at Yakou dam site is calculated. In 2012, the measured data about water level from the dedicated gauging station of Yakou dam site was analyzed and calculated. According to the measured data, the maximum flood peak discharge is 26,000m^3/s, occuring in 1983.

The relationship between water level and discharge of Yakou dam site is shown in Figure 4.1.2-1.

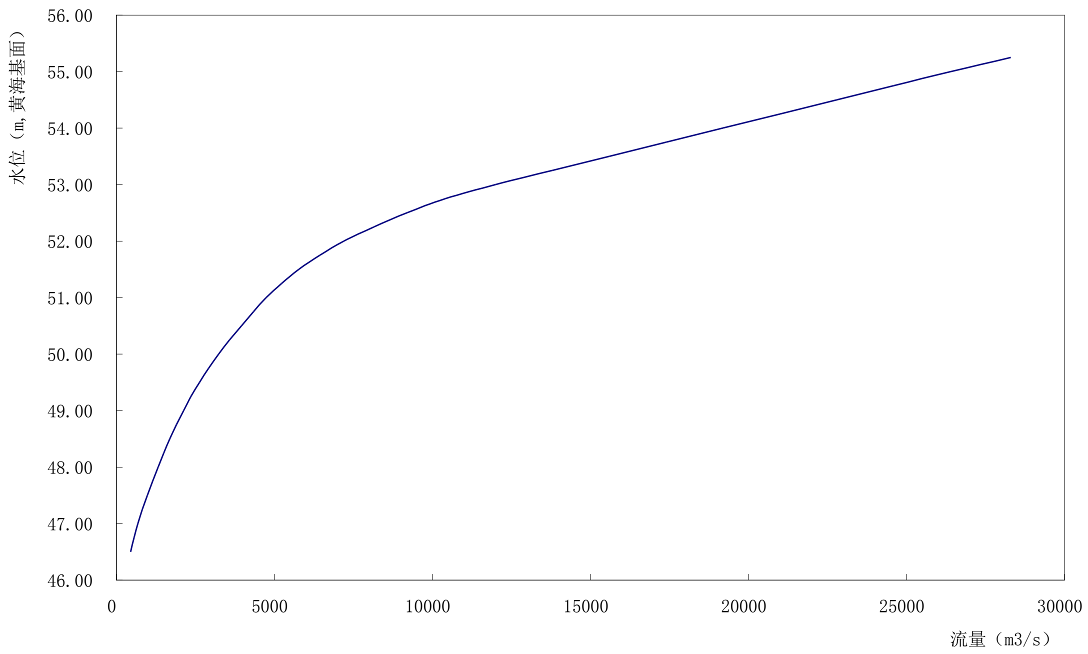


Figure 4.1.2-1 Relationship curve between water level and discharge of Yakou dam site

水位	Water level
黄海基面	Yellow Sea base level
流量	Discharge

4.1.2.4 Flood

a) Characteristics of rainstorm and flood

Rainstorm may occur in all regions in Han River basin. The rainstorm in summer mainly occurs in the area of Du River, Nan River, Dan River and Tangbai River below Bai River, and the rainstorm in autumn mostly occurs in the area of Micang Mountain and Daba Mountain in the southwest area above Bai River. In terms of season, rainstorm mainly occurs in July, August and September and may be postponed to the first ten days of October in individual years. The heavy rain with daily precipitation greater than 100mm mainly occurs in July, September second, and August third.

The flood of Han River is caused by rainstorm, and the spatial and time distribution of flood is consistent with that of rainstorm. Obvious rainstorm staging in summer and autumn is the most significant characteristic of the flood in this basin. Seen from the regional composition of flood, the major rainstorm areas causing flood in summer are Du River, Nan River and Tangbai River basins below Bai River, and the flood duration is short, the flood peak is high, and the flood often meets the flood of Yangtze River. The flood in autumn mainly occurs above Bai River, and the inflow of Ren River above Ankang is the largest. Besides, the flood in autumn usually has several successive peaks, and the peak discharge is large.

The annual average regional composition of the flood in Han River basin is shown in Table 4.1.2-3, and the discharge volume between Danjiangkou and Nianpanshan in the flood period (July ~ October) is 2% of that of Nianpanshan. In terms of season, the inflow of the summer flood between Danjiangkou and Nianpanshan is greater than that of autumn flood. Above Bai River, the inflow of summer flood is comparable to that of autumn flood.

Table 4.1.2-3 Annual average regional composition of flood in Nianpanshan between 1956 and 2003

Item		Bai River	Danjiangkou	Danjiangkou ~ Nianpanshan	Nianpanshan
Area (km^2)		59115	95217	45123	140340
July and August	Discharge volume (100 million m^3)	74.2	113	40.9	154
	% of Nianpanshan (%)	48.2	73.4	26.6	100
September and October	Discharge volume (100 million m^3)	73.8	105	23.1	128
	% of Nianpanshan (%)	57.6	82.0	18.0	100
July ~ November	Discharge volume (100 million m^3)	148	218	64.0	282
	% of Nianpanshan (%)	52.6	77.3	22.7	100

After Danjiangkou was put into operation at preliminary scale, the flood of Nianpanshan reduced significantly: in the period of “75.8” and “83.10” flood, the natural flood peak discharge of Nianpanshan reached 27,500m3/s and 40,400m3/s; after regulation and impounding at Danjiangkou, the downstream flood greatly reduced, and the actual flood peak discharge at Nianpanshan was 19,200m3/s and 26,100m3/s respectively.

b) Design flood of Yakou hub

The design inflow flood of Nianpanshan Shipping Hub comprises two parts: discharge flood after regulation and impounding of Danjiangkou Reservoir and the interval flood between Danjiangkou and Nianpanshan.

The design flood of Nianpanshan considers two combinations, namely, Danjiangkou

Reservoir and Nianpanshan have the same frequency and the interval from Danjiangkou to Nianpanshan is corresponding (Type A); and the interval from Danjiangkou to Nianpanshan and Nianpanshan have the same frequency and Danjiangkou is corresponding (Type B). Typical cases of flood select four typical cases: July in 1935, October in 1964, August in 1975 and October in 1983.

Table 4.1.2-4 Design flood results of Yakou Hub (Danjiangkou later-stage scale)

Unit m^3/s

Frequency	20%	10%	5%	2%	1%	0.33%
Flood peak	12000	13500	17000	20200	23000	27300

4.1.3 Water temperature

After Danjiangkou Reservoir was built, the water temperature of the main stream at middle and lower reaches of Han River is mainly affected by the low water temperature of regulation and discharge of Danjiangkou. According to the water temperature monitoring data of each regular monitoring section from December in 2008 to December in 2011 provided by Hubei Environment Monitoring Center, the values of water temperature at each monitoring section at middle and lower reaches of Han River and Tangbai River are obtained, as shown in Table 4.1.3.

Table 4.1.3 Water temperature statistics at different monitoring sections at middle and lower reaches of Han River (2008~2011)

Month	1	2	3	4	5	6	7	8	9	10	11	12	年平均
Above dam	9.5	9.5	11.5	12.0	22.0	20.0	29.0	30.0	26.0	21.0	19.0	12.6	18.5
Shenwan	8.8	9.0	7.5	11.5	14.0	18.5	20.5	24.3	22.4	22.0	24.0	10.5	16.1
Baijiawan	8.5	8.0	7.0	12.0	17.5	20.0	24.0	25.0	22.6	23.0	16.5	10.9	16.2
Yujiahu	11.3	11.4	7.5	14.3	19.5	21.5	25.6	26.0	24.0	23.5	17.0	12.6	17.8
Huangzhuang	6.8	7.5	7.5	13.5	20.0	20.0	25.5	24.5	24.5	21.5	14.0	11.0	16.4
Zekou of Qian River	6.6	10.1	9.4	16.5	22.4	23.4	27.8	27.0	23.2	21.5	12.6	12.0	17.7
Zhangwan of Tangbai River	9.4	9.6	11.5	12.2	22.3	23.0	28.6	29.0	26.5	22.8	18.3	13.7	18.9

Affected by the low-temperature water discharged from Danjiangkou, the water temperature at each monitoring section below Danjiangkou dam is generally lower than that at the monitoring section above dam, and the water temperature at the monitoring sections below Danjiangkou along the river shows a trend of increasing (except for individual monitoring sections). From August to October, from December to April and in June, the water temperature downstream from the dam site changes slightly along the river and the water temperature changes drastically along the river in other months, and the change in November is the largest. For the whole of the year, when air temperature is lower than water temperature, the water temperature along the river falls slightly; when air temperature is higher than water temperature, the water temperature along the river rises; when there is great difference between air temperature and water temperature, the water temperature along the river changes drastically.

4.1.4 Geological environment

4.1.4.1 Landform

a) Project area

Yakou Shipping Hub is located in the zone transition between Nanxiang Basin and Jianghan Plain. The elevation of northern Nanxiang Basin is 86.0 ~ 99.0m, the terrain slants towards southwest, and the elevation of surrounding mound and monadnock is 130 ~ 220m; southern Jianghan Plain is low and flat, the terrain slants to southeast from northwest, and the elevation is 23.0 ~ 40 .0m; to the east is low-relief mountainous area of Dahong Mountain, the terrain is high in north and low in south, the mountain top elevation is 600 ~ 900m, the main peak is 1,055m high, and the general cutting depth is 500 ~ 700m; to the east is the subregion of Zhongshan Valley in western Hubei Province, and it is the transition area from Daba Mountain to Jianghan Plain; the terrain is high in west and low in east, the elevation of mountain land usually is about 2,000m, and the highest land is 2,600 ~ 2,800m.

In the area, the spreading zone of Han River is a valley extending from north to south, the ground elevation is about 53 ~ 75m, and the riverbed width usually is 800 ~ 2,000m.

b) Dam site area

The dam site area is an open river valley in shallow U shape, and the riverbed is wide and shallow. The water level is affected by precipitation flood and the impounding and dischage of upstream reservoirs. The elevation usually is 47.0 ~ 49.5m, the water depth usually is 0.2 ~ 8.0m, and the width of water surface at dam axis is about 1,000m. The main riverway of Han River is located on the riverbed close to right bank, the width of water surface is about 500 ~ 1000m, the water depth usually is 4.0 ~ 6.0m, the maximum stream depth is about 8.0m, and the elevation of river bottom mostly is 43.5 ~ 45.4m.

The elevation of Grade-III terrace on the left bank is 63.0 ~ 72.0m, the height of riverside bank slope is 15.0 ~ 20.0m, and the gradient is 40° ~ 50°. On the right bank is flat and open Grade-I terrace, the width of terrace surface is 1,800 ~ 3,500m, and the ground elevation is about 53.0m. Yixi Levee is located on Grade-I terrace, 200~600m away from the riverside, the elevation of levee crown is 58.0m, the width is 5 ~ 7m, and the height is about 6m.

4.1.4.2 Formation lithology

a) Project area

Main exposed formation lithology in the project area is as below:

Sinian system: mainly sericite-quartz schist, calcareous slate and dolomite of Doushantuo Formation (Z2d) and dolomite of Dengying Formation (Z2dn);

Cambrian system: mainly dolomite, dolomite limestone and shale of Xihucun Formation (Є1y);

Cretaceous system: main tilloid, sandstone, glutenite, pelsparite containing silt and dolomite of Paomagang Formation (K2p);

Neogene system: mainly clay rock, glutenite, sandstone and marlstone of Duodaoshi Formation(Nd), and adhesion of partial glutenite and sandstone is loose;

Quaternary system: mainly Shanxi Formation (Q2s) of middle pleistocene series, Yiduyao Formation (Q3 y)of upper pleistocene and holocene series (Q4). The cause mainly is alluvial-diluvial, and it is distributed on Grade-III, II and I terrace and flood plain and riverbed. The upper mainly is silty soil, silty clay or sandy loam soil and sily-fine sand, and the lower mainly is gravel-cobble. Besides, stripped levee formed through artificial stacking (Qml) is distributed, and the ingradients mainly include silty loam with interbedded silt and silty-fine sand.

b) Dam site area

The bedrock in the dam site area is Duodaoshi Formation (Nd) of neogene system, which is sporadically exposed on the left bank. Alluvial layer and alluvial-diluvial layer of quaternary system are extensively distributed.

4.1.4.3 Geological structure

a) Project area

The region within a 300km radius around the dam site is divided into south and north Grade-I geootectonic elements with Xiangfan – Guangji fault as the border. On the north is Qinling Mountains fold system and on the south is Yangtze paraplatform.Yakou Shipping Hub is located in the south of Shangyangzi platform, a secondary tectonic element of Yangtze paraplatform (I).

The deformation of Yangtze paraplatform is weak as a whole, and the laying characteristic of earthcrust is good, steady and continuous. Its secondary tectonic element, Yangtze platform, is a relatively stable tectonic element formed on the base of presinian system. Within a 300km radius around the dam site, the faults are developed, and the large-size regionla faults include Xiangfan – Guangji Fault, Ankuang Fault, Danfeng – Shangnan Fault, Tongbai Fault, Nanzhang – Jingmen Fault, Wuan – Shiqiao Fault, Huji – Shayang Fault, Yonglong River Fault, Tongcheng River Fault, Wudu River Fault, Jiuxiwan Fault and Yuan'an Fault.

b) Dam site area

Bedrock is only exposed on the left bank, and the rock stratum is almost horizontal and is in the shape of gentle wave. The dip angle is 5° ~ 10°, and the inclination is 170° ~ 220° . There is no indication of great facture structure. In the dam site, there are two groups of developed faults: ①extending direction 300° ~ 355°， consistent with the extending direction of bank slope; the dip agle is approximately up-right and the fault surface is basically straight, the gap width is 0.5 ~ 10mm, filled with mud, and after unloading the gap may expand to 2 ~ 5cm. ② extending direction 25° ~ 30°, oblique to the bank slope, approximately up-right, fault surface is mostly closed and straight, visible mark length 2.0m.

4.1.4.4 Earthquake

According to *Zoning Plan of Ground Motion Parameters in China* (GB18306-2001), in the project area, the horizontal peak ground motion acceleration of bedrock with exceeding probability of 10% for 50 years is 0.05g, the characteristic period of ground motion response spectrum is 0.35s, and the corresponding seismic basic intensity is VI.

4.1.4.5 Hydrogeological conditions

a) Project area

In the area, the groundwater is mainly porous phreatic water and porous confined water existing in the loose stack layer of quaternary system, and the relative aquifers are deep and thick medium-fine sand and snad gravel. The groundwater is mainly recharged by atmospheric precipitation and groundwater in mountainous land at the edge of Hanshui channel land, and the volume is large. In the reservoir area, (local) confined water exits in the tertiary system stratum. As a whole, the groundwater in bedrock is lacking, and is recharged by atmospheric precipitation and river water and discharged to piedmont and plain area. The regional hydrogeology is shown in Attached Figure 13.

The recharging, runoff and discharge of groundwater in this area is mainly affected and controlled by vairous factors such as lithology, landform, structure, weather and hydrology. Extensively developed aquifer of porous water in quaternary system are spreaded in strap and fan shapes depending the rivers. Because the overlying lithology of the porous phreatic water in first-grade terrace is loamy soil, it is directly recharged by atmospheric precipitation and has strong hydraulic connection with precipitation, and there is a mutual recharging relationship between them. The overyling clay on second-grade terrace usually is 4-15m thick, and the groundwater is confined water, which is recharged by a certain volume of atmospheric precipitation and by river water. The groundwater in first-grade and second-grade terraces flows and is discharged to Han River. The aquifer of fractured porous water in cretaceous and tertiary systems is extensively distributed in low-relief terrain on the right bank of Han River and below the sediments of quaternary system in downland, and the water is recharged by atmospheric precipitation, flows to river and is dicharged to porous water aquifer and rivers in the form of spring and leakage flow.

b) Dam site area

The groundwater in the dam site is porous phreatic water in the loose layer of quaternary system, and the groundwater is lacking in the bedrock. Confined water only exists local sandstone and sand gravel.

Porous phreatic water of the quaternary system exits in fine sand and sand gravel layers in riverbed, flood plain and first-grade terrace. Because the aquifer is distributed continuously and has good connectivity, the phreatic water of the quarternary has unified groundwater surface. In the period of exploration, the groundwater level is basically flush with the river water surface, and is 48.5 ~ 49.5m.

The phreatic water is mainly recharged by surface water and atmospheric precipitation, and is discharged into Han River. In flood season, the water of Han River flows backward.

4.1.5 Soil

The results of general soil survey of the Overall Planning for Land Utilization of Xiangyang City (1997-2010), the soil in Xiangyang City is divided into six classes, 57 categories and 226 soil species. Main soil types include yellowish-brown soil, limestone soil, paddy soil, moisture soil, purple soil and brunisolic soil in mountainous land. Yellowish-brown soil is the major soil type, accounting for 65.3% of the total area, and is centralized in downland and some hilly area; soil ph is moderate, tilth and moiture saving capacity are bad, organic content is low and kalium content is high, which is favorable to the growth of various plants. Limestone is mainly distributed in low mountainous and hilly areas, accouting for 15.0% of the total area, the soil layer is thick, the texture is heavy, the soil is rich in calcium and organic matters, and it is favorable to growing rice, wheat, cotton and corn. In general moisture soil is distributed on the two banks of the river, the soil layer is deep, and the soil texture is loose. Purple soil is extensively distributed in most areas, and is suitable for planting wheat, rape, corn, peanut and citrus. Brunisolic soil is centralized in high cold mountainous area in Baokang County, and is suitable for wood growth.

In the project area, the soil types mainly include yellowrish-brown soil, moisture soil and paddy soil. Yellowish-brown soil is mainly distributed in downland, hilly land and shallow mountainous area, and crop yield is low and unsteady. Moisture soil is mainly distributed on both banks of Han River and generally in the alluvium of quaternary system, and the soil is loose and with high water permeability, the layer is thick and has good fertility. It is suitable for crop gwoth. Paddy soil is distributed in hilly land, gullies and rice planting region on both banks of the river, this type of soil is in long-term moist status, and the soil particle is fine and granular structure is good.

4.2 Ecological environment

4.2.1 Terrestrial ecology

To understand the current situation of terrestrial ecological environment of project-impacted area, we entrusted Wuhan Imaginationnovo Co., Ltd to conducted two terrestrial ecological survey in September 2013 and April 2014.

4.2.1.1 Survey method and process

(1) Data collection

Current biodiversity documents of the area include *Xiangyang City Record*, *Statistical Yearbook*, and relevant documents provided by forestry, environmental protection, water resources, agricultural and land resources departments, as well as works and literatures such as *Hubei Provincial Terrestrial Wild Animal Resources Survey Report*.

(2) Field site inspection

① GPS land type and vegetation survey sampling

GPS sampling point is the basis of identifying the types of landscape by satellite remote sensing. According to indoor image identification of vegetation and land utilization type, accuracy of the identification was verified on site and the following information about each GPS sampling point was recorded: elevation and geographic coordinates readings by elevation table, vegetation form (in terms of flora together with aspect, gradient and soil type), dominant plants, as well as observation of animal activities and filming macroscopic and features of typical vegetation.

② Terrestrial plant survey

On the basis of searching and analyzing historical data on terrestrial organism resources of the survey area, field survey was conducted. Belt transect survey was conducted on areas with no native vegetation, quadrat special investigation was conducted on key construction areas (for instance dam site) and area with good vegetation. Plant flora survey adopted sample-plot method, with quadrat area of macrophanerophytes flora 20m×20m, quadrat area of bamboo forest and shrub 5m×5m, and herb quadrat 1m×1m. All species of the sample-plot areas were recorded and according to Braun-Blanquet abundance/dominance -clustering regarding all 35 quadrats with their locations determined using GPS. For survey of rare and protected plants, a combination of field survey, local interview and market survey was adopted. For unidentifiable plants, economic plants as well as rare and protected plants, voucher specimen and picture were also taken.

③ Terrestrial animal survey

The speices and habitation situation of animals, in particular key protected animals of the assessment area were determined, with survey methods mainly including line transect method, sampling point method, interview and data inquiry. Animal species and quantity were determined mainly by combining site environmental survey and field trace survey with interview and market survey. For birds, line transect method and sampling point method were adopted according to habitat types and sizes. Given that amphibians and reptiles are less active, sampling point method was mainly adopted for observing their species and quantity. Further inspection and verification were conducted to determine the species and numbers of key protected animals. Special survey was conducted in key construction areas (for instance dam site construction area) and special areas (or instance road section with good vegetation, and natural reserve).

④ Field inspection

Site survey of current ecological environmental situation was conducted in construction area and reservoir area. Field inspection points of the construction area include waste dump, temporary soil storage site, access roads and construction camps; field inspection of the reservoir area includes protection engineering projects of the reservoir area and some resettlement areas. See Figure 15 attached for route and quadrat distribution of terrestrial ecological survey, and Table 1 attached for typical vegetation quadrat survey.

4.2.1.2 Ecological system, current situation of ecological environmental quality, and scenic ecological system

a) Current land utilization

Survey of the current situation of land utilization of the assessment area was conducted by analyzing satellite images and existing data. Landscape blocks of five major land utilization patterns were divided namely forest land, scrub-grassland, arable land, water area and building lot, among which well-developed overflow lands on the two banks of Han River was cultivated into arable land for planting crops such as maize and other vegetables as it rose above water seasonally. Therefore, this report classifies overflow lands with seasonal planting as arable land. To stress land utilization of areas directly affected by the project, data listed excluded Yanshan forest park and Cuijiaying provincial wetland park.

See Table 4.2.1-1 for statistics.

Table 4.2.1-1 Current land utilization situation of the assessment area

Block type	Forest land	Scrub-grassland	Arable land	Water area	Building lot	Total
Area (hm^2)	1997.60	2251.62	11130.39	3701.81	2950.61	22302.00
Proportion of assessment area (%)	9.07	10.22	50.52	16.80	13.39	100.00

According to the table, total land area surveyed is 22,302.00 hm^2, among which arable land area is of the biggest proportion, taking up 50.52%; water area is the second, taking up 16.80%; building lot and scrub-grassland takes up 13.39% and 10.22% respectively; the 1997.60 hm^2 of forest land is the smallest taking up only 9.07%. This indicates that arable land is the major land type being utilized.

b) Ecological baseline

Corresponding to the land use types, the assessment area was divided into four major ecological systems: forest ecological system, wetland ecological system, agricultural ecological system and urban/rural ecological system.

Agricultural ecological system: spreading over relatively open and flat alluvial land and overflow lands on the two banks of Han River, hill and plain in the assessment area that are less than 100m elevation are perfect for agricultural areas due to fertile soil and favoring hydrothermal conditions. Vegetation of the agricultural ecological system is artificial vegetations such as cultivated and planted crops, economic forest and fruit tree forest, mainly including crops such as maize, rice, beans, peanuts, sesame, etc; fruit trees such as citrus, peaches, pears; economic forests such as Italian poplars (*Populus euramevicana cv.'I-214')*. In addition, on either side of Han River overflow lands are developed and cultivated to plant crops seasonally during dry flow seasons. Given the long history of overflow lands cultivation on either side of Han River, it is included into the agricultural ecological system.

Agricultural ecological system has simple vegetation types and it is prone to human interference as it is relatively close to residential community. Therefore, animal species of the farmland ecological system are not plentiful, including mainly *Pelophylax nigromaculata*, *Pelophylax hubeiensis, Bufo gargarizans, Fejervarya multistriata*, *Microhyla ornata*, *Gekko japonicus, Eumeces chinensis*, *Plestiodon elegans*, *Erinaceus amurensis*, *Lepus capensis* and *Mustela sibirica*. Bird species such as *Passer, Turdus merula, Acridotheres cristatellus, Pica pica*, *Lanius schach, Motacilla alba, Hirundo rustica, Egretta* and *Ardeola bacchus* that live around human beings are extensively distributed in farmlands.

Forest ecological system: in the assessment area, with native vegetation already extinct, forest ecological system has relatively simple vegetation, mainly with artificial vegetation such as *Populus euramevicana cv.'I-214'* forest and Salix matsudana forest that are of single component, average cover degree and without patch distribution, scattering over the entire assessment area. Forest ecological system of the assessment area is mainly distributed on the main dyke, central bar and lake shoal of Han River as well as on either side of roads.

Vegetation of the forest ecological system of the assessment area mainly includes deciduous and broadleaved forest, *Populus euramevicana cv.'I-214'*forest, *Salix matsudana* forest, *Pterocarya stenoptera* forest, *Robinia pseudoacacia* forest and miscellaneous trees, with the majority being artificially cultivated which then became secondary forests for lack of human management and protection. In the assessment area, *Populus euramevicana cv.'I-214'forest*, as a typical artificial cultigen, is extensively distributed on the two banks, overflow lands and central bar of Han River.

Simple vegetation composition of the forest ecological system leads to simple animal distribution with average diversity. Animals distributed in the assessment area include land amphibians; reptiles favoring woods and water area such as *Bufo gargarizans, Fejervarya multistriata, Microhyla ornata, Dinodon rufozonatum, Elaphe taeniura, Rhabdophis tigrinus, Zaocys dhumnades* and *Elaphe rufodorsata*; beast species such as *Erinaceus amurensis, Lepus capensis* and *Microtus fortis*; bird species of terrestrial bird, bird of prey, scansores and songbird such as *Cuculus canorus, Alcedo atthis, Ceryle rudis, Upupa epops, Phasianus coichicus, Streptopelia orientalis* and *Streptopelia chinensis*.

Wetland ecological system: wetland ecological system is a unique system in between of aquatic and terrestrial ecological systems featured with hydric soil, mainly including the main stream, tributary, waterfront overflow lands and central bar of Han River within the assessment area.

Vegetation in the wetland ecological system is mostly plants favoring humid environments. Vegetation mainly includes *Populus euramevicana cv.'I-214'*forest, *Salix matsudana* forest, *Cynodon dactylon* scrub-grassland and *Conyza canadensis* scrub-grassland. Other commonly seen plants of this system include *Phragmites australis, Equisetum arvense, Malachium aquaticum, Rumex japonicus, Equisetum ramosissimum, Alternanthera Philoxeroides, Duchesnea indica, Polygonum hydropiper, Oenanthe javanica, Juncus effusus, Ranunculus japonicus* and *Hemarthria altissima*.

Wetland ecological system providing inhabitation, reproduction, migration and wintering areas for wild animals is an important habitat for wild animals of the assessment area. Animal distributed in the wetland ecological system of the assessment area include amphibious species favoring still water, reptilian species favoring woods and water, and aquatic reptiles, such as *Pelophylax nigromaculata, Pelophylax hubeiensis, Dinodon rufozonatum, Elaphe taeniura, Rhabdophis tigrinus, Zaocys dhumnades, Elaphe rufodorsata, Trionyx sinensis* and *Tortoise*. Animals with other inhabitation habits also need wetland for water. Therefore, wetland is an indespensible condition for wild animals living in the assessment area. Wetland also has all natatores species including *Podicipediformes*, *Anseriformes*, *Charadriiformes Laridae* and *Sterna*, as well as all wader species (excluding *Laridae* and *Sterna*) including *Ciconiiformes*, *Gruiformes* and *Charadriiformes*. Wetland is an important element needed for their survival, as they forage, build nests, reproduce and pass winter in wetland of the assessment area, in particular in Han River overflow lands .

c) Current eco-environmental quality situation

On the basis of field site survey and analysis of satellite images, combined with data analysis of vegetation coverage and location, ligneous and herb vegetation of the assessment area are divided into the following seven types. See Table 4.2.1-2 for area, average productivity and total productivity of various vegetation of the assessment area.

Table 4.2.1-2 Current productivity of various vegetation of the assessment area

Vegetation type	Typical plant	Area (hm^2)	Proportion of assessment area %	Average biomass (t/hm^2)	Total biomass	Proportion of total biomass of assessment area (%)
Coniferous forest	*Pinus massoniana*	256.43	1.16	26.13	6700.52	2.52
Broadleaved forest	*Populus euramevicana cv.'I-214'*, *Salix matsudana* , *Pterocarya stenoptera*	1558.44	7.07	89.11	138872.59	52.28
Bamboo forest	*Phyllostachys heteroclada* , *Phyllostachys glauca*	63.68	0.29	24	1528.32	0.58
Shrubland and scrub-grassland	*Broussonetia papyrifera*, *Cynodon dactylon*	2251.62	10.22	19.76	44492.01	16.75
Economic forest	*Amygdalus Persica*, *Pyrus spp*	119.05	0.54	23.74	2826.25	1.06
Crops	*Oryza sativa*, *Zea mays*	11130.39	50.52	6	66782.34	25.14
River water area	freshwater algae	3701.81	16.81	1.2	4442.17	1.67
total		19081.42	86.61	13.92	265644.19	100

Note: (1) Table does not include the 2,950.61hm^2 of building lot, taking up 13.39% of the assessment area;

(2) Average biomass data of various vegetation types are obtained through sample measurement and

according to *Biomass and Net Productivity of Chinese Forest Vegetation* (Fang Jingyun, 1996).

① *Coniferous* forest is mainly comprised of *Pinus massoniana* scattered in the assessment area. This vegetation type area has 256.43 hm^2 taking up 1.16% of the assessment area, with a biomass of 6700.52 t taking up 2.52% of the total biomass of the assessment area.

② Broadleaved forest is mainly comprised of commonly seen species of *Populus euramevicana cv.'I-214'*, *Salix matsudana* and *Pterocarya stenoptera* in the assessment area. This vegetation type area has 1558.44hm^2 taking up 7.07% of the assessment area, with a biomass of 138872.59t taking up a large proportion of 52.28% of the total biomass of the assessment area.

③ Bamboo forest is includes *Phyllostachys heteroclada* which is commonly seen in the assessment area. This vegetation type area has 63.68hm^2 taking up 0.29% of the assessment area, with a biomass of 1528.32t taking up 0.58% of the total biomass of the assessment area.

④ Shrubland and scrub-grassland includes mainly *Broussonetia papyrifera shrubland* and *Vitex negundo* shrubland. Scrub-grassland area is larger and mainly of *Cynodon dactylon* scrub-grassland. This vegetation type area has 2251.62hm^2 taking up 10.22% of the assessment area, with a biomass of 44492.01t taking up 16.75% of the total biomass of the assessment area.

⑤ Economic forest is mainly of *Amygdalus persica* and *Pyrus spp*. This vegetation type area has 119.05hm^2 taking up 0.54% of the assessment area, with a biomass of 2826.25t taking up 1.06% of the total biomass of the assessment area.

⑥ Crops are mainly of *Oryza sativa*, *Zea mays*, *Ipomoea batatas* and *Gossypium spp* in the assessment area. It has 11130.39hm^2 taking up 50.52% of the assessment area, with a biomass of 66782.34 t taking up 25.14% of the total biomass of the assessment area.

⑦ River water area is mainly of fresh water algae living in the river waters of the assessment area. Water area of the assessment area has 119.05hm^2 taking up 0.54% of the total, with a biomass of 2826.25t taking up 1.06% of the total biomass.

d) Baseline of scenic ecological system

In Yakou Village, Yicheng City where the project is situated, Han River is of typical alluvial plain with flat and open topography, which have mostly been developed into arable land with relatively high level of land development and utilization. Due to frequent interference of human activities, project affected areas have basically no native forest vegetation and instead have surface areas covered mainly by crops, shrubland and scrub-grassland.

Current quality situation of a landscape ecological system is determined by complicated interactions of natural environment, various organisms and human society of the ecological area evaluated. From the theoretical perspective of landscape ecological structure matching with function, functional strength and weakness of a landscape is determined by whether or not its structure is reasonable. As for various components of a landscape ecological system, template, the background area of a landscape, is largely responsible for its characters by posing a leading role in affecting landscape dynamics. Templates of this evaluation are is mostly determined by traditional ecological approach which calculates the dominance level values (Do) of various landscape patches, and the one with the highest dominance level value is the template.

Density Rd ＝ block number I /total block number ×100%

Frequency Rf ＝ number of quadrat with block I / total quadrat number ×100%

Landscape ratio (Lp) = block I area / total quadrat area ×100%

Through the three parameters above, dominance level value (Do) is calculated:

Dominance level value (Do) = {(Rd+Rf)/2 + Lp}/2 ×100%

See Table 4.2.1-3 for calculated values of density (Rd), frequency (Rf) and landscape proportion (Lp) of various patches of assessment area and their levels of dominance.

Table 4.2.1-3 Statistics of current dominance level values of various patches (prior inundation) of assessment area

Landscape type	Density Rd	Frequency Rf	Landscape proportion Lp	Dominance level Do

Landscape type	Density Rd	Frequency Rf	Landscape proportion Lp	Dominance level Do
Forest land	26.95	8.94	9.07	13.51
Grass land	28.24	12.81	10.22	15.37
Arable land	28.76	53.69	50.52	45.87
Water area	1.37	15.37	16.80	12.59
Building lot and other land use	14.68	10.53	13.39	13.00
Total	100	100	100	100

According to dominance level values of various types of landscape listed in the table above, arable land surpasses other types of patch in areas of dominance level value Do (45.87%), density Rd (28.76%), frequency Rf (53.69%) and landscape proportion Lp (50.52%).

e) Ecological system stability situation

Stability of an ecological system is closely related to its scenic ecological quality, as the level of scenic ecological quality is determined by characters and features of landscape elements, as well as structural and spatial pattern features of the landscape. In various types of landscape, green vegetation forming the majority of terrestrial ecological system is the most obvious indicator of environmental quality being good or bad. Contribute largely to environmental quality are also native vegetation that are mostly of high cover degree, complete flora structure, abundant and diverse species, high biological productivity and great renewal potentials. Generally speaking, compared with shrubland and scrub-grassland, forest has a more complicated flora structure, higher biological productivity, bigger ecological potentials and more influence over environmental quality. Farmland, orchard and other artificially allocated flora are less stable and capable of resisting outside interference as they feature simple structure and Simple species dependent upon human maintenance.

According to compositional and structural analyses of vegetation ecological landscape of the assessment area, arable land is the landscape type with the highest dominance level. In addition, *Populus euramevicana cv.'I-214'*forest, shrubland and scrub-grassland are also of relatively high landscape proportions. Therefore, the dominant ecological system of the assessment area is not native vegetation and is farmland and arable land ecological landscape that have long been interfered and controlled by human activities. Given the ecological systems of the area is mainly controlled and affected by human activities, artificial ecological systems are proportionally high in the assessment area with relatively low stability.

4.2.1.3 Current situation of terrestrial plant resources

Located in Yicheng city of Hubei province, according to *China Spermatophyta Flora Geography* (Wu Zheng yi et al., 2001), Han River Yakou shipping hub belongs to East Asian plant region—China-Japan forest plant sub-region—East China area—Qinling Mountains-Ta-pa Mountains sub-area.

Through systematically arranging materials from site survey of plant resources of the assessment area, combining with relevant data and literatures, according to *Engler Classification* (1964) and *Qin Renchang Pteridophyta Classification* (1978), there were altogether 123 families, 366 genera and 578 species (cultigen included), among which were 16 families, 19 genera and 28 species of *Pteridophyta*; 4 families, 9 genera and 11 species of *Gymnospermae*; 103 families, 338 genera and 539 species of *Angiospermae* with 84 families, 236 genera and 430 species of *Dicotyledons* as well as 19 families, 75 genera and 109 species of *Monocotyledons* (See Table 4.2.1-4 below for details).

Table 4.2.1-4 List of vascular plants of Yakou assessment area

Item	*Pteridophyta*			*Gymnospermae*			*Angiospermae*		
	Family	Genus	Species	Family	Genus	Species	Family	Genus	Species
Assessment area	16	19	28	4	9	11	103	338	539
Hubei	40	93	335	7	22	46	171	1144	4523
National	63	228	3000	10	34	238	291	2940	25000
Assessment area of Hubei (%)	40.00	20.43	8.36	57.14	40.91	23.91	60.23	29.55	11.92
Assessment area of the country (%)	25.40	8.33	0.93	40	26.47	4.62	35.40	11.50	2.16

a) Plant fauna analysis

According to *Distribution Division System of Chinese Spermatophyta* (cultigen and exotic species excluded) by Wu Zheng yi et al., plant genera of the assessment area can be divided into 14 types, among which are 37 genera of global distribution; 115 genera of tropical distribution taking up 50% of the total flora genera of the area; 114 genera of temperate zone distribution taking up 49.57% of the total flora genera of the area; 1 genera uniquely distributed in China taking up 0.43% of the total flora genera of the area. See Table 4.2.1-5 for details.

Table 4.2.1-5 Distribution statistics of main Spermatophyta within the assessment area

SERIAL NO.	DISTRIBUTION AREA TYPE	TOTAL	PERCENTAGE %	LARGER DISTRIBUTION AREA	TOTAL	PERCENTAGE %
1	Global distribution	37	—	Global distribution	37	—
2	Pantropical distribution	72	31.31	Tropical distribution	115	50.00
3	Tropical Asian and tropical American disjunctive distribution	3	1.30			
4	Tropical distribution in the old world	15	6.52			
5	Tropical Asian to tropical Oceanian distribution	6	2.61			
6	Tropical Asian to tropical African distribution	7	3.04			
7	Tropical Asian distribution	12	5.22			
8	North temperate zone distribution	53	23.04	Temperate zone distribution	114	49.57
9	East Asian and North American disjunctive distribution	13	5.65			
10	Temperate zone distribution in the old world	17	7.39			
11	Temperate zone Asian distribution	3	1.31			
12	Mediterranean, West Asian to central Asian distribution	1	0.44			
13	Central Asian distribution	0	0.00			
14	East Asian distribution	27	11.74			
15	Uniquely distributed in China	1	0.43	Uniquely distributed in China	1	0.43
	Total	267	100		267	100

Note: cultigen and exotic species are not included in statistics of this table.

b) Vegetation type of the assessment area

According to *China Vegetation*, the assessment area belongs to subtropical evergeen broadleaved forest region—eastern (humid) evergeen broadleaved forest sub-region—north Asian tropical mixed belt of evergreen, deciduous and broadleaved forests—mountainous and hilly region of Tongbai mountains, Ta-pieh mountains—Cultivation area of Cyclobalanopsis glauca forest and Pinus taiwanensis of Quercus L. According to vegetation division of *Hubei Vegetation Division*, the assessment area further belongs to eastern (humid) evergeen broadleaved forest sub-region—north Asian tropical mixed belt of evergreen, broadleaved and deciduous forests sub-region of north Hubei—hilly and low mountainous vegetation area of Tongbai mountains and Ta-pieh mountains—hilly and low mountainous vegetation sub-area of Dahong mountain.

The vegetation sub-are is mostly of plain within 100m elevation with few downland 100-250m elevation in the northwest, developed into vegetation cultivation area of typical farmland vegetation. Flood lands and forest lands are mostly concentrated in the Han River area, among which are artificial forest or protection forest such *as Salix matsudana* and *Populus* × *Canadensis*; economic forests such as *Vernicia fordii*, *Sapium sebiferum*, *Camellia sinensis*, *Camellia oleifera* and *Morus alba*; grain crops such as *Oryza sativa*, *Zea mays*, *Ipomoea batatas*; economic crops such as various vegetables and *Camellia oleifera*.

Through field inspection and consulting various forestry survey materials, various plant communities are divided according to communal features and differences following natural vegetation classification system division of China Vegetation. Natural vegetation of the assessment area can be divided into 2vegetation type groups, 4 vegetation types and 18 formation plants. See Table 4.2.1-6 for vegetation classification systems, general situation of major vegetation and their distributions in the assessment area.

Table 4.2.1-6 Collection of major vegetation types of the assessment area

	VEGETATION GROUP	VEGETATION TYPE	FLORA	SCIENTIFIC NAME OF FLORA
Natural vegetation	1. Broadleaved forest	1.Deciduousbroadleaved forest	1. 楝树林	Form. *Melia azedarach*
			2. 枫杨林	Form. *Pterocarya stenoptera*
		2. Bamboo forest	3. 水竹林	Form. *Phyllostachys heteroclada*
	2. Shrubland and scrub-grassland	3. Shrubland	4. 柘木灌丛	Form. *Maclura tricuspidata*
			5. 八角枫灌丛	Form. *Alangium chinense*
			6. 牡荆灌丛	Form. *Vitex negondo var. cannabifolia var. cannabifolia*
			7. 盐肤木灌丛	Form. Rhus chinensis
			8. 构树灌丛	Form.*Broussonetia papyifera*
		4.Scrub-	9. 野艾蒿草丛	Form. *Humulus scandens*

	VEGETATION GROUP	VEGETATION TYPE	FLORA	SCIENTIFIC NAME OF FLORA
		grassland	10. 芒灌草丛	Form. *Miscanthus sinensis*
			11. 芦苇灌草丛	Form. *Phragmites communis*
			12. 喜旱莲子草灌草丛	Form. *Alternanthera philoxeroides*
			13. 牛鞭草灌草丛	Form. *Hemarthria sibirica*
			14. 小蓬草灌草丛	Form. *Conyza canadensis*
			15. 狗牙根灌草丛	Form. *Cynodon dactylon*
			16. 白茅灌草丛	Form. *Imperata cylindrica*
			17. 藜灌草丛	Form *Chenopodium album*
			18. 益母草灌草丛	Form.*Leonurus japonicus*
Artificial vegetation	Economic forest	5. Economic forest	19. 池杉林	Form. *Taxodium ascendens*
			20. 旱柳林	Form. *Salix matsudana*
			21. 意杨林	Form. *Populus* × *Canadensis*
Agricultural vegetation	Crops	Crops	Grain crops: *Oryza sativa, Zea mays, Ipomoea batatas* and etc.	
			Economic crops: *Brassica campestris, Sesamum indicum, Glycine max* and various vegetables	

c) Major vegetation features of the assessment area

Broadleaved forest

I Deciduous broadleaved forest

Deciduous broadleaved forests in the assessment area mainly include *Melia azedarach* and *Pterocarya stenoptera*.

Melia azedarach* forest (Form. *Melia azedarach)

Melia azedarach grows rapidly on soil that is humid and fertile, without demanding soil requirements, and is relatively commonly seen in various Chinese provinces and regions south of the Yellow River. *Melia azedarach* forest of the assessment area is secondary forest distributed mainly on river dyke and road sides.

Dominant species of arborous layer is *Melia azedarach* of a canopy density of 0.7, height of 4-8m, average breast-height diameter of 15-20cm，canopy breadth of 5m×4m, with associated *Sapium sebiferum, Pterocarya stenoptera and Populus euramevicana cv.'I-214'*. Shrub layer has about 25% of cover degree, including *Morus alba, Amygdalus persica, Pterocarya stenoptera* sapling*, Melia azedarach* sapling *and Vitex negundo*. Herb layer includes *Senecio scandens, Setaria viridis, Kalimeris integrtifolia, Dendranthema indicum, Dendranthema indicum and Arthraxon prionodes*.

Quadrat location: Yujiahu N:31°56′12.00″; E:112°09′26.13″, elevation: 57m

Pterocarya stenoptera* forest (Form. *Pterocarya stenoptera)

Pterocarya stenoptera forests distribute extensively in north China, central China, south China and west China and are most commonly seen in Yangtze River basin and Huai River basin, mainly in flood lands along creeks and forest lands in dark and damp hillsides 1500m below sea level. In the assessment area, it is mainly distributed on river dyke of the two banks of Han River, mostly in belt and block distributions. With a canopy density of 0.75, *Pterocarya stenoptera* is 10-25m high with a breast-height diameter of 10-25cm, an average canopy breadth of 5m×4m and associated *Populus canadensis* and *Melia azedarach.*

With a layer cover degree of 20%, species of shrub layer include *Rosa multiflora,* *Vitex negundo, Polygonum cuspidatum, Ligustrum quihoui* and *Phyllostachys heteroclada*.

With a layer cover degree of around 30%, herb layer has relatively plentiful component species, mainly including *Conyza canadensis, Kalimeris integrtifolia, Acalypha australis, Xanthium sibiricum, Crassocephalum crepidioides, Cynodon dactylon, Clinopodium chinense, Trigonotis peduncularis, Oxalis corniculata, Geranium wilfordii, Duchesnea indica, Stellaria media, Boehmeria nivea, Alternanthera Philoxeroides, Plantago asiatica, Torilis scabra, Daucus carota, Erigeron annuus, Oenanthe javanica, Polygonum hydropiper, Dendranthema indicum, Humulus scandens, Rorippa montana, Veronica peregrina* and *Capsella bursa-pastoris*.

Extra-stratum plants include *Paederia scandens, Cayratia japonica, Humulus scandens* and *Polygonum perfoliatum*.

Quadrat location: Yujiahu N:31°56′12.00″; E:112°09′26.13″, elevation: 57m

Bamboo forest

II Bamboo forest

Bamboo forests in the assessment area mainly include *Phyllostachys heteroclada* forest.

***Phyllostachys heteroclada* forest (Form. *Phyllostachys heteroclada*)**

Phyllostachys heteroclada favors warm, wet and well-ventilated semi-shade environment with abundant sunlight, with extensive distribution in Yangtze River basin, mostly on river banks, lake sides or rocky hillsides. In the assessment area, *Phyllostachys heteroclada* is mainly distributed in wet areas on the foot of hillsides, with mostly scattering distributions. *Phyllostachys heteroclada* forest has around 70% of cover degree and is 1.5-2.5m tall, with associated *Pterocarya stenoptera* sapling *and Morus alba*. Herb layer has around 30-50% cover degree, including *Equisetum arvense, Oxalis corniculata, Senecio scandens, Achyranthes aspera, Commelina communis, Commelina bengalensis, Oenanthe javanica, Conyza canadensis* and *Rostellularia procumbens*. Extra-stratum plants include *Solanum lyratum, Humulus scandens* and *Paederia scandens.*

Quadrat location: 1000m downstream of the right bank of Cuijiaying junction N:

31°56′51.62″; E: 112°09′20.98″, elevation: 62m.

Shrubland and scrub-grassland

IIIShrubland

Shrubland includes vegetation type composed by shrub being the dominant species and is often with a communal height below 5m and around 30%-40% cover degree. Besides its height difference with macrophanerophytes, more importantly shrubland communities mostly grow in fasciation. In the assessment area, there are mainly four types of shrublands, namely *Cudrania tricuspidata* shrubland, *Rhus chinensis* shrubland, *Broussonetia papyrifera* shrubland *and Vitex negondo var. cannabifolia* shrubland.

Broussonetia papyrifera* shrubland (Form. *Broussonetia papyrifera)

Broussonetia papyrifera is another volunteer of extremely extensive distribution. In the assessment area, it is distributed in road sides, uncultivated land surrounding village, and forest edge with larger distribution areas. Shrub layer has a cover degree of 60-75% and is 1.5-2.5m high, with associated *Morus alba, Melia azedarach, Vitex negundo, Rosa multiflora, Rubus corchorifolius, Sapium sebiferum, Mallotus apelta,* and *Sida acuta*. Herb layer has a cover degree of 20-50%, including mainly *Dendranthema indicum, Arthraxon hispidus, Rumex japonicus, Kochia scoparia, Phytolacca Americana, Amaranthus retroflexus, Eclipta prostrata, Setaria viridis, Duchesnea indica,* and *Kalimeris integrtifolia*. Extra-stratum plants include *Cayratia japonica, Lonicera japonica, Fallopia multiflora, Pharbitis purpurea* and *Humulus scandens.*

Quadrat location 1: 1000m downstream of the right bank of Cuijiaying junction N: 31°56'50.39"; E: 112° 9'21.22", elevation: 62m.

Quadrat location 2: Chenjiachong of Oumiao county on the right bank of Xiangcheng district N: 31°48'44.81"; E: 112° 9'17.86", elevation: 59m.

Quadrat location 3: Left bank of Yakou dam site N: 31°40′02.36″; E112°23′07.25″, elevation: 59m.

Rhus chinensis* shrubland (Form. *Rhus chinensis)

This type of shrubland is mostly of vegetation type in succession to forest land that was cut down. Rhus chinensis is the dominant species, with a cover degree of around 50-75%, and 0.5-1.2m high. Associated plants of shrub layer mainly include *Indigofera pseudotinctoria, Rosa multiflora,* and *Vitex negundo*. Herb layer has a cover degree of 40%, mainly including *Lysimachia congestiflora, Dendranthema indicum, Memorialis hirta, Dendranthema indicum, Phytolacca Americana, Parathelypteris nipponica, Glechoma longituba, Senecio scandens, Oxalis corniculata, Boehmeria nivea, Ixeridium chinense* and *Hedyotis chrysotricha.*

Quadrat location: Chenjiachong of Oumiao county on the right bank of Xiangcheng district N: 31°48'44.81"; E: 112° 9'17.86", elevation: 59m.

Vitex negondo* var. *cannabifolia* shrubland (Form. *Vitex negondo* var. *cannabifolia)

Scattering on the two banks of Han River in the assessment area, *Vitex negondo var. cannabifolia* shrubland has a communal cover degree of around 60% and is 1.5-2m high, with associated *Pterocarya stenoptera* sapling, *Broussonetia papyrifera* , and *Melia azedarach* sapling. Herb layer has a low cover degree of around 30% with few species mainly including *Conyza canadensis, Kalimeris integrtifolia, Erigeron annuus, Acalypha australis, Xanthium sibiricum, Crassocephalum crepidioides, Cynodon dactylon, Achyranthes aspera* and *Clinopodium chinense*. Extra-stratum plants include *Humulus scandens* and *Cayratia japonica*.

Quadrat location: Shuiwa Village of Xiangcheng District on the right bank of Han River N: 31°55′39.46″; E: 112°09′40.31″, elevation: 61m.

Ⅴ Scrub-grassland

Scrub-grassland refers to plant community mainly built by herb plants of mesophyte, dry mesophyte and perennial herb, and with few scattered shrubs. This type of community is a secondary type formed in increasingly dry habitats in tropical areas of central Asia where soil is increasingly barren due to soil erosion caused by repeatedly cutting down and burning forest and shrub. There are nine types of scrub-grasslands in the assessment area, namely *Humulus scandens* scrub-grassland, *Miscanthus sinensis* scrub-grassland, *Phragmites australis* scrub-grassland, *Alternanthera Philoxeroides* scrub-grassland, *Hemarthria altissima* scrub-grassland, *Conyza Canadensis* scrub-grassland, *Cynodon dactylon* scrub-grassland, *Imperata cylindrical* scrub-grassland, and *Leonurus artemisia* scrub-grassland.

Humulus scandens* shrub-grassland (Form. *Humulus scandens)

Humulus scandens scrub-grassland of the assessment area is mainly distributed in forest edge of macrophanerophytes forest land, river dyke, field ridge, uncultivated hill slope and around houses. Communal cover degree is 50 ~ 70% and height is between 0.3 ~ 0.6m, with *Humulus scandens* being the dominant species as well as associated *Cynodon dactylon, Abutilon theophrasti, Setaria viridis, Chenopodium album, Alternanthera Philoxeroides, Cyperus rotundus, Clinopodium chinense, Imperata cylindrica, Arthraxon hispidus* and *Euphorbia lathyris*.

Quadrat location: Wangji township on the right bank of Han River N: 112°13'36.68"; E: 112°13'36.68", elevation: 56m.

Miscanthus sinensis* shrub-grassland (Form. *Miscanthus sinensis)

Miscanthus sinensis scrub-grasslands are widely distributed in the assessment area, mainly on overflow lands slopes, road sides and uncultivated hilly slopes on the two banks of Han River, distributed mostly in blocks or patches. Herb layer has a cover degree as high as 90%, and is 1-2m high, with *Miscanthus sinensis* being the dominant species as well as associated *P. Aquilinum, Erigeron annuus, Kummerowia stipulacea, Plantago asiatica, Humulus scandens, Torilis scabr , Senecio scandens, Boehmeria nivea, Polygonum chinense, Plantago asiatica, Poa annua, Galium aparine , Elsholtzia densa, Ixeridium chinense, Roegneria kamoji. Extra-stratum plants include Polygonum perfoliatum,* and *Calystegia hederacea.*

Quadrat location: Qingshui harbor of Nanzhou Village on the left bank N: 31°42′03.65″; E: 112°22′03.43″, elevation: 50m.

Alternanthera philoxeroides* shrub-grassland (Form. *Alternanthera philoxeroides)

Alternanthera Philoxeroides scrub-grassland scatters in the assessment area, mainly distributed on wetland near ditches or roads. Originated in Brazil, this species is currently in wide distribution in temperate zone areas in the world. *Aternanthera Philoxeroides* can grow on land and float on water as the plant forms a monodominant community with relatively high purification capability by developing a veneer layer with a thickness of dozens of centimeters on the water surface. This species reproduce by seed and trophosome and is difficult to be eradicated for it has numerous and deeply buried underground root stems that take roots individually and reproduce rapidly. Reproduction of the species is mainly to the detriment of various crops such as *Oryza sativa, Gossypium spp* and fruit trees, and may even clog riveyway under severe circumstances affecting aquaculture industrial development. *Alternanthera Philoxeroides* in the assessment area are mostly monodominant communities of 0.2m height occasionally with associated plants such as *Acorus calamus* and *Polygonum orientale.*

Quadrat location: Qingshui harbor of Nanzhou Village on the left bank N: 31°42′03.65″; E: 112°22′03.43″, elevation: 50m.

Phragmites communis* shrub-grassland (Form. *Phragmites communis)

Phragmites australis shrubland scatters on the two banks of Han River and its tributaries in the assessment area. With a average height between 1.5-3m, it can grow on the ground without water during dry flow season, and on water surface over 2m during flood season. Its communal cover degree can be as high as 80% and its main associated species include *Dendranthema indicum, Conyza canadensis, Equisetum arvense, Alternanthera Philoxeroides, Bidens tripartita* , *Humulus scandens,* and *Aster subulatus*. *Phragmites australis* is widely used not only as raw material in paper-making industry, but also in construction materials. *Phragmites australis* community is an important habitat for water birds and a key element in stabilizing ecological balance.

Quadrat location: 900m downstream of the right bank of Cuijiaying junction N: 31°56′51.62″; E: 112°09′20.98″, elevation: 62m.

Cynodon dactylon* shrub-grassland (Form. *Cynodon dactylon)

In the assessment area, *Cynodon dactylon* scrub-grassland is widely distributed, mainly in areas such as river banks of Han River, field ridge and road sides, with patch distributions covering large areas. It has a communal height between 3-20cm and a cover degree as high as 95%. Besides the dominant species of *Cynodon dactylon*, commonly seen associated plants include *Verbena officinalis, Alternanthera Philoxeroides, Leonurus artemisia, Conyza canadensis, Artemisia carvifolia, Digitaria sanguinalis, Heteropappus*

Less, Humulus scandens, and Phyla nodiflora.

Spreading forcefully *Cynodon dactylon* is excellent in soil conservation and grassland pavement. In addition, *Cynodon dactylon* is also of high tread-on resistance, which is particularly good as turfs on playgrounds and sports fields. Meanwhile, *Cynodon dactylon* is also a fine feed that is grazing-resistant. Its root stock can be used as medicine for blood purification.

Quadrat location 1: Shuiwa Village of Xiangcheng District on the right bank of Han River N: 31°55′39.46″; E: 112°09′40.31″, elevation: 61m.

Quadrat location 2: Baojiatai of Xiangcheng District on the right bank of Han River N: 31°55'41.81"; E: 112° 9'32.05", elevation: 61m.

Imperata cylindrical* shrub-grassland (Form. *Imperata cylindrical)

Imperata cylindrica scrub-grassland is relatively widely distributed in China, mainly in tropical and subtropical areas of as far north as North China. In the assessment area, *Imperata cylindrica* scrub-grasslands mainly distribute on flood lands of the two banks of Han River and on roadsides. Herb layer has a layer height of 0.4-0.5m, and a cover degree of as high as 80%. *Imperata cylindrica* is the dominant species in the community, and other associated plants include *Cynodon dactylon, Arthraxon hispidus, Commelina communis, Galium asperuloides, Taraxacum mongolicum, Dendranthema indicum, Cirsium japonicum*, and *Veronica persica*.

Quadrat location: 900m downstream of the right bank of Cuijiaying junction N: 31°56′51.62″; E: 112°09′20.98″, elevation: 62m.

Leonurus japonicus* shrub-grassland (Form. *Leonurus japonicus)

It favors warm and wet climate as well as sunlight. Its distribution all over the country mainly include uncultivated land, roadsides, field ridge, grassland on hilly slope, and riversides that mostly face the sun. Its community has a cover degree of around 50% and is 0.3-0.5m high, with associated *Cynodon dactylon, Apium leptophyllum, Alternanthera Philoxeroides, Humulus scandens, Malachium aquaticum, Dendranthema indicum, Taraxacum mongolicum, Daucus carota,* and *Verbena officinalis*.

Quadrat location: Qingshui harbor of Nanzhou Village on the left bank N:

31°42′03.65″; E: 112°22′03.43″, elevation: 50m.

VI Economic forest

In the assessment area, there are many artificial protection forests including mainly Taxodium ascendens forest and *Populus euramevicana cv.'I-214'*forest.

Taxodium ascendens* forest (Form. *Taxodium ascendens)

Originated in Virginia of America, *Taxodium ascendens* was firstly introduced to China in areas such as Jiangsu in the early 20th century, and is currently an important forest building and garden tree species in northern and southern water network areas of Yangtze River.

In the assessment area, Taxodium ascendens is mainly distributed on the right side of Yicheng Han River bridge with belt distribution. *Taxodium ascendens* is the monodominant species of the arborous layer, with a height between 15-20m, a canopy density between 0.7 ~ 0.8, and associated species such as *Populus euramevicana cv.'I-214'*scattered.

Shrub layer is 1.5 ~ 3.0m high, with a cover degree between 20% ~ 30%, and has belt distributions, mainly on the edge of *Taxodium ascendens* forest. It is of relatively Simple species composition, mainly including *Rosa multiflora, Morus alba, Melia azedarach* and *Broussonetia papyrifera.*

Herb layer has relatively more species with a cover degree of 40%, mainly including *Plantago asiatica*, *Arthraxon hispidus, Acalypha brachystachya*, *Setaria viridis*, *Bidens tripartita*, *Cynodon dactylon*, *Digitaria sanguinalis* , *Imperata cylindrica* and *Lolium perenne.*

Quadrat location: Baojiatai of Xiangcheng district on the right bank of Han River N: 31°55'41.81"E: 112° 9'32.05", elevation: 65m.

***Populus euramevicana* cv.'I-214' forest (Form. *Populus euramevicana* cv.'I-214')**

Populus euramevicana cv.'I-214' is a deciduous megaphanerophyte with its canopy being a long oval shape. Originated in Italy, it was firstly introduced to China from East Germany in 1958, then introduced from Romania in 1965 and finally introduced from Italy in 1972. *Populus euramevicana cv.'I-214'* favors light, water and fertilizer, and grows rapidly under sufficiently sunlight, water and fertilizer, growing into full size in 7 to 10 years. Seven-year-old trees can be 22 to 25m high, with an average breast-height diameter of 30 ~ 32cm. Given its rapid growth *Populus euramevicana cv.'I-214'* is the most widely planted protection forest along Han River and its tributaries in the assessment area.

In the assessment area, *Populus euramevicana cv.'I-214'* is 10-25m high, with a average breast-height diameter of 10 ~ 30cm, canopy breadth of 5m×4m, and is occasionally with associated *Pterocarya stenoptera* and *Melia azedarach*.

Shrub layer is relatively sparse, with a cover degree of 10%, including mainly *Pterocarya stenoptera* sapling, *Phyllostachys heteroclada, Glochidion puberum, Rosa multiflora* and *Alangium platanifolium*.

Herb plants are relatively plentiful with a cover degree of 40 ~ 65%, including mainly *Carpesium abrotanoides, Leonurus artemisia, Amaranthus retroflexus, Cynodon dactylon, Polygonum aviculare, Humulus scandens, Perilla frutescens, Dendranthema indicum, Chenopodium album, Alternanthera Philoxeroides, Kalimeris integrtifolia, Phytolacca Americana, Polygonum orientale, Dendranthema indicum, Solanum surattense, Eleusine indica, Clinopodium chinense* and *Siegesbeckia orientalis.*

Extra-stratum plants include *Rubia cordifolia*.

Quadrat location: Group 9 of Nanzhou village on the left bank N: 31°41′56.21″; E: 112°22′05.24″; N: 31°41'57.15"; E: 112°22'6.43", elevation: 55m.

Ⅷ Agricultural vegetation

The assessment area belongs to Hubei agricultural crop planting area. In the assessment area, agricultural vegetation is of relatively large proportion, distributed mainly on are relatively open and flat alluvial flatlands on the two banks of Han River. Crops cover grain, oil, fruits and vegetables, including *Zea mays, Oryza sativa, Boehmeria nivea, Arachis hypogaea, Brassica campestris, Ipomoea batatas,* and *Trigonella foenum-graecum.*

d) Vegetation distributive features of the assessment area

Located in Xiangyang city and Yicheng city of Hubei province, the assessment area belongs to eastern (humid) evergeen broadleaved forest sub-region—north Asian tropical mixed belt of evergreen, broadleaved and deciduous forests sub-region of north Hubei—hilly and low mountainous vegetation area of Tongbai mountains and Ta-pieh mountains—hilly and low mountainous vegetation sub-area of Dahong mountain. Currently, assessment area is an excellent regional agricultural production area of hills and plains below 100m above sea level with fertile soil and excellent hydrothermal conditions. Native vegetation of the region is extinct due to years of human interfering activities and is replaced by artificial vegetation or semi-artificial vegetation. Macrophanerophytes in the area is of Simple species, among which *Populus euramevicana cv.'I-214'* is the dominant tree species, both a protection forest and a widely popular timberland, commonly planted on dyke, overflow lands and central bar; *Taxodium ascendens* and *Metasequoia glyptostroboides* are mostly shade tree or garden tree distributed in belt or scattered in gardens; other tree species include *Salix matsudana, Pterocarya stenoptera, Melia azedarach* and *Alangium chinense*. Shrublands of the area have low abundance and belt distributions on field ridge, road side and forest edge, with *Broussonetia papyrifera* being the dominant species. Scrub-grasslands are mostly of waterfront distribution and much distribution in dyke concave bank, with *Cynodon dactylon* community being the typical community.

Wetland vegetation in the assessment area has noteworthy features in terms of its horizontal distribution: woody wetland vegetation are distributed on dyke and flood plain on either side of the river as well as central bar, with *Populus euramevicana cv.'I-214'* forest, *Salix matsudana* forest, *Pterocarya stenoptera* forest widely distributed on dyke and some *Populus euramevicana cv.'I-214'* forest cultivated on central bar. Generally speaking, overflow lands developed in the assessment area, in particular on the right bank of the reservoir area, are mostly been cultivated to plant crops including major grain crops such as *Triticum aestivum* and *Zea mays*; major economic crops such as *Gossypium spp, Arachis hypogaea, Brassica campestris* and *Benincasa hispida.*

e) Rare and protected plant as well as ancient and famous tree

Through site survey and consulting relevant materials, there is no national-level key protected wild plant in the assessment area.

In the assessment area, there is one ancient tree of *Pistacia chinensis*, located in

Luojiahe of N31°46'31.00" and E112°10'32.00". It is about 110 years old, about 17m high, with a breast-height diameter of about 59m and a canopy breadth of 16*16m. Situated 550m from the reservoir inundation line, it is not affected by project construction or by reservoir inundation.

4.2.1.4 Terrestrial animal

Entrusted by our company, professionals of Wuhan Imaginationovo Co., Ltd conducted field survey on current biodiversity situation of the Yakou project affected area in August 2012 and August 2013. Focus areas of the survey were junction project area, Waste dump, storage site, construction camp, inundation area, protection project area, resettlement area and the area from dam to backwater area in the upstream. Field survey mainly inspected and recorded habitat situation of terrestrial animals. Interview and inspection survey mainly inquired staff of Forestry Bureau and local resident about wild Vertebrata situation, and consulted relevant literatures such as Xiangyang City Record, and Hubei Provincial Terrestrial Wild Animal Resources Survey Report, thus arriving at current situation of animal resources of the project assessment area.

According to the geographical divisions of Chinese animals in *China Animal Geography* (Zhang Rongzu, Science Press, 2011), animals within the planning range are of subtropical broadleaved-evergreen deciduous forest shrub fauna of Funiu-Ta-pieh Province of eastern mountain plain sub-region of North China of palearctic realm.

According to comprehensive analysis of field survey and relevant data, it is concluded that terrestrial vertebrata in the assessment area are of 4 classes 20 orders, 44 families and 81 species, among which are 26 oriental species, 25 palaearctic species and 30 cosmopolitan species; 3 species of national Class II key protected animal and 26 species of Hubei provincial protected animal. See attached table for species, composition, fauna and protection level of various classes of amphibians, reptiles, birds and beasts of the assessment area.

Table 4.2.1-7 Species, composition, fauna and protection level of terrestrial vertebrata of the assessment area

Species composition				Animal fauna			Protected animal		
Class	Orde	Fa	Spec	Oriental	Palaearcti	Cosmop	Grade	Grade	Hubei

	r	mil y	ies	species	c species	olitan species	I	II	provincial level
Amphibia	1	3	5	3	0	2	0	0	5
Reptilia	2	5	10	4	0	6	0	0	2
Aves	12	31	56	17	22	17	0	3	18
Mammalia	5	5	10	2	3	5	0	0	1
Total	20	44	81	26	25	30	0	3	26

a) Amphibians

1) Species, number and distribution

In the assessment area, there are altogether one order, three families and five species of amphibians, among which *Ranidae* is of the most with three species taking up 60.00% of the amphibian species with absolute dominance. Five amphibians of the assessment area are all Hubei provincial-level key protected wild animals. See attached table for numbers and distribution details in the assessment area of various species.

2) Fauna composition

In the assessment area, among the five species of amphibians, three are oriental species taking up 60.00%; none is palaearctic species; two are cosmopolitan species taking up 40.00%. Oriental amphibians are the absolute dominant species, which is in line with the geographic location of the assessment area being oriental realm.

3) Ecological type

According to different living habits, five species of amphibians in the assessment area can be divided into two ecological types:

Still water type (foraging in still water or slow flow) includes the two species of *Pelophylax nigromaculata* and *Pelophylax hubeiensis*, mainly distributed in still water areas such as paddy field and pond of the assessment area, closely relating to human activities.

Terrestrial type (living and foraging on land)) includes the three species of *Bufo gargarizans*, *Fejervarya multistriata* and *Microhyla ornata*, mainly living in land habitats not far from water source such as grassland, under a rock, and field ridge of the assessment area, closely relating to human activities.

b) Reptiles

1) Species, number and distribution

In the assessment area, there are altogether two orders, five families and ten species of reptiles, among which *Colubridae* is of the most with five species taking up 50.00% of the reptile species with absolute dominance. In the assessment area, there was no national-level key protected wild reptile distributed and two species of Hubei provincial key protected reptiles of *Zaocys dhumnades* and *Elaphe taeniura*. See attached table for detail.

2) Fauna composition

In the assessment area, among the ten species of reptiles, four are oriental species taking up 40.00% of the total reptile species; six are cosmopolitan species taking up 60.00%; none is palaearctic species. Oriental reptiles are the absolute dominant species, which is in line with the geographic location of the assessment area being oriental realm.

3) Ecological type

According to different living habits of reptiles of the assessment area, ten reptiles can be divided into the following four ecological types:

Residential type (reptiles building nests, reproducing and living in structures in residential community) includes only one species of *Gekko japonicus*, mostly living nearby residential areas.

Shrubland rock crevice type (reptiles often living under shrubland and pavement crevice) includes two species of *Eumeces chinensis* and *Plestiodon elegans*, mostly living in shrubland of the assessment area, relatively closely relating to human activities.

Woods and water type (living under humid woods) includes five species of *Dinodon rufozonatum, Elaphe taeniura, Rhabdophis tigrinus, Zaocys dhumnades* and *Elaphe rufodorsata*, mostly living in humid woods of *Populus euramevicana, Salix matsudana and Broussonetia papyrifera* shrubland on overflow lands nearing water of the assessment area. Number of this ecological type of reptile is the biggest in the assessment area, making it the dominant reptile of the area.

Water type (reptiles living and foraging in water) include the two species of *Trionyx sinensis* and *Tortoise*, mostly living in water body of the assessment area.

c) Birds

1) Species, number and distribution

In the assessment area, there are altogether 12 orders, 31 families and 56 species of birds, among which Passeriformes is of the most with 25 species taking up 44.64% of the birds species in the assessment area with absolute dominance. There are also 3 species of national Class II key protected wild birds of *Buteo buteo, Milvus migrans and Falco tinnunculus*; 18 species of Hubei provincial-level key protected birds. See attached table for number and distribution of various species in the assessment areas.

2) Fauna composition

In the assessment area, there are 20 oriental species taking up 35.71% of the total bird species; 23 oriental species taking up 41.07% of the total bird species; 13 oriental species taking up 23.21% of the total bird species. As the assessment area is located in oriental realm, from perspective of fauna composition, the number of palaearctic birds being larger than that of the oriental birds is the result of the strong migratory ability and seasonal migration of birds. Another reason is that in the assessment area, wetland bird species is relatively large, mostly winter birds and passing migrant birds, with many belonging to palearctic realm.

3) Ecological type

According to different living habits, 56 birds can be divided into the following six ecological types:

Natatores (has flat and wide or pointed beak and webs between toes; leans backwards in walking and swimming; good at swimming, diving and foraging in water; not good at walking on land; flies fast and mostly lives on water) include *Podicipediformes* and *Anseriformes* as well as all species of *Hirundinidae* and *Laridae* under *Charadriiformes,* covering all 9 species of *Podiceps cristatus*, *Tachybaptus ruficollis, Anas crecca, Anas platyrhynchos, Anas poecilorhyncha, Larus ridibundus, Larus glaucescens, Sterna hirundo* and *Sterna albifrons*; they live and forage in Han River of the assessment area.

Wader (has relatively long beak, neck, feet and toes; adpats to wading in water but cannot swim; often sticking its long beak into water or ground for food) include all species of *Ciconiiformes, Gruiformes* and *Charadriiformes* (excluding *Laridae* and *Hirundinidae*) covering 12 species such as *Egretta, Amaurornis phoenicurus, Glareola maldivarum and*

Tringa ochropus; they distribute mainly on mud flat on the two banks of Han River, marsh and paddy field of the assessment area.

Terrestrial bird (has solid built, hard beak, strong and powerful feet; good at digging; mostly forages on the ground) include all three species of *Galliformes* and *Columbiformes*, namely *Phasianus coichicus*, *Streptopelia orientalis* and *Streptopelia chinensis*; they distribute mainly in forest land and other areas of human activities of the assessment area.

Scansores (has specially structured beak, feet and tail; good at tree climbing) include all three species of *Cuculiformes, Coraciiformes, Upupiformes* and *Piciformes*. There are altogether 4 species of scansores in the assessment area, namely *Cuculus canorus*, *Alcedo atthis*, *Ceryle rudis* and *Upupa epops*. Expect for *Alcedinidae* species being depend on water and living near water area, other scansores are all forest birds, distributed in *Populus euramevicana* forest and *Salix matsudana* forest of the assessment area, with some also living in village on forest edge.

Bird of prey (has bending hook-like and sharp beak and claws, strong and powerful wings; can fly or slide in the sky; forage in the air or on ground for hunt) include all species of *Falconiformes,* covering 3 species of *Buteo buteo*, *Milvus migrans* and *Falco tinnunculus* in the assessment area. Bird of prey is on top of the food chain and is of great significance in ecological system. They control the number of *Glires*, and play an indispensable role in maintaining environmental health and ecological balance. Given their limited number, China has listed all birds of prey as national-level key protected birds. Covers extensive areas, birds of prey have wide activity range and are distributed widely in the assessment area.

Songbird (has especially developed syrinx and singing muscle; generally of relatively small body that is light, fast, active and nimble; good at tweeting and singing and smart at build nest) include 25 species of *Passeriformes* widely distributed in the assessment area, with most of them being forest birds.

4) Inhabitation type

Bird migration refers to regular and long-distance migratory activities of birds following seasonal changes with determined destinations. According to migratory behaviors, birds of the assessment area can be divided into the following 4 types:

Resident bird (birds staying in living and reproduction areas without periodic migration) includes 24 species taking up 42.86% of all the birds in the assessment area. Species with larger proportions include *Phasianidae*, *Columbidae* and *Alcedinidae*, as well as some species of *Passeriformes* such as *Timaliidae*.

Winter bird (birds living in certain area in winter and returning to the same area for autumn after reproduction in far-away and colder area in Spring) includes 10 species taking up 17.86% of all the birds in the assessment area, mostly being wetland birds such as most of *Anatidae* species, *Scolopacidae*, some species of *Charadriidae*, and several species of *Passeriformes*.

Summer bird (summer bird refers too birds reproducing in certain areas in spring or summer, and returns to the same area in the spring of next year after fly to warmer areas to pass winter) includes 17 species taking up 30.36% of all the birds in the assessment area, mainly including species of *Ardeidae* and *Cuculidae*.

Passing migrant bird (refers to birds stopping in certain areas during migration, without staying in that area for reproduction or passing winter) includes 5 species taking up 8.92% of all the birds in the assessment area, with the smallest proportion. Passing migrant birds in the assessment area are mainly *Passeriformes* together with some species of *Charadriiformes* and *Falconiformes*.

In conclusion, out of all birds of the assessment area, birds reproducing in the area (including 41 species of resident birds and summer birds, taking up 73.21%) are of a large proportion of more than half, indicating more than half of the birds in the assessment area reproduce in the area; wintering birds are also of large proportion and passing birds are of relatively small proportion.

d) Beasts

1) Species, number and distribution

In the assessment area, there are altogether 5 orders, 5 families and 10 species of beasts, among which *Muridae* is of the most with 5 species taking up 50.00% of the beast species in the evaluation. There are no national-level key protected wild beasts and 1 species of Hubei provincial key protected beast of *Meles meles*. See attached Table 5 for number and distribution of various species in the assessment areas.

2) Fauna composition

In the assessment area, among the ten species of beasts, one is oriental species taking up 10.00% of the total beast species; five are palaearctic species taking up 50.00%; four are cosmopolitan species taking up 40.00%, indicating a strong penetrating trend of palearctic composition due to relatively strong migratory ability of beasts in the assessment area as it is located in the oriental realm bordering with palearctic realm.

3) Ecological type

Semi-underground type (foraging, living mostly on the ground, avoiding enemy in cave, with some also foraging underground) include altogether 9 species such as *Erinaceus amurensis, Lepus capensis* and *Mustela sibirica*. Their assessment area is mainly distributed in fields, among which species of *Muridae* are closely related to human.

Grotto type (small beasts hanging upside down in grottos) include the one species of *Pipistrellus pipistrellus*, with its assessment area mainly distributed close to villages.

4) National-level and provincial-level key protection animal

Among terrestrial vertebrata of the assessment area, there is no national Class I key protected wild animal, and are 3 species of national Class II key protected wild animals, namely *Buteo buteo, Milvus migrans* and *Falco tinnunculus*.

According to local resources survey report of Wangyangzhou national wetland park, there are 4 species of national Class II protected animals, namely *Anser albifrons*, *Aix galericulata, Milvus migrans* and *Merops viridis*. Except for *Milvus migrans,* other three species of birds are not included in the list of birds of this feature evaluation, mainly for reasons listed as follows. *Merops viridis* is neither a national key protected wild animal, nor a Hubei provincial-level protected wild animal. In multiple field surveys these species were not found in the assessment area. Although highly entertaining, *Merops viridis* is not commonly seen as it favors open area such as woodside open forest, shrubland and grass slope, and mainly feeds on *Apoidea* whereas honey plants are few in the wetland park, meaning few food sources for *Merops viridis*. Therefore, it is deduced that the possibility of *Merops viridis* appearing in the wetland park is relatively low.

Anser albifrons favors habitats such as lake, water pond, river and marsh abundant with dwarfs whereas vegetation of the wetland park is mainly broadleaved forest and grass, with relatively less shrubland vegetation. Therefore it is not included in the species list. *Aix galericulata* favors mountain area, river valley, coniferous and broadleaved mingled forest, as well as nearby creek, marsh, reed field, paddy field and lake, and flies back to forest at night. Located in plain area, the wetland park has *Populus euramevicana* forest on the two banks, but *Aix galericulata* is inherently vigilant and extremely good at hiding, whereas man-made interference is quite obvious around the wetland park. Therefore, it is deduced that the possibility of *Aix galericulata* appearing is relatively low.

From September 2014 to April 2015, ecological survey unit conducted multiple wetland bird surveys in the middle and lower reaches of Han River and did not discover the three species. Therefore, only three species, see Table 4.2.1-8, are listed as no national key protected wild animals in this report.

Table 4.2.1-8 List of national key protected wild animals in the assessment area

Serial No.	Chinese name and scientific name	Habitat	Order of magnitude	Level of protection
1	黑鸢 *Milvus migrans*	Inhabits open plain, grassland, wasteland and low hilly land, mainly appearing and circling above key project affected area with a small number.	+	National Class II
2	普通鵟 *Buteo buteo*	Winter bird; inhabits mainly forest edges of mountainous forest and forest land. Mostly appearing in arable area of low hilly land of the project affected area and circling and hovering above village.	+	National Class II
3	红隼 *Falco tinnunculus*	Inhabits various habitats of mountainous forest, low hilly land, forest plain, farmland and arable land as well as village surroundings, and appears mostly in forest edge, slash and open farmland areas with open forest and scattered trees in the key project affected area.	+	National Class II

Milvus migrans: medium-sized bird of prey of *Accipitridae* under *Falconiformes*, with a body length between 54~69cm. It has dark brown upper body, sepia lower body, both with black brown rachis wrinkles, relatively long tail that is fork-shaped, horizontal speckles in black and brown alternating between same width, and a large white speckle under either wing when flying. It inhabits open plain, grassland, wasteland and low hilly land, feeding mainly on animals such as small birds, mouse, snake, frog, fish, hare, lizard and insects. Taking advantage of its sharp vision, it usually observes and forages food hovering in the air. In key assessment area, it is mainly distributed in the air above open grassland and wetland. Distribution: relatively widely distributed in the assessment area.

Buteo buteo: medium-sized bird of prey of *Buteo* under *Accipitridae*, with a body length between 50~59cm. It has dark brown upper body, dark brown or light brown lower body flying in a shallow “V” shape with its two wings slightly raised. It is commonly seen hovering and flying in the air above open plain, desert, open field, cultivated arable area, grassland on forest edge and village. With a large appetite it feeds on animals such as forest *Muridae*, *Glires*, frog, lizard, snake, hare, small bird and large insect, and occasionally preys on poultry such as chicken in villages. Some are winter birds and passing migrant birds. Migration period is March to April in spring, and October to November in autumn. In key assessment area, it is mainly distributed in open land and forest edges nearby.

Falco tinnunculus: small-sized bird of prey, with a body length between 31~36cm. Its reproduction period is between May to July. It usually build nest in soil cave, tree hold and old tree nest of *Pica pica*, *Corvus* and other birds. It feeds mainly on insect, amphibian, small reptile, small bird and small mammals. *Falco tinnunculus* likes to act solo, and it is particularly active at dusk. With excellent flying ability, it likes to fly against the wind and it can stop in the air by moving its wings very quickly. With excellent vision it captures food rapidly as it dives down quickly once there is food on the ground, and sometimes it also captures small bird or dragonfly in the air. In the key assessment area, it inhabits various habitats such as mountainous forest, low hilly land, forest plain, farmland and arable land as well as village surroundings, especially commonly seen in forest edge, slash and open farmland areas with open forest and scattered trees.

In the assessment area, there are 26 species of Hubei provincial key protected wild animals, among which are 5 species of amphibians namely *Bufo gargarizans*, *Pelophylax* *nigromaculata, Fejervarya multistriata, Microhyla ornata* and *Pelophylax hubeiensis;* 2 species of reptiles namely *Elaphe taeniura* and *Zaocys dhumnades*; 18 species of birds namely *Podiceps cristatus, Egretta, Anas platyrhynchos, Phasianus coichicus, Sterna hirundo, Streptopelia chinensis, Cuculus canorus, Upupa epops, Hirundo rustica, Hirundo daurica, Lanius cristatus, Lanius schach, Oriolus chinensis, Dicrurus macrocercus, Acridotheres cristatellus, Cyanopica cyana, Pica pica* and *Turdus merula*, as well as 1 species of beast namely *Meles meles*.

4) Animal situation of construction area and reservoir inundation area

Yakou shipping hub is flanked by mainly arable land and overflow lands on either side of Han River, involving some *Populus euramevicana* forest, shrubland and scrub-grassland. The area has frequent human activities and terrestrial animals mainly of commonly seen aquatic birds and amphibians.

Amphibians: number of amphibians seen in the construction area is relatively few, mainly including *Bufo gargarizans, Microhyla butleri, Microhyla ornata* and *Fejervarya limnocharis.*

Reptiles: reptile species in the construction area is relatively few, mainly including *Eumeces chinensis, Rhabdophis tigrinus* and *Gekko japonicus*.

Birds: Natatores and waders such as *Egretta, Ardeola bacchus, Charadrius alexandrinus* and *Tadorna ferruginea* are commonly seen in the two banks of Han River. In the construction camp and quarry site areas, terrestrial birds are the majority, including *Streptopelia chinensis, Streptopelia turtur* and *Phasianus colchicus*, as well as Passeriformes species such as *Lanius schach, Dicrurus macrocercus* and *Pica pica*.

Beasts: cave type and small terrestrial type are the main species, living mostly in woodland where human activities are rare. Its distribution within the construction area mainly includes *Cricetulus Barabensis* and *Rattus norvegicus* of *Rodentia*, small numbers of *Lepus capensis* of *Lagomorpha*, and *Mustela sibirica* of *Carnivora*.

4.2.1.5 Current ecological situation of the project area

a) Permanently occupied area

1) Junction structure

The flow of Han River at the dam site is generally from south to north, with broad river surface and developed overflow lands . Inflow of tributary Ying River is about 250m downstream of the left bank of the dam site, and main riverbed is on the right bank with a maximum thalweg of about 8m. Main vegetation of the central bar is artificial woods of *Populus euramevicana* and then *Salix matsudana*. Low floodplain on either side of Han River is of flat and wide open topography. Left bank of the dam site is Grade III terrace with a top elevation between 63.0 and 72.0m, and a steep slope on the river-facing side. Vegetation type is *Broussonetia papyrifera* shrubland, with *Amygdalus persica, Citrullus lanatus, Gossypium spp* as well as *Populus euramevicana* and *Sophora japonica* of macrophanerophytes planted in the cultivated dry land on the bank. There are *Sophora japonica* scattered around housing. Right bank of the dam site is Grade I terrace with a ground elevation of about 53.0m, with *Populus euramevicana* woods and shrubland of mainly *Broussonetia papyrifera* planted near the bank. Right bank of the dam site has wide overflow lands that are cultivated dry lands growing *Zea mays, Gossypium spp* and vegetables, with Han River floodwall built on the right side of the terrace. Commonly seen on the two banks are broadleaved macrophanerophytes such as *Sect. Camphora, Ligustrum lucidum* and *Sect. Camphora,* as well as shrubs such as *Rosa laevigata, Vitex negundo, Rhus chinensis* and *Dalbergia hupeana.*

2) Construction site and domestic and office areas

Construction site is situated on the overflow lands upstream of the earth dam on the right bank, and it has concrete and gravel system, comprehensive processing plant, metal structured assembling plant and repairing facility for machinery equipment. PIU camp is preliminarily considered to be in the upstream of the dam site on the right bank, and is to include comprehensive office building, ship gate management institute, staff dormitory, activity center, canteen, warehouse, and substation. Located on flood land, the area will be inundated during low flow season and above water surface in other times. On cultivated dry land, crops such as vegetables and *Zea mays* are planted, with few *Populus euramevicana* and *Salix matsudana* scatted. Other commonly seen vegetation include *Broussonetia papyrifera* shrubland, *Artemisia lavandulaefolia* scrub-grassland and *Cynodon dactylon* scrub-grassland

b) Temporarily occupied area

1) Soil storage site

Yakou soil storage site is situated in Yujiawan of Yakou village in Liushui county on the left bank, about 2km from Yakou dam site, connected by village roads with good road conditions and convenient transport. Main vegetation of borrow pit is currently crops such as *Zea mays*, *Glycine max*, *Solanum tuberosum*, *Brassica campestris, and Populus euramevicana*, as well as main shrubland types of *Broussonetia papyrifera*, and scattered *Phyllostachys heterocycla* and *Sect. Camphora*.

2) Temporary soil storage site

One the overflow lands on either side of the junction project area, one temporary soil storage site (Temporary storage site) is set up to meet the project requirement. Temporary storage site on the right bank covers $7hm^2$ and is dry land with main plants such as *Zea mays* and *Oryza sativa*. Temporary storage site on the left bank covers $21hm^2$ and is woodland with main vegetation such as *Salix matsudana*, *Broussonetia papyrifera* shrubland and *Vitex negundo* shrubland, as well as commonly seen plants such as *Melia azedarach*, *Dalbergia hupeana, Phytolacca acinosa, Oxalis corniculata, Geranium wilfordii*, *Boehmeria nivea, Alternanthera Philoxeroides*, *Erigeron annuus* and *Hemarthria altissima*.

3) Waste disposal area

Three Waste dumps are to be set in the project area, among which two Waste dumps are on the left bank of Han River, namely on the bund upstream of Han River left bank, and on the Han River bund on the left bank of Ying River estuary. Vegetation of the area mainly includes *Broussonetia papyrifera* shrubland, *Nelumbo nucifera* scrub-grassland and *Cynodon dactylon* scrub-grassland. One Waste dumps is on the right bank of Han River, located on the bund upstream of the right dyke of Han River. Right bank overflow lands is cultivated dry land with no original vegetation due to agricultural development, growing *Benincasa hispida* and *Zea mays*, as well as other vegetation such as *Broussonetia papyrifera* shrubland, *Populus euramevicana* woodland, *Cynodon dactylon* scrub-grassland, and scattered *Pterocarya stenoptera*. Other commonly seen plants include

Artemisia lavandulaefolia, Arthraxon hispidus, Oxalis corniculata, Perilla frutescens, Pilea notata, Phytolacca Americana and *Erigeron annuus.*

4) Temporary road

Five trunk roads are to be laid, namely dam road on the left bank, floodwall road on the right bank (dam road on the right bank), Yipokong road on the right bank into the site, road of construction and living quarters on the right bank, storage site road and other temporary construction roads within the site. A temporary wharf is set nearby Hanqiying and is about 1km downstream of the right bank of the dam site area. Most are of renovating existing roads mostly with farmlands of *Oryza sativa, Zea mays, Brassica campestris* and seasonal vegetables on either side. On either side of roads are also *Broussonetia papyrifera* shrubland, *Vitex negundo* shrubland, and scrub-grasslands such as *Cynodon dactylon* and *Erigeron annuus*. Commonly seen plants within the area include *Boehmeria nivea, Imperata cylindrica, Glechoma longituba, Plantago asiatica, Oxalis corniculata* and *Kummerowia stipulacea*.

c) Current biological situation of the inundation area

Yakou reservoir returns water to the dam site of Cuijiaying Hydro-junction. The reservoir area is about 52.67km long, with reservoir inundation area mostly in Yicheng city districts and only a very small part in Xiangcheng district. Tributary inflows of Chun River and Wei River into Han River are within the reservoir area of Yakou junction. Developed overflow lands of the inundation area is mostly cultivated for the plantation of crops or trees, including main grain crops of *Triticum aestivum* and *Zea mays,* as well as main economic crops of *Gossypium spp, Arachis hypogaea* and *Brassica campestris*.

Reservoir inundation mainly affects overflow lands on the right bank of Han River and central bar. Woods in the inundation area mainly include artificial *Populus euramevicana*, followed by *Pterocarya stenoptera*, *Melia azedarach* and *Salix matsudana*; shrubland mainly includes *Broussonetia papyrifera* and *Vitex negundo*; grassland mainly includes *Cynodon dactylon* scrub-grassland, *Conyza canadensis* scrub-grassland and *Hemarthria altissima* scrub-grassland; agricultural vegetation mainly includes vegetables such as *Zea mays* and *Benincasa hispida*, as well as *Gossypium spp*.

Central bar

Left bank of dam site

Right bank of dam site

Current situation of construction site and living and office areas

Current situation of construction site and living and office areas

Yakou soil storage site

Bund waste disposal area upstream of the right embankment of Han River

Han River bund waste disposal area on the left bank of Ying River mouth

Current vegetation situation of the inundation area

Current vegetation situation of the inundation area

Figure 4.2.1 Figure of current ecological environmental situation of the assessment area

4.2.2 Aquatic ecology

4.2.2.1 Survey method and process

According to survey, aquatic ecological environmental surveys of the project river section were conducted in 1977, 1996, 1997, 1998, 2004 and 2009. This report analyzes aquatic ecological changes of the project river section according to aquatic ecological survey results over the years. To further understand the current aquatic ecological environmental situation of the project river section, in August 2012 and August 2014, our company entrusted the Institute of Hydroecology of the Ministry of Water Resources and Chinese Academy of Sciences to conducted detailed surveys of current aquatic ecological situations regarding the upstream, downstream and tributary of the river section where Yakou shipping hub is located.

a) Material collection

Survey unit collected and investigated materials on the current situations of the natural environment, socio-economic development, aquatic ecological environment and fishery development of the basin from relevant authority departments, examined relevant research findings of aquatic ecology of the river section, and adopted methods such as field survey and interview to acquire relevant material on aquatic ecology.

b) Field sampling analysis

1) Survey period and scope

Time of aquatic organism survey was from April to May 2014; range of aquatic organism survey includes Han River from Cuijiaying hydro-junction to Nianpanshan dam site, and inflowing tributaries such as Wei River, Chun River and Ying River.

Fish species survey were conducted in the Yicheng-Zhongxiang river section in the middle and lower reaches of Han River during April 10 to 19, and July 2 to August 2 of 2014. Sections with main survey points include Yicheng county section, Zhongxiang-Lingkuang county section and Zhongxiang city gate-Huangzhuang section. From April 11 to 18 2014, survey was conducted on spawning grounds for fishes with adhesive eggs; from July 2 to August 2, and August 26 to September 10, 2014, spawning survey was conducted on fish with pelagic eggs.

2) Survey method

Field survey was carried out mainly by means of hiring local fisherman for fishing, purchasing commercial catch, and interview, inquiry and picture identification with professional and amateur fisherman as well as long-time local residents. Fishing tools include drift gillnet, fixes gillnet, ground cage, seine, electric fishing machine and fish hook.

3) Survey cross section

Based on controllability and representation principles, monitoring survey of aquatic organism and water quality proposed to set eight cross sections on the main stream and major tributaries as illustrated in Figure 4.2.2-1, among which five sampling cross sections are on the main stream namely, from upstream to downstream, upstream of Cuijiaying dam, downstream of Cuijiaying dam, Yicheng bridge, Yakou dam site and Huji, and three sampling cross sections are on tributaries of Wei River, Chun River and Ying River.

With no fixed cross section set, the focus of fish species resources survey are water areas of catch survey and statistics including the Han River from Cuijiaying junction to Xinglong reservoir rear, as well as the various tributaries within the section. With one monitoring cross section in Zhongxiang and Hanchuan, larval resources monitoring of fish species also include necessary floating monitoring of the abovementioned river sections.

Figure 4.2.2-1 Sketch map of aquatic organism sampling cross section

原文	English
襄阳	Xiangyang
崔家营	Cuijiaying
淳河	Chun River
渭水	Wei River
宜城	Yicheng
雅口	Yakou
莺河	Ying River
流水	Liushui county
磷矿	Linkuang county
碾盘山	Nianpanshan
钟祥	Zhongxiang
图例	Legend
河流	River
已建枢纽	Developed junction

采样断面	Sampling cross section
规划枢纽	Planned junction

c) Survey content

Survey content includes habitat feature, aquatic organism, current fish species and fishery situation.

4.2.2.2 Bait organism

a) Phytoplankton

1) Historical survey result

In 1977, in the middle reach there were 4.64×10^5 ind./L in summer, 6.33×10^5 ind./L in autumn and 0.65×10^5 ind./L in winter, and in the lower reach, there were 0.66×10^5 ind./L in autumn and 0.41×10^5 ind./L in winter; survey result of 1996 was 0.15×10^7 ind./L; survey result of 1997 was 1.0×10^7 ind./L; survey result of 1998 was 1.7×10^7 ind./L; survey result of 2000 was 3.62×10^7 ind./L. Results show that the number of phytoplankton in the middle and lower reaches of Han River is on the rise year by year, indicating a gradual deterioration of water quality in Han River.

2) Current survey result

(1) Species

During the two phytoplankton surveys of the area from April and July 2014, there were altogether 8 Phylum, 65 Genus and 124 species of phytoplankton detected (Attached Table 1), among which were 71 species of *Bacillariophyta*, accounting for 57.26% of the detected species; 10 species of *Cyanophyta*, accounting for 8.06% of the detected species; 29 species of *Chlorophyta*, accounting for 23.39% of the detected species; 3 species of *Pyrrophyta*, accounting for 2.42% of the detected species; 2 species of *Chrysophyta* and *Cryptophyta* each, accounting for 1.61% of the detected species respectively; 6 species of *Euglenophyta*, accounting for 4.84% of the detected species; and 1 species of *Rhodophyta* , accounting for 0.81% of the detected species.

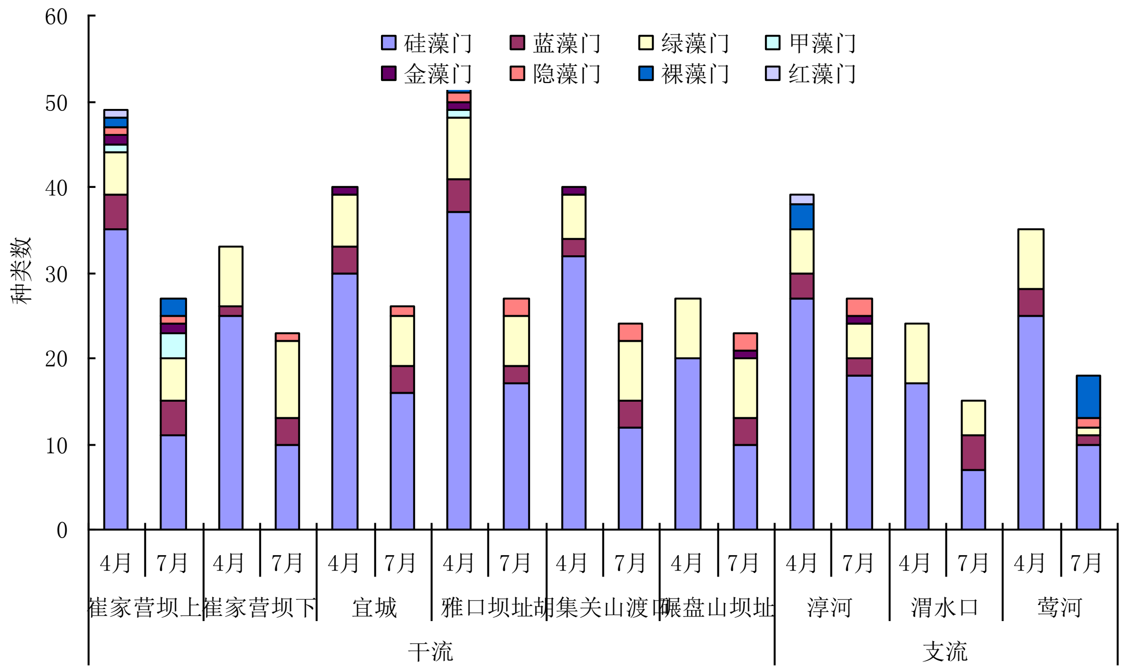


Figure 4.2.2-2 Phytoplankton species composition of various cross sections of the survey area

原文	English
硅藻门	*Bacillariophyta*
蓝藻门	*Cyanophyta*
绿藻门	*Chlorophyta*
甲藻门	*Pyrrophyta*
金藻门	*Chrysophyta*
隐藻门	*Cryptophyta*
裸藻门	*Euglenophyta*
红藻门	*Rhodophyta*
种类数	Species number
四月	April
七月	July
干流	Main stream
崔家营坝上	Upstream of Cuijiaying dam
崔家营坝下	Downstream of Cuijiaying dam
宜城	Yicheng
雅口坝址	Yakou dam site
胡集关山渡口	Gushan ferry of Huji county
碾盘山坝址	Nianpanshan dam site
支流	tributary
淳河	Chun River
渭水口	Wei River mouth
莺河	Ying River

In the assessment area, species of phytoplankton detected in the main stream is more than that of in the tributaries, and the number of phytoplankton species detected in April 2014 was higher than that of in July 2014. Phytoplankton species composition of both the main stream and tributaries are mainly of *Bacillariophyta* and then *Chlorophyta*. Dominant phytoplankton species in the assessment area are mainly *Synedra*, *Cymbella*, *Fragilaria* and *Diatoma of Bacillariophyta*.

(2) Current stock

In the survey area, average density of phytoplankton is 3357742ind./L, with *Bacillariophyta* taking up 30.30%, *Cyanophyta* taking up 60.01%, *Chlorophyta* taking up 5.29%, *Pyrrophyta* taking up 0.18%, *Cryptophyta* taking up 3.90%, and *Euglenophyta* taking up 0.31%. Average density of phytoplankton in the main stream of the survey area is 2852247ind./L, and average density of phytoplankton in the tributaries of the survey area is 4368732ind./L.

Average phytoplankton biomass of the survey area is 2.3312mg/L, with *Bacillariophyta* taking up 76.15%, *Cyanophyta* taking up 5.06%, *Chlorophyta* taking up 7.06%, *Pyrrophyta* taking up 3.08%, *Cryptophyta* taking up 5.06%, *Euglenophyta* taking up 3.59% and *Chlorophyta* taking up 5.06%. Average phytoplankton biomass in the main stream of the survey area is 1.8257mg/L, and average phytoplankton biomass in the tributaries of the survey area is 3.3423mg/L.

(3) Biodiversity

Algae biodiversity was calculated using Shannon-Wiener index formula. See Table 4.2.2-1 for phytoplankton biodiversity indexes of various cross sections of the survey area.

Table 4.2.2-1 Phytoplankton diversity index and species number of the survey area

Cross section			Species number	Diversity index
Main stream	Upstream of Cuijiaying dam	April	49	0.78
		July	27	0.88
	Downstream of Cuijiaying dam	April	33	1.58
		July	23	1.77
	Yicheng	April	40	2.88
		July	26	3.59
	Yakou dam site	April	53	2.35
		July	27	2.70

	Gushan ferry of Huji county	April	40	1.85
		July	24	2.07
	Nianpanshan dam site	April	27	2.56
		July	23	2.89
Tributary	Chun River	April	39	1.89
		July	27	2.32
	Wei River mouth	April	24	2.11
		July	15	1.98
	Ying River	April	35	2.56
		July	18	3.13

b) Zooplankton

1) Historical survey result

In 1977, in Han River the number of zooplankton was 10.37ind/L in the middle reach, and 3.42ind/L in the lower reach; in 1994, there were over 40 species of zooplankton totaling 1047.9ind/L; in 2003, there was 10.05ind/L (protozoon excluded); in March 2004, there was 31.42ind/L (protozoon excluded); in 2009, there were 158 species of zooplankton totaling 438.15ind/L. according to longitudinal comparison, zooplankton species in the middle and lower reaches of Han River was substantially increased, with clear growth in number. Comparing compositions of four major zooplankton species with that of in 1977, the proportion of protozoon in zooplankton rose from 52.6% to 66.8%, and *Cladocera* went down from 8.2% to 0.6%. Change trend of zooplankton was towards smaller size and pond-oriented development.

2) Current survey result

(1) Species

During the two monitoring of the Yakou section of Han River in April and July 2014, there were altogether 62 Genus and 110 species of zooplankton detected (Attached Table 2), among which were 33 species of protozoon, accounting for 30% of the total; 41 species of *Rotifera*, accounting for 37.27%of the total; 16 species of *Cladocera*, accounting for 14.55% of the total; 20 species of *Copepods*, accounting for 18.18% of the total. From the perspective of zooplankton composition in the Yakou survey water area of Han River, the dominating species is *Rotifera*, followed by protozoon, and *Cladocera* and *Copepods* are of certain proportions.

(2) Current stock

In the survey area, density of zooplankton is 125.55 to 3510.75ind./L (average being 1384.81ind./L), among which the density of protozoon is 1019.44ind./L taking up 73.62%; the density of *Rotifera* is 346.67ind./L taking up 25.03%; the density of *Cladocera* is 5.23ind./L taking up 0.38%; the density of *Copepods* is 13.47ind./L taking up 0.97%.

Biomass is 0.0434 to 1.0738mg/L(average being 0.1775 mg/L), among which the biomass of protozoon is 0.0029mg/L taking up 1.65%; the biomass of *Rotifera* is 0.0620mg/L taking up 34.95%; the biomass of *Cladocera* is 0.0523mg/L taking up 29.46%; the biomass of *Copepods* is 0.0602mg/L taking up 33.94%.

In the water area surveyed, there was clearly difference of zooplankton density in April and July, with density of April being lower as 904.15 ind./L, and density of July being higher as 1865.48ind./L. Changes of biomass is the same with that of density (See Figure 4.2.2-14), with biomass of July being higher as 0.2947mg/L, and biomass of April being lower as 0.0603mg/L.

(3) Biodiversity

Calculation results of zooplankton diversity indexes of the nine monitoring points of the water area surveyed reveal that Cuijiaying has the higher indexes in July with Shannon-Wiener index being 2.098 and Margalef being 1.439, and diversity indexes of other monitoring points are all below 2. Water body of Han River of the survey area has high sediment discharge, turbid water, relatively low nutrient substance, relatively few zooplankton species, relatively low biomass, extremely low zooplankton diversity index, and relatively simple zooplankton community feature.

c) Zoobenthos

1) Historical survey result

In 1977, 33 species of zoobenthos (among which were 18 species of aquatic insects, 6 species of *Oligochaeta*, 6 species of mollusk, and 3 species of others) were collected in the middle and lower reaches of Han River, and zoobenthos density was 102.8 ind./m^2; in 2003, 24 species of zoobenthos (among which were 1 species of aquatic insects, 3 species of *Oligochaeta*, 20 species of mollusk, and 1 species of *Hirudinea*) were collected, and zoobenthos biomass was 50.24mg/m^2; in the survey from September 7 to 12 of 2014, 18 species of zoobenthos (among which were 6 species of mollusk, 3 species of *Oligochaeta*, and 9 species of aquatic insects) were included in the quantitative sample; in the 2009 survey of the middle and lower reaches, zoobenthos density was 360 ind./m^2, and biomass was 46518 mg/m^2, whereas biomass in the lower reach was 21142.6mg/m^2, 480 times that of in 2003. Survey reveals the number and biomass of zoobenthos is on a gradual rise, indicating water quality deterioration in Han River.

2) Current survey result

(1) Species

In the assessment area, 36 species of zoobenthos were detected (Attached Table 3), among which were 5 species of *Annelida* taking up 13.89%; 10 species of *Mollusk* taking up 27.78%; 20 species of *Arthropoda* taking up 55.55%; 1 species of others taking up 2.78%. Dominant species include *Limnodrilus hoffmeisteri, Branchiura sowerbyi, Semisulcospira cancellata, Bellamya aeruginosa, Radix swinhoei, Limnoperna fortune, Corbicula fluminea* and *Procladius*.

In the assessment area, seasonal change of zoobenthos species were relatively obvious, with 28 species of zoobenthos in April, namely 5, 8 and 15 species of *Annelida*, *Mollusk* and *Arthropoda* respectively; 25 species of zoobenthos in July, namely 4, 9, 11 and 1 species of *Annelida, Mollusk*, *Arthropoda* and others respectively.

(2) Current stock

In the assessment area, zoobenthos density was 2549ind./m^2, with *Annelida, Mollusk, Arthropoda* and others taking up 4.119%, 33.072%, 62.770% and 0.039% respectively; biomass was 495.30g/m^2, with *Annelida, Mollusk, Arthropoda* and others taking up 0.079%, 99.380%, 0.539% and 0.002% respectively.

In the assessment area, zoobenthos density was 1094ind./m^2 and biomass was 73.56g/m^2 in April; zoobenthos density was 4004ind./m^2 and biomass was 917.04 g/m^2 in July. Current stock of zoobenthos in July was more than that of in April.

(3) Biodiversity

Zoobenthos Shannon-Wiener indexes of all cross sections in the assessment area are all below 2.00, which is relatively low as a whole in terms of diversity, among which zoobenthos diversity indexes of Chun River and Ying River are relatively high, and diversity index of Wei River is relatively low, indicating water quality of the river section evaluated was polluted to a certain extent. The evaluation section on Han River is of wide river surface, and mostly sand in substratum. Given the various types of habitats, ecological factors are fitting for the survival of large mollusk. The number and current stock of zoobenthos species in the main stream is higher than that of in tributary.

d) Periphytic algae

In the survey area, there were altogether 3 phylum, 25 genus and 124 species of periphytic algae detected, among which were 26 species of *Bacillariophyta*, accounting for 66.67% of the detected species; 9 species of *Chlorophyta*, accounting for 66.67% of the detected species; 4 species of *Cyanophyta*, accounting for 10.26%of the detected species. In the survey area, periphytic algae are mainly *Bacillariophyta*, then *Chlorophyta*, and followed by *Cyanophyta*. Commonly seen species include *Melosira granulate, Asterionella Formosa, Fragilaria capucina, Fragilariacrotomensis chocephala, Synedra amphicephal* and *Cymbella naviculiformis.*

e) Aquatic vascular plant

Aquatic vascular plant is a generic term for vascular plants living in water and wetland, and its distribution is affected by water depth, transparency, water quality, substratum and other organisms. It is feed to many herbivorous and omnivorous fish species, and spawning grounds to fishes with adhesive eggs. Traditionally it is mainly divided into the four ecological groups of emerged plant, floating-leaved plants, submerged plants and fluitante. Given the feature of Han River, it is mainly of emerged plant and submerged plants.

Acocring ot relavent material of Han River and field sampling analysis, ther are altogether 19 family of 36 species of aquatic vascular plants in the middle and lower reach of Han River, among which wre 15 species of emerged plant, 2 species of floating-leaved plants, 13 species of submerged plants and 6 species of fluitante. See Table 5 Directory of aquatic vascular plants in the middle and lower reach of Han River of Appendix 3 for details

4.2.2.3 Fish species

a) Fish fauna composition

River section from Danjiangkou to Xiangfan has limpid water quality and relatively rapid flow, with mostly hilly terrace on its two banks. Although the completion of Wangfuzhou reservoir widened the existing riverway, and slowed its water flow, its impact was relatively limited because it is a low dam with small water storage volume and it is only 30km from Danjiangkou dam. In addtion, with clean water discharged from Danjiangkou dam, riverway was eroded, undercut and contracted, forming pebble substrata in many river sections due to substratum gravel coarsening. Therefore, the river section still maintains many good water habitat, inhabitating some species favoring flowing water, such as *Zacco platypus, Opsariicjthys bidens, Distoechodon tumirostris, Sinibrama wui, Saurogobio gracilicaudatus, Gobiobotia filifer, Varicorhinus macrolepis, Leiobagrus marginatus* and *Glyptothorax sinense,* which are rarely seen in the river section downstream of Shayang. *Rhinogobio* fish species have close relations with river substratum for they favor gravel substratum and river section with relatively rapid water flow. Their distributions are mostly in river section upstream of Xiangfan, gradually decreasing downstream of Xiangfan, and getting less downstream of Shayang. *Rhinogobio cylindricus* generally lives in river section with sandy riverbed, and is therefore mainly distributed in river section downstream of Xiangfan, with very small amount in river section upstream of Xiangfan. Rhinogobio ventralis is rarely seen and is only distributed in the lower reach of Han River. Distributions of different Cyprinus flammans species are quite different. *Erythroculter ilishaeformis* has relatively large species distribution in both the middle and lower reaches of Han River, whereas *Erythroculter mongolicus, Erythroculter oxycephaloides, Erythroculter dabryi* and *Culter erythropterus* are mainly distributed in river section downstream of Xiangfan, and are extremely rarely seen in river section upstream of Xiangfan.

According to record in *Hubei Ichthyography* (1987), 93 fish species were distributed in the river section of Han River downstream of Danjiangkou, including the river section surveyed. During 2003 to 2004, Reservoir Fishery Institue surveyed 81 fish species in the middle and lower reaches of Han River downstream of Danjiangkou, among which 76 fish species were survyed in the middle and lower reaches of Han River from Xiangfan to Shayang, covering the river section of this survey, including *Megalobrama amblycephala* which was not included in the 92 species distributed in this river section as recorded in *Hubei Ichthyography*, making it altogether 93 species recorded.

Over 1200 fish were collected during this survey in Yicheng-Zhongxiang river section and tributaries of Han River. According to catch collected as well as market inspection and interview with fisherman, by summerizing the abovementioned material collected and checking for correction with literatures such as *Fauna Sinica Osteichthyes Cypriniformes (volume II), Fauna Sinica Osteichthyes Cypriniformes (volume III), Fauna Sinica Siluriformes* and *Catalogue of Life China (Internet)*, as well as survey of Yicheng river section conducted by Institute of Hydroecology in August 2012, 63 fish species are distributed in the Yicheng-Zhongxiang river section of Han River and its tributaries, including 5 orders, 13 families and 51 genera.

Among the 63 fish species surveyed, there are 38 genera and 46 species of *Cypriniformes* taking up 73.0% of the total; 6 genera and 8 species of *Siluriformes* taking up 12.7% of the total; 5 genera and 7 species of *Perciformes* taking up 11.1%of the total; 1 genera and 1 species of *Beloniformes* and *Synbgranchiforme* each. On family level, the top three are successively Cyprinidae of 38 genera and 46 species taking up 63.5%; Bagridae of 4 genera and 6 species taking up 9.5%; Cobitidae of 4 genera and 5 species taking up7.9%.

Table 4.2.2-2 Classification and composition of fish species of the surveyed river section

Order	Family	Historical record			Current survey		
		Genus	Species	%	Genus	Species	%
Salmoniformes	*Salangidae*	2	2	2.6			
Anguilla japonica	*Anguillidae*	1	1	1.3			
Cypriniformes	*Cobitidae*	5	6	7.9	4	5	7.9
	Cyprinidae	35	46	60.5	33	40	63.5
	Homalopteridae	1	1	1.3	1	1	1.6
Siluriform	*Siluridae*	1	1	1.3	1	1	1.6

Order	Family	Historical record			Current survey		
		Genus	Species	%	Genus	Species	%
es	*Bagridae*	4	8	10.5	4	6	9.5
	Amblycipitidae	1	1	1.3			
	Sisoridae	1	1	1.3	1	1	1.6
Beloniformes	*Hemiramphidae*	1	1	1.3	1	1	1.6
Synbgranchiformes	*Synbranchidae*	1	1	1.3	1	1	1.6
Perciformes	*Serranidae*	1	3	3.9	1	3	4.8
	Odontobutidae	1	1	1.3	1	1	1.6
	Gobiidae	1	1	1.3	1	1	1.6
	Channidae	1	1	1.3	1	1	1.6
	Mastacembelidae	1	1	1.3	1	1	1.6
Total		58	76	100.0	51	63	100.0

b) Rare and protected fish species

In the 1958 survey prior to hydropower development project, there was record of *Acipenser dabryanus*. *Psephurus gladius* was also recorded in the 1950s, but was not found in 1970s and in this survey, nor was it found by fisherman. Acipenser dabryanus and *Psephurus gladius* mainly lives in the main stream of Yangtze River, with extremly rare resources and mostly in the upper reach. So even if some gets into Han River, they are limited to esturay section of the river. According to literature, there are *Myxocyprinus asiaticus* currently distributed in Han River, feeding on the abundant *Limnoperna fortunei* of Han River, but *Myxocyprinus asiaticus* was not found in three large-scaled surveys. *Myxocyprinus asiaticus* lives in water area similar to *Acipenser dabryanus*, so even if it enters Han River, it is in river section downstream of Hanchuan. Migratory economic fish species of *Anguilla japonica* and *Coilia macrognathos* are still distributed in the middle and lower reaches of Han River, and extremely limited number of *Anguilla japonica* is distributed in river section downstream of Wangfuzhou. *Coilia macrognathos* has a relatively large population, and is mainly distributed in river section downstream of Shayang.

In the 93 species recorded were no national-level protected fish species, and 5 aquatic wild animals of Hubei provincial protection, namely *Luciobrama microcephalus, Ochetobibus elongates, Saurogobio gracilicaudatus, Onychostoma macrolepis (Varicorhinus macrolepis)* and *Leiocassis longirostris*. No species of *Red Data Book* is recorded. One species of *Leiobagrus marginatus* is listed in Red List, and is endangered (EN). One river and ocean migratory species of *Anguilla japonica* is recorded. Only one exotic species of *Protosalanx hyalocranius* is recorded, and is an inflow species from upstream reservoir instead of resident species of the river section surveyed.

In the 63 species surveyed, there were no other varieties of the abovementioned species.

c) Fauna feature

fish species are living in mixed area of Han River plain downland, hill and plain, with a river elevation less than one hundred meter. Fish species surveyed and recorded in literatures can be roughly divided into the following six fauna groups:

(1) River plain group including *Botia superciliaris, Parabotia fasciata, Parabotia banarescui, Leptobotia taeniaps, Cobitis sinensis, Zacco platypus, Opsariicjthys bidens, Mylopharyngodon piceus, Ctenopharyngodon idellus, Squaliobarbus curriculus, Xenocypris argentea, Xenocypris davidi, Xenocypris microlepis, Distoechodon tumirostris, Aristichthys nobilis, Hypophthalmichthys molitrix, Pseudolaubuca, PseudOlaubuca engraulis, Sinibrama wui, Cultrichthys erythropterus, Culter alburnus, Culter mongolicus, Culter dabryi, Culter oxycephaloides, Hemibarbus labeo, H.maculatus, Sarcocheilichthys sinensis, Sarcocheilichthys nigripinnis, Squalidus argentatus, Coreius heterokon, Rhinogobio typus, Pseudogobio vaillanti vaillant, Saurogobio dabryi, Saurogobio gracilicaudatus, Gobiobotia filifer, Siniperca chuatsi, Siniperca kneri Garman* and *Siniperca scherzer*, taking up over 50% of fish species of the water area.

(2) Southern plain group including *Onychostoma macrolepis, Pelteobagrus fulvidraco, Pelteobaggrus vachelli, Pelteobaggrus nitidus, Leiocassis longirostris, Leiocassis crassilabris, Pseudobagrus truncatus, Pseudobagrus tenuis, Mystus macropterus, Monopterus albus, Odontobutis obscura, Rhinogobius giurinus* and *Ophiocephalus argus.*

(3) Paleogene period group including *Misgurnus anguillicaudatus, Rhodeus ocellatus, Acheilognathus macropterus, Pseudorasbora parva, Abbottina rivularis, Cyprinus carpio, Carassius auratus* and *Siluriformes.*

(4) China-India mountain area group are small-sized fish species favoring rapid flow including the three species of *Lepturichthys fimbriata, Leiobagrus marginatus* and *Glyptothorax sinense.*

(5) River and ocean migratory group has one species of *Anguilla japonica*.

(6) Exotic fish species group are *Protosalanx hyalocranius* and *Neosalanx taihuensis* inflowing from upstream reservoir, and they enters the survey water area as reservoir discharges instead of being resident group of the water area. Previously they were caught during early resouces survey period, but are not seen in larval resources survey of Zhongxiang and Huangzhuang this time.

In conclusion, the main body of fish species in the water area surveyed are Cyprinidae of river plain group, followed by southern plain group and paleogene period group, with small amout of China-India mountain area group and individual river and ocean migratory group. Although there is some diversity in the fauna compoistion of fish species, the main fauna feature of temperate-zone East Asian fish species is still revealing.

d) Fish species ecological feature

As the biggest tributaries of Yangtze River, Han River has a total length of 1570km, among which 878km is in Hubei province, taking up 56% of the total. Its middle reach is from Danjiangkou to Zhongxiang, and it is 270km long with a gradient of 0.12 to 0.27‰, with winding riverway, many sandbanks and gravel banks, and a riverbed wider than that of the upstream. Fish species living here favoring the geograhpical environment and hydrological conditions of this area are of the following features.

1) Inhabitation habit

Middle reach of Han River in the evalation area is of relatively open and broad riverway, relatively stable and slow water flow, relatively developed marginal bank and river island, tributary inflows from Man River and Xiang River, mainly sediment substratum with some gravel substratum, relatviely abuandant aquatic plant and relatively high habitat diversity. Correspondingly, fish species composition include both fish species favoring rapid water flow and creek torrents, and lacustrine facies fish species favoring slow water flow and still water, with a relatively diverse inhabitation habits. Based on major life activities and ecological envrironmental requirements, they are divided into the following main types:

(1) Fish species living in flowing water habitat are fish species not adapting to slow water flow and open and broad area of still water, mainly completing thier entire lives in mountainous creeks or torrents, inlcuding mainly *Onychostoma macrolepis, Opsariicjthys bidens, Coreius heterokon, Rhinogobio typus, Saurogobio dabryi, Gobiobotia filifer, Zacco platypus, Squalidus argentatus, Pseudolaubuca sinensis, Pseudolaubuca engraulis, Lepturichthys fimbriata*, *Glyptothorax sinense*, *Botia* and *some Leiocassis longirostris*. These fish species mainly appear in and are of relatively high porportion of the catch from flowing habitat in the main stream and tributires of the river section surveyed.

(2) Fish species adapt to slow water flow and open and broad area of still water, but complete major life activities such as reproduction in flowing water environment. Most fish species in the middle and lower reach of Han River and even some fish species of the upper reach reproduce in flowing water habitats, with juvenile fish carried by water to lakes and river downstream for fattening, adapting over the years to the compound ecological system in rivers and lakes in the main stream and tributaries of the middle and lower reaches of Han River. This type mainly includes fishes with pelagic eggs such as *Ctenopharyngodon idellus, Hypophthalmichthys molitrix, Aristichthys nobilis, Mylopharyngodon piceus, Squaliobarbus curriculus, Parabramis pekinensis, Elopichthys bambusa*, as well as fish with adhesive eggs in flowing water such as *Rhinogobio typus*, *Xenocypris, Cypriniformes* and *some Bagridae*, taking up a relatively high proportion in flowing water habitats in the main stream and tributaries of the assessment area.

(3) Fish species adapted to water flow and open and broad area of still water are mainly common species in lakes and small reservoirs in hilly areas in the middle and lower

reach of Yangtze River, including *Cyprinus carpio, Carassius auratus, Siluriformes, Aphyocypris chinensis, Abbottina rivularis, Oryzias latipes, Ophiocephalus argus, Monopterus albus, Misgurnus anguillicaudatus, Rhodeus, Pseudorasbora parva* and *Micropercops swinhonis*, many with very large species population. They are an important part of the catch from the river section surveyed.

2) Reproduction habit

Fish species of the surveyed water area can be divided into four groups according to reproductive habits.

(1) Fish species with pelagic eggs

Typical fish species with pelagic eggs are actually with demersal eggs of relatively large perivitelline space which swells to a specific weight close to water after absorbing water and then incubates under certain velocity conditions as it drifts with flowing water. Without sufficient flow velocity, unincubated embryo sinks down to water bottom and its incubation rate will be clearly reduced. This type includes *Ctenopharyngodon idellus, Hypophthalmichthys molitrix, Aristichthys nobilis, Parabramis pekinensis, Squaliobarbus curriculus, Ochetobibus elongatus, Elopichthys bambusa, PseudOlaubuca engraulis, Lepturichthys fimbriata,* and *Pseudobrama simoni*. When surveying spawning grounds of fish with pelagic eggs, varieties of samples collected will be many, with relatively complicated spawning types. Some fish with weakly adhesive eggs may lose egg adhesiveness in turbid or torrent environment or blasted by water flow, which may then incubate as egg drifts with flowing water. In the survey, fish species with this type of eggs takes a relatively large proportion in spawning grounds of fish species with pelagic eggs, including *Rhinogobio typus, Cypriniformes* and *Gnathopogon taeniellus*. In addtion, fish with pelagic eggs has yolk oil, which developes in still water environment as it floats on water surface and may incubate as it drifts with flowing water in flowing water environment, such species include Siniperca.

Spawning period of typical fish species with pelagic eggs are from April to August, mostly from May to July, with a spawning water temperature betwwen 16 and

32°C.Various major economic fish species start spawning when water temperature is around 18°C, with a spawning peak happening between 20 to 24°C. Typical fish species with pelagic eggs mostly spawn in open water area with relatively high requirements of hydrological process, often needing clear flood peak process, and flowing water environment with certain velocity for oosperm incubation and juvenile fish just incubated and without the ability to swim on its own. Or else survival rate will be severely affected. Fish species with floating and adhesive eggs are relatively less depending on hydrological regime.

(2) Fish species with adhesive and demersal eggs

Adhesive eggs obtain adhesiveness when encountered with water right after spawning, and adheres to *Fimbristylis milliacea*, tree root, rock and gravel for incubation; demersal eggs have a relatively large diameter and much yolk, with perivitelline space narrowing as egg membrane swells after absorbing water, scattering in gravel nest or gravel intervals and incubating by continued water waves. Fish with demersal eggs and fish with gravel-adhesive eggs are quite similar in terms of spawning and reproduction requirements on ecological environment, which is why fish with demersal and adhesive eggs are often analyzed together.

According to different adhering base materials, they can be divided into the two types of fish with grass-adhesive eggs and gravel-adhesive eggs.

① Fish with grass-adhesive eggs mainly include *Siluriformes, Megalobrama skolkovii, Cypriniformes, Opsariicjthys bidens, Misgurnus anguillicaudatus* and *Rhinogobius giurinus*, mostly spawning in slow flowing and still water areas with relatively abundant hygrophyte and even terrestrial plants, with adhering base materials mostly being aquatic vegetation, inundated hygrophyte and terrestrial vegetation, as well as other underwater base materials such as net cage placed by human. *Leiocassis crassilabris* spawns between August and September in shallow *Fimbristylis milliacea* with its eggs incubating adhering to *Fimbristylis milliacea*; *Cultrichthys erythropterus* spawns between May and July in still water environments such as lake, with eggs adhering right away to *Fimbristylis milliacea* including *Potamogeton distinctus* and *Myriophyllum spicatum* for devleopment.

② Fish with gravel-adhesive eggs mainly include *Xenocypris microlepis*, *Abbottina rivularis*, and *Glyptothorax sinense*, mostly spawning in gravel and reef banks of flowing water, with reef, gravel and sanding being ahdering base materials. Few species also spawn in still waters of gravel enviornment, such as *Abbottina rivularis*. *Zacco platypus* spawns between April and June in water bank; *Hemibarbus labeo* spawns strongly adhesive eggs between March and May on water bank with pebble or gravel substrata and a flow velocity between 0.5 to 1.0m/s; *Pelteobaggrus vachelli* spawns between April and May in shallow water bank of slow water flow with eggs adhereing to pebble for development; *Mystus macropterus* spawns between May and June in shallow water bank of slow water flow.

(3) Fish species with pelagic eggs

Some fish species with pelagic eggs have oil globule in yolk, which incubate as they float on water surface, such as *Siniperca chuatsi*; other fish species adpots the method of floating by aid, making demersal eggs float, such as *Monopterus albus.* Parent *Monopterus albus* spits bubbles in large quantity after spawning, elevating its eggs to the water surface for incubation.

(4) Fish species with other peculiar eggs

Some fish species are of the habit to build nests for spawning, such as *Ophiocephalus argus*. *Rhodeus sinensisfish* directly spawns into mantle cavity of shellfish, whereas *Oryzias latipes* spawns eggs that are connected to ovarial membrane of the parent, wichi incubates as it is carried by the parent.

3) Feeding habit

Fish species in the water area surveyed can be divided into the following groups based on feeding habits.

(1) Fish species mainly feeds on animal are the three types of ferocious carnivorous fish species often feeding on large living *Vertebrata*, including mainly fish and even other ferocious carnivorous fish species; mild carnivorous fish species mainly feeding on shrimp, aquatic insects and other Invertebrate, with some also feeding on certain periphytic algae;

and carnivorous fish species feeding on zooplankton.

This type includes *Siniperca chuatsi, Siniperca kneri Garman, Siniperca scherzeri, Culter alburnus, Culter mongolicus, Culter oxycephaloides, Siluriformes, Pelteobagrus fulvidraco, Pelteobaggrus vachelli, Pelteobaggrus nitidus, Leiocassis longirostris, Leiocassis crassilabris, Pseudobagrus truncatus, Pseudobagrus tenuis, Mystus macropterus, Botia superciliaris, Parabotia fasciata*, *Parabotia banarescui, Leptobotia taeniaps, Glyptothorax sinense, Opsariicjthys bidens, Zacco platypus, Hemibarbus labeo, H.maculatus, Rhinogobio typus, Coreius heterokon, Abbottina rivularis, Saurogobio dabryi, Saurogobio gracilicaudatus, Gobiobotia filifer*, *Monopterus albus* and *Rhinogobius giurinus*. The group is mainly comprised of *Siluriformes, Perciformes, Cypriniformes Cobitidae*, *Culterinae*, and *Gobioninae*.

This group also include the four Chinese carpsof Mylopharyngodon piceus mainly feeding on mollusk such as *Viviparidae*, and *Aristichthys nobilis* mainly feeding on zooplankton.

(2)Fish species mainly feeds on hydrophyte are the three types mainly feeding on sessile algae, aquatic vascular plants and phytoplankton, including *Ctenopharyngodon idellus, Parabramis pekinensis* and *Hypophthalmichthys molitrix.*

(3) Omnivory fish species. This type of fish feed on an relatively extensive food sources, with some being mainly carnivorous but also feeding on plants on the side and other being the opposite. Food for this type of fish species often include *Fimbristylis milliacea*, detritus, plankton, aquatic insects, sessile algae and sometimes also include shrimp and small fish. The group includes *Cyprinus carpio, Carassius auratus, Squaliobarbus curriculus, Misgurnus anguillicaudatus, Pseudolaubuca, PseudOlaubuca engraulis, Pseudorasbora parva*, *Sarcocheilichthys sinensis*, *Sarcocheilichthys nigripinnis* and *Squalidus argentatus*.

(4) Detritus-feeding fish species. Fish species feeding on sucking or scraping bottom detritus or periphyton and are essentially of omnivory fish species. They are mostly with a lower mouth and relatively strong underjaw cutin, often taking in massive humus or

scraping food from bottom, and in their intestinal tubes are often a mixture of sediment and bodies of animal and plant, combined with some small-sized zoobenthos.

4.2.2.4 Important fish habitats

a) Spawning ground

1) Spawning ground of fish species with adhesive and demersal eggs

(1) Spawning type

In the river section surveyed, fish species with adhesive and demersal eggs are relatively many, which are also the biggest species in the several spawning stocks at the moment.

Differences of reproduction periods among the fish species with adhesive and demersal eggs are relatively larger, mostly from March to September. Reproduction happens when river water temperature reaches a certain degree (generally above 16°C) and in appropriate spawning water area. Spawning water area are mainly of certain flow conditions— torrents or still and slowly flowing waters, as well as certain spawning base material environment of waterweed, gravel, grit, rock crack or stone cavern, with mostly two types.

One type is spawning stock favoring still and slowly flowing waters, with spawning grounds mainly in still and slowly flowing waters such as river branch, river bend, older riverway and slowly flowing water area along the river. Spawning base materials include waterweed and gravel, with oosperm adhering to waterweed and gravel for growth and incubation. This type include *Cyprinus carpio*, the largest species of the water area evaluated, *Carassius auratus, Siluriformes of Siluriformes , Pelteobagrus fulvidraco, P. vachelli, Pelteobaggrus nitidus, Leiocassis longirostris, Leiocassis crassilabris, Pseudobagrus truncatus and Pseudobagrus tenuis*, as well as most of the small-sized fish species such as *Abbottina rivularis* and *Pseudorasbora parva*. This type of spawning water areas are extensively scatterd in the river section surveyed.

The other type is spawning stock favoring torrents with spawning grounds mainly in rapidly flowing flood lands of gravel or reef and adhesive eggs adhering to gravel or falling betwwen rock cracks for growth. This type mainly include *Mystus macropterus, Glyptothorax sinensis* and *Leiobagrus marginatus of Siluriformes*, as well as *Zacco platypus, Opsariichthys bidens, Xenocypris davidi, Hemibarbus labeo, H.maculatus, Onychostoma macrolepis of Cyprinidae*. This type of spawning water areas are substantially narrowed in the river section surveyed as various hydropower development projects are completed.

(2) Historical record

Currently, there is no material or reporting on spawning grounds of fish with adhesive eggs in the middle and lower reaches of Han River. According to spawning survey of fish with pelagic eggs in the middle reach of Han River and tributaries of Tang River and Bai River conducted by Institute of Hydroecology from May to August of 2004, fish with adhesive eggs mainly include *Cyprinus carpio, Carassius auratus, Pelteobagrus fulvidraco, P. vachelli, Siluriformes, Xenocypris davidi, Misgurnus anguillicaudatus* and *H.maculatus.* According to differences of base materials, adhesive eggs can be mainly divided into species adhering aquatic plants, terrestrial plants and floating herbaceous materials, such as *Cyprinus carpio, Carassius auratus, Siluriformes* and *H.maculatus,* as well as gravel-adhering species such as *Pelteobagrus fulvidraco, P. vachelli* and *Xenocypris davidi*.

Spawning grounds are mainly situated in slowly flowing area, bending riverway of Han River or wide wetland areas such as estuaries of Nan River, Bei River, Du River, Xiaoqing River, Tangbai River, Man River, Hanbei River as well as wetlands of Wangfuzhou, Cihe, Yaoji, Gaoshibei and Chenghuang. According to survey, in the middle and lower reaches of Han River, spawning grounds of fish with adhesive eggs are concentrated in areas such as Fujiazhai-Wangfuzhou, Bayi village-Malinggou, Miaotan-Niushou-Dongjin, Douzhuan-Linkuang, Huangzhuang, Yaoji, Gaoshibei, Zekou, Qiukou, Chenghuang and Xinggou. Spawning scale cannot be estimated without detailed qualitative survey.

(3) Field survey situation

Comprehensive survey on habitat of the evaluated river section was conducted from

April 10 to 19 of 2014 so as to understand habitat situations concerning river overflow lands , river bend and river mouth, in particular situations of hygrophilous and aquatic vegetation, as well as riverbed substrata. Meanwhile, combining catch sampling and fisherman interview, a keep watch survey of key water area was conducted. In May 2014, in a river bend with abudant submerged plants close to Ying River estuary, spawning behavior of *Cyprinus carpio* was observed and oosperm was collected. Water areas surveyed include Ying River and its river mouth on the left bank of Han River, small river and its river mouth on the right bank, and Wanqiying downstream of the dam, with extensive and large distribution of aquatic plants and hygrophyte, suitable of spawning and reproduction for fish with adhesive eggs such as *Cyprinus carpio* and *Carassius auratus*. In Wanqiying water area with relatively abundant aquatic plants, spawning behavior of *Cyprinus carpio* was discovered and 3563 egg granules were collected. This area is deep and transparent, with a water temperature of 19.3°C, stable and slowly water flow, a flow velocity of 0.2/s and a sediment substratum.

Wangqiying spawning ground of fish species with adhesive and demersal eggs

(4) Habitat feature and spawning ground distribution

Located in the lower end of the middle reach of Han River, flanked by alluvial plains with flat topography, the water area evaluated has a relatively wide riverway, generally between 700 to 1500m, a stable and smooth water flow, and substrata of mostly gravel, sediment and even sludge instead of gravel rock or pebble riverbeds. There are many overflow lands s, sandbeaches and river branches on the riverway, with relatively high habitat diversity in areas close to tributary river mouth. Generally speaking, water flow is relatively rapid in the front area, with mostly gravel substrata and few vegetation; water flow is relatively stable and slow in the rear area, with extensive distribution of aquatic vegetation. Overflow lands generally has relatively abundant terrestrial and hygrophilous vegetation. Stable and slowly flowing water areas such as overflow lands with many branches, river bend and hole pool also have relatively abundant aquatic vegetation. Generally speaking, overflow lands is of relatively extensive distribution, and river sections with relatively large areas mainly include estuaries of Chun River, Wei River and Ying River, as well as river section close to Yicheng city.

Table 4.2.2-3 Main spawning ground and species type of fish with adhesive and demersal eggs of Yakou assessment area

Name of spawning ground	spawning ground feature	Major spawning species
Front area of overflow lands opposite to Chun River mouth, downstream of Ying River	gravel-adhering	*P. vachelli, H.maculatus, Siluriformes, Abbottina rivularis, Zacco platypus, Pseudorasbora parva, Mystus macropterus* and etc.
Sanzhou village	Grass-adhering base material	*Cyprinus carpio, Carassius auratus, Misgurnus anguillicaudatus* and etc.
Wei Riverestuary (Xiaohe county)	Grass-adhering base material	*Cyprinus carpio, Carassius auratus, Misgurnus anguillicaudatus* and etc.
Yicheng	Grass-adhering base material	*Cyprinus carpio, Carassius auratus* and etc.
Ying River estuary	Grass-adhering base material	*Cyprinus carpio, Carassius auratus, Misgurnus anguillicaudatus* and etc.

From the distributive feature of riverway habitat, in the evaluated area, overflow lands are mostly with sediment and gravel substrata whereas overflow lands with gravel or pebble substrata are rarely seen. Correspondingly, aquatic, hygrophilous and terrestrial vegetation are relatively abundant in overflow lands and river bend. Base materials for fish with adhesive eggs are mainly vegetation, in particular during water-rising period when spawning water areas for fish with grass-adhering eggs are relatively extensive after hygrophilous and terrestrial vegetation are inundated. Spawning grounds for fish with grass-adhering eggs are relatively concentrated in water areas close to Sanzhou village, Wei Riverestuary (close to Xiaohe county), Yicheng city and Ying River estuary. Spawning grounds of fish with gravel-adhesive eggs are relatively less, mainly in the front area of overflow lands in Chenjiahe opposite to Chun River estuary, and in the downstream tributary area of Ying River.

Figure 4.2.2-3 Water area sketch map of fish species with adhesive and demersal eggs of Yakou assessment area

原文	English
图例	Legend
河流	River
砾石基质产卵鱼类产卵水域	Spawning water area with gravel base material
粘草性卵鱼类产卵水域	Spawning water area of fish with grass-adhering eggs
已建枢纽	Developed junction
规划枢纽	Proposed junction
襄阳	Xiangyang
崔家营	Cuijiaying

淳河	Chun River
渭水	Wei River
宜城	Yicheng
雅口	Yakou
莺河	Ying River
流水	Liushui
磷矿	Linkuang
碾盘山	Nianpanshan
钟祥	Zhongxiang

Riverway habitat from Chun River mouth to Wei River mouth

Riverway habitat near Yicheng

Habitat near Ying River mouth

2) Spawning ground of fish species with pelagic eggs

According to spawning grounds of fish with pelagic eggs in the river section surveyed, verified species include *Hypophthalmichthys molitrix, Aristichthys nobilis, Ctenopharyngodon idellus*, *Mylopharyngodon piceus, Saurogobio dabryi, Squalidus argentatus, Coreius heterokon, Rhinogobio typus, Lepturichthys fimbriata, Xenocypris argentea, Culter alburnus, Squaliobarbus curriculus, Parabotia fasciata,* and *Siniperca scherzeri*. In addition to typical fish with pelagic eggs such as *Hypophthalmichthys molitrix*, *Aristichthys nobilis*, *Ctenopharyngodon idellus*, *Mylopharyngodon piceus*, *Coreius heterokon*, *Lepturichthys fimbriata* and *Squaliobarbus curriculus*, there are fish with weakly adhesive eggs such as *Squalidus argentatus* and *Culter alburnus*, as well as fish with pelagic eggs such *as Siniperca scherzeri.*

For small-sized fish with pelagic eggs such as *Lepturichthys fimbriata*, *Saurogobio dabryi,* fish with weakly adhesive eggs such as *Squalidus argentatus, Culter alburnus,* and fish with pelagic eggs such as *Siniperca scherzeri*, they are not demanding in terms of spawning environments, resulting in scattered and samll-scaleed spawning grounds. For larger fish species spawning pelagic eggs in wide water areas such as the four Chinese carpsand Coreius heterokon, there are relatively high requirements on hydrological processess of spawning and reproduction, among which are the common occurrence of “boil-eddy flow” feature, with a water surface resembling that of the boiled water in a pot, often resulting from relatively stable river structures such as river bottom ledge, island and the bending of a river, featuring relatively stable spawning grounds. Therefore, the key point in the spawning ground suvey of fish with pelagic eggs includes the four major domestic fisheses.

(1) Historical record

As the largest tributary to the middle and lower reaches of Yangtze River, Han River is one of the distribution water areas of spawning grounds of fish with pelagic eggs. Since the completion of Danjiangkou reservoir, spawning grounds in the middle and lower reaches of Han River have undergone changes in terms of spawning period and scale with changing water temperature and hydrological regime under the impact of water discharged from Danjiangkou dam. However, there are still many spawning grounds giving of their ecological effects correspondingly. In recent years, relevant authorities have conducted multiple surveys on spawning grounds of fish with pelagic eggs in the middle and lower reaches of Han River.

① According to spawning survey of fish with pelagic eggs in the middle reach of Han River and tributaries of Tang River and Bai River conducted by Institute of Hydroecology from May to August of 2004, there were altogether 16 species of fish with pelagic eggs in the middle reach of Han River main stream, which were divided into two types based on different egg forms, namely typical pelagic type (four major domestic fisheses, *Parabramis pekinensis*, *Squaliobarbus curriculus* and etc) and slightly adhesive type(*Culter alburnus, Squalidus argentatus* and etc). Five spawning grounds of the four Chinese carpsin the main stream of the middle reach were Miaotan, Yicheng, Guanjiashan, Zhongxiang and Maliang (see Figure 4.2.2-3 and Table 4.2.2-4).

Table 4.2.2-4 Spawning ground distribution of four Chinese carpsin the middle reach section of Han River

Name	Area	Spawning ground length (km)	Spawning amount (ten thousand seed)				Total (ten thousand seed)
			Ctenopharyngodon idellus	*Mylopharyngodon piceus*	*Hypophthalmichthys molitrix*	*Aristichthys nobilis*	
Miaotan	Huiliuwan-Cihe	22.2	1750	416	510	164	2840
Yicheng	Xiaohe-Yicheng	21	770	104	102	82	1058
Guanjiashan	Liushui-Guanjiashan	12	455	52	51	41	599
Zhongxi	Nianpanshan-	43			1301	123	1424

ang	Tanggang						
Maliang	Maliang-Yaoji	21.5	3150	156	103		3409
Total		119.7	6125	728	2067	410	9330

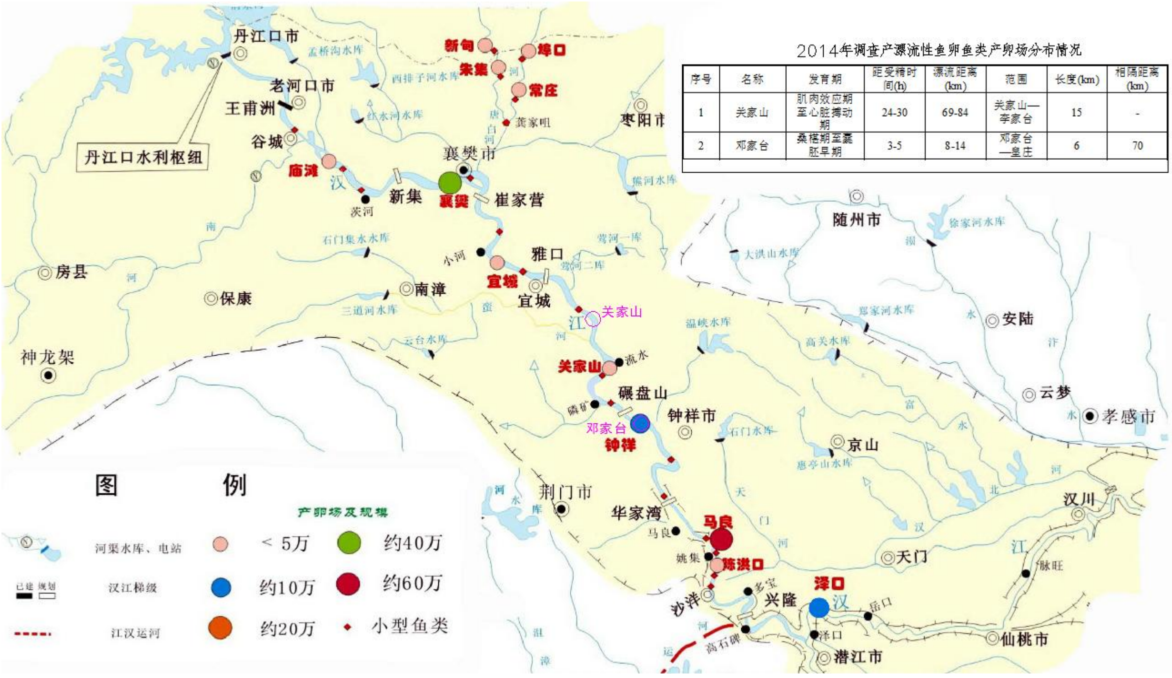


Figure 4.2.2-4 Spawning distribution of fish species with pelagic eggs in the middle and lower reaches of Han River

原文	English
图例	Legend
河渠水库, 电站	River channel reservoir, power station
汉江阶梯	Han River hydropower development project
Han River 运河	Han River canal
产卵场及规模	Spawning ground and scale
＜5 万	Less than 50 thousand
约 10 万	Around 100 thousand
约 20 万	Around 200 thousand
约 40 万	Around 400 thousand
约 60 万	Around 600 thousand
小型鱼类	Small-sized fish species
右上角图见表 4.2.2-7	See Table 4.2.2-7 for the Table on upright corner

There were seven spawning grounds of Miaotan, Xiangfan, Yicheng, Guanjiashan, Zhongxiang, Maliang, Chenhongkou for other economic fish species, with a total egg laying amount of 16.326 billion granules, among which four Chinese carpshave 93.3 million granules taking up 0.57%; other economic fish species have 364 million granules taking up 2.23%; small-sized fish species have 15.869 billion granules.

In the tributary Tangbai River, there were no four Chinese carpsspawning, four spawning grounds for other economic fish species in Xindian, Zhuji, Bukou, Changzhuang and five spawning grounds for small-sized fish species, with a total egg laying amount of 530 million granules, among which other economic fish species have 75 million granules taking up 14.15% and small-sized fish species have 455 million.

② Wang Li et al. conducted survey on current larval resources situation of fish with pelagic eggs in Shangyang cross section of the middle and lower reaches of Han River from June to August of 2009. Result revealed in the 152.28 km of main stream river section monitored by Han River Shangyang station, there were three spawning grounds of Yicheng, Guanjiashan and Zhongxiang, with a total length of 42.12 km taking up 27.7% of the length of the river section, and a total egg laying amount of 5.66×10^8 granules. There were about 21 species of fish with pelagic eggs including dominant species such as *Culter oxycephaloides, Saurogobio dabryi, Parabotia bimaculata, Culter alburnus, Rhinogobio typus* and *Squaliobarbus curriculus*, with no four major domestic fisheses. *Pseudorasbora parva* fingerling takes up 19.4%; *PseudOlaubuca engraulis* takes up 19.4%; *Pelteobagrus fulvidraco* takes up 6.5%; *Rhodeus sinensistakes* up 25.8%; *Cyprinus carpiotakes* up 9.7%; other species such as *Odontobutis obscurus, Acheilognathus chankaensis, Hyporhamphus intermedius* takes up a relatively smaller percentage, without fingerlings of four major domestic fisheses.

In conclusion, in the middle and lower reaches of Han River, in particular in the area from Danjiangkou to Xiangyang, in the fish reproduction season from May to August, hydrological conditions required for spawning are difficult to meet as the process of water rising required in fish reproduction has basically disappeared with a very limited water level variation amplitude (within 0.3m) due to the adjusting effect of Danjiangkou reservoir. Therefore, spawning grounds existed prior the dam construction of Danjiangkou reservoir have either already disappeared or scaled down, and spawning grounds of four Chinese carpsupstream of Xiangfan river section has already disappeared entirely.

Major spawning grounds in the middle and lower reaches of Han River are distributed in the river section between Xiangfan to Zhongxiang, with hydrological conditions meeting fish spawning requirements mostly created by tributary inflows of Tangbai River and Nan River, as well as regional precipitation. Water rising level from May to August may exceed 1.2m, satisfying fish with pelagic eggs, in particular spawning requirements of four major domestic fisheses. However, river floods during spawning season are all relatively short and uneven in scale.

In addition, reproduction peroids of fish in the middle and lower reaches of Han River have been postponed for 20 to 30 days compared with that of prior dam construction due to low-temperature water discharged from Danjiangkou reservoir. Fish reproduction periods are generally postponed to mid-August to late Augugst.

(2) Field survey

① Composition of fish species with pelagic eggs and character of early egg seed

From July 7 to September 7 of 2014, fish larval resources were monitored in the water intake of Zhongixang water plant in Zhongxiang city. Data on egg collection time, type, growth period, number, river flow velocity at the time, net neck flow velocity, water temperature and transparency were recorded during the sampling period; location and distribution of spawning grounds of fish with pelagic eggs were then estimated.

All together 14356 egg granules were collected during the sampling period (See Table 4.2.2-5), among were 7252 granules of *Squalidus argentatus*, 3914 granules of *Saurogobio dabryi*, 2036 granules of *Xenocypris argentea*, 858 granules of *Culter alburnus*, 284 granules of *Parabramis pekinensis*, and 12 granules of *Mylopharyngodon piceus*. According to calculation result of spawning runoff equation, there were 1.4046×10^{8} granules spawned during the sampling period.

Table 4.2.2-5 Composition of fish species with pelagic eggs

Species	Egg seed	Egg-spawn ratio
银鮈 *Squalidus argentatus*	3452	50.11
蛇鮈 *Saurogobio dabryi*	1870	27.43
翘嘴鲌 *Culter alburnus*	975	14.3
银鲴 *Xenocypris argentea*	398	5.84
鳊 *Parabramis pekinensis* (Basilewsky)	122	1.79
青鱼 *Mylopharyngodon piceus*	12	0.08
Total	14356	100.0

See Table 4.2.2-6 for spawning characters and types. Accoring to the table, range of membrane diameter after absorbing water is 2.6 ~ 5.5mm, with yolk colors including Apricot yellow, inner bamboo stem yellow and cheese yellow. Expect for *Squalidus argentatus* and *Culter alburnus* with slightly adhesive eggs, others are of typicla pelagic eggs. Siniperca scherzeri, Fish with pelagic eggs, was collected.

Table 4.2.2-6 Spawn character and type of fish species with pelagic eggs

Species	Early spawn character		Type of pelagic egg	
	Swelling diameter of water-absorbing membrane mm	Yolk color	typical	Slightly adhesive
Squalidus argentatus	2.6-3.5	Apricot yellow		+
Saurogobio dabryi	3.1-4.2	inner bamboo stem yellow	+	
Xenocypris argentea	3.6-4.6	inner bamboo stem yellow	+	
Culter alburnus	4.5-5.3	cheese yellow		+
Parabramis pekinensis (Basilewsky)	3.8-4.6	inner bamboo stem yellow	+	
Mylopharyngodon piceus	4.8-5.5	inner bamboo stem yellow	+	

② Spawning ground distribution

Accoring to hydrological data of the growth period and survey period of spawn, it is estimated after analysis that there are two spawning grounds of fish with pelagic eggs upstream of the monitoring point.

A. Guanjiashan spawning ground

Guanjiashan spawning ground has a river section about 5km, estimated by muscle effect stage and cardiac impulse stage.

B. Dengjiatai spawning ground

Dengjiatai spawning ground has a river section about 6km, estimated by mulberry stage and blastula stage.

Table 4.2.2-7 Spawning ground distribution of fish species with pelagic eggs

Serial No.	Name	Growth period	Time to fertilization (h)	drifting distance (km)	Range	Length (km)	Interval distance (km)	Relation to the dam site
1	Guanjiashan	Muscle effect stage and cardiac impulse stage	24-30	69-84	Guanjiashan—Lijiatai	15	-	15.5km downstream of the dam
2	Dengjiatai	Mulberry stage and blastula stage	3-5	8-14	Dengjiatai—Huangzhuang	6	70	61.8km downstream of the dam

③ Spawning scale

A. Yolk color of sampling period

In the 2014 sampling period (July 7-September 7) altogether 14356 egg granules were collected, among which were 7252 egg granules of *Squalidus argentatus*, 3914 egg granules of *Saurogobio dabryi*, 2036 egg granules of *Xenocypris*, 858 egg granules of *Culter alburnus*, 284 egg granules of *Parabramis pekinensis* and 12 egg granules of *Mylopharyngodon piceus*. According to calculation result of spawning runoff equation, there were 1.4046×10^{8} egg granules spawned during the sampling period, among which were 0.709×10^{8} egg granules of *Squalidus argentatus* taking up 50.48%; 0.3827×10^{8} egg granules of *Saurogobio dabryi* taking up 27.25%; 0.1988×10^{8} egg granules of *Xenocypris argentea* taking up 14.15%; 0.0841×10^{8} egg granules of *Culter alburnus* taking up 5.99%; 0.0281×10^{8} egg granules of *Parabramis pekinensis* taking up 2.00%; 0.0018×10^{8} egg granules of *Mylopharyngodon piceus* taking up 0.13%.

B. Spawning ground scale

Guanjiashan: pelagic egg laying amount were 1.3826×10^{8} granules taking up 98.43% of total egg laying amount of the sampling period, being a spawning ground with relatively large spawning scale of fish with pelagic eggs, among which *Squalidus argentatus* had 0.6952×10^{8} egg granules taking up 50.28%; *Saurogobio dabryi* had 0.3746×10^{8}egg granules taking up 27.09%; *Xenocypris argentea* had 0.1988×10^{8}egg granules taking up

14.38%; *Culter alburnus* had 0.0841×10^8 egg granules taking up 6.08%; *Parabramis pekinensis* had 0.2814×10^8 egg granules taking up 2.04%; *Mylopharyngodon piceus* had 0.0018×10^8 egg granules taking up 0.13% (Table 4.2.2-6).

Dengjiatai: pelagic egg laying amount were 0.022×10^8 granules taking up 1.57%% of total egg laying amount of the sampling period, among which *Squalidus argentatus* had 0.014×10^8 egg granules taking up 62.83%; *Saurogobio dabryi* had 0.008×10^8egg granules taking up 37.17% (Table 4.2.2-8).

Table 4.2.2-8 Spawning scale and species of fish species with pelagic eggs

Species	Guanjiashan spawning ground		Dengjiatai spawning ground		Total	Ratio (%)
	Spawning scale ($\times10^8$ seed)	Species composition (%)	Spawning scale ($\times10^8$ seed)	Species composition (%)		
Squalidus argentatus	0.6952	50.28	0.014	62.83	0.7092	50.48
Saurogobio dabryi	0.3746	27.09	0.008	37.17	0.3826	27.25
Xenocypris argentea	0.1988	14.38	0	0	0.1988	14.15
Culter alburnus	0.0841	6.08	0	0	0.0841	5.99
Parabramis pekinensis (Basilewsky)	0.0281	2.04	0	0	0.0281	2.00
Mylopharyngodon piceus	0.0018	0.13	0	0	0.0018	0.13
Total	1.3826	100	0.022	100	1.4046	100
Each spawning ground (%)	98.43		1.57		100	

④ Spatial distribution of larval resources

According to Table 4.2.2-8, in terms of larval resources spatial distribution, *Squalidus argentatus* and *Saurogobio dabryi* are both distributed in two spawning grounds; *Squalidus argentatus* takes up 98.03% of egg laying amount in Guanjiashan spawning ground and 1.97% of egg laying amount in Dengjiatai spawning ground; *Saurogobio dabryi* takes up 97.91%of egg laying amount in Guanjiashan spawning ground and 2.89% of egg laying amount in Dengjiatai spawning ground; *Xenocypris argentea*, *Culter alburnus* and

Parabramis pekinensis are only distributed in Guanjiashan spawning ground.

Table 4.2.2-9 Proportion of fish species with pelagic eggs in various spawning ground (%)

Species	Guanjiashan spawning ground	Dengjiatai spawning ground	Total
Squalidus argentatus	98.03	1.97	100
Saurogobio dabryi	97.91	2.09	100
Xenocypris argentea	100	0	100
Culter alburnus	100	0	100
Parabramis pekinensis (Basilewsky)	100	0	100

⑤ Spawning ground evolution of fish species with pelagic eggs and its factor analysis

Comparing the survey result with historical data, spawning grounds of fish with pelagic eggs gradually scaled down from five spawning grounds of four Chinese carpsin the middle reach to one location (two spawning grounds of fish with pelagic eggs, but Mylopharyngodon piceus spawned in only one location) in the 2014 survey, showing substantial decline in terms of spawning scale and reproductive fish species. Only *Mylopharyngodon piceus* larval resources were collected among four major domestic fisheses, and major reason includes the following aspects:

A. Impact of hydropower development project in Han River main stream

Construction of hydropower developemnt projects in Han River have blocked matured parent fish from the middle and lower reaches of Han River and Yangtze River main stream to swim upstream to spawning grounds in the middle reach of Han River and tributary Tangbai River, causing substantial decrease of reproduction populationn of fish with pelagic eggs.

In 2009, three spawning grounds of Yicheng, Guanjiashan and Zhongxiang of the middle reach of Han River were surveyed and there were no four Chinese carpsspawning. Compared with survey result from 2004, there were no spawning in Miaotan and Xiangfan because Miaotan spawning ground basically losed its functions after Cuijiaying completion. There were no spawning in Maliang and Chenhongkou and reason of such change was related to survey purpose (for Three Gorges ecological operation), survey timing, survey range, survey depth, sampling cross section and cocurrent flood condition, and it could not be determined that Maliang and Chenhongkou spawning grounds had disappeared, nor the reason why there were no four Chinese carpsspawning. Given that Cuijiaying and Xinglong were not constructed, Wangfuzhou was the main barrier.

In 2014, only two spawning grounds of fish with pelagic eggs in Guanjiashan and Dengjiatai (Zhongxiang) were surveyed and only in one location (Guanjiashan) Mylopharyngodon piceus spawning was monitored (*Mylopharyngodon piceus* being the only four Chinese carpsmonitored is related to a postponed flood coming only in September and the relatively late spawning season of Mylopharyngodon piceus). Reasons behind were the inundation and loss of functions of Maliang and Chenhongkou spawning grounds after Xinglong completion. Given that 2014 were a low flow year, survey result may not be able to fully reflect spawning ground situations of fish with pelagic eggs in the middle and lower reaches of Han River. The construction of Xinglong Hydro-junction blocked fish in the lower reach of Han River downstream of Zekou and Yangtze River main stream from swimming upstream to the migration passageway in the middle and lower reaches of Han River. Cuijiaying Hydro-junction blocked fish in the downstream from swimming upstream to Miaotan upstream and spawning ground in the tributary of Tangbai River. Although fishway was built to alleviate barrier effect, barrier effect still existed. Water storage of Xinglong Hydro-junction inundated Maliang and Chenhongkou spawning grounds. Meanwhile, construction of Cuijiaying and Xinglong divided fish habitat in the middle and lower reaches of Han River, reducing fish reproductive drifting distance and narrowing the scale of Zhongxiang spawning ground.

B. Impact of South-to-North Water Transfer

In recently year, Han River basin has been through continuous droughts and Danjiangkou reservoir has long been operating on low water level. Water inflow in September 2014 was relatively abundant, but reservoir blocked flood peak discharge with basically no discharge due to the official water passing of South-to-North Water Transfer. Flood peak process of the middle and lower reaches of Han River was mainly dependent upon flood from Tangbai River, and the already limited flood peak discharge was attenuated by Cuijiaying reservoir area leaving only about 1600m^3/s. There was basically no flood peak process after attenuation by Xinglong reservoir area. After official operation of South-to-North Water Transfer, the current hydrological regime change could be the new norm.

C Overfishing caused decline in resources amount. Given its relatively smooth and slow river regime and larger waterfront population, the middle and lower reaches of Han River has always had intense fishing, in particular with the use of electronic trawl-mesh net, severely damaging fish resources.

D. In waterfront areas of the assessed water area, relatively developed socio-economy, intense human activities, waste water from industries and mining, as well as urban domestic sewage all affects water quality of the main stream and tributaries in the middle and lower reaches of Han River. Take Tangbai River as an example, in history it had major spawning ground for fish with pelagic eggs with an egg laying amount basically equal to that of main stream in Xiangyang section, but there was no four Chinese carps spawning in Tangbai River according to survey result from 2004 due to water body pollution. However, after treatment measures taken in recent years, water quality has been obviously improved.

Gravid *Xenocypris argentea* awaiting delivery

b) Nursing ground

Nursing ground is important in ensuring a suitable environment of growth and development for juvenile fish. Analyzing from hydrological conditions, nursing ground requires stable water flow, appropriate and abundant bait feed, as well as relatively stable water level, similar to spawning grounds of fish with adhesive eggs favoring still water and slow flow, which are the reasons of nursing grounds generally situating in river branch, river bend, older riverway and waterfront overflow lands with slow flow with pebble or waterweed substrata, relatively shallow water level, broad water surface and relatively fast temperature rise under sunshine; adjacent to profundal zone avoiding enemies. In the survey water area, nursing grounds matching these requirements are extensively distributed, such as in the slow flowing river section of Yicheng downstream of Cuijiaying dam, and broad river section upstream of Zhongxiang and Huangzhuang.

c) Wintering ground

Approaching winter, Han River experiences decreases of water volume, water level, air temperature and water temperature, as well as less fish activities as some fish go to main stream or pool via tributaries or shallow areas for winter passing so as to ensure appropriate inhabitation conditions in cold season. Fish wintering grounds are in the depths of main stream riverbed, being generally more than 3 to 4m deep, and mostly in river bay, river channel and bench bay areas of backwater, slow flowing and flowing water, with uneven substrata of rock or reef. Fish species of the surveyed water area is mainly in Maliang-Gaoshibei river section of the reservoir area of Xinglong Hydro-junction.

4.2.2.5 Current situation and evolution of fish resources

a) Historical survey result

Variations of major catch subjects in the various river sections in the middle and lower reaches of Han River was not obvious, including *Cyprinus carpio, Parabramis pekinensis, Carassius auratus, Pelteobagrus fulvidraco* and *Ctenopharyngodon idellus*. However, Squaliobarbus curriculus yield in the river section upstream of Shayang was relatively large, and catch of Erythroculter mongolicus yield in the river section downstream of Shayang was obviously increased. As for catch composition, cosmopolitan fish species and fish species favoring flowing and slowly flowing water environments are the majority, with a clear feature of river fish composition. Number of catch species in the river section upstream of Xiangfan was relatively less with only 32 species; number of catch species in the river section downstream of Xiangfan was clearly increased including plain and lake fish species favoring still water such as *Hemiramphus far, Rhodeus sinensis, Odontobutis obscurus, Hemisalanx prognathus* and *Macropodus chinensis*. Relatively larger population of migratory fish species of Coilia macrognathos appeared in catch from the river section downstream of Shayang.

Average catch weight from the middle and lower reaches of Han River was only 147.56g, with fish slightly weight more on average in the river section downstream of Xiangfan than that of in the upstream. *Ctenopharyngodon idellus* was the heaviest with an average weight of 1,161.3g. Those averagely weighted above 500g also included *Cyprinus carpio* (931.8g), *Aristichthys nobilis* (800g), *Hypophthalmichthys molitrix* (690.2g), *Erythroculter ilishaeformis* (796.8g), *Siniperca roulei* (600g) and *Siniperca chuatsi* (647.1g). For fish species weighted below 100g, there were 20 species in the river section upstream of Xiangfan, 27 species in Xiangfan-Shayang river section, and 27 species in Shayang-Hanchuan river section. Fish resources of Han River were clearly becoming smaller, which was supported by the survey result of spawning ground for fish with pelagic eggs, for spawning scales of four Chinese carps clearly went down while spawning scales of small-sized fish species clearly went up.

Age structure of economic fish species in the middle and lower reaches of Han River was mainly of the three age groups of 0^+, 1^+ and 2^+, among which over 60% of *Cyprinus carpio*, *Hypophthalmichthys molitrix* and *Carassius auratus* were 1^+; over 50% of *Parabramis pekinensis, Erythroculter ilishaeformis* and *Xenocypris davidi* were 2^+; *Ctenopharyngodon idellus* and *Coreius heterokon* were mainly 1^+ and 2^+ with a relatively high proportion of 3^+; *Squaliobarbus curriculus* were mainly 2^+ and 3^+ with a relatively high proportion of 1^+; extremely few individuals were of or above the age of 4^+. As for catch of major economic fish species in Han River, including populations of juvenile, additional and remaining fish, in particular given that the major catching tools being trammel net of 6-8cm mesh and electronic trawl-net of 1-2cm mesh with great catch intensity, the smallest individual was only 2g. Additional, even juvenile fish populations were of high proportions of the catch. In the catch, all of the *Ctenopharyngodon idellus* and 94% of *Hypophthalmichthys molitrix* and *Erythroculter ilishaeformis* were of additional population. Remaining populations of *Parabramis pekinensis, Squaliobarbus curriculus, Coreius heterokon* and *Xenocypris davidi* were larger than their additional populations. In terms of length and weight distributions of economic fish species of the various river sections, average length and weight of *Cyprinus carpio, Hypophthalmichthys molitrix* and *Carassius auratus* downstream of Xiangfan were slightly larger than that of in the upstream, whereas *Squaliobarbus curriculus* was the opposite. Differences in other fish species were not obvious.

b) Current survey result

1) Fish species of Yicheng city gate area

Located downstream of Cuijiaying Hydro-junction, Yicheng river section has broad riverbed as well as stable and slow water flow.

In terms of catch surveyed, species taking up over 10% of catch weight include Cyprinus carpio (19.4%), Culter mongolicus (15.9%), Culter alburnus (10.7%) and Hypophthalmichthys molitrix(10.0%), followed by Carassius auratus, Xenocypris argentea, Siluriformes, Parabramis pekinensis. Species with the top three numbers are all small-sized fish, namely 18.0% of *Squalidus argentatus,* 12.0% of *Saurogobio dabryi* and 9.6% of *Hemiculter leucisculus*. despite abovementioned species ranking high in weight and number, commonly seen species also include over 20 species of *Pseudolaubuca, Opsariichthys bidens, Siniperca scherzeri, Pseudogobio vaillanti vaillant, Zacco platypus, Pelteobagrus fulvidraco, P. Vachelli, H.maculatus, Parabotia fasciata, Hemiramphus far, Pseudorasbora parva, Abbottina rivularis* and *Rhinogobius giurinus.*

Generally speaking, catch comprises mainly *Cypriniformes* and *Siluriformes* favoring still and slowly flowing waters, as well as few favoring flowing water.

Comparing with the survey of the sam river section conducted by Institute of Hydroecology in August 2012, with the few exceptions of torrent species such as *Glyptothorax sinensis* and *Lepturichthys fimbriata,* other species such as *Parabotia banarescui, Rhinogobio typus, Leptobotia taeniaps* and *Culter oxycephaloides* were also excluded from the catch surveyed, generally reflecting the impact of the completion of Cuijiaying junction on fish resources of Yicheng river section.

In the catch surveyed, small-sized fish species were the majority, with mostly relatively small individuals. Species with average weight exceeding 700g are only the three species of *Culter mongolicus, Culter alburnus* and *Hypophthalmichthys molitrix*. Ages of various fish species are relatively low, basically being under 3 with very few individuals above 4.

In the catch, *Hypophthalmichthys molitrix* is the only species of the four major domestic fisheses.

Table 4.2.2-10 Catch composition of Yicheng city gate section

Species	Length (cm)		Weight (g)		Ratio (%)	
	Range	Average	Range	Average	Number	weight
Cyprinus carpio	23.3 ~ 35.0	27.6	266.5 ~ 843.1	443.3	4.1	19.4
Culter mongolicus	35.6 ~ 43.3	38.7	613.0 ~ 1250	779	1.9	15.9
Culter alburnus	36.0 ~ 48.3	39.5	555.0 ~ 1355	733	1.4	10.7
Hypophthalmichthys molitrix	33.9 ~ 42.0	37.3	665.7 ~ 1230	855	1.1	10.0
Carassius auratus	10.1 ~ 13.9	12.7	42.3 ~ 110.5	83.9	6.3	5.6
Xenocypris argentea	19.5 ~ 23.3	21.4	120.7 ~ 195.3	155.2	3.6	5.9
Siluriformes	27.7 ~ 33.4	31.1	211.5 ~ 407.6	307.3	1.4	4.5
Parabramis pekinensis	30.5 ~ 35.7	32.8	400.7 ~ 622.8	483.2	0.8	4.2
Hemiculter leucisculus	12.7 ~ 15.9	14.3	21.7 ~ 42.6	31.9	9.6	3.3
Squalidus argentatus	7.7 ~ 10.1	8.9	10.2 ~ 21.0	15.3	18.0	3.0
Saurogobio dabryi	11.1 ~ 13.5	12.3	15.4 ~ 25.3	18.7	12.0	2.4
Pseudolaubuca	12.6 ~ 14.5	13.0	20.8 ~ 33.3	24.5	9.0	2.4
Opsariichthys bidens	11.9 ~ 15.7	13.5	35.2 ~ 78.8	50.8	4.1	2.2
Siniperca scherzeri	15.8 ~ 19.6	17.7	93.1 ~ 165.2	128.4	1.4	1.9
Pseudogobio vaillanti vaillant	11.1 ~ 14.2	12.4	15.6 ~ 27.9	21.5	7.7	1.8
Zacco platypus	13.0 ~ 17.0	15.7	40.5 ~ 95.4	75.6	2.2	1.8
Pelteobagrus fulvidraco	13.2 ~ 14.9	13.8	37.6 ~ 55.4	43.4	3.6	1.6
P. vachelli	11.2 ~ 14.5	12.3	26.9 ~ 51.5	32.3	3.0	1.0
Hemiculter bleekeri	11.8 ~ 13.3	12.9	19.6 ~ 27.4	24.2	3.6	0.9
H.maculatus	10.7 ~ 12.3	11.3	16.8 ~ 34.0	23.2	3.3	0.8
Parabotia fasciata	10.8 ~ 13.5	12.2	16.3 ~ 37.0	25.9	2.2	0.6

2) Fish species of Linkuang county

Linkuang county river section is deep and broad, with a catch composition including species favoring flowing water that are unseen upstream such as *Mystus macropterus* and *Rhinogobio typus*, as well as other species favoring flowing water such as *Opsariichthys bidens, Zacco platypus, Saurogobio dabryi, Squalidus argentatus, H.maculatus* and *Parabotia fasciata*, exceeding 30% of catch species commonly seen in this river section.

In the catch surveyed, species with the top three weights are namely *Cyprinus carpio* taking up 26.4%, *Culter mongolicus* taking up 16.5% and *Carassius auratus* taking up 9.9%; species with the top three numbers are namely *Squalidus argentatus* taking up 19.7%, *Saurogobio dabryi* taking up 11.7% and *Hemiculter leucisculus* taking up 11.3%. Other commonly seen species include more than 20 species such as *Hypophthalmichthys molitrix, Xenocypris argentea, Parabramis pekinensis, Siniperca scherzeri, Pseudolaubuca, Hemiculter bleekeri, P. Vachelli, Sarcocheilichthys sinensis, Cobitis sinensis* and *Mastacembelus aculeatus.*

Small-sized fish species are still the majority, with mostly relatively small individuals. Species with an average weight exceeding 500g are only the three species of *Cyprinus carpio, Culter mongolicus* and *Hypophthalmichthys molitrix.*

Hypophthalmichthys molitrix is the only four Chinese carpsin the catch.

Table 4.2.2-11 Catch composition of Linkuang county

Species	Length (cm)		Weight (g)		Ratio (%)	
	Range	Average	Range	Average	Number	Weight
Cyprinus carpio	25.8 ~ 36.6	29.1	380.5 ~ 967.5	525.7	4.4	26.4
Culter mongolicus	37.8 ~ 42.4	40.3	735.5 ~ 1150	915	1.6	16.5
Carassius auratus	12.6 ~ 14.8	13.6	78.3 ~ 125.7	94.8	9.1	9.9
Hypophthalmichthys molitrix	32.0 ~ 40.2	35.8	566.5 ~ 1055	773	0.9	7.8
Mystus macropterus	23.3 ~ 29.5	26.7	125.3 ~ 238.1	181.0	2.3	4.7
Xenocypris argentea	18.6 ~ 21.7	19.8	113.5 ~ 171.3	132.4	3.0	4.5
Parabramis pekinensis	34.8 ~ 39.5	37.3	566.7 ~ 838.1	713.3	0.5	4.3
Squalidus argentatus	8.2 ~ 9.6	9.3	12.6 ~ 16.7	14.9	19.7	3.4
Siniperca	16.9 ~ 20.5	18.3	115.0 ~ 189.5	144.7	1.9	3.2

scherzeri						
□	9.9 ~ 12.7	11.6	13.2 ~ 24.6	21.1	11.3	2.8
Pseudolaubuca	12.7 ~ 13.6	13.2	21.1 ~ 25.8	23.9	9.6	2.6
Opsariichthys bidens	12.6 ~ 16.3	14.4	31.9 ~ 73.1	46.5	4.7	2.6
Saurogobio dabryi	9.5 ~ 13.7	12.1	9.2 ~ 28.3	17.6	11.7	2.4
Hemiculter bleekeri	12.7 ~ 15.9	14.5	22.7 ~ 46.1	32.6	5.9	2.2
P. vachelli	11.6 ~ 17.8	14.3	20.1 ~ 65.0	38.4	4.2	1.8
H.maculatus□	16.9 ~ 19.7	19.2	50.6 ~ 115.3	78.1	1.6	1.4
Zacco platypus	12.6 ~ 15.3	13.3	35.6 ~ 74.3	44.8	2.6	1.3
Rhinogobio typus	20.5 ~ 25.9	22.9	85.7 ~ 163.5	115.9	0.9	1.2
Sarcocheilichthys sinensis	11.2 ~ 12.8	11.7	39.7 ~ 57.5	44.2	0.9	0.4
Cobitis sinensis	9.8 ~ 11.6	10.5	8.3 ~ 13.1	9.9	2.3	0.3
Parabotia fasciata	10.6 ~ 13.3	12.0	20.0 ~ 30.8	24.4	1.2	0.3

3) Fish species of Zhongxiang city gate section

River regime and flow of Zhongxiang river section is similar to that of the Linkuang county river section in the upstream. Comparing the two sections, the two species of *Culter dabryi* and *Squaliobarbus curriculus* are added to the catch surveyed. Commonly seen catch includes *Cyprinus carpio*, *Squalidus argentatus*, *Saurogobio dabryi*, *Hemiculter leucisculus*, *Culter alburnus*, *Parabramis pekinensis*, *Xenocypris argentea*, *Carassius auratus*, *Culter mongolicus*, *Hypophthalmichthys molitrix*, *Siluriformes*, *Ophiocephalus argus*, *Opsariichthys bidens*, *Pelteobagrus fulvidraco*, *Pseudobrama simoni*, *Sarcocheilichthys sinensis*, *Odontobutis obscura* and *Mastacembelus aculeatus.*

Species with the top three weights in the catch are namely *Cyprinus carpio* taking up 16.9%, *Culter alburnus* taking up 13.8% and *Culter dabryi* taking up 8.2%; Species with the top three numbers in the catch are namely *Squalidus argentatus* taking up 18.2%, *Saurogobio dabryi* taking up 13.3% and *Hemiculter leucisculus* taking up 10.1%.

Comparing species ranking high in terms of weight and number with that of the two river sections discussed above, *Cyprinus carpio* ranks top in terms of weight, and other relatively species with relatively heavier weights include *Carassius auratus* of *Cyprininae, Culter alburnus*, *Culter mongolicus*, *Culter dabryi* of *Culterinae*, *Xenocypris argentea* of *Xenocyprininae*, and *Hypophthalmichthys molitrix* (also the only species of the four

Chinese carpscollected) of *Hypophthalmichthyinae*. *Squalidus argentatus* ranks top in terms of number, and other species with relatively larger numbers include *Saurogobio dabryi* of *Gobioninae*, *Pseudolaubuca* of *Culterinae*, as well as *Carassius auratus* of *Cyprininae*. *Carassius auratus* is of certain shares in terms of weight and number.

The survey was conducted shortly after fishing moratorium, thus was able to refelct main species and composition of the catch.

Table 4.2.2-12 Catch composition of Zhongxiang city gate section

Species	Length (cm)		Weight (g)		Ratio (%)	
	Range	Average	Range	Average	Number	Weight
Cyprinus carpio	20.2 ~ 37.3	29.1	180.3 ~ 1150	507	4.1	16.9
Culter alburnus	38.0 ~ 43.3	40.5	646.5 ~ 986.4	778	2.2	13.8
Culter dabryi	18.7 ~ 23.2	20.7	95.6 ~ 185.3	127.2	7.9	8.2
Parabramis pekinensis	29.5 ~ 38.8	34.6	347.0 ~ 788.6	563.5	1.6	7.5
Xenocypris argentea	21.4 ~ 24.2	22.3	179.0 ~ 246.3	206.7	4.3	7.3
Carassius auratus	14.7 ~ 16.9	15.6	83.4 ~ 133.9	100.7	8.7	7.2
Culter mongolicus	27.7 ~ 42.4	32.6	378.3 ~ 1100	455	1.9	7.1
Hypophthalmichthys molitrix	33.9 ~ 39.7	36.8	568.9 ~ 935.8	767.6	1.1	6.8
Siluriformes	26.7 ~ 36.8	30.2	195.5 ~ 537.5	287.6	2.4	5.7
Squaliobarbus curriculus	17.5 ~ 23.1	19.3	105.5 ~ 197.8	131.4	3.0	3.2
Ophiocephalus argus	23.4 ~ 33.5	27.2	188.7 ~ 550.0	289.6	1.4	3.2
Opsariichthys bidens	12.7 ~ 14.8	13.9	43.4 ~ 70.0	57.1	5.2	2.4
Pelteobagrus fulvidraco	12.7 ~ 16.9	14.4	38.8 ~ 72.6	49.2	5.7	2.3
Squalidus argentatus	6.9 ~ 9.5	8.7	7.8 ~ 17.5	14.1	18.2	2.1
Saurogobio dabryi	11.5 ~ 13.8	12.4	13.9 ~ 27.2	17.7	13.3	1.9
□	9.2 ~ 13.3	12.1	11.5 ~ 31.4	23.3	10.1	1.9
Pseudobrama simoni	10.7 ~ 13.5	11.9	26.2 ~ 53.1	32.6	5.2	1.4
Sarcocheilichthys sinensis	10.5 ~ 13.3	12.1	33.5 ~ 65.2	49.4	1.6	0.7
Odontobutis obscura	8.5 ~ 9.6	9.1	15.5 ~ 23.4	19.7	2.2	0.3

c) Fish resources assessment

1) Overall fish resources

Water area survey is in the middle reach of Han River. According to survey by Yu

Zhitang and others during the 1970s to 1980s, 75 fish species were collected in the Han River section downstream of Danjiangkou, among which over 30 fish species were of relatively high economic value accoring to the statistical analysis of altogether 9000 kg of catch of the river section from Danjiangkou to Tianmen county using five fishing tools in 1976 to 1977, including ten of relatively larger number such as *Ctenopharyngodon idellus, Coreius heterokon, Parabramis pekinensis(Parabramis pekinensis), Cyprinus carpio, Erythroculter mongolicus*, *Xenocypris microlepis*, *Rhinogobio typus* and *Rhinogobio cylindricus*, taking up an important position in the fishery industry. Comparing with situation prior the construction of Danjiangkou Hydro-junction, *Acipenser dabryanus, Spinibarbus sinensis, Onychostoma sima* and *Tor sinensis* previously distributed in the river section downstream of Danjiangkou are no longer seen.

Accoring to survey of Han River section downstream of Danjiangkou from 2003 to 2004 by Institute of Hydroecology, catch of Xiangfan-Maliang section which covers the river section surveyed currently mainly include *Cyprinus carpio, Parabramis pekinensis*, *Pelteobagrus fulvidraco, Carassius auratus, Ctenopharyngodon idellus and Squaliobarbus curriculus* (taking up 87.8%of the catch). Comparing with that of the 1970s, *Coreius heterokon, Erythroculter mongolicus(Culter mongolicus), Xenocypris microlepis, Rhinogobio typus* and *Rhinogobio cylindricus* are excluded from the main catch.

In this survey, major catch weight ratios are mainly *Cyprinus carpio, Carassius auratus,* and *Culter alburnus* and *Culter mongolicus of Culterinae*, where as number ratios are dominated by *Squalidus argentatus* and *Saurogobio dabryi* of *Gobioninae,* and *Pseudolaubuca* of *Culterinae*. Compared with the 2003-2004 survey, total catch went down dramatically (complete data analysis is yet to be done due to time constrain, but it is evident by massive unemployment of fisherman and the opinions of fisherman interviewed and surveyed). In the six major catch, *Pelteobagrus fulvidraco, Ctenopharyngodon idellus*, *Squaliobarbus curriculus* and *Parabramis pekinensis* are no loger included, *Ctenopharyngodon idellus* was unable to be collected in all river sections surveyed, *Squaliobarbus curriculus* was only collected in Zhongxiang and Huangzhuang markets in small amount, and *Pelteobagrus fulvidraco* and *Parabramis pekinensis* are only rarely distributed in all river sections. The rising of weight ratioes of *Culter alburnus* and *Culter mongolicus* in catch is related to the drastic decrease of the abovementioned species.

Compared with 1970s, *Coreius heterokon* and *Rhinogobio cylindricus* are no loger seen in catch of the river section, *Xenocypris microlepis* are of extremly limited number, small number of *Culter mongolicus* are distributed in various survey sections, and *Rhinogobio typus* can only be collected in the Linkuang county river section.

Compared with the 2012 survey of river section of the Yicheng city gate area, the then commonly seen catch of *Glyptothorax sinensis, Lepturichthys fimbriata, Rhinogobio typus* and *Leptobotia taeniaps* are no longer included in this survey.

2) Important fish species including four major domestic fishes

Hypophthalmichthys molitrix is the only four Chinese carpscollected in this survey. According to fisherman, *Ctenopharyngodon idellus* and *Mylopharyngodon piceus* have been caught in small amounts over the years. Compared with the 1976-1978 survey of the last century, the previously dominating *Ctenopharyngodon idellus* (taking up 22.18% of catch weight), *Coreius heterokon* (16.37%) and *Parabramis pekinensis* (8.05%) have been replaced by *Cyprinus carpio* (20.9%), *Culter mongolicus* (13.2%) and *Culter alburnus* (8.2%), among which *Cyprinus carpio* takes up 1/5 of the catch weight. The number of four Chinese carpspoplution is rapidly decreasing, which is difficult to contribute to catch yeild.

According to result of statistical analysis of catch of the three river sections, average catch weight is only 210.25g. As for fish below 100g, Yicheng city gate river section have 13 species, Linkuang county river section have 12 species, Zhongxiang river section have 8 species. The biggest fish in the catch is Culter mongolicus with only 915g and mostly small sizes. Fish resources in Han River are clearly getting smaller.

3) Resources of fish species with pelagic eggs

In the late 1970s, Zhou Chunsheng and others conducted survey on the Han River sections upstream and downstream of Danjiangkou, and at least 25 fish species with pelagic eggs were found, among which are economic fish species including *Ctenopharyngodon idellus, Mylopharyngodon piceus, Hypophthalmichthys molitrix, Aristichthys nobilis, Parabramis pekinensis (Parabramis pekinensis), Squaliobarbus curriculus, Coreius heterokon, Rhinogobio typus, Rhinogobio cylindricus, Elopichthys bambusa, Luciobrama macrocephalus, Culter mongolicus, Culter alburnus, Culter oxycephaloides, and small-sized fish species of Lepturichthys fimbriata, Parabotia fasciata,* *Hemiculter bleekeri, Pseudobrama simoni, Xenocypris argentea, Squalidus argentatus* and *Saurogobio dabryi.*

During 2003 and 2004, Institute of Hydroecology surveyed 16 fish species with pelagic eggs in the Han River section downstream of Danjiangkou, and there are *Ctenopharyngodon idellus, Mylopharyngodon piceus, Squaliobarbus curriculus, Hypophthalmichthys molitrix, Aristichthys nobilis, Hemiculter leucisculus, Parabramis pekinensis (Parabramis pekinensis), Culter alburnus, Rhinogobio typus, Rhinogobio cylindricus, Squalidus argentatus, Saurogobio dabryi, Saurogobio gracilicaudatus, Botia superciliaris, Parabotia fasciata, Lepturichthys fimbriata*; comparing with survey of the late 1970s, *Elopichthys bambusa, Luciobrama macrocephalus* and *Culter oxycephaloides* were not surveyed.

In the catch collected in this survey, fish species with pelagic eggs include the eight species such as *Squalidus argentatus, Saurogobio dabryi, Rhinogobio typus, Parabotia fasciata, Squaliobarbus curriculus, Parabramis pekinensis* and *Hypophthalmichthys molitrix*. Comparing with the 2003-2004 survey, *Mylopharyngodon piceus, Ctenopharyngodon idellus, Aristichthys nobilis, Rhinogobio cylindricus, Saurogobio gracilicaudatus, Botia superciliaris* and *Lepturichthys fimbriata* were not collected in catch.

In early resouces survey of Zhongxiang and Huangzhuang, over 90% of pelagic eggs collected are of *Squalidus argentatus*, and the rest are of *Saurogobio dabryi* , *Hemiculter leucisculus* and *Pseudolaubuca.*

4) Reason

(1) Water resources, hydropower project and South-to-North Water Transfer

After the completion of Danjiangkou dam, hydrological regime of the middle and lower reaches of Han River changed tremendously. Resulting from the adjusting and storaging effects of reservoir, variations of flow volume and water level in the middle and lower reaches of Han River became smaller; transparency was improved because of clean water discharged; river erosion was reinforced; river water temperature went down in seasons with high temperature and went up in winter because of discharge of middle and lower layers of reservoir water. Results of the 1977-1978 fishery resources survey reveals that dam construction changes existing river ecological environment resulting in some widely distributed economic fish species only living in isolated water bodies and causing adverse impacts such as delays in gonad development and reproduction season of fish species, as well as the downwarding and disappearing of some spawning grounds for fish with pelagic eggs, and shortened growth period. However, it is conducive to the rising biological productivity of water body, spawning reproduction of winter fish species and fish with adhesive eggs, and the fattening of some fish species. As time passes, fish species are adapted to such changed envrionment and are able to practice variously life cycles of reproduction, foraging, growth and wintering while maintaining a certain population.

Construction of Wangfuzhou Hydro-junction caused the disappearance of Wangfuzhouspawning ground; construction of Cuijiaying Hydro-junction caused fish species in the middle and lower reaches of Han River becoming unable to go upstream to Riverspawning grounds in Miaotan and tributary Tangbai Rivers for reproduction; slowing water flow of the reservoir area made oosperm sink to the bottom of reservoir instead of drifting downstream from the dam leading to a substantially increased death rate; Xinglong Hydro-junction blocked the migratory passes in the lower reach of Han River, as well as from main stream Yangtze River to the middle and lower reaches of Han River. In addtional, its reservoir inundated Maliang spawning ground, narrowed Zhongxiang spawning ground, and adversly affected fish reprodcution in spawning grounds situated downstream of the dam such as Zekou due to attenuation effect of the reservoir on flood peak.

(2) Overfishing

According to suvey, fishing tools and methods have been continuously renewed, in particular since the late 1970s, with increasing catching intensity. Traditional fishing tools of the middle and lower reaches of Han River include gill net, trammel net, multicodend seine, ditch net, fishing jig and fishing clip. In the late 1970s, electric fishing and explosive fishing spread unchecked, and densely holed net tools became increasingly commomplace. In the 1990s, the use of electronic trawl-net began with rapid development due to high efficiency. As catching intensity increased, quantity of fish resources and unit catch of ship went down, hence the increasingly densely holed meshs and horsepower of electronic trawl-net ships with beefed up voltage. According to survey, currently electronic trawl-nets are mostly of 1-2cm mesh, and some electronic trawl-nets have thousands of voltages under joint operation of multiple ships. High-intensity catching, in particular electronic trawl-net is very destructive to resources.

(3) Water quality deteriaration

According to water quality monitoring results over the years, prior 2000 water quality of the main tributaries in the middle and lower reaches of Han River were severely polluted, among which Xiaoqing River, Zhupi River, Tangbai River and Man River suffered the most serious pollution, with many organic pollution indicators reaching Class IV-V surface water and some even exceeding Class V standards . Tributary diffused pollution is of relatively large impact on water quality of the main stream, with major pollutants such as COD and suspended matter. Tangbai River had the lager pollution load inflow, and was followed by Man River and Nan River. Main stream suffered mostly from organic pollution with major pollutants being COD, BOD_5, NH_3—N, NO_2—N and TP. Urban river sections had waterfront pollution belts of varying degrees. Xiantao-Zongguan section in the downstream was prone to eutrophication with increasing "water bloom" phenomena as it was jacked by high water level of Yangtze River during low flow season. Since “water bloom” first occured in Han River in 1992, altogether seven outbreaks had happened till 2003.

With rising nutrient level of water body in the middle and lower reaches of Han River main stream, decreased sediment charge of the water body, and increased transparency, biological productivity of the water body was cleared improved, which may be the main reason of catch yields staying on relatively high levels. However, severe eutrophication of water quality, in particular frequently occuring water blooms will lead to reduced aquatic biodiversity and increasing simplified structure of fish species as it affects the reproduction, growth and development of fish species favoring flowing water. Some severely polluted tributaries in the middle and lower reaches of Han River no longer suits fish.

4.2.3 Ecologically sensitive region

4.2.3.1 Xiangyang Cuijiaying provincial wetland park

a) Wetland park overview

On December 29, 2010, Provincial Forestry Department (ELHH [2010] No. 547) approved to establish “Xiangyang Cuijiaying provincial wetland park”. The park borders Xiangfan No. 1 Han River Bridge on the North via Yangjiahe and Sunjiagang of Xiangcheng district, 100m of Xiaoqing River and its embankment on the Northeast, 300m downstream of Cuijiaying dam on the South via Tangbai River bridge, Laoying of Dongjin county along Dongjin Road, Shangzhou and Zhongshou, and north of Han River embankment on the West, covering an total area of 3428hm^2.

According to functional division, Cuijiaying wetland park is divided into the four areas of ecological conservation zone, water leisure zone, Yuliangzhou ecological city and dam tourism zone. Cuijiaying wetland is a riverine wetland typically representing Han River basin, featuring unique wetland type, excellent ecological environment and abundant biodiversity.

b) Locational relation with wetland park

As the area from the backwater end of Han River Yakou shipping hub to Cuijiaying hydro-junction involves the dam tourism zone of Cuijiaying provincial wetland park,

See Figure 4.2.3-1 for the locational relation of the project and Cuijiaying wetland park.

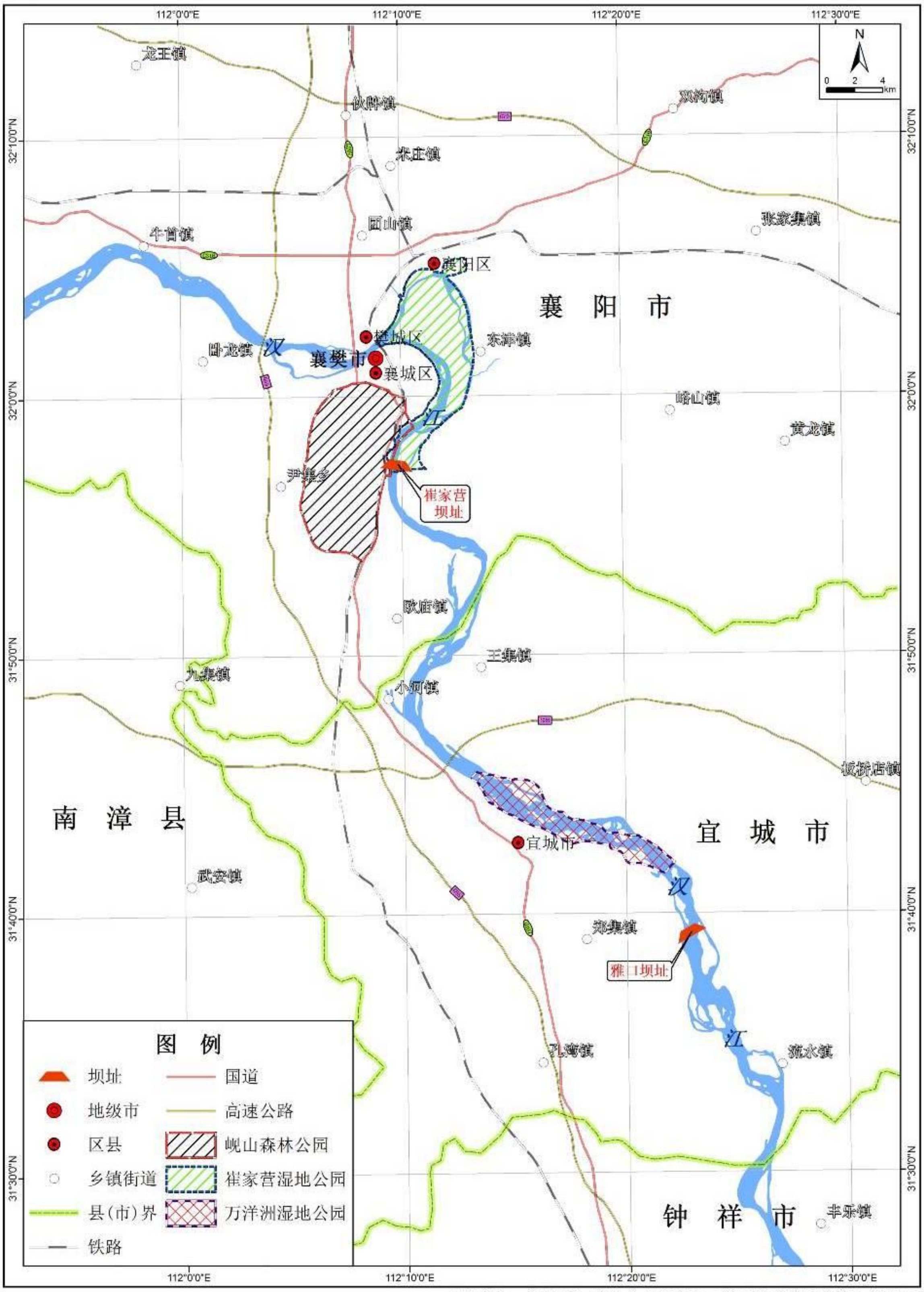


Figure 4.2.3-1 Distribution map of ecologically sensitive area of Han River Yakou Shipping Hub Project

原文	English

图例	Legend
坝址	Dam site
地级市	Prefecture-level city
区县	County
乡镇街道	Township and sub-district
县(市)界	County (city) border
铁路	Railway
国道	National highway
高速公路	Highway
砚山森林公园	Yanshan forest park
崔家营湿地公园	Cuijiaying wetland park
万洋洲湿地公园	Wanyangzhou wetland park

4.2.3.2 Yicheng Wanyangzhou national wetland park

a) Wetland park overview

On December 31, 2013, State Forestry Administration approved, under Document LSF [2013] No. 243, the establishment of Yicheng Wanyangzhou national wetland park (trial) and agreed to carry out trial work.

Yicheng Wanyangzhou national wetland park, mainly of Han River (Yicheng section), is situated on the North of Yicheng county. It is mainly comprised of the section of Han River flowing from northwest to southeast, with the geographic coordinates of N31°41′28″-31°45′32″ and E112°13′07″-112°22′08″, covering an total area of 2466.03hm^2, among which wetland area of the entire wetland park is 1714.81 hm^2 with a 69.53% of wetland rate. Wetland type includes permanent riverine wetland and flood plain wetland, among which permanent riverine wetland covers the main part of Han River riverway, totaling an area of 1147.06 hm^2; flood plain wetland covers mud flats on either side of the Han River riverway and part of the sandbank, totaling an area of 567.75 hm^2.

Wetland park plans to build project and supporting facilities concerning wetland resources and biodiversity protection, scientific research and monitoring and publicity and education by stages and step by step, so as to fully utilize the ecological, environmental and social benefits of the wetland, with a plan to, in about eight years, build the wetland into a national wetland park, featuring healthy ecological system, beautiful natural scenery, well-developed publicity facility and profound cultural heritage, which is of great significance to protecting the existing wetland resources of Han River, preserving ecology, and raising the image of Yicheng. Main content includes wetland protection project, wetland restoration project, popular science and publicity project, scientific research and monitoring, disaster prevention project, regional coordination project, reasonable utilization project, and infrastructure project.

The wetland park is divided into five functional zones: wetland conservation zone, with an area of 1458.27hm^2 accounting for 59.13% of the entire wetland park area; restoration and reconstruction zone, with an area of 741.72hm^2 accounting for 30.08% of the entire wetland park area; publicity and educational exhibition zone, with an area of 189.75hm^2 accounting for 7.7% of the entire wetland park area; reasonable utilization zone, with an area of 75.99hm^2 accounting for 3.08% of the entire wetland park area; and management and service zone, with an area of 0.31hm^2 accounting for 0.01% of the entire wetland park area. See functional division in Figure 4.2.3-2.

b) Locational relation with wetland park

Han River Yakou shipping hub project is situated around 4.5km downstream of the wetland park. After project completion and reservoir water storage, the entire water area of Wanyangzhou national wetland park will be under the inundation line. With the adoption of reservoir embankment for protection in the popular science and education zone and reasonable utilization zone, inundation area will be about 2055hm^2, among which submerged land area will be 340.19hm^2 accounting for 45.29% of the entire land area of the wetland park. See Figure 4.2.3-1 for the locational relation between this project and Wanyangzhou national wetland park.

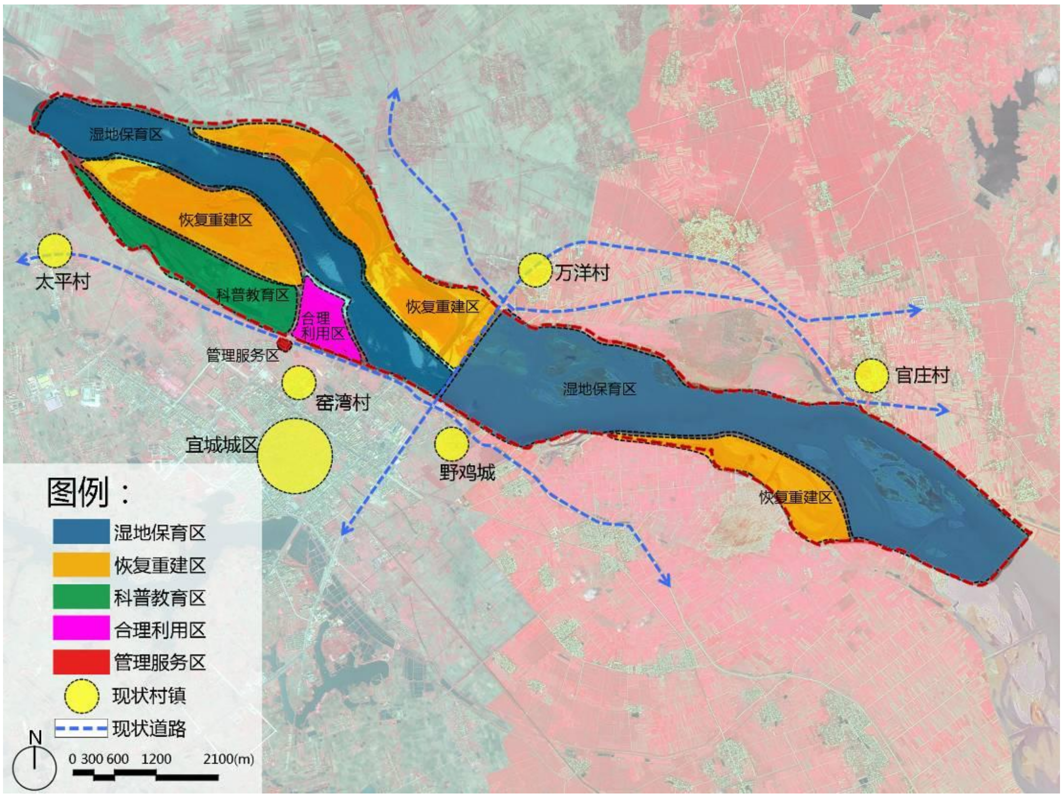


Figure 4.2.3-2 Functional division map of Yicheng Wanyangzhou national wetland park

原文	English
图例	Legend
湿地保育区	Wetland conservation zone
恢复重建区	Restoration and reconstruction zone
科普教育区	Popular science and education zone
合理利用区	Reasonable utilization zone
管理服务区	Management and service zone
现状村镇	Current situation of villages and townships
现状道路	Current road situation

4.2.3.3 Yanshan forest park

a) Forest park overview

Planning area of Yanshan forest park includes: southern section of the Ring Road on the North, the old National Highway 207 on the East, the new National Highway 207 on the West and South, covering an area of 68 km^2. Wan Mountain is not included in the park planning. According to regulation, Yanshan forest park is divided into six major scenic zones: Zhenhu mountain-Hutou mountain-Yangu mountain scenic zone, Yanshou mountain scenic zone, Xijia pond scenic zone, Longjing lake scenic zone, Bian mountain scenic zone, and Yanxi village cultural zone.

b) Locational relation with forest park

Normal water storage level of Han RiverYakou shipping hub is 55.22m, which does not involve the forest park in terms of inundation area, but the minimum distance of forest park border from the inundation line is 270m. See Figure 4.2.3 locational relation between this project and Yanshan forest park.

4.2.4 Soil erosion

4.2.4.1 Soil erosion prevention and treatment zone of the project area

According to the Announcement No. 2 of *Announcement on Dividing National-level Soil Erosion Key Protection and Treatment Zone* of the Ministry of Water Resources from April 29, 2006, Yicheng city, Xiangcheng district and Xiangzhou district, involved in this project, are not national-level protection and treatment zone. According to Announcement of Provincial People's Government on Dividing *Soil Erosion Key Protection and Treatment Zone* (EZF [2000] No. 47) issued by Hubei Provincial People's Government in August 2000, Xiangcheng district and Xiangzhou district are part of Hubei provincial soil erosion key treatment area the area where this project is located has an allowed soil erosion value of 500t/km²•a.

4.2.4.2 Current situation of soil erosion

The main soil erosion type of the project area is water erosion, which is mainly the erosion, carrying and deposition of soil parent material by surface runoff produced by atmospheric precipitation. As soil particle experiences water erosion, there is also the loss of organic matter and mineral nutritive element from the soil. Soil erosion mainly include sheet erosion and surface erosion.

According to classification standard determined by *Soil Erosion Classification Standard,* and the result of the Hubei provincial soil erosion remote sensing survey from 2006, soil erosion area of the county and city where the project is located is 891.73km², accounting for 17.5% of the total land area, among which there are mild erosion of 532.04km² accounting for 59.7% of the erosion area; medium erosion of 311.74km² accounting for 37.2% of the erosion area; severe erosion of 27.95km² accounting for 33.1% of the erosion area.

See Table 4.2.4 for details of the current situation of soil erosion of the area where this project is located.

Table 4.2.4 Current situation of regional soil erosion

Administrative division			Yicheng city	Xiangcheng district	Xiangzhou district	Total
Territorial area (hm²)			2115.11	684.00	2305.99	5105.10
Soil erosion area	Area (hm²)		591.54	48.76	251.43	891.73
	Total area percentage (%)		28.0	7.1	10.9	17.5
Area without clear soil erosion	Area (hm²)		1523.57	635.24	2054.56	4213.37
	Total area percentage (%)		72.0	92.9	89.1	82.6
Erosion area	Mild erosion	Area (hm²)	311.99	38.23	181.82	532.04
		Total area percentage (%)	52.7	78.4	72.3	59.7
	Medium erosion	Area (hm²)	269.40	10.53	51.81	331.74
		Total area percentage (%)	45.5	21.6	20.6	37.2
	Severe erosion	Area (hm²)	10.15		17.80	27.95
		Total area percentage (%)	1.7	0.0	7.1	3.1
	Extremely severe erosion	Area (hm²)	0.00	0.00	0.00	0.00
		Total area percentage (%)	0.0	0.0	0.0	0.0

4.3 Social environment

4.3.1 Social economy

Under the jurisdiction of Xiangyang city, and located in the northwest of Hubei Province, and the middle reach of Han River, Yicheng city is 76 km long from east to west and 53km wide from south to north, covering an area of 2,115 km². Currently, it administers eight townships, two sub-district offices, one industrial park and one provincial-level economic development zone. In 2012, with an entire population of 569.7 thousand, Yicheng city had an annual GDP of 20.19 billion Yuan, comparable growth rate 13.6%, among which annual increase in the primary industry was 4.333 billion Yuan, with comparable growth rate 2.0%; annual increase in the secondary industry was 10.991 billion Yuan, comparable growth rate 18.0%; annual increase in the tertiary industry was 4.869

billion Yuan, comparable growth rate 14.3%. Annual disposal income of urban resident was 15,366 Yuan, increased by 2,107 Yuan from last year, and annual income of rural resident was 9,639 Yuan, increased by 1,258 Yuan from last year.

Located in the northwest area of Huber province, and the south bank of the middle reach of Han River, Xiangcheng district borders Han River on the East and North, Xiangzhou district on the East, across the river from Fancheng district on the North, Yicheng city on the South, Nanzhang county on the Southwest, and Gucheng county on the Northwest, covering an area of 684.00km². Currently, Xiangcheng district administers one village, two townships, six sub-district offices, 123 village committees, 48 community residential committees, 151.8 thousand households. By the end of 2012, it had a total population of 505,000, among which agricultural population was 205,000. In 2012, gross regional production of the area was 24.056 billion Yuan, a 12.6% increase from last year, among which annual increase in the primary industry was 1.59 billion Yuan, with a growth rate of 4.8%; annual increase in the secondary industry was 6.623 billion Yuan, with a growth rate of 13.7%; annual increase in the tertiary industry was 15.843 billion Yuan, with a growth rate of 12.7%. Annual disposal income of urban residents and rural residents rural were 18,885 Yuan and 9,480 Yuan respectively, a 12.1% and 15% year-on-year increase respectively.

Located in the northwest of Hubei province, and on the edge of Nanyang Basin in the middle reach of Han River, Xiangzhou district borders Zaoyang on the East, Laohekou and Gucheng on the West, Yicheng and Nanzhang on the South, and Dengzhou, Xinye and Tang River of Henan province on the North. It is about 79.6km long from south to north, and 77.2km wide from east to west, covering a total area of 2,305.99km². Currently, Xiangzhou district administers 12 townships, 1 sub-district office, 420 village committees, 47 community residential committees, and has a total population of 1.058 million people, among which agricultural population is 472,000. Gross regional production of the area is 31.825 billion Yuan, among which annual increase in the primary industry was 5.113 billion Yuan, annual increase in the secondary industry was 12.597 billion Yuan, and annual increase in the tertiary industry was 14.115 billion Yuan, annual disposal income of urban residents and rural residents is 15,100 Yuan and 10,100 Yuan respectively.

Table 4.3.1 Social economic situation (2012)

Administrative district	Total area	Population (ten thousand people)		Population density	Land per capita	Arable land per capita	Total output				Farmer annual average net income	Urban resident per capita disposable income
							Total	Primary industry	Secondary industry	Tertiary industry		
	(km²)	Total population	Rural population	(person/km²)	(hm²/person)	(hm²/person)	100 million Yuan	100 million Yuan	100 million Yuan	100 million Yuan	Yuan	Yuan
Yicheng city	2115.11	57.2	32.9	270	0.37	0.07	201.93	43.33	109.91	48.69	9639	15366
Xiangcheng district	684.00	50.5	20.5	738	0.14	0.03	240.56	15.90	66.23	158.43	9480	18885
Xiangzhou district	2305.99	105.8	47.2	459	0.22	0.08	318.25	51.13	125.97	141.15	10100	15100

4.3.2 Land utilization

Total land area of Yicheng city, Xiangcheng district and Xiangzhou district, which are involved in this project, is 5,105.10km², among which arable land covers 1,452.44km², accounting for 28.5% of the total land area; forest land covers 1,040.26km², accounting for 20.4% of the total land area; garden plot covers 39.25km², accounting for 0.8% of the total land area; grass land covers 12.97km², accounting for 0.3% of the total land area; water area covers 761.16km², accounting for14.9% of the total land area, and other land covers 1,799.02km², accounting for 35.2% of the total land area. Per capita agricultural arable land is 0.13hm² in Yicheng city, 0.08hm² in Xiangcheng district, and 0.19hm² in Xiangzhou district. See Table 4.3.2 for the current land utilization situation.

4.3.2 Current land utilization situation Unit: km²

Administrative district	Yicheng city		Xiangcheng district		Xiangzhou district		Total	
Type	Area (km²)	Ratio (%)	Area (km²)	Ratio (%)	Area (km²)	Ratio (%)	Area (km²)	Ratio (%)
Total land area	2115.11		684.00		2305.99		5105.10	
Arable land	421.40	19.9	155.36	22.7	875.68	38.0	1452.44	28.5
Forest land	652.33	30.8	139.93	20.5	248.00	10.8	1040.26	20.4
Garden plot	3.30	0.2	4.04	0.6	31.91	1.4	39.25	0.8
Grass land	6.01	0.3	5.04	0.7	1.92	0.1	12.97	0.3
Water area	257.37	12.2	205.81	30.1	297.98	12.9	761.16	14.9
Other land	774.70	36.6	173.82	25.4	850.50	36.9	1799.02	35.2
Agricultural arable	0.13		0.08		0.19		0.14	

land per capita (hm²/person)				

4.3.3 Water supply and disposal

According to preliminary project survey, on the Han River between Yakou hydro-junction and upstream of Cuijiaying power station, as well as between Yakou dam site and Nianpanshan power station downstream, major water intake and usage facilities are for agricultural irrigation, drainage of water logging area, and domestic and industrial water usage, mainly of culvert pipe, sluice and water pump. After reservoir water storage, as water level of Han River is raised, the existing drainage sluice gate will be permanently submerged, resulting in drainage capability decline, and causing more loss from logging disasters in the discharge area; sluice gate damage will be accelerated as sluice gate carries long-term water pressure and water erosion, increasing the difficulty of sluice gate maintenance and the amount of maintenance fees, which is not conducive to the operation and management of sluice gate. After field survey of item by item, 9 sluice gates of the reservoir area of Yakou shipping hub will be affected by inundation.

See Table 4.3.3-1 for statistics of sluice gate inundation of Yakou shipping hub.

Table 4.3.3-1 Inundation statistics of sluice gate of Yakou shipping hub

Serial no.	Sluice name	Location	catchment area (km^2)	Gate width (m)	Gate height (m)	Bottom plate Wusong elevation (m)
1	Yijicheng sluice	Right bank	15.3	3×4	3	54
2	Nan River sluice	Right bank	16.5	2.8	2.6	53.63
3	Huangjiagou sluice	Right bank	38	4	3	51.4
4	Baijiatao sluice	Left bank	20	2×1.2	1.8	55.66
5	Guhegou sluice	Left bank	10	3	2.6	54.74
6	Gongnao sluice	Left bank	24.3	3	2.6	53.81
7	Annao sluice	Left bank	17	2×2.2	2.6	53.27
8	Guanzhuang sluice	Left bank	17	2×2.2	2.6	53.4
9	Nanzhou sluice	Left bank	49.2	2×4.0	3	50.2

Water quality of Han River is quite good, and there are many domestic water intakes along the line. There are altogether 5 intakes in the reservoir area, among which the intake closest to the dam is the Liushui county tap water plant intake, located 8.0km downstream of the dam. Yicheng city Yicheng water plant intake is listed in drinking water source protection zone. See Table 4.3.3-2 for intake situation.

Table 4.3.3-2 Intake situation of Yakou hydropower station assessment area

Name	Location	Water intake mode	Water intake scale (ten thousand t/d)	Water source type	Water intake purpose	Whether or not affected
Wangji county water plant intake	33.0km upstream of dam site, left bank	Separate construction near bank	0.5	Han River riverway	Domestic	Not affected
Yicheng water plant intake of Yicheng city	20km upstream of dam site, right bank	Integrated construction near bank	2.5	Han River riverway	Industrial and domestic	Water intake affected by inundation
Xiangnan prison water plant	1.2km upstream of dam site, left bank	Shield near bank	0.2	Han River riverway	Domestic	Not affected
Danjiangkou resettlement community water plant	2.8km upstream of dam site, left bank	Pontoon near bank	0.5	Han River riverway	Domestic	Not affected
Liushui county tap water plant intake	8.0km upstream of dam site, left bank	Separate construction near bank	0.5	Han River riverway	Domestic	Not affected

4.3.4 Population health

a) Infectious disease situation

According to survey, in recent years, major infectious diseases within Xiangyang city are Category B infectious diseases. According to *Xiangyang city 2008 Infectious Disease and Public Health Emergency Outbreak Survey Report*, major infectious diseases of Xiangyang city include: TB, hepatitis B, measles, syphilis, malaria and dysentery, among which TB, hepatitis B and measles are with a relatively high morbidity rate. In 2008, there were 5788 cases of TB, with a morbidity rate of 162 out of 100 thousand, and a mortality rate of 0.05%; 403 cases of hepatitis B, with a morbidity rate of 74.09 out of 100 thousand, and a mortality rate of 0.25%, and 634 cases of measles, with a morbidity rate of 11.64 out of 100 thousand, and no mortality case.

b) Endemic disease situation

According to survey, major endemic diseases of Xiangyang city are schistosomiasis and malaria. Schistosomiasis mainly occurs in Gucheng, Xiangcheng district and Nanzhang County. After intense treatment in recent year, Oncomelania hupensis area was reduced to 142 Mu from 526 Mu, without new patient of acute infection, and transmission blocking standard was reached in 2008. Epidemic of malaria is throughout Xiangyang city, among which Zaoyang county, Xiangzhou district and Laohekou city are of relatively higher morbidity. After years of prevention, morbidity rate has been reduced by a certain degrees in recent year. In 2008, there were 587 cases of malaria, with a morbidity rate of 10.78 out of 100 thousand, and epidemic of this disease is mainly in rural area where farmer have the highest morbidity rate.

c) Medical and health facility situation

County hospital, township health center and village infirmary have been extensively established in various counties, forming a three-tiered medical and health network of county, township and village. By the end of 2012, there were 3052 health institutions in the city, among which there were 191 hospitals and health centers, 8 disease control centers (epidemic prevention station), 6 health supervision bureaus, and 9 maternal and child care service centers. Health institutions had 18836 beds and 31146 staff, among which were 26505 health technicians, 9642 licensed doctors and 8416 registered nurse practitioners and nurses.

Health facilities of Xiangcheng district and Fancheng district are included into that of the city area, with a 98% and 100% coverage rate of village infirmary and urban community health service institutes respectively. In the city area, there are 177 health institutions, among which there are 61 hospitals with 5577 beds and 6616 health technicians. Gucheng County has 279 health institutions, 17 hospitals, 1446 beds and 2341 health technicians. Laohekou city has 304 health institutions, 19 hospitals, 1160 beds and 2010 health technicians.

4.3.5 Regional Transport

There are railway, national highway and provincial highway across the region. It has well-developed traffic and a relatively good Transport condition.

a) Railway Transport

In the project area, national trunk railways of Handan (Wuhan to Danjiang), Xiangyu (Xiangyang to Chongqing), and Jiaozhi (Jiaozuo to Liuzhou) meet in Xiangyang city area. Zhupo Station near the project site may be used to load and unload cargo. City area is equipped with a special-grade marshalling train station of 113 tracks, with railway Transport extending to all directions.

b) Road Transport

As the second largest road Transport hub of Hubei province, Xiangyang area has an interconnected network of roads including trunk lines such as G207, G316, G312, G209and S207 national highways, highways such as Jingzhu, Xiangshi and Xiangjing, and various roads of county, district and township levels. The project area only needs to build link roads.

c) Water Transport

Main channel of water Transport is Han River main stream. Shipping condition of the channel in this section has been greatly improved to be excellent deep-water channel thanks to the constructions of Hydro-junctions such as Danjiangkou, Ankang and Shiquan. Currently, Danjiangkou-Xiangyang carries 100-200t ship, and channel downstream of Xiangyang carries 300-500t ship. Channel treatment projects of a 117km section of class IV channel from Danjiangkou to Xiangyang, and a 33km section of class III channel from Han River Caidian to estuary are both completed. Water Transport is convenient in the project area.

d) Air Transport

Currently, Liuji airport of Xiangyang and Laohekou airport can fly and land large passenger plane and have flights to 10 cities such as Beijing, Guangzhou, Chongqing, Chengdu, Shanghai, Xi’an, Shenzhen, Wuhan, Foshan and Xiamen, forming an air corridor connecting most parts of China, thus providing a fast and effective air transport condition to the construction of the project.

4.3.6 Minerals, cultural relics and tourism

a) Minerals

In Xiangyang city area, proven mineral resources are of five major catogories and 57 types, among which 24 types have reserves. In the 520 ore fields, various sites of Class D and above mineral resources have an ore reserve of 1.06520 billion ton and an extractable reserve of 1.03885 billion ton. There are 24 mineral types listed in Hubei Provincial Mineral Reserve, namely, in a descending order of advantages, rutile, garnet, bauxite, calcium carbide limestone, building limestone, rectorite, as well as other mineral resources such as phosphorus, limestone, coal, decorative granite and silica rock.

Situated at Yangtze Platform and the southern rim of tectonic unit of Qinling Mountains orogenic belt, the project area and inundation area are of mainly Cretaceous laver of the quaternary period, with stratum outcrop from mesoproterozoic erathem to quaternary system.

According to the feature evaluation report of mineral resources beneath the project area, mineral resources of the reservoir inundation area and its surroundings are mainly building sand, brick and tile clay and building stones, which are all non-key nonmetallic mineral resources, without key mineral deposits. There are 5 proved ore fields, among which three mineral sites (iron sand and building sand) are beneath the project area, and two mineral sites (clay) are in the project surroundings. See Figure 4.3-1 for the distributive locations of mineral resources.

b) Cultural relics

Listed in the top-ten provincial counties and cities of cultural relics, Yicheng city boasts abundant resources of cultural relics of over 300 historical sites, including over 60 ruins of Chu cultural relics, among which over 20 are from the neolithic age. Cultural relics can be divided into three categories based on how they are gathered. The first is Eastern Zhou cultural relic complex centered on the ancient city of Chuhuang. Surrounding Chuhuang city are over 30 ruins from the Eastern Zhou Dynasty including Xiaohugang ruins, Luojiagang ruins, Tongshuyuan ruins, Gulougang ruins, Taojiata ruins, Chihugang ruins, and Munian mountain ancient cemetery complex. The second is the ancient cultural concentration area along the Yicheng section of Han River basin, including Bajiaogang ruins and Miaoergang ruins representing Juejialing culture; Zhaojiagnag ruins and Yaopo ruins representing Shijiahe culture; Duimianshan ruins bearing Ying-Shang cultural heritage; and Xiaojialing ruins piling up cultural relics from the Eastern Zhou Dynasty. The third is ancient village complex of the Man River basin, including Dafenchang ruins, Zhangjiakengzi ruins, Shangliujiaying ruins, Gujiapo ruins, Maojiawa ruins symbolizing primitive agricultural culture; Yangjiatai, Leijiagang and Guojiagang ruins, Shangquan ruins, Hujiazhuang ruins and Guojiahu ruins representing Eastern Zhou culture; Fenghuangshan ancient cemetery complex and Taojiawa ancient cemetery complex reflecting funeral customs of the Eastern Zhou Dynasty. In decades, over 9000 objects have been unearthed, among which the larger-sized Eastern Zhou chariot and steed burial pit unearthed in 1989 was among the top-ten provincial archaeological discoveries of the year. Municipal museum has class one national cultural relics such as copper food container (pair) and copper seasoning container from the Warring States period, and jade human statue from the Han Dynasty.

In July 2012, Hubei Provincial Institute of cultural relics and Archaeology conducted field survey on the project, and the survey altogether determined 12 underground sites of cultural relics. See Table 4.3.6.

c) Tourism

Xiangyang enjoys abundant tourism resources, mainly including seven scenic areas, such as ancient Longzhong, Guangde temple and Migong ancestral hall, and over 700 sites of cultural relics and scenic spots, among which 6 are national-level scenic spots and over 30 are provincial level scenic spots, such as the 4A national-level scenic spot of ancient Longzhong, and Diaolongbei ruins of ancient agricultural civilization in Zaoyang dating back over 6000 years, Jing-Chu culture and Three Kingdoms culture. Over the years, 708 sites of cultural relics have been explored, among which are 185 medieval ruins, 220 ancient cemeteries, 110 ancient stone inscriptions, 106 ancient trees and 4 ancient fossils. Natural scenic spots mainly include mountain and forest type such as Xie mountain and Lumen temple; karst cave hot spring type such as Baokang hot spring; river and lake type such as small three gorges of Nan River; and other types such as underground palace tourism of the mausoleum of Chu Ruler in NanZhang, as well as sightseeing and agricultural tourism of Shennong garden.

According to *Xiangyang City Tourism Development Planning*, Xiangyang has brought out "three major tourism fronts" of local characteristics, namely prestigious ancient city cultural tourism zone of the central region, Jing mountain ecological tourism resort zone of the southwest region, and historical relics tourism zone of the northeast region, creating a golden holiday tourism zone centered on Xiangyang with a 200km radius, bringing together surrounding tourism sites such as Wudang mountains, Shennongjia, three gorges dam of Yangtze River, home village of Emperor Yan, and Xianling mausoleum of the Ming Dynasty.

Impact area of this project does not include tourism scenic zones or scenic spots.

Table 4.3.6 Basic situation of cultural relics of the Yakou shipping hub project area

Serial No.	Name	Location	Coordinates	Elevation (m)	Period	Cultural relics class	Preservation status	Relation with route	Protection advice
1	Guanzhuang Han dynasty cemetery	Group 6, Guanzhuang village, Nanying street sub-district office, Yicheng city	N31°42′56.2″ E112°20′46″	53.5	Eastern Han Dynasty, Six Dynasties and Ming Dynasty	Unclassified	So so	inundation	Exploration, excavation
2	Haogou Ring cemetery complex	Ziran village, Haogou Ring, Ronghe village Xiaohe county, Yicheng city	N31°47′11.0″ E112°9′33.0″	68	Han Dynasty	Unclassified	So so	Erosion	Exploration, excavation
3	Wangjiafang cemetery	Wangjiagang, Mingzheng village, Xiaohe county, Yicheng city	N31°45′24.0″ E112°12′30.0″	71	Han Dynasty	County level	Relatively good	Erosion	Exploration, key excavation
4	Tongmei cemetery complex	Tongmei village, Zhengji county, Yicheng city	N31°39′38.0″ E112°19′16.0″	57	Wei and Jin Dynasties to Sui Dynasty	Unclassified	So so	Erosion	Exploration, excavation
5	Six Dynasties cemetery of Tongmei village group 3	Group 3, Tongmei village, Zhengji county, Yicheng city	N31°40′12.0″ E112°19′23.5″	53	Six Dynasties	Unclassified	So so	inundation	Exploration
6	Heluo village Six dynasties cemetery	Group 6, Heluo village, Zhengji county, Yicheng city	N31°40′5.9″ E112°20′45.3″	52	Six Dynasties	Unclassified	So so	inundation	Exploration, excavation
7	Six dynasties cemetery of	Group 3, Maocao village,	N31°39′31.1″ E112°21′25.3″	53.5	Six Dynasties	Unclassified	So so	inundation	Exploration

Serial No.	Name	Location	Coordinates	Elevation (m)	Period	Cultural relics class	Preservation status	Relation with route	Protection advice
	Maocao group 3	Zhengji county, Yicheng city							
8	Tai Mountain temple cemetery	Group 5, Tannao village, Yancheng office, Yicheng city	N31°42′22.7″ E112°17′29.2″	55	Ming and Qing Dynasties	Unclassified	Relatively poor	inundation	Exploration
9	Ming dynasty cemetery of Tannao group	Group 3, Tannao village, Yancheng office, Yicheng city	N31°42′23.1″ E112°18′15.2″	53.5	Ming and Qing Dynasties	Unclassified	Relatively poor	inundation	Exploration
10	Han dynasty cemetery of Tannao group 3	Group 3, Tannao village, Yancheng office, Yicheng city	N31°42′23.1″ E112°18′15.2″	53	Han Dynasty to Six Dynasties	Unclassified	So so	inundation	Exploration
11	Nan River village Miaotai cemetery	Group 11, Nan River village, Yancheng office, Yicheng city	N31°40′57.3″ E112°19′6.9″	54	Ming and Qing Dynasties	Unclassified	Relatively poor	inundation	Exploration
12	Yakou village cemetery	Fishery community of Liushui county, Yicheng city	N31°39′51.3″ E112°23′15.7″	54	Six Dynasties and Ming Dynasty	Unclassified	So so	inundation	Exploration

4.3.7 Utilization & development along Han River

Xiangyang city is located in the middle reach of Han River, which is a typical braided river. Water and sediment inflow conditions have undergone transformational changes and river regime has been basically stable due to continued construction and operation of Danjiangkou reservoir, Wangfuzhou reservoir and Cuijiaying hydo-junction, as well as the implementation of riverway treatment works during the seventh and eighth Five-year periods. Currently, there are some factors restraining shipping development: unverified structures such as pipelines, cables, bridges, and sluice dams impede navigation; serious damage of some section of Han River results from over exploitation, which hampers the normal riverway operation. Shipping conditions of the river section will be greatly improved with the launch of continued Han River riverway treatment project and the development of Hydro-junctions such as Xingji and Yakou.

Yicheng city has 111.4km of Han River running through its territory, among which

15.8km are utilized and 95.6km are not utilized, with a utilization rate of 14.2%. See Table 4.3.7 for wharf development situation.

Table 4.3.7 Yicheng City Han River ferry and wharf development situation

Serial No.	Starting and ending geographical locations	Name of wharf constructed	Number	Bankline length taken (m)	Note
1	Lijiazhou-Xiaohe outlet (7,000m)	Zhangju vehicle ferry	1	100	Including conservation area
2	Xiaohe outlet-Hongshantou (7,100m)	Sanzhouren ferry	1	50	constructed
		Wangjixiang sand wharf	1(berth)	50	constructed
		Wuxianlai sand wharf	2(berth)	160	constructed
		Guoshiming sand wharf	1(berth)	50	constructed
		Yangchenghong sand wharf	1	50	constructed
		Hongshantou sand wharf	3	360	constructed
3	Hongshantou-Yicheng city (5,700m)	-	-	-	-
4	Yicheng city-Yejicheng (3,100m)	Tianxing sand wharf	1(berth)	80	constructed
		Yangfan sand wharf	1(berth)	60	constructed
		Funing sand wharf	1(berth)	60	constructed
		Meizhong sand wharf	2(berth)	200	constructed
		Yumeng trading company wharf	2(berth)	160	constructed
		Guyuhong sand wharf	3(berth)	450	constructed
5	Yejicheng-Huangjiagou outlet (4,100m)	Nan river sluice	1	250	Including conservation area
		Huangjiagou sluice	1	250	Including conservation area
6	Huangjiagou outlet-Haoji (9,500m)	Maocao Yakou passenger ferry	1	50	Including conservation area
		Haoji passenger ferry	1	50	constructed
		Haoji sand wharf	1(berth)	60	constructed
7	Haoji-Zhoujialou (1,200m)	Xiaorui sand wharf	2(berth)	160	constructed
		Jiawenhua sand wharf	1(berth)	50	constructed
8	Zhoujialou-Beilongling (9,500m)	Guohai passenger ferry	1	50	constructed
		Shixun passenger ferry	1	50	constructed
		Zhengji Puyu sand wharf	2(berth)	240	constructed

Table 4.3.7(continued)

Serial No.	Starting and ending geographical locations	Name of wharf constructed	Number	Bankline length taken (m)	Note
10	Guoan village – Manhe village (6,100m)	Guoanvehicle ferry	1	100	constructed
		Biajiaomiao ferry	1	50	constructed

Serial No.	Starting and ending geographical locations	Name of wharf constructed	Number	Bankline length taken (m)	Note
11	Kongjiaying-Yingshan electric pumping station (1900m)	-	-	-	-
12	Yingshan electric pumping station-Hanshui village (8500m)	Yingshan passenger ferry	1	50	constructed
13	Hanshui village-Yicheng Han River bridge (17700m)	Zhangju vehicle ferry	1	100	constructed
		Han River Yandong sand wharf	1(berth)	100	constructed
		Sanzhou passenger ferry	1	50	constructed
14	YichengHan River bridge-Guanzhuang(4200m)	-	-	-	-
15	Guanzhuang-Nanzhou sluice (4300m)	Guanzhuang peacetime union wharf	2(berth)	100	constructed
16	Nanzhou sluice gate-Lijiashantou (2700m)	-	-	-	-
17	Lijiashantou-Linjiazhuang (5300m)	-	-	-	-
18	Linjiazhuang-Yujiahu(12800m)	Guohai passenger ferry	1	50	Including conservation area
		Shisun passenger ferry	1	50	Including conservation area
		Yuming sand wharf	1	50	constructed
		Lidexiang wharf	1	60	constructed
		Zhnaghua sand wharf	1	80	constructed
		Guoan vehicle ferry	1	100	Including conservation area

According to Xiangyang City Port Overall Planning, Xiangyang port is divided into 7 major port areas, mainly Yujiahu port area, Xiaohe port area, Tangbai River port area, city tourism port area, Chenbu port area, Yujiawan port area, and Guoan port area. Among which Xiaohe port area is planned to be mainly of large bulk cargo and general cargo, energy chemicals and container, including, from upstream to downstream of Xianhe port area, four 1000t multi-purposed berths, eleven 1000t general berths and six 1000t chemical berths, covering around 2235m of the bank with a bank development reserve of 1595m.

The only cargo terminal developed in the Yicheng section of Han River is a comprehensive terminal in Xiaohe port area of Xiangyang port, about 23km from upstream of the dam site of Yakou shipping hub, with three newly built general cargo berths of 1000t cargo ship, one bulk cargo berth, and a designed annual handling capacity of 2.2 million ton. It is also equipped with production and supporting structures such as storage yard and road, loading, unloading and Transport machinery equipment, water and electricity facilities, and is without ship pollution receiving and incident emergency facilities.

4.3.8 Relevant water emergency system construction planning

Han River emergency system construction was planned by *Hubei Provincial “Eleventh Five” Period Water Emergency System Construction Planning*, and has been completed:

a) Construction objective

In 2010, water emergency system would be basically completed in key water area, and water emergency system would be started in other water area, demonstrating a clear improvement of water emergency rescue capability and a stable water Transport safety situation; water safety monitoring and warning system would be started; water emergency information platform would be basically completed with 24-hour emergency dispatch of rescue forces under normal weather conditions; rescue arrival time of would not exceed 15 minutes to central port area and key passenger area, 40 minutes to key channel, and 90 minutes to ordinary navigable water area.

b) Overall planning program

1) Systematic composition

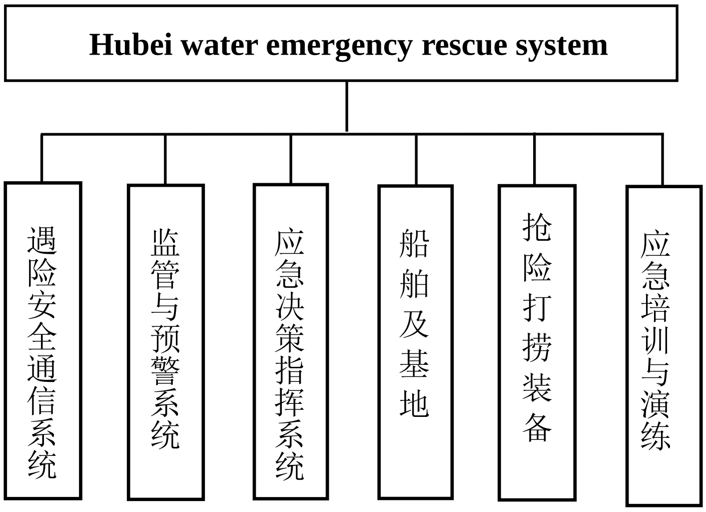


Figure 4.3.8 Hubei provincial water emergency rescue system

原文	English
应急培训与演练	Emergency training and drill
抢险打捞装备	Emergency salvage equipment
船舶及基地	Ship and base
应急决策指挥系统	Emergency decision-making and command system
监管与预警系统	Supervision and warning system
遇险安全通信系统	Distress safety communication system

2) Planning program

◆ Distress safety communication system

Five water emergency information application system need to be built, including creating a 12395 special telephone line of water rescue, establishing a Ship-bank communication system of Han River section, upgrading and renewing equipment of provincial network center, building local area networks for 16 cities (prefectures) and 78 counties within the province, researching and promoting GPS-operated ship management information system and Han River channel geographical information system.

◆ Surveillance and warning system

Carry out research on water safety monitoring system, build sub-centers of water Transport surveillance and command, and use remote internet video monitoring technology to obtain video information of safety, dispatching and management of key reservoir area and Han River channel.

◆ Decision-making and command system

Build emergency decision-making and command system on the basis on improving rescue institution in the locations (city) of 16 key lake reservoirs and Han River.

◆ Ship and comprehensive base

Equip Han River and 50 relatively larger navigable lakes and reservoirs with 58 emergency rescue ships, and allocate medium and small-sized multi-functional inland river emergency rescue ship in Danjiangkou reservoir and along the line of Han River.

◆ Emergency salvage equipment

Equip Danjiang reservoir of Shiyan city with one 300t emergency rescue, salvage and crane ship each. By 2020, equip Han River with a 1000t emergency rescue, salvage and crane ship.

4.4 Environmental situation of resettlement area

The resettlement number of this project is relatively small and scattered, totaling 1805 people from Xiangcheng district and Xiangyang district of Xiangyang city as well as Yicheng city. Resettlement will be conducted within the village with separated or centralized methods, and the environmental situation of the resettlement area is similar to that of the project area.

According to survey of the current situation of ecological environment of the resettlement area, resettlement area is mainly of arable land and shrub-grassland, among which arable land are mostly dry lands, and a small part of paddy field. Major crops include *Triticum aestivum, Oryza sativa, Zea mays, Solanum tuberosum, Arachis hypogaea*; shrub-grassland mainly includes dominant shrublands that are commonly seen locally such as *Vitex negundo, Broussonetia papyrifera, Rosa cymosa, Alchornea davidii, Caesalpinia decapetala*. Resettlement construction also involves some artificial economic forest land, mainly including *Populus euramevicana cv.I-214’* forest. There is no national-level rare and protected plant discovered in various resettlement areas.

Resettlement area is an area of relatively frequent human activities, with relatively small amount of wild animals which are all small-sized animals, such as the commonly seen *Muridae, Dendroaspis polylepis* and *Aves*. According to survey, *Amphibians* of the resettlement area mainly include *Bufo gargarizans* and *Rana plancyi*; *Reptilia* include common species such as *Eumeces chinensis*, *Elaphe rufodorsata* and *Rhabdophis tigrinus*; *Mammalia* are mostly small-sized commonly seen species including *Insectivora*, *Vespertilio superans* and *Lagomorpha*, as well as small-sized species such as *Sciuridae* and *Muridae* of *Rodentia*. Aves are relatively less than that of in the project area, but *Milvus Korschun*, a national Class II key protected bird appears in the surroundings of resettlement area. *Milvus Korschun* is bird of prey with a relatively large activity range and 12 have been found in the resettlement area. In addition, *Hirundo rustica* occasionally appears in the surroundings of residential area in the resettlement area.

4.5 Regional environmental quality and major environmental problem

4.5.1 Current situation of environmental quality

4.5.1.1 Current situation of pollution source

a) Industrial pollution source

To grasp the distribution and intensity of industrial pollution source of the project impacting area, and to provide basic data of impact predication analysis of water environment from project construction and operation after completion, our company conducted survey on industrial pollution source of both banks of the river section, and the main content of the survey was industrial sewage discharge river, location of discharge outlet, discharge volume, sewage type and yearly total discharge volume. Survey result reveals that there are altogether 31 industrial pollution sources surveyed in Yicheng city, covering industries such as chemical engineering, medicine, textile, fertilizer, papermaking and food, discharging 16.9632 million ton of industrial sewage, among which discharge volume of main pollutants include 1,607.834t of COD and 432.64t of AN. See Figure 19 for the distribution of main industrial pollution sources; see Table 4.5.1-1 for discharge situation of various industries; see Table 4.5.1-2 for sewage survey result of main industrial pollution sources.

Table 4.5.1-1 Disposal situation of various industries

Industry	COD discharge amount	Proportion (%)	An discharge amount	Proportion (%)
Fertilizer-making	423	26.30	170.03	39.30

Papermaking	124.53	7.75		
Textile	154.5	9.61	0.08	0.018
Food	167.13	10.39	12.68	2.93
Chemical engineering	738.17	45.91	249.85	57.75
Pharmaceutical	0.5	0.03		

According to sewage discharge volumes of various industries, chemical raw materials and chemicals manufacturing accounts for 87.4%, the largest porportion, of the city sewage discharge, followed by food and bewerage industry, papermaking industry, and textile industry. Industrial sewage of Yicheng city is mainly from Yicheng city Xinfu Fertializer Limited, Xiangdeng Fertilizer Plant of Hubei provincial Denglin farm, Hubei East Chemical Engineering Limted, Hubei Jingyuan Chemical Engineering Stock Limted, Yanjing Beer (Xiangfan) Limited, Hubei Guangfa Paper Limited, as well as enterprises of the Danyan industrial zone such as Minghua Chemical Fiber Pulp Limited and Xiangfan Chutian Chemical Fiber Limited, and their sewage discharge volume accounts for 94% of the city’s total industrial sewage discharge volume.

According to Table 4.5.1-2, industiral pullution sewage in Yakou reservoir area is mainly from companies discharging into Wangjiada ditch and Xiangdeng Fertilizer Plant of Hubei provincial Denglin farm directly discharging into Han River, among which yearly total COD and AN discharged into Han River via Wangjiada ditch are 193.15t and 18.42t respectively; yearly total COD and AN directly discharged into Han River by Xiangdeng Fertilizer Plant of Hubei provincial Denglin farm are 258.9t and 137.2 t respectively. Industrial sewage recieved by sectio downstream of Yakou dam site are mainly from companies discharging into Yidaoda ditch and Man River, among which yearly total COD and AN discharged into Han River via Yidaoda ditch are 111.85t and 17.01t respectively; yearly total COD and AN directly discharged into Man River are 133.76t and 20.47 t respectively.

Table 4.5.1-2 Major industrial pollution source waste water discharge situation

District/county	Company Name	Village or town located	Industry/main product	Waste water discharge amount t/a	Receiving water body	Discharge orientation	Discharge amount t/a		
							COD	AN	Petroleum
Xiangcheng district	1. Hubei Shierjia Fertilizer Co., Ltd	Oumiao County	Phosphate fertilizer manufacturing	25500	Han River	Into city sewage treatment plant, then into Han River via Wangjiada ditch after treatment	40.00	1.00	
	2. Hubei Lingsheng Pharmaceutical Co., Ltd	Oumiao County	Chemical pharmaceuticals and antibiotics material manufacturing	29000	Han River	Into city sewage treatment plant, then into Han River via Wangjiada ditch after treatment	14.21	1.50	
	3. Xiangyang Zedong Chemical Engineering Co., Ltd	Oumiao County	Phosphate fertilizer manufacturing	1370000	Han River	Into city sewage treatment plant, then into Han River via Wangjiada ditch after treatment	133.14	15.74	
	4. Xiangfan city Yujue Chemical Engineering Co., Ltd	Oumiao County	Organic chemical materials manufacturing/ nitrobenzene	8957	Han River	Into city sewage treatment plant, then into Han River via Wangjiada ditch after treatment	4.30	0.13	
	5. Xiangfan city Xinshenhua Chemical Engineering Co., Ltd	Oumiao County	Organic chemical materials manufacturing/ Resin, gum	16130	Han River	Into city sewage treatment plant, then into Han River via Wangjiada ditch after treatment	1.50	0.05	
Yicheng city	6. Hubei Guangfa Paper Co., Ltd	Economic and development zone	Machine-made paper and cardboard manufacturing	668200	Han River	Into city sewage treatment plant, then into Han River via Yidaoda ditch and Guohai sluice after treatment	57.30	4.46	

District/county	Company Name	Village or town located	Industry/main product	Waste water discharge amount t/a	Receiving water body	Discharge orientation	Discharge amount t/a		
							COD	AN	Petroleum
	7. Anneng (Yicheng) Biomass Co., Ltd	Yancheng street	Other power production	230000	Han River	Into city sewage treatment plant, then into Han River via Yidaoda ditch and Guohai sluice after treatment	4.35		
	8. Hubei Nuoxin Biotech Co., Ltd	Dayan industrial zone	Inorganic acid manufacturing	17490	Man River	Directly into Man River	0.80		
	9. HubeiXinchuzhong Fertilizer Co., Ltd	Dayan industrial zone	Phosphate fertilizer manufacturing	130000	Man River	Directly into Man River	5.50	0.50	
	10. Yanjing Beer (Yicheng) Co., Ltd	Yancheng street	Beer manufacturing	550000	Han River	Into city sewage treatment plant, then into Han River via Yidaoda ditch and Guohai sluice after treatment	44.00	12.00	
	11. Yicheng city Changfeng Paper Co., Ltd	Dayan industrial zone	Other paper product manufacturing	103100	Man River	Directly into Man River	17.43	1.04	

Table 4.5.1-2(continued)

District/county	Company Name	Village or town located	Industry/main product	Waste water discharge amount t/a	Receiving water body	Discharge orientation	Discharge amount t/a		
							COD	AN	Petroleum
Yicheng city	12. Hubei Longxiang Phosphate Chemicals Co., Ltd	Dayan industrial zone	Other fertilizer manufacturing	8800	Man River	Directly into Man River	0.38		
	13. Yicheng Ruilong Sci-tech Co., Ltd	Dayan industrial zone	Chemical fiber pulp manufacturing	935000	Man River	Directly into Man River	70.00	11.22	

District/county	Company Name	Village or town located	Industry/main product	Waste water discharge amount t/a	Receiving water body	Discharge orientation	Discharge amount t/a		
							COD	AN	Petroleum
Yicheng city	12. Hubei Longxiang Phosphate Chemicals Co., Ltd	Dayan industrial zone	Other fertilizer manufacturing	8800	Man River	Directly into Man River	0.38		
	14. Xiangfan Chutian Chemical Fiber Co., Ltd	Dayan industrial zone	Chemical fiber pulp manufacturing	921600	Man River	Directly into Man River	39.12	7.68	3.00
	15. Yicheng Yaxing Home Textiles Co., Ltd	Chudu Avenue	Bedding manufacturing	97100	Han River	Into city sewage treatment plant, then into Han River via Yidaoda ditch and Guohai sluice after treatment	5.94	0.55	
	16. Xiangfan Dongfeng Tianshen Storage Battery Co., Ltd	Economic and development zone	Other battery manufacturing	1000	Han River	Into city sewage treatment plant, then into Han River via Yidaoda ditch and Guohai sluice after treatment	0.136		
	17. Hubei Chudu Liquor Co., Ltd	Xiaohe county	Liquid manufacturing	1400	Man River	Directly into Man River	0.11	0.025	
	18. Xiangdeng Fertilizer Plant of Hubei provincial Denglin farm	Liushui county	Nitrogenous fertilizer manufacturing	2100000	Han River	Directly into Han River	258.9	137.2	1.50
	19. Hubei Qianxing Chemical Engineering Co., Ltd	Economic and development zone	Coating material manufacturing	1600	Han River	Into city sewage treatment plant, then into Han River via Yidaoda ditch and Guohai sluice after treatment	0.12		
	20. Yicheng city Gongtong Pharmaceutical Co., Ltd	Xiaohe county	Chemical pharmaceuticals material manufacturing/ Steroid	10176	Man River	Directly into Man River	0.42		

District/county	Company Name	Village or town located	Industry/main product	Waste water discharge amount t/a	Receiving water body	Discharge orientation	Discharge amount t/a		
							COD	AN	Petroleum
Yicheng city	12. Hubei Longxiang Phosphate Chemicals Co., Ltd	Dayan industrial zone	Other fertilizer manufacturing	8800	Man River	Directly into Man River	0.38		
			hormone						

Note: ① Wangjiada ditch is located in Xiaohe county of the reservoir area, and its estuary is about 29km upstream of Yakou dam site; Yidaoda ditch, as one of the main sewage recieving ditches of Yicheng city, has a rain collection area of 38km^2 and a total length of 15.8km; Laojiang ditch, located in the middle of Yicheng urban area, is 3.5km long and is followed by Yidaoda ditch into Han River via Guohai sluice, which is located about 3.0km downstream of Yakou dam site; ② Wangjiada ditch and Yidaoda ditch are not classified in terms of water body function, and had relatively poor water quality according to a 2004 survey, for major standard-exceeding factors such as CODcr, AN, TN, TP and CODmn.

b) Agricultural pollution source

Agricultural pollution source mainly refers to residue of nutritive salt from fertilizer applied into farmland by agricultural production unabsorbed by crops leaking into water body carried by surface runoff. Agricultural fertilizer application around the reservoir area are mainly nitrogenous fertilizer and phosphorus fertilizer, which are leached by rain after plant absorbsion and then carried into water body by surface runoff. According to *First National Pollution Source Census- Agricultural Pollution Source Fertilizer Loss Coeffiecnt Manual*, and taking into account the recommanded value from *National Water Environmental Capacity Ratification Guide*, model 65 and 66 are selected as agricultural pollution source calculation coefficient this time, because the project area is of southern humid plain area, with mostly dry land and a plantation structure including large farmland plantation with two yields and fruit trees. Specific value selection is as follows: for arable land, TN being 0.668kg/Mu, TP being 0.037kg/Mu and fertilizer loss coefficient being 1.052% for TN and 0.410% for TP; for garden plot, TN being 1.331kg/Mu, TP being 0.107kg/Mu and fertilizer loss coefficient being 0.855% for TN and 0.514% for TP. Given that non-point source pollution has extensive sources and is difficult to monitor, relevant research is still in its intial phase. Non-point source pollution research result of Huai River basin reveals that the amount of non-point source pollution into river is below 10% of the discharged volume, with a coefficient between 0.01~0.2, whereas the coefficient is generally seleted between 0.03-0.05 in pollution source survey in Hubei province. Considering the topographic feature of Xiangyang city, coefficient of agricultural diffused pollutant into reservoir is selected as 0.03. See Table 4.5.1-3 for production volume of agricultural diffused pollution of reservoir surroundings and the amount into reservoir based on this calculation.

Table 4.5.1-3 Agricultural diffused pollution production volume and the amount into reservoir from reservoir surroundings

Unit：t/a

County/city	Arable land (Mu)	Garden plot (Mu)	Total TN loss	Total TP loss	TN into reservoir from surrounding township	TP into reservoir from surrounding township
Xiangcheng district	101859.4	6259.1	787.0	18.9	23.6	0.6
Xiangyang district	121726.8	4936.6	911.6	21.2	27.3	0.6
Yicheng city	730652.4	20916	5372.6	122.3	161.2	3.7
Total	954238.6	32111.7	7071.2	162.4	212.1	4.9

c) Livestock breeding pollution source

Areas surrounding the reservoir are mainly Xiangcheng district, Xiangyang district and Yicheng city. Livestock and poultry raised in villages and townships surrounding the reservoir area are counted to be 216 thousand cows, 565 thousand pigs, 152 thousand sheep and 16.8 million poultry. Livestock breeding pollutant is calculated according to *First National Pollution Source Census- Livestock and Poultry Breeding Industry Pollution Source Production and Discharge Coeffiecnt Manual*, and taking into account *Livestock and Poultry Breeding Industry Pollutant Discharge Standard*(GB18596-2001). As the project area is of the "central southern area", its inventory cow and sheep pollution producing coefficients can be selected as COD being 800g/head/day, TN being 200g/head/day and TP being 25g/head/day; inventory pig pollution producing coefficient can be selected as COD being 160g/head/day, TN being 20g/head/day and TP being 4g/head/day; inventory poultry pollution producing coefficient can be selected as COD being 8g/head/day, TN being 0.5g/head/day and TP being 0.2g/head/day. Coeffiecient of larger-scale foultry breeding pollution is dependent upon its way of discharging, and the coefficient can be selected as 0.12, given that arger-scale foultry breeding pollution is generally discharged into nearby pond or lake in Xiangyang city according to field survey and research result of *Xiangyang City Large-scale Breeding Pollution Survey*.

Table 4.5.1-4 Calculation map of amount of Livestock breeding pollution source into reservoir

County/city	Production amount (t/a)			Amount into reservoir (t/a)		
	COD	TN	TP	COD	TN	TP
Xiangcheng district	70430.3	12575.0	1930.7	8451.6	1509.0	231.7
Xiangyang district	71113.4	12834.4	2030.2	8533.6	1540.1	243.6
Yicheng city	47964.3	8645.0	1448.3	5755.7	1037.4	173.8
Total	189508.0	34054.4	5409.2	22741.0	4086.5	649.1

d) Domestic pollution source

1) Urban domestic sewage

According to *First National Pollution Source Census: Urban Domestic Pollution Source Production and Discharge Coeffiecnt Manual*, and taking into account the recommanded value from *National Water Environmental Capacity Ratification Guide*, given that the project area is situated in Xiangyang city (former Xiangfan city) of Hubei province, urban domestic pollution source calculation coefficients are selected as follows: water discharge volume being 172L/person/day, COD being 68g /person/day, AN being 7.60g/person/day, TN being 9.92g/person/day, and TP being 0.78g/person/day. Adopting urban population (non-agricultural population), domestic pollution discharge volume of various villages and townships are calculated. Taking into account of opinions from Hubei Provincial Surface Water Environmental Capacity Ratification Technical Report, 0.8 is selected as the river inflow coeffiecient of urban domestic pollution source.

There are three cities (district) and eight villages and townships (sub-district office) surrounding the Yakou reservoir area, and the amouts of theri urban domestic sewage into reservoir are listed in Table 4.5.1-5. Sewage are mainly directly discharged into Han River via ditches or channels, as villages and townships currently have no sewage plant for sewage treatment.

Table 4.5.1-5 Amount of domestic pollution into reservoir from reservoir surroundings

County	Township	Urban population	Domestic sewage amount (Ten thousand m^3)	COD_{Cr} t	NH_3-N t	TN t	TP t
Xiangcheng district	Oumiao county	32908	165.3	653.4	73.0	95.3	7.5
Xiangyang district	Dongjin county	60863	305.7	1208.5	135.1	176.3	13.9
Yicheng city	Liushui	20570	103.3	408.4	45.6	59.6	4.7
	Nanying	8285	41.6	164.5	18.4	24.0	1.9
	Wangji	16815	84.5	333.9	37.3	48.7	3.8
	Zhengji	45723	229.6	907.9	101.5	132.4	10.4
	Yancheng	29617	148.7	588.1	65.7	85.8	6.7
	Xiaohe	41151	206.7	817.1	91.3	119.2	9.4
Total		226315	1285.4	5081.8	567.9	741.3	58.3

Note: population number and population growth rate is 4.1‰, from Xiangyang Municipal statistical yearbook.

2) Rurual domestic sewage

Agricultrual domestic pollution is mainly produced by domestic sewage, trash and human and animal excreta discharged into surrounding farmland, ditches and channels as part of the pollutant leaks into water body through surface runoff. Rural domestic pollutant discharge coefficient is selected according to the recommended value from *National Water Environmental Capacity Ratification Guide* of Chinese Academy for Environmental Planning of the State Environmental Protection Administration, and the source of rural population is *Xiangyang Municipal Statistics Yearbook*. Rural domestic pollutant discharge coefficient values are as follows: water discharge volume being 80L/person/day, COD being 70g /person/day, AN being 7.6g/person/day, TN being 9.62g/person/day, and TP being 0.68g /person/day. Given that non-point source pollution has extensive sources and is difficult to monitor, relevant research is still in its intial phase. Non-point source pollution research result of Huai River basin reveals that the amount of non-point source pollution into river is below 10% of the discharged volume, with a coefficient between 0.01~0.2, whereas the coefficient is generally seleted between 0.03-0.05 in pollution source survey in Hubei province. Considering the topographic feature of Xiangyang city, coefficient of rural domestic pollutant into reservoir is selected to be 0.03. See Table 4.5.1-6 for the reservoir inflow volume of rural domestic sewage.

Table 4.5.1-6 Reservoir inflow volume of rural domestic pollution from reservoir surroundings

County	Township	Urban population (person)	Domestic sewage amount (Ten thousand m^3)	COD_{Cr} t	NH_3-N t	TN t	TP t
Xiangcheng district	Oumiao county	40220	3.5	30.8	3.3	4.2	0.3
Xiangyang district	Dongjin county	74388	6.5	57.0	6.2	7.8	0.6
Yicheng city	Liushui	25142	2.2	19.3	2.1	2.6	0.2
	Nanying	10126	0.9	7.8	0.8	1.1	0.1
	Wangji	20552	1.8	15.8	1.7	2.2	0.2
	Zhengji	55884	4.9	42.8	4.7	5.9	0.4
	Yancheng	36198	3.2	27.7	3.0	3.8	0.3
	Xiaohe	50296	4.4	38.6	4.2	5.3	0.4
Total		312806	27.4	239.8	26	32.9	2.5

Yanjing beer brewery sewage treatment station

Yicheng city sewage treatment plant

Yidaoda ditch (main sewage discharge channel of Yicheng city)

Guohai sluice (estuary of Yidaoda ditch)

Wangjiada ditch industrial waste water drainage channel

Wangjiada ditch estuary

Figure 4.5.1-1 Current situation of domestic pollution source from reservoir surroundings

4.5.1.2 Surface water environmental quality

a) Conventional cross section monitoring result analysis

1) Conventional water quality monitoring of Xiangyang section of Han River

Conventional water quality monitoring of the Xiangyang section of Han River is carried out by Xiangyang Municipal Environmental Monitoring Station, including water quality monitoring of surface water environment of Han River and other seven major tributaries within Xiangyang area, Tang River and Bai River on the provincial border of Henan and Hubei, and small water bodies within Xiangyang urban area such as Nan channel and Xiangyang city moat.

Monitoring is conducted monthly in the first ten-day period of a month and 12 times in a year. Monitoring items are according to regulations of national and Hubei provincial environmental protection authorities, namely the twelve items of water temperature, pH value, conductivity, DO, CODmn, five-day BOD, AN, TP, Hg, Pb, volatile penol and petroleum.

There are altogether six monitoring cross sections in Han River (Xiangyang section), namely two cross sections of Fujiazhai and Xianrendu in Laohekou city, three cross sections of Baijiawan, Qianying and Yujiahu in Xiangyang urban area, and one cross section of Guonan in Yicheng city. This report collects yearly water quality monitoring result of Han River from 2013, which was evaluated according to the national *Surface Water Environmental Quality Standard* (GB3838-2002) and *Hubei Surface Water Environment Functional Zoning* (EZF [2002] No. 10) issued by Hubei Provincial Government. See Table 4.5.1-6 for evaluation result. Monitoring result reveals: Xiangyang section of Han River has excellent water quality, and water quality of the six cross sections of Fujiazhai, Xianrendu, Baijiawan, Qianying, Yujiahu and Guoan are of Type II to Type III respectively.

Table 4.5.1-6 Water quality type evaluation of Han River basin of Xiangyang city from 2011 to 2013

Cross section	Cross section type	regulation	Year	Water quality type											
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Fujiazhai	Xiangyang city entry cross section	II	2011	II	II	II	II	II	II	II	II	II	II	II	II
			2012	II	II	II	I	II	II	II	II	II	II	II	II
			2013	II	II	II	II	II	II	II	II	II	II	II	II
Xianrendu	Laohekou city control cross section	III	2011	II	II	II	II	II	II	II	I	II	II	II	II
			2012	II	II	II	II	II	II	II	II	III	III	II	II
			2013	II	II	II	II	II	II	II	II	III	II	II	II

Baijiawan	Xiangyang city urban comparison cross section	II	2011	II	II	II	II	II	II	II	II	II	II	II	II
			2012	II	II	II	II	II	II	II	II	II	II	II	II
			2013	II	II	II	II	II	II	II	II	II	II	II	II
Qianying	Xiangyang city urban control cross section	III	2011	II	II	III	II	II	II	II	II	II	II	III	II
			2012	II	II	II	II	II	II	II	II	II	II	II	II
			2013	II	II	II	II	II	II	II	III	II	II	II	II
Yujiahu	Xiangyang city urban control cross section	III	2011	II	II	II	II	II	III	II	II	II	II	III	II
			2012	II	II	II	II	II	II	II	II	II	II	II	II
			2013	II	II	II	II	II	II	II	III	II	II	II	II
Guoan	Xiangyang city exit cross section	III	2011	II	II	II	II	II	II	II	II	II	II	II	II
			2012	II	II	II	II	II	II	III	II	II	II	II	II
			2013	II	II	II	II	II	II	III	II	II	II	II	III

Table 4.5.1-7 Conventional monitoring data of Xiangyang section of Han River from 2011 to 2013

Unit: mg/L (pH and flora excluded)

Cross section	Year	Water period	Monitoring item									
			pH	DO	CODmn	BOD5	AN	petroleum	TP	COD	Fecal Coliform (number per liter)	TN
Fujiazhai	2011	dry	8.15	9.68	1.72	1.6	0.159	0.023	0.024			
		normal	8.21	8.43	1.83	1.2	0.099	0.025	0.026			
		wet	8.06	6.18	1.97	1.0	0.066	0.028	0.028			
	2012	dry	8.30	9.75	2.04	1.5	0.146	0.023	0.033	5.00	545	1.93
		normal	8.26	8.74	2.08	2.2	0.108	0.028	0.024	5.00	417	1.55
		wet	8.23	6.63	1.82	1.3	0.029	0.025	0.020	5.00	438	1.63
	2013	dry	8.29	9.76	1.95	2.0	0.126	0.024	0.026	5.08	588	1.49
		normal	8.30	7.66	1.93	1.4	0.120	0.019	0.020	5.67	630	1.64
		wet	8.25	6.35	1.81	1.1	0.049	0.018	0.015	5.75	630	1.46

Table 4.5.1-7(continued)

Cross section	Year	Water period	Monitoring item									
			pH	DO	CODmn	BOD5	AN	petroleum	TP	COD	Fecal Coliform (number per liter)	TN
Xianrendu	2011	dry	8.29	10.68	2.15	2.4	0.217	0.023	0.040			
		normal	8.33	8.73	1.89	2.4	0.189	0.026	0.037			

		wet	8.26	6.65	1.80	1.6	0.106	0.028	0.045			
	2012	dry	8.35	10.33	2.40	2.2	0.220	0.024	0.033	5.17	648	1.53
		normal	8.39	9.86	2.22	2.5	0.108	0.027	0.056	5.33	630	1.48
		wet	8.36	6.87	1.94	1.8	0.090	0.025	0.072	5.00	503	1.38
	2013	dry	8.31	10.67	2.23	2.1	0.143	0.031	0.044	5.42	648	1.56
		normal	8.32	7.90	1.91	1.2	0.144	0.036	0.024	5.25	659	1.56
		wet	8.28	6.49	1.83	1.9	0.046	0.037	0.023	5.33	648	1.61
Baijiawan	2011	dry	8.2	10.39	2.40	2.1	0.126	0.023	0.037	5	671	1.56
		normal	8.2	8.91	2.33	1.6	0.068	0.026	0.042	5	613	1.55
		wet	8.2	7.01	2.62	1.1	0.062	0.024	0.020	5	651	1.48
	2012	dry	8.4	10.99	2.65	1.8	0.129	0.025	0.031	5	665	1.43
		normal	8.3	9.07	2.31	1.6	0.150	0.028	0.035	5	648	1.36
		wet	8.3	7.01	2.51	1.6	0.036	0.025	0.025	5	648	1.30
	2013	dry	8.3	10.83	2.35	2.1	0.207	0.031	0.035	6	636	1.43
		normal	8.3	8.35	2.58	1.9	0.101	0.033	0.027	6	636	1.44
		wet	8.3	7.06	2.47	1.9	0.099	0.033	0.034	6	630	1.33
Qianying	2011	dry	8.21	10.50	2.69	2.3	0.208	0.023	0.045			
		normal	8.23	8.75	2.56	1.7	0.201	0.029	0.072			
		wet	8.23	7.21	2.55	1.7	0.094	0.023	0.025			
	2012	dry	8.33	10.52	2.76	1.9	0.132	0.024	0.033			
		normal	8.32	9.21	2.53	1.4	0.108	0.026	0.036			
		wet	8.28	6.54	2.68	1.3	0.070	0.026	0.039			
	2013	dry	8.28	10.71	2.37	2.2	0.151	0.033	0.039			
		normal	8.28	8.26	2.77	1.7	0.167	0.031	0.031			
		wet	8.29	6.86	3.17	1.7	0.128	0.032	0.035			
Yujiahu	2011	dry	8.18	10.27	2.78	2.0	0.29	0.02	0.053	5.00	800	1.93
		normal	8.22	8.42	2.69	1.9	0.275	0.0311	0.073	5.00	820	1.91
		wet	8.21	6.80	2.64	2.5	0.190	0.034	0.038	5.00	784	1.48
	2012	dry	8.31	10.07	2.82	2.2	0.15	0.03	0.039	5.00	700	1.38
		normal	8.27	7.84	2.64	1.8	0.20	0.03	0.050	5.42	688	1.60

Table 4.5.1-7(continued)

Cross section	Year	Water period	Monitoring item									
			pH	DO	CO	BOD5	AN	petrole	TP	COD	Fecal	TN

on		d			Dmn			um			Coliform (number per liter)	
Yujiahu	2012	wet	8.28	6.51	2.87	1.9	0.09	0.03	0.039	5.00	694	1.58
	2013	dry	8.25	10.42	2.43	2.1	0.18	0.04	0.052	5.83	671	1.45
		normal	8.24	7.84	2.98	1.7	0.22	0.04	0.041	6.67	703	1.36
		wet	8.28	6.32	3.17	2.4	0.20	0.03	0.039	7.08	653	1.70
Guoan	2011	dry	8.23	10.00	2.67	1.8	0.297	0.025	0.063			
		normal	8.25	8.30	2.45	1.8	0.149	0.028	0.057			
		wet	8.24	6.83	2.48	1.4	0.074	0.033	0.057			
	2012	dry	8.29	9.37	2.61	1.3	0.270	0.026	0.062	5	683	1.40
		normal	8.31	8.46	2.36	2.3	0.119	0.027	0.063	5	665	1.76
		wet	8.26	6.65	2.05	1.6	0.034	0.026	0.076	5	665	1.52
	2013	dry	8.30	9.91	2.41	2.4	0.242	0.028	0.052	5	636	1.78
		normal	8.28	7.73	2.37	1.5	0.262	0.026	0.056	6	636	2.01
		wet	8.29	6.18	2.37	2.0	0.119	0.026	0.061	5	630	2.09

Figure 4.5.1-2 Sketch map of conventional monitoring cross section of Han River

(Xiangyang section)

原文	English
付家寨断面	Fujiazhai cross section
仙人渡断面	Xianrendu cross section
白家湾断面	Baijiawan cross section
钱营断面	Qianying cross section
余家湖断面	Yujiahu cross section

According to water quality monitoring dataof recent years, generally speaking, water quality of Xiangyang section of Han River is mainly of organic pollution and water quality in Yujiahu in the downstream is apparently worse than that of Baijiawan in the upstream, indicating the impact of city sewage discharge on river water quality.

2) Yicheng city conventional water quality monitoring

According to current pollution source survey, more than 90% of industrially and agriculturally discharged pollutants of Yicheng city all end up into Han River and Man River via different channels. See Table 4.5.1-8 for details.

Table 4.5.1-8 Pollutant river inflow data

Year	Project	Waste water discharge volume (ten thousand ton/ year)	Waste water discharged into river (ten thousand ton/ year)	AN (ton/year)	COD (ton/year)
2010	Industrial	1365.14	1228.63	1224.72	1850.47
	Domestic	1097.92	988.13	384.27	3293.76
2011	Industrial	1512.37	1361.13	1176.29	1691.06
	Domestic	1103.03	992.73	386.06	3309.09
2012	Industrial	1696.32	1526.69	432.64	1607.83
	Domestic	1402.33	1262.09	664.86	5144.38

Given pollutant discharge situation of the pollution sources and water quality situation of water bodies, conventional water quality monitoring cross sections are set in Han River and Man River. See Table 4.5.1-8 for water quality monitoring results of Han River and Man River from 2011 to 2013. See Table 4.5.1-9 to 11 for water quality monitoring results from conventional monitoring cross sections of Han River and Man River in wet, normal and dry flow seasons of 2013.

Table 4.5.1-9 Han River and Man River monitoring result statistics

Unit: mg/L (PH value excluded)

Water area	Year	PH	BOD_5	NH_3--N	Volatile penol	As	TP	Cr^{6+}	CODmn	Conductivity us/cm	DO
Han River	2010	8.17	2.4	1.015	0.001	0.004	0.067	0.002	3.42	22.99	11.4
	2011	8.16	1.0	0.085	0.001	0.004	0.038	0.002	2.65	30.16	8.6
	2012	8.01	1.0	0.376	0.001	0.004	0.039	0.002	1.60	28	8.15
Man River	2010	8.19	3.2	1.177	0.011	0.004	0.184	0.010	6.44	29.94	11.1
	2011	8.07	2.2	0.410	0.001	0.004	0.269	0.002	4.23	33.74	7.8
	2012	7.94	1.0	0.404	0.001	0.004	0.039	0.002	1.60	28	8.15

Figure 4.5.1-3 Sketch map of surface water monitoring cross section

原文	English
雅口航运枢纽	Yakou shipping hub
朱市断面	Zhushi cross section

宜城取水口断面	Yicheng intake cross section
孔湾断面	Kongwan cross section
洪山头断面	Hongshantou cross section

Table 4.5.1-10 Monitoring result statistics of Yicheng section of Han River main stream

Unit: mg/L (PH value excluded)

Monitoring item	Han River cross section						Type II water quality standard
	Yicheng intake cross section			Hongshantou cross section			
	April	July	December	April	July	December	
Water temperature (°C)	10	24	10	14	26	14	/
pH	6~9	6~9	6~9	6~9	6~9	6~9	6~9
DO	10.57	7.1	9.63	11.44	7.57	11.65	≥6
CODmn	1.59	2.64	1.86	1.96	2.91	2.45	≤4
BOD_5	1.92	1	1.38	2.72	1.53	2.33	≤3
AN	0.05	0.07	0.08	0.34	0.19	0.38	≤0.5
Volatile penol	0.001	0.001	0.001	0.001	0.001	0.001	≤0.002
Cyanide	0.002	0.002	0.002	0.002	0.002	0.002	≤0.05
As	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	≤0.05
TM	0.000025	0.000025	0.000025	0.000025	0.000025	0.000037	≤0.00005
Cr 6+	0.002	0.002	0.002	0.002	0.003	0.002	≤0.05
Pb	0.01	0.01	0.01	0.01	0.01	0.01	≤0.01
Cd	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	≤0.005
Oils	0.023	0.032	0.023	0.034	0.035	0.034	≤0.05
TP	0.015	0.008	0.04	0.044	0.082	0.097	≤0.1
Sulfide	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	≤0.1

Table 4.5.1-10 (continued)

Monitoring item	Han River cross section						Type II water quality standard
	Yicheng intake cross section			Hongshantou cross section			
	April	July	December	April	July	December	
LAS	0.025	0.025	0.025	0.025	0.025	0.025	≤0.2
Fluoride	0.196	0.196	0.196	0.222	0.225	0.269	≤1.0
TN	1.26	1.74	1.17	1.64	1.83	1.83	
Zn	0.025	0.025	0.025	0.025	0.025	0.025	≤1.0
Cu	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	≤1.0
Fecal Coliform (number per	630	700	700	780	860	860	≤2000

Monitoring item	Han River cross section						Type II water quality standard
	Yicheng intake cross section			Hongshantou cross section			
	April	July	December	April	July	December	
liter)							
Se	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	≤0.1
COD	5	5	5	5	5	5	≤15

Table 4.5.1-11 Monitoring result statistics of tributary Man River

Unit: mg/L (PH value excluded)

Monitoring item	Tributary cross section						Type III water quality standard
	Zhushi cross section			Kongwan cross section			
	April	July	December	April	July	December	
Water temperature (°C)	12	27	6	12	27	6	/
pH	6~9	6~9	6~9	6~9	6~9	6~9	6~9
DO	10.61	8.22	10.12	10.87	8.58	9.82	≥5
CODmn	1.7	2.64	1.51	1.68	2.73	4.46	≤6
BOD_5	2.74	1	3.08	2.2	1	1	≤4
AN	0.11	0.102	0.046	0.254	0.106	0.380	≤1.0
Volatile penol	0.001	0.001	0.001	0.001	0.001	0.001	≤0.005
Cyanide	0.002	0.002	0.002	0.002	0.002	0.002	≤0.2
As	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	≤0.05
TM	0.000025	0.00006	0.000025	0.000025	0.000025	0.000025	≤0.0001
Cr 6+	0.016	0.004	0.008	0.046	0.007	0.013	≤0.05
Pb	0.005	0.005	0.005	0.005	0.005	0.005	≤0.05
Cd	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	≤0.005
Oils	0.037	0.035	0.023	0.034	0.034	0.023	≤0.05
TP	0.024	0.036	0.039	0.018	0.024	0.029	≤0.2
Sulfide	/	/	/	/	/	/	≤0.2
LAS	0.243	0.174	0.185	0.210	0.383	0.220	≤0.2
Fluoride	0.056	0.056	0.086	0.238	0.109	0.175	≤1.0
TN	/	/	/	/	/	/	
Zn	0.025	0.025	0.025	0.025	0.025	0.025	≤1.0
Cu	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	≤1.0
Fecal Coliform (number per liter)	/	/	/	/	/	/	≤10000
CODcr	20.0	20.9	29.5	24.0	25.8	35.7	≤20

According to *Surface Water Environmental Quality Standard* (GB3838-2002), Han River is evaluated following Type II surface water standard, and Man River is evaluated following Type III surface water standard. Results show Guoan cross section of Han River

(Yicheng section) as its evaluating factor reaches Class II standards of *Surface Water Environmental Quality Standard* (GB3838-2002); Man River (Yicheng section) cross section has relatively serious pollution and main pollution factors of various pollutants are CODmn, TP and AN. Although water quality has been improved year by year, it cannot stably reach Class III standards of *Surface Water Environmental Quality Standard* (GB3838-2002).

b) Current monitoring result analysis

1) Current situation monitoring of Han River water quality

In August 2013 and December 2014, our company entrusted Shenzhen Centre Testing International Co., Ltd. to conduct two monitoring of current water quality situations in four cross sections of upstream, dam site and downstream of Han River main stream.

Monitoring cross sections: four water quality monitoring cross sections of the Han River Yakou shipping hub project area are situated in 500m downstream of Cuijiaying junction dam (Yakou reservoir end), 200m downstream of Yicheng Han River bridge (middle of Yakou reservoir), Yakou dam site, and 5000m downstream of Yakou dam. See Figure 4.5.1-4 for each monitoring cross section.

Each cross section has three sampling perpendiculars on left, center and right, with a sampling point set 0.5m beneath water surface, and a water sample mixing the three samples is selected from each monitoring cross section.

Monitoring item: altogether 23 namely pH value, SS, DO, COD, BOD_5, CODmn, volatile penol, AN, TP, TN, Pb, As, Cd, Cu, Zn, Hg, Cr 6+, sulfide , Cyanide, fluoride , petroleum, fecal coliform and LAS, flow velocity and volume are also synchronously monitored.

Monitoring timing: main stream in August 2013 and December 2014.

Monitoring frequency: two-time monitoring, each time for three days.

Monitoring result: see Table 4.5.1-12 to 13. Han River of the Project area is of Type II water functional area.

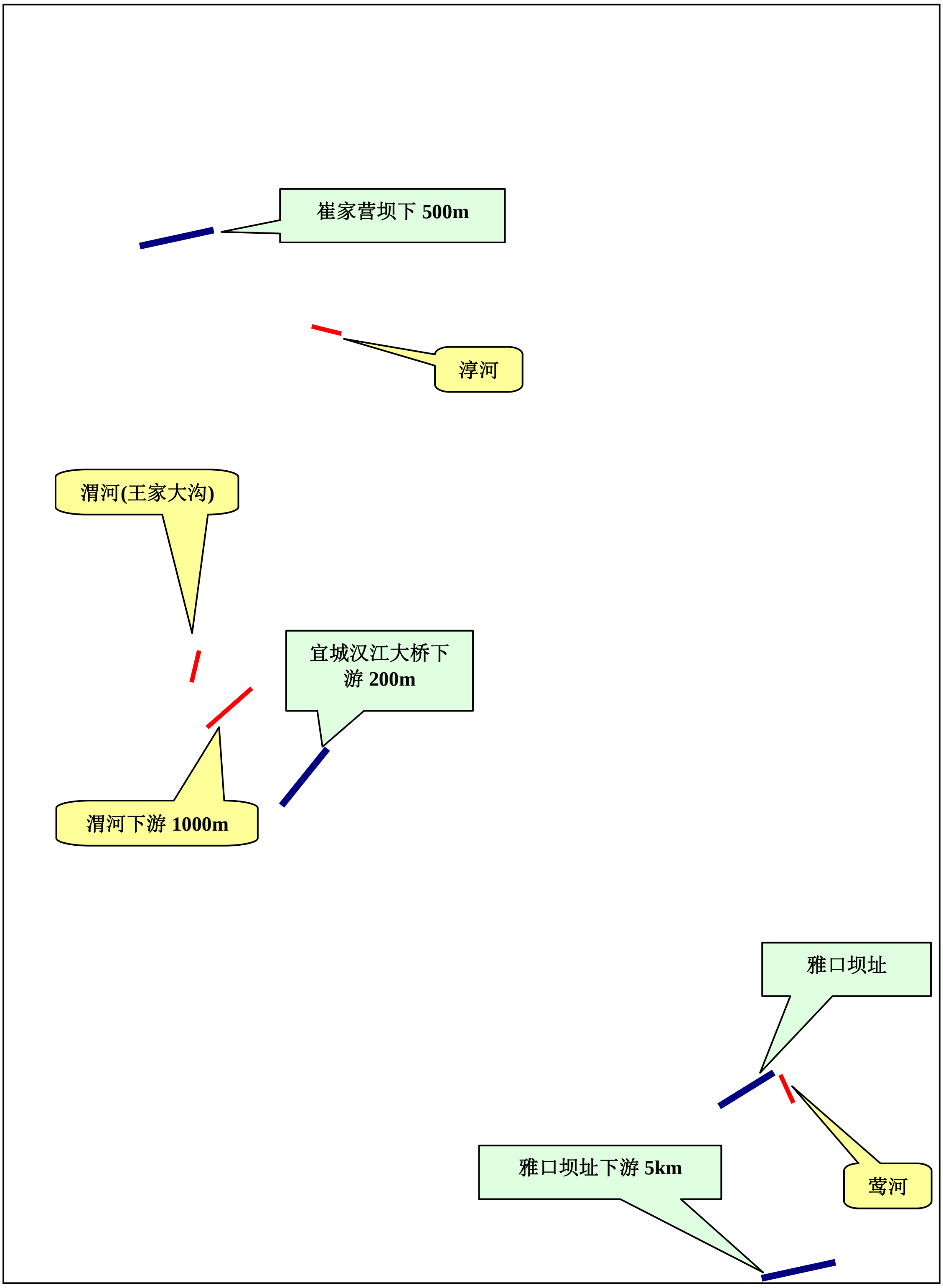


Figure 4.5.1-4 Sketch map of current-situation surface water monitoring cross section of tributary and main stream of Han River

原文	English
图例	Legend
区县	District/county

乡镇街道	Village and township road
坝址	Dam site
高速公路	Highway
国道	National highway
铁路	Railway
河流水域	River water area
淹没范围	Inundation area
崔家营坝址	Cuijiaying dam site
崔家营坝下 500m	500m downstream of Cuijiaying dam
淳河	Chun River
渭河 (王家大沟)	Wei River (Wangjiada ditch)
宜城汉江大桥下游 200m	200m downstream of Yicheng Han River bridge
渭河下游 1000m	1000m downstream of Wei River
雅口坝址	Yakou dam site,
莺河	Ying River
雅口坝址下游 5km	5000m downstream of Yakou dam

Table 4.5.1-12 Water quality monitoring of main stream cross section of August 2013

Unit: mg/L (temperature, pH and flora excluded)

Serial No.	Monitoring cross section	Han River cross section												Type II water quality standard
		500m downstream of Cuijiaying junction			200m downstream of Yicheng Han River bridge			Yakou dam site			5000m downstream of Yakou dam			
	Date	8.12	8.13	8.14	8.12	8.13	8.14	8.12	8.13	8.14	8.12	8.13	8.14	
1	pH	7.75	7.83	7.78	7.82	7.72	7.76	7.65	7.69	7.77	7.78	7.81	7.84	6~9
2	SS	14	18	14	18	25	22	23	24	25	13	14	12	\
3	Do	**3.12**	**3.14**	**3.07**	**3.11**	**3.1**	**3.09**	**3.09**	**3.07**	**3.11**	**3.36**	**3.24**	**3.19**	≥6
4	COD	5.6	5L	5L	5L	5L	5L	5.67	5.12	5L	7.77	7.47	7.12	≤15
5	BOD_5	1.5	0.8	0.5L	1.2	0.9	0.9	1.4	1.2	0.9	1.8	1.7	0.9	≤3
6	CODmn	2.6	2.6	2.7	2.6	2.6	2.7	2.6	2.6	2.7	2.2	2.3	2.4	≤4
7	Volatile penol	0.0003L	0.0003L	0.0003L	0.0003L	0.0003L	0.0003L	0.0003L	0.0003L	0.0003L	0.0003L	0.0003L	0.0003L	≤0.002
8	AN	0.025L	0.025L	0.025L	0.026	0.03	0.03	0.045	0.053	0.042	0.032	0.042	0.042	≤0.5
9	TP	0.08	0.08	0.06	0.06	0.08	0.05	0.06	0.07	0.04	0.07	0.06	0.05	≤0.1(lake, reservoir 0.025)
10	TN	**1.47**	**1.32**	**1.49**	**1.32**	**1.25**	**1.3**	**1.63**	**1.64**	**1.71**	**1.74**	**1.36**	**1.4**	≤0.5
11	Pb	0.00016	0.00012	0.00008	0.0001	0.00012	0.00017	0.00007L	0.00007L	0.00007L	0.00007L	0.00007L	0.00007L	≤0.01
12	As	0.0023	0.00234	0.00236	0.00232	0.00238	0.0023	0.00267	0.00259	0.0026	0.00251	0.00259	0.00254	≤0.05
13	Cd	0.00006L	0.00006L	0.00006L	0.00006L	0.00006L	0.00006L	0.00006L	0.00006L	0.00006L	0.00006L	0.00006L	0.00006L	≤0.005
14	Cu	0.009L	0.009L	0.009L	0.009L	0.009L	0.009L	0.009L	0.009L	0.009L	0.009L	0.009L	0.009L	≤1.0
15	Zn	0.001L	0.001L	0.001L	0.001L	0.001L	0.001L	0.001L	0.001L	0.001L	0.001L	0.001L	0.001L	≤1.0
16	Hg	0.00005	**0.00007**	0.00005	0.00005	0.00005	0.00002L	**0.00008**	0.00005	0.00002L	0.00002L	0.00002L	0.00002L	≤0.00005
17	Cr 6+	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L	≤0.05
18	Sulfide	0.02L	0.02L	0.02L	0.02L	0.02L	0.02L	0.02L	0.02L	0.02L	0.02L	0.02L	0.02L	≤0.1
19	Cyanide	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L	≤0.05
20	Fluoride	0.17	0.19	0.19	0.2	0.2	0.17	0.22	0.22	0.21	0.21	0.21	0.21	≤1.0
21	Petroleum	0.01L	0.01L	0.01L	0.01L	0.01L	0.01L	0.01L	0.01L	0.01L	0.01L	0.01L	0.01L	≤0.05

22	Fecal Coliform	230	130	230	130	130	230	130	80	130	80	80	130	≤2000
23	LAS	0.05L	0.05L	0.05L	0.05L	0.05L	0.05L	0.05L	0.05L	0.05L	0.05L	0.05L	0.05L	≤0.2

Table 4.5.1-13 Water quality monitoring of main stream cross section of December 2014

Unit: mg/L (temperature, pH and flora excluded)

Serial No.	Monitoring cross section	Han River cross section												Type II water quality standard
		500m downstream of Cuijiaying junction			200m downstream of Yicheng Han River bridge			Yakou dam site			5000m downstream of Yakou dam			
	Date	12.15	12.16	12.17	12.15	12.16	12.17	12.15	12.16	12.17	12.15	12.16	12.17	
1	pH	7.96	7.9	7.84	8.03	8.12	8.06	7.84	7.79	7.81	7.71	7.63	7.6	6~9
2	SS	12	14	10	16	16	10	16	15	11	16	16	16	\
3	Do	9.73	9.7	9.73	10.8	10.6	10.6	9.65	9.59	9.62	9.78	9.8	9.74	≥6
4	COD	12.1	11.1	11.8	13.9	12.3	11.3	12.2	11.7	14.3	14.6	14.6	14.2	≤15
5	BOD_5	2.5	2.4	2.5	2.6	2.7	2.4	2.7	2.6	2.7	2.7	2.5	2.3	≤3
6	CODmn	1.58	1.82	1.75	1.89	1.68	1.66	1.66	1.71	1.61	1.79	1.9	1.8	≤4
7	Volatile penol	0.0003L	0.0003L	0.0003L	0.0003L	0.0003L	0.0003L	0.0003L	0.0003L	0.0003L	0.0003L	0.0003L	0.0003L	≤0.002
8	AN	0.12	0.1	0.13	0.1	0.05	0.07	0.13	0.12	0.11	0.07	0.06	0.06	≤0.5
9	TP	0.07	0.06	0.07	0.07	0.06	0.07	0.07	0.05	0.05	0.06	0.06	0.06	≤0.1(lake, reservoir 0.025)
10	TN	**1.63**	**1.64**	**1.78**	**1.59**	**1.81**	**1.58**	**1.96**	**2.04**	**1.91**	**1.88**	**1.86**	**1.85**	≤0.5
11	Pb	0.00054	0.00063	0.00032	0.00047	0.00036	0.00051	0.0007	0.00071	0.00044	0.00057	0.00032	0.00031	≤0.01
12	As	0.00236	0.0034	0.00335	0.00405	0.0042	0.00414	0.00361	0.00373	0.00366	0.00364	0.00352	0.00349	≤0.05
13	Cd	0.00455	0.00038	0.00014	0.00043	0.00037	0.00107	0.00258	0.00027	0.00068	0.00051	0.00131	0.0029	≤0.005
14	Cu	0.009L	0.009L	0.009L	0.009L	0.009L	0.009L	0.009L	0.009L	0.009L	0.009L	0.009L	0.009L	≤1.0
15	Zn	0.002	0.001L	0.001L	0.001L	0.001L	0.001L	0.001L	0.001L	0.001L	0.001L	0.001L	0.001L	≤1.0
16	Hg	0.00003	0.00003	0.00002L	0.00002L	**0.00009**	0.00002L	0.00002L	0.00002L	0.00002L	**0.00006**	0.00002L	0.00002L	≤0.00005
17	Cr 6+	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L	≤0.05
18	Sulfide	0.02L	0.02L	0.02L	0.02L	0.02L	0.02L	0.02L	0.02L	0.02L	0.02L	0.02L	0.02L	≤0.1
19	Cyanide	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L	≤0.05

20	Fluoride	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	≤1.0
21	Petroleum	0.01L	0.01L	0.01L	0.01L	0.01L	0.01L	0.01L	0.01L	0.01L	0.01L	0.01L	0.01L	≤0.05
22	Fecal Coliform	33	23	27	23	22	27	33	49	27	33	49	33	≤2000
23	LAS	0.05L	0.05L	0.05L	0.05L	0.05L	0.05L	0.05L	0.05L	0.05L	0.05L	0.05L	0.05L	≤0.2

According to Table 4.5.1-12 to 13, among the four cross sections of Han River from Cuijiaying to Yakou dam downstream implementing Class II standards of *Surface Water Environmental Quality Standard* (GB3838-2002), with the exceptions of DO(Type IV type), TN(Type IV or V) and Hg(Type III) from August 2013, and TN(Type IV or V) and Hg(Type III) from December 2014, the remaining 20 monitoring factors are all in line with Type II standard, with basically no water temperature differences between various monitoring cross sections. Generally speaking, current water quality situation of the project assessment area is quite good. DO exceeding standard is mainly because of air temperature being relatively high in August and is related to oxygen dissolved as water body and air contacts, as well as oxygen dissolved by algae growth in the water; TN exceeding standard is related to domestic sewage from villages and townships along the river directly discharged into water body only after simple treatment and regional agricultural diffused pollution.

Mercury detected in some cross sections of current situations (500m downstream of Cuijiaying junction dam and Yakou dam site in August 2013; 200m downstream of Yicheng Han River bridge and 5000m downstream of Yakou dam in December 2014) exceeded Type II standard. According to regional pollution source survey material, there is no enterprise involving mercury in the surroundings of the evaluation section, and no industrial pollution incident occurred in the upstream area during the same period. Therefore, reason of exceeding standard might be due to lab testing analysis error. Given this situation, in June 2015 our company entrusted monitoring company to conduct an additional monitoring of the previously four cross sections (500m downstream of Cuijiaying junction dam, 200m downstream of Yicheng Han River bridge, Yakou dam site and 5000m downstream of Yakou dam) and two additional monitoring cross sections of Wangji county intake and 200m downstream of Wangjiada ditch. See 4.5.1-14 for monitoring result. Total mercury of all cross sections are in line with Class II standards of *Surface Water Environmental Quality Standard* (GB3838-2002). In October 2015, an another additional cross section on Han River was added, being 1000m downstream of Wei River (Wangjiada ditch). The cross section is within Yakou reservoir, situated downstream of Wangjiada ditch, the main pollutant discharge outlet of Yakou reservoir area, and its monitoring result can represent the water quality situation of the evaluation section. See Table 4.5.1-16 for monitoring result, with total mercury meeting Type II standard. The abovementioned two additional monitoring selected June (flood season) and October (normal season) respectively, and are in line with the current monitoring timing of August (flood season) and December (dry flow season), so the monitoring timings are representational.

Table 4.5.1-14 Additional monitoring result of surface water

Unit: mg/L

Inspection date	Inspection item	Result					
		500m downstream of Cuijiaying junction dam	Wangji county intake cross section	200m downstream of Wangjiada ditch	200m downstream of Yicheng Han River bridge	Yakou dam site	5000m downstream of Yakou dam
June 7	Hg	ND	ND	0.00003	ND	ND	0.00002
June 8	Hg	ND	ND	0.00002	ND	ND	0.00002
June 9	Hg	ND	ND	0.00002	ND	ND	ND

Note: ND=not detected

Yearly total mercury monitoring data of Xiangyang section of Han River from 2011 to 2014 by Xiangyang Environmental Monitoring Station is also collected, among which Qianying cross section and Yujiahu cross section are close to the current monitoring cross section 500m downstream of Cuijiaying dam (respectively situated in 1km upstream and 3km downstream of Cuijiaying dam), Guoan cross section is close to the current monitoring cross section 5km downstream of Yakou dam (situated in 10km downstream of Yakou dam). See Table 4.5.1-15 for monitoring result, with total mercury of all cross sections meeting Class II standards of *Surface Water Environmental Quality Standard* (GB3838-2002).

Table 4.5.1-15 2011-2014 Total mercury monitoring data of Xiangyang section of Han River main stream

Unit: mg/L

Monitoring cross section	Year	Total mercury		
		Dry	Normal	Wet
Fujiazhai	2011	not detected	not detected	not detected
	2012	not detected	not detected	not detected
	2013	not detected	not detected	not detected
	2014	not detected	not detected	not detected
Xianrendu	2011	not detected	not detected	not detected
	2012	not detected	not detected	not detected
	2013	not detected	not detected	not detected
	2014	not detected	not detected	not detected
Baijiawan	2011	not detected	not detected	not detected
	2012	not detected	not detected	not detected
	2013	not detected	not detected	not detected
	2014	not detected	not detected	not detected
Qianying	2011	not detected	not detected	not detected
	2012	not detected	not detected	not detected
	2013	not detected	not detected	not detected
	2014	not detected	not detected	not detected
Yujiahu	2011	not detected	not detected	not detected
	2012	not detected	not detected	not detected
	2013	not detected	not detected	not detected
	2014	not detected	not detected	not detected
Guoan	2011	not detected	not detected	not detected
	2012	not detected	not detected	not detected
	2013	not detected	not detected	not detected
	2014	not detected	not detected	not detected

Note: monitoring data source is Xiangyang Municipal Environmental Monitoring station.

See Table 4.5.1-16 for analysis of total mercury monitoring data of the evaluation section of Han River according to current situation monitoring, additional monitoring, and basin conventional monitoring data of many years. Given that there is no inflow of industrial pollution source involving mercury in the evaluation river section, and results of additional monitoring is in line with that of conventional monitoring all factually reflecting the total mercury situation of the evaluation river section in terms of water quality, result demonstrates that total mercury exceeding Class II standards in the current situation monitoring may be due to lab testing analysis error and total mercury of the evaluation river section is in line with Class II standards of *Surface Water Environmental Quality Standard* (GB3838-2002).

Table 4.5.1-16 Total mercury monitoring data analysis of Han River evaluation section

Monitoring time	Cross section exceeding standard	Upstream monitoring situation of the same period	Distance between upstream monitoring cross section and cross section exceeding standard, pollution source distribution situation	Additional monitoring situation	Basin conventional monitoring situation for years
August 2013	500m downstream of Cuijiaying junction dam	Not detected from Qianying cross section	1.5km, no industrial pollution source discharged in between	Not detected in June 2015	Not detected in many years
	Yakou dam site	Not exceeding standard from cross section 200m downstream of Yicheng Han River bridge	15km, no industrial pollution source discharged in between	Not detected in June 2015	Not detected in many years
December 2014	200m downstream of Yicheng Han River bridge	Not exceeding standard from cross section 500m downstream of Cuijiaying junction dam	37km, inflows of Wangjiada ditch in the region, without mercury pollution source, involving industries mainly of chemical materials and chemicals manufacturing, pollutant being COD and AN	Not detected in June 2015	Not detected in many years
	5000m downstream of Yakou dam	Not exceeding standard from cross section of Yakou dam site	5km, inflows of Yidaoda ditch in the region, without mercury pollution source, involving industries mainly of chemical materials and chemicals manufacturing, pollutant being COD and AN	Not detected in June 2015	Not detected in many years

2) Current monitoring of water quality of the evaluated river section

(1) Water quality monitoring overview

To further understand water quality situation of the river section where the project is located, in October 2015 the same monitoring agency was entrusted to conduct current situation monitoring of tributaries on Wei River (Wangjiada ditch) of the reservoir area, Chun River and Ying River downstream of the dam. In addition, to verify the impact of

Wangjiada ditch on Han River water quality, a cross section was set for synchronous monitoring in Han River which is 1000m downstream of Wangjiada ditch inlet. See Figure 4.5.1-4 for each monitoring cross section; see Table 4.5.1-16 for monitoring result.

(2) Representational analysis of water quality monitoring material

On the basis of survey research result and comprehensive analysis of relevant data, location selection of tributary monitoring cross sections of Wei River (Wangjiada ditch), Chun River and Ying River downstream of the dam all have, avoiding dead water area and backwater area, smooth and straight river section, solid riverbed, stable water flow, and no torrent shoal, among which sampling point is situated at a location of relatively straight channel, stable water flow and no upstream sewage inflow. Sampling locations are all 1/4 to 1/2 beneath water surface to represent average concentration water sampling collection. Considering the character, charge range and monitoring requirement of the monitoring subjects, appropriate sampling and monitoring method and technology are selected. Monitoring result can basically reflect, in a relatively authentic and comprehensive manner, regional water quality and spatial distribution law of pollutant. However, given that during monitoring sampling of Wei River (Wangjiada ditch), industrial park upstream was closed, its water quality result only reflect background situation, and sewage volume and pollutant concentration within the discharge standard need to be added for prediction analysis.

Table 4.5.1-16 Water quality monitoring data analysis of main tributaries of the river section evaluated of October 2015

Unit: mg/L (temperature, pH and flora excluded)

Serial No.	Monitoring cross section	Han River tributary cross section						Han River cross section		Type II water quality standard
		Chun River cross section		Wei River(Wangjiada ditch) cross section		Ying River cross section		cross section 1000m downstream of Wei River(Wangjiada ditch)		
	Date	10.28	10.29	10.28	10.29	10.28	10.29	10.28	10.29	
1	pH	7.17	7.21	7.12	7.19	7.14	7.2	7.2	7.32	6~9
2	SS	14	13	17	16	15	15	13	12	\
3	Do	8.72	8.57	8.38	8.24	8.43	8.01	9.12	9.12	≥6
4	COD	7	12	12	11	12	12	10	10	≤15
5	BOD_5	2.5	2.1	2.3	1.9	2.2	2.2	2.8	2.3	≤3
6	CODmn	2.9	2.6	3.4	2.3	3.2	2.8	2.7	2.1	≤4
7	Volatile penol	0.0012	0.0002	0.0006	0.0006	0.0004	0.0008	0.0009	0.0004	≤0.002
8	AN	0.315	0.398	0.389	0.411	0.16	0.071	0.051	0.056	≤0.5
9	TP	0.05	0.06	0.06	0.06	0.05	0.04	0.03	0.03	≤0.1((lake, reservoir 0.025)
10	TN	**1.34**	**1.31**	**1.46**	**1.25**	**1.21**	**1.12**	**1.02**	**1.03**	≤0.5
11	Pb	ND	ND	ND	ND	ND	ND	ND	ND	≤0.01
12	As	ND	ND	ND	ND	ND	ND	ND	ND	≤0.05
13	Cd	0.0002	0.0005	0.0001	0.0008	0.0001	0.0003	0.0001	0.0002	≤0.005
14	Cu	ND	ND	ND	ND	ND	ND	ND	ND	≤1.0
15	Zn	ND	ND	ND	ND	ND	ND	ND	ND	≤1.0
16	Hg	ND	ND	ND	ND	ND	ND	ND	ND	≤0.00005
17	Cr 6+	ND	ND	ND	ND	ND	ND	ND	ND	≤0.05
18	Sulfide	ND	ND	0.005	0.005	0.005	ND	0.006	ND	≤0.1
19	Cyanide	ND	ND	ND	ND	ND	ND	ND	ND	≤0.05
20	Fluoride	0.2	0.26	0.16	0.31	0.17	0.31	0.19	0.21	≤1.0
21	Petroleum	0.04	0.04	0.05	0.05	0.03	ND	0.03	ND	≤0.05
22	Fecal Coliform	1.3×10^{3}	940	1.1×10^{3}	790	940	700	490	330	≤2000
23	LAS	ND	ND	ND	ND	ND	ND	ND	ND	≤0.2

Note: 1.ND=not dected; 2. GB 3838-2002 standard does not include limitation on SS.

(3) Tributary water quality monitoring result analysis

According to Table 4.5.1-14, current water quality is quite good in the project assessment area. For water quality of the three tributaries, TN excluded, the 22 remaining monitoring factors are all in line with Type II standard. TN exceeding standard is related to regional agricultural diffused pollution and relatively high background concentration. According to survey, Xiaohe county industrial zone upstream of Wangjiada ditch is currently carrying out a sewage treatment reform project, with six companies in the industrial zone being closed, therefore water quality is not affected by industrial sewage discharge. Except for TN, other water quality indicators of the cross section 1000m downstream of Wangjiada ditch in Han River are all in line with Class III standards of *Surface Water Environmental Quality Standard* (GB3838-2002).

4.5.1.3 Groundwater environmental quality

Groundwater within the area is mainly pore phreatic water and pore confined water in loose accumulated strata of the Quaternary system, with a comparative water-bearing stratum of solid medium-fine sand and sand gravel, mainly receiving recharges from atmospheric precipitation and mountain area groundwater of Han River trough, enjoying abundant water quantity. Strata of the Tertiary system have (partial) confined water, generally short of groundwater in bed rock, discharging into piedmont and plain areas after receiving recharges from atmospheric precipitation and river.

Groundwater of the dam site area is pore phreatic water, and confined water within loose sandstone and sand gravel from the Quaternary system. Groundwater water within base rock is generally lacking, with confined waterhead being 0.7 to 3m in loose sandstone and sand gravel and unit soakage generally being 0.1 to 0.36L/min·m·m, possessing relatively high water permeability. Water permeability is second in medium-coarse sandstone, relatively weak in sandstone and sand gravel with good diagenesis, and worst in clay rock and marlstone. Pore phreatic water from the Quaternary system is within find sand and sand gravel of riverbed, flood plain and Grade I terrace, with the groundwater level of Grade I terrace slightly exceeding the undersurface of the overlying cohesive soil and slightly resembling confined water. Phreatic water is mainly recharged by surface water and atmospheric precipitation, and is discharged into Han River. According to water quality analysis result of nearby groundwater and surface water, chemical types of groundwater and surface water are generally HCO_3-Ca and HCO_3-Ca•Mg, with a PH value from 6.4 to 6.6. Surface water and groundwater is slightly corrosive to concrete.

In August 2013, our company entrusted Shenzhen Centre Testing International Co., Ltd. to conduct a two-day consecutive monitoring of current water quality situation.

Monitoring points include one groundwater monitoring point on each bank of the Han River Yakou shipping hub project construction area, three groundwater monitoring points along each bank of the reservoir area, which is altogether eight groundwater monitoring points, all using dug wells. Interval between each point is at least over 5km.

Monitoring indicators include altogether 19 items of such as pH, total hardness, AN, nitrate, sulphate, volatile penol, chloridate , cyanide, CODmn, Cd, Pb, Hg, As, Cr 6+, Cu and Fe.

Monitoring result: see Table 4.5.1-15.

Table 4.5.1-15 Groundwater environment monitoring result (August 12)

Unit: mg/L except for separate annotation

Serial No.	Monitoring item	Class III standards value	Sampling location							
			Nanzhou village group six	Sengzhuang	Yakou village group five	Yakou village group seven	Heluo village group five	Heluo village group ten	Maocao village group two	Maocao village group six
1	pH	6.5~8.5	7.54	7.5	7.4	7.31	7.37	7.26	7.31	7.52
2	Total hardness	≤450	**489**	314	346	**635**	403	**516**	**479**	403
3	An	≤0.2	**0.62**	0.04	0.05	0.04	**0.29**	**0.27**	0.13	0.05
4	Nitrate	≤20	0.53	4.32	13.7	32.8	0.33	8.83	12.9	7.26
5	Sulphate	≤250	23.1	47.2	37.6	149	42.9	202	125	52
6	Volatile penol	≤0.002	0.002L	0.002L	0.002L	0.002L	0.002L	0.002L	0.002L	0.002L
7	Chloride	≤250	53.3	16	17.8	53.3	93.4	125	124	48.3
8	Cyanide	≤0.05	0.002L	0.002L	0.002L	0.002L	0.002L	0.002L	0.002L	0.002L
9	CODmn	≤3.0	1.33	0.28	0.32	0.59	0.8	1.32	0.77	0.44
10	Cd	≤0.01	0.00006L	0.00006L	0.00006L	0.00006L	0.00011	0.00029	0.00016	0.00006L
11	Pb	≤0.05	0.00007L	0.00012	0.0001	0.00017	0.00014	0.00017	0.00019	0.00007L
12	Hg	≤0.001	0.0004	0.0002	0.0002	0.0001	0.0002	0.0002	0.0001	0.0002
13	As	≤0.05	0.00761	0.00506	0.00259	0.00626	0.00156	0.00179	0.00271	0.00206
14	Cr 6+	≤0.05	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L
15	Cu	≤1.0	0.009L	0.009L	0.009L	0.009L	0.009L	0.009L	0.009L	0.009L
16	Fe	≤0.3	0.0304	0.0045L	0.0045L	0.0045L	0.0045L	0.0045L	0.0045L	0.0045L
17	Mn	≤0.1	**3.11**	0.0087	0.0086	0.0058	0.62	**5.71**	**0.113**	**0.12**
18	TDS	≤1000	494	350	372	688	625	928	757	485
19	Total coliform	≤3	**13**	**240**	**1.3×10^3**	**350**	2L	2L	**9.2×10^3**	**790**

	group									

Note: result with “L” represents non-detection, and its value is the detection limit of the item.

Table 4.5.1-15 Groundwater environment monitoring result (August 14)

Unit: mg/L except for separate annotation

Serial No.	Monitoring item	Class III standards value	Sampling location							
			Nanzhou village group six	Sengzhuang	Yakou village group five	Yakou village group seven	Heluo village group five	Heluo village group ten	Maocao village group two	Maocao village group six
1	pH	6.5~8.5	7.53	7.42	7.32	7.41	7.47	7.24	7.34	7.44
2	Total hardness	≤450	**476**	272	281	**675**	316	**506**	**460**	379
3	An	≤0.2	**0.52**	0.05	0.06	0.05	**0.3**	0.2	0.08	0.07
4	Nitrate	≤20	0.37	4.27	13.8	30	0.33	8.34	11.5	6.27
5	Sulphate	≤250	21.9	47.2	38.6	137	38.9	196	117	47.6
6	Volatile penol	≤0.002	0.002L	0.002L	0.002L	0.002L	0.002L	0.002L	0.002L	0.002L
7	Chloride	≤250	48.9	15.9	18.1	55.7	84.1	121	114	43.8
8	Cyanide	≤0.05	0.002L	0.002L	0.002L	0.002L	0.002L	0.002L	0.002L	0.002L
9	CODmn	≤3.0	1.29	0.36	0.3	0.65	0.8	1.36	0.82	0.46
10	Cd	≤0.01	0.00006	0.00006L	0.00006L	0.00006L	0.0001	0.00028	0.00013	0.00006L
11	Pb	≤0.05	0.00114	0.00013	0.00007L	0.00015	0.00018	0.00011	0.0001	0.00007L
12	Hg	≤0.001	0.0002	0.0001	0.0001	0.0001	0.0002	0.0002	0.0001	0.0002
13	As	≤0.05	0.00788	0.00577	0.00184	0.00637	0.00168	0.00169	0.00213	0.00161
14	Cr 6+	≤0.05	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L	0.004L
15	Cu	≤1.0	0.009L	0.009L	0.009L	0.009L	0.009L	0.009L	0.009L	0.009L
16	Fe	≤0.3	0.0299	0.0045L	0.0045L	0.0045L	0.0045L	0.0045L	0.0045L	0.0045L
17	Mn	≤0.1	**3.31**	**0.0076**	**0.0049**	**0.0045**	**0.744**	**5.08**	**0.096**	**0.15**

18	TDS	≤1000	489	345	372	693	605	929	753	490
19	Total coliform group	≤3	**8**	**350**	**1.1×10^{3}**	**280**	2L	2L	**2.8×10^{3}**	**540**

Note: result with “L” represents non-detection, and its value is the detection limit of the item.

According to monitoring data listed in the table above, with the exceptions of total hardness, AN, MN and total coliform group, all other monitoring factors of regional groundwater are in line with Class III standards of Groundwater Quality Standard (GB/T 14848-1993), indicating good groundwater quality in the reservoir area. Total hardness exceeding standard is related to the large amount of calcium and magnesium dissolved in water, and is generally of geographical reason; manganese exceeding standard is related to relatively high manganese background value in regional soil; AN and total coliform group exceeding standards are related to the burial depth of the well, and the leakage through soil pore of direct discharge of rural domestic sewage without treatment, in particular, total coliform group exceeding standard is affected by excreta from poultry breeding discharged randomly via surface runoff nearby the monitoring point location.

4.5.1.4 Environmental air quality

In August 2013, one point was set on each bank of the construction area of Han River Yakou shipping hub project to conduct atmospheric environmental quality monitoring, with main monitoring items being PM_{10}, NO_2 and SO_2. See Table 4.5.1-16 for monitoring results.

Table 4.5.1-16 Environmental air monitoring result of the project area

Unit: mg/m^3

Monitoring period	SO_2(hourly value)		NO_2(hourly value)	
	Left bank	Right bank	Left bank	Right bank
August 10	0.018~0.021	0.016~0.025	0.021~0.043	0.023~0.036
August 11	0.017~0.023	0.017~0.022	0.026~0.038	0.023~0.044
August 12	0.016~0.020	0.017~0.021	0.023~0.037	0.024~0.044
August 13	0.019~0.021	0.015~0.022	0.027~0.037	0.025~0.036
August 14	0.015~0.020	0.017~0.022	0.025~0.038	0.026~0.045
August 15	0.010~0.022	0.013~0.019	0.022~0.042	0.023~0.051
August 16	0.013~0.016	0.013~0.018	0.024~0.036	0.026~0.049
Class two standard value	0.50		0.12	

Table 4.5.1-17 Monitoring result of environmental air quality of the project area

Unit: mg/m^3

Item	Left bank (Daily mean value)	Right bank (Daily mean value)	Class two standard value
SO_2	0.014~0.020	0.016~0.021	0.15
NO_2	0.025~0.032	0.027~0.035	0.08
PM_{10}	0.059~0.084	0.054~0.085	0.15

The project area is rural area, and according to Xiangyang urban environment functional classification, environmental air quality of the assessment area is Class II. According to the table above, monitoring results of SO_2, NO_2 and PM_{10} of the project area are all in line with Class II standards of *Environmental Air Quality Standard* (GB3095-1996), and the requirements of Class II functional classification.

4.5.1.5 Acoustic environmental quality

In August 2013, Acoustic environmental quality monitoring was conducted in the project area. According to the distribution situation of sensitive receptors of the project, altogether seven monitoring points were set. Monitoring timings are daytime and nighttime. See Table 4.5.1-18 for monitoring results.

Table 4.5.1-18 Monitoring result of current situation of acoustic environmental quality

Unit: dB (A)

Serial No.	Monitoring point location	Main sound source	Monitoring time	Result		
				August 13	August 14	August 15
1	Right bank of dam site	Social and domestic noise	Daytime	52.3	53.4	53
			Nighttime	44.5	44.8	44.7
2	Slag yard	Social and domestic noise	Daytime	51.6	52	52.4
			Nighttime	44.7	44.2	43.9
3	Stock ground	Social and domestic noise	Daytime	51.8	51.9	52.7
			Nighttime	45.2	44.7	46
4	Transport road	Social and domestic noise	Daytime	53.4	52.8	52.8
			Nighttime	45.1	44.6	45.3
5	Yakou village	Social and domestic noise	Daytime	50.6	50.9	51.2
			Nighttime	44.4	43.8	45.3

6	Left bank of dam site	Social and domestic noise	Daytime	52.8	52.2	52.6
			Nighttime	45.3	45.6	46.4
7	Access road	Transport noise	Daytime	53.6	54.2	54.5
			Nighttime	44.7	45.3	46.2

Domestic noise on either side of road to project site implements Type 4a standard of *Acoustic Environmental Quality Standard* (GB3096-2008), and other monitoring points implement Type 2 standard in *Letter of Reply on the Confirmation of EIA Standards for Han River Yakou Shipping Hub Project* (EHH [2014] No. 393). See Table 4.5.1-7 for monitoring results, and all points are in line with Type 4a standard of *Acoustic Environmental Quality Standard* (GB3096-2008) and Type 2 standard.

4.5.1.6 Soil environmental quality

a) Monitoring point setting

Altogether ten soil monitoring points are set, among which eight soil monitoring points are set in the two banks of the reservoir area, namely two in the downstream of Cuijiaying junction dam (inside and outside of river embankment), two in Xiaohe county (inside and outside of river embankment), two in the downstream of Yicheng Han River bridge (inside and outside of river embankment), and two in Yakou village (inside and outside of river embankment); and one soil monitoring point is set in the left and right bank of Yakou project construction area.

b) Monitoring item

Altogether nine items: pH, Pb, Cd, Zn, Mn, Cr^{6+}, Cu, As and Hg.

c) Monitoring period and frequency

In August 2013, soil sampling was collected once for one monitoring.

d) Monitoring method

Monitoring method is in line with *Soil Environmental Monitoring Technical Specification*, and analysis method is according to regulations of *Soil Environmental Quality Standard* (GB15618 ~ 1995).

e) Monitoring result

See Table 4.5.1-19 for monitoring result of current soil quality situation, which indicates that soil in reservoir surroundings are in line with Class II standards of *Soil Environmental Quality Standard* (GB15618 ~ 1995).

Table 4.5.1-19 Monitoring result of current situation of soil of the reservoir area

Unit: mg/kg

Sampling location	Locational relation	Analysis item (mg/Kg)								
		pH	Pb	Cd	Zn	Mn	Cr^{6+}	Cu	As	Hg
Downstream of Cuijiaying junction dam	Inside dyke	8.45	25.8	0.14	76.9	720	0.143	33.1	13.7	0.076
	Outside dyke	7.44	32.7	0.19	77.1	828	0.206	30	13.3	0.024
Xiaohe county	Inside dyke	7.39	26.1	0.05	65.2	773	0.316	31	14.1	0.053
	Outside dyke	7.53	23	0.04	81.6	731	0.207	33.1	13.8	0.016
Downstream of Yicheng Han River bridge	Inside dyke	8.11	25.2	0.23	95.5	737	0.39	41.7	8.8	0.024
	Outside dyke	8.03	19.4	0.24	92.3	691	0.366	32.6	9.1	0.017
Yakou village	Inside dyke	7.92	26	0.19	83.8	743	0.315	29.5	12.2	0.038
	Outside dyke	8.04	26.7	0.26	91.5	830	0.31	32.4	13.8	0.043
Left bank of construction area	Inside dyke	7.75	31.6	0.22	69.4	941	0.287	30.1	17.9	0.01
Right bank of construction area	Outside dyke	7.88	21.2	0.24	89.9	730	0.31	32.8	10.1	0.013
Standard		>7.5	350	0.6	300	-	300	100	25	1.0

4.5.1.7 Bottom mud monitoring

a) Monitoring of current situation of bottom mud

To grasp the current situation of bottom mud heavy metal in Yakou section of the Han River main stream, in December 2014, our company entrusted Shenzhen Centre Testing International Stock Ltd. to conduct a current situation monitoring of bottom mud of Han River main stream.

Monitoring items: nine items of Pb, Hg, As, Cd, Cr, Cu, Zn, OM and sulfide.

Monitoring point: five monitoring cross sections were set in a descending order, with seven monitoring points, namely 500m downstream of Cuijiaying junction dam, 200m downstream of Yicheng Han River bridge, left, center and right of Yakou dam site, 5000m downstream of Yakou dam site, and Yicheng tap water company intake.

Monitoring timing and frequency: Bottom mud sample was taken once in December

2014.

Monitoring analysis method: according to HJ/T 91-2002 Surface Water and Sewage Monitoring Technical Specification and Water and Waste Water Monitoring Analysis Method, bottom mud sample was collected using Peterson sampler, and then stored in sampling bottles for storage and analysis after pre-treatments such as numbering, moisture determination, and air-dry levigation going through nylon sieve.

See Table 4.5.1-20 for monitoring result.

Table 4.5.1-20 Current situation monitoring of bottom mud of Han River main stream

Inspection item	Unit	Evaluation Standard	Monitoring cross section and point						
			500m downstream of Cuijiaying junction dam	200m downstream of Yicheng Han River bridge	Left of Yakou dam site	Within Yakou dam site	Right of Yakou dam site	5000m downstream of Yakou dam	Intake of Yicheng tap water company
Pb	mg/kg	300	17.0	14.5	6.6	13.8	14.9	14.2	14.4
Hg	mg/kg	0.5	0.019	0.019	0.026	0.018	0.016	0.018	0.018
As	mg/kg	25	8.2	9.8	6.2	8.3	9.2	8.6	10.3
Cd	mg/kg	0.6	0.20	0.21	0.10	0.24	0.25	0.19	0.18
Cr	mg/kg	300	55.3	61.6	23.1	50.0	58.9	58.0	56.6
Cu	mg/kg	100	23.8	25.4	8.3	19.4	22.8	24.5	22.1
Zn	mg/kg	250	70.3	71.6	31.0	64.6	68.7	70.6	69.8
OM	g/kg	-	9.09	9.03	8.86	7.88	8.40	7.16	8.28
Sulfide	mg/kg	-	ND	ND	ND	2.3	1.6	ND	ND

Result is evaluation according to *Soil Environmental Quality Standard* (GB15618 ~ 1995). Pollutant evaluation standard is based on type two of national soil standard. Samples were treated with total quantity deposition method for result of this monitoring, and can only represent the content level of pollutant in bottom mud. Result reveals that all monitoring indicators of bottom mud samples from all cross sections are all in line with with Class II standards of *Soil Environmental Quality Standard* (GB15618 ~ 1995), indicating no pollution risk for bottom mud in Han River for the moment.

b) Toxicity test of bottom mud leaching

Considering the possible pollution risk resulting from bottom mud disturbed by riverbed excavation of the dam site during the construction period of Yakou shipping hub project, leachate of bottom mud samples from the three points of left, center and right of the dam site was tested and differentiated according to toxicity monitoring analysis method and taking in account the toxicity differentiation standard values of table one of *Dangerous Waste Material Differentiation Standard-Leaching Toxicity Differentiation* (GB5085.3-2007). See Table 4.5.1-21 for monitoring result. In addition, the maximum discharge concentration standard values of the first type of pollutants of table one of *Sewage Comprehensive Discharge Standard* (GB8978-2002) was also taken into consideration for classification determination of general industrial solid waste.

Table 4.5.1-21 Han River bottom mud leaching toxicity test result

Name of sampling point	Monitoring result (mg/L)							
	pH	Pb	Hg	As	Cd	Cu	Zn	Cr 6+
Left of Yakou dam site	8.02	Not detected	0.0042	0.0008	Not detected	Not detected	Not detected	Not detected
Within Yakou dam site	8.01	Not detected	0.0037	0.0002	Not detected	Not detected	0.017	Not detected
Right of Yakou dam site	7.92	Not detected	0.0029	0.0008	Not detected	Not detected	Not detected	Not detected
GB8978-2002 Maximum discharge concentration allowed	-	1.0	0.05	0.5	0.1	0.5	2.0	0.5

Note: Maximum discharge concentration allowed for total Cu and Zn should be in line with the standard value of Maximum discharge concentration allowed of Type II pollutant of Table 4 of *Sewage Comprehensive Discharge Standard* (GB8978-2002)

According to the monitoring result of leaching test, pollution concentration of various factors of bottom mud leachate of the project river section are far less than the toxicity differentiation standard values of *Dangerous Waste Material Differentiation Standard-Leaching Toxicity Differentiation* (GB5085.3-2007), not belonging to dangerous waste material. No single pollution concentration exceeds the maximum discharge concentration standard value of *Sewage Comprehensive Discharge Standard* (GB8978-2002), and is all within 6 to 9 for pH value, belonging to Type I general industrial solid waste.

4.5.2 Major environmental issues

a) Frequent natural disaster

Flood and drought disasters alternates in the region, in particular given the large proportion of hilly land in the region that is of weak water-retaining ability, and prone to drought in years without sufficiently yearly precipitation, causing decreased agricultural yield. Drought is the most severe natural disasters of the region.

Precipitation has uneven distributions within the year and between years. Flood and drought are relatively frequent. Due to uneven temporary and spatial precipitation distribution, flood and drought happen repeatedly, including eight major flood disasters happening sequentially in 1954, 1964, 1975, 1983, 1996, 1998, 2003 and 2005; and seven major drought disasters happened sequentially in 1966, 1968, 1972, 1978, 1988, 1994 and 2000. In particular in 2000, a drought unseen in a hundred years struck the middle and lower reaches of Han River, causing many sites getting water by constructing dam along Han River, Dongjing River drying up and severe loss due to the drought.

b) Water body pollution upstream of the reservoir

Discharges of urban domestic sewage and some industrial waste water along the line of Han River upstream of the project have polluted the upstream water body and to a certain extent affected water quality of Han River, leaving a relatively high nitrogen content in the water body. Han River water quality is hugely affected and phenomena of pollutant exceeding standards often happen, even to the degree of “water bloom”, because the majority of industrial and domestic sewage of cities in the middle and lower reaches of Han River is discharged into riverway downstream or Han River without treatment, and combined with the large discharge of agricultural diffused pollution. “Water bloom” phenomenon first happened in Han River in the dry flow season (late February to early March) of 1992, and happened again in the same periods in 1998 and 2000, extending its scopes to Shayang-Wuhan river section, which severely affected water supply safety as algae massively reproduced in the water body.

c) Forest ecological function deterioration and soil erosion acceleration

Although Regional forest coverage rate is on the rise, forest coverage rate is still relatively low and population structure is yet to restore, with continued resource quality loss and ecological functional deterioration. Forest category and varieties of trees are not reasonable structurally in the forest, as there is more coniferous forest and young and middle aged forests, and fewer broad-leaved forest, near-mature forest, mature forest and over-mature forest. The number and quality of forests are problematic, severely reducing the ecological functions of forest such as water source conservation, soil conservation and wind sheltering and sand stabilizing. Yakou reservoir area is mainly of a single-type landform of alluvial plain, with crops being the absolute dominating vegetation, and accelerated soil erosion resulting from human activities.

d) Substantial change of fish stock structure and yearly decreases of catch yield

Hydro junction (especially Danjiangkou dam) has caused man-made barrier in the fish survival environment of Han River. In addition, hydrological regime change, water quality pollution, and blind fishing all are attributable to hardly any traces of precious fish species such as *Myxocyprinus asiaticus* and *Luciobrama microcephalus* in the middle and lower reaches of Han River, the basic disappearance of migratory fish species, decrease of the number and scale of spawning grounds of fish with pelagic eggs and the disappearance of spawning ground of "four major domestic fisheses" in the upstream of Cuijiaying dam site, thus affecting biodiversity and genetic diversity of fish species in Han River, substantially changing fish composition, and reducing catch yields year by year.

e) Profound impact of South-to-North Water Transfer on ecological environment in the middle and lower reaches of Han River

Han River is the longest tributary of Yangtze River, and the middle and lower reaches of the Han River is one of the most important areas in terms of socio-economic development in Hubei province. According to statistics, average annual water inflow of Han River is 38 billion m^3, and water diversion volume of the first phase of central route of South-to-North Water Transfer project is 9.5 billion m^3. According to estimation, after central route water diversion, water environmental capacity of the middle and lower reaches of Han River will be reduced by 26%, increasing the difficulty of water pollution prevention and treatment. Water supply and irrigation along the river will also be affected with an increased cost of water resources utilization as average water level will be reduced to 0.29m to 0.51m.

f) Biodiversity index deterioration

The number of terrestrial and aquatic organism is reduced as their habitats are severely damaged and survival conditions are deteriorated. The number of rare and endangered animals and plants are generally on decreasing trends, some species in particular the density of economic animal groups are clearly decreasing. According to census of national key protected wild animal and plant resources in Hubei province from

1997 to 2001, some wild animal have low frequency being spotted, the previously common species such as wolf and fox are clearly decreased, even to the level of rarely seen, the number of frogs and snakes are rapidly decreasing, and the number of bird of prey and wintering birds are gradually decreasing. Meanwhile, the number of some wild protected plants are also few, on the edge of being endangered or even close to extinction.

g) Lack of ship pollution receiving and emergency response facility

The information level of Han River water emergency management is not high. “12395” special rescue line and command network are not established, lacking an well-developed information reporting and transmission system. The number of rescue ship is clearly insufficient, with only 27 emergency rescue ships in Han River and seven emergency rescue ships in reservoir. Meanwhile, the existing emergency rescue ships are functionally deficient. Pollution emergency professional equipment and rebuilding capacity are also lacking.

5 Analysis of Developed Hydropower Projects

As for various junction development projects in the same basin of Han River, impacts of their constructions on regional environment share similarities. Therefore, based on data collected this report selects the actual situations before and after the constructions of Wangfuzhou Hydro-junction and Cuijiaying Hydro-junction for reference, conducts analogy evaluation on environmental impact of junctions constructed, analyzes changes regarding riverway hydrology, water quality and aquatic organism before and after junction construction, and determines the actual impact of junction development on Han River in terms of water environment and aquatic ecology.

5.1 Analogy overview of hydropower development projects

5.1.1 Projects overview

a) Wangfuzhou Hydro-junction

Completed in 1999, Wangfuzhou Hydro-junction, 30 km from Danjiangkou Hydro-junction, is built mainly for power generation, and it also facilitates shipping, irrigation, cultivation and travel. Reservoir has a normal storage level of 86.23 m, a reservoir capacity of 149.5 million m^3, a dead storage level of 85.48 m and a total installed capacity of 10.9 mw, with a ship lock allowing 300t fleet. Wangfuzhou Hydro-junction returns water to the dam of Danjiangkou power station to converge with tail water from Danjiangkou power generation.

The hydro-junction has synchronized operation with Danjiangkou was implemented at the early stage which synchronously increase or decrease output, with a minimum shipping discharge of 200 m^3/s; the abovementioned principle remains as Danjiangkou was heightened and stared to carry out South-to-North Water Transfer. Wangfuzhou reservoir counter-regulates when average discharge of Danjiangkou hydro station approaches or becomes less than navigable discharge.

Construction of Wangfuzhou hydro-junction officially began in February 1995; the main riverbed was closed in December 1998; gate closure and water storage officially began in January 2000; the first two units were put into operation in May 2000 and all four units began to generate power in November of the same year.

b) Cuijiaying Hydro-junction

Situated at 17 km downstream from Xiangyang City, Cuijiaying Hydro-junction controls a basin area of 13.06×104 km^2 and it is 142km downstream from Danjiangkou Hydro-junction, 109km from Wangfuzhou Hydro-junction, and 515km upstream from estuary, with a dam site average discharge of 1,470 m^3/s. It is a project of comprehensive utilization of mainly shipping combined with power generation, promoting shipping through power generation. Reservoir has a normal storage level of 62.73m, a reservoir capacity of 245 million m^3, and a total installed capacity of 96 mw. Cuijiaying junction is a category II project with a large (2) scale. Main structures of the project include the four parts of sluice, hydropower station, ship lock (1000t, one-way) and retaining dam. It has a maximum navigable discharge of 11,340 m^3/s and a minimum navigable discharge of 470 m^3/s.

The main work of Cuijiaying Hydro-junction has been completed and currently it enters a trial operation of power generation. Operation method of its reservoir: reservoir shall remain its normal water level of 62.73m and power station shall generate according to natural discharge when reservoir inflow is less than or equal to the maximum station inflow during the flood season; reservoir shall remain its normal water level with all units put into operation and excess water discharged through sluice when reservoir inflow is more than the maximum station inflow but less than the shutdown discharge; sluice shall be gradually opened to fully opened according to the actual situation when reservoir inflow is more than the shutdown discharge, i.e. station water head is below 1.5m, but the maximum discharge shall not be more than the maximum peak discharge of the current flood under natural conditions.

5.1.2 Development situation of EIA

a) Wangfuzhou Hydro-junction

In the preparation phase of Wangfuzhou Hydro-junction project of Han River in

Hubei Province, China's environmental protection was only just started. As a result, many regulations on environmental protection were being drafted and environmental protection work regarding construction project was still in its initial phase. Following regulations of *Construction Project Environmental Protection Management Measure* ((86) National Environment Document No. 003), the former Yangtze River basin planning office entrusted Changjiang Water Resources Protection Institute to compose *Environmental Impact Report on Wangfuzhou Hydro Junction of Han River* in 1988. On October 17, 1988, entrusted by the former National Environmental Protection Agency, Hubei Provincial Environmental Protection Bureau approved the environmental impact report as Hubei Environmental Management [1988] No. 44.

In June 2004 and June 2005, completion acceptances regarding water and soil conservation facility and environmental protection were passed respectively.

b) Cuijiaying hydro-junction

Environmental Impact Report on Cuijiaying Hydro-junction Project of Han River was composed by CCCC Second Harbor Consultants in Mar. 2005 and approved by the former State Environmental Protection Administration in May 2005.

In April 2012 and May 2014, completion acceptances regarding water and soil conservation facility and environmental protection were passed respectively.

5.2 Analogy survey analysis of hydrological regime impact

5.2.1 Hydrological regime impact

5.2.1.1 Impact on discharge

a) Wangfuzhou Hydro-junction

Reservoir capacity of 149.5 million m^3 under normal storage level of Wangfuzhou Hydro-junction serves as a daily-regulated reservoir which has almost no regulating effect on annual or monthly discharge. The discharges before and after constructing Wangfuzhou Hydro-junction are mainly effected by the regulated discharge from the upstream Danjiangkou as Wangfuzhou and Danjiangkou are under synchronized operation. As a result, discharge from Danjiangkou basically equals the inflow and outflow of Wangfuzhou, with maximum discharge of many years in August and September and minimum discharge of many years in January to March. The construction of Wangfuzhou Hydro-junction is basically of no effect to dam site discharge.

According to statistical analysis of the reservoir operation data of Wangfuzhou Hydro-junction in from 2000 to 2014, Figure 5.2.2-1 shows detailed reservoir inflow and generation discharge. Besides generation discharge is abandoned water. Figure 5.2.2-2 shows the average reservoir inflow of Wangfuzhou Hydro-junction in the recent three years indicating almost no difference between upstream inflow and reservoir outflow in various month of the year. In 2014, reservoir inflow throughout the year was substantially decreased as affected by the completion of the Middle Route of South-to-North Water Transfer Project.

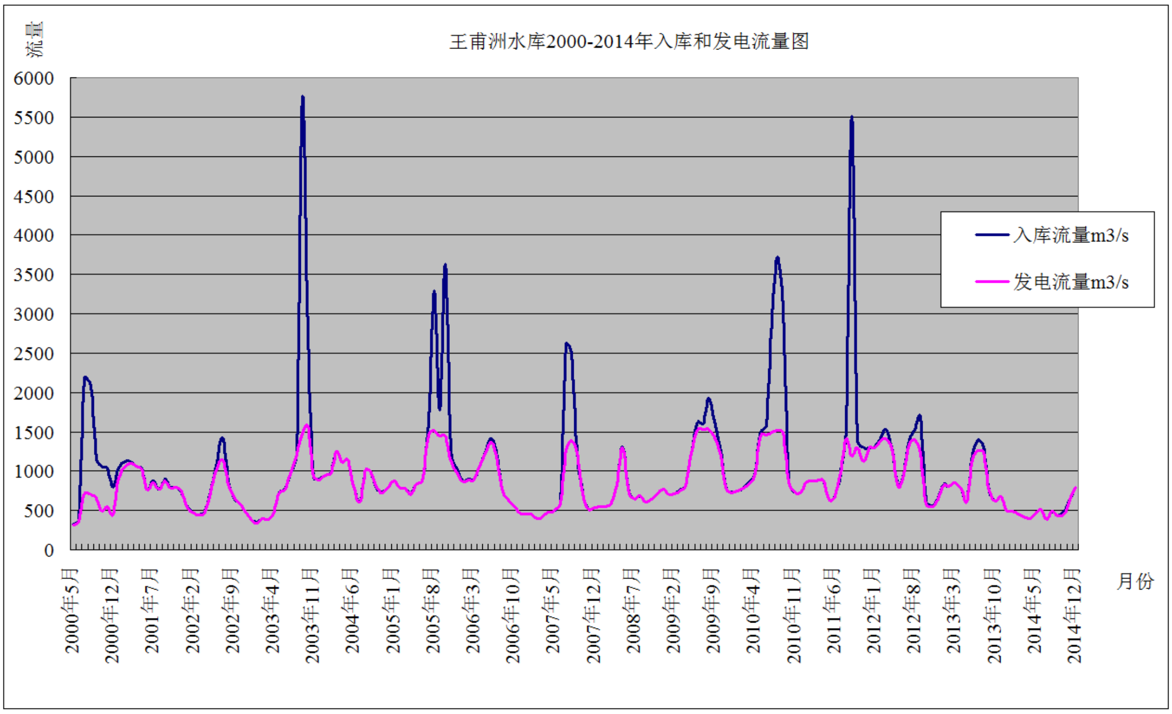


Figure 5.2.2-1 Daily reservoir inflow and generation discharge of Wangfuzhou Hydro-junction from 2000 to 2014

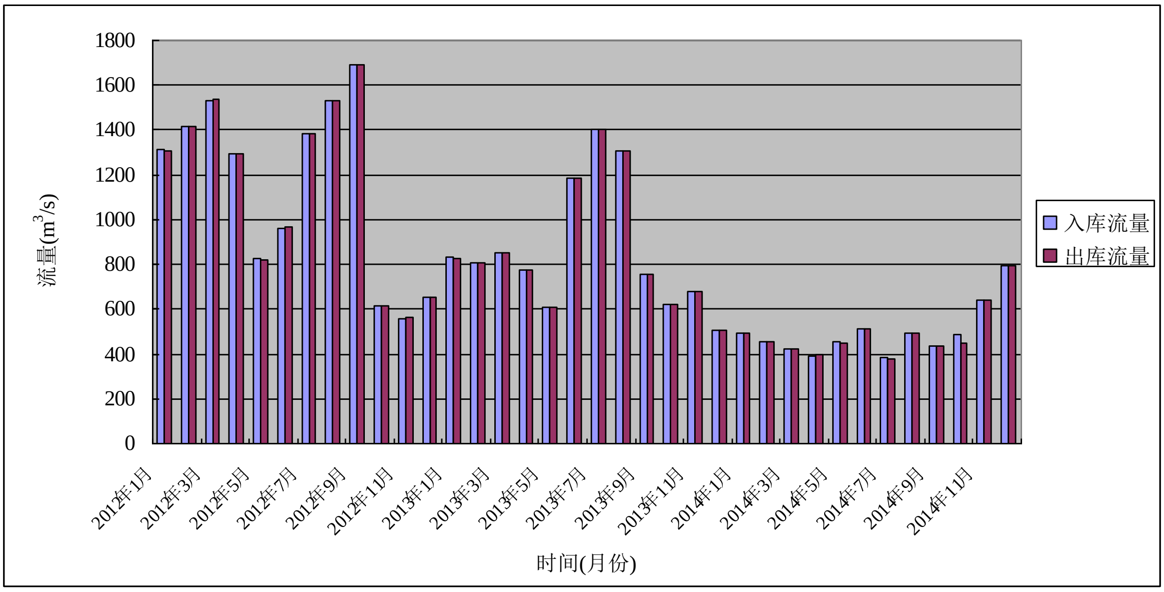


Figure 5.2.2-1 Average reservoir inflow (m^3/s) of Wangfuzhou Hydro-junction in the recent three years (2012-2014)

b) Cuijiaying hydro-junction

Cuijiaying reservoir is situated in the Danjiangkou-Zhongxiang Reach of the midstream Han River and 17 km downstream of Xiangyang City. The hydro-junction is a daily regulating reservoir, similar to Wangfuzhou Hydro-junction, and has almost no regulating effect on monthly discharge. According to the average daily reservoir inflow and outflow after the construction of Cuijiaying Hydro-junction as shown in Figure 5.2.2-3, it is seen that there is almost no difference between reservoir inflow and outflow throughout the year, with a maximum discharge in September, a minimum discharge in May, and without clearly changing monthly water distribution throughout the year. Monthly inflow is slightly below outflow due to inflows of tributaries such as Tangbai River and Nan River.

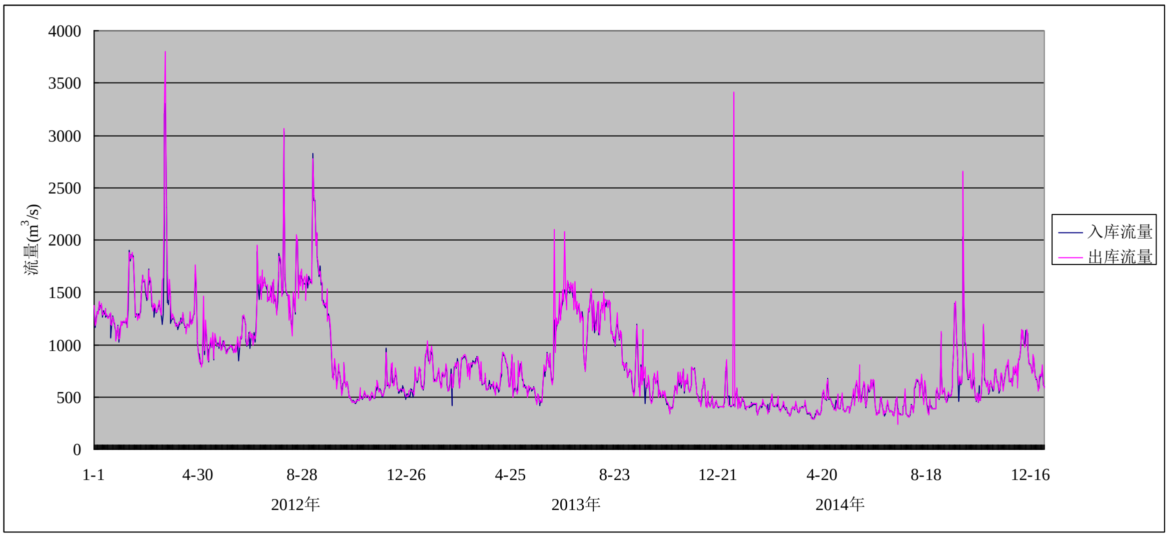


Figure 5.2.2-3 Average daily reservoir inflow and outflow of Cuijiaying Hydro-junction from 2012 to 2014

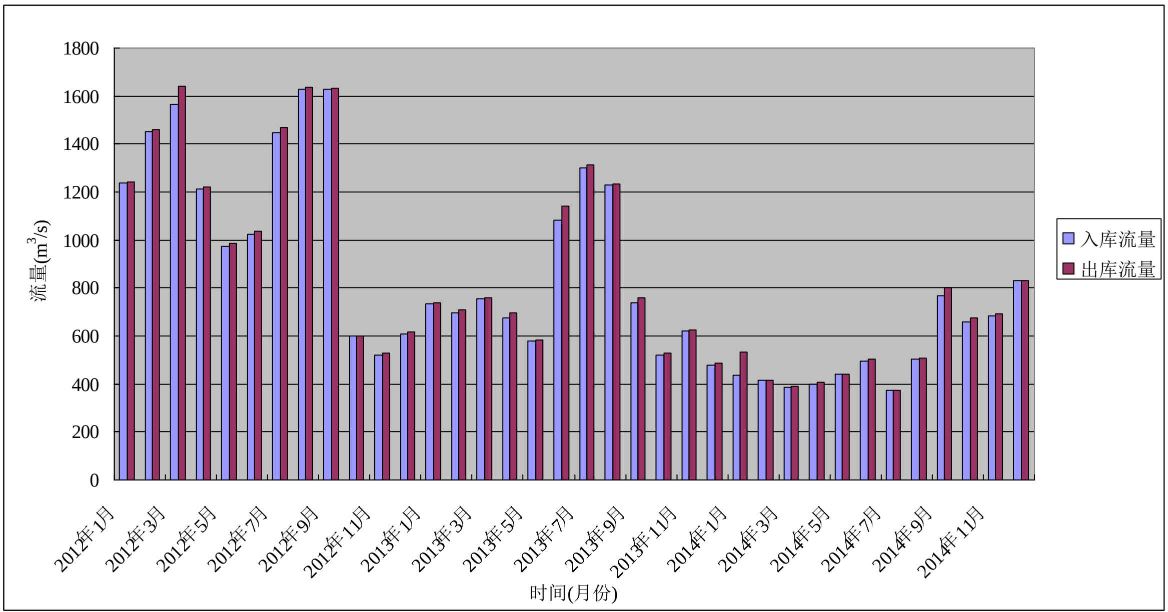


Figure 5.2.2-4 Monthly reservoir inflow and outflow of Cuijiaying Hydro-junction in the recent three years (2012-2014) after completion

In addition, statistical analysis of discharge variations in different periods of five hydrologic stations along the mainstream of the mid and downstream Han River during the 12 years from 2000 to 2011 are shown in Figures 5.2.2-5 and 5.2.2-6. According to the Figures, average discharge variations in different periods within the year are basically the same as between the years in all five hydrologic stations, which may be analyzed to represent that development projects on the mid and downstream Han River have no substantial impact on main stream discharge. Cuijiaying Hydro-junction was completed and started water storage in 2010. As there were no substantial variations occurred within and between the years in the hydrological stations situated upstream and downstream before and after 2010, it may be analyzed to represent that no substantial variations occurred regarding discharge trend of the hydrological stations situated upstream and downstream after the construction of Cuijiaying reservoir.

Figure 5.2.2-1 Runoff results of various hydrological stations from 2000 to 2011

Hydrological Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Huangjiagang	694	699	709	777	933	954	1497	1716	2010	1254	794	761	1135
Xiangyang	768	775	775	824	983	1007	1596	1956	2163	1397	904	839	1236
Huangzhuang	824	788	821	888	1071	1219	2383	2720	2714	1673	1074	927	1481
Shayang	867	837	870	920	1108	1231	2355	2683	2698	1703	1113	954	1487
Xiantao	781	748	776	787	912	1001	1844	2087	2187	1408	984	864	1262

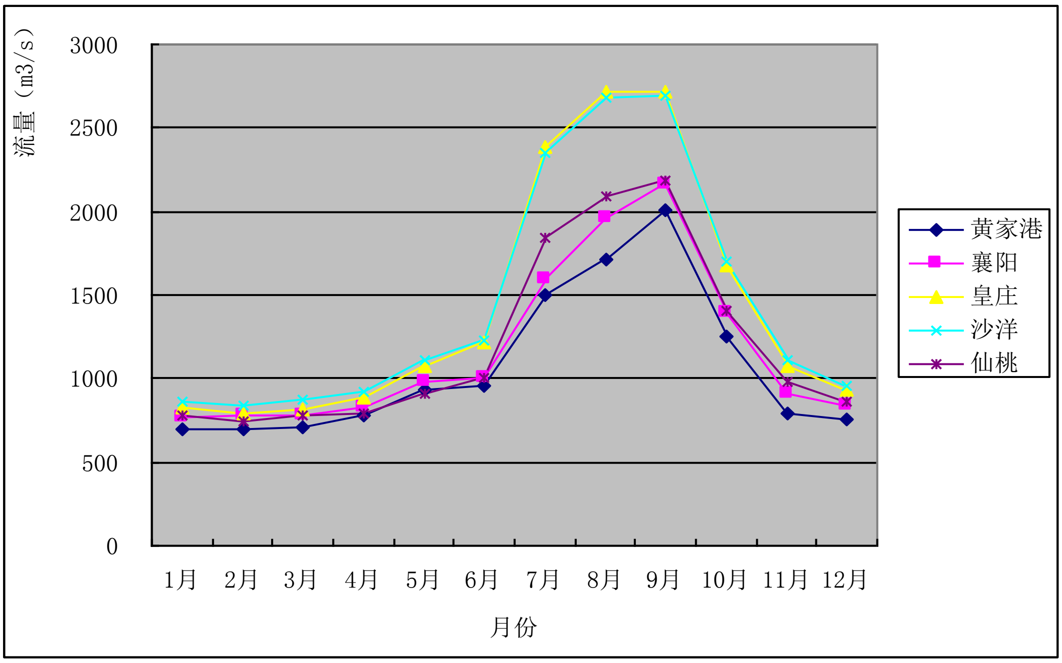


Figure 5.2.2-5 Scatter Figure of average discharge variations for many years within the year of various hydrological stations (2000-2011)

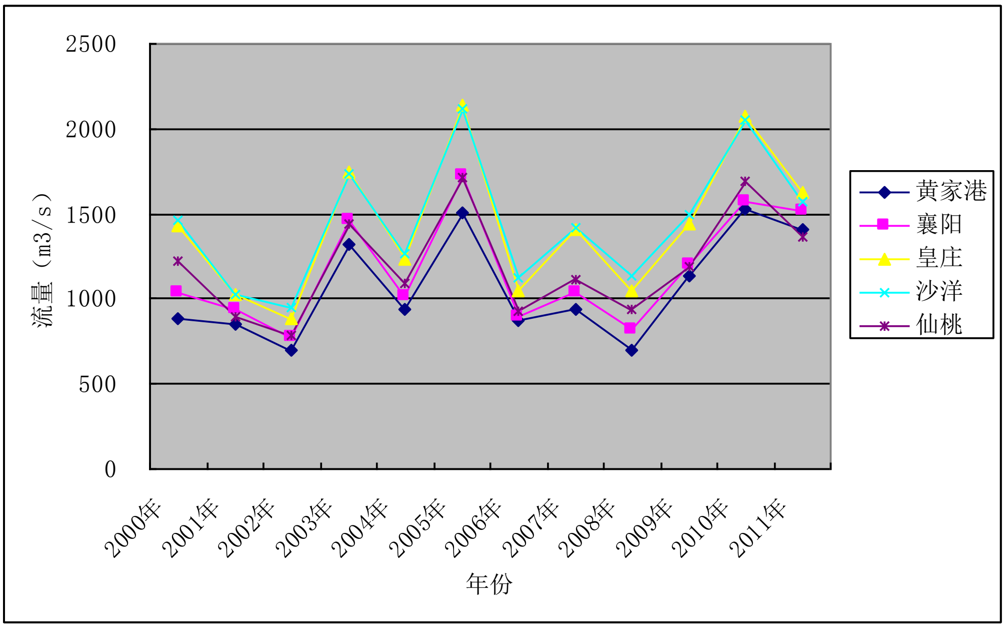


Figure 5.2.2-6 Scatter Figure of average annual discharge variations of various hydrological stations (2000-2011)

5.2.1.2 Morphological variations of river water body

The average surface width at main control section of the mid and downstream Han River is at its maximum in the Huangjiagang Reach, gradually narrows toward Xiangyang Reach, then widens from Xiangyang towards Shayang Reach, and narrows onwards to its minimum width in Xiantao Reach. The variation range of average surface width for many years is 329.2 to 555.7m. The average water depth at main control section of the mid and downstream Han River deepens from Huangjiagang towards Xiangyang Reach and shallows from Xiangyang towards Huangzhuang Reach, then deepens again from Huangzhuang towards Shayang Reach, and approaches the maximum depth in Xiantao Reach. The variation range of average water depth for many years is 2.15 to 5.07m.

Comparing with natural conditions, after the completion of development projects of Wangfuzhou and Cuijiaying, the surface width and water depth of the reaches where the projects are situated have undergone obvious changes. Refer to Figure 5.2.1-2 for variations of hydrological parameters before and after the operation of the junctions.

Figure 5.2.1-2 Hydrological parameters variation comparison before and after the completion of development projects on the main stream of the mid and downstream Han River

Junction	Project	Unit	Before reservoir completion	After reservoir completion	reservoir completion after/ before
Wangfu zhou	Reservoir (water) area	km^2	9.84	30.8	3.13
	Reservoir (water) volume	One hundred million m^3	0.78	1.495	1.92
	Average flow velocity	m/s	0.51	0.17	0.33
	Average water depth	m	0.79	4.85	6.14
	Average water surface width	m	328	1488	4.54
Cuijiayi ng	Reservoir(water) area	km^2	51.48	71.56	1.39
	Reservoir(water) volume	One hundred million m^3	1.4	2.85	2.04
	Average flow velocity	m/s	0.83	0.16	0.19
	Average water depth	m	0.65	3.98	6.12
	Average water surface width	m	627	2196	3.50

Compared with natural riverway prior the construction of reservoir, after the completion of Wangfuzhou reservoir, the water level was raised, surface area widened, water depth deepened, and the previously natural riverway was turned into the form of a reservoir above the dam and riverway below the dam; from Figure 5.2.1-2 it is known that after the operation of Wangfuzhou Hydro-junction, water body area, volume, water depth and surface width has become 3.13, 1.92, 6.14 and 4.54 times that of under the natural condition, while the velocity of the water body has decreased to be 0.33 times that of under the natural condition.

After the construction of Cuijiaying reservoir, surface area and water depth of the reservoir area has also substantially increased by around 39%. Generally speaking, the construction of various-leveled hydro junctions on the main stream of the mid and downstream Han River have remarkably changes the form of water body of Han River, turning the previously natural riverway connecting upstream and downstream into the combination of riverway and reservoir. After the operation of Cuijiaying hydro-junction, water body area, volume, water depth and surface width has become 1.39, 2.04, 6.12 and 3.5 times that of under the natural condition, while the velocity of the water body has decreased to be 0.19 times that of under the natural condition.

5.2.1.3 Discharge variations in reservoir area

After the operation of Wangfuzhou Hydro-junction, velocity has decreased due to morphological variations of the reservoir area and velocity in the reservoir area has been only 0.04 times that of under the natural condition after the completion of Wangfuzhou reservoir

After the operation of Cuijiaying Hydro-junction, velocity in the reservoir area has been only 0.05 times that of under the natural condition.

5.2.1.4 Water level variations in the reservoir area

a) Wangfuzhou Hydro-junction

After the completion of a reservoir, generally reservoir water level is between normal storage level and dead storage level. After the construction of Wangfuzhou Hydro-junction, considering that Wangfuzhou Hydro-junction and Danjiangkou reservoir are under synchronized operation, making the discharge of Danjiangkou reservoir about the same as the inflow and outflow of Wangfuzhou reservoir. There is no inflow of major tributary between Danjiangkou and Wangfuzhou Hydro-junction, therefore, water level of Wangfuzhou reservoir is mainly related to the regulated discharge from Danjiangkou. See Figure 5.2.1-7 for the monthly reservoir water level and downstream water level of Wangfuzhou Hydro-junction in the recent three years, and it is seen that reservoir water level has basically kept normal storage level operation.

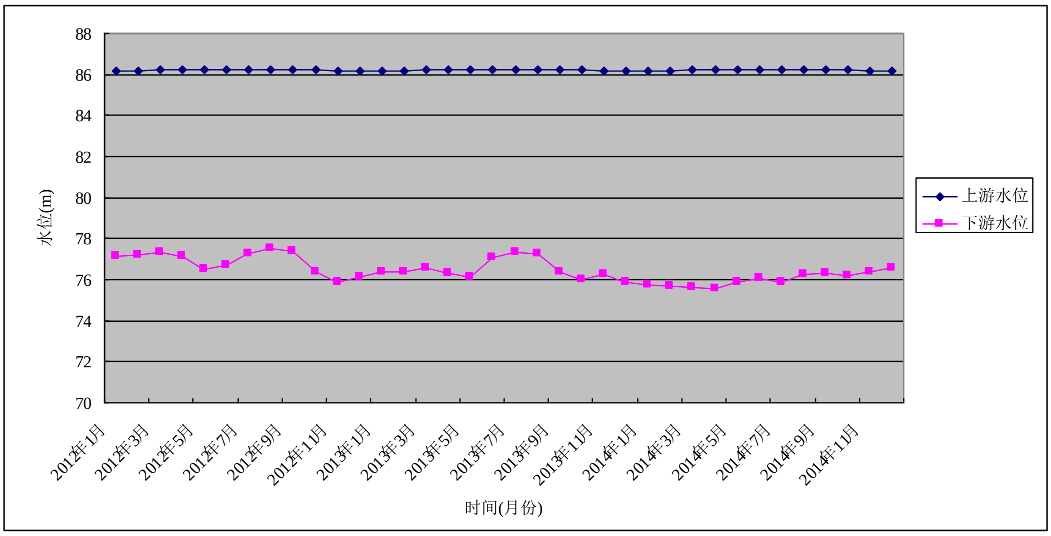


Figure 5.2.1-7 Monthly reservoir water level and downstream water level of Wangfuzhou Hydro-junction (2012-2014)

See Table 5.2.1-3 and Figure 5.2.1-8 for Wangfuzhou reservoir water level variations from 2001 to 2011. According to Figure 5.2.1-8, Wangfuzhou water levels are relatively high during the flood season from June to September, which are above normal storage level mainly caused by instant inflow from upstream. Water levels of other months are all controlled to be below the normal storage level.

Table 5.2.1-3 Statistical table of monthly average water level of Wangfuzhou Hydro-junction (2000-2011)

Unit: m

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Water level	86.15	86.18	86.15	86.19	86.22	86.26	86.27	86.26	86.23	86.18	86.19	86.17

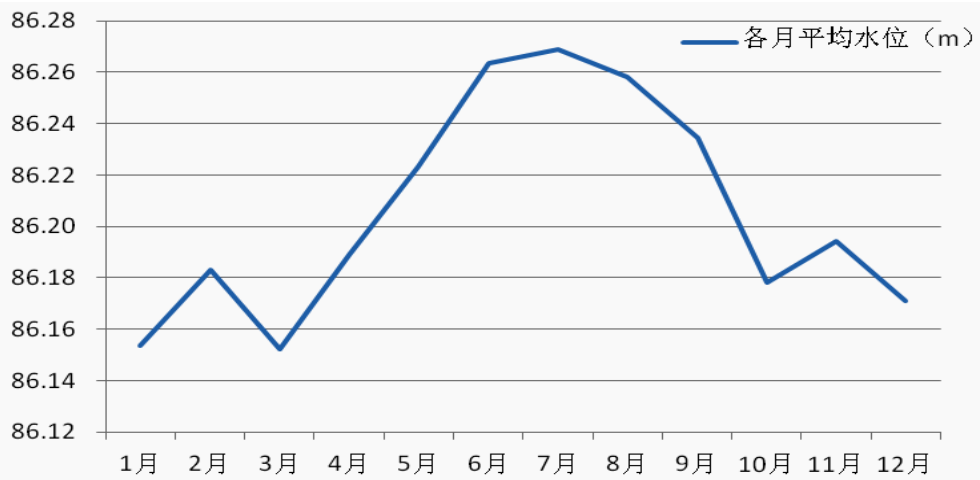


Figure 5.2.1-8 Monthly reservoir water level of Wangfuzhou Hydro-junction (2001-2011)

b) Cuijiaying hydro-junction

After the completion of Cuijiaying dam, reservoir water level was raised from natural riverway due to reservoir water storage. As the biggest impact of dam construction on flood stage is on the reach close to the dam, the impact on water level of Xiangyang hydrological station is fairly small. There is no impact on the water level at sluice of a proposed upstream power station after the construction of Cuijiaying dam.

Wangfuzhou and Cuijiaying reservoirs are daily regulating reservoirs, with a fairly small regulating capacity and almost no regulating capability, and reservoir water level variations are basically the same as variations of upstream inflows after the operation of the projects. See Figure 5.2.1-9 for monthly upstream and downstream water levels of

Cuijiaying Hydro-junction in the recent three years (2012-2014).

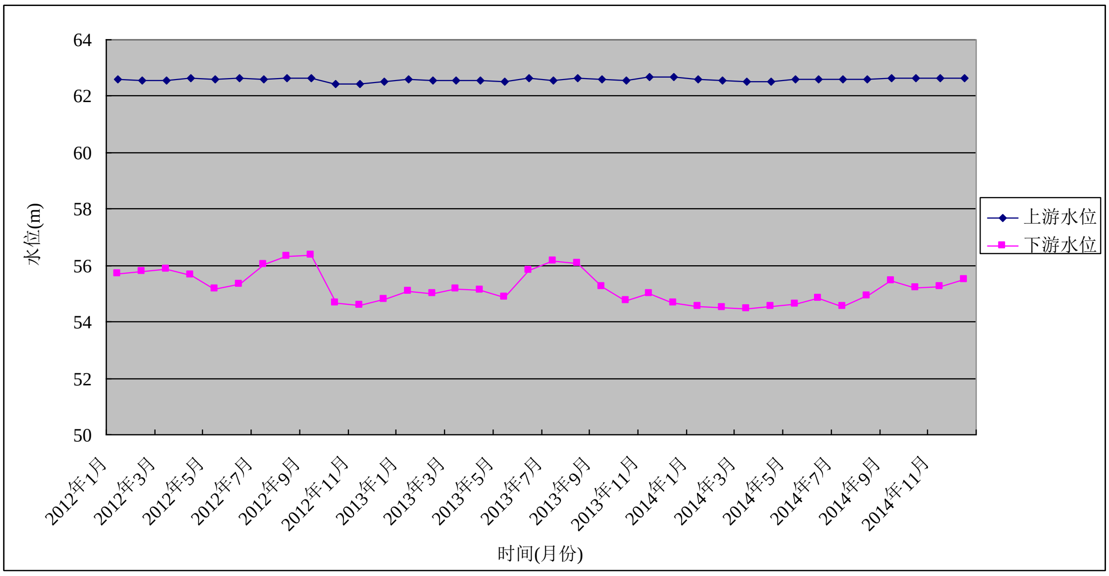


Figure 5.2.1-9 Monthly upstream and downstream water levels of Cuijiaying Hydro-junction in the recent three years (2012-2014)

5.2.2 Ecological flow discharge situation

a) Ecological flow discharge requirement

In 2006 State Environmental Protection Administration issued *Water Resources and Hydropower Construction Project Water Environment and Aquatic Ecology Protection Technology Policy Seminar Minutes* and *Water Resources and Hydropower Construction Project Riverway Ecological Water* (HBH [2006] No. 11), *Low-temperature Water and Fish Pass Facility Environmental Impact Evaluation Technical Manual (Trial)* respectively (HPH [2006] No. 4), proposed to maintain the basic ecological requirement of the river, and included a certain ecological discharge concerning water resources and hydropower project into the overall consideration of water resources allocation of the project

b) Ecological flow discharge requirement by environmental impact report and environmental assessment approval document

Initial work of Danjiangkou was not assessed environmentally due to its early construction time; Wangfuzhou Hydro-junction was constructed relatively early when environmental assessment document and approval suggestion did not propose specific requirement regarding ecological flow discharge. Although Cuijiaying Hydro-junction was a newly-built project, it did not by itself specify requirement regarding ecological flow discharge. According to requirements in *Water Resources and Hydropower Construction Project Water Environment and Aquatic Ecology Protection Technology Policy Seminar Minutes* issued in 2006, the minimum water required to maintain the stability of an aquatic eco-system generally shall not be less than 5% of the average discharge of riverway control section (average runoff for many years>80 m^3/s), therefore this document calculates the basic requirements of ecological flow based on the dam site average discharge data for many years of various power stations (See Table 5.2.3-1). However, considering the basin planning of the mid and downstream Han River as well as functions and features of various power station, to meet shipping requirement, Danjiangkou hydro junction shoulders the task of regulation and has a minimum discharge requirement of 200 m^3/s; Wangfuzhou Hydro-junction and Cuijiaying Hydro-junction have minimum discharges respectively meeting the flow requirement of 200 m^3/s and 470 m^3/s.

Table 5.2.3-1 Calculation table of minimum discharge of various power station

Project	Danjiangkou	Wangfuzhou	Cuijiaying
Main task	Flood control, power generation, water conservancy, shipping	Power generation, water conservancy, shipping	Power generation, shipping
Average dam site discharge for many years	1230	1215	1470
Basic requirement of ecological discharge m^3/s (5%)	61.5	60.75	73.5
“Favorable” requirement of ecological discharge m^3/s (20%)	246	243	294
Minimum navigable discharge requiem m^3/s	200	200	470
Project minimum discharge requirement	200	200	470
Actual discharge	above 300 m^3/s	above 300 m^3/s	above 500 m^3/s

c) Actual discharge of various power stations

According to the Wangfuzhou operating and dispatching program, it meets the minimum discharge requirement when its reservoir inflow is less than 200 m^3/s with a discharge of 200 m^3/s. The Cuijiaying reservoir operating and dispatching program meets shipping requirement when inflow is less than 470m^3/s and a shipping base-load discharge from both the power station and sluice.

Through statistically analyzing operation data of various power stations, from 2011 to 2013 the minimum daily discharge of Wangfuzhou Hydro-junction all exceeded 300 m^3/s and the minimum daily discharge of Cuijiaying Hydro-junction all exceeded $500m^3/s$. Judging by Tenant method, as the minimum daily discharges of Wangfuzhou Hydro-junction and Cuijiaying Hydro-junction exceed 20% of their average runoffs for many years, they are of "favorable" levels, meaning they are able to provide the require amount of water needed to maintaining a stable aquatic eco-system and to meet the discharge requirement of shipping. However, 2014 suffered from relatively smaller amount of natural water inflow and the impact of the first phase of the Central Route of the South-to-North Water Transfer Project, and could not meet the minimum discharge requirement as they could only discharge according to natural inflow during dry flow season.

See Figure 5.2.3-1 to 6 for 24-hour operation of a typical day in dry flow, high flow and normal flow season of Wangfuzhou Hydro-junction and Cuijiaying Hydro-junction. It is seen that the minimum daily discharge of Wangfuzhou Hydro-junction exceeds 300 m^3/s; Cuijiaying Hydro-junction cannot meet the minimum discharge requirement of $470m^3/s$ by discharging inflow during dry flow season as it is affected by the inflow.

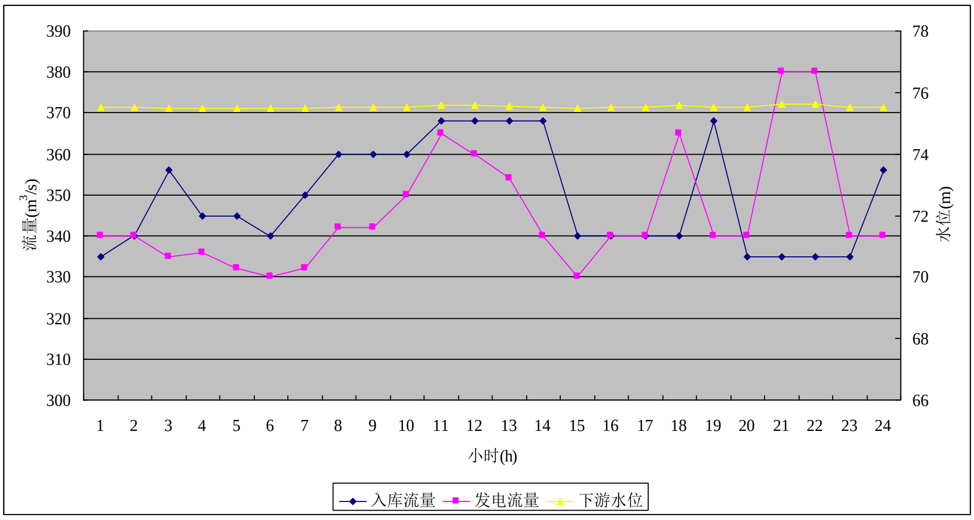


Figure 5.2.3-1 24-hour operation of a typical day in dry flow season of Wangfuzhou Hydro-junction (April 23, 2014)

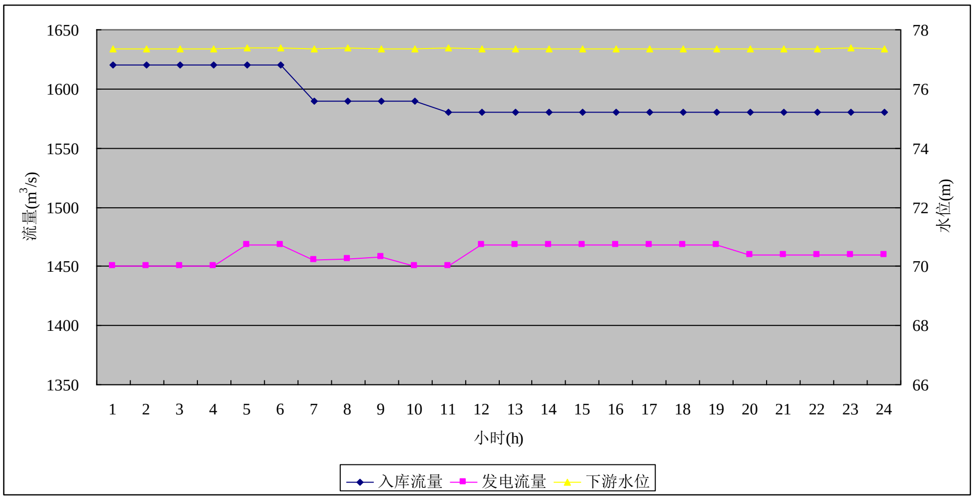


Figure 5.2.3-2 24-hour operation of a typical day in high flow season of Wangfuzhou Hydro-junction (March 7, 2012)

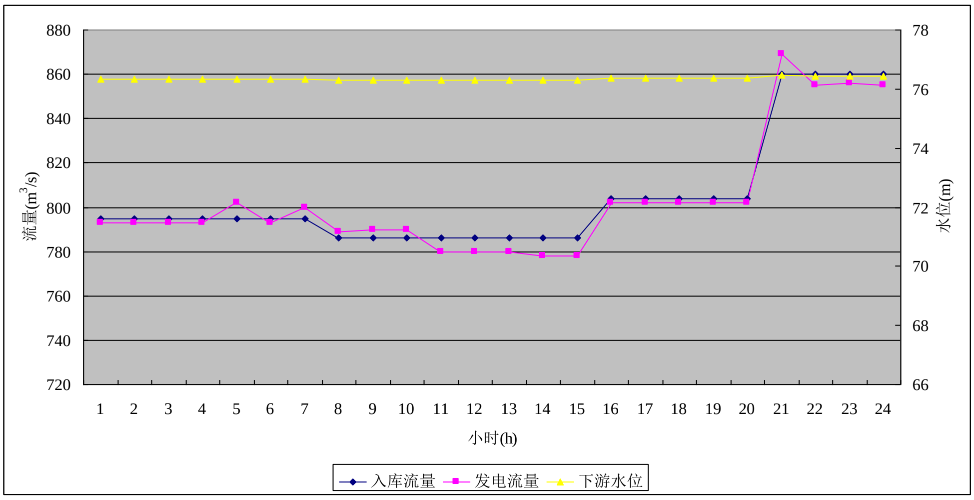


Figure 5.2.3-3 24-hour operation of a typical day in normal flow season of Wangfuzhou Hydro-junction (February 6, 2013)

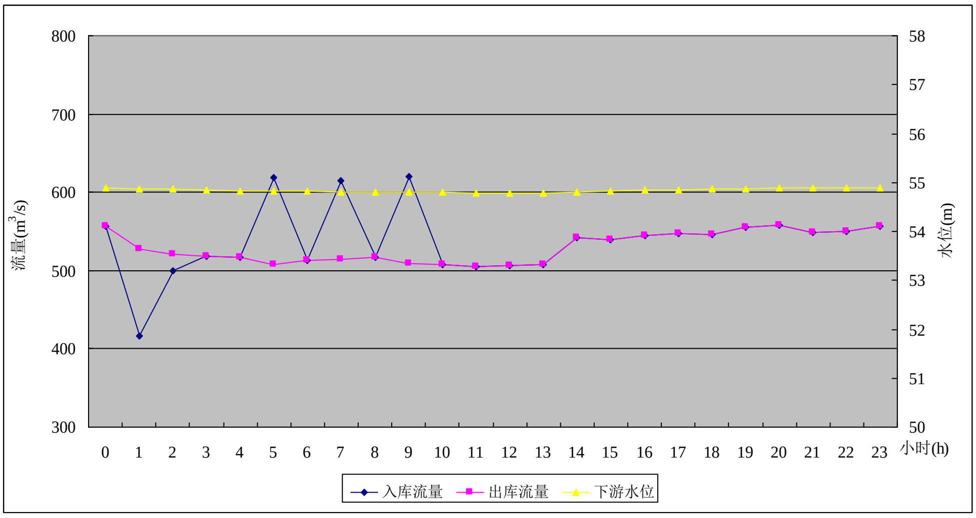


Figure 5.2.3-4 24-hour operation of a typical day in dry flow season of Cuijiaying Hydro-junction (January 2, 2015)

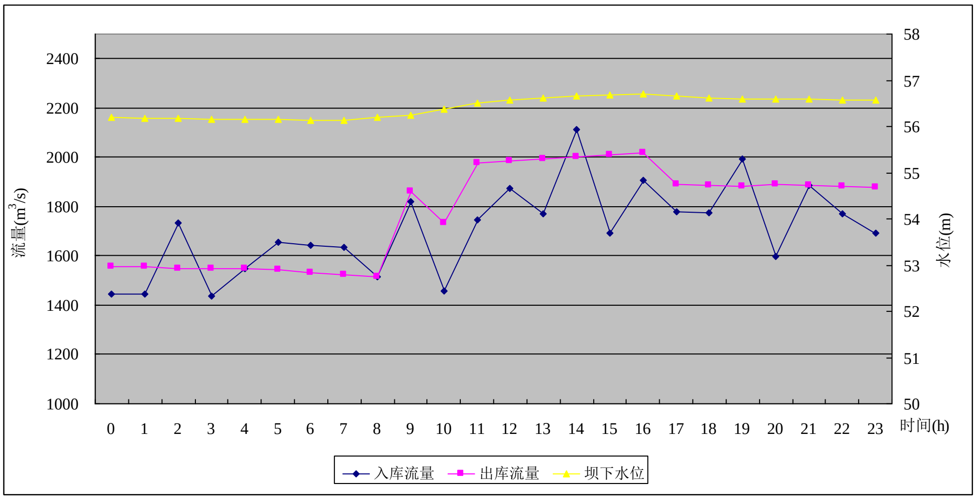


Figure 5.2.3-5 24-hour operation of a typical day in high flow season of Cuijiaying Hydro-junction (September 8, 2012)

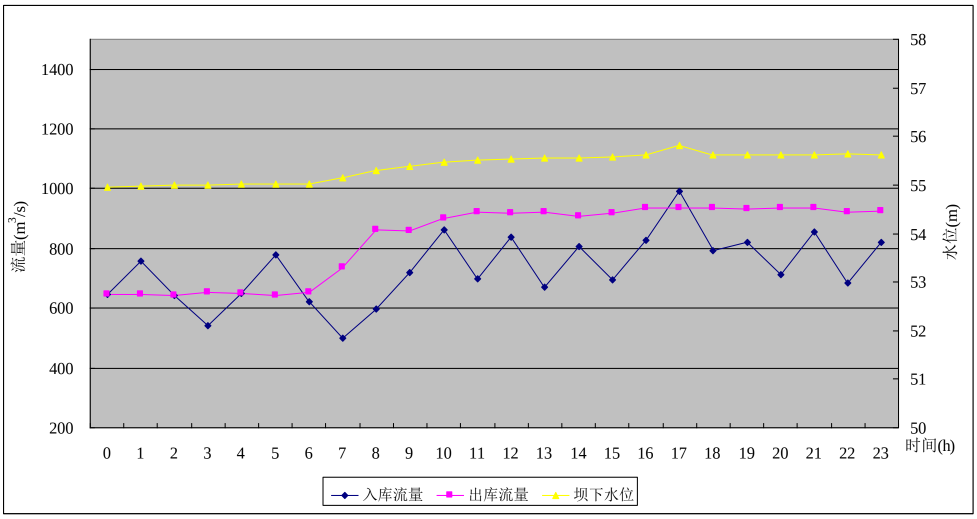


Figure 5.2.3-6 24-hour operation of a typical day in normal flow season of Cuijiaying Hydro-junction (May 4, 2013)

5.2.3 Sediment charge variations

a) Main stream sediment temporal and spatial distribution analysis

1) Temporal distribution

Prior constructing Danjiangkou reservoir, sediment in the midstream Han River was mainly from Danjiangkou upstream and according to survey, prior reservoir construction Huangjiagang hydrological station had an average annual sediment discharge of 127 million t/a (See Table 5.2.4-1), and an average sediment charge of 2.92kg/m^3. Sediment discharge was uneven during the year with the three months of July, August and September in the flood season taking up 80% of the annual sediment; the three months of December, January and February in the dry flow season taking up less than 1% of the annual sediment discharge.

After constructing Danjiangkou reservoir, sediment in the midstream Han River has been much reduced due to the blocking effect of Danjiangkou dam. Prior 2000, sediment discharge of Huangjiagang was less than 1% (about 1 million t/a) that of before, Xiangyang was only 7.5% that of before and Huangzhuang and Shayang were 21% and 22% that of before respectively. After reservoir construction, peak discharge was substantially reduced, normal flow season was extended, and dry flow season discharge was up. Heavy riverbed erosion occurred in midstream Han River due to clean water discharge, and sediment in the middle and lower reaches are mainly from erosion recharge in midstream riverbed and regional tributary inflows.

Table 5.2.4-1 Statistical values of water and sand features of Huangjiagang hydrological station in midstream Han River

Project	Average water level (m)	Average runoff discharge (100 million m^3)	Average discharge (m^3/s)	Average sediment charge (kg/m^3)	Average sediment discharge (10^4t)
Prior reservoir construction(1954-1959)	90.04	1310	413	2.92	12700
Flood detention period (1960-1967)	89.32	1310	412.6	1.73	7260
Water storage period (1968-1987, 1989, 1990, 1998, 2000-2005)	88.68	1090	1344.8	0.03	124.6

2) Sediment spatial distribution

See Table 5.2.4-2 for sediment charge situations of the five hydrological stations in the middle and lower reaches of Han River. According to the table, currently the annual average sediment discharge and charge in the middle and lower reaches of Han River is on the rise from Danjiangkou to estuary. Sediment of Xiangyang hydrological station is mainly from midstream riverbed erosion and sediment carried by the tributaries of Tangbai River and Nan River.

Table 5.2.4-2 Value map of sediment features of various hydrological stations in the middle and lower reaches of Han River (2000-2006)

Survey station	Average sediment discharge (10^4t)	Average sediment charge (kg/m^3)	Average annual maximum sediment charge (kg/m^3)	Average annual minimum sediment charge (kg/m^3)
Huangjiagang	7.15	0.00192		
Xiangyang	217	0.0578		
Huangzhuang	667	0.20	1.28	0.037
Shayang	720	0.23	1.10	0.045
Xiantao	1450	0.42	2.24	0.091

By analyzing Table 5.2.4-3, it can be known that erosion in the middle and lower reaches of Han River is mainly in the mountain basin in the middle reach, namely Tangbai River, Nan River and Bei River, amongst with the sediment discharge of Tangbai River and Nan River are of relatively higher proportions of 27.34% and 18.17% respectively.

Table 5.2.4-3 Different basin erosion, sediment loss and runoff discharge in the middle and lower reaches of Han River

Basin name	Runoff discharge (10^8m^3)	Erosion (10^4t)	Sediment loss	
			Sediment discharge (10^4t)	Sharing rate (%)
Directly into Han River	69.9	1403.7	564.3	36.03
Xiaoqing River	5.4	47.4	14.8	0.94
Tangbai River	56.4	3510.4	428.3	27.34
Bei River	4.8	361.9	116.5	7.44
Nan River	22.9	1872.3	284.6	18.17
Man River	16.3	364.9	93.4	5.96
Zhupi River	3.4	39.4	14.1	0.90
Hanbei River	34.8	546.8	50.3	3.21
Total	214.2	8146.8	1566.3	100

3) Temporal and spatial variation of riverbed accretion and erosion

Riverbed sediment accretion and erosion was calculated based on the topographic data of the three surveys in 1978, 1987 and 2005, and the fix section data from 1997 and 2003.

① Danjiangkou-Xiangfan

From 1978 to 2005, there was riverway erosion with an average thalweg erosion depth of 1.1m and a maximum erosion depth of 4.1m in Danjiangkou-Xiangfan section where erosion occurred mostly from 1978 to 1987. Danjiangkou-Gucheng section had a relatively high erosion resistance. Sediment erosion of the entire river section was 72.84 million m^3, among which Danjiangkou-Gucheng section representing 25% of the entire section length had only a sediment erosion of 10.03 million m^3 accounting for 13.8% of the total; Taipingdian-Xiangfan section representing 39.7% of the entire section length had a sediment erosion of 42.44 million m^3 accounting for 58.3% of the total. Currently, Danjiangkou-Gucheng has reached erosion balance and it has a coarsened pebble riverbed, a discharge volume within 5000 m^3/s, basically no accretion and erosion change in river channel, and a limpid water body.

② Xiangfan-Nianpanshan

Xiangfan-Nianpanshan section had no clear changes of thalweg elevation along the line from 1978 to 2005, and had mainly accretion and erosion with an average thalweg depth of 1.3m. Xiangyang-Zhuandou had a relatively high erosion resistance, whereas Zhuandou-Nianpanshan had a relatively low erosion resistance. Main river channel of Xiangfan-Nianpanshan section had 128 million m^3 of sediment erosion from 1978 to 2005, among which Xiangfan-Cuijiaying section had 24 million m^3 of sediment erosion accounting for 18.7% of the total erosion; Cuijiaying-Nianpanshan section had 104 million m^3 of sediment erosion accounting for 81.3% of the total erosion.

Table 5.2.4-4 Thalweg elevation variation and erosion along the middle and lower reaches of Han River

Survey station	Average erosion depth m	Maximum erosion depth m	erosion (ten thousand m^3)	Erosion resistance
Danjiangkou-Xiangyang	1.1	4.1	7284	
Among which: Danjiangkou-Gucheng	0.2	1.8	1003	Highest
Gucheng-Taipingdian	0.9	2.8	2037	
Taipingdian-Xiangyang	1.7	4.1	4244	Lowest
Xiangyang-Nianpanshan	1.3		128000	
Among which: Xiangyang-Guanyinge	1.2	3.7	2400	
Guanyinge-Yicheng	1.1	3.9	10400	
Yicheng-Zhuandou	1.2	3.8		
Zhuandou-Nianpanshan	1.5	4.4		

b) Review analysis of impact on sediment of various hydropower development projects

1) Sediment review analysis before and after Danjiangkou reservoir construction

Danjiangkou hydro junction started construction on September 1, 1958; began river closure in December 1959; officially started water storage in November 1967 after years of flood detention; entered storage water usage period in 1968. Hydrological and sediment features of the middle and lower reaches of Han River has undergone substantial changes due to the regulating effect of Danjiangkou reservoir.

After the completion and operation of Danjiangkou reservoir, sand inflow process has been fully regulated and sediment discharge situation has undergone great change, mainly including:

① Prior reservoir construction, the average sediment charges of Huangjiagang, Xiangyang, Huangzhuang, Shayang and Xiantao were 2.92kg/m^3, 2.67 kg/m^3, 2.60kg/m^3, 2.13 kg/m^3 and 1.45 kg/m^3 respectively, and were reduced to 0.0019 kg/m^3, 0.0578kg/m^3, 0.2kg/m^3, 0.23 kg/m^3 and 0.42kg/m^3 respectively after reservoir water storage. After reservoir construction, sediment was substantially reduced in the middle and lower reaches of Han River main stream, with an ascending sediment charge along the line from the dam to estuary.

② After the completion and operation of Danjiangkou reservoir, monthly distribution ratio of maximum and minimum sediment charge of various stations mentioned above went down from 1003, 271, 174, 212 and 116 times to 102, 15, 10, 11 and 5 times after water storage, with a more balanced sediment discharge compared with that of before reservoir construction.

③ After the completion and operation of Danjiangkou reservoir, regional sediment formation in the middle and lower reaches were changed. Prior reservoir construction, 96.0% of the annual sediment discharge of Huangzhuang station was from the annual sediment discharge of Huangjiagang station, and 10.3% was from tributary sediment inflow; after reservoir construction, only 4.15% of the annual sediment discharge of Huangzhuang station was from Huangjiagang station and the proportion of tributary sediment inflow to Huangzhuang station was increased to 43.4%.

2) Sediment review analysis of situations before and after Wangfuzhou reservoir construction

Wangfuzhou reservoir is situated at the downstream of Danjiangkou. After the completion of Danjiangkou reservoir, around 98% of upstream sand inflow was blocked within Danjiangkou reservoir, leaving very little sediment discharged to Wangfuzhou reservoir. And the discharge was only during the short flood season whereas other times clear water was discharged, causing severe erosion of riverbed in the middle reach of Han River. After years of clear water erosion, Danjiangkou-Wangfuzhou section has a undercut riverbed reaching erosion balance, a coarsened pebble riverbed, basically no accretion and erosion change in river channel and a limpid water body.

After the completion of Wangfuzhou Hydro-junction, Wangfuzhou Hydro-junction did not encounter the common issue of sediment accretion and erosion troubling other reservoirs because Wangfuzhou reservoir dispatched in synchronized operation with Danjiangkou, and their discharge gates were synchronously opened for flood discharge even during flood seasons with a slightly higher sediment charge.

3) Sediment review analysis of situations before and after Cuijiaying reservoir construction

Currently, sediment of the Cuijiaying reservoir area is mainly from tributaries such as

Nan River and Tangbei River between the Danjiangkou-Cuijiaying section, as well as riverbed erosion of main stream riverbed of Wangfuzhou-Cuijiaying section.

According to analysis of *Han River Cuijiaying Hydro-junction Project Environmental Impact Report*, after the completion of Cuijiaying junction, evolutionary trend of “river channel erosion and overflow lands accretion” occurred within the range of sections 30km downstream. For areas downstream of the dam, the limit erosion is below $1400\times104m^3$, thalweg erosion values are all decreased by more than 1.16m with a maximum of 2.23m. For areas within 7km of the dam, erosion discharge is $603.9\times104m^3$, with an average erosion depth of 1.25m, among which riverbed in deep river channel and the middle part nearing the left bank suffers a relatively high erosion with a regional maximum erosion depth of 5m and an average erosion of around 2m. It causes only a limiting impact on river regime on the whole, but certain sections could be more prone to bank carving. Given that Cuijiaying only operated for one year, sediment charge and accretion and erosion effect of river section downstream of the dam were not clearly shown, so no monitoring review was conducted regarding those.

5.3 Analogy survey of water environmental impact

5.3.1 Implementation situation of water mitigation measures

a) Wangfuzhou Hydro-junction

To protection water quality of Wangfuzhou reservoir, Wangfuzhou Water Resources and Hydropower Corporation invested in renovating drainage system in Laohekou city, including building a main barrier channel and the east side of urban area, and a large open channel, 6.8km long and 10-22mm wide, along the left bank of Wangfuzhou dam, for the purpose of blocking water bodies of Longhu Ditch, Qingshui Ditch, Wangxin River and Lijia River, which then discharge into Han River after joining urban inflow downstream of the Wangfuzhou power station.

Office area and water plant of the power station are both equipped with integrated domestic sewage treatment facility, mainly with A/O biochemical technique which integrates sewage settling biodegradation and oxidation disinfection and has a treatment scale of 1m^3/h. Water quality after treatment can reach the first class effluent standard of *Sewage Comprehensive Disposal Standard* (GB8978-1996) and treated tail water is used for greening nearby. After bank inspection and local environmental and public survey, currently there is no centralized sewage disposal outlet in Wangfuzhou reservoir area.

b) Cuijiaying Hydro-junction

During operation, plant area of the power station is equipped with integrated domestic sewage treatment facility, mainly with A/O biochemical technique which integrates sewage settling biodegradation and oxidation disinfection and has a treatment scale of 1m^3/h. Water quality after treatment can reach the first class effluent standard of *Sewage Comprehensive Disposal Standard* (GB8978-1996) and treated tail water is used for greening nearby.

5.3.2 Analogy survey of water environmental impact

5.3.2.1 Surface water quality impact

a) Wangfuzhou Hydro-junction

1) Water quality situation prior development

According to *Wangfuzhou Hydro Junction Project Environmental Impact Report*, prior reservoir construction, main pollution sources of Wangfuzhou reservoir area was industrial and domestic sewage disposal of Laokekou city and Danjiangkou city as well as agricultural pollution of the surrounding area. PH value, indicators of DO, COD and AN were all in line with second-class surface water quality standard, and COD was in all in line with first-class standard. Water quality of the reservoir section was quite good with a low COD and a high DO.

2) According to *Hubei Han River Wangfuzhou Hydro Junction Completion Acceptance Environmental Impact Survey Report*, during the construction of Wangfuzhou project, the existing drainage system of Laohekou city was rechanneled to discharge sewage into the river section downstream of the dam. After drainage system rechanneling work, water quality of the Wangfuzhou reservoir area, in particular water quality of the dam site section was clearly improved compared with that of before reservoir construction. After dam construction, reservoir water body will not have clearly decreased dissolved

oxygen, nor will it have odorous smell and stink, as Wangfuzhou project is a runoff power station with a low water head, a small reservoir capacity, a shallow water depth, with frequent reservoir water exchange.

3) Project completion environmental protection acceptance survey

According to *Hubei Han River Wangfuzhou Hydro Junction Completion Acceptance Environmental Impact Survey Report*, in the mid-1990s, Hubei provincial environmental protection system set up five water quality monitoring cross sections, with one in backwater end in the reservoir area, two within reservoir and two below dam, in the river section about 40km downstream from Danjiangkou reservoir to Wangfuzhou reservoir, and conducted monitoring projects on permanganate index, BOD5, ammonia nitrogen, volatile penol, hexavalent chromium, cyanide, arsenic, mercury, petroleum, total phosphorus, plumbum and cadmium. Survey result revealed water quality of various Wangfuzhou cross sections of Han River were all in line with Class II standards of GB3838-2002 *Surface Water Environmental Quality Standard*.

Entrusted by construction unit, from June 3 to 8 of 2004, Xiangfan Municipal Environmental Protection Monitoring Station conducted water quality monitoring in four cross sections of Wangfuzhou reservoir, namely Huangjiagang (reference cross section), under Han River Bridge in Laohekou city (control cross section), Chenjiabu of Laohekou city (control cross section), and Laohekou (attenuation cross section), and monitored three perpendiculars of left, center and right in each cross section. Survey result revealed water quality indicators of various cross sections were in line with Type I standard, except for the two indicators of dissolved oxygen (cross sections 1, 3, 4) and fecal coliform which were in line with Class II standards. Compared with the historical data of provincial controlled water quality monitoring cross section, Wangfuzhou section have not suffer water quality deterioration due to reservoir construction.

4) Water quality impact review

(1) Main conclusion of basin review evaluation

Environmental Impact Review Evaluation Research Report of Hydropower Development Project in Middle and Lower Reaches of Han River Main Stream has selected and analyzed water quality data of Shenwan cross section upstream of the dam and Xianrendu cross section downstream of the dam from 2001 to 2011. Four indicators of permanganate index representing water body pollution, dissolved oxygen as predicted in the EIA report, as well as ammonia nitrogen and total phosphorus representing eutrophication, were chosen for analysis.

Analysis conclusion: from 2001 to 2011, dissolved oxygen and permanganate concentration index was basically stable during different water periods in the Shenwan cross section upstream of Wangfuzhou hydropower development project, without clear decrease of permanganate index concentration nor dissolved oxygen concentration, as predicted by the EIA report. From 2001 to 2011, ammonia nitrogen and total phosphorus concentrations during different water periods in the Shenwan cross section were clearly declined because regional pollution was controlled to a certain extent represented by less discharge of ammonia nitrogen and total phosphorus. According to water quality monitoring data during different water periods from the Xianrendu cross section downstream of Wangfuzhou hydropower development project, permanganate concentration index and total phosphorus concentration went down to a certain extent whereas ammonia nitrogen concentration went up to a certain extent in 2011 compared with that of 2001; dissolved oxygen concentration went up during dry flow and normal flow seasons and went down during high flow season in 2011 compared with that of 2001, indicating a reduction of point source pollution of oxygen consuming matter to a certain extent, as well as the feature of diffused organic pollution as diffused pollution of oxygen consuming matter went up slightly.

(2) Additional survey result

This evaluation has further collected water quality data from Fujiazhai cross section upstream of the dam and Xianrendu cross section downstream of the dam from 2004 to 2013. Six indicators of dissolved oxygen, permanganate index, BOD_5, ammonia nitrogen, total phosphorus and PH value representing pollutant features of Han River were chosen for analysis.

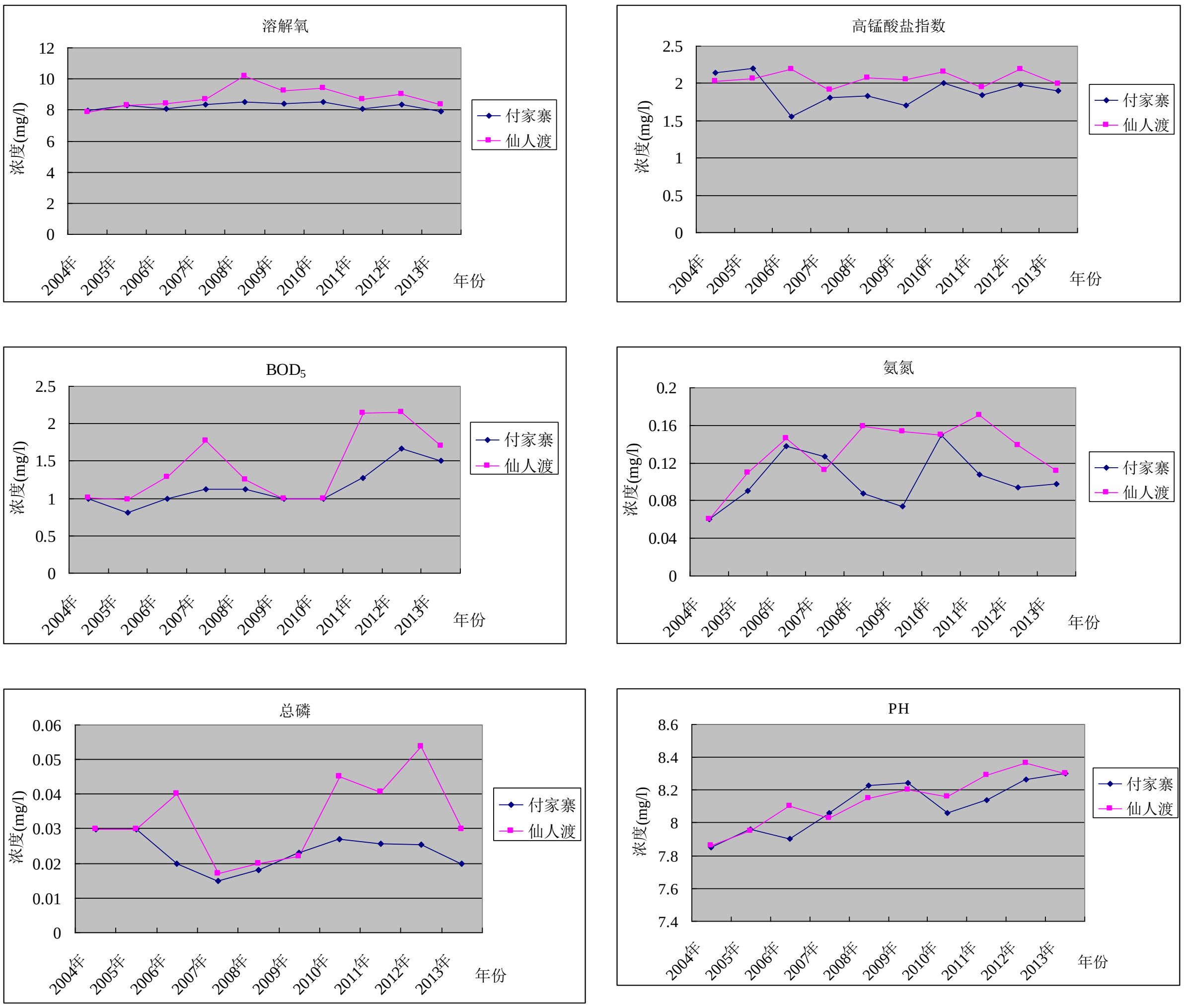


Figure 5.3.2-1 Variation trend of reservoir water quality after Wangfuzhou Hydro-junction operation

原文	English
浓度	Concentration
付家寨	Fujiazhai cross section
仙人渡	Xianrendu cross section
溶解氧	Dissolved oxygen
高锰酸盐指数	Permanganate index
氨氮,	Ammonia nitrogen
总磷	Total phosphorus
pH 值	pH value

According to the Figure, from 2004 to 2013, dissolved oxygen and permanganate concentration index was basically stable during different water periods in the Fujiazhai cross section upstream of Wangfuzhou hydropower development project, without clear decrease of permanganate index concentration nor dissolved oxygen concentration, as predicted by the EIA report. From 2004 to 2013, ammonia nitrogen and total phosphorus concentrations during different water periods in the Fujiazhai cross section fluctuated whereas total phosphorus concentration went down. The quality of reservoir water body was stable, but attention need to be paid as PH value went up every year. From 2004 to 2013, dissolved oxygen and permanganate concentration indexes were basically stable during different water periods in the Xianrendu cross section downstream of Wangfuzhou hydropower development project, whereas BOD_5, total phosphorus, ammonia nitrogen and PH value went up slightly indicating a slight increase of diffused pollution of oxygen consuming matter, and the feature of diffused organic pollution.

b) Cuijiaying Hydro-junction

1) Water quality situation prior development

According to Han River Cuijiaying Hydro-junction Project EIA Report, point source pollution in the reservoir area before and after the construction of Cuijiaying reservoir was mainly industrial and domestic sewage disposal from Gucheng county and Xiangyang city. In evaluated section, pollution during high flow season was more than that of during the normal flow season, and organic pollution indicator was higher than that of during dry flow season, particularly high in high flow season, indicating relatively severe non-point source (diffused) pollution.

Among the various discharge outlets in the evaluated section and waste water pollution sources in Han River tributaries, Tangbai River had the most loading indexes of pollutant in water discharged accounting for 69.76% of the regional equal-standard pollutant load; Xiaoqing River had the second most, accounting for 16.09% of the regional equal-standard pollutant load. Main waste water pollutant in Xiangyang section of Han River was ammonia nitrogen, accounting for 34.61% of the equal-standard pollution load, whereas total phosphorus was the second most, accounting for 26.46% of the equal-standard pollution load, with a pollutant discharge order of AN>TP>COD>BOD_5>SS.

2) According to Han River Cuijiaying Hydro-junction Project EIA Report, after the completion of Cuijiaying reservoir,

given that the hydrological conditions of average discharge, industrial waste water, and domestic sewage water all reaching standards in dry flow season of 90% water diversion pledge probability of heightened Danjiangkou, permanganate concentration index was 2.66mg/L in 2010 before Cuijiaying dam construction; overall water quality of Cuijiaying reservoir area is slightly worse than that of prior dam construction.

After Danjiangkou dam was heightened for water diversion and the construction of Cuijiaying junction, algae concentration in the Cuijiaying reservoir area was increased to a certain extent compared with that of before Danjiangkou dam was heightened for water diversion and the construction of Cuijiaying junction, among which algae concentration upstream of the dam was the highest by 209.20mg/L with an increase rate of 7.84%; algae concentration went down as distance from dam site increased; newly formed algae concentration in the tail area of the reservoir was 149.20g/L with an increase rate of 2.81%. In the river section of the reservoir area, algae concentration in the tail area of the reservoir was least affected.

3) Water quality impact review

(1) Main conclusion of basin review evaluation

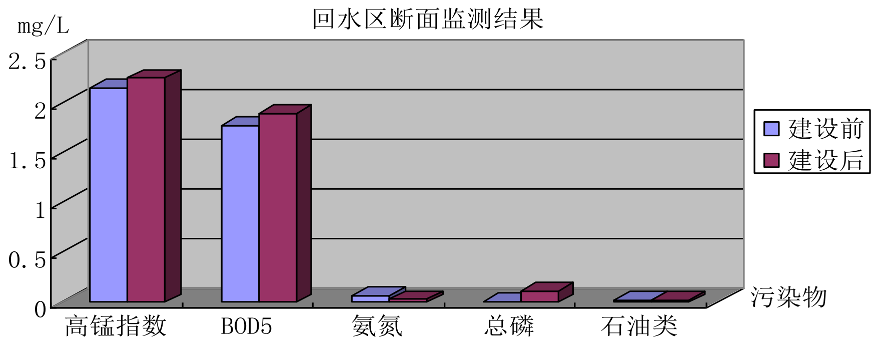
Environmental Impact Review Evaluation Research Report of Hydropower Development Project in Middle and Lower Reaches of Han River Main Stream has selected and analyzed water quality data from the same reservoir cross section (Baijiawan cross section) before and after the construction of Cuijiaying navigation-power junction and a cross section downstream of the dam (Yujiahu cross section) for comparative analysis. The main project of Cuijiaying Hydro-junction was completed and put into operation in July 2010. This evaluation uses 2009 to represent the period prior reservoir construction and 2011 for after reservoir construction. Four indicators of dissolved oxygen, permanganate index, as well as ammonia nitrogen and total phosphorus representing eutrophication, were chosen for analysis.

Result reveals: dissolved oxygen concentration did not change much downstream of the dam or before and after the construction of Cuijiaying reservoir, corresponding to low in high flow season, second in normal flow season and highest in dry flow season; permanganate index concentration went up to a certain extent downstream of the dam and after reservoir construction and was in line with Class III water quality standard of *Surface Water Environmental Quality Standard* (GB3838-2002), as the average permanganate index in the reservoir area was around 2.5mg/L, basically matching with prediction result. After reservoir construction, ammonia nitrogen and total phosphorus concentration downstream and within the dam area were lower than that of before reservoir construction in high flow season and was slightly higher during normal and dry flow season.

(2) Main conclusion of project completion environmental protection acceptance survey

From September 12 to 14 of 2012, Xiangyang Municipal Environmental Protection Monitoring Station conducted water environmental monitoring in the Han River cross section 100m upstream and downstream of the dam, and collected water quality monitoring data of February 2011 and June 2012 from Baijiawan, Qianying, Xiaoqing River (estuary) and Tangbai River (Zhangwan section). According to monitoring result, BOD_5, permanganate index, ammonia nitrogen and petroleum in of the monitored cross section of Han River in the reservoir area were in line with relevant water quality standards, and only total phosphorus slightly exceeded standard in the cross section 100m upstream of the dam. BOD_5, ammonia nitrogen and total phosphorus of Tangbai River and Xiaoqing River, both heading into Han River main stream, all slightly exceeded standards.

To further analyze the impact of project construction on water environment of the reservoir area, current monitoring data of water environmental quality of the reservoir area was compared with water environment monitoring data prior project construction. There has been no clear change of water quality during the environmental assessment period prior Han River cross-section monitoring project and the acceptance period, as shown in Figure 5.3.2-2. For water quality of Tangbai River and Xiaoqing River, only BOD_5, ammonia nitrogen and total phosphorus slightly exceeded standards, which was much improved from the environmental assessment period when indicators such as permanganate index, total phosphorus ammonia nitrogen, BOD_5 and petroleum all seriously exceeded standards.



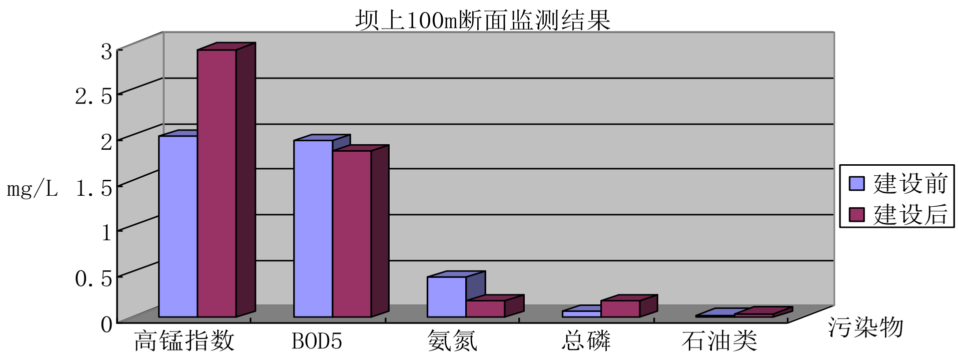


Figure 5.3.2-2 Water quality results comparison from upstream of the dam between monitoring cross section acceptance period and environmental assessment

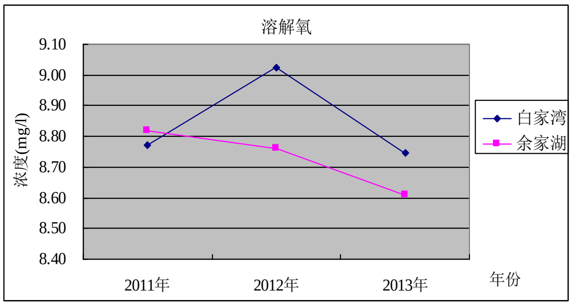
原文	English
回水区断面监测结果	Cross section monitoring result of backwater area
坝上 100m 断面监测结果	Monitoring result of cross section 100m upstream of the dam
建设前	Before construction
建设后	After construction
污染物	Pollutant
高锰酸盐指数	permanganate index
总磷	total phosphorus
氨氮	ammonia nitrogen,

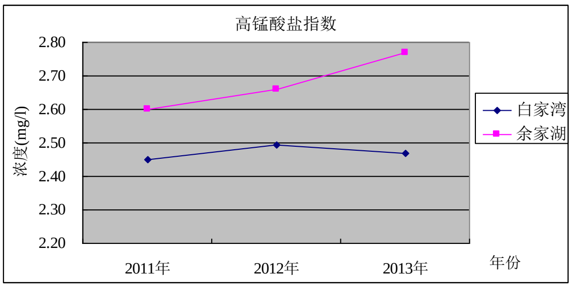
石油类	petroleum

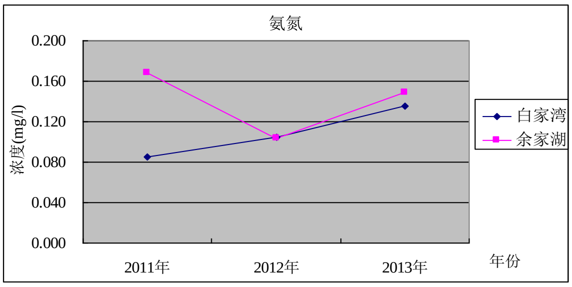
Generally speaking, through the active effort of Xiangyang Municipal Government in intensifying the treatment of urban domestic sewage and production waste water, water quality of Han River in the reservoir area had not clearly changed compared with that of before project construction, and certain indicators of Han River tributaries of Tangbai River and Xiaoqing River were improved. The operation of navigation-power junction had little impact on Han River water environment.

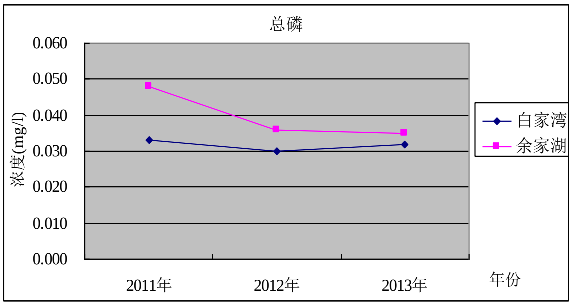
(3) Additional survey result

This evaluation has further collected water quality monitoring data from cross section of the reservoir area of Cuijiaying Hydro-junction(Baijiawan cross section) and a cross section downstream of the dam (Yujiahu cross section) of the recent three years. Six indicators of dissolved oxygen, permanganate index, BOD_5, ammonia nitrogen, total phosphorus and petroleum representing pollutant features of Han River were chosen for analysis.









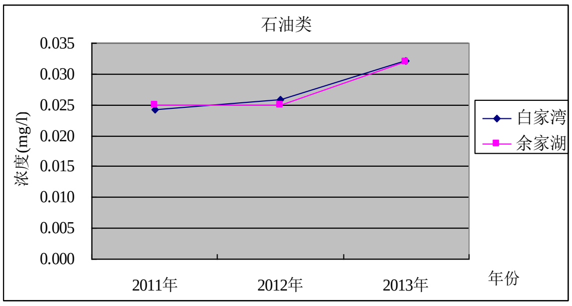


Figure 5.3.2-3 Variations of reservoir water quality after the operation of Cuijiaying hydro-junction

原文	English
浓度	Concentration
付家寨	Fujiazhai cross section
仙人渡	Xianrendu cross section
溶解氧	dissolved oxygen
高锰酸盐指数	permanganate index
氨氮	ammonia nitrogen
总磷	total phosphorus
pH 值	pH value

According to the Figure, after Cuijiaying reservoir construction, permanganate concentration index, total phosphorus pollutant concentration were basically stable, BOD_5, ammonia nitrogen and petroleum slightly went up, and dissolved oxygen fluctuated as it went up then down, which is in line with the environmental assessment prediction result of “overall water quality of Cuijiaying reservoir area is slightly worse than that of before dam construction”. Pollutant concentration of cross section downstream of the dam (Yujiahu cross section) was basically in line with that of the cross section of the reservoir area with little variations, indicating a generally stable water quality of the reservoir area. Water quality of Han River did not clearly went worse after reservoir completion and operation, and was in line with Class III water quality standard of *Surface Water Environmental Quality Standard* (GB3838-2002)

5.3.2.2 Eutrophication survey evaluation

From August 6 to 8 of 2012, Xiangyang Municipal Environmental Protection Monitoring Station conducted water body monitoring in Wangfuzhou and Cuijiaying reservoirs. Twelve main monitoring indicators included water temperature, transparency, PH value, dissolved oxygen, total phosphorus, total nitrogen, suspended solids, permanganate index, BOD_5, chemical oxygen demand, ammonia nitrogen and chlorophyll α.

Table 5.3.2-1 Water quality monitoring data of Cuijiaying reservoir area

Monitoring Project	Monitoring Time	Location of monitoring point					
		1km) Cuijiaying 1# (1km upstream of Baijiawan water intake)	1km) Cuijiaying 2# (1km upstream of Huoxingguan water intake)	Cuijiaying 3# (3km downstream of Yuliangzhou sewage treatment plant)	Cuijiaying 4# (Qianying monitoring cross section)	Wangfuzhou 5# (upstream of Lihua Lake wetland conservation area)	Wangfuzhou 6# (downstream of Laohekou urban area)
Water temperature (°C)	August 6	26	27	28	27	27	27
	August 8	27	27	27	27	27	27
SD (m)	August 6	0.1	0.2	0.2	0.3	1.0	1.2
	August 8	0.1	0.1	0.1	0.1	1.0	1.1
pH	August 6	7.9	7.8	7.9	8.0	8.0	8.0
	August 8	8.0	7.9	7.9	8.0	8.0	8.0
DO	August 6	5.16	5.58	7.08	5.85	5.84	6.15
	August 8	5.80	5.66	4.74	5.16	6.75	6.85
TP	August 6	0.074	0.070	0.113	0.032	0.042	0.038
	August 8	0.054	0.048	0.087	0.028	0.030	0.031
TN	August 6	1.12	1.18	2.79	1.34	1.27	1.47
	August 8	1.12	1.17	2.79	1.30	1.27	1.45
SS	August 6	16	41	10	12	8	7
	August 8	23	29	26	21	9	8
COD_{Mn}	August 6	5.70	6.45	6.74	3.51	5.64	5.02
	August 8	7.82	8.22	8.38	8.42	5.68	3.76
Five-day BOD	August 6	1.6	1.6	3.3	1.0	2.4	3.6
	August 8	2.0	2.4	2.5	2.5	0.9	1.0
COD	August 6	12	15	15	8	14	11
	August 8	18	19	19	19	13	9
AN	August 6	0.218	0.282	0.822	0.106	0.198	0.088
	August 8	0.066	0.076	0.326	0.088	0.025	0.038
$chla_{\alpha}$	August 6	10.8	5.85	5.62	4.35	8.43	4.48
	August 8	5.01	2.95	9.60	5.27	2.93	1.35

Five indicators of chla, TP, TN, SD and COD_{mn} were selected to evaluate the eutrophication in Wangfuzhou and Cuijiaying reservoirs using relevant weighted composite nutrition state index methods.

Calculation formula of composite nutrition state index is :

$$TLI(\Sigma) = \sum_{j=1}^{m} W_j \bullet TLI(j)$$

In which: $TLI(\Sigma)$—composite nutrition state index;

W_j—relevant weighed nutrition state index of parameter j;

$TLI(j)$—nutrition state index of parameter j.

A (chla) being the basic parameter, weighted calculation formula of parameter j normalization is:

$$W_j = r_{ij}^2 / \sum_{j=1}^{m} r_{ij}^2$$

In which: r_{ij} —relevant coefficient of parameter j and basic parameter a (chla);

m —number of evaluation parameter.

Correlations of a (chla) and some parameters of Chinese Lake and Reservoir

Parameter	chla	TP	TN	SD	CODmn
rij	1	0.84	0.82	-0.83	0.83
rij2	1	0.7056	0.6724	0.6889	0.6889

Nutrition state index calculation formula:

⑴ TLI(chla)=10(2.5+1.086lnchl)

⑵ TLI(TP)=10(9.436+1.624lnTP)

⑶ TLI(TN)=10(5.453+1.694lnTN)

⑷ TLI(SD)=10(5.118-1.94lnSD)

⑸ TLI(COD_{Mn})=10(0.109+2.661lnCOD)

in which: chla unit is mg/m^3, SD unit is m; unit of other indicators is all mg/L.

Nutrition state stratification:

TLI(∑)＜30　Oligotropher

30≤TLI(∑)≤50　Mesotropher

TLI(∑)>50　Eutropher

50＜TLI(∑)≤60 Light eutropher

60＜TLI(∑)≤70 Middle eutropher

TLI(∑)>70 Hyper eutropher

See Table 5.3.2-3 for evaluation result:

Table 5.3.2-3 Eutrophication level of reservoir water bodies

Reservoir	Point location	TLI(∑)	Eutrophication level
Cuijiaying reservoir	1#	59.4	Light eutropher
	2#	56.5	Light eutropher
	3#	62.5	Middle eutropher
	4#	53.0	Light eutropher
Wangfuzhou reservoir	5#	48.0	Mesotropher
	6#	44.6	Mesotropher

According to Table 5.3.2-3, composite eutrophication state index TLI(∑) of Cuijiaying reservoir is between 53.0 to 62.5, evaluated as light eutropher and middle eutropher, for it has a relatively short completion period, and pollutant source releasing from reservoir bottom has caused a temporary increase of pollutant concentrations such as TA and TN. Composite eutrophication state index TLI(∑) of Wangfuzhou reservoir is between 44.6 to 48.0, evaluated as mesotropher and having good water quality.

5.3.2.3 Water temperature impact survey

Wangfuzhou Hydro-junction and Cuijiaying hydro junction are both daily adjusting hydropower stations.

(1) Prediction result of EIA report

EIA report has adopted α and β methods to judge reservoir water temperature structure. According to calculation, Wangfuzhou dam has α value of 256.3, substantially exceeding 30. Therefore, water temperature of Wangfuzhou reservoir is of mixed type, and reservoir will not experience water temperature stratification.

With α value substantially exceeding 30, water temperature of Cuijiaying reservoir is of mixed type, with an average reservoir water depth of around 6m and frequently exchanged water body. Therefore, reservoir will not experience water temperature stratification.

(2) Water temperature review

Yujiahu monitoring cross section is situated 4km downstream of Cuijiaying reservoir. This evaluation uses water temperature data from Yujiahu monitoring cross section to review downstream water temperature variations before and after Cuijiaying reservoir construction.

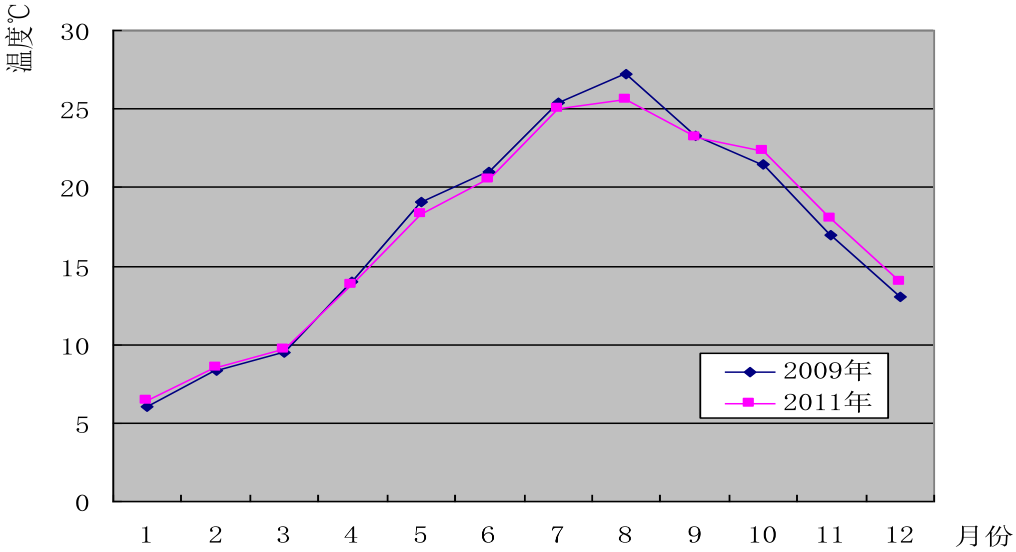


Figure 5.3.2-4 Variations of water temperature of Yujiahu monitoring cross section before and after Cuijiaying reservoir construction

原文	English
温度	Temperature
月份	Month

According to Figure 5.3.2-3, water temperature variation of Yujiahu monitoring cross section was relatively small prior Cuijiaying reservoir construction, having a slight drop of water temperature from April to August with a drop range of 0.1 to 0.8°C, and a slight increase of water temperature during the other seven months with an increase range of 0.2 ~ 1.0°C. Through data analysis, reservoir water temperature of Cuijiaying hydro-junction in the middle and lower reaches of Han River will not experience stratification, as water body temperature within the reservoir is mainly related to water temperature of upstream inflow (Discharged water temperature from Danjiangkou) and air temperature, thus causing no adverse impact on industrial, agricultural and domestic water use, as well as living conditions of aquatic organism.

5.3.3 Water quality impact downstream of the Dam

During Sept. 12~ 14, 2012, Xiangyang Municipal Environmental Protection Monitoring Station conducted water quality monitoring in the Han River cross section 100m downstream of Cuijiaying hydro-junction.

Table 5.3.3 Surface water monitoring results of cross section 100m downstream of the dam

Monitoring project	100m downstream of the dam			Class III standards	Standard exceeding rate (%)
	Left	Central	Right		
Water temperature	23 ~ 24	23 ~ 24	23 ~ 24	\	0
pH	7.9~8.0	7.9~8	7.9~8	6 ~ 9	0
SS	14	15	13	150	0
DO	6.38	7.28	6.43	5	0
BOD_5 (mg/L)	0.9	0.9	1.2	4	0
CODMn (mg/L)	3.61	3.14	2.82	6	0
TP (mg/L)	0.265	0.111	0.057	0.2	Left exceeded 0.32
AN (mg/L)	0.267	0.107	0.056	1.0	0
Petroleum (mg/L)	0.034	0.034	0.043	0.05	0

According to Table 5.3.3, BOD_5, CODMn index, AN and petroleum are all in line with relevant water quality standards, and only TP slightly exceeded standard in the left perpendicular of the cross section. See Figure 5.3.3 for comparison of water quality results downstream of the dam between the monitoring cross section acceptance period and the environmental assessment period. BOD_5 and AN in water body downstream of the dam went down by a certain degree compared with that of during the environmental assessment period, and other indicators had no clear change.

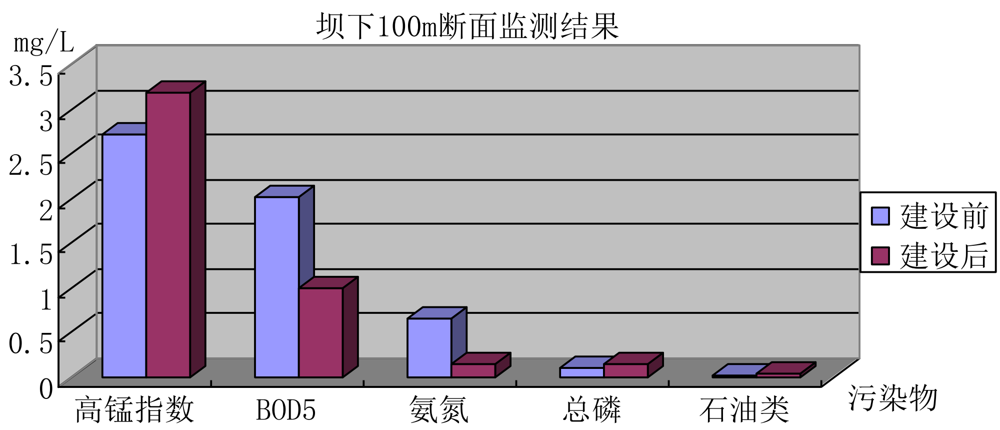


Figure 5.3.3 Comparison of water quality results downstream of the dam between monitoring cross section acceptance period and environmental assessment period

原文	English
回水区断面监测结果	Cross section monitoring result of backwater area
坝下 100m 断面监测结果	Monitoring result of cross section 100m downstream of the dam
建设前	Before construction
建设后	After construction
污染物	Pollutant
高锰酸盐指数	CODmn index
总磷	TP
氨氮	AN
石油类	petroleum

5.3.4 Groundwater impact analogy survey

a) Wangfuzhou Hydro-junction

Earth dam and embankment of Wangfuzhou Hydro-junction is in the shape of a pocket and is about 19km long, with a 6km gap between the dam site (and hydropower station) and sluice. See Figure 5.3.4-1 for the general layout of the junction. As there are similarities between the regional geological conditions, ecological environment and climate features of the project and Yakou Shipping Hub, According to results of the project completion acceptance survey of Wangfuzhou Hydro-junction regarding environmental protection and field survey of the Yakou project, in Dongqi Street of Laohekou city urban area, an area closest to the reservoir, there was no adverse impact of groundwater on main structures or the environment after the completion of the project. Through comparative analysis of surrounding environmental conditions after the completion of Wangfuzhou Hydro-junction, changes of groundwater level posed relatively small impact on the regional ecological environment (vegetation and terrestrial animal), water intake and use, and ditch surface water, without causing much change to the surrounding environment. See

Figure 5.3.4-2 for the current surroundings.

According to *Hubei Han River Wangfuzhou Hydro Junction Completion Acceptance Environmental Impact Survey Report*, after water storage Wangfuzhou Hydro-junction has three major impacts on groundwater:

(1) Burial depth of urban groundwater near the river was raised 0.5 to 3m from the previous 3 to 6m before reservoir construction. There was no impact on main structures in the main city area when carrying out drainage renovation project in Laohekou city because drainage and soaking were fully considered in building drainage projects such as Longhu channel and large open channel;

(2) After the completion of Wangfuzhou Hydro-junction, part of the left reservoir bank and part of Wangfuzhou overflow lands were impacted due to soaking. To decrease soaking impact on arable land, Wangfuzhou company offered a one-time compensation and the following construction measures: on one hand build drainage ditch behind the dam to effectively block groundwater generated by the reservoir; one the other hand build connected drainage ditch in farmland area that might be subjected to soaking, which are then connected to the drainage ditch behind the dam, in so doing not only further bringing down groundwater level and also contributing to flood drainage and drought resistance, combined with turning heavily soaked farmland into fish fond to develop aquaculture, thus effectively eliminating the impact of soaking to farmland.

(3) Project impact and measure to urban drainage and agricultural recession

Prediction result of the environmental assessment indicates that after the completion of Wangfuzhou reservoir groundwater level will approach or surpass the ground in the area to the east of urban Laohekou city and Chenjiabu area which is south to the urban area and close to the power station. Those areas will suffer from soaking, therefore, within the overall length of 4000m from Hangkou Street section of Laokekou city to Longhu channel section, relief wells will be drilled into the strong permeable lay beneath and the water discharged will be channeled to Longhu channel. Meanwhile, water-blocking trunk channel will be built on the river facing side of the Laokekou city and the east side of the urban area. A large open channel of about 6.8km long and 10 to 22m wide will be built along the left reservoir bank of Wangfuzhou to block water from Longhu channel, Qingshui channel, Wangxin River and Lijia River, which will then be joined by urban outflow to be discharged into Han River from downstream Wangfuzhou power station. Building the abovementioned projects will not only control groundwater level in most areas, but also greatly improve situations regarding urban sewage discharge, thus laying a good foundation to carrying out Laohekou urban sewage treatment project.

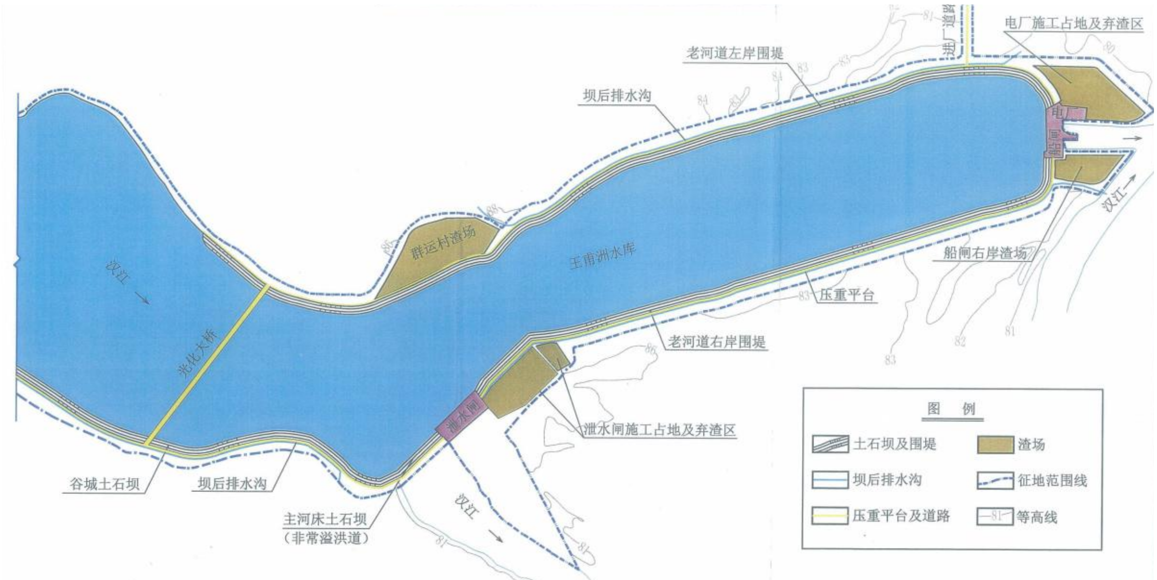


Figure 5.3.4-1 General layout of Wangfuzhou Hydro-junction

Current situation of reservoir

Reservoir bank

Farmland surrounding reservoir

Drainage channel

Figure 5.3.4-2 Current environmental conditions surrounding Wangfuzhou hydro station

b) Cuijiaying hydro-junction

The designed storage level of Cuijiaying Hydro-junction is 62.73m. Average groundwater level in the Xiangyang reach of Han River was raised due to the construction of Cuijiaying junction project. In that reach, Han River reservoir water level was raised by 3 to 6m, groundwater lever was raised by around 4m with an increased groundwater pressure, changing the recharge relation between the two banks of Han River. Groundwater receives recharge from Han River when water level of Han River is above that of the groundwater; groundwater discharges to Han River when water level of Han River is below that of the groundwater. Water from Han River has a long-term impact on groundwater, with a gradual variation from strong to weak as distance grows from near to far, and the recharge relation between water from Han River and groundwater also experiences a gradation of strong to weak and then to none.

However, there are close hydrological relations between water from Han River and groundwater in its surrounding first and second terraces. Han River is now making recharge to groundwater in the two banks where groundwater in the two banks used to make recharge for Han River in the most time before reservoir construction, and inundated areas are formed surrounding the reservoir area. By survey, there will be five major inundated areas after the project starts storing water, including Dawangzhou farmland inundated area, Xiejiatai inundated area, Yuliangzhou inundated area, Dongjin inundated area and Laolongdi inundated area. The locations and detailed treatment of the abovementioned inundated areas are list below:

(1) Dawangzhou farmland inundated area: it covers the area from the Dawangzhou on the left bank of Cuijiaying dam to Laoying, and it covers Laoying in the north and the left side of the dam in the south. There are two measures adopted in soaking treatment: one is in the area of Dawangzhou dam site where an area of about 100 hm^2 was treated by excavating diversion channel from December 2005 to March 2006 and backfilling with waste slag to 70m above the Yellow Sea elevation; the other is in the area of Laoying where an area of about 33.4hm^2 was treated by excavating open drainage channel and raising to 64m above the Yellow Sea elevation by backfilling. Currently all farmland in the area is tilled without suffering from soaking.

(2) Xiejiatai inundated area: it covers the area from the upstream right bank of the Cuijiaying dam to the left side of railway in the southeast suburb of Xiangyang city. Soaking treatment of the area was carried out in accordance with a program designed by Xiangyang Municipal Water Resources and Hydropower Survey and Design Institute. The area was previously purchased and stored by the municipal government as it was designated as urban construction land according to Xiangyang urban construction planning. To avoid redundant construction and with the approval of Xiangyang Municipal Government after conducting research, it was decided that Xiejiatai inundated area would not be treated for farmland soaking and would be implemented together with urban construction in the future. Currently, the area has a Xiejiatai sewage plant and a Tangcheng Studio City under construction.

(3) Yuliangzhou inundated area: it is situated in Jiangxinzhou of the reservoir area. Soaking treatment in the area was combined with the first and second overflow lands treatment of Yuliangzhou from 2007 to 2009 where it was raised to 64.23m above the Yellow Sea elevation and the urban area would not suffer from soaking after treatment. Currently, Yuliangzhou has been approved as a provincial level wetland park.

(4) Dongjin inundated area: it is situated on the upstream left bank of Cuijiaying dam. An area about 100 hm^2 was treated and backfilled to 64-64.5m above the Yellow Sea elevation by adopting the treatment measure of combining excavation and backfilling in relevant areas from May to August in 2009. It no longer suffers from soaking of the

reservoir area after the treatment.

(5) Laolongdi inundated area: it is situated in the area of Tanxi Street of Xiangyang city urban area. The urban area was already built during the project construction in the area and soaking treatment was already done during the urban construction. Currently, offices of Xiangyang Municipal Party Committee and Government have already been relocated to the area.

According to the outcome of the abovementioned survey, inundated areas formed after water storage of the project are mainly located in the lowland surrounding the reservoir area and are mostly treated by raising elevation through backfilling the inundated area. Meanwhile, this time the survey has also investigated village groundwater situations in the villages surrounding the reservoir area such as Daqiao village (Tangbai River estuary), Baiwan village (backwater area), and Qianying village (near dam site). Survey outcome reveals that well groundwater levels in the abovementioned villages have all gone up in varying degrees in a 1 to 2m range. No residential house in the villages surveyed was identified as been affected by soaking given that villages surrounding the reservoir area are on relatively higher grounds. Therefore, the project has relatively small impact on the inundated areas discussed above.

However, considering the fact that the impact of the project on groundwater will be a long-term process, it is suggested that groundwater levels in villages such as Daqiao village, Baiwan village and Qianying village shall be closely observed during the operation of the project, so as to reduce the impact of reservoir soaking on the lives and production of residents in the surrounding areas.

5.4 Aquatic ecology impact analogy survey

5.4.1 Aquatic ecology protection measures

5.4.1.1 Aquatic ecology protection measures

a) Wangfuzhou power station

There is no need to build fish pass facility given that Danjiangkou dam is built on the upstream of Wangfuzhou Hydro-junction and Han River has no typical migratory fish that spawn upstream. Yet environmental assessment requires setting up a no-fishing zone in the river section around the dam during breeding seasons of four Chinese carps and *Coreius heterokonto* protect spawning population stuck by the dam. The annual fishing moratorium (including this section) in Han River is from April 1 to June 3; Laokekou city on the upstream of Wangfuzhou reservoir annually releases 30-250g fingerlings *of Parabramis pekinensis, Ctenopharyngodon idellus , Hypophthalmichthys molitrix, Aristichthys nobilis* and *Carassius auratus* to Han River.

There are spawning grounds for fishes with pelagic eggs located in the upstream of Wangfuzhou Hydro-junction. There were records of four Chinese carps and Coreius heterokon breeding here from May to June. Setting up no-fishing zone during breeding season can protect natural spawning of fishes and matured parent fish. As China implements the policy of fishing moratorium during the breeding season of most fishes, no-fishing work of the power station is further reinforced.

b) Cuijiaying hydro-junction

1) Enhancement and releasing station

The former State Environmental Protection Administration put forward enhancement and releasing requirements in Environmental Approval [2005] No. 401 *Reply Letter on Han River Cuijiaying Hydro-junction Project Environmental Impact Report Office Action*: enhancement, releasing and fish protection station not only needs investment to construct but also daily maintaining management and it needs to be equipped with professionals. There are dams proposed to be built on both the upstream and downstream of the project, as a result enhancement, releasing and fish protection station should be considered on the basis of sufficient research and the cost should be settled by relevant departments through coordination.

To reduce the impact of Han River Cuijiaying Hydro-junction project on Han River fishery resources, construction unit has built fish stock enhancement and releasing station according to the requirement in environmental impact report and approval document.

(1) Enhancement station site selection and main structure

Fish stock enhancement station is location in the power station site on the left side of Cuijiaying dam. With water diverted from Han River and a 0.5km distance from the enhancement station, it enjoys good water quality and a natural riverway temperature throughout the year; it is conveniently assessable with traffic and power facilities available.

Main structures of fish stock enhancement station include stock ecological pond, parent fish pond, fingerling rearing pond and fry pond.

Stock ecological pond: it has an area of $6106m^2$, a depth of around 2.5m, a floor gradient of 0.3% and a pond slope ratio of 1:1 with cement slope protection.

Parent fish pond: it has an area of $6391m^2$, a depth of around 2 to 2.5m, a floor gradient of 0.5% and a pond slope ratio of 1:1 with cement slope protection of 2.0m wide. The entire pond is rectangle.

Fingerling rearing pond: it has an area of $2646m^2$, a depth of around 1.5 to 2m, a floor gradient of 0.5% and a pond slope ratio of 1:1 with cement slope protection of 2.0m wide. The entire pond is rectangle.

Fry pond: it has an area of $552m^2$ and it has a mixed structure of cement and bricks with filter and overfall units including both spawning pond and incubation tank. Spawning pond: it is round in shape with a 5m radius and a 1.5m depth. Its surroundings tilt towards the center with a floor gradient of 10% and it has inflow, outflow and overfall outlets. It has a mixed structure of cement and bricks with a 370mm pond wall and floor both covered by cement. There are two in total. Incubation tank: it is 2m long, 1.5m wide and 1.2m deep. With a curved inner angle and curved inner wall, water flow always rolls evenly. Filtering screen window is installed at 30 to 45 angles. The entire incubation tank comprises groups of two where two overfall ditches are placed on either side of the room and an enhancement ditch is built at the center.

(2) Enhancement and releasing situation

EIA report points out that the releasing types should include *Myxocyprinus asiaticus* (second-class national level protected animal), *Culter alburnus, Cyprinus carpio, Carassius auratus, Mylopharyngodon piceus, Ctenopharyngodon idellus, Hypophthalmichthys molitrix* and *Aristichthys nobilis*. The management office of Cuijiaying Hydro-junctionstarted operating fish stock enhancement station and launched the Million Fry Enhancement and Releasing Event in May 2012. Currently, the construction unit has been carrying out enhancement and releasing events irregularly since May 2012. From 2012 to 2013, there were altogether over 940 thousand releases including 2000 *Myxocyprinus asiaticus*, 60000 *Cyprinus carpio*, 350000 *Ctenopharyngodon idellus*, 50000 *Parabramis pekinensiss*, 100000 *Hypophthalmichthys molitrixs*, *250000 Silurus asotus*, 80000 *Carassius auratuss*, 50000 *Aristichthys nobilis* and 40 *Tortoise*.

Cuijiaying Hydro-junction fish stock enhancement station (1)

Cuijiaying Hydro-junction fish stock enhancement station (2)

Enhancement and releasing event site (1)

Enhancement and releasing event site (2)

2) Fishway

To avoid as much as possible the adverse impact of Cuijiaying Hydro-junction project construction and operation on aquatic conditions and fishery resources in the power station area and downstream, protect fishery resources in the basin, and preserve bio-diversity in the region, the construction has adopted measures to build fishway as required by environmental impact report and approval document, so as to meet the demand of fishes upstream and downstream of the dam to exchange and complete their life circles. Designed by Hunan Hydro & Power Design Institute, and based on the passing fishes, riverway typography and hydrological features of the river section, the fishway is transverse diaphragm plate and slot fishway, a design most commonly used in modern China. Main advantages of the fishway include easily controllable flow (flow velocity, flow regime), being adaptable to relatively large water level difference, and to the passing of fishes of different habitual nature by adjusting the type, location and size of the orifice, as well as simple structure, convenient construction and maintenance management.

(1) Fishway design standard

According to *Flood Control Standard* (GB50201-94) and *Water Resources and Hydropower Junction Projection Classification and Flood Standard* (SL252-2000), the classes of main structure and secondary structure (fishway) of Cuijiaying Hydro-junction project, a grade two project, were determined to be class two and class three. Fishway design flood adopted a 20-year frequency standard corresponding to a flood flow of 15820m^3/s and check flood standard adopted a 100-year frequency standard corresponding to a flood flow of 21710m^3/s.

(2) Fishway design conditions

Main fish-passing subjects of the project fishway are: parent and adult fishes such as migratory fish species of *Anguilla japonica* and *Coilia macrognathos*, as well as semi-migratory fish species of *Ctenopharyngodon idellus, Mylopharyngodon piceus, Hypophthalmichthys molitrix, Aristichthys nobilis* and *Coreius heterokon*. It is suitable mainly for economic fish species such as the "four Chinese carps ". The fish-passing season is from May to August. Fishway design adopts the normal reservoir storage level of ∇62.73m upstream and the average annual water level of ∇57.23m from May to August downstream. Considering factors such as dam height, water level drop, main passing fish species and fish-passing time, by learning from and comparing with foreign fishway experience, and combining with features of the project, fishway design parameters are determined as follows: fishway flow velocity should be within 0.5 to 0.8m/s, discharge should be within 1.8 to 2.8m^3/s, inter-pond drop should be within 0.02 ~ 0.04m and pond depth should be within 1.8 ~ 2.0m.

(3) Fishway layout

The location of the fishway entrance directly impacts fish-passing effect. Considering the layout of various structures of the junction, riverway typography and hydrological feature, and also taking into account that fish stock usually clusters around the tail water pipe where there is often water discharge from the power station, the main entrance of the fishway is determined to be on the left side of the tail water channel of the hydropower station and it is connected with the fish collection system (fish collection system aims to extend the length of the fish-entering front and is located at the platform above the entire tail water pipe) of the tail water platform of the power station. Upstream water enters recharge system through special recharge channel, then enters fish collection system through recharge orifice on the wall between recharge system and fish collection system, and allures fish with the sound of water dropping. Fish collection system has four fish entering orifices (size 650mm×650mm) of various heights facilitating the entering of fish. Fish entering the fish collection system meet fish entering from the main fishway entrance in the meeting pond and then go upstream along the fishway. Fishway outlet is on the upstream of the inflow channel floating track rack of the hydropower station, and is should be located in a place far away from discharge channel and with relatively small flow velocity so as to facilitate fish species going further upstream.

(4) Main structural dimensions of the Fishway

Considering both the fish-passing amount and subjects, fishway is determined to be 2m wide. Taking into account a series of parameters mentioned above and the general layout of the station, fishway route is determined with a total length of 487.2m and an average gradient of 1/85. Fishway pond chamber length L is determined to be 2.6m and depth is determined to be 2m. A 5m long resting pond is set up in between every ten fish ponds, with 200mm diaphragm plate. Diaphragm plate in the fishway open channel section is pre-fabricated steel-mesh cement plate for easy maintenance, and has two 300mm×300mm fish-passing orifices on the plate bottom, as well as a 1000mm×1000mm fish-passing orifice (orifice location alternates on adjacent plates for energy dissipation) on one side. Side wall in the fishway culvert section is determined to be 800mm wide and 2000mm high with connected circular arch for top structure. Fishway culvert section adopts lighting to allure fish. Two plate gates are situated in the upstream outlet of the fishway, with one for maintenance and the other for flood control and fish collection system discharge adjustment, and are of both manual and electrical screw headstock gear for opening and closing.

A plate gate, of both manual and electrical screw headstock gear for opening and closing, is placed at the bottom plate of upstream recharge channel entrance, for the purpose of flood control and recharge channel discharge adjustment. Discharged water from recharge channel outlet hits the surface of downstream recharge system and then enters into the fish collection system through 300 φ80mm-sized recharge orifices on the walls between the recharge system and the fish collection system. Recharge channel is 201.97m long; recharge system and fish collection system are 1000mm and 2000mm wide respectively and both 125m long, overhanging from the tail water pipe of the hydropower station. Bottom elevations of recharge system, fish collection system, meeting pond and main fish entrance are all ∇55.0m. Fish entering orifices (size 650mm×650mm) are placed on elevations ∇55.3 m and ∇56.95m of the fish collection system.

Fishway main entrance

Cuijiaying Hydro-junction fishway

Fishway outlet

5.4.1.2 Cuijiaying aquatic ecology protection measures effect and problem survey

a) Enhancement releasing

Facilities such as stock ecology pond, parent fish pond, fry rearing pond, spawning induction pond and water diversion pipeline are completed and can be operated, but supporting facilities such as incubation facility and fry pond are not completed and not able to operate because they have not met the original design functions and are in need of renovation. Currently, the enhancement and releasing station of the project is of a single working method of rearing purchased fry in the station before releasing, and is without professional staff. To better utilize the functions of the enhancement and releasing station, it is suggested that operation unit should employ professionals or cooperate with local department of fishery and aquatic product according to the actual situation, so as to improve works on the collection, taming, rearing and artificial reproduction of wild parent fish, and continue to optimize functions of the enhancement and releasing station in terms of its actual work in releasing species pointed out by the environmental assessment report as well as additional species based on the actual situation of the current Han River fishery resources, thus becoming a multi-functional and multi-releasing station.

As to problems of Cuijiaying enhancement and releasing station, construction unit plans to raise fund from multiple channels targeting the improvement renovation of the station, and entrust Hubei Provincial Transportation Planning Design Institute and Hunan Hydro & Power Design Institute with project design. It mainly increases 480m^2 of production plant, 30,000m^2 of fry pond, 1200m^2 of popular science exhibition, lab and office, as well as other supporting facilities and lab testing equipment, with a total investment of 10.3 million Yuan, amongst which 2.7 million Yuan is from the 2015 financial allocation and 7.6 million are surplus construction fund. Public bidding regarding production plant and supporting buildings was on September 28, 2015. The entire renovation project was estimated to be completed in May 2016.

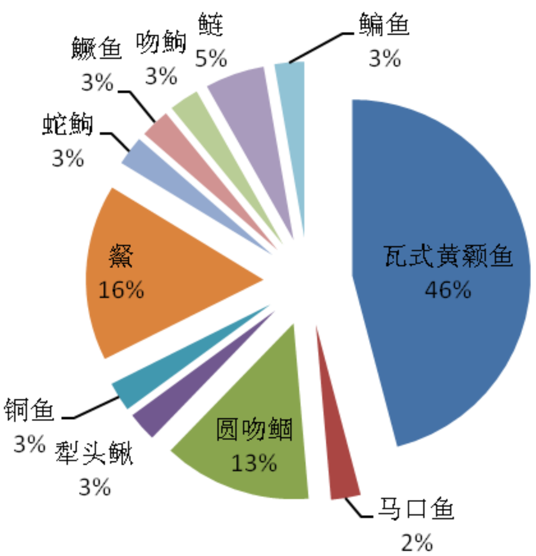
In terms of operation and management, *Cuijiaying Enhancement and Releasing Station Operation Management Regulation* was improved to standardize the requirements on managing the enhancement and releasing station such as operation procedure, production technique, equipment management and safe operation. It is planned to entrust professional agency to provide technical support for the daily operation of the station, and to gradually build an exhibition base featuring fish stock enhancement and releasing, artificial reproduction technology research and fish stock popular science of Han River.

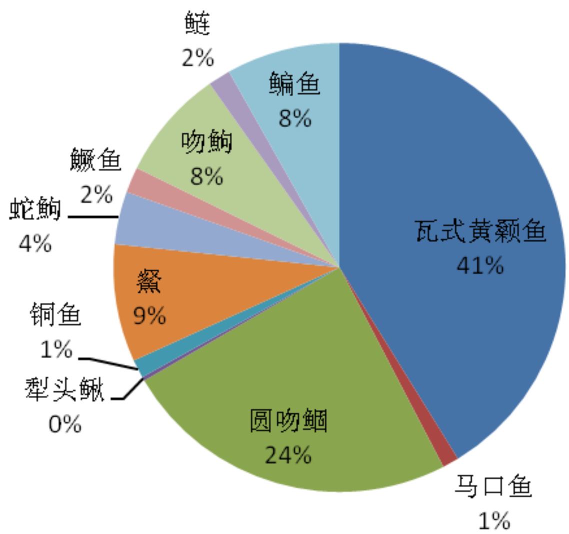
b) Fishway

To find out the operation effect of the project fishway, construction unit entrusted Yangtze River Fisheries Research Institute of Chinese Academy of Fishery Sciences to monitor fish-passing effect of the project fishway from 19 to 26 of September in 2012. Important data on the species and number of the passing fish, and biological features were obtained by applying the combined methods of recapturing and hydroacoustic monitoring with a triple-layered drift net.

Triple-layered drift net was used in an experimental net capturing in the fishway of Cuijiaying Hydro-junction project in late September 2012. Net was lowered twice per day at 6 am and 6 pm. Each time with three pieces of triple-layered drift net of about 15m long were placed with the first net positioned at 8m from orifice of the fishway outlet, and the other two nets placed with 10m intervals, and the duration of each net capturing continues for 10 hours.

The experimental capturing has captured fishes of three orders, four families and eleven species, namely *Pelteobaggrus vachelli*, *Rhinogobio typus*, *Parabramis pekinensis*, *Saurogobio dabryi*, *Opsariichthys bidens*, *Distoechodon tumirostris*, *Lepturichthys fimbriata*, *Coreius heterokon*, *Siniperca chuatsi*, *Hypophthalmichthys molitrix*, and *Hemiculter leucisculus*. Among the recaptured fish, *Cypriniformes* are most common with nine species accounting for 81.8% of the total; next are one species each of *Siluriformes* and *Perciformes*, accounting for 9.1% of the total respectively. Amongst all the 37 captured fish, *Pelteobaggrus vachelli* are the most, and *Hemiculter leucisculus* and *Distoechodon tumirostris* are the second most; See Figure 5.4.1-1 for fish quantitative distribution. Total weight of the captured fish is 2813.4g, in which *Pelteobaggrus vachelli* is of the most weight, and *Distoechodon tumirostris* is of the second most weight; See Figure 5.4.1-2 for fish weight distribution.





原文	English
瓦氏黄颡鱼	*Pelteobaggrus vachelli*

吻鮈	*Rhinogobio typus*
鳊鱼	*Parabramis pekinensis*
蛇鮈	*Saurogobio dabryi*
马口鱼	*Opsariichthys bidens*
圆吻鲴	*Distoechodon tumirostris*
犁头鳅	*Lepturichthys fimbriata*
铜鱼	*Coreius heterokon*
鳜鱼	*Siniperca chuatsi*
鲢	*Hypophthalmichthys molitrix*
鳘	*Hemiculter leucisculus*

Figure 5.4.1-1 Fish quantitative proportion of Cuijiaying fishway net recapturing

Figure 5.4.1-2 Fish weight proportion of Cuijiaying fishway net recapturing

Sixteen fish species (Table 5.3-5) of three orders, six families and sixteen species, were gathered in the dam site of Han River Cuijiaying power station in September 2012, among which *Cypriniformes* are most common with twelve species accounting for 75% of the total; *Siluriformes* are of three species accounting for 18.75%; *Perciformes* is of one species accounting for 7.25%. In *Cypriniformes, Cyprinidae* are most common with eleven species accounting for 91.7% of the total *Cypriniformes; Siluriformes* are of one species each of *Bagridae, Serranidae* and *Siluridae.*

Following environmental assessment and approval requirements, the project set up fishway online observation equipment to observe the operation effect of the fishway. The online observation equipment include three underwater cameras located in fishway entrance, middle and upper section of the fishway and the middle and lower section of the fishway respectively, and it has been included into the overall monitoring system of the dam area. According to fish situation monitoring from May to August in 2013, although the number of fish in fishway entrance was relatively large, fish-passing phenomenon observed in the middle section of the fishway was not clear and it was almost unable to identify detailed situations such as type and number of the passing fish. Operation unit examined the camera in the middle section, and found out that the camera was unable to monitor largely due to aquatic plant and sediment coverage.

5.4.2 Aquatic ecology impact analogy survey

5.4.2.1 Impact of developed hydropower projects on fish stock

a) Fishery yield evolution

Average annual yield in the three years (1958 to 1960) prior the construction of Danjiangkou reservoir dam was 47.3t in Gucheng, 17.5t in Xiangfan and 38.5t in Yicheng; Average annual yield after the dam construction was 77t in Gucheng, 25.5t in Xiangfan and 57.5t in Yicheng. Annual yield after dam construction was substantially higher than that of before dam construction. In 2004, Institute of Hydroecology counted the capturing yield from 1995 to 2003 of the eleven counties from Danjiangkou to Hanchuan in the middle and lower reaches of Han River

In the approximate ten years between 1994 to 2003, capturing yield in various counties and cities were substantially higher than that of the average annual yield of the seventeen years (1961 to 1977) after the dam construction, among which the average annual fishery yields of Gucheng, Xiangfan and Yicheng of the recent ten years were 409t, 761t and 656t respectively, ten to thirty times that of the average annual yield of the seventeen years after the dam construction, and yield increased by much more in the downstream instead of the upstream river section of Xiangfan. Analyzing yield variations of the recent ten years, the maximum value of fishery yield for various counties and cities along the Han River appeared from 1997 to 1999, which was then followed by annual declines. Currently, there is a rapid downward trend of fishery yield in Han River.

b) Fish species and major economic fish formation evolution

By counting the catch of major fishing tools such as triple-layered drift net, electronic trawl-net, ditch net, silk fishing net and cormorant in the approximate 550-kilo long river section from the middle and lower reaches of Han River to Hanchuan during July to September of 2004, major economic fish species in the middle and lower reaches of Han River are listed according to yield: *Cyprinus carpio, Carassius auratus, Parabramis pekinensis, Pelteobagrus fulvidraco, Ctenopharyngodon idellus, Squaliobarbus curriculus, Hypophthalmichthys molitrix, Silurus spp, Culter alburnus, Opsariichthys bidens, Pelteobagrus fulvidraco* and *Mystus macropterus.* Comparing with the 1976-1978 survey, *Ctenopharyngodon idellus* (accounting for 22.18% of the catch weight), *Coreius heterokon* (16.37%) and *Parabramis pekinensis* (8.05%) which were of prominent status in the fishery industry, were replaced by *Cyprinus carpio* (48.13%), *Carassius auratus* (9.73%), *Parabramis pekinensis* (9.47%) and *Pelteobagrus fulvidraco* (8.97%), in particular with *Cyprinus carpio* accounting for half of the catch weight and *Coreius heterokon* stock hardly able to contribute in yield due to rapid decrease. In addition, *Aristichthys nobilis*, *Mylopharyngodon piceus* and *Elopichthys bambusa* were rarely seen. *Luciobrama microcephalus* and *Ochetobius elongatus* were not found in years and are endangered.

According to analysis outcome of catch from the three river sections, the average catch weight was only 147.56g. In terms of fish weighing less than 100g, there were 20 species in the river section in the upstream of Xiangfan, 27 species in the Xiangfan-Shayang section, and 27 species in Shayang-Hanchuan section, with the top 10 species of the catch except for *Cyprinus carpio* being relatively large fish and the rest being small fish. Han River fishery resources are clearly becoming smaller in size. The trend can be supported by the survey outcome of spawning ground of fish species with pelagic eggs as the spawning scale of the four Chinese carps substantially narrows and the spawning scale of small-sized fish obviously expands.

c) Spawning ground evolution

Most of the fish species in the middle and lower reaches of Han River are of pelagic eggs, among which around 80 % are spawning slightly adhesive eggs and pelagic eggs in flowing water. Spawning season is often from May to August. *Parabramis pekinensis*, *Elopichthysbambusa*, *Siniperca chuatsi* and *Rhinogobio typus* have a relatively early spawning period while *Mylopharyngodon piceus*, *Luciobrama microcephalus* and *Aristichthys nobilis* have a relatively late spawning period.

Wangfuzhou was completed and started power generation in 2000, and passed various project acceptances in 2003; Cuijiaying's main structure was completed and started operation in 2010; Xinglong started in 2009 and is currently under construction. Each project construction involves variations of hydrology and riverbed conditions of the relevant sections of Han River, which to a certain extent impact fish spawning ground.

See Table 5.4.2-1 for outcome comparison of spawning ground survey of fish with pelagic eggs in the middle and lower reaches of Han River during May to August of 2004 and the 1976-1978 survey. From 1978 to 2004, economic fish with pelagic eggs was reduced from the "Four Chinese carps", *Luciobrama microcephalus, Elopichthysbambusa, Parabramis pekinensis, Squaliobarbus curriculus, Rhinogobio typus, Erythroculter Genus, Siniperca chuatsi* and *Coreius heterokon* to the "Four Chinese carps", *Parabramis pekinensis, Squaliobarbus curriculus, Rhinogobio typus* and *Erythroculter Genus*. The former Wangfuzhou spawning ground in the middle and lower reaches of Han River disappeared due to the construction of Wangfuzhou Hydro-junction; number of spawning grounds of the four Chinese carps was reduced by one, and with changing locations; Xiangfan spawning ground disappeared; spawning grounds of other types of economic fish increased by one, with locations shifting up and down; number of small fish spawning ground was substantially increased to be scattered throughout the middle reach. The spawning scale of the four Chinese carps and other economic fish with pelagic eggs was substantially reduced to 457 million from 1374 million seeds; spawning scale of small fish with pelagic eggs was increased by over ten times from 1104 million to 1.5869 billion seeds. Spawning grounds of the four Chinese carps disappeared in the tributary Tangbei River (See Table 5.4.2-2), where the only economic fish species left was *Squaliobarbus curriculus* with only 48% of the previous spawning amount, and the spawning scale of small fish was maintained.

Table 5.4.2-1 Variations of spawning grounds of fish with pelagic eggs in the middle reach of Han River

Type		1976 to 1978	2004	Explanation
Spawning ground	Four Chinese carps	Six in Wangfuzhou, Cihe, Xiangfan, Yicheng, Zhongxiang and Maliang	Five in Miaotan, Yicheng, Guanjiashan, Zhongxiang and Maliang	Wangfuzhou spawning ground disappeared; Xiangfan spawning ground of four Chinese carps
	Other economic fish species	Six in Wangfuzhou, Cihe, Xiangfan, Yicheng, Zhongxiang and Maliang	Seven in Miaotan, Xiangfan, Yicheng, Guanjiashan, Zhongxiang ,Maliang	

			and Chenjiakou	disappeared; small-sized fish species scatted throughout the middle reach
	Small-sized fish species	Six in Wangfuzhou, Cihe, Xiangfan, Yicheng, Zhongxiang and Maliang	Fifteen in Wangfuzhou to Shayang	
Spawning km number	Four Chinese carps	169	120	Domestic fish and economic fish species reduced; small-sized fish species increased
	Other economic fish species	169	135.4	
	Small-sized fish species	169	195.1	
Spawning scale	Four Chinese carps	470.78 million seeds	93.30 million seeds	Domestic fish and economic fish species reduced; small-sized fish species increased
	Other economic fish species	903.42 million seeds	364.16 million seeds	
	Small-sized fish species	1.10380 billion seeds	15.86905 billion seeds	
Spawning economic fish species		"Four Chinese carps", *Luciobrama microcephalus, Elopichthysbambusa, Parabramis pekinensis, Squaliobarbus curriculus, Rhinogobio typus, Erythroculter Genus, Siniperca chuatsi, Coreius heterokon* and etc	Eight species of "Four Chinese carps", *Parabramis pekinensis, Squaliobarbus curriculus, Rhinogobio typus* and *Erythroculter Genus*	Spawning economic fish reduced by 4 species
Economic fish species: small-sized fish species		1.24:1	1:34.69	

* Economic fish species refer to the four Chinese carps and other economic fish species.

Table 5.4.2-2 Variations of spawning grounds of fish with pelagic eggs in the Tangbai tributary in the middle reach of Han River

Type		1976 to 1978	2004	Explanation
Spawning ground	Four Chinese carps	Guotan and Bukou	None	Spawning ground of four Chinese carps disappeared; small-sized fish species increased
	Other economic fish species	Guotan and Bukou	Xiandian, Zhuji, Bukou and Changzhuang	

Type		1976 to 1978	2004	Explanation
	Small-sized fish species	Guotan and Bukou	Xiandian, Zhuji, Bukou, Changzhuang and Gongjiazui	
Spawning km number	Four Chinese carps	63	0	No domestic fish; economic fish and small-sized fish species reduced
	Other economic fish species	63	34.8	
	Small-sized fish species	63	38.3	
Spawning scale	Four Chinese carps	458.98 million seeds	0 seeds	No domestic fish; economic fish species reduced; small-sized fish species increased
	Other economic fish species	1.31088 billion seeds	74.94 million seeds	
	Small-sized fish species	453.63 million seeds	529.85 million seeds	
Spawning economic fish species		"Four Chinese carps", *Luciobrama microcephalus, Elopichthysbambusa, Parabramis pekinensis, Squaliobarbus curriculus, Rhinogobio typus and Erythroculter Genus, Siniperca chuatsi, Coreius heterokon* and etc	One species of *Squaliobarbus curriculus*	Spawning economic fish reduced by 11 species
Economic fish species: small-sized fish species		3.90:1	1:7.07	

* Economic fish species refer to the four Chinese carps and other economic fish species.

5.4.2.2 Impact of Wangfuzhou Hydro-junction construction on fish species

a) Species composition

Han River Wangfuzhou Hydro-junction Environmental Impact Report holds: dam construction caused fish stock in the reservoir area to be mainly lacustrine fishes fitting to live in still waters and slowly flowing waters; regional structure of the fish species will not change much.

According to the 2012 survey, species such as *Varicorhinus macrolepis, Sinibrama wui, Opsariichthys bidens, Gobiobotia filifer, Lepturichthys fimbriata* and *Glyptothorax sinense* of Wangfuzhou reservoir were still distributed in the section, accounting for only a small portion of the catch, and small-sized fishes are mainly *Hemiculter leucisculus, Acanthorhodeus macropterus, Leptobotia taeniaps, Hypseleotris swinhonis* and *Rhinogobius candidianus*. Some fish species favoring still waters such as main economic fish species of *Cyprinus carpio, Carassius auratus, Siniperca chuatsi* and *Pelteobagrus fulvidraco* accounted for over 60% of the catch, in particular with an increased number of *Hemisalanx prognathous*.

The blocking effect of Wangfuzhou dam on fish species favoring still waters is not big. The number of organisms of broadly distributed fish species increased and *Coreius heterokon* disappeared from the reservoir area.

Analogy survey holds that the current condition is in line with the prediction of the 1998 environmental impact evaluation.

b) Spawning ground

Fish species in the middle and lower Han River feature a relatively large number of economic fish species, among which important economic fish that are commonly seen include *Parabramis pekinensis, Culter mongolicus, Culter alburnus, Cyprinus carpio, Carassius auratus, Coreius heterokon, Mylopharyngodon piceus, Ctenopharyngodon idellus, Hypophthalmichthys molitrix, Aristichthys nobilis, Squaliobarbus curriculus, Leiocassis longirostris, Silurus asotus, Pelteobagrus fulvidraco, Siniperca chuatsi, Elopichthys bambusa* and *Cypriniformes type*, with most of them having pelagic eggs including both slightly viscous egg type and pelagic egg type. Spawning period of fishes with pelagic eggs is generally from May to August, among which *Hemiculter leucisculus, Pseudobrama simoni, Elopichthys bambusa, Acanthobrama simoni* and *Rhinogobio typus* have a relatively early spawning period starting from early May; *Coreius heterokon, Parabramis pekinensis, Squaliobarbus curriculus, Ctenopharyngodon idellus* and *Hypophthalmichthys molitrix* generally start from mid-May; *Mylopharyngodon piceus* and *Luciobrama macrocephalus* have a relatively late spawning period generally starting from late May; *Aristichthys nobilis* starts in mid-June. There are also differences in spawning periods as affected by Danjiangkou hydro junction project, including a 20 to 30 days delay compared with that of before dam construction regarding fish reproduction in the middle and lower reaches of Han River due to low-temperature water discharge, with fish reproduction period generally extending to mid-August or late August.

The construction of Wangfuzhou Hydro-junction and hydrological changes caused clearly changed the spawning ground conditions of fishes with pelagic eggs, which led to the disappearance of the spawning ground. Danjiangkou hydro junction has caused overlapping impact on water environment as winter water temperature is raised, thus keeping the scale of the former wintering ground. The rock bottom features and relatively good transparency of the river section are conducive to massively reproducing aquatic plant, filamentous algae and mollusk, thus becoming feeding ground or fishing ground of phytophagous fish species such as *Ctenopharyngodon idellus* and *Parabramis pekinensis*, as well as species such as *Coreius heterokon*, *Cyprinus carpio* and *Mylopharyngodon piceus*.

Han River Wangfuzhou Hydro-junction Environmental Impact Report holds: dam construction might establish new spawning ground downstream the dam and yield will be increased compared with under natural conditions. Survey points out that the current condition is not in line with the prediction of the 1998 environmental impact evaluation for there is no new spawning ground identified and no visible yield increase.

5.4.2.3 Impact of Wangfuzhou Hydro-junction construction on fish species

a) Species composition

The reservoir receives inflows from main stream Han River and Tangbai River. It is rich in fish species, existing species in the middle and lower reaches of Han River are all found here with the exception of *Anguilla japonica, Coreius heterokon, Acipenser sinensis, Luciobrama microcephalus, Coilia macrognathos*, *Myxocyprinus asiaticus*, *Ochetobibus elongatus* and *Luciobrama microcephalus*. Main economic fish species include *Cyprinus carpio, Carassius auratus, Erythroculter ilishaeformis, Squaliobarbus curriculus, Megalobrama skolkovii, Silurus asotus*, *Monopterus albus* and *Misgurnus anguillicaudatus*. Stock number of fish species favoring still waters has increased.

To understand the impact of project trial operation on aquatic organism in the water area, survey unit entrusted Wuhan University to survey the current conditions of aquatic organism resources in the area in August 2012. The survey selected two locations, one being 100m upstream and the other 100m downstream of Cuijiaying power station, and altogether collected 19 fish species (Table 5.4.2-3) of three families and three orders, among which *Cypriniformes* are most common with 16 species accounting for 84.2% of the total; *Siluriformes* have 2 species accounting for 10.5%; *Perciformes* has one species accounting for 5.3%. Catches in the upstream and downstream of the dam are basically similar, with 16 species collected upstream and 19 species collected downstream of the dam, and there are all common economic fish species in Han River.

Table 5.4.2-3 Types and distribution of fish species

Serial No.	Species name	Scientific name	Upstream of the dam	Downstream of the dam
1	鲤	*Cyprinus (Cyprinus) carpio haematopterus*	+	+
2	鲫	*Carassius auratus*	+	+
3	多鳞铲颌鱼	*Varicorhinus macrolepis*		+
4	唇鲳	*Hemibarbus labeo*	+	+
5	花鲳	*H.maculatus*	+	+
6	银鮈	*Squalidus argentatus*	+	+
7	似鮈	*Pseudogobio vaillanti*		+
8	蛇鮈	*Saurogobio dabryi*	+	+
9	吻鮈	*Rhinogobio typus*	+	+
10	𩾌	*Hemiculter leucisculus*	+	+
11	鳊	*Parabramis pekinensis*	+	+
12	草鱼	*Ctenopharyngodon idellus*	+	+
13	青鱼	*Mylopharyngodon piceus*	+	+
14	马口鱼	*Opsariichthys bidens*	+	+
15	鲢	*Hypophthalmichthys molitrix*	+	+
16	鳙	*Aristichthys nobilis*	+	+
17	光泽黄颡鱼	*P. nitidus*		+
18	瓦氏黄颡鱼	*P. vachelli*	+	+
19	鳜	*Siniperca chuatsi*	+	+

Samples were collected at a location 1 km upstream of the Cuijiaying dam site through normal and hyper-normal (electric shocking) capturing methods during the environmental assessment, and investigated by local fishermen and fishery department. 11

species of fish were collected including *Opsariichthys bidens, Hemiculter leucisculus, Sarcocheilichthys nigripinnis, Gnathopogon imberbis, Cyprinus carpio, Carassius auratus, Squalidus argentatus, Huigobio chinssuensis, Acheilognathus barbatulus, Cobitis sinensis* and *Pelteobaggrus nitidus*.

Acceptance survey collected 19 species in the upstream and downstream of the dam site of Han River Cuijiaying power station. Catches in the upstream and downstream of the dam are basically similar, with 16 species collected upstream and 19 species collected downstream of the dam. The number of fish species collected in the survey is slightly more than that of the environmental assessment, with no clear change in terms of species composition and there are all common economic fish species in Han River. The survey is also basically similar with catch collected in the upstream and downstream of the dam site by Yangtze River Fisheries Research Institute of Chinese Academy of Fishery Sciences in September 2012. Generally speaking, fishway and fish stock enhancement and releasing station built by Cuijiaying Hydro-junction have to a certain extent reduced the impact of project construction on Han River fish resources.

Environmental impact report holds: after dam construction, the number of *Myxocyprinus asiaticus* gradually went down for lack of recharge of parent fish from upstream, but the species is unlikely to be extinct. In the 2012 survey, no sample of *Myxocyprinus asiaticus* was collected in Cuijiaying reservoir and further observation is needed to verify the environmental assessment outcome.

b) Spawning ground

According to the 2004 survey outcome, there were seven spawning grounds in the middle reach of Han River, namely Miaotan, Xiangfan, Yicheng, Guanjiashan, Zhongxiang, Maliang and Chenkongkou, among which were five spawning grounds for the Four Chinese carps, namely Miaotan, Yicheng, Guanjiashan, Zhongxiang and Maliang. According to the 2009 survey outcome, there were three spawning grounds in the middle reach of Han River, namely Yicheng, Guanjiashan and Zhongxiang. In 2014, pelagic eggs were only found in Guangjiashan and Zhongxiang sections. It can be determined that spawning grounds in Wangfuzhou-Cuijiaying river section, and tributaries such as Miaotan and Xiangfan were disappeared prior the construction of Cuijiaying hydro junction, whereas spawning grounds in Yicheng, Guangjiashan and Zhongxiang were reduced to spawning grounds for other economic fish species and small-sized fish species. Therefore, it is deduced that Miaotan spawning ground will be basically dysfunctional as the “Four Chinese carps” go upstream of Cuijiaying and form barrier after the completion of Cuijiaying. In 2014, early fish resources was not found in Yicheng spawning ground due to reasons such as Danjiangkou reservoir water storage, Xinglong barrier, Tangbei River having late flood (September) with small discharge, and Cuijiaying reservoir planarization.

The completion of Cuijiaying reservoir improves transparency and is conducive to the development of periphytic algae, *Limnoperna fortunei* and fish-type forage. Currently the section downstream of the dam is a relatively large fishing ground. The 2004 *Han River Cuijiaying Hydro-junction Project Environmental Protection Report* holds: after dam construction, new spawning ground will be hard to form as spawning ground in the upstream of the reservoir no longer meets the requirements due to the slowed water flow. Survey holds that the current condition is basically in line with the environmental impact evaluation prediction outcome of 2004, but there are still spawning grounds in the upstream of the reservoir for other economic fish species and small-sized fish species that have lower hydrological demand. However the scale of those remaining spawning grounds was narrowed and the previously existed spawning grounds for small-sized fish species in the middle and lower sections of the reservoir area were completed gone. The disappearance of spawning grounds of the “Four Chinese carps” was largely because of hydrological regime change caused by the construction of Danjiangkou, Wangfuzhou reservoir and Cuijiaying junction as well as the severe pollution of Tangbei River.

5.5 Resettlement environmental impact survey

5.5.1 Resettlement mitigation measures

a) Wangfuzhou Hydro-junction

According to the survey, the actual resettlement of Wangfuzhou Hydro-junction project includes 96 immigrants of 22 households and 4866 people in terms of production resettlement. Resettlement work was led by the Xiangyang Municipal People's Government, and carried out by Laohekou city and Gucheng county adopting the management mechanism of taking responsibility for one's surpluses or deficits. Relocation and settlement work has built biogas digesters as supporting facility and implemented environmental and water protection measures such as road block drainage ditch and vegetation restoration. There were three ways of production resettlement according to different local features: ① 6100 mu low-yielding land and overflow lands were restored and 800 mu villagers' land was adjusted to ensure land for the resettled immigrants whose livelihood are dependent on land; ②utilize opportunities brought to the reservoir area by project construction and actively develop the second and tertiary industries; ③ After gaining consent of the immigrants use land compensation fee as a capital fund for the project and give out dividend based on shares during resettlement. Through visit and survey, it is known that immigrants are all quite satisfied about the current living conditions and arable land, and they have basically adapted to the way of life and production after the relocation and have a harmonious relation with resident previously residing in the relocated area.

b) Cuijiaying hydro-junction

The resettlement work, protection of reservoir area and reconstruction work regarding Cuijiaying project construction was entrusted to be implemented and executed by Xiangyang Municipal Government in the form of all-in cost where it would take responsibility for its surpluses or deficits. 34560.9 mu of land was inundated and 223 people of 57 households were relocated because of the project. In resettlement, relevant units did sufficient work on publicizing knowledge on infectious disease prevention and raising health knowledge level and health maintenance awareness among immigrants; carrying out targeted environmental and health cleaning and disinfection of new homes before immigrants moving in. There was no outbreak of epidemic disease during the resettlement. By implementing land treatment and overflow lands protection, the project altogether treated 14754 mu of land in the reservoir area, conducive to the reasonably develop and utilize land resources in the affected area, improve land productivity and effectively reduce the economic pressure from project construction on the affected population in the reservoir area.

5.5.2 Resettlement environmental protection impact survey

a) Wangfuzhou Hydro-junction

Resettlement planning was optimally designed to reduce as many as possible the number of immigrants experiencing land acquisition. Design changes regarding axes in embankment of Laokekou city Luying village and Gucheng village alone were able to decrease land acquisition by 3300 Mu, reduce 425 immigrants and save inundation treatment compensation investment of 23 million Yuan. In the process of project construction, the construction unit utilized all available resources, such as machinery, vehicles and construction material supply channels that are stable and reliable, and offered much support in terms of helping the relocation and transportation of immigrants, site leveling, farmland-building soil improvement and production restoration.

In terms of production resettlement of immigrants, PIU actively contacted the local government to introduce preferential policies conducive to immigrant stability and production development. Meanwhile, three effectively resettlement measures were implemented, namely agricultural resettlement, development of second and tertiary industries, and land compensation fee for the inundated area used as capital fund for the project, in accordance with the inundation feature of the Wangfuzhou Hydro-junction as well as natural and social conditions of the reservoir area. Sticking to a development-oriented immigrant policy, relying on the understanding and support of the local government and the large numbers of immigrants, fully utilizing the motivations of officials and the general public, through multiple endeavors and multi-channeled resettlement, it was not only able to foster a good external environment for project construction, but also able to create favorable conditions for immigrants to develop economy, increase income, and live and work in peace and happiness.

b) Cuijiaying hydro-junction

According to *World Bank Financed Hubei Provincial Cuijiaying Hydro-junction Project Resettlement Final Report* and field survey, Qianying village resettlement housing is of brick and concrete structure and the average household resettlement housing area is $142m^2$; resettlement housing uses tap water. After resettlement, Qianying village residents have enjoyed much improvement in terms of housing conditions, and other service infrastructure such as water, electricity and road. Meanwhile, residents have been engaged in various business operations by taking advantage of the excellent location as resettlement housing is close to the National Highway 207. Resettlement situation has been quite satisfactory as residents have enjoyed substantial income increase and improved living quality.

Generally speaking, the resettlement work of Hubei provincial Cuijiaying Hydro-junction project has been a success. To make project-related information conveniently available to all population affected along the line, the project resettlement office has adopted a series of measures to distribute important information such as policies and standards relating to land acquisition and relocation to the large number of people affected, and has fully coordinated with the affected public. The significant achievements of the resettlement work mainly include:

①Socio-economy of the affected area has maintained a continued development momentum, and rapid development and economic structural improvement were achieved by fully taking advantage of investment opportunities brought by the project construction. People have generally benefited from the project construction.

②Production and life of the directly affected population have not become worse due to the project, and on the contrary improvements were achieved right after land acquisition and relocation of the project. In terms of production conditions, although there was certain loss on land resources, land compensation fund helped channel other productive operations and increased the production efficiency of the existing production resources. In terms of living conditions, housing condition was greatly improved and other service infrastructure such as water, electricity and road were also significantly improved.

③The directly affected population has positive evaluation towards the resettlement work and the majority of the affected population has accepted the project.

④Comparisons of objective living condition and subjective assessment of the affected population before and after the resettlement also reveals that during the resettlement processes the affected population has an affirmative attitude towards changes of production and living conditions, and has a positive evaluation of the resettlement work.

5.6 Analogy survey results

5.6.1 Analogy survey results

5.6.1.1 Hydrological regime

According to survey analysis, the three hydropower development projects completed in the middle and lower reaches of Han River have greatly changed the form of water body in Han River, turning the previously connected natural riverway into a combination of riverway and reservoir. Hydropower development projects in the middle and lower reaches of Han River have little impact on main stream discharge. Wangfuzhou and Cuijiaying reservoirs downstream of Danjiangkou are of daily adjustment functions, and are of almost no annual or monthly adjusting effects on discharge or quantity. Impacts on the temporal and spatial distributions of upstream discharge before and after reservoir constructions were little. The operation of Cuijiaying and Wangfuzhou power stations not only provide for navigation, also ensure downstream ecological water use.

After the completion of Danjiangkou reservoir, 98% of sand from upstream is stuck within Danjiangkou reservoir causing serious erosion in riverbed of the middle reach of Han River. Sediments in the middle and lower reaches of Han River are mainly from main stream riverbed erosion in the middle reach downstream of Danjiangkou, and tributary inflows of Tangbai River and Nan River, with a largely decreased annual sediment discharge causing sediment formation coarsening. Currently, annual average sediment discharge and sediment recharge from Danjiangkou to estuary are on a rising trend.

Currently, Danjiangkou-Xiangyang section and Danjiangkou-Gucheng section have achieved erosion balance and are of coarsened pebble riverbeds; Xiangyang-Nianpanshan section has relatively high erosion resistance; Zhuandou-Nianpanshan section has relatively low erosion resistance. As daily adjusting reservoirs, Wangfuzhou and Cuijiaying have little blocking effect of sediment after completion. According to survey, daily average discharged volume of various dam sites can all meet the requirement of “good” ecological discharge.

5.6.1.2 Water environment

a) Water quality

Permanganate index concentration is basically stable before and after Wangfuzhou reservoir construction, and is in line with environmental impact report prediction; ammonia nitrogen and total phosphorus concentrations have substantially decreased indicating a decreased emission volume of ammonia nitrogen and total phosphorus as regional pollution have been controlled to a certain extent. The construction of Cuijiaying Hydro-junction has to a certain extent adversely impacted water quality of the river section in the reservoir area as indicators of permanganate, ammonia nitrogen and total phosphorus have to a certain extent gone up compared with that of before the construction, yet they are all in line with *Surface Water Environment Quality Standard* (GB3838-2002) Class III water quality standard. There are two reasons causing the increase of permanganate index, ammonia nitrogen and total phosphorus concentration: one is concentration increase caused by emission of pollutants in soil and organic matter residue of the reservoir bottom as Cuijiaying reservoir was only completed not long ago; the other is after reservoir construction the slowing of water flow of the river section in the reservoir area resulting in a weaker diluting and degrading capability of the water body regarding pollutant. The annual average concentration of permanganate index in the reservoir area is around 2.6mg/L after the reservoir construction, and is basically in line with prediction outcome. Although still under construction, Xinglong hydro junction has little impact towards water quality upstream and downstream of the dam site during the construction period, which is in line with the prediction outcome of the EIA report. Generally speaking, BOD_5 and ammonia nitrogen concentration in Luohan gate and Zekou cross section went down from 2008 to 2011, indicating less polluting volume as regional pollution was controlled to a certain extent.

b) Water temperature

Among the three hydropower development projects completed in the middle and lower reaches of Han River main stream, Danjiangkou reservoir is the only one with stable stratification, which is why water temperature distribution in the middle and lower reaches of Han River is mainly affected by the low-temperature water discharged from Danjiangkou reservoir. There was no water temperature stratification after the completion of Wangfuzhou Hydro-junction and Cuijiaying hydro junction, and water temperature within the reservoir is mainly related to water temperature of upstream inflows (Danjiangkou discharged water temperature) and air temperature.

After the completion of Danjiangkou reservoir, water temperature in the middle and lower reaches of Han River is mainly affected by the low-temperature discharge dispatched by Danjiangkou. Annual changes of water temperature in the middle and lower reaches of Han River are basically in line with air temperature changes along the line, with a relatively low water temperature from January to March and a relatively high water temperature from July to August. Affected by low-temperature discharge from Danjiangkou, water temperatures of various monitoring cross sections downstream of Danjiangkou are generally higher than that of cross sections upstream, with an increasing trend along the line (except for certain cross sections). Throughout the year, water temperatures along the line decrease slightly as water temperature trumps air temperature; water temperatures along the line increase as air temperature trumps water temperature; water temperatures along the line varies greatly as the gap between air temperature and water temperature substantially widens. The low-temperature discharge has impacted fish growth and spawning to a certain extent.

c) Groundwater level

After the completion of Wangfuzhou reservoir and Cuijiaying reservoir, average annual groundwater level of Han River surroundings has to a certain extent changed, changing the previously existing recharge relations. Through drainage renovation measures, Laokekou city brought down the impact of rising groundwater level on architectural foundation and farmland inundation. Drainage project is under construction in Xiangyang city. The construction of Cuijiaying reservoir has caused rising groundwater level surrounding Han River, changing the groundwater recharge relation of the two banks of Han River, as currently Han River recharges groundwater of the two banks whereas Han River was recharged by groundwater of the two banks in most time before reservoir construction. Farmland inundation happened in some parts of the two banks of Han River. To reduce the impact of inundation, a network of drainage channel has been designed to bring down groundwater level, and the abovementioned project is under construction.

5.6.1.3 Aquatic organism

In the middle and lower reaches of Han River, the constructions of the existing hydropower development projects (Danjiangkou, Wangfuzhou, Cuijiaying) has caused the number of plankton and zoobenthos to increase, changing the previous stock structures of plankton and zoobenthos, among which Bacillariophyta has become the dominant species of plankton, for plankton *Cladocera* biomass and *Copepods* number have clearly increased, and for zoobenthos the species and number of mollusk has clearly increased.

Given the low-temperature water discharged from Danjiangkou reservoir, the barrier effects of Wangfuzhou and Cuijiaying junctions, and the hydrological regime change from flowing water to still water, fish species in the Danjiangkou-Cuijiaying section of Han River have been greatly impacted: the proportions of fish favoring still waters and fish species with pelagic eggs have clearly gone up; former spawning grounds of the four Chinese carps in Sanguandian, Wangfuzhou, Cihe and Xiangfan basically disappeared, with only spawning grounds of other economic fish species and small-sized fish species left, and the fish egg amount has been substantially reduced as affected by Danjiangkou junction, Wangfuzhou junction and Cuijiaying junction in a descending order. On the other hand, temperature of water discharged from Danjiangkou reservoir in winter is higher than that of natural riverway, combined with the increased amount of plankton and zoobenthos, allowing fish feeding ground and wintering ground to be formed in Danjiangkou-

Cuijiaying section.

5.6.2 Major environmental impact recognition

According to regional resource environmental features and environmental impact review of hydropower projects developed in Han River, the environmental assessment points out that probable environmental impact of executing the project may include:

a) Whether or not Han River water quality can carry junction project construction

The middle and lower reaches of Han River is a densely populated region in the Hubei province with advanced agricultural and industrial development, receiving much urban sewage, industrial waste water and agricultural diffused pollution. After the implementation of the first phase of central route of South-to-North Water Transfer in 2014, the decrease of inflow in the middle and lower reaches of Han River caused a volume decrease of water environment in the middle and lower reaches of Han River. Self-purifying capability of the water body was further reduced by rising water level and slowing flow velocity resulting from hydropower project development, increasing pressure on water environment protection, thus becoming a limiting factor in hydropower project development in the middle and lower reaches of Han River.

The construction of Yakou shipping hub will to a certain extent affect water environment for changing riverbed hydrological conditions. Given the current situation of regional environmental quality, some sections of Han River have serious water quality pollution. One of the major issues of attention in this environmental assessment is whether or not Han River can carry the pollution increase brought by changing hydrological conditions.

b) Adverse impact of junction project on aquatic ecology

Only four major distribution zones in Han River are left as spawning grounds of Four Chinese carps, among which Yicheng, Zhongxiang and Maliang spawning grounds are located in Yakou, Nianpanshan and Xinglong reservoir areas respectively. The abovementioned spawning grounds will be affected by hydrological regime changes and dam barrier caused by hydropower project development. The part of Cihe in the upstream of Cuijiaying has spawning grounds of economic fish species and small-sized fish species, and will be impacted by the construction of Yakou shipping hub.

The construction of hydro junction changes the water level and flow velocity of the river section. On one hand, it may cause certain spawning grounds to shrink or disappear; on the other hand, it blocks the migratory channel of parent fish making it difficult for parent fish to overcome and arrive at spawning ground.

6 Prediction and assessment of environmental impact

6.1 Prediction and assessment of environmental impact

6.1.1 Analysis of impact on hydrology and sediment

6.1.1.1 Data on Yakou dam site runoff

Data on Yakou dam site runoff in this phase is offered by Hydrology Bureau of Changjiang Water Resources Commission and includes 10-day runoff data in the period from 1956 to 1998 and daily runoff data in high flow year (P=10%), normal flow year (P=50%) and low flow year (P=90%). The above data is the result after taking storage function of cascade reservoirs in the upper reaches of Han River and impact of the middle route of south-to-north water diversion project into consideration. Therefore, the boundary conditions of prediction in this chapter is that Danjiangkou dam is heightened and annual water diversion of the Middle Route (Phase I) of the South-to-North Water Transfer Project is 9.5 billion cubic meters.

After diversion of the Middle Route (Phase I) of the South-to-North Water Transfer Project in 2010 (a normal flow year), the average annual water discharge of Danjiangkou reservoir is 25.8 billion cubic meters and the average annual runoff from Danjiangkou to Yakou dam site is 9 billion cubic meters. Then the average annual runoff inflow of Yakou Shipping Hub Project after water diversion will be about 34.8 billion cubic meters and the average annual flow will be 1,100m^3/s. The changing process of runoff of dam cross-section in the typical hydrological years (high flow year, normal flow year and low flow year) is shown in Figure 6.1.1-1.

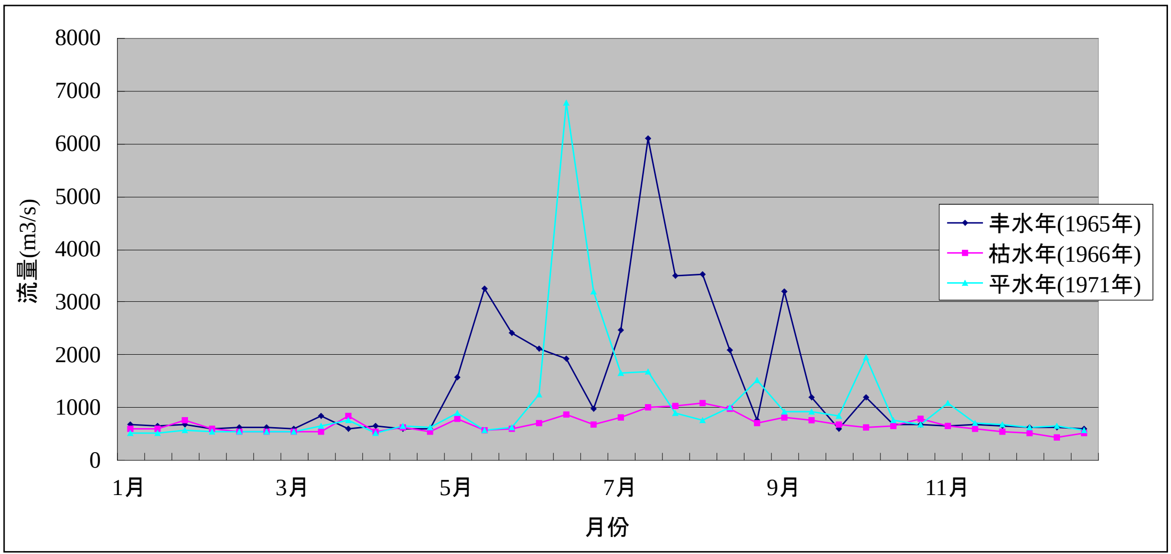


Figure 6.1.1-1 Changing process of runoff of Yakou dam section in high flow year, normal flow year and low flow year

流量	Flow
月份	Month
丰水年	High flow year
枯水年	Low flow year
平水年	Normal flow year

6.1.1.2 Analysis of minimum discharge volume

a) Minimum discharge volume which has been considered in the project design

Main function of Yakou shipping hub will be shipping. Therefore, the navigable discharge and shipping safety in lower reaches of Han River needs to be guaranteed first. In order to meet the requirements of downstream shipping on minimum depth of water, base-load flow of Yakou Shipping Hub is determined to be 450m^3/s after comprehensive analysis. After taking regulation and counter regulation of the upstream Danjiangkou and Wangfuzhou hydro-junctions into consideration, the daily runoff inflow of Cuijiaying which has been put into operation does not change too much and Cuijiaying hydro-junction has not undertaken systemic peak regulation for the time being yet; in addition, viewing from the daily runoff at Yakou dam site in typical years, the corresponding guarantee rate of runoff inflow of Yakou hub which is 450 m^3/s is about 98% after taking water diversion of the upstream hydro-junctions; hence, generating power on incoming flow can basically meet the shipping needs in lower reaches.

b) Analysis of minimum discharge volume

1) Analysis scope

(1) Water flow necessary for maintaining stability of aquatic ecosystem

Aquatic creatures living in reaches of Yakou Shipping Hub mainly include bacillariophyta, chlorophyte, cyanophyta, protozoan, rotifer, physa foncinalis, radix swinhoei, cloeon dipterum, gammarus, water spider, anguilla japonica, onychostoma macrolepis, gracilicaudatus. In order to make them live, spawn, breed and inhabit normally in the project-affected reaches, certain base-load flow must be guaranteed.

(2) Minimum dilution and purification flow for maintaining water quality

Water quality under Yakou Shipping Hub dam site is classified as Class II. In accordance with inventory survey, areas along the reaches are mainly rural areas with distribution of certain industrial, domestic and agricultural pollution sources. In accordance with the prediction on water quality of the reservoir area in operation period (Section 6.1.3), water quality can meet the requirements of water quality classification. Since water quality of Man River can meet Class III standard in *Environmental Quality Standard for Surface Water* (GB3838-2002) and part of factors can meet Class II standard, minimum dilution and purification flow of Man River section will not be calculated. Main water pollution sources in Jian River section are discharge of Yidao Ditch which receives industrial wastewater and domestic sewage. Therefore, steady water quality modeling method is to be used to calculate the minimum dilution and purification flow necessary for maintaining water quality of reaches where Yidao Ditch is located. The formula is as follows:

$$Q_0 = (W_i - C_s q_i) / [C_s - C_0 \exp(-\frac{Kx_i}{u})]$$

In the formula: Q_0 —— incoming water from the upper reaches, namely the minimum dilution and purification flow for maintaining water quality of the reaches, m^3/s;

Wi ——Allowable quantity of pollutant discharged and actual pollutant discharged in section i, g/s;

Cs —— Water quality standard that pollutants concentration flowing out of certain section must meet, mg/L;

q_i —— sewage flow in section i, m^3/s;

C_0 —— pollutants concentration in water flowing from upper reaches, mg/L;

K —— attenuation coefficient of pollutants, d^{-1};

x_i —— length of mixing process section in section i, m;

u —— average velocity, m/s.

In accordance with *12th Five-Year Special Planning on Environmental Protection of Yicheng City*, sewage pipe network is built in Yicheng urban areas and Yicheng implements combined sewer discharge system and discharges sewer to Han River through Laojiang Ditch and Yidao Ditch. First-phase of Yicheng Domestic Sewer Treatment Plant is 20,000t/d and will discharge them into Yidao Ditch after treatment. Calculating at the minimum navigable flow of $450m^3/s$, the average velocity is 0.5m/s and length of mixing process section is 13.45km. Other parameter values and calculation results are shown in Table 6.1.1-2.

Table 6.1.1-2 Calculation results of the minimum dilution and purification flow for maintaining water quality of lower reaches of Yankou Hub dam site

Parameter		Unit	COD_{Cr}	BOD_5	NH_3-N	Total nitrogen content	Total phosphorus content
C_s		mg/L	15	3	0.5	0.5	0.1
C_0		mg/L	7.12	1.8	0.07	1.74	0.07
K		d^{-1}	0.2	0	0.2	0	0
Yidao ditch section	W_i	g/s	111.8	18.9	9.64	14.1	0.92
	q_i	m^3/s	1.35	1.35	1.35	1.35	1.35
	Q_0	m^3/s	6.12	12.38	17.94	-	26.17

Note: water quality in downstream reaches which is 5km away from Yakou Hub dam site is as the base value of this calculation.

It shows that the minimum dilution and purification flow is small since Yicheng discharges few water pollutants. The minimum flow required for water purification of Yidao Ditch section is only $26.17m^3/s$.

(3) Ground water replenishment flow

Ground water in project area comprises porous phreatic water, bedrock fissure water and karst water. Bedrock fissure water is formed by infiltration of the atmospheric precipitation or river water and is of small quantity since fissure in project area is underdeveloped. Karst water is unevenly distributed and recharged by the atmospheric precipitation and infiltrates into deep karst fissure with good connection or flows into Han River. Porous phreatic water is mainly recharged by atmospheric precipitation and is abundant. It flows into Han River along the edge of river valley and is recharged by water of Han River in flood season. Recharge of ground water in reaches under the dam site is mainly influenced by the atmospheric precipitation and under little influence of water discharge; but under bigger influence of water discharge in flood season and will not affect the water recharge of Han River.

(4) Demand of shipping and landscape on water flow

Mainstream of Han River where the project is located is good deep waterway which is convenient for water transportation. Hence, certain water flow must be guaranteed to meet the shipping requirements.

There is no tourism development planning in project reaches. Maintaining the water liquidity and continuity of river will be the main measures for water flow demand of landscape. Water flow demand of landscape can be met when ecological base flow necessary for demands of shipping on water and maintaining aquatic ecosystem are satisfied.

(5) Water consumption of production and living

Main water intake and utilization facilities in mainstream of Han River from reaches under Yakou dam to Cuijiaying dam is for agricultural irrigation, drainage and domestic and industrial water. The facilities are mainly culverts, sluice and pump station, etc. which are located in Yakou reservoir area. Therefore, it is unnecessary to consider water discharge to guarantee water intake.

In conclusion, when determining water discharge of Yakou Shipping Hub, we mainly need to consider the water flow for shipping and the water flow for maintaining stability of aquatic ecosystem. We take the bigger value of these two for once such demand is met, the other demand will be satisfied, too.

2) Determination of minimum discharge volume

Water used for ecological environment in reaches under Yakou dam site is calculated with Tennant method as specified in *Technical Guidance for Environmental Impact Assessment of Ecological Water Demand, Low-temperature Water and Fishing Facilities in River Reaches of Water Conservancy and Hydropower Project* (trial) (hereinafter referred to as the Technical Guidance). The average flow of Yakou Shipping Hub in 47 years from May 1956 to April 2003 was 1,100m^3/s and the average annual runoff was 34,719,000,000m^3. Considering the diversion influence of Danjiangkou reservoir and Middle Route (Phase I) of the South-to-North Water Transfer Project and in accordance with requirements of the Technical Guidance, it is recommended that water discharge of the power station should not be less than 10% of the average annual runoff and the minimum ecological water discharge of Yakou Shipping Hub dam site should be 110m^3/s. If the ecosystem is well maintained, then the water discharge will be 220m^3/s when we consider it as 20% of the average annual runoff.

Yakou Shipping Hub is constructed mainly for power generation and shipping. In accordance with provisions of *Standards for Inland River Navigation* and requirement of waterway grades, the minimum navigable water depth in this section is 2.0m and the base shipping flow is 450m^3/s. In order to meet the demands of shipping in lower reaches on minimum water depth, the water discharge of power station is determined not to be less than 450m^3/s.

In accordance with the above principles, the minimum water discharge of Yakou Shipping Hub is 450m^3/s which can meet the demands of ecological water consumption and shipping in lower reaches.

c) Analysis on assurance degree of minimum water discharge

After Danjiangkou dam is heightened, the normal pool level of Danjiangkou reservoir is 168.23m, the limited water level is 143.23m and the regulated reservoir capacity is 19.05 billion cubic meters, enabling multi-years regulation. The primary task of Danjiangkou reservoir is to guarantee flood control safety with water supply, power generation and shipping as the auxiliary functions. The operation mode of Danjiangkou reservoir is to evenly supply water to water-receiving area as much as possible through storage of the reservoir under the premise of guaranteeing industrial, agricultural, domestic and environmental water consumption in middle and lower reaches of Han River. In order to meet the demands of departments in middle and lower reaches of Han River for water, water discharge of Danjiangkou hydro-junction is required not to be less than $490m^3/s$ in years when reliability of water inflow is smaller than 90%. Water inflow of Yakou Shipping Hub is relatively even after storage of Danjiangkou reservoir and can ensure the minimum flow requirements of Wangfuzhou power station, Yakou power station and Xinglong power station.

The minimum navigable discharge of Wangfuzhou hydro-junction in upper reaches is $200m^3/s$ and that of Cuijiaying hydro-junction in upper reaches is $470m^3/s$; Yakou project adopts the minimum navigable discharge of 450 m^3/s. Usually, Wangfuzhou hydro-junction operates synchronously with Danjiangkou reservoir, so the water discharge meets the requirements of minimum navigable discharge and is $200m^3/s$. Only when the water flow from upper reaches is close to or less than the navigable discharge will counter regulation be implemented (the operation and storage mode of Danjiangkou reservoir after it is heightened will not enable the occurrence of this situation). The average daily water inflow of Yakou Shipping Hub in low flow years (typical daily load in November) is $735m^3/s$. The power station will operate in two control periods and the surplus storage capacity can work under shoulder load of the system on the basis of meeting the base shipping flow of $450m^3/s$. Storage capacity of Yakou Shipping Hub is 41,500,000 m^3 and daily regulation operates. Even if the minimum navigable discharge of Wangfuzhou hydro-junction is $200m^3/s$, the daily water inflow can meet the minimum base shipping flow of $450m^3/s$ of Yakou project (can actually meet the average daily flow of 490 m^3/s).

Since Wangfuzhou, Yakou and Cuijiaying hydro-junctions are not constructed and operated by the same unit, the unified and coordinated operation of these hydro-junctions is unable to be realized. However, Wangfuzhou, Yakou and Cuijiaying hydro-junctions are reservoir of daily regulation and have requirements on minimum navigable flow. They can completely meet the requirements on minimum water discharge when the water discharge is guaranteed according to the designed operation mode after Danjiangkou hydro-junction is heightened and by combining with their storage capacity and water inflow from the tributaries.

c) Coordination and rationality analysis of the minimum water discharge

1) Coordination with minimum water discharge indicator of the control section

Control indicator of section minimum discharge refers to the minimum water discharge of section which is determined by comprehensively considering the demands of production, living and shipping for water in lower reaches of the section on the basis of maintaining the basic form of riverbed, carrying capacity of waterway and self-purification ability of the water. Such indicator reflects the control requirements on section discharge in normal flow years. In particularly low flow year, warning water level indicator of water supply will be adopted and emergency plan will be timely initiated. *Total Amount Control Indicator Scheme of Water Resources in Yangtze River* and *Water Resource Allocation Plan of Han River* all specify the minimum water discharge control indicator of control section in mainstream of Han River which is shown in Table 6.1.1. The minimum water discharge of Yakou Shipping Hub is 450m^3/s, water inflow from reaches between Yakou and Nianpanshan is 30m^3/s (the area is 8969km^2 and converge the flow of Man River and Li River) and the water inflow of Huangzhuang section is 480m^3/s which is basically the same as the minimum control discharge.

Table 6.1.1-1 Control indicator of section water discharge

Item	Minimum control discharge (m^3/s)	
	Huangjiagang	Huangzhuang
Total Amount Control Indicator Scheme of Water Resources in Yangtze River	490	490
Water Resource Allocation Plan of Han River	490	500

2) Coordination with minimum water discharge of hydro-junctions in both upstream and downstream of the project

Cuijiaying hydro-junction is located in upstream of Yakou Shipping Hub and Nianpanshan hydro-junction is located in downstream of Yakou project. Cuijiaying junction have been built in 2010 and put into operation and its minimum navigable discharge is 470m^3/s; while Nianpanshan hydro-junction is in the phase of feasibility study and design and the minimum water discharge can be 450m^3/s which has been approved in the feasibility study phase.

The minimum water discharge of Yakou Shipping Hub is 450m^3/s which is basically coordinated with the minimum water discharge of both upstream and downstream hydro-junctions.

3) Rationality analysis of the minimum water discharge

In conclusion, the minimum water discharge of Yakou Shipping Hub is set as 450m^3/s. This can meet the demands of downstream ecosystem and shipping for water, is basically equivalent to the minimum water discharge indicator of control section in mainstream of Han River and coordinated with the minimum water discharge of both upstream and downstream hydro-junctions. Therefore, set it as 450m^3/s is reasonable.

6.1.1.2 Impact analysis of reservoir initial filling

In accordance with water discharge analysis and reservoir initial filling plan, shipping and ecosystem in lower reaches of Yakou Shipping Hub will require certain water discharge. Hence, certain amount water needs to be discharged at the time of reservoir initial filling to guarantee the water consumption of lower reaches. At the time, the water flow between Cuijiaying and Yakou and that between Yakou and Nianpanshan will be 74m^3/s and 180 m^3/s respectively.

In accordance with Section 5.1.1.1 Analysis of water discharge, in order to guarantee the demands of downstream shipping for water, the minimum water discharge should be 450m^3/s. According to construction planning and water diversion procedures, the reservoir will store water in October of the fifth year. Calculating at the designed initial filling reliability of 85% and controlling the minimum water discharge to be 450m^3/s, it would take 20.2 days to store water to the dead pool level of 54.72 and it would take 2.69 days to store the water from the dead pool level to the normal pool level of 55.22m. If the water inflow is less than 450m^3/s, then it would take more days to store water but the minimum ecological flow will not be affected and the downstream waterway will not be dry, either.

In conclusion, initial filling of Yakou reservoir will not exert bigger influence on the downstream ecological water consumption and shipping.

6.1.1.3 Hydrological regime of reservoir area during operation period

After formation of Yakou reservoir, changes in water surface area, water depth and flow regime will occur and such changes will be more significantly in low flow years. The comparison of hydrologic parameter before and after formation of Yakou reservoir in low-flow months of low flow years and when the reliability of water inflow is 95% are shown in Table 6.1.1-2.

Table 6.1.1-2 Comparison table of changes in hydrologic parameters before and after formation of Yakou reservoir (with reliability of 95% in typical low flow years and months)

Item	Measurement unit	Before formation of the reservoir	After formation of the reservoir	after/before formation of the reservoir
Reservoir area	km^2	35.5	111.75	3.15
Reservoir volume	One hundred million m^3	0.35	6.99	19.97
Average velocity	m/s	0.8	0.11	0.13
Average depth	m	0.98	6.26	6.39
Average width of water surface	m	710	2235	3.15

From the table we can see that reservoir area and volume, water depth and water surface width after formation of the reservoir will significantly increase in particular low-flow periods by about 3.15 times, 19.97 times, 6.39 times and 3.17 times of that before formation of the reservoir respectively. However, the flow velocity will decrease, being only 0.13 times of that before formation and the rapid flow regime will become slowly.

From table 6.1.1-5 we can see that water diversion of Danjiangkou reservoir will not exert impact on inter-annual changes in runoff into the reservoir and the changes in runoff into the reservoir during one year due to the reservoir's weak regulation performance for it is daily regulated. After considering the function of south-to-north water transfer of Danjiangkou reservoir, the average annual flow of the dam site will reduce to 1100m^3/s, the average annual runoff will be 34.8 billion cubic meter and the annual exchanges are about 99.4 times. It is unnecessary to set daily regulation capacity of Yakou project from the perspective of taking full advantage of the hydropower resources and improving power generation benefits. We only need to generate power according to stack interval flow of water discharge from upstream Cuijiaying hydro-junction and maintain the water level of reservoir at 55.22m as possible as practical in the power generation process. In order to guarantee the minimum navigable discharge, we set the regulation capacity to be small and the limited water level is only 0.5m due to influence of natural inflow. This is conducive to shipping.

Table 6.1.1-3 Operation of Yakou reservoir in high flow year after water diversion of Danjiangkou reservoir (1965)

Month	Water inflow (m^3/s)	Power generation flow (m^3/s)	Wastewater discharge (m)	Water level of reservoir (m)	Downstream water level (m)	Generating head (ten thousand kW)	Rated output (ten thousand kW)
January	670.83	670.83	0	55.22	46.98	8.04	4.64
February	611.50	611.50	0.00	55.22	46.86	8.16	4.29
March	675.50	675.50	0.00	55.22	46.98	8.04	4.65
April	610.50	610.50	0.00	55.22	46.85	8.17	4.29
May	2410.17	1506.93	903.23	55.22	49.21	5.81	7.42
June	1663.17	1257.14	406.02	55.22	48.41	6.61	7.03
July	4023.17	1103.01	2920.15	55.22	50.36	4.49	4.95
August	2117.50	1323.16	794.34	55.22	48.76	6.26	6.66
September	1657.50	1159.58	497.92	55.22	48.19	6.83	6.30
October	852.60	852.60	0.00	55.22	47.27	7.75	5.60
November	656.50	656.50	0.00	55.22	46.95	8.07	4.56
December	611.83	611.83	0.00	55.22	46.86	8.16	4.30

Table 6.1.1-4 Operation of Yakou reservoir in normal flow year after water diversion of Danjiangkou reservoir (1971)

Month	Water inflow (m^3/s)	Power generation flow (m^3/s)	Wastewater discharge (m)	Water level of reservoir (m)	Downstream water level (m)	Generating head (ten thousand kW)	Rated output (ten thousand kW)
January	534.17	534.17	0.00	55.22	46.69	8.33	3.83
February	542.83	542.83	0.00	55.22	46.71	8.31	3.88
March	655.83	655.83	0.00	55.22	46.94	8.08	4.54
April	592.17	592.17	0.00	55.22	46.81	8.21	4.17
May	690.83	690.83	0.00	55.22	47.00	8.02	4.73
June	3738.83	972.29	2766.55	55.22	49.88	4.98	4.95

Table 61.1-4 (continued)

Month	Water inflow (m^3/s)	Power generation flow (m^3/s)	Wastewater discharge (m)	Water level of reservoir (m)	Downstream water level (m)	Generating head (ten thousand kW)	Rated output (ten thousand kW)
July	1402.60	1173.96	228.54	55.22	48.09	6.93	6.91
August	1086.50	1007.18	79.32	55.22	47.64	7.38	6.31
September	887.83	887.83	0.00	55.22	47.36	7.66	5.85
October	1129.83	939.88	189.95	55.22	47.65	7.37	5.73
November	818.50	818.50	0.00	55.22	47.22	7.80	5.44
December	609.83	609.83	0.00	55.22	46.85	8.17	4.28

Table 6.1.1-5 Operation of Yakou reservoir in low flow year after water diversion of Danjiangkou reservoir (1966)

Month	Water inflow (m^3/s)	Power generation flow (m^3/s)	Wastewater discharge (m)	Water level of reservoir (m)	Downstream water level (m)	Generating head (ten thousand kW)	Rated output (ten thousand kW)
January	641.50	641.50	0.00	55.22	46.92	8.10	4.46
February	548.17	548.17	0.00	55.22	46.72	8.30	3.91
March	638.83	638.83	0.00	55.22	46.90	8.12	4.43
April	569.83	569.83	0.00	55.22	46.77	8.25	4.04
May	646.83	646.83	0.00	55.22	46.92	8.10	4.49
June	734.50	734.50	0.00	55.22	47.09	7.93	5.00
July	945.83	945.83	0.00	55.22	47.44	7.58	6.15
August	912.83	912.83	0.00	55.22	47.38	7.64	5.96
September	745.50	745.50	0.00	55.22	47.12	7.90	5.06

October	677.17	677.17	0.00	55.22	46.98	8.04	4.67
November	587.17	587.17	0.00	55.22	46.81	8.21	4.14
December	479.83	479.83	0.00	55.22	46.59	8.43	3.48

6.1.1.4 Hydrologic analysis of downstream waterway in the operation period

a) Hydrological regime of downstream waterway in normal flow years

Yakou Shipping Hub uses water of inland river. Its normal pool level is 55.22m and dead pool level is 54.72m. The project is of daily regulation with regulation capacity of 41,500,000 cubic meters. The daily water inflow of Yakou reservoir in high flow years, normal flow years and low flow years is basically the same as that of water discharge in the same period. Therefore, after completion of the construction, Yakou Shipping Hub will not exert any impact on annual runoff, monthly runoff and daily runoff of the dam site and will exert small impact on the downstream hydrological regime.

Hydrological regime in lower reaches of Yakou Shipping Hub dam site is mainly controlled by both upstream and downstream hydro-junctions. Influenced by daily water discharge of the upstream Cuijiaying hydro-junction, the daily discharge process of waterway in lower reaches of Yakou dam is different from that under natural conditions. From the perspective of downstream shipping demands, the primary task of Yakou project is for shipping. Hence, we should give priority to the demands of downstream shipping for discharge and shipping safety. Upon analysis, the base-load flow for shipping of Yakou Shipping Hub is 450m^3/s. After taking regulation and counter regulation of Danjiangkou reservoir and Wangfuzhou hydro-junction in the upper reaches, the daily water inflow of Cuijiaying hydro-junction does not change significantly and Cuijiaying hydro-junction has not undertaken the systemic regulation task for the time being. In addition, the corresponding reliability of water inflow of Yakou reservoir (450m^3/s) is about 98% after considering the water diversion of the upstream projects. Hence, power generation of Yakou project on the basis of water inflow can meet the downstream shipping demands under current conditions, namely guaranteeing the downstream waterway not to be dry. Since the designed daily regulation capacity of Yakou project is about 32.4 million m^3/s, discharge reliability of base flow for downstream shipping of Yakou project can be further improved.

In order to meet demands of the downstream shipping for water level, power generation of Yakou Shipping Hub must on the basis of base load. Counting the water level amplitude of the outlet of approach channel below Yakou dam in accordance with daily regulation calculation of Yakou Hub in typical years, the water level amplitude below Yakou dam is basically the same as that before construction of Yakou reservoir: the maximum hourly amplitude in low flow years is 0.88m and the daily amplitude is 1.74m; the maximum hourly amplitude in high flow years is 0.84m and the daily amplitude is 2.01m. These can all meet the shipping demand of these reaches. After completion of construction of the downstream Nianpanshan hydro-junction, the water level will be connected with Yakou reservoir and downstream reaches of the dam will be controlled by the operation of downstream hydro-junctions.

b) Hydrological regime of downstream waterway in flood season

Under normal conditions, the water inflow will equal to the water discharge of Yakou project (regulating through power generation output) so as to maintain the normal pool level of Yakou reservoir. When the water inflow is bigger than 5,000m^3/s in flood season, Yakou project will be operated by gradually reducing the water level. When the water level in front of the dam is lower than the dead pool level or the power head is shorter than 2m, the operation of power station will be stopped and Yakou project will completely undertake the task of flood control. Since the area of flow cross-section in the reservoir area is bigger than that below the dam and the flow velocity is relatively small, it is basically in the state of natural flood-control. In addition, Cuijiaying, Yakou and Xinglong hydro-junctions will largely discharge water during joint ecological operation period of projects in lower reaches of Danjiangkou reservoir, the hydrological regime below the dam in such period can be restored to the natural status.

6.1.1.5 Analysis of sediment regime

a) Sediment inflow

Yakou dam controls basin of 133,087km^2. Since there are no observed data on sediment of Yakou dam, sorting and analysis of sediment will base on data of Huangzhuang station in lower reaches. In accordance with the observed data on sediment of Huangzhuang station in 31 years from 1980 to 2010, the period from 1984 to 1993 is chosen as the typical years for calculation. The average suspended load discharge in these 10 years was 13,190,000 tons and the average flow was 1,485m^3/s.

The average erosion modulus between Huangzhuang and Xiangyang was 469t/km^2 in accordance with the preliminary design results of Cuijiaying. On such basis, we deduce that the natural average suspended load discharge between Yakou dam and Huangzhuang was 4,210,000 tons and further calculate and get that the average suspended load discharge of Yakou dam was 8,390,000 tons.

Cuijiaying hydro-junction in upper reaches of Yakou has been put into operation in 2009. In calculation of the sediment regime, we take the sediment interception of Cuijiaying hydro-junction into consideration. In accordance with relevant design data, the sediment discharge ratio of Cuijiaying hydro-junction is about 80%. We then deduce that the actual average suspended load discharge of Yakou dam after considering the sediment interception action of Cuijiaying will be 6,710,000 tons.

Ten-day average suspended load discharge of Yakou in typical years is calculated according to the ratio between the average suspended load discharge of Yakou and that of Huangzhuang. When adopting ten-day runoff process, we take the corresponding ten-day runoff data of water diversion of Danjiangkou reservoir in later periods.

b) Sediment deposition characteristics of the reservoir area

Yakou Shipping Hub is located in section between Xiangyang and Zhongxiang in middle reaches of Han River. It is at 13.7km downstream of Yicheng City, Hubei Province, 201km away from Danjiangkou hydro-junction and 448km away from Hekou. It is the sixth hydro-junction among 8 hydro-junctions in main stream of Han River in Hubei Province. Its main function is shipping with power vernation, irrigation and tourism as the auxiliary functions.

There are Danjiangkou, Wangfuzhou and Cuijiaying hydro-junctions in upper reaches of Yakou Shipping Hub. Operation of the upstream reservoirs reduces the amount of sediment in lower reaches to some degree. With water storage of Yakou Shipping Hub after its completion, the water level of Yakou reservoir will be heightened, the water surface slope will flatten and the flow velocity will decrease. Therefore, certain siltation will be formed in the reservoir area. Since there is no inflow from tributaries, water and sediment inflow of Yakou reservoir will be calculated on the basis of the water and sediment inflow at the dam site. The step size for calculation is ten-day and the calculation years are 100. Calculation results of sediment of Yakou Shipping Hub in different years are shown in Table 6.1.1-6. From the table we can see that the suspended load siltation volume of the reservoir in 20 years will be 24,930,000m^3 and sediment discharge ratio of suspended load in 80 to 100-year's operation of the reservoir will be 86.56% to 88.28%. The sediment deposition becomes balanced.

Table 6.1.1-6 Calculation results of sediment deposition of Yakou Shipping Hub

Item	Measurement unit	Sediment years				
		20 years	40 years	60 years	80 years	100 years
Siltation volume of suspended load	Ten thousand m^3	2493	3843	4688	5326	5803
Sediment discharge ratio of suspended load	%	74.82	80.60	84.22	86.56	88.28

Note: the siltation volume in the table is the results after considering porosity.

Changes in thalweg and elevation of riverbank of Yakou reservoir area in different years are shown in Figure 6.1.1-2 and zonal sediment deposition shows in reaches of the reservoir area. Due to sediment retention action of reservoirs in the upper reaches, sediment inflow of Yakou reservoir is small and sediment deposition in the reservoir is not serious. There is little longitudinal deformation of riverbed and difference between the siltation sites and deformation of riverbed is small.

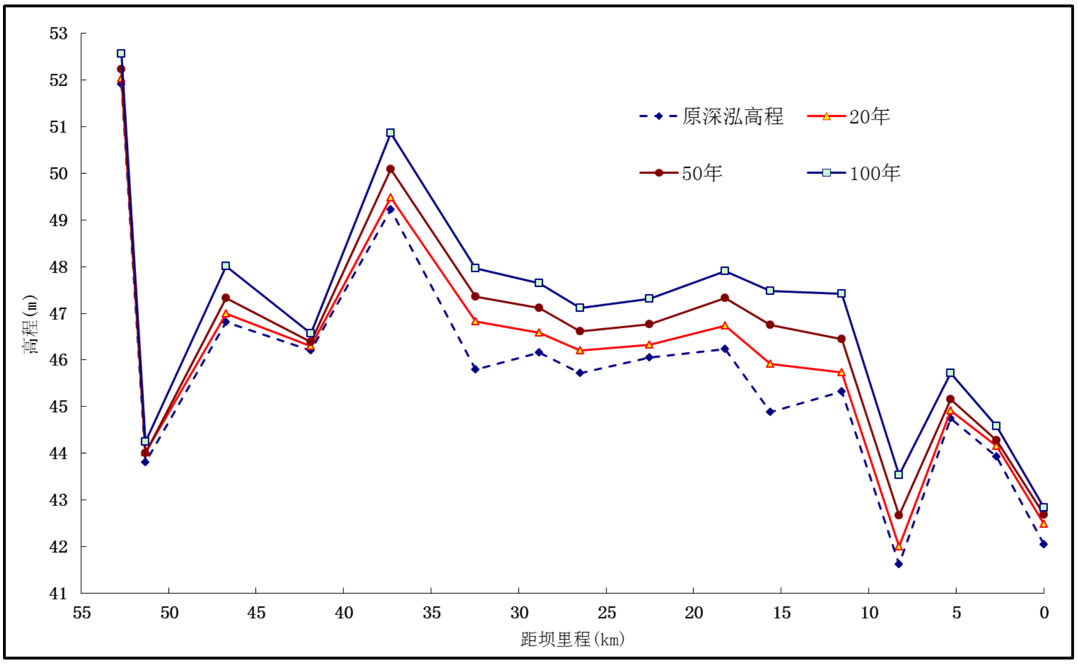


Figure 6.1.1-2 Thalweg and elevation contrasting figure of siltation of Yakou reservoir in different years

流量	Flow
距坝里程(km)	Distance to the dam (km)
原深泓高程	Thalweg and elevation
年	Years

We can know from longitudinal siltation morphology that there is little siltation in waterway of the reservoir areas and there are a few changes in riverbed morphology. The siltation volume near the dam site is relatively bigger and cross-sectional changes are relatively obvious. Analyze the transversal siltation morphology with Yicheng gauging station and cross-section of Yakou dam site as the typical cases and the cross-sectional changes are shown in Figure 6.1.1-3 and Figure 6.1.1-4. Sediments of these two cross-sections are levelly laid at the bottom of riverbed. The average siltation height in 100 years is 2.27m and 0.87m respectively and the maximum siltation height is 2.60m and 2.26m respectively. Deformation of riverbed of Yicheng gauging station is bigger whereas that of Yakou dam site is smaller.

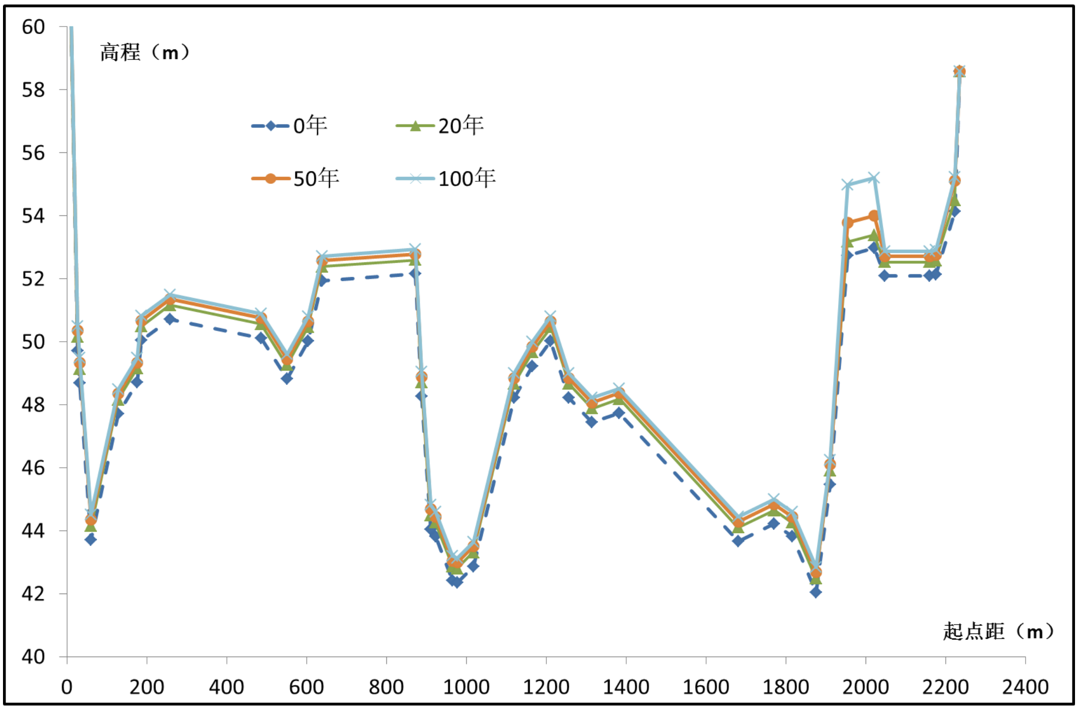


Table 6.1.1-3 Contrasting figure of cross-section siltation in Yicheng hydrologic station of Yakou reservoir area

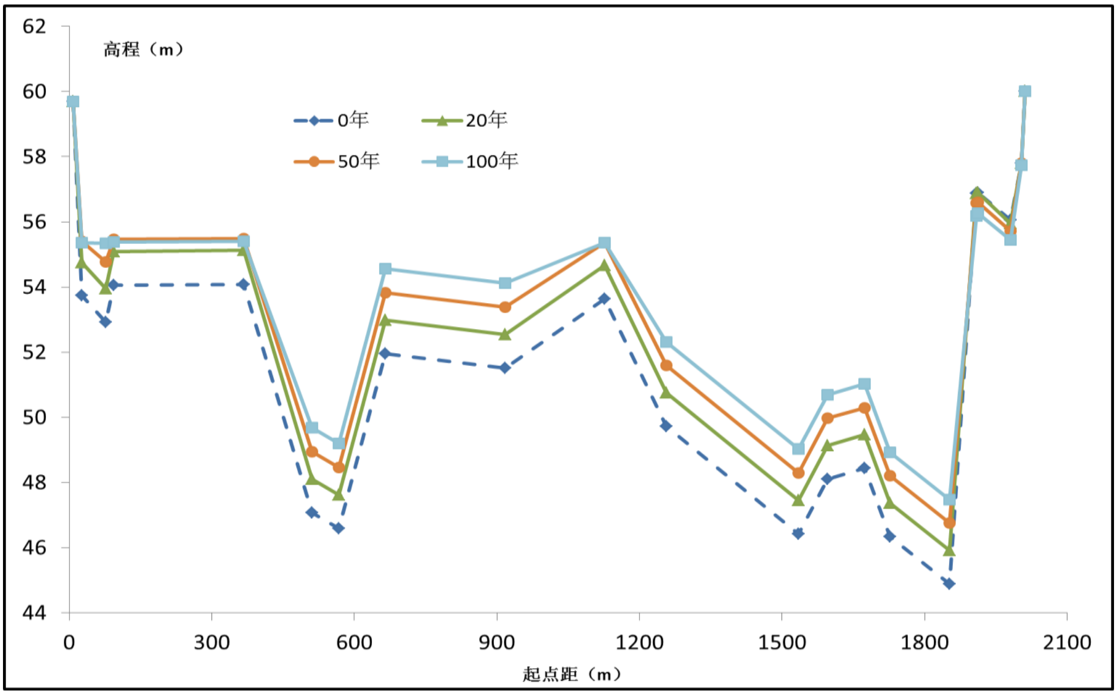


Table 6.1.1-4 Contrasting figure of cross-section siltation in Yakou dam of Yakou reservoir area

c) Impact analysis of river regime below Yakou dam

Calculation of one-dimensional sediment mathematic model of downstream reaches of the dam shows that: some changes in waterway topography in downstream reaches of the dam will occur. Generally, the topography in downstream reaches of the dam is alluvial land. However, since Nianpanshan reservoir area is located in downstream reaches of Yakou dam, the siltation and water storage action of Nianpanshan reservoir makes topography of the reaches within 5km of Yakou dam is slightly alluvial land, topography of reaches with 5km to 30km of Yakou dam is alluvial land and slow siltation in reaches between 30km away from Yakou dam and Nianpanshan reservoir area is formed. End of the fluctuating backwater area between Yakou dam site and Nianpanshan reservoir area has always been the alluvial land upon action of water and sediment discharge of Yakou reservoir since it is no longer under influence of Nianpanshan reservoir. But the wash load is small and only $1.98*10^{10}m^3$ in 50 years and the average annual wash thickness is 0.6cm. Area between end of the fluctuating backwater area and Nianpanshan dam site is in the scope of Nianpanshan reservoir area and slow siltation in such area under action of water and sediment discharge of Yakou reservoir is formed. The wash load in 50 years is $6.97*10^4m^3$ and the average annual siltation thickness is 0.205cm.

Calculation of two-dimensional sediment mathematic model of some downstream reaches of the dam shows that: the overall topography of riverbed in downstream reaches within 5.8km of the dam is alluvial land and the slight siltation in riverbed in reaches beyond the aforesaid scope is formed. Riverbed scour near downstream reaches of left and right sluices is the most obvious and the maximum scouring depth can be 5m and 6m respectively. The scouring depth of riverbed in downstream reaches within 50m of left sluice can be 4m and that of downstream reaches within 70m of right sluice can be 4m; the scope that the scouring depth can be 3m can be expanded to downstream reaches of 1500m away from the dam, the scope that the scouring depth can be 1m can be expanded to downstream reaches of 2800m away from the dam and the scope that the scouring depth can be 0.5m can be expanded to downstream reaches of 5200m away from the dam. The reaches which are 6.0km away from the dam and below is the fluctuating backwater area of Nianpanshan reservoir and the average siltation thickness after 20-year’s operation of Yakou Shipping Hub is 0.2 to 0.4m.

In conclusion, after completion of construction, Yakou Shipping Hub will exert some impacts on river regime of the downstream reaches of Yakou dam but the influence is little.

6.1.2 Impact on water temperature

6.1.2.1Temporal and spatial changes in water temperature along main stream of middle and lower reaches of Han River

According to observations, after formation of Danjiangkou reservoir, the average annual water temperature of Huangjiagang is 15.3°C(from 1981 to 1982), the average annual water temperature of Xiangyang gauging station is 15.7°C(from 1981 to 1982). Water temperature in downstream reaches of Danjiangkou reservoir gradually rises and returns to the normal value under natural conditions in Xiantao reaches (refer to the diagram 6.1.2-1).

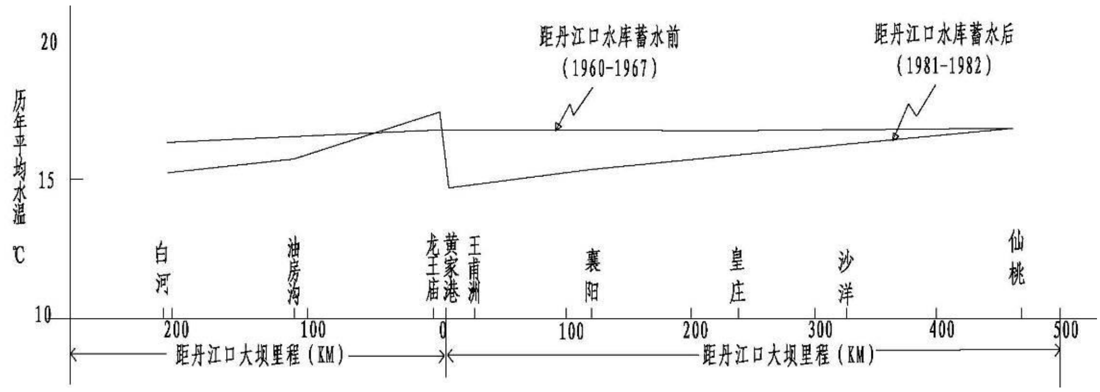


Figure 6.1.2-1 Diagram of changes in average annual water temperature along reaches from Bai River to Xiantao of Han River

历年平均水温	The average annual water temperature
白河	Bai River
浊房沟	Zhuofang Ditch
龙王庙	Dragon Temple
黄家港	Huangjiagang
王甫洲	Wangfuzhou
襄阳	Xiangyang
皇庄	Huangzhuang
沙洋	Shayang
仙桃	Xiantao
距丹江口大坝里程(km)	Distance to Danjiangkou Dam
距丹江口水库蓄水前	Before water storage of Danjiangkou reservoir
距丹江口水库蓄水后	After water storage of Danjiangkou reservoir

Huangjiagang gauging station is located at 6km downstream of Danjiangkou dam. Hence, monitoring data on water temperature of Huangjiagang gauging station is used to illustrate the impact of water temperature stratification and discharge of low-temperature water of Danjiangkou reservoir on downstream water temperature of reservoir dam. We found out through analyzing the monitoring data of Huangjiagang gauging station for years that the average annual water temperature of Huangjiagang gauging station after completion of Danjiangkou reservoir is 0.7°C lower than that before construction of Danjiangkou reservoir; the water temperature in February to August averagely decreases by 3 to 5°C; the water temperature from April to June averagely decreases by 4.4°C and from original 16 to 20°C to 11 to 16°C; water temperature in other five months averagely increases by 2.8°C with maximum increase of 4.9°C; the annual amplitude of water temperature decreases from 22.7°C to 18.9°C.

After completion of Danjiangkou reservoir, water temperature in main stream in middle and lower reaches of Han River is mainly affected by discharge of low-temperature water of Danjiangkou reservoir. In accordance with the monitoring data on water temperature of various routine monitoring cross-sections from December 2008 to December 2011 as provided by Hubei Environment Monitoring Center, we got the water temperature value of various monitoring cross-sections in middle and lower reaches of Han River in different months. Shenwan monitoring cross-section is the routine monitoring cross-section which is closest to Danjiangkou dam, only 16km away. The water temperature monitoring results of Shenwan section is consistent with that of Huangjiagang gauging station.

Temporal changes: changes in water temperature along main stream in middle and lower reaches of Han River (figure 6.1.2-2) show that: the changes in water temperature of various monitoring cross-section in a year is basically the same as the atmospheric temperature change tendency along main stream in middle and lower reaches of Han River, namely, the water temperature in January to March is relatively lower and in July to August is relatively higher.

Spatial changes: changes in water temperature along downstream waterways of Danjiangkou reservoir (figure 6.1.2-3) shows that: influenced by low-temperature water discharge of Danjiangkou reservoir, the water temperature of downstream monitoring cross-sections of Danjiangkou dam is universally lower than that of the upstream monitoring cross-sections of Danjiangkou dam and water temperature of downstream monitoring cross-sections of Danjiangkou dam shows tendency of increase (except some sections). Temperature of downstream water of Danjiangkou reservoir in August to October, December to April and June shows fewer changes but change greatly in other months with maximum change in November. Generally, the water temperature slightly decreases when the atmospheric temperature is lower than the water temperature and increases when the atmospheric temperature is higher than the water temperature; when difference between the atmospheric temperature and water temperature is bigger, then the water temperature changes drastically.

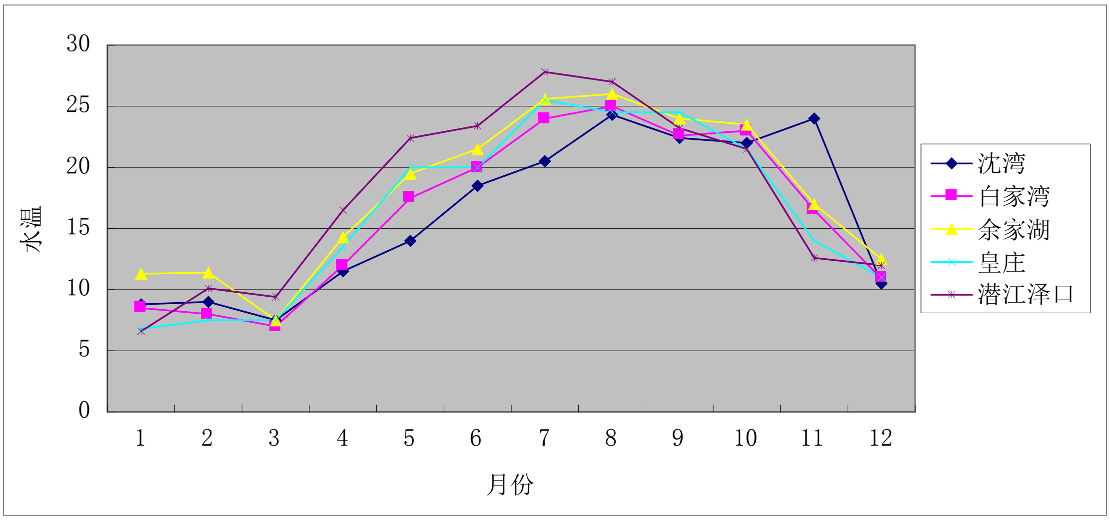


Figure 6.1.2-2 Monthly changes of water temperature of various monitoring cross-sections in middle and lower reaches of Han River (changes in a year)

水温	Water temperature
月份	Month
沈湾	Shenwan
白家湾	Baijiawan
余家湖	Yujiahu
皇庄	Huangzhuang
潜江泽口	Zekou, Qianjiang

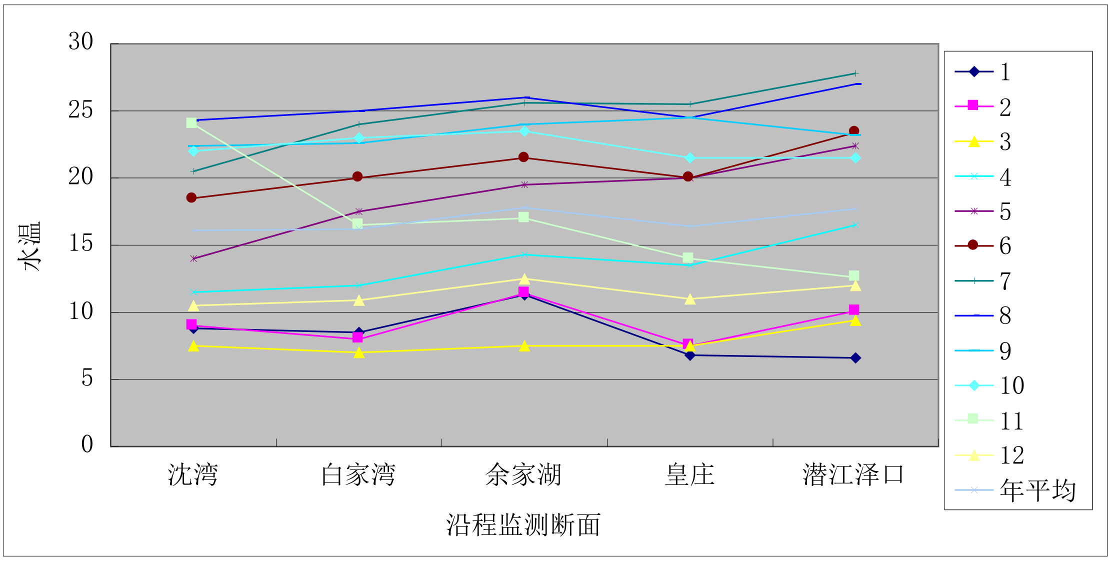


Figure 6.1.2-3 Changes of water temperature of various monitoring cross-sections in middle and lower reaches of Han River (spatial changes)

水温	Water temperature
月份	Month
沈湾	Shenwan
白家湾	Baijiawan
余家湖	Yujiahu
皇庄	Huangzhuang
潜江泽口	Zekou, Qianjiang
沿程监测断面	Monitoring cross-section along the waterway
年平均	The average annual value

6.1.2.2 Prediction on impact of heightening of Danjiangkou dam on water temperature of main stream of Han River

Danjiangkou reservoir is the one among hydro-junctions in middle and lower reaches of Han River that plays the control role in water temperature. Danjiangkou reservoir is a stratified reservoir with annual regulation capacity and other hydro-junctions are mixed reservoir with daily regulation capacity which exerts little influence on water temperature. Relevant research results of *Assessment Report on Impact of Middle Route of the South-to-North Water Diversion Project on Environment of Middle and Lower Reaches of Han River* are used in this assessment report to predict the impact of heightening of Danjiangkou dam on water temperature of main stream in middle and lower reaches of Han River.

Temperature of water discharge from bottom outlet of Danjiangkou reservoir in January, February, March, November and December after heightening of the dam is slightly higher than that before heightening of the dam and the temperature rises by 0.01°C (March) to 0.96°C(November). The water temperature gradually decreases along downstream waters of Danjiangkou reservoir. In November (the month with biggest temperature rise), the difference between water temperature in reaches which are 40km away from the dam after heightening of Danjiangkou dam and the current water temperature of the same location is only 0.5°C and the temperature of reaches which are 100km away from the dam (i.e. near Xinji dam site) is basically the same as current water temperature of the same location.

Temperature of water discharge from bottom outlet of Danjiangkou reservoir from April to October after heightening of the dam is lower than that before heightening of the dam and the temperature decreases by 0.04°C (October) to 2.30°C (July). The water temperature gradually increases along downstream waters of Danjiangkou reservoir. In July (the month with biggest temperature decrease), the difference between water temperature in reaches which are 120km away from the dam (i.e. near end of Cuijiaying reservoir) after heightening of Danjiangkou dam and the current water temperature of the same location is only 0.56°C and the temperature of reaches which are about 200km away from the dam (i.e. near Yakou dam site) is basically the same as current water temperature of the same location. In conclusion, the wide water surface of Wangfuzhou reservoir area and Xinji reservoir area can restore the temperature of low-temperature water to some degree after heightening of Danjiangkou dam and make the water temperature of Yakou dam return to the ones under normal conditions. Hence, water temperature of Yakou hydro-junction is not affected by discharge of low-temperature water.

6.1.2.3 Prediction on impact on water temperature of this project.

α index method is used in accordance with *Specifications for Environmental Impact Assessment of Water Conservancy and Hydropower Engineering* (SDJ302-88) to distinguish overall water temperature structure of the reservoir: α= total annual water inflow of the reservoir/total capacity of the reservoir.

When α<10, the water temperature structure is of stratification type, the water temperature in the temperature rise stratification is obviously higher than that in middle and lower stratification and the temperature difference can be above 1.5°C/m; when $\alpha>20$, it is of mixed type and water temperature distribution within the reservoir at any time during one year is relatively even; when $10<\alpha<20$, it is of transition type and characteristics of water temperature distribution of the above two types co-exist. When the normal pool level of Yakou reservoir is 55.22m, the total capacity is 407,300,000m^3 and the average annual runoff is 34.8 Billion m^3, we can get $\alpha=85.44>20$.

Hence, water temperature structure of Yakou reservoir is of mixed type and water storage of Yakou reservoir will not cause significant changes in water temperature distribution. Temperature of water flowing into the reservoir, in the reservoir and discharged from the reservoir is basically the same, i.e. water temperature distribution of the whole reservoir during one year is relatively even, there is no obvious change in longitudinal water temperature and stable stratification of water temperature will not occur. Temperature of discharged water is close to the temperature under natural conditions and no low-temperature water will be discharged.

This project is similar to the above mentioned project and water temperature structure of the reservoir area is of mixed type. So the natural temperature will not be affected by construction of Yakou dam.

6.1.3 Prediction and analysis of impact on water quality of Yakou reservoir

6.1.3.1 Impact on water quality at preliminary stage of water storage

At preliminary stage of water storage, decayed matters (such as weeds, trees, branches and leaves) and soil in the inundated area will all be decomposed and release organic matters. Decomposition of organic matters will increase concentration of BOD_5, COD, nitrogen and phosphorus and reduce the concentration of dissolved oxygen in the water. If clearing of the reservoir was not done according to the specifications, there may be many extracts at the bottom of reservoir, thus affecting water quality at preliminary stage of water storage.

This project is located in plain and hilly terrain. Except two industrial wastewater discharge outlet in the water catchment area (Wangjia Ditch and discharge outlet of Xiangdeng Chemical Fertilizer Plant in Denglin Farm), pollutants of the reservoir during water storage period are mainly the organic matters released by decay of plants on cultivated land and forest land around the reservoir area and the soil.

Since Yakou reservoir inundates a small area of land and there is not so many potential pollution sources within the inundated area; the water storage is only for a short period of time and there is still a large amount of water discharged, water quality of the reservoir at the preliminary stage of water storage will decrease to some degree but such situation will not last long.

6.1.3.2 Analysis of change tendency of pollution sources in the reservoir area

a) Industrial pollution sources

The main industrial pollutants discharge outlets in the reservoir area are: Wangjia Ditch and discharge outlet of Xiangdeng Chemical Fertilizer Plant in Denglin Farm. Pollutants of Wangjia Ditch mainly come from wastes of phosphate fertilizer production, pharmaceutical products production and production of organic chemical raw materials in Xiangcheng industrial park. With construction of model city for national environmental protection, it is expected that new increment of oxygen demand of industrial chemistry industry of Yicheng City in the 12th Five-Year Period will be decreased year by year.

Since there are water intakes scattered in Yakou section in main stream of Han River and class II standard as specified in *Environmental Quality Standard for Surface Water* (GB3838-2002) is carried out, new industrial pollution sources should not be increased around the reservoir area and wastewater shall not be directly discharged into the reservoir. In other words, there is no obvious tendency that industrial pollution in the reservoir area will be increased in the future. Hence, we can consider that the total pollution sources will remain unchanged during the planned years.

b) Domestic pollution sources

New increment in COD and ammonia nitrogen in urban domestic sewage can be predicted in accordance with development scale of urban population. Except that domestic sewage of Yancheng Sub-district is discharged into downstream of the dam through Yidao ditch upon treatment of Sanda Water Co., Ltd., domestic sewage of other seven towns (sub-districts) are discharged into the reservoir area through channels, culverts and sluices. The prediction on discharge of domestic sewage in the reservoir area is shown in Table 6.1.3-1.

Table 6.1.3-1 Prediction on domestic sewage amount around the reservoir area

County	Town	Current population	Expected population in 2020	Amount of domestic sewage (ten thousand m^3/a)	COD_{Cr} (t)	Ammonia nitrogen (t)
Xiangcheng district	Oumiao Town	32908	33726	169.4	669.56	74.82
Xiangyang district	Dongjin Town	60863	62376	313.3	1238.36	138.37
Yicheng City	Liushui Town	20570	21081	105.9	418.70	46.80
	Nanying Sub-district	8285	8491	42.6	168.43	18.82
	Wangji Town	16815	17233	86.6	342.01	38.26
	Zhengji Town	45723	46859	235.3	930.54	104.01
	Xiaohe Town	41151	42174	211.8	837.53	93.57
Total		226315	231940	1164.9	4605.12	514.64

In accordance with requirements of relevant documents of Hubei province, Xiangyang city has made vigorous efforts on building domestic sewage treatment plant and accelerating construction of sewage treatment facilities in counties and some key towns. The city reforms the urban domestic sewage treatment facilities to improve the effect of removing phosphorus and nitrogen, implements phase II construction of Sanda Water Co., Ltd. to increase its capacity by 20,000 tons per day and increases daily treatment capacity of Xiaohe Town Sewage Treatment Plant by 10,000 tons. In addition, the city takes scattered and centralized manner to build recycled water treatment station and booster pumping station and build new reuse system of recycled water in governmental institutions, schools and residential areas when the conditions permit. By 2018, urban sewage will all be treated by sewage treatment plant and will be discharged after meeting Level-one B standard (i.e. concentration of COD_{cr} is 60mg/L) upon treatment. When the sewage discharge of other towns remains unchanged, discharge of CODcr will be lower than the predicted value in the above table.

c) Agricultural and livestock and poultry pollution sources

Cultivated land of the reservoir area will decrease after completion of the reservoir construction. With gradual implementation of “replacing coal by electricity” and construction of soil and water conservation engineering and ecological environment project, soil erosion will be gradually controlled. It is expected that agricultural non-point source pollution in the planned year will decrease after completion of the reservoir construction. The current breeding pollution sources are shown in table 4.5.1-4.

d) Prediction on pollution sources of the reservoir area

Pollution sources of the reaches of Han River in which Yakou reservoir area is located mainly are domestic pollution sources, industrial pollution sources and agricultural non-point sources. Domestic pollution sources and agricultural non-point sources are discharged into the river along the waterway. Yidao Ditch which receives urban domestic sewage (discharge outlet of Sanda Water Co., Ltd.) and industrial pollution sources confluences into Han River through downstream Guohai sluice of Yakou project. Wangjia Ditch mainly receives pollutants discharged by Xiaohe Town Industrial Park in Xiangcheng Economic and Technological Development Zone and general discharge outlet of Xiangdeng Chemical Fertilizer Plant in Denglin Farm. Pollutants of these two discharge outlets flow together into Han River in Xiaohe Town and Nanying sub-strict respectively.

Table 6.1.3-2 Pollutants discharged into the reservoir and concentration of pollutants.

Type of pollutants	Distance to the dam site	Discharge (m^3/s)	COD concentration (mg/L)	Ammonia nitrogen concentration (mg/L)
Main stream (downstream of Cuijiaying hydro-junction)	52.67	470	5.20	0.025
Wangjia ditch	29.0	1.15	17.24	3.15
Xiangdeng Chemical Fertilizer Plant in Denglin Farm	4.8	0.07	123.30	12.0
Domestic sewage	-	0.42	400	25.0
Agricultural non-point source	545.4g/s			

6.1.3.3 Prediction on overall water quality of the reservoir area

a) Predictors

In accordance with main featured pollutants of pollution sources, the predictors for water quality are determined as COD_{Cr}, ammonia nitrogen, TN and TP.

b) Prediction model

Backwater length of Yakou reservoir is 52.67km and river width after water storage is 0.8 to 4km. Generally, Yakou reservoir shows characteristics of river-type reservoir. The water retention time is short and the reservoir is not deep and has no obvious water temperature stratification. Hence, overall water quality of the reservoir area can be predicted with one-dimensional water quality model analysis.

$$C_x = C_0 \exp\left(-K\frac{X}{u}\right)$$

In the equation:

C_x—pollutants concentration in water after flowing X (distance), mg/L;

C_o—pollutants concentration at the starting section (X=0), mg/L;

u—average flow velocity, m/s;

x—fore-and-aft distance, m;

K—comprehensive attenuation coefficient of pollutants, s^{-1}.

Determination of K value: comprehensive attenuation coefficient of pollutants reflects the degradation speed of organic pollutants under action of water and is related to hydrologic conditions of river, such as, flow, flow velocity, river width, water depth, contents of sediments, etc. Comprehensive attenuation coefficient of pollutants of this report is determined on the basis of backward reasoning over observed data of typical sections of the reservoir area before water storage and comparing with observed data of other rivers in China. K value before construction of the reservoir is determined as 0.2(1/d). In consideration of changes in hydrologic conditions after construction the reservoir, K value is determined as 0.06(1/d).

Determination of C_o value: since domestic and agricultural pollution sources are evenly discharged into the river and two major industrial pollution sources are converged at Xiaohe Town and Liushui Town, then complete-mixing model can be used approximately to predict C_o value if not considering the attenuation.

$$C_o=(C_p Q_p+C_h Q)/(Q_p+Q)$$

In the equation: Q_p, C_p—sewage discharge and concentration, m^3/s, mg/L;

Q—flow of the section, m^3/s;

C_h—pollutants concentration in upstream reaches, mg/L.

Take the average value of observed pollutants concentration of the monitoring cross-sections in the reservoir area as C_h. For example, the COD_{Cr} concentration of middle section of Yakou reservoir (at 200m downstream of Yicheng bridge) in normal flow years and low flow years is 5.0 mg/L and 12.5 mg/L respectively.

Q takes the minimum water discharge of Cuijiaying hydro-junction, $Q=470m^3/s$.

c) Prediction results on overall water quality of the reservoir

The prediction results are shown in Table 6.1.3-3 to 6.1.3-6. After water storage, concentration scope of COD_{Cr}, ammonia nitrogen, TN and TP of the reservoir area in normal flow years is 5.42mg/L to 8.57 mg/L, 0.040mg/L to 0.059 mg/L, 1.43mg/L to 1.61 mg/L and 0.05mg/L to 0.09 mg/L respectively. COD_{Cr} concentration of the downstream section which is 200m away from Wangjia Ditch, middle section of Yakou reservoir (i.e. 200m downstream of Yicheng Bridge) and section of Yakou dam site is 8.57mg/L, 5.42 mg/L and 6.14mg/L respectively and ammonia nitrogen concentration of the above three sections is 0.059mg/L, 0.040 mg/L and 0.052mg/L respectively.

After water storage, concentration scope of COD_{Cr}, ammonia nitrogen, TN and TP of the reservoir area in low flow years is 13.54mg/L to 13.89 mg/L, 0.082mg/L to 0.090mg/L, 1.81mg/L to 2.13mg/L and 0.06mg/L to 0.10 mg/L respectively. COD_{Cr} concentration of the downstream section which is 200m away from Wangjia Ditch, middle section of Yakou reservoir (i.e. 200m downstream of Yicheng Bridge) and section of Yakou dam site is 13.89mg/L, 13.54 mg/L and 13.79mg/L respectively and ammonia nitrogen concentration of the above three sections is 0.085mg/L, 0.082 mg/L and 0.090mg/L respectively.

In conclusion, the overall water quality of the reservoir area will not change greatly. Concentration of the predictors after construction of the reservoir is slightly higher than that before reservoir construction. Total nitrogen still exceeds the standard with maximum exceeding of 3.26 times. Other indicators all satisfy Class II standard in *Environmental Quality Standard for Surface Water* (GB3838-2002) (total phosphorus shall be subject to the river standard). if total phosphorus follows the standard of lake and reservoir, then it exceeds the standard by 3.0 times (maximum). Hence, attention must be paid to and efforts should be made on eutrophication of the reservoir area.

Table 6.1.3-3 Prediction results of COD_{Cr} concentration of the reservoir area

Unit: mg/l

Section	Hydrologic year	Fore-and-aft distance (m)	0	50	100	150	200	300	500	1000	1800
downstream section which is 200m	Normal	Before reservoir construction	7.93	7.92	7.92	7.91	7.90	7.88	7.83	7.75	7.93
		After reservoir construction	8.57	8.56	8.55	8.55	8.53	8.51	8.44	8.32	8.32

away from Wangjia Ditch	Low-flow	Before reservoir construction	12.85	12.83	12.83	12.82	12.80	12.77	12.69	12.56	12.85
		After reservoir construction	13.89	13.87	13.85	13.85	13.82	13.79	13.68	13.48	13.48
middle section of Yakou reservoir (i.e. 200m downstream of Yicheng Bridge)	Normal	Before reservoir construction	5.00	5.00	5.00	4.99	4.99	4.98	4.97	4.94	4.88
		After reservoir construction	5.42	5.40	5.40	5.39	5.39	5.38	5.37	5.32	5.24
	Low-flow	Before reservoir construction	12.50	12.50	12.50	12.48	12.48	12.45	12.43	12.35	12.21
		After reservoir construction	13.54	13.50	13.50	13.47	13.47	13.45	13.42	13.30	13.11
section of Yakou dam site	Normal	Before reservoir construction	5.67	5.66	5.66	5.66	5.65	5.65	5.63	5.60	5.53
		After reservoir construction	6.14	6.12	6.12	6.11	6.11	6.10	6.08	6.03	5.95
	Low-flow	Before reservoir construction	12.73	12.71	12.71	12.71	12.69	12.69	12.64	12.57	12.42
		After reservoir construction	13.79	13.74	13.74	13.72	13.72	13.70	13.65	13.54	13.36

Table 6.1.3-4 Prediction results of ammonia nitrogen concentration of the reservoir area

Unit: mg/l

Section	Hydrologic year	Fore-and-aft distance (m)	0	50	100	150	200	300	500	1000	1800
downstream section which is 200m away from Wangjia Ditch	Normal	Before reservoir construction	0.055	0.055	0.055	0.055	0.054	0.054	0.054	0.053	0.055
		After reservoir construction	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.058	0.059
	Low-flow	Before reservoir construction	0.079	0.079	0.079	0.079	0.078	0.078	0.078	0.077	0.079
		After reservoir construction	0.085	0.085	0.085	0.085	0.085	0.084	0.084	0.083	0.085
middle section of Yakou reservoir (i.e. 200m downstream of Yicheng Bridge)	Normal	Before reservoir construction	0.037	0.037	0.037	0.037	0.037	0.036	0.036	0.036	0.036
		After reservoir construction	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.039	0.039
	Low-flow	Before reservoir construction	0.076	0.076	0.076	0.076	0.076	0.075	0.075	0.075	0.074
		After reservoir construction	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.080	0.079
section of Yakou dam site	Normal	Before reservoir construction	0.048	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047
		After reservoir construction	0.052	0.052	0.052	0.051	0.051	0.051	0.051	0.051	0.050
	Low-flow	Before reservoir construction	0.083	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.081
		After reservoir construction	0.090	0.090	0.090	0.088	0.088	0.088	0.088	0.087	0.086

Table 6.1.3-6 Prediction results of total nitrogen concentration of the reservoir area

Unit: mg/l

Section	Hydrologic year	Fore-and-aft distance (m)	0	50	100	150	200	300	500	1000	1800
downstream section which is 200m away from Wangjia Ditch	Normal	Before reservoir construction	1.49	1.49	1.49	1.49	1.48	1.48	1.47	1.46	1.49
		After reservoir construction	1.61	1.61	1.61	1.61	1.60	1.60	1.59	1.56	1.61
	Low-flow	Before reservoir construction	1.72	1.72	1.72	1.72	1.71	1.71	1.70	1.69	1.72
		After reservoir construction	1.86	1.86	1.86	1.86	1.85	1.85	1.84	1.80	1.86
middle section of Yakou reservoir (i.e. 200m downstream of Yicheng Bridge)	Normal	Before reservoir construction	1.32	1.32	1.32	1.32	1.32	1.31	1.31	1.30	1.29
		After reservoir construction	1.43	1.43	1.43	1.42	1.42	1.42	1.42	1.40	1.38
	Low-flow	Before reservoir construction	1.67	1.67	1.67	1.67	1.67	1.66	1.66	1.64	1.63
		After reservoir construction	1.81	1.81	1.81	1.80	1.80	1.80	1.80	1.77	1.75
section of Yakou dam site	Normal	Before reservoir construction	1.63	1.63	1.63	1.63	1.62	1.62	1.62	1.61	1.59
		After reservoir construction	1.77	1.76	1.76	1.76	1.76	1.75	1.75	1.73	1.71
	Low-flow	Before reservoir construction	1.96	1.96	1.96	1.96	1.95	1.95	1.95	1.94	1.91
		After reservoir construction	2.13	2.12	2.12	2.12	2.12	2.10	2.10	2.08	2.06

Table 6.1.3-6 Prediction results of total phosphorus concentration of the reservoir area

Unit: mg/l

Section	Hydrologic year	Fore-and-aft distance (m)	0	50	100	150	200	300	500	1000	1800
downstream section which is 200m away from Wangjia Ditch	Normal	Before reservoir construction	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
		After reservoir construction	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08
	Low-flow	Before reservoir construction	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
		After reservoir construction	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.09	0.09
middle section of Yakou reservoir (i.e. 200m downstre	Normal	Before reservoir construction	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
		After reservoir construction	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.07
	Low-flow	Before reservoir construction	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
		After reservoir	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08

am of Yicheng Bridge)		construction									
section of Yakou dam site	Normal	Before reservoir construction	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		After reservoir construction	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	Low-flow	Before reservoir construction	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
		After reservoir construction	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06

d) Analysis of impact on water quality of bay

Usually, bay or dead water will be formed in the reservoir area after completion of the reservoir. Water quality of such areas may be bad when pollutants accumulate here. Yakou reservoir is river-type reservoir with relatively straight waterway and obvious dead water will not be formed. The main tributaries are Chun River and Wei River which are located above end of backwater (p=20% of flood inflow). Backwater of reservoir reaches to entrance of Wei River. The bay conditions and analysis of impact on water quality are shown in Table 6.1.3-7.

Table 6.1.3-7 Bay conditions and analysis of impact on water quality

Name	Location (distance to the dam site)	Conditions of the tributary	Pollutant carrying capacity and water quality	Analysis of impact on water quality of bay after reservoir construction
Chun River	Left bank, the reservoir end 40km	Length: 37.9km, Area of the basin: 100.8km^2	The river system is developed. Reservoir in the upper reaches has been built. Pollution sources are industrial pollution, domestic pollution and agricultural pollution. The water quality is of class III and meets requirements of function zoning.	Located above backwater of the reservoir end, not affected by backwater and will not exert impact on water quality

Name	Location (distance to the dam site)	Conditions of the tributary	Pollutant carrying capacity and water quality	Analysis of impact on water quality of bay after reservoir construction
Wei River	Right bank Xiaohe Town, 29km	Length: 32.6km, Area of the basin : 97km^2	The river system is developed with dendritic watershed system and reservoir in the upper reaches has been built. Flow together with Wangjia Ditch into Han River. Wangjia Ditch receives wastewater of Xiaohe Town industrial park in the upper reaches and main pollution sources are industrial pollution, domestic pollution and agricultural pollution. So the water quality of Wangjia ditch is bad. In order to protect water quality of main stream of Han River and prevent backwater of Han River in the flood season from being polluted by the polluted water, an unsurfaced road at location which is 2.5km away from the estuary of Han River and in the lower reaches of Wei River has been built to intercept the water. Culvert pipes are used to diverse the water (shown in Figure 6.1.3-6). After construction of reservoir, water quality of the bay can still meet the standard of class III and the requirements of water function zoning.	Backwater of reservoir has small influence on water level jacking and the influence mainly occur in estuary reaches in flood season and within the dam. The backwater will not be beyond the riverbed and will not cause dead water or still water area. Hence, the possibility that water quality deteriorates is small. However, since there are inflow of industrial wastewater and domestic sewage and concentration of total nitrogen in the upper reaches of reservoir end is relatively higher, eutrophication may occur.

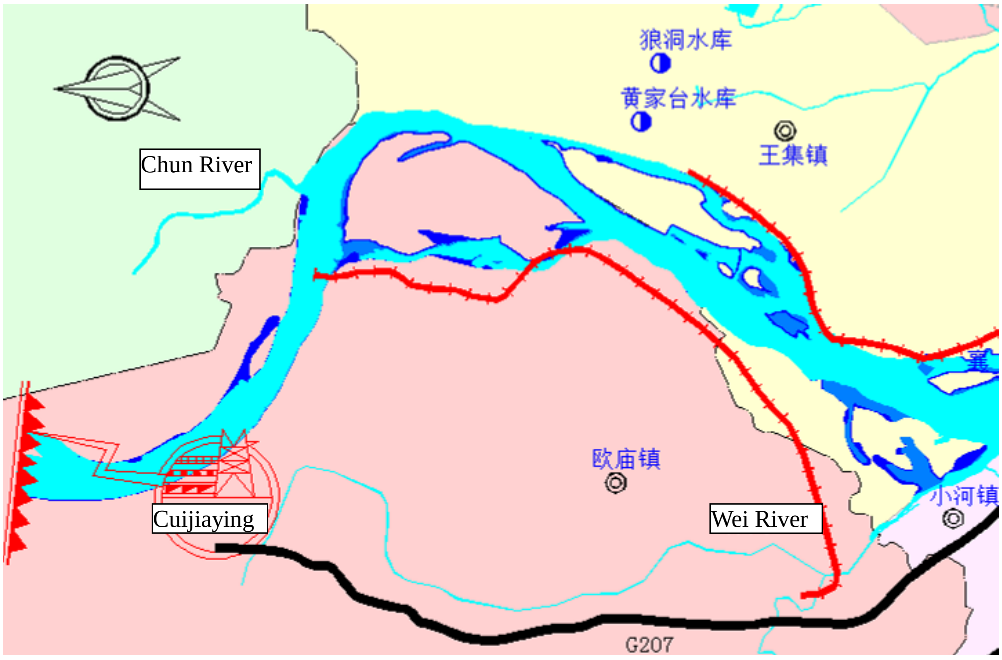


Figure 6.1.3-1 Location diagram of Chun River and Wei River in the reservoir area

6.1.3.4 Analysis of impact on water quality of water source conservation area and water intake

a) Impact on water source conservation area

In accordance with Scheme for Classification of Centralized Drinking Water Source Protection Area of above County Level in Hubei Province, one drinking water sources protection area (including level-one and level-two), namely Yicheng Water Plant, was set. The scope of level-two protection area is 3,000m upstream of the water intake of Yicheng Water Plant to 300m of the water intake. Since sewage and wastewater discharge outlet of Wangjia Ditch is close to the downstream water intake of Yicheng Water Plant, about 9.0km, we need to estimate the impact of pollution source diffusion in local waters. Considering that the pollution sources are discharged through the onshore discharge outlet and water surface of such reaches is wide, it is unnecessary to take reflection effect of the opposite bank into consideration and the following planar two-dimensional steady mixing model is used:

$$c(x, y) = c_h + \frac{c_p Q_p}{H\sqrt{\pi M_y x u}} \exp\left(-\frac{u y^2}{4 M_y x}\right)$$

In the equation:

x—distance between prediction point and discharge point, m;

y—lateral distance between prediction point and discharge point (not offshore distance, positive or negative value $0 \leq a+y$), m;

c—pollutant concentration at prediction point (x, y), mg/l;

a—distance between sewage discharge outlet and the bay bank ($0 \leq a$), m. Discharge at the bank is a=0;

c_p—pollutant concentration in the sewage, mg/l;

Q_p—sewage flow, m^3/s;

c_h—background pollutant concentration of the bay, mg/l;

H—average depth of bay in the prediction area, m;

M_y—lateral mixing (diffusion) coefficient of the bay, m^2/s;

u—water flow velocity, m/s;

π—pi.

1) Calculation conditions

A Hydrological conditions

The water inflow mainly comes from water discharge of Cuijiaying hydro-junction. In this report, two conditions are selected for the calculation, namely, the minimum water discharge of Cuijiaying hydro-junction ($470m^3/s$), the average annual water inflow of Cuijiaying hydro-junction during later period of Danjiangkou reservoir construction ($1,080m^3/s$) and the average flow of Chun River ($1.2m^3/s$) (in February of low flow years with reliability of 95%).

Wangjia Ditch receives wastewater of Xiaohe Town industrial park and flows together with Wei River into Han River. The wastewater amount is in connection with waterwaste produced and discharged by enterprises. Hence, the average annual flow of Wangjia Ditch calculated according to precipitation characteristics of the region is shown in Table 6.1.3-8.

Table 6.1.3-8 The average annual flow of Wangjia Ditch Unit: m^3/s

Month	5	6	7	8	9	10	11	12	1	2	3	4	Annual
Wangjia Ditch	1.45	1.95	2.58	2.16	2.37	1.24	0.90	0.78	0.73	0.73	0.77	0.85	1.38

B Background conditions of water quality

Concentration of COD_{Cr}, ammonia nitrogen, total nitrogen and total phosphorus in downstream section which is 200m away from Wangjia Ditch is 8.57mg/L, 0.059mg/L, 1.61mg/L and 0.10mg/L respectively in normal flow years and is 13.89mg/L, 0.085mg/L, 1.86mg/L and 0.09mg/L in low flow years.

C Lateral mixing coefficient M_y

Taylor method as recommended in the guidelines is used to determine the lateral mixing coefficient M_y, namely

$$M_y = (0.058H + 0.0065B)\sqrt{gHI}$$

In accordance with the above equation and calculation results of the section under conditions of normal pool level, the lateral mixing coefficient is $0.38m^2/s$.

2) Concentration at water intake of Yicheng Water Plant

Upon prediction, when the minimum water discharge is implemented in Cuijiaying hydro-junction, concentration of COD_{Cr}, ammonia nitrogen, total nitrogen and total phosphorus of water intake of Yicheng Water Plant in normal flow years is 7.87 mg/L, 0.048 mg/L, 1.47mg/L and 0.08mg/L respectively and in low flow years is 11.83mg/L, 0.069 mg/L, 1.83mg/L and 0.09mg/L respectively. Except that total nitrogen concentration exceeds the standard and total phosphorus concentration exceeds the standard when following the standard of lake and reservoir, other indicators all meet the standard of class II.

The given background value surpass the given standard, thus causing concentration of total nitrogen to exceed the standard value.

When Cuijiaying hydro-junction discharges water according to the average annual water inflow, concentration of COD_{Cr}, ammonia nitrogen, total nitrogen and total phosphorus of water intake of Yicheng Water Plant in normal flow years is6.69mg/L, 0.036 mg/L,1.25mg/L and 0.07mg/L respectively and in low flow years is 10.11mg/L, 0.064 mg/L, 1.56mg/L and 0.08mg/L respectively. Except that total nitrogen concentration exceeds the standard and total phosphorus concentration exceeds the standard when following the standard of lake and reservoir, other indicators all meet the standard of class II.

b) Impact on water quality of other water intakes in the reservoir area

There are altogether 4 water intakes in Yakou reservoir area. Influenced by inundation of Yakou reservoir area, water intake pump room of Wangji Town Water Plant needs to be lifted and then the water intake after construction of Yakou reservoir can be guaranteed. No adverse impact will be exerted on water intake of Wangji Town Water Plant and the water quality is still decided by water discharge of the upper reaches.

Water quality of Wangji Town Water Plant is mainly affected by that of water discharge of the upper reaches. In accordance with "6.1.3.3 prediction on overall water quality of the reservoir area", water quality of water intake of Wangji Town Water Plant will be under small influence after construction of Yakou reservoir and concentration of COD_{Cr} and ammonia nitrogen can still meet requirements of class II water quality function zoning.

Water intakes of Xiangnan Prison Water Plant and Danjiangkou Resettlement Residential Area are close to the dam site and discharge outlet of Xiangdeng Chemical Fertilizer Plant in Denglin Farm (4.3km away from the dam) is about 1.5km and 3.1km away from the above water intakes, we need to estimate the impact of pollution source diffusion in local waters. Considering that the pollution sources are discharged through the onshore discharge outlet and water surface of such reaches is wide, it is unnecessary to take reflection effect of the opposite bank into consideration and the aforesaid planar two-dimensional steady mixing mode is used. The average annual water inflow of Cuijiaying hydro-junction, i.e. 1, 080m^3/s, is taken as water discharge of the upper reaches.

Upon estimation, the concentration of COD_{Cr}, ammonia nitrogen, total nitrogen and total phosphorus of water intake of Xiangnan Prison Water Plant is 6.59mg/L, 0.052mg/L, 1.50 mg/L and 0.06 mg/L respectively in normal flow years and is 10.81mg/L, 0.085mg/L, 1.75mg/L and 0.06 mg/L respectively in low flow years; the concentration of COD_{Cr}, ammonia nitrogen, total nitrogen and total phosphorus of water intake of Danjiangkou

Resettlement Residential Area is 6.27 mg/L, 0.055mg/L, 1.49mg/L and 0.05 mg/L respectively in normal flow years and is 10.11 mg/L, 0.085mg/L, 1.71mg/L and 0.05mg/L respectively in low flow years. Except that concentration of total nitrogen exceeds the standard and concentration of total phosphorus surpasses the given standard if standard of lake and reservoir is followed, other predictors can meet requirements of class II water quality standard.

Water intake of Wangji Town Water Plant is located at reservoir end and has rapid flow velocity. The water quality of such water intake is influenced by water discharge of the upper reaches. Concentration of COD_{Cr}, ammonia nitrogen, total nitrogen and total phosphorus of the water intake is 5.65mg/L, 0.028mg/L, 1.45mg/L and 0.07mg/L respectively in normal flow years and 11.7mg/L, 0.085mg/L, 1.67mg/L and 0.06 mg/L respectively in low flow years. Except that concentration of total nitrogen exceeds the standard and concentration of total phosphorus surpasses the given standard if standard of lake and reservoir is followed, other predictors can meet requirements of class II water quality standard.

In accordance with “6.1.3.5 Prediction and assessment of eutrophication in reservoir and the tributaries”, mild eutrophication and moderate eutrophication will occur during normal flow years and low flow years respectively. The possibility of algae outbreak is small. Since high nitrogen and phosphorus concentration and increase of algae will exert adverse impact on infiltration effect of water plants in the reservoir area and increase the difficulties and cost of water treatment, we suggest strengthening the sewage treatment in Han River and the upper reaches and reducing the discharge of pollutants, especially nitrogen and phosphorus and other nutrient salt to reduce the possibility of eutrophication in water around the water intake.

c) Impact on water quality of downstream water intakes of Yakou dam

The water intake which is nearest to Yakou dam is water intake of Liushui Town, Xiangyang, and the distance is 8.0km. This water intake is located in Nianpanshan reservoir area and construction and operation of this project will not discharge any wastewater to this water area. Changes of hydrological regime of the water around the water intake is under limited influence of daily changes of water inflow and no adverse impact will be exerted on water quality of the water intake of Liushui Town.

6.1.3.5 Prediction and assessment of eutrophication in reservoir and the tributaries

a) Prediction on eutrophication of the reservoir

1) Assessment standard

In accordance with *Technical Specifications for Assessment of Surface Water Resources Quality* (SL 395-2007), assessment standard and grading methods of eutrophication of the reservoir is shown in Table 6.1.3-9.

Table 6.1.3-9 Assessment standard and grading method of eutrophication of reservoirs in China

Eutrophic state EI=trophic status index	Value of evaluation items En	TP (mg/L)	TN (mg/L)	Chla (mg/L)	COD_{Mn} (mg/L)	Transparency (m)
Oligotrophic 0≤EI≤20	10	0.001	0.02	0.0005	0.15	10
	20	0.004	0.05	0.001	0.4	5.0
Mesotrophic 20<EI≤50	30	0.010	0.1	0.002	1.0	3
	40	0.025	0.3	0.004	2.0	1.5
	50	0.05	0.5	0.01	4.0	1.0
Mild eutrophication 50<EI≤60	60	0.10	1.0	0.026	8.0	0.5
Moderation eutrophication 60<EI≤80	70	0.2	2.0	0.064	10	0.4
	80	0.6	6.0	0.16	25	0.3
Heavy eutrophication 80<EI≤100	90	0.9	9.0	0.4	40	0.2
	100	1.3	16.0	1.0	60	0.12

2) Assessment method

Assessment value of each item is gotten in accordance with the above mentioned predicted value and the grading standard. Then the comprehensive assessment value of different years is obtained according to the following equation. Finally, the eutrophic state of such monitoring points in different years is deduced by comparing the comprehensive assessment value with the grading standard.

$$\mathrm{EI} = \sum_{\mathrm{n}=1}^{N} E\mathrm{n} / N$$

In the equation: EI—trophic status index;

En—value of the evaluation item;

N—number of evaluation items.

In accordance with the above prediction, concentration of total nitrogen and total phosphorus is 1.65 mg/L and 0.08mg/L respectively. Concentration of COD_{Mn} is conversed from predicted results of COD and is 2.46mg/L in normal flow years and 6.15mg/L in low flow years. Then the EI in normal flow years and low flow years is 57.3 and 64.9 respectively. Therefore, we can preliminarily conclude that mild eutrophication and moderate eutrophication happen in the reservoir area during normal flow years and low flow years respectively.

Many factors cause eutrophication of the reservoir: concentration of total phosphorus, and concentration of total nitrogen, geographical location of the reservoir, and shape and operation characteristics of the reservoir, temperature and sunlight. Eutrophication is extremely easy to occur in sunny days of hot season with continuous high temperature and low pressure after heavy rain and under the conditions of weak wind, slow flow velocity and relatively stable water. In flood season, the water temperature of the reservoir area is relatively high. This is when eutrophication is easy to occur. Water exchange of Yakou reservoir is frequently and the annual frequency still exceeds 99 times after heightening and water storage of Danjiangkou reservoir. Yakou reservoir is daily regulated reservoir and does not have flood regulation capacity. In flood season with high temperature, the residence time of water is short and water flows fast. These can all effectively inhibit growth and breeding of alga. Even if the concentration of nitrogen and phosphorus is high, the possibility of eutrophication due to algae outbreak is still not big. However, since there are many total nitrogen contents flowing into the reservoir (concentration of total nitrogen behind Cuijiaying dam is 1.57 mg/L), pollution source control and management in upper reaches and around the reservoir should be strengthened to control eutrophication level of the reservoir area and prevent eutrophication from occurring in areas where the water flows slowly or is relatively still in summer.

3) Reasonability analysis of the predicted results

In accordance with analogy analysis of trophic status monitoring results of Cuijiaying reservoir after it is put into operation (for details, see “5.3.2.2 Eutrophication Investigation and Assessment”), mild or moderation of eutrophication is likely to happen in Yakou reservoir area.

b) Prediction on eutrophication of the tributaries

Main pollution sources around the reservoir area come from industrial wastewater of Xiangcheng Economic and Technological Development Zone which is in upper reaches of Wei River. Although the discharge is of low amount, affected by jacking of backwater of the reservoir after construction of Yakou reservoir, water of Wei River flows slowly, it is possible to have eutrophication. The total nitrogen and total phosphorus in Wei River mainly come from discharge of industrial wastes and agricultural runoff. And background concentration of total nitrogen and total phosphorus is higher and the average concentration is 1.24mg/L and 0.11mg/L respectively upon calculation of discharge amount and surface runoff. It is judged that eutrophic state of estuary of Wei River is eutrophication (when concentration of total phosphorus is ≥0.03mg/L and concentration of total nitrogen is ≥0.3mg/L, the eutrophic state is eutrophication; when concentration of total phosphorus is<0.02mg/L mg/L and concentration of total nitrogen is ≤0.2mg/L, the eutrophic state is oligotrophgication; otherwise, it is transition status). After water storage of the reservoir and affected by jacking of the reservoir, conditions for eutrophication are ready in estuary of Wei River, to which we should pay attention.

6.1.4 Prediction and analysis of pollutant carrying capacity and water environmental capacity

6.1.4.1 Prediction on pollutant carrying capacity

Construction of the reservoir will reduce the flow velocity and transfers the supercritical flow into subcritical flow. This will exert impact on pollutant carrying capacity of the water in such reaches.

The following two-dimensional convection diffusion equation is used to calculate the pollutants carrying capacity of the reaches in reservoir area before construction of the reservoir.

$$u\frac{\partial C}{\partial x}=\frac{\partial}{\partial y}\left(E_y\frac{\partial C}{\partial y}\right)-KC$$

In the equation:

C——concentration of pollutants, mg/L;

x——fore-and-aft distance, m;

y——lateral distance between the calculation point and the bank, m;

E_y——lateral diffusion coefficient of pollutants, m^2/s;

When the pollutant concentration at riverbank is taken as control concentration of the downstream control section, the pollutant carrying capacity of the corresponding reaches is calculated thought the following equation:

$$M=\left[C_s-\left(C_0+\frac{m}{h\sqrt{\pi E_y xv}}\right)\exp\left(-K\frac{x}{v}\right)\right]Q$$

In the equation:

M——pollutant carrying capacity;

Cs——concentration of target pollutants, mg/L, Cs of COD is 15 and Cs of ammonia nitrogen is 05;

C_0——background concentration, mg/L, according to water quality monitoring results of the reservoir area, COD is lower than the tested lower limit. Calculating conservatively, the background concentration is 5 and concentration of ammonia nitrogen is 0.084;

Q——flow of the section;

K——comprehensive auto purification coefficient of pollutants, 1/s, use monitoring result of the sections at reservoir and dam site respectively to deduce;

u——average flow velocity under designed flow, m/s;

h——average depth of the water under designed flow, m.

After construction of the reservoir, pollutant carrying capacity of the reservoir is calculated with heterogeneous mixing model of lake and reservoir type as specified in *Specifications for Calculating Pollutants Carrying Capacity of the Water* (GB/T 25173-

2010):

$$M=\left(C_s-C_0\right)\exp\left(\frac{K\Phi h_L r^2}{2Q_P}\right)Q_P$$

In the equation:

Φ——spread angle, when vertically discharging at wide bank, Φ=π;

H_L——average depth of lake and reservoir in the diffusion areas, m;

r——distance between the boundary of calculated water area and the discharge outlet, m;

Other symbols have the same meaning as those mentioned above.

COD and ammonia nitrogen carrying capacity of Yakou hub reservoir area before and after construction of the reservoir is shown in Table 6.1.4-1.

Table 6.1.4-1 COD and ammonia nitrogen carrying capacity of Yakou hub reservoir area

Item		COD	Ammonia nitrogen
Pollutant carrying capacity (t/a)	Before reservoir construction	3224	414
	After reservoir construction	2811	378

From the table we can see that water quality of the reservoir area meets standard of class II and the water after construction of the reservoir still has certain pollutant carrying capacity. However, the water after reservoir construction flows slowly and becomes deeper, in other words, it has weaker capacity to dilute and move COD and ammonia nitrogen, so pollutant carrying capacity of the water after the reservoir construction is weakened to some degree.

6.1.4.2 Analysis and calculation of water environmental capacity

Formula of water environmental capacity calculation of the reservoir is:

$$W=W_k((C_s-C_0)V/\Delta t+q(C_s-C_0)+KVCs)$$

In the equation: Wk ——non-uniform coefficient (take 0.2 for the recent periods);

Δt ——take 150d during low-flow periods;

C_s ——target concentration for water environmental control (water quality standard) mg/L;

C_0 ——background concentration, mg/L;

q ——discharge from the reservoir during safe volume period, m^3/d;

K ——natural attenuation coefficient of pollutants (0.1 l/d for ammonia nitrogen, 0.22 l/d for BOD_5 and 0.06 l/d for COD);

V ——water storage capacity in the lowest flow year in the history, volume of the water during low flow years is usually taken as safe volume, m^3;

Calculating according to average daily flow under reliability of 95%, COD water environmental capacity of the reservoir area during operation of the project is 2996t/a and ammonia nitrogen water environmental capacity is368.8t/a; annual COD emission of the reservoir area during operation of the project is 2759.7t/a and annual emission of ammonia nitrogen is 352.5t/a, slightly lower than the environmental capacity of the reservoir. In conclusion, water in main stream of Han River after construction of Yakou reservoir still has certain environmental capacity.

Water quality planning goal of *Water Pollution Prevention and Management Plan of Middle and Lower Reaches of Han River in Hubei Province* is: ① quality of centralized drinking water sources in main stream of Han River reaches to or is better than quality of class II; Overall water quality of main stream of Han River meets quality standard of class II. Pollution prevention and management goal is: comprehensively control the total discharge of pollutants into Han River and focus on controlling the discharge of COD, ammonia nitrogen and total phosphorus and preventing eutrophication and “water bloom” pollution. Therefore, reduction of major pollutants discharge will also provide certain environmental capacity for implementation of the plan. In addition, discharge of major pollutants like COD and ammonia nitrogen into the reservoir area is lower than the water environmental capacity of the project located reaches of Han River. This complies with *Water Pollution Prevention and Management Plan of Middle and Lower Reaches of Han River in Hubei Province*.

6.1.5 Analysis and assessment of impact on water quality of downstream reaches of Yakou dam

We can see from the inventory survey on pollution sources of the regions that COD and NH_3-N mainly come from the domestic sewage discharge of cities and towns and then the industrial pollutants and rural domestic sewage and wastes from breeding. As main receiver of pollutants of Yicheng City, pollutants of Yidao Ditch are discharged into Han River via Guohai Sluice. Guohai Sluice is located at about 3.0km downstream of Yakou dam site. In this section, we mainly predict the impact of Yidao Ditch on water quality of Han River. Pollutant discharge of Yidao Ditch is predicted on the basis of current industrial wastewater discharge and comprehensive wastewater discharge per person and the results are shown in Table 6.1.5-1.

Table 6.1.5-1 Prediction result of wastewater discharge of Yidao Ditch and wastewater input to Han River

Name of discharge outlet to the river	Sources of wastewater	Sewage discharge (ten thousand t/a)	COD input to the river (t/a)	NH_3-N input to the river (t/a)
Discharge outlet of Yidao Ditch	Domestic sewage of cities and towns	1334.78	2910.59	497.08
	Industrial wastewater	154.79	111.85	17.01
	Rural domestic sewage	160.17	349.27	59.65
	Wates from breeding	78.87	146.47	7.57
	Farmland runoff pollution	178.22	339.8	65.8
	Total	1906.83	3857.98	647.11

Yidao Ditch can be viewed as an onshore discharge outlet. In accordance with requirements of *Guideline for Environmental Impact Assessment—Surface Water Environment* (HJ/T2.3-93), impact of the discharged wastewater on water quality of rivers should be predicted with the following two-dimensional steady mixing and attenuation mode of onshore discharge.

$$c(x,y)=\left\{c_h+\frac{c_p Q_p}{H(\pi M_y x u)^{1/2}}\left[\exp\left(-\frac{uy^2}{4M_y x}\right)+\exp\left(-\frac{u(2B-y)^2}{4M_y x}\right)\right]\right\}\exp\left(-K_1\frac{x}{86400}\right)$$

In the equation:

C(x, y)- vertical mean concentration of pollutants at (x, y), mg/L;

H-average depth of water, m;

B-width of the river, m;

M_y-lateral mixing coefficient, m^2/s;

K_1-alleviation coefficient, 1/d;

C_p-concentration of pollutant discharge, mg/L;

Q_p-wastewater discharge, m^3/s;

C_h-background concentration of pollutants in river, mg/L;

Q_h-flow of the reaches, m^3/s.

M_y is the lateral mixing coefficient and calculated with Taylor formula according to recommendation of the Guideline. The formula is as follows:

$$M_y = (0.058H + 0.0065B) \bullet \sqrt{gHI}$$

In the equation:

M_y—lateral diffusion coefficient, m^3/s;

H—average water depth, m;

B—width of the river, m;

I—water surface slope, ‰;

g—calculation constant.

A. Hydrologic conditions

Yidao Ditch is receptor of domestic sewage and part of industrial wastewater of Yicheng city. The sewage discharge is in connection with amount of urban sewage discahrge and wastewater discharge of enterprise production. Hence, the average annual flow of Yidao Ditch calculated according to precipitation characteristics of the region is shown in Table 6.1.5-2.

Table 6.1.5-2 Average annual flow of Yidao Ditch Unit: m^3/s

Month	5	6	7	8	9	10	11	12	1	2	3	4	Annual
Yidao Ditch	1.01	1.36	1.80	1.51	1.66	0.87	0.63	0.54	0.51	0.51	0.54	0.60	0.96

Hydraulic parameters of the waterway are shown in Table 6.1.5-3.

Table 6.1.5-3 Hydraulic Parameters of Downstream Waterways of Yakou Shipping Hub

Parameter	Flow in low flow years m^3/s	Average water depth m	Width of the river m	Average velocity m/s	Average gradient ‰	Lateral diffusion coefficient My m^2/s
Value	387	2.7	430	0.33	0.061	0.512

B. Background conditions of water quality

c_h represents current pollutants concentration of the reservoir. Concentration of COD_{Cr} and ammonia nitrogen of Yakou dam site section as predicted in Table 6.1.3.3 is 6.14mg/L and 0.082mg/L respectively. These values are taken as the background value.

C. Lateral mixing coefficient M_y

Taylor method as recommended in the Guideline is used to determine the lateral mixing coefficient M_y, namely:

$$M_y = (0.058H + 0.0065B)\sqrt{gHI}$$

In accordance with the above equation and calculation result of the river section under conditions of normal pool level, the lateral mixing coefficient is calculated to be $0.38m^2/s$.

2) Calculation results

The scope in which concentration of COD_{Cr} and ammonia nitrogen can meet the predicted value of Yakou dam site is the belt affected by discharge of Yidao Ditch which is shown in Table 6.1.5-3. The longest distance affected is about 730m, happening in the lowest flow month (March). Discharge of Yidao Ditch will not affect water quality of water intake of Liushui Town Tap Water Plant which is at the downstream opposite bank of 5km away from the ditch.

Table 6.1.5-3 Belt affected by discharge of Yidao Ditch Unit: m

Month	1	2	3	4	5	6	7	8	9	10	11	12
Length	580	700	730	450	430	340	150	140	140	190	380	590
Width	35	40	41	27	26	30	28	27	27	22	24	35

Hence, concentration of COD_{Cr} and ammonia nitrogen in reaches below Yidao Ditch section is 7.21 mg/L and 0.135 mg/L respectively and the water quality can meet standard of class II.

6.1.6 Prediction on impact of ship sewage

6.1.6.1 Analysis of impact of ship domestic sewage in waterways of the reservoir area

Quantity of ships and sailing time are estimated on the basis of typical ship types in accordance with prediction results of freight amount in different years and amount of ship domestic sewage in different years is shown in Table 3.4.2-1. In accordance with the prediction results, amount of ship domestic sewage in 2020, 2040 and 2050 is 1017.59, 1569.49 and 1996.00 t/a respectively.

In accordance with *Management Regulations on Preventing Ships from Polluting Inland Water Environment and the Controlling* (the Ministry of Transport, No. 11 in 2005), domestic sewage of large-scale ships shall be treated with the domestic sewage treatment facilities on ships. Meanwhile, according to relevant provisions on discharge of ship pollutants, ship domestic sewage shall be received and treated by ships with qualifications as recognized by the maritime departments after the ship arrives at the port and the untreated sewage shall not be discharged at will. Upon improvement of waterway conditions, there are more and more large-tonnage ships with better pollutants treatment facilities. This is conducive to improving water quality of the project-located reaches. During operation of the project, the maritime departments will strengthen management over shipping sewage in waterways and the ship domestic sewage will not cause pollution to water environment of within the waterways.

6.1.6.2 Analysis of impact of oil bilge in waterways of the reservoir area

According to the current distribution and operation pattern of transport ship within the region, it is predicted that cargo vessel, pusher train and barges will sail in middle and lower reaches of Han River and transportation of 500-ton to 1000-ton single cargo vessel and fleet will gradually develop into the main operation pattern. The designed shipping capacity of the ship lock is 1000t, so 1000t ship is taken as the typical ship to estimate the amount of ship sewage discharge.

In accordance with *Design Code for Environmental Protection of Port Engineering* (JTS149-1-2007), the statistics of oil bilge of ships of different tons is shown in Table 3.4.2-2 and the average oil concentration is 5000mg/L. In this report, 1000t ship is taken as the typical ship and amount of oil bilge is 0.27t/d per ship. The amount of oil bilge in different years is shown in table 3.4.2-3. In accordance with prediction results, the oil bilge in 2020, 2040 and 2050 will be 228.96, 353.14 and 449.10 t/a respectively.

In accordance with *Management Regulations on Preventing Ships from Polluting Inland Water Environment and the Controlling* (the Ministry of Transport, No. 11 in 2005), oil bilge of large-scale ships shall be treated with the sewage treatment facilities on ships. Meanwhile, according to relevant provisions on discharge of ship pollutants, oil bilge shall be received and treated by ships with qualifications as recognized by the maritime departments after the ship arrives at the port and the untreated oil bilge shall not be discharged at will. Upon improvement of waterway conditions, there are more and more large-tonnage ships with better pollutants treatment facilities. This is conducive to improving water quality of the project-located reaches. During operation of the project, the maritime departments will strengthen management over oil bilge in waterways and the oil bilge will not cause pollution to water environment of within the waterways.

6.1.7 Analysis of impact on ground water environment

6.1.7.1 Hydrogeological and engineering geological conditions

River valley in dam site areas of Yakou Shipping Hub Project is wide and shows “U” shape. The riverbed is wide and shallow. Water level of Han river is affected by precipitation, flood and discharge of the upstream reservoirs. The elevation is usually 47.0 to 49.5m and the depth is usually 0.2 to 8.0m. The width of water surface at axis of the dam is about 1,000m. Phreatic water and confined water exist in Quaternary Period loose accumulations. Relative aquifer has deep fine sand and sandy gravel and is mainly supplied by atmospheric precipitation and ground water of mountainous region around geosyncline of Han River. The water resources are abundant here. New stratum of the reservoir area has (partially) confined water and the overall ground water within bedrock is in short, supplied by atmospheric precipitation and river and discharges to foot of hills and the plain area. Water surface of Han River is the lowest base level of ground water discharge.

Ground water is mainly supplied by precipitation. In high flow season, water level of Han River is higher than that of ground water and Han river supplies the underground water; in low flow season, ground water discharges to Han River. Soil within the embankment is fertile and crops grow very well. Evaporation is the main consumption way of underground water. Since the ground water level changes not so much for years, ground water replenishment is basically the same as the ground water discharge. In accordance with geological exploration data of the reservoir area, the plane position of geological prospecting cross-sections is shown in Figure 6.1.7-1 and location of the cross-sections is shown in Table 6.1.7-1. Soil at both band of Yakou reservoir area is mainly the Quaternary cover. Sandy loam and silty find sand on the surface have good permeability and constitute the main permeable stratum at both banks of the reservoir area. Leakage of reservoir water into the dam may cause serious inundation issues.

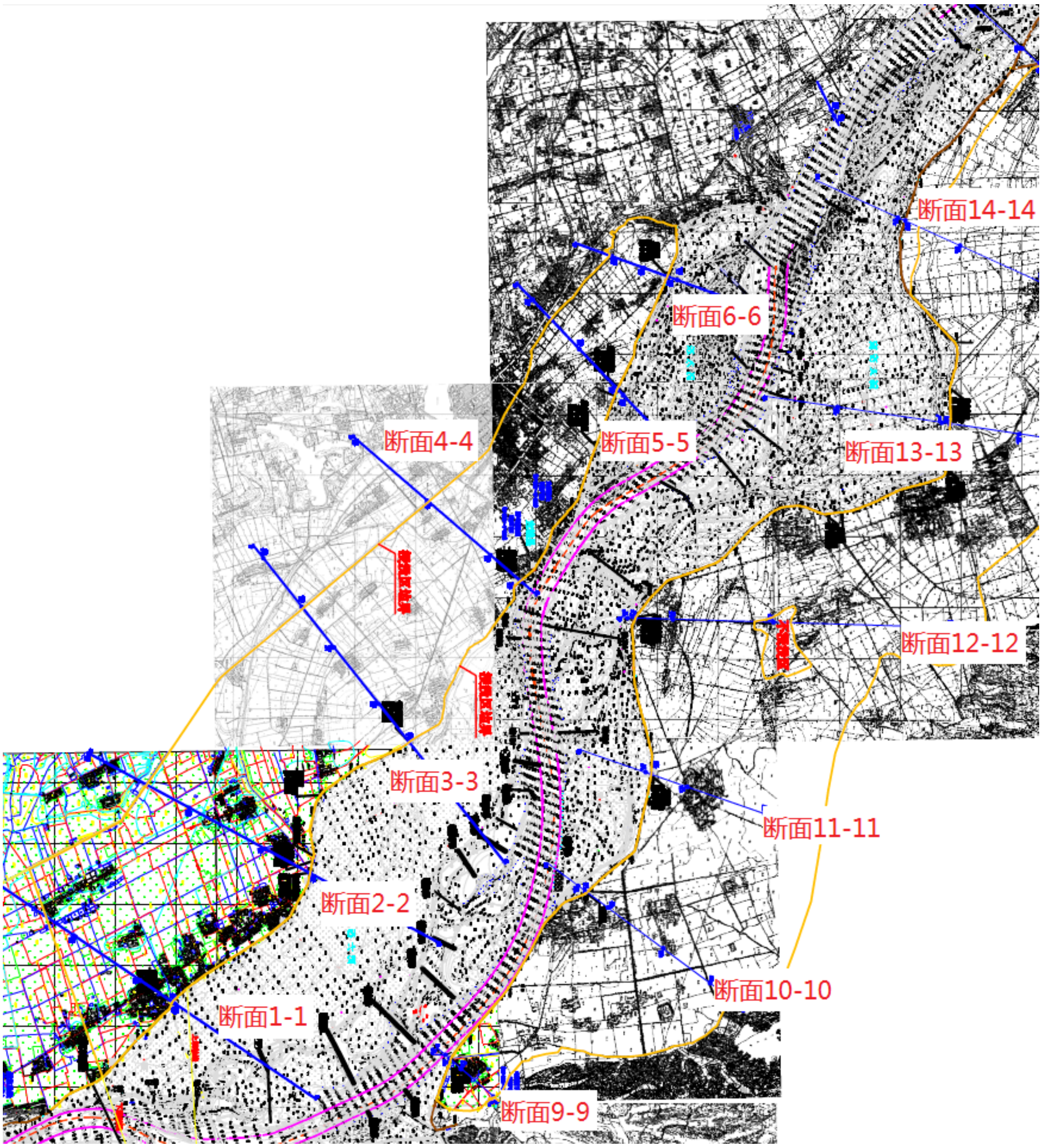


Figure 6.1.7-1 Location map of geological prospecting cross-sections

Table 6.1.7-1 Location of the cross-sections

Cross-section	Location	Cross-section	Location
Right bank 1-1′	Pile No. 16+123, Yangsimiao sluice	Left bank 10-10′	Pile No. 27+928, Guanzhuang sluice
Right bank 2-2′	Pile No. 12+934, Huangjiagou sluice	Left bank 11-11′	Pile No. 25+627, Annao sluice
Right bank 3-3′	Pile No. 9+890, Tannao village sluice	Left bank 12-12′	Pile No. 23+051, Wanyang irrigation sluice
Right bank 4-4′	Pile No. 6+499, Yejicheng sluice	Left bank 13-13′	Pile No. 16+375, Baijiatao sluice
Right bank 5-5′	Pile No. 2+899, Longtou irrigation sluice	Left bank 14-14′	Pile No. 12+688, at 12.8km of Yidong dam
Right bank 6-6′	Pile No. 0+880, Longtou sluice	Left bank 15-15′	Pile No. 9+218, at 9km of Yidong dam
Right bank 9-9′	Pile No. 31+480, Nanzhou sluice	Left bank 16-16′	Pile No. 5+089, Zhangjiazui irrigation sluice

6.1.7.2 Analysis of impact on ground water level and reservoir inundation

a) Impact on ground water level

The overall hydrogeological conditions of the reservoir area are simple and depth of ground water level is shallow. Types of ground water are bedrock fissure water, confined water and phreatic water in loose accumulations. Bedrock fissure water mainly exists in sandstone, slate, mudstone and siltstone. Controlled by geological fault, joint fissure and interstratal fissure, reservoir water after water storage will exert limited impact on dynamic changes of bedrock fissure water. Phreatic water in loose accumulations is intermittently distributed along both banks of Han River and shows the shape of narrow stripe. The depth of ground water level is 2m to 15m. Phreatic water is supplied by atmospheric precipitation and surface water. In high flow seasons, the river usually supplies the ground water whereas the ground water usually supplies the river in low flow seasons. After water storage, ground water level will have little changes than it under natural conditions, so the dynamic recharge and discharge relationship of ground water may change.

Before water storage, recharge-runoff relationship between river and ground water changes along with the season. In low flow years, water level of Han River is slightly lower than ground water level within the embankment, then ground water discharges to Han River and both water level of Han River and ground water level are low; in high flow years, water level of Han River is higher than ground water level within the embankment and water of Han River supplies the underground water. Since the precipitation in such period is big, failure in drainage in time will cause water logging. After normal water storage of Yakou reservoir, water level of the reservoir will be heightened and normal pool level of the majority of reservoirs along Han River is higher or basically the same as surface elevation. The alternative runoff between ground water and Han River is changed into the following pattern: water of Han River always flows into the underground and makes the ground water be supplied all the year around. In addition, the drainage system needs to be improved. These may cause the soil within the embankment to be affected by inundation. Inundation of reservoir area is the main issue of impact on ground water of this project.

b) Depth of critical ground water and inundation type

For historical reasons, we are lack of long-term observed data on ground water level along both banks. During the investigation period (September 2014), the depth of ground water level of the project area was usually 1.5m to 2.0m and was 1.0m in some locations. Soil in the project area has many wormholes and grassroots and the result of on-the-spot capillary water height tests is not satisfactory. The capillary water height is selected by experiences (refer to Table 6.1.7-2).

Table 6.1.7-2 Empirical value of capillary water height in soil of the inundated area

Soil name	Natural water content	Dry unit weight	Porosity ratio	Coefficient of permeability	Capillary water height
	ω	γ_d	e	k	H_k
	%	kN/m^3		cm/s	m
Silty loam	29.5	14.6	0.850	3.82×10^{-6} ~ 5.20×10^{-5}	1.5
Sandy loam	23.3	19.5	0.722	2.63×10^{-5} ~ 2.60×10^{-4}	0.9
Silty fine sand	27.2	15.0	0.734	2.12×10^{-4} ~ 2.00×10^{-3}	0.6

In low flow seasons, ground water level at both banks is higher than water level of Han River, ground water flows towards the waterway; after heightening of water level of Han River, water level of the water way is higher than ground water level at both banks, then water of Han River permeate into the underground to supply the underground water.

Ground water level of some regions along the dam maintains high level for a long term, particularly the right bank where the surface elevation is lower. After water storage of Yakou reservoir, water level of Han River is higher and ground water level within the embankment will be heightened. In accordance with the geological survey report in feasibility study phase, the suggested value of critical gradient of different soil is shown in Table 6.1.7-3.

Table 6.1.7-3 Suggested value of critical gradient

Soil type	silty soil r_Q	Silty clay Q_4^{al-1}	Silty and fine sand Q_4^{al-2}	Sandy gravel Q_3	Silty loam Q_4^{al-1}
Critical gradient	0.45	0.60	0.25 ~ 0.28	0.22 ~ 0.25	0.40

Land within Han River dam of the reservoir area is mainly for growing crops and some of the land is for residence. The crops are mainly cotton, wheat and rape, etc. Most of these crops are usually planted twice in one year; wheat, rape and cotton are planted once in a year. Wheat and rape are usually planted in November and harvested in May; cotton is usually planted in April and harvested in October. Wheat is usually intercropped with cotton and the intercropping period is about one month. The suitable depth of ground water level for growth of these crops is usually 0.9m to 1.2m. Residential buildings in rural areas are usually of one to two stories whereas those in towns are usually of three to four stories. The foundation is usually filled with brick slags or crushed stone and a few of the foundation is filled with grouted concrete. Most of the buildings are undergone moisture proof treatment.

In accordance with relevant specifications, experiences of other projects and actual conditions of this project area, the critical depth of inundation is preliminarily determined as: 1.2m to 1.5m in the residential area and 0.8m to 1.5m for growing crops.

Inundation prediction principles are determined in accordance with the predicted depth of ground water level and the critical value: when the depth of ground water level is bigger than the critical value, inundation does not exist; when the depth of ground water level is smaller than the critical value, inundation will occur. The studies show that there are mainly two inundation types in the inundated area (Figure 6.1.7-2).

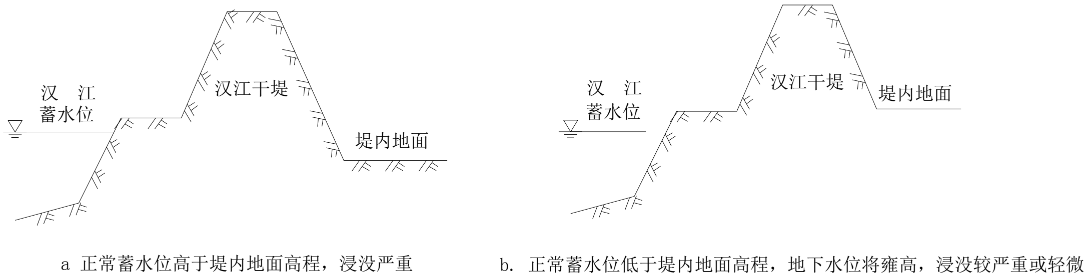


Figure 6.1.7-2 Diagram of inundation impact types

汉江蓄水位	Pool level of Han River
汉江干堤	Main embankment of Han River
堤内地面	Surface within the embankment
正常蓄水位高于堤内地面高程，浸没严重	When the normal pool level is higher than the surface elevation within the embankment, the inundation will be severe
正常蓄水位低于堤内地面高程，地下水位将雍高，浸没较严重或轻微	When the normal pool level is lower than the surface elevation within the embankment, the inundation will be relatively severe or slight

First, when normal pool level is higher than the surface elevation within the embankment, reservoir water will permeate into land within the embankment under action of water head pressure and ground water level within the embankment will reach to the surface. Under such circumstances, marsh formation and severe inundation may occur. Then such area is the severely inundated areas. Secondly, when normal pool level is lower than the surface elevation within the embankment, ground water level will be dammed up at the time of normal operation of the reservoir. The area can be divided into severely inundated area and slightly inundated area. The severely inundated area refers to that the depth of ground water level is smaller than the lower limit of critical depth, namely, smaller than 1.2m for the residential area and 0.8m for the crops growing area. The slightly inundated area refers to that the depth of ground water level is between the lower limit and upper limit of critical depth, namely between 1.2m to 1.5m for residential area and 0.8m to 1.5m for crops growing area.

c) Impact scope of inundation

When the reservoir runs normally, surface elevation of the upstream reaches of Zhangjiazui at left bank is above 60m, so inundation does not exist. The surface elevation of the section from Zhangjiazui to Nanying is 55.8m to 57.3m, inundation may occur; the surface elevation of the section from Nanying to Nanzhou is 54.2 to 55.8m, inundation may occur; the section from Nanzhou to Yakou dam site is of bedrock bank slope and no inundation issue exists. Most of surface elevation within dam of the upstream river sections of Ruanjiapo at right bank is above 59m. This is 3m higher than the normal pool level (55.22m), so inundation will usually not exist. However, the surface elevation of the section from Zhangjiazui to Lijiadian is 57.7m to 58.6m, so there may be inundation issue. The section from Ruanjiapo at right bank to Yakou dam site is called Yixi dam and the elevation within the embankment is 53.7m to 57.3m. The elevation gradually decreased from the upper reaches to the lower reaches and elevation of most of areas is below the normal pool level of 55.22m, so there may be inundation issues.

In conclusion, inundation issue of Yakou reservoir mainly occur in the section from Zhangjiazui to Nanzhou at left bank, the section from Zhangjiazui to Lijiadian at right bank and the section from Ruanjiapo to both banks of Yakou dam site

d) Qualitative analysis of impact of inundation

Both banks of Yakou reservoir area are mainly the quaternary alluvial deposit which has good dual structure. Part of areas at both bank have permeable stratum with sandy loam and silty and fine sand. After water storage of the reservoir, this geological condition will cause inundation within the embankment under conditions of steady seepage. Apart from the lithological feature of the soil within the embankment, severity of inundation is also decided by the relationship between normal pool level and surface elevation within the embankment. The scope of possible inundation can be decided preliminarily according to such relationship.

Select different cross-sections in upper reaches of the dam site in accordance with normal pool level and elevation and carry out seepage analysis on the possible areas to be inundated in accordance with the inundation scope as determined above to further determine the influence degree and the possible control measures of inundation.

In order to determine the scope of inundated area at both banks formed after water storage, we have selected 14 featured cross-sections in upper reaches of the dam site and the water level value of reservoir corresponding to the cross-section location after water storage is shown in Table 6.1.7-4.

Table 6.1.7-4 Location and water level of the cross-sections

No.	Measurement No.	Cross-section name	Mileage away from the dam km	Q=1200m^3/s	
				Natural parting	Backwater parting
cs2	cy32	Upper dam line	0	47.78	55.22
cs3	cy31		1760	47.99	55.22
cs4	cy30		3450	48.18	55.22
cs5	cy29		5150	48.39	55.23
cs6	cy28		6930	48.60	55.23
cs7	cy27		8620	48.82	55.23
cs8	cy26		10160	49.03	55.23
cs9	cy25		11980	49.14	55.24

Table 6.1.7-4 (Continued)

No.	Measurement No.	Cross-section name	Mileage away from the dam km	Q=1200m^3/s	
cs10	cy24	Yicheng gauging station	13460	49.17	55.24
cs11	cy23		15180	49.41	55.25
cs12	cy22		16470	49.96	55.25
cs13	cy21		17880	50.53	55.27
cs14	cy20		19470	50.74	55.28
cs15	cy19		21040	50.83	55.31
cs16	cy18		22600	51.08	55.33
cs17	cy17		24370	51.78	55.37
cs18	cy16		25800	52.08	55.4
cs19	cy15		26900	52.23	55.43
cs20	cy14		28070	52.58	55.47
cs21	cy13		29700	53.08	55.52
cs22	cy12	Wangji	31640	53.40	55.58
cs23	cy11		33290	53.75	55.65
cs24	cy10		35110	53.95	55.71
cs25	cy9		36740	54.09	55.77
cs26	cy8		38450	54.28	55.88
cs27	cy7		39950	54.59	56.03
cs28	cy6		41200	55.20	56.22

No.	Measurement No.	Cross-section name	Mileage away from the dam km	Q=1200m^3/s	
cs29	cy5		42780	55.33	56.3
cs30	cy4		44560	55.40	56.36
cs31	cy3		46160	55.49	56.42
cs32	cy2		47780	55.53	56.46
cs33	cy1		48920	55.55	56.48
cs34	Cuijiaying power station	Cuijiaying dam site	49430	55.58	56.51

The whole region can be divided into the following four parts through analysis of the above tables:

The first part is the section from Yicheng city to Yakou dam site and typical cross-sections are 1-1′, 2-2′, 3-3′ and 4-4′. The surface elevation is usually lower than the backwater level of Han River of the corresponding cross-section. These cross-sections are dangerous when the reservoir is at normal pool level and underground seepage will exert adverse impact on stability of the river embankment, buildings within the embankment and crops growing.

The second part is the section from Ruanjiapo to Yicheng city and the typical cross-sections are 5-5′ and 6-6′. The surface elevation is usually higher than the backwater level of Han River of the corresponding cross-section. Hence, these cross-sections are safer than the first part during normal water storage period of reservoir.

The third part is the section from Nanzhou to Nanying and the typical cross-sections are 9-9′, 10-10′ and11-11′. The surface elevation is usually about 0.2m to 0.5m lower than the normal pool level of the corresponding cross-sections. Surface elevation of cross-section 12-12′ is the same as backwater level of the reservoir. These indicate that water level of Han River is higher than the surface elevation within the embankment for a long term at the time of normal water storage and difference between head pressure outside and within the embankment is bigger. After water storage, water of Han River of these cross-sections steadily supplies water to aquifer within the embankment and seepage and inundation may be formed on the surface.

The fourth part is the section from Zhangjiazui to Nanying and the typical cross-sections are 13-13′, 14-14′, 15-15′ and 16-16′. The surface elevation is 1m to 2m higher than the backwater level of reservoir. This indicates that water of Han River of these cross-sections under conditions of normal pool level may not steadily supplies the aquifer and no water logging will occur.

6.1.7.3 Establishment of numerical mode and seepage analysis

Numerical analysis method and international three-dimensional underground seepage analysis software Visual ModFlow (version 2000) were applied in seepage analysis of this report. Such software is practical interface tool developed by Waterloo Hydrogeologic In. according to ModFLow core module and has been successfully applied in a large amount of engineering consultancy and seepage analysis around the world. Currently, many units in China have applied such software to study ground water sources. Such software was once applied in assessment of ground water sources in Hongwei experimental area in Inner Mongolia, seepage analysis of ash dam of certain power plant in Shanxi province and seepage analysis of impact of Yangtze River embankment engineering on environment within the embankment. These applications prove that the calculation procedures are correct and reliable and such software can be used study on inundation issue of this project.

a) Generalization of calculation and analysis model

In accordance with requirements of *Specifications for Geological Investigation of Water Conservancy and Hydropower Engineering* on inundation assessment, preliminary judgment of inundation is to predict and calculate backwater of the areas which may be inundated on the basis of geological and hydrogeological conditions of the invested reservoir area. Select several typical cross-sections which are perpendicular to the embankment of the reservoir and calculate and analyze with two-dimensional seepage model in accordance with topography, landforms, and geology and hydrogeological conditions of the areas which may be inundated after water storage of Yakou reservoir and on the basis of qualitative analysis of the inundated areas. The typical cross-sections selected include: (1) right bank 1-1′, 2-2′, 3-3′, 4-4′, 5-5′ and 6-6′; (2) left bank 9-9′, 10-10′, 11-11′, 12-12′, 13-13′, 14-14′, 15-15′ and 16-16′. The plane location of these cross-sections is shown in Figure 6.1.7-1.

Upon investigation, ground water level of both banks of the reservoir areas maintains stable for years. It changes seasonally due to different precipitation in one year and remains basically unchanged due to seepage of rainfall and phreatic water evaporation in different years. Since we do not have long-term observed data on rainfall seepage and phreatic water evaporation, we did not consider the boundary conditions of rainfall and evaporation in seepage analysis during the preliminary judgement phase of inundation. Ground water level at both banks of the reservoir will be heightened under conditions of water storage. Usually, evaporation of phreatic water will increase along with heightening of ground water level. Therefore, not considering the rainfall seepage and phreatic water evaporation would be safer.

Data on typical cross-sections for which two-dimensional seepage analysis is to be conducted is supplied by *Engineering Geological Section of the Reservoir Area*. Exploration range of cross-sections 1-1′, 2-2′, 3-3′, 4-4′, 5-5′ and 6-6′ includes Yidao Ditch which is the main ditch in Yicheng at right bank of Han River and 4m deep. The controlled area of Yidao Ditch within the planned area of water logging control is 38.2km^2 and the normal water depth for water logging control is 0.5m. Hence, Yidao Ditch can be viewed as boundary of class I invariable underground water. Inundation impact mainly occurs in low flow seasons. Naturally, water level of the waterway in low flow seasons is lower than ground water level at both banks and the ground water discharges into Han River. However, after water storage of the reservoir, water level of the waterway will be higher and ground water at both banks may discharge into Yidao Ditch and inundate both banks. Hence, the drainage water level of Yidao Ditch and natural ground water level in location indefinitely far away are selected as the boundary conditions of the calculation.

In accordance with the geological data and field investigation, cross-sections 9-9′, 10-10′, 11-11′, 12-12′, 13-13′, 14-14′, 15-15′ and 16-16′ at left bank extend until the foot of mountain and the depth of ground water level at the mountain foot is about 6 to 9m. Hence, under the circumstance that we do not have long-term observed data on ground water level, the natural depth of ground water level at the downstream boundary of these cross-sections is taken as boundary invariable ground water for calculation and analysis.

When the control length of the actually investigated cross-sections is shorter than the length of calculating cross-sections, formation lithology is obtained by extrapolation of the existing data. The formation lithology cannot be obtained from drilling data. Surface elevation of the calculating cross-sections is determined according to topographic map with scale of 1:10000 as supplied by the entrusting party.

b) Determination of boundary conditions

For two-dimensional seepage calculation of the cross-sections, boundary conditions include the upstream boundary, downstream boundary, boundary of surface and boundary of the bottom of those cross-sections.

The upstream boundary is water level after water storage of the reservoir and is boundary of class I invariable water level. The upstream water level of cross-sections is calculated according to backwater curve under conditions of the average annual flow of Yakou as supplied by the entrusting party and the results are shown in Table 6.1.7-4.

The downstream boundary of cross-sections 1-1′, 2-2′, 3-3′, 4-4′, 5-5′ and 6-6′ is water level of Yidao Ditch (the actual measurement result of engineering geological investigation shall prevail) and the natural ground water level in location indefinitely far away. There are no obvious downstream boundary characteristics of other calculating cross-sections. Therefore, the natural ground water level in location indefinitely far away (natural ground water level basically maintains stable upon investigation and analysis) is taken as boundary of class I invariable underground water.

Surface boundary of the model does not taken rainfall seepage, irrigation seepage and phreatic water evaporation into consideration. Bottom boundary is the depth to relative aquitard and thickness that exploration depth can reach. Since water at the bottom mainly flows horizontally, so nature of the bottom boundary is confining boundary.

Depressions near foot of embankment are viewed as free seepage surface during the calculation. When the ground water level is higher than surface elevation, water in the depressions will flow out. When the ground water level is lower than surface elevation, boundary of the seepage surface does not have impact on seepage of underground water.

In accordance with the above calculation conditions and respectively considering the circumstance with engineering measures and without engineering measures, we have altogether analyzed 46 calculation schemes.

c) Selection of stratigraphic parameters

Selection of stratigraphic parameters of these typical cross-sections is mainly in accordance with lithological classification of geological cross-sections as specified in Inundated Cross-sections in Reservoir Area of Yakou Shipping Hub Project and is determined through comprehensive analysis on the basis of test data on these cross-sections and suggested value of soil permeability coefficient of the cross-section located area (refer to Table 6.1.7-3).

d) Analysis of inundation impact within the embankment

Analysis method of inundation impact scope should be determined according to the relationship between critical depth of ground water level during inundation and depth of backwater level of phreatic water. When the predicted depth of backwater level of phreatic water is lower than the critical depth of ground water level during inundation, then it is viewed that such area will be affected by inundation. Restricted by study depth, the downstream boundary conditions of the cross-sections are estimated according to the investigation and reliability of boundary water level estimation will have certain impact on depth distribution of underground water. Hence, the basic idea of current inundation analysis is to define the impact scope of the inundated areas under conditions of normal water storage of reservoir on the basis of normal ground water level. In addition, comparing changes in ground water within the embankment before and after water storage of the reservoir can roughly determine the scope which may be affected by inundation.

According to the impact scope and possible impact degree of inundation, geological location and existing irrigation and drainage conditions of the areas which may be affected by inundation and inundation impact within the embankment after water storage of the reservoir, the study can be divided into the following four phases: (1) the first part is areas within cross-sections of 1-1′, 2-2′, 3-3′ and 4-4′; the surface elevation is usually lower than the water level of Han River; these areas are dangerous at the time of normal water storage of reservoir and underground seepage will exert adverse impact on embankment stability, buildings within the embankment and crops growing; (2) the second part is areas within cross-section 5-5′ and 6-6′; the surface elevation is usually higher than the water level of Han River; these areas are relatively safe at the time of normal water storage of reservoir; (3) the third part is areas from Nanzhou to Nanying controlled by cross-sections 9-9′, 10-10′ and 11-11′; the surface elevation is about 0.2m to 0.5m lower than the normal pool level; surface elevation of cross-section 12-12′ is the same as the backwater level of reservoir; namely, water level of Han River at these cross-sections is higher than the surface elevation for a long time and difference between water head pressure within and outside the embankment is bigger, causing water of Han River at these cross-sections after normal water storage of reservoir to stably supply the aquifer within the embankment and occur seepage and inundation on the surface; (4) the fourth part is areas within cross-section 13-13′, 14-14′, 15-15′ and 16-16′; the surface elevation is 1m to 2m higher than the backwater level of reservoir, indicating that water of Han River at these cross-sections will not stably supply aquifer within the embankment and no water logging will occur.

1) Calculation and analysis of inundation impact within the embankment from Yicheng city to Yakou dam site

Inundation impact on Yicheng city is mainly based on seepage analysis results of cross-sections 1-1′, 2-2′, 3-3′ and 4-4′. For all cross-sections, the actually measured ground water level is taken as the downstream boundary. There is a 4m deep Yidao Ditch 2m to 3m far away from the embankment and water depth of 0.5m under normal conditions can be selected in accordance with the field investigation.

In accordance with calculation of cross-sections 1-1′, 2-2′, 3-3′ and 4-4′ under natural conditions, depth of ground water level cannot be controlled below critical depth of ground water level during inundation, indicating that water storage of reservoir will add inundation impact within the embankment. Scope of areas (measuring according to the distance away from the embankment) which may be affected inundation under conditions of normal pool level is obtained according to the calculation results figure of six cross-sections (refer to Table 6.1.7-5).

Table 6.1.7-5 Scope of inundation-affected areas from Yicheng city to Yakou dam site under conditions of normal pool level

Analyzing cross-sections	Normal pool level (m)	Scope of areas which may be affected by inundation (m)
1-1′	55.22	1990
2-2′	55.23	1960
3-3′	55.24	1230
4-4′	55.24	1090

In conclusion, the impact scope at cross-sections 1-1′, 2-2′, 3-3′ and 4-4′ is between 1,000 and 2,000m.

2) Impact analysis of inundation within embankment from Ruanjiapo to Yicheng city

Impact of inundation within embankment from Ruanjiapo to Yicheng city is mainly based on seepage analysis of cross-section 5-5′ and 6-6′. For all cross-sections, the actually measured ground water level is taken as the downstream boundary. There is a 4m deep Yidao Ditch 2m to 3m far away from the embankment and water depth of 0.5m under normal conditions can be selected in accordance with the field investigation.

In accordance with calculation of cross-sections 5-5′ and 6-6′ under natural conditions, depth of ground water level cannot be controlled below critical depth of ground water level during inundation, indicating that water storage of reservoir will add inundation impact within the embankment. Scope of areas which may be affected inundation under conditions of normal pool level is obtained through analysis (refer to Table 6.1.7-6).

Table 6.1.7-6 Scope of inundation-affected areas from Ruanjiapo to Yicheng city under conditions of normal pool level

Cross-section	Normal pool level of reservoir (m)	Possible impact scope (m)
5-5	55.25	100
6-6	55.25	0

In conclusion, there is only a few of the inundation-affected areas at cross-section 5-5′ and 6-6′ and management should be focused on the area from Yakou dam site to cross-section 5-5′.

3) Impact analysis of inundation within the embankment from Nanzhou to Nanying

Impact of inundation within embankment from Nanzhou to Nanying is mainly based on seepage analysis of cross-sections 9-9′, 10-10′, 11-11′ and 12-12′. Table 6.1.7-7 and Table 6.1.7-8 respectively show the inundation scope of cross-sections 9-9′, 10-10′, 11-11′ and 12-12′ and depth of ground water level at different distances from the foot of embankment.

Table 6.1.7-7 Inundation scope in section from Nanzhou to Nanying under conditions of normal pool level

Unit: m

Cross-section	Inundation scope
9-9′	426
10-10′	511
11-11′	164
12-12′	672

Table 6.1.7-8 Depth of ground water level within the embankment under conditions of normal pool level of reservoir

Unit: m

Simulation conditions		Distance to foot of the embankment				
		100	200	300	500	1000
Cross-section	9-9′	0	0.15	0.8878	1.39	-
	10-10′	0.1344	0.3457	0.5575	0.9782	1.9743
	11-11′	0.4390	2.0613	-	-	-
	12-12′	0.7602	0.7827	0.8034	0.8935	1.5724

Under conditions of normal pool level, depth of ground water within the embankment is universally lower than 1.0m, 0.5m lower than the critical depth as require for crops growing. From Table 6.1.6-8 we can see that depth of ground water level at cross-sections 9-9′, 10-10′ and 12-12′ and areas within 500m away from the embankment foot cannot meet the requirement of critical depth.

4) Impact analysis of inundation within embankment from Zhangjiazui to Nanying

In this section, cross-section 13-13′, 14-14′, 15-15′ and 16-16′ are selected to carry out seepage calculation and analysis. The natural ground water at downstream location which is indefinitely far away is taken as boundary of invariable underground water.

Comparing the calculation results of depth of ground water level under conditions of normal pool level and critical depth of ground water level during inundation, we can get the scope of inundation-affected areas under conditions of different normal pool level (refer to Table 6.1.7-9 and Table 6.1.7-10).

Table 6.1.7-9 Depth of ground water level within the embankment under conditions of normal pool level of reservoir

Unit: m

Simulation conditions		Distance to foot of the embankment				
		100	200	300	500	1000
Cross-section	13-13′	1.7333	-	-	-	-
	14-14′	2.1703	-	-	-	-
	15-15′	2.7801	-	-	-	-
	16-16′	4.8080	1.4	1.6	2.1	2.5

Table 6.1.7-10 Scope of inundation-affected areas under conditional of normal pool level

Cross-section	Normal pool level of reservoir (m)	Impact scope
13-13′	55.25	0
14-14′	55.29	0
15-15′	55.37	0
16-16′	55.52	0

In conclusion, if the areas with the depth of ground water level of 0 to 0.5m after normal water storage of reservoir are defined as severe inundation-affected areas and the areas with depth of ground water level of 0.5m to 1.0m are relatively severe inundation-affected areas, then the impact degree of inundation at different cross-sections is shown in Table 6.1.7-11.

Table 6.1.7-11 Impact degree at different cross-sections Unit: m

Cross-section	Backwater level	Severe	Relatively severe
1-1′	55.22	0-1020	1020-1990
2-2′	55.23	0-447	447-1960
3-3′	55.24	0-532	532-1230
4-4′	55.24	0-704	704-1090
5-5′	55.25	1263-1518	1176-1263
6-6′	55.25	0	0
9-9′	55.23	0~310	310~426
10-10′	55.23	0~274	274~511
11-11′	55.23	0~108	108~164

Cross-section	Backwater level	Severe	Relatively severe
12-12′	55.24	0	0~672
13-13′	55.25	0	0
14-14′	55.29	0	0
15-15′	55.37	0	0
16-16′	55.52	0	0

In conclusion, raise the water head by 0.5m on the basis of designed backwater level in front of the dam and use Modflow to carry out simulated seepage calculation of the cross-sections. The number of cross-sections is 1-1’, 2-2’, 3-3’, 4-4’, 5-5’ and 6-6’. In accordance with *Technical Specifications for Drainage of Agricultural Land* and *Specifications for Geological Investigation of Water Conservancy and Hydropower Engineering* and the actual conditions of crops planting and buildings of Yicheng city, critical depth of ground water in farmland areas is 1m, that in towns is 1.5m and that in cities is 2m. In accordance with the calculation results, area of the inundated land at right bank within the project area is 18.71 km^2.

Raise the water head by 0.5m on the basis of designed backwater level in front of the dam and use Modflow to carry out simulated seepage calculation of the cross-sections. The number of cross-sections is 9-9’, 10-10’, 11-11’, 12-12’, 13-13’, 14-14’, 15-15’ and 16-16’. In accordance with the calculation results, area of the inundated land at right bank within the project area is 9.01 km^2.

6.1.7.4 Impact on surrounding environment

a) Impact on water in-taking and use

Upon investigation, there is no centralized utilization of ground water within the project-affected area. After formation of the reservoir, it is predicted that water quality will not change greatly and no obvious adverse impact will be exerted on quality of underground water.

b) Impact on surface water and spring

① Analysis of impact on surface water

Ground water within the project area mainly comes from precipitation. According to occurrence conditions, ground water can be divided into bedrock fissure water and porous phreatic water. Bedrock fissure water occurs in bedrock fissure and fault fracture zone.

Since fissure in rocks is underdeveloped and occurrence conditions for ground water are bad, the ground water in bedrock is usually not abundant. Porous phreatic water mainly exists in sand stratum and sandy gravel stratum in quaternary high flood plain and class I terrace. Depth of ground water level in high flood plain is 3m to 5m and in class I terrace is 2.2m to 4.5m. The ground water in these areas flows into Han River. Ground water level in quaternary class II terrace and Longgang area is deeper and occurrence conditions for ground water in these areas are bad.

The conditions for surface runoff in the project area are good and water flows towards Han River. Water level of Han River is the lowest base level of erosion. Precipitation directly supplies the Han River or flows into Han River through ditches and tributaries.

Ground water level during construction and operation of the project will be raised to some degree and water in ditches will increase. Project construction will have limited impact on surface water.

② Analysis of impact on spring

Upon investigation, there are no important and valuable spring and special ground water source protection zone (mineral water and thermal spring water) within the project-affected areas and project construction will not exert big influence on spring.

c) Analysis of impact on ecological environment

Changes in ground water indirectly affect the vegetation. Such impact is mainly decided by hydrogeological conditions of the stratums, height of natural ground water level and perch ground water. However, growth of plants is not decided by karst fissure water and fracture ground water. Roots need both water and oxygen for growing and often grown in shallow stratum, so the characteristics of soil structure and water amount are more important for growth of plants. Water contents in soil are an important factor deciding distribution of vegetation and growth of plants. Since ground water in the project area is porous phreatic water, mainly exists in sand stratum and sandy gravel stratum in quaternary high flood plain and class I terrace and is abundant. Depth of ground water level in high flood plain is 3m to 5m and in class I terrace is 2.2m to 4.5m. The ground water in these areas flows into Han River. After water storage of the reservoir, part of river sections will be inundated, including Miaotan (length: 5km) at right bank and areas from Gongjiazhou to Xiaofanzhou (length: 8.5km), and the ground water level of the surrounding areas will be raised. In accordance with analysis of section 5.2.1, inundation will affect water in soils and further affect the vegetation. Therefore, engineering measures must be taken.

6.1.7.5 Impact of Yakou dam construction on underground water

a) Hydrogeological conditions at the dam site area

1) Types and characteristics of ground water

Ground water in the dam site is mainly comprised of porous phreatic water and bedrock fissure water. The former exists in Quaternary Period loose accumulations and the latter is in short and there is only little confined water in some loose sandstone and glutenite.

Porous phreatic water in Quaternary Period loose accumulations: the aquifer is mainly distributed in riverbed, flood plain and alluvial sandy loam, find sand and glutenite stratums in class I terrace and glutenite stratum in lower part of class II terrace at left bank. Porous phreatic water mainly comes from atmospheric precipitation and discharges into Han River. The amount is good. Depth of ground water of class I terrace at right bank is 7m to 10m and water table elevation is 45.5m to 50m; depth of ground water of class II terrace at left bank is 9m to 10m and water table elevation is 56m to 57m; the amount is moderate. Ground water level and the changes in mudflat and land near to the river are basically the same as that of Han River and the dynamic changes are slightly later than water fluctuation of Han River. Generally, ground water of the mudflat flows from upstream to downstream of Han River. Dynamic changes of ground water in terrace are later than water fluctuation of Han River and the flow direction is approximately perpendicular to the bank slope.

Bedrock fissure water: bedrock fissure of the dam site is underdeveloped and porous and fracture water mainly exists in glutenite stratum and loose glutenite stratum and is distributed with the shape of lenticle. The water is scarce and confined due to cover of upper water isolation rock. We have altogether drilled 48 holes in riverbed during the feasibility study phase and 98 holes in riverbed during the preliminary design phase and altogether 5 holes show that there is confined water.

Confined water at Z6, Z46, ZK38 and ZK39 exists in loose glutenite and thickness of the aquifer is usually 1.0m to 7.4m. The aquifer is distributed with the shape of lenticle and aquiclude consists of claystone and mudstone with weak permeability or sandstone with good cementation. Level of confined water is 0.2m to 1.4m higher than water surface of Han River and the flow is 0.3 to 2.4L/min. Confined water at Z9 exists in some fractures of glutenite and thickness of the aquifer is 3.5m. The aquifer is distributed with the shape of lenticle and aquiclude consists of claystone with weak permeability. Level of confined water is 1.6m higher than water surface of Han River and the flow is 0.9L/min.

On the whole, only a few of holes show that there is confined water in the project area and the confined water is distributed in upstream cofferdam of the lower dam line, sluice axis and power station of the upper dam line. The depth is deeper than 30m. Foundation excavation for buildings in these areas will not involve aquifer of confined water, so the confined water will do harms to the buildings and the foundation.

2) Permeability of rock-soil mass

① Permeability of Quaternary cover

Permeability of quaternary cover is mainly decided by particle composition and compaction degree. Viewing from indoor seepage experiment, field trial pit seepage experiment, water injection test in borehole and pumping test, cohesive soil of class I terrace at right bank of the dam site has layers of weak permeability; class I terrace, high flood plain and sandy loam have layers of medium permeability; most of class I terrace, flood plain, channel sand and sandy gravel are stratum with medium permeability; most of flood plain and channel sand are stratum with strong permeability.

Sandy soil has strong permeability and is susceptible to seepage and deformation under certain action of water head. For this, we carried out sampling indoor seepage and deformation test on sand and sandy gravel. According to the test results, destruction type of silty and fine sand is flowing soil type and the critical gradient for seepage is 0.20 to 0.35; destruction type of sandy gravel is flowing soil type and transition type between flowing soil and piping and the critical gradient for seepage is 0.20 to 0.29. Considering the disturbance of sampling on original structure and referring to the relevant procedures and specifications, the allowable hydraulic gradient of silty and fine sand is 0.25 to 0.28 and that of sandy gravel is 0.22 to 0.25.

② Permeability of bedrock

Geofault at the dam site area is underdeveloped and the bedrocks are rock-like soil. Permeability of the rocks is mainly decided by the development and cementation degree of lithological character and joint fissure. The statistics on water pressures test of the bedrock in the dam site area is shown in Table 6.1.7-12.

Table 6.1.7-12 Statistics on permeability of rocks in the dam site area

Type	Permeability q(lu)							
	Sections	0.1 ~ 1 (%)	1 ~ 5 (%)	5 ~ 10 (%)	≥10 (%)	Interval value	The mean	Permeability grade
Claystone	262	9.55	72.82	17.63	0	0.3 ~ 9.8	3.46	Slight to weak
Mudstone	4	0	75.03	24.97	0	3.4 ~ 7.7	4.84	weak
Fine silty sandstone	68	1.47	79.42	17.65	1.46	0.6 ~ 19.0	3.86	Slight to medium
Medium gritstone	16	0	56.25	37.49	6.26	1.6 ~ 10.2	5.02	Weak to medium
Sandy gravel	36	0	55.56	30.56	13.88	1.6 ~ 51.1	7.12	Weak to medium
Weak-cemented fine silty sandstone	37	0	75.67	13.52	10.81	2.0 ~ 26.3	5.12	Weak to medium
Loose sandy gravel	62	0	71.93	15.16	12.91	1.2 ~ 55.8	9.07	Weak to medium

From the table we can see that the permeability of claystone is the weakest and the claystone with q＜1Lu accounts for 9.55%, that with q between 1Lu and 5Lu accounts for 72.82% and that with q between 5Lu and 10Lu accounts for 17.63%. The maximum test value is 9.8Lu and the mean is 3.46Lu. On the whole, the permeability of claystone is weak.

There is little distribution of mudstone in the dam site area. The mudstone with q between 1Lu and 5Lu accounts for 75.03% and that with q between 5Lu and 10Lu accounts for 24.97%. The maximum test value is 7.7Lu and the mean is 4.84LU. On the whole, the permeability of mudstone is better than that of claystone, but is also weak.

Fine silty sandstone with q between 1Lu and 5Lu accounts for 79.42%, that with q between 5Lu and 10Lu accounts for 17.65% and that with q≥10Lu accounts for 1.46%.

The maximum test value is 19.0Lu and the mean is 3.86Lu. On the whole, the permeability of fine silty sandstone is better than that of claystone and mudstone but the value is also small.

Medium gritstone with q between 5Lu and 10Lu accounts for 37.49% and that with q≥10Lu accounts for 6.26%. The maximum test value is 10.2Lu and the mean is 5.02Lu. On the whole, average permeability of medium gritstone is better than that of fine silty sandstone.

Sandy gravel with q between 1Lu and 5Lu accounts for 55.56%, that with q between 5Lu and 10Lu accounts for 30.56% and that with q≥10Lu accounts for 13.88%. The maximum test value is 51.1Lu and the mean is 7.12Lu. On the whole, permeability value of sandy gravel spans wide: the minimum value can be smaller than 5Lu but the maximum value can be 51.1Lu, indicating that when sandy gravel is well cemented and has complete core, the permeability is weak and when the core is fractured, the permeability is strong. However, the average permeability is smaller than 10Lu.

Weak cemented fine silty sandstone with q between 1Lu and 5Lu accounts for 71.93%, that with q between 5Lu and 10Lu accounts for 13.52% and that with q≥10Lu accounts for 10.81%. The maximum test value is 26.3Lu and the mean is 5.12Lu. On the whole, permeability of weak cemented fine silty sandstone is not particularly strong and the mean is also not big.

Loose sandy gravel with q between 1Lu and 5Lu accounts for 71.93%, that with q between 5Lu and 10Lu accounts for 15.16% and that with q≥10Lu accounts for 12.91%. The maximum test value is 55.76Lu and the mean is 9.07Lu. On the whole, loose sandy gravel has good permeability and the mean is relatively bigger.

b) Impact of dam work on ground water

Stage diversion is implemented during construction of the dam work and concrete cutoff wall is used to prevent seepage in both upper and lower reaches of the dam and the longitudinal cofferdam. In the excavation process of riverbed dam section, ground water level near left bank will reduce due to drainage of pit. But such impact is temporary in limited scope and the ground water will be restored upon completion of drainage. Bedrock distributed at right bank is the relatively water isolation rocks and there is sparsely distributed fissure water. Hardly any impact will be exerted on ground water at right bank.

In addition, after commencement of the dam work, higher layer of the riverbed in the dam site area is lower than the elevation of surrounding areas and basically the pit wastewater in the construction site will not permeate towards the surrounding areas, thus exerting no impact on quality of the ground water of the surrounding areas. On the contrary, excavation of the dam may cause ground water to permeate towards the construction site and increase the drainage of pit. Wastewater of the construction site will be reused upon recycling. Therefore, wastewater in the construction site of the dam will not influence the surrounding water environment.

6.2 Assessment of impact on aquatic ecosystem

6.2.1 Impact on aquatic habitat

6.2.1.1 Changes in hydrological regime

Yakou Shipping Hub is located in lower reaches of Danjiangkou hydro-junction and Cuijiaying Hydro-junction is located in-between. Runoff of Yakou Shipping Hub comprises discharge of Danjiangkou hydro-junction, discharge of Cuijiaying Hydro-junction and water inflow between Danjiangkou and Yakou.

After completion of Yakou Hydropower Station, backwater length of the reservoir area is about 55.22km. The water becomes deeper and flows slowly. The habitat in swift current shrinks. Hydrodynamic process of the river changes drastically and water of reservoir end is basically the natural river area and has hydrological and hydrodynamic characteristics of river. Water in front of the dam is deep and wide and is proximately static water. Hydrological regime from river sections in the reservoir area to that in front of the dam is transformed from swift current into slow and static current. Yakou hydropower station does not have regulation capacity and water level of the reservoir usually not changes.

After completion of Yakou Hydropower Station, the water in front of the dam shows hydrodynamic characteristics of lakes and the water in middle of the reservoir shows transitional hydrodynamic characteristics of river and lakes.

Yakou Hydropower Station does not have regulation capacity and the reservoir capacity is relatively small. This means Yakou Hydropower Station has weaker regulation capacity on runoff and has little influence on annual and monthly outflow runoff.

6.2.1.2 Changes in physical and chemical properties of the water

After water storage of the reservoir, the water flows more slowly and water exchange frequency reduces, making the capacity to diffuse pollutants and the reoxygenation ability reduce and lower dissolved oxygen contents in deep water. During initial period of water storage, nitrogen, phosphorus and organic matters enter the water due to decomposition of organic matters left at bottom the reservoir and eutrophic substance contents may increase in the short term. After stable operation of the power station, retention time of water prolongs and load of eutrophic substance in the water of reservoir area will increase against that in the river section before reservoir construction. However, since Yakou reservoir has small regulation capacity and retention time of eutrophic substance in the reservoir area is relatively shorter, water quality of the reservoir area is under limited influence.

6.2.2 Impact on food organism

a) Phytoplankton

1) Impact on phytoplankton in the reservoir area

The planned Yakou power station is the six one among hydro-junction development of Hubei province in main stream of Han River. Such project is a comprehensive development project with shipping as the main function and power generation, irrigation and tourism as the auxiliary functions. After formation of the reservoir area, hydrological regime and ecological environment will change. Exudation of eutrophic substances in vegetable and soil of the inundated areas causes increase in organic matters and mineral substances in water. Meanwhile, prolongation of water retention time and sediment deposition causes accumulation of eutrophic substances. These are conducive to growth of phytoplankton. In accordance with phytoplankton evolution of Cuijiaying reservoir area after formation of Cuijiaying Hydro-junction, the evolution of phytoplankton shows the following characteristics: increase of types and quantity; apparently higher density and biomass than that in downstream reaches of the dam. However, Yakou reservoir does not have strong regulation capacity and the water in most areas of the reservoir still flows, so the changes in types are not obvious and bacillariophyta is still the major phytoplankton in the reservoir area.

2) Impact on phytoplankton in the tributaries

There are 3 tributaries in the investigated river sections of Han River. There are fewer types and quantity of phytoplankton in these tributaries. After formation of the reservoir, under action of jacking of water level of the reservoir area, flow of the waterways will become slowly and eutrophic substances will increase, and types and quantity of phytoplankton especially the bacillariophyta will increase. Chun River and Wei River have more eutrophic substances and large quantity of phytoplankton and eutrophication in some areas in estuary of these tributaries may occur. But since Chun River is located in river section of the reservoir end, the impact is limited.

b) Zooplankton

1) Impact on zooplankton in the reservoir area

The planned Yakou power station is the six one among hydro-junction development of Hubei province in main stream of Han River. Such project is a comprehensive development project with shipping as the main function and power generation, irrigation and tourism as the auxiliary functions. After formation of the reservoir area, hydrological regime and ecological environment will change. Exudation of eutrophic substances in vegetable and soil of the inundated areas causes increase in organic matters and mineral substances in water. Meanwhile, prolongation of water retention time and sediment deposition causes accumulation of eutrophic substances. These are conducive to growth of zooplankton. In accordance with zooplankton evolution of Cuijiaying reservoir area, the evolution of zooplankton shows the following characteristics: ciliates, such as strobilidium gyrans and tintinnopsis wangi, tend to increase; rotifer tends to occur and become the dominant species; cladocerans and copepod will increase remarkably; daphnia hyaline and cyclops will be the frequently-seen or dominant species. Both density and biomass of zooplankton at sampling points of Cuijiaying reservoir area are higher than that of other main streams and that of downstream sampling points of the dam is also obviously higher than that of other sampling points of flowing river sections in lower reaches of the dam due to water discharge of the reservoir.

2) Impact on zooplankton in tributaries

There are 3 tributaries in the investigated river sections of Han River. Ying River is located in lower reaches of the dam and will not be affected by backwater of the reservoir area; Chun River is located in reservoir end and only the estuary is affected by backwater. Flowing river sections above backwaters of the tributaries will not be affected by the reservoir area and changes of the backwater-inundated areas are similar to that of the reservoir area. Wei River has more eutrophic substances and density and biomass of zooplankton may be higher than that at other cross-sections of the reservoir area.

c) Zoobenthos

1) Impact on zoobenthos in the reservoir area

Yakou project is low-head hydropower station, water level of the reservoir during operation of the power station maintains high and the reservoir is of daily regulation type. After water storage, water level of the reservoir area will be heightened, the water is relatively static and water environment of the area is relatively stable. This is conducive to growth of annelids and chironomus which love static water. Currently, there are 15 types of zoobenthos in river sections of Yakou reservoir area (at Yicheng, Yakou dam site cross-sections). The main species are semisulcospira cancellata, lymnaea swinhoei, limnoperna lacustris, corbicula fluminea and poypedilum. Density and biomass of zoobenthos are 467ind./m^2 and 90.21g/m^2 respectively. Referring to the current conditions of zoobenthos in Cuijiaying reservoir area, it is predicted that the dominant zoobenthos in Yakou reservoir area will be limnodrilus hoffmeisteri, branchiura sowerbyi, cryptochironomus, procladius choreus and corbicula fluminea. The overall distribution of zoonbenthos species will reduce, the density basically remains unchanged and the biomass may reduce.

2) Impact on zoobenthos under the dam

The current average annual flow at cross-section of Yakou dam site is 1,490m^3/s. In order to meet demands of the downstream shipping, the base-load flow for shipping must be 450m^3/s. Therefore, operation of Yakou hydro-junction will reduce flow of river sections under the dam and thus exert certain influence on zoobenthos. Referring to the current conditions of zoobenthos in Cuijiaying reservoir area, it is predicted that the dominant zoobenthos in Yakou reservoir area will be limnodrilus hoffmeisteri, semisulcospira cancellata, limnoperna lacustris, corbicula fluminea and procladius choreus. Type distribution will not change greatly but the density and biomass will increase against that before operation of the project.

3) Impact on zoobenthos in the tributaries

Major tributary in Yakou reservoir area is Chun River and Wei River which confluence into Han River at the reservoir end at left bank and Xiaohe Town at right bank. Currently there are 7 types of zoobenthos with annelids and mollusks as the dominant type. Since estuary of Chun River is located at the reservoir end, overall impact of water storage on zoobenthos in Chun River is limited. Water quality of Wei River is bad and currently there are 7 types of zoobenthos with limnodrilus hoffmeisteri, chironomus and procladius choreus as the dominant type. The density and biomass in Wei River is 5762ind./m^2 and 8.34g/m^2 respectively and density of oxygen-resistant limnodrilus hoffmeisteri and chironomus is extremely high. Under influence of backwater after storage of Yakou hydro-junction, it is predicted that the dominant zoobenthos in Wei River will still be pollution tolerant annelids and chironomus and the types, density and biomass will basically remain unchanged. Ying River is located under dam of Yakou hydro-junction and storage of Yakou hydro-junction will not exert any impact on zoobenthos.

6.2.3 Impact on fishes

a) Barrier impact on fish resources

Completion of Xinglong Navigation and Hydropower Junction at downstream of Yakou hydro-junction has cut off activities of eels and other migration fishes. Cuijiaying

Hydro-junction and Wangfuzhou Hydro-junction have been built in upper reaches of Han River, Nianpanshan Navigation and Hydropower Junction in lower reaches and Xinji in upper reaches are also under development. A number of hydropower junctions have been built on tributaries in middle and lower reaches of Han River. Construction of these hydropower junctions has cut off activities of fishes in different reaches of Han River and the tributaries.

Construction of Yakou Shipping Hub will cut the river sections of 210km between Cuijiaying and Xinglong Navigation and Hydropower Junction into 2 isolated island habitat and migration and communications between fishes will be further hindered. Damage to continuity of river will strongly cut off activities of both migration fishes and non-migration fishes. The studies show that fragmentation of habitat due to barrier of the dam will lead to heterogeneous species groups with different size and these groups cannot communicate with each other. Genetic differentiation will occur in fish groups with large quantity whereas species with small quantity will gradually lose the genetic diversity, endangering long-term survival of the species.

Analyzing from living habits of fishes, relatively stable water level, wide water surface, gentle river regime and abundant aquatic vegetation and hygrophilous vegetation are good for breeding and growth of fishes spawning on plants, for example, carp, crucian, cultrins, xenocypris argentea, catfish, squalidus argentatus, opsariichthys bidens, siniperca scherzeri, pelteobagrus fulvidraco, pelteobagrus vachelli, Bayesian, pseudorasbora parva, abbottina rivularis and rhinogobius giurinus. These fishes may become the dominant species. Heightening of water level will lead to loss of spawning water for fishes spawning on gravels, such as xenocypris davidi, and the bad quality of spawning water in Chun River and Wei River will also made it difficult for fishes spawning on gravels to survive. For fishes spawning floating eggs, since all spawning areas are inundated, only when the hydro-junctions discharge water and velocity at the sluice is 0.55 to 2.41m/s in flood season can some fishes swim to the reaches above the dam where there are satisfactory conditions for breeding of such fishes. However, there is little possibility for occurrence of open discharge flow upon operation of South-to-North Water Transfer Project, so it is also difficult for this species to survive.

b) Impact of hydrological regime changes on fish resources

After operation of Yakou Shipping Hub Project, the reservoir will operate at the normal pool level of 55.22m in low flow seasons. The natural conditions of the river are changed and hydrodynamic process of the river will have certain changes due to decrease of flow velocity, increase of water depth, volume and area. The water in front of the dam shows “hydrodynamic characteristics of lakes”. However, Yakou navigation and hydropower junction is low-head hydropower station and water at the reservoir end is close to natural river, flow in areas from water in front of the dam to the middle of reservoir reduce slightly and water of these areas show hydrodynamic characteristics of river. When the flow at the dam site equals to or is larger than 8,710m^3/s but is smaller than 13,500m^3/s, Yakou power station will stop power generation, sluice will operate normally and more water will be discharged to reduce water level of the reservoir until the normal water level is restored. When flow at the dam site is larger than 13,500m^3/s, Yakou power station will stop power generation, shipping will stop, water will be discharge openly and operation of the whole project is to control the flood. After that, water level rising in front of the dam will disappear quickly and waterway is basically in the natural state, exerting limited impact on both the upstream and downstream hydrological regime.

Fishes adopting themselves to swift current, gravel, caves and laccolite environment and spawning sticky sinking eggs in river sections of the reservoir, such as lepturichthys fimbriata, glyptothorax sinense and pearlite rim, etc., will gradually swim to Chun River and Wei River. But water quality of these tributaries is not good for breeding and growth of such fishes, causing significant decrease in quantity and even extinction of this type of fishes. Fishes loving subcritical flow or static water environment, such as, carp, Mongolian culter, culter alburnus, crucian carp, catfish, squalidus argentatus, opsariichthys bidens, siniperca scherzeri, pseudogobio vaillanti, zacco platypus, pelteobagrus fulvidraco, pelteobagrus vachelli, bayesian, pseudorasbora parva, abbottina rivularis and rhinogobius giurinus, will develop very well and become the main object for fishing. Except open discharge of the reservoir, there will be no breeding conditions for fishes spawning floating eggs, such as, grass carp, black carp, silver carp, bighead, xenocypris argentea, bream, saurogobio dabryi, pseudolaubuca sinensis and coreius heterodon. Quantity of this type of fishes will significantly decrease and they even extinct.

Increase in water volume and area, expansion of habitat and activity space and improvement of biological productivity will lead to increase of total amount of fish resources and fish catches. Since backwater of the lower hydro-junction reaches to the dam site, changes in discharge volume, flow velocity and water level will have limited impact scope and degree and thus limited action on fishes.

c) Impact of water quality changes on fish resources

Water of the reservoir area flows slowly, the sediment deposits and the eutrophic substance stagnates. But the reservoir has poor regulation capacity and no obvious changes in nutritive salt of the reservoir area will occur. Biological productivity of water in the reservoir area will be improved in a limited way. Phytoplankton in the reservoir area will increase. This is good for growth of larval and young fish and the fishes eating phytoplankton, such as silver carp and bighead. But open discharge will cause loss of primary productivity and fish species accumulated in the reservoir area and also bring the fish species in the upper reaches. Total fish types will always fluctuate.

Yakou Shipping Hub Project is a project with daily regulation and water temperature changes are not obvious, the possibility of gas super-saturation is extremely small and thus the impact on fishes under the dam is not obvious.

d) Impact of changes in biological base of food on fish resources

Upon formation of the reservoir, water of the reservoir area will be deepened, becomes wider and flow slowly. Eutrophic substance stagnates here and biological productivity of the water is improved. These are good for breeding and growth of phytoplankton. Types and current quantity of phytoplankton will increase. This is good for growth of larval and young fish and fish living in subcritical flow or static water environment, such as carp, crucian carp, silver carp and bighead. Amount of fish resources and fishery production will increase. However, without artificial release, it is impossible that quantity of silver carp and bighead will increase. After formation of the reservoir, improvement in transparency and nutrient load of the water is good for breeding and growth of periphyton, zoobenthos and aquatic vascular plant. This further provides rich food for fish like xenocypris argentea, onychostoma sima and rhinogobio typus. Yakou power station generates power on the basis of base-load flow and water level under the dam does not fluctuate greatly, exerting limited impact on growth and amount increase of such fishes. Types of zoobenthos living in flowing water will decrease while the types and quantity of limnodrilus sp and chironomidae living in static water or slightly flowing water will increase. Mollusks living in static water or sand may also occur. This is good for growth and development of fish living at the bottom of static or slowly flowing water but the food resources for fishes living in flowing water will decrease significantly.

Since food resources for fishes change greatly after formation of the reservoir and transfer from nektonic organism, zoobenthos and periphytic algae to phytoplankton, the types of corresponding fish resources will also change. Fish loving flowing water environment will migrate towards the reaches above the reservoir end and the tributaries and even disappear from the reservoir area, the fish living in slowly flowing and static water with phytoplankton as food will become the dominant species.

Yakou Shipping Hub generates power on the basis of base-load inflow. The current quantity of phytoplankton in downstream reaches of Yakou dam is basically the same as that in water in front of the dam. The dominant zoobenthos is flowing river sections under the dam is still the species living in flowing water and current quantity of periphyton will increase after improvement in transparency of the water. But there will still be zoobenthos and perphyton for fishes loving flowing water, indicating that the impact on fish resources is little.

f) Impact on fish types

After formation of Yakou power station, owing to changes of hydrological regime, the main fish species in the reservoir area will gradually transfer from fishes loving swift current, flowing water into fishes loving slowly flowing water and static water. Fishes fitting flowing water, habituating at the bottom of water, in swift current, on gravels, in caves and laccolith will gradually migrate to the tributaries and the fish species in the reservoir area will gradually decrease. Fishes fitting environment of slowly flowing water or static water will increase and become the dominant species in the reservoir area due to widening of the water surface and improvement of primary productivity of water.

Yakou Shipping Hub is of low-head daily regulation type and generates power on the basis of base-load flow. Water level under the dam when discharging fluctuates not greatly and water temperature changes are not obvious, the possibility of gas super-saturation is extremely small. In order to meet the demands of downstream shipping, the base-load flow for shipping is $450m^3/s$. Therefore, the impact on fishes under the dam is not obvious.

The dominant fish in the Yakou reservoir area will be fish living in flowing and slowly flowing water, such as, carp, Mongolian culter, culter alburnus, silver carp, crucian carp, xenocypris argentea, catfish, parabramis pekinensis, squalidus argentatus, saurogobio dabryi, pseudolaubuca sinensis, opsariichthys bidens, siniperca scherzeri, pseudogobio vaillanti, zacco platypus, pelteobagrus fulvidraco, pelteobagrus vachelli, bayesian, pseudorasbora parva, abbottina rivularis, rhinogobius giurinus, siniperca scherzeri and Chinese fat minnow, etc. The habitat for these fishes will change greatly after operation of Yakou power station and types will change remarkably, particularly the fish spawning on gravels and floating eggs. These fishes may even disappear from such water area.

g) Impact on fish protection

There are no fish species under protection of central government of China but there are 5 fish species under protection of Hubei provincial government. These fishes are luciobrama microcephalus, ochetobius elongates, onychostoma macrolepis, gracilicaudatus and leiocassis longirostris. In the survey, we failed to catch any of these five provincially protected fishes.

Analysis of impact on these five provincially protected fish species is implemented according to their habits:

(1) Luciobrama microcephalus is ferocious carnivorous fish and ochetobius elongates is mild carnivorous fish. Increase of water surface area and improvement of productivity of water due to construction of Yakou power station provide more food for these two fish species and may be good for their development. However, these two types of fish spawn

floating eggs and there are no conditions for their spawning in most years. Currently, under the circumstance of severe depletion of luciobrama microcephalus and ochetobius elongates resources, it is hard for them to live in water of the reservoir area.

(2) Onychostoma macrolepis habitats at the bottom of water, spawns sticky and sinking eggs and loves living in flowing water. Such species is mainly distributed in tributaries with crystal clear water. Main stream of Han River is not their main habitats and the environmental conditions after formation of the reservoir will still be unable to meet their demands for breeding and growth.

(3) Gracilicaudatus living at the bottom of water, loves slowly flowing water and spawns sticky and sinking eggs. It mainly feeds on zoobenthos. After formation of the reservoir, deepening of the water in reservoir area is not good for inhabiting and feeding of gracilicaudatus. Shrinking of its habitats causes decrease of the quantity of such fish species.

(4) Leiocassis longirostris lives at the bottom of water, loves environment of flowing water and spawns floating eggs. After formation of the reservoir area, its habitats will further shrink and the quantity will further significantly decrease; such fish species will even disappear from the reservoir area.

6.2.4 Impact on important habit of fish

a) Impact on spawning ground

1) Impact on spawning ground and larval resources of grass carp, black carp, silver carp and bighead

In accordance with Research Report on Impact of Middle Route (Phase I) of South-to-North Water Transfer Project on Fish Resources in Han River and the Protection Techniques prepared by Institute of Hydroecology of the Ministry of Water Resources and Chinese Academy of Sciences in 2004 on the basis of investigation on spawning of fishes spawning floating eggs in middle reaches of Han River, there are five major spawning grounds for grass carp, black carp, silver carp and bighead. They are Miaotan, Yicheng, Guanjiashan, Zhongxiang and Maliang. There are three spawning grounds in the project-affected areas. They are Yicheng, Guanjiashan and Zhongxiang spawning grounds.

Currently, with construction and operation of Wangfuzhou hydro-junction, Cuijiaying hydro-junction, Xinglong hydro-junction and Xinji hydro-junction in middle and lower reaches of Han River and impact of overfishing and water quality, the scale of spawning grounds for fishes spawning floating eggs in middle and lower reaches of Han River decrease sharply and even disappear.

According to the investigation in 2014, no spawning grounds for grass carp, black carp, silver carp and bighead were found in Yakou reservoir area and Guanjiashan and Dengjiatai spawning grounds were found in sections from Xinglong reservoir end to water under Yakou dam. Since Yakou Shipping Hub does not have the regulation capacity, it usually will not exert obvious impact on the downstream spawning grounds. However, the reservoir can still flatten the flood peak to some degree, the downstream flood peak will not be obvious under the circumstance of low-flow flood peak. For example, the maximum peak discharge at Huangzhuang gauging station in early September 2014 was 1, 040m^3/s, but flood peak was still formed under Cuijiaying dam after flattening of Cuijiaying reservoir; but the flood peak was hardly formed under Xinglong dam after flattening of Xinglong dam and the maximum flow was 400m^3/s. Therefore, low-flow flood peak may be difficult to meet demands of the downstream spawning grounds for flood peak after double flattening of Cuijiaying and Yakou reservoir area. In recent years which are the consecutive low flow years, Danjiangkou reservoir operates at low water level and there was only one small flood peak in early September 2014. Meanwhile, Danjiangkou reservoir does not discharge water in this year due to water storage for South-to-North Water Transfer Project and flood peak in middle and lower reaches of Han River mainly comes from outflow of Bai River and the tributaries, then basically no flood peak is formed under Xinglong dam after double regulation of Cuijiaying and Xinglong reservoir when the flow is 1,040m^3/s. Results of one monitoring on larval resources are unable to comprehensively reflect the breeding of fishes spawning floating eggs in middle and lower reaches of Han River. Therefore, investigation results of 2004 on the spawning ground are combined for the analysis.

According to the investigation in 2004, Yicheng spawning ground is located in Yakou reservoir area and extends from Xiaohe Town to Yicheng with length of 21km. Grass carp, black carp, silver carp and bighead altogether spawned 10,580,000 eggs. Except that Yakou Shipping Hub reservoir area discharges water openly, Yicheng spawning ground will be entirely inundated after water storage of Yakou reservoir area due to connection of Yakou Shipping Hub reservoir area and Cuijiaying reservoir area. In accordance with preliminary scheduling plan of Yakou Shipping Hub project, the plants will stop power generation and water discharge will be increased when the flow is 8,710m^3/s; when the flow is 13,500m^3/s, the hub project will discharge water openly. But operation of South-to-North Water Transfer Project will remarkably reduce the chances for occurrence of flow of 8,710m^3/s. As a matter of fact, the function of spawning grounds for fishes spawning floating eggs is basically lost.

Table 6.2.4 Impact of Yakou Shipping Hub Project on the spawning grounds

Spawning grounds	Location	Impact analysis
Yicheng	In the reservoir area and about 14.5km away from Yakou dam	This spawning ground is located in water in front of Yakou dam and construction of Yakou power station will inundate it due to heightening of water level of Yakou reservoir, changes in hydrological regime and reduction of flow velocity.
Guanjiashan	Under the dam and about 13.5km away from Yakou dam	During spawning season, Yakou Shipping Hub project basically does not regulate the runoff and the conditions of Guanjiashan spawning ground will remain unchanged. But under the circumstance of low-flow flood peak, flattening of Yakou reservoir will make flood peak of the spawning ground be unobvious, thus affecting breeding of fishes.
Zhongxiang	Under the dam and about 61.8km away from the dam	During spawning season, Yakou Shipping Hub project basically does not regulate the runoff and the conditions of Zhongxiang spawning ground will remain unchanged. But under the circumstance of low-flow flood peak, flattening of Yakou reservoir will make flood peak of the spawning ground be unobvious, thus affecting breeding of fishes.

Cumulative impact on spawning ground of fishes laying pelagic eggs:

Han River is the largest tributary of Yangtze River. Fish resources in Han River are highly similar to that in Yangtze River and fishes in both rivers frequently migrate and communicate. Usually, the fattened fish in water and lakes in middle and lower reaches of Yangtze River migrate to Han River to feed and breed and larval fish of Han River will migrate to water and lakes in middle and lower reaches of Yangtze River to feed and fatten. Construction of Danjiangkou reservoir blocks out the migration fishes in upper reaches of

Han River and fishes in middle and lower reaches of Han River as well as Yangtze River; construction of Cuijiaying reservoir blocks out migration of the fishes in Han River above Cuijiaying Dam and the tributary Tangbai River and the fishes in middle and lower reaches of Han River and Yangtze River; construction of Xinglong hydro-junction further blocks out migration of the fishes in reaches between Xinglong to Cuijiaying dam site and the fishes in lower reaches of Han River and Yangtze River. Currently, communication between fishes in water from Xinglong dam to Cuijiaying dam site is still smooth and the length of flowing river section above Xinglong reservoir end is about 210km.

After construction, Yakou Shipping Hub will further block out the migration and communications between fishes in different river sections. Only Guanjiashan and Zhongxiang spawning ground for grass carp, black carp, silver carp and bighead are remained. Although there are environmental conditions for spawning of the fishes spawning floating eggs, the river sections above Xinglong reservoir end is of limited length and medium and small sized fertilized eggs will sink into the reservoir area and are unable to float over the dam. They can only float over the dam when the flow conditions are met. Blocked out by the dam, the fertilized eggs and larval fish which have floated over the dam find it difficult to migrate to the water under Xinglong dam. Meanwhile, due to barrier of multiple hydro-junctions in reaches above Xinglong, the hydrological regime is also insufficient to satisfy the spawning and breeding conditions which can only be stored at the time of open discharge.

Yicheng spawning ground will be inundated due to connection between Yakou reservoir and Cuijiaying reservoir and shrinking of habitat in flowing water. Yicheng spawning ground will basically lose its function and the spawning conditions are met only at the time of open discharge. In addition, due to barrier of the dam, the fertilized eggs and larval fish which have migrated to the water under the dam will find it difficult to migrate back. So the fish resources will significantly reduce.

2) Impact on spawning ground of fishes spawning sticky eggs

Spawning ground for fish spawning eggs on plants usually needs to have aquatic plants to which the eggs can stick. After formation of Yakou reservoir, aquatic plants in slope, bay and estuary as well as the inundated flat areas are abundant. This is good for spawning and breeding of fishes spawning sticky eggs. In March to May during which such type of fishes spawn and breed, sudden changes of water level both above and under the dam should be prevented when scheduling and operating the reservoir to avoid death of eggs.

Currently, there are limited spawning grounds for fishes spawning eggs on gravels. After formation of the reservoir, these spawning grounds will be inundated. But new spawning grounds are hard to form since most of riverbank lands in the reservoir area are sandy gravel and sand. Similar spawning grounds may exist in part of sections of Chun River and Wei River. But quality of water in these two rivers is bad and under big influence of activities of human beings. Hence, the corresponding ecological function of the spawning grounds in these two rivers is hard to play and the spawning grounds for such type of fishes basically disappear from the reservoir area.

b) Impact on feeding and nursing ground and wintering ground

After formation of Yakou reservoir, the relatively static water environment will be formed, sediment will deposit and the water will be more transparent. These are good for photosynthesis of aquatic plants. In addition, during the preliminary stage of water storage, inundation of large amount of cultivated land and forest land and other residues will increase the content of inorganic salt and organic nutrients in the water. This plus increase of water temperature in the surface of the reservoir area provides good conditions for breeding of phytoplankton in the reservoir area. Increase in quantity of phytoplankton provides abundant food for most of the larval fish. Hence, the area of nursing ground will increase. Those species which inhabit in flowing water and swift current will also find new nursing ground in the tributary although they are unable to take advantage of the rich food resources in the reservoir area.

Wintering grounds are mainly distributed in deep water of main waterway in main stream. Heightening of water level of the reservoir area due to water storage is good for fishes to get through the winter.

6.2.5 Impact on national level aquatic germplasm resources protection area of elopichthys bambus, ochetobius elongates and luciobrama microcephalus at Zhongxiang river section

National level aquatic germplasm resources protection area of elopichthys bambus, ochetobius elongates and luciobrama microcephalus at Zhongxiang river section in Han River is established in accordance with No. 1130 announcement of the Ministry of Agriculture of the People's Republic of China in October 2008 and is classified into second batch of national level aquatic germplasm resource protection area on December 22, 2008.

The protection area totally occupies land of 4,320 hm^2. Of which, the core area occupies land of 1,720 hm^2 and the experimental area occupies land of 2,600 hm^2. The protection area is located between east longitude 112°25′25″-112°36′18″ and north latitude 31°18′34″—30°57′52″ and has total length of 108km. The core area extends from Zhongshan-Nianpanshan river section to Liugang-Rentan with total length of 43km. The core area occupies land of 17.2km^2, accounting for 39.8% of the total area of the protection area, and is under close-end management. Inflection point coordinates of the core area are (E112°31′21″, N31°13′41″; E112°32′20″, N31°05′12″; E112°32′38″, N31°05′28″; E112°31′20″, N31°13′14″). The particular protection period of the core areas is from April 1 to June 30.

The experimental area is divided into two parts. The upper part extends from Jinhuatan-phosphorus mine to Zhongshan-Nianpanshan river section and the total length is 25km. The inflection point coordinates are (E112°25′25″, N31°18′34″; E112°31′21″, N31°13′41″; E112°31′20″, N31°13′14″; E112°25′25″, N31°17′50″). The lower part extends from Rentan-Liugang to Caihu-Wanglong river section and the total length is 40km. the inflection point coordinates are (E112°32′20″, N31°05′12″; E112°33′07″, N30°57′52″; E112°32′29″, N30°57′57″; E112°32′38″, N31°05′28″) respectively.

Yakou Shipping Hub Project is 58km away from the planned Nianpanshan Hydro-junction. Nianpanshan dam site is located in the experimental area of the national level aquatic germplasm resources protection area of elopichthys bambus, ochetobius elongates and luciobrama microcephalus at Zhongxiang river section and is 1.6km away from boundary of the core area of the downstream protection area. Yakou dam site is 31.4km away from boundary of the upper experimental area of the national protection area. Since Yakou hydropower station is far away from the national protection area, it will not exert direct impact on habitat and biological structure of the protection area and the main possible influential factor is changes of hydrological regime due to scheduling of Yakou Shipping Hub Project. Elopichthys bambus, ochetobius elongates and luciobrama microcephalus in the protection area spawn in the flood season. Since Yakou Shipping Hub has limited action on flood peak, it will not affect the hydrological and hydraulic conditions necessary for spawning of these fishes in the protection area. Meanwhile, the daily change extent of water level of Yakou reservoir area is not big since Yakou Shipping Hub generates power on the basis of base-load flow and discharges water according to the inflow, so it will not exert obvious impact on spawning of other fishes spawning sticky and sinking eggs in the protection area. In conclusion, the impact of construction and operation of Yakou Shipping Hub on structure and function of the national level aquatic germplasm resources protection area of elopichthys bambus, ochetobius elongates and luciobrama microcephalus at Zhongxiang river section is not obvious.

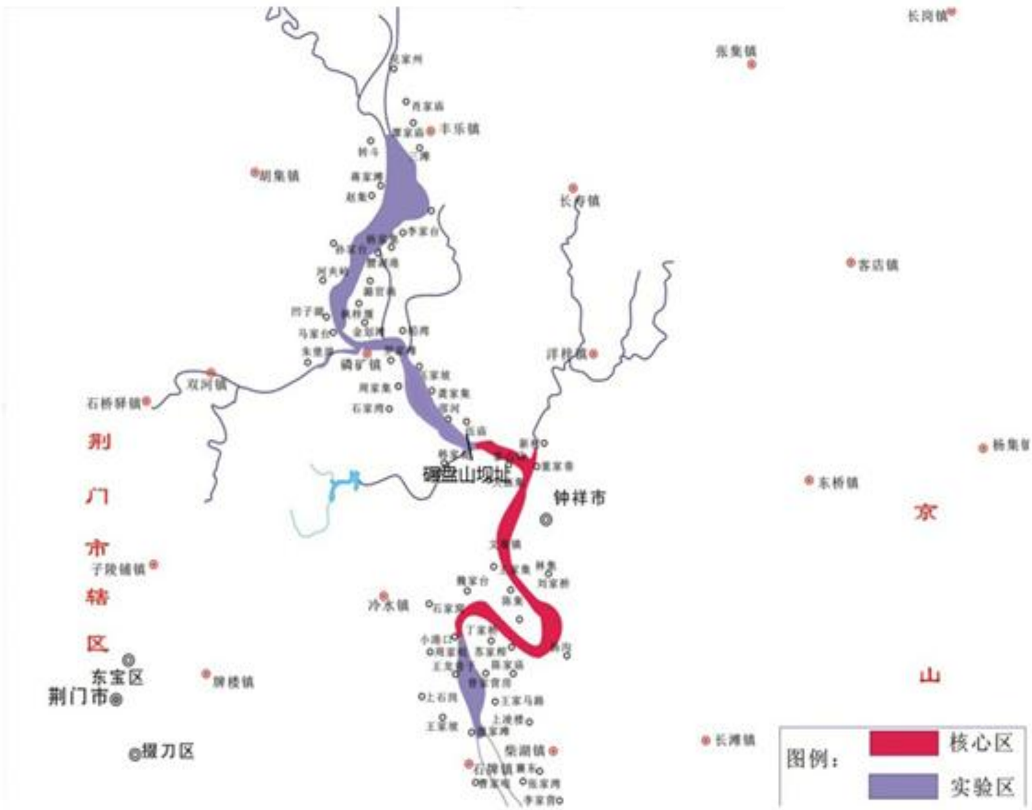


Figure 6.2.5 Diagram of national level aquatic germplasm protection area of elopichthys bambus, ochetobius elongates and luciobrama microcephalus at Zhongxiang river section in Hubei Province

核心区	**Core area**
实验区	**Experimental area**

6.2.6 Impact of construction on aquatic ecosystem

This project is mainly constructed on the dry land and the construction period will be 58 months. Construction of some part of approach channels involves underwater works. Sewage and wastewater during the construction period will not be discharged into the Han River and will be comprehensively used upon treatment. Sound, light and electricity in underwater works will have adverse impact on inhabiting, growth and breeding of fishes in the construction river section. The main works will be completed within the cofferdam and the construction will affect the zoobenthos and fishes living in the cofferdam. In accordance with the inventory survey, there are no wintering ground, spawning ground and feeding ground in the cofferdam areas. After closure of the river, the flow velocity will slightly increase due to stage diversion. But the water level will not apparently be heightened. Hence, migration of fishes in the downstream reaches towards the upstream reaches will not be affected. In addition, fishing of the construction personnel and their demands for aquatic products will greatly do harms to the fish resources. Hence, inspection and management should be strengthened to mitigate the adverse impact. On the whole, the construction will exert little impact on aquatic ecosystem and the impact will end along with completion of the construction.

6.2.7 Impact of construction of Yakou hydro-junction on aquatic ecosystem

a) Impact of the built hydro-junctions on aquatic ecosystem

Hydrological regime in middle and lower reaches of Han River after formation of Danjiangkou Dam will change greatly. These changes are: flow and water level variation in middle and lower reaches of Han River will reduce; discharge of clear water will increase the transparency of water; scouring action of waterway increases; water temperature will decrease in hot seasons and increase in winter due to discharge of bottom water of the reservoir. The survey on fish resources in 1977 to 1978 shows that dam formation changed the ecological environment of original waterway, make some widely distributed commercial fishes can only live in the isolated water and defer the development of sexual gland of fish, postpone the breeding season, move down some spawning grounds for fishes spawning floating eggs or make them disappear and shorten the growth period. But it is good for improvement in biological productivity of the water, wintering of fishes, spawning and breeding of fishes spawning sticky eggs and development of some fishes. With the time elapses, the fishes have gradually adopt themselves to the changed environment and can breed, feed, grow and get through the winter in middle and lower reaches of Han River.

Wangfuzhou hydro-junction causes Wangfuzhou spawning ground to disappear. Construction of Cuijiaying Hydro-junction causes fishes in middle and lower reaches of Han River under Cuijiaying dam not be able to migrate towards Miaotan and Tangbai River spawning grounds for breeding; reduction of flow velocity in Cuijiaying reservoir area also causes the fertilized eggs not be able to float over the dam but to sink into the bottom of the reservoir, thus causing an significant increase of mortality. Xinglong hydro-junction also blocks out the migration of fishes in lower reaches of Han River and even fishes in main stream of Yangtze River. Even if some mature breeder can migrate towards middle and lower reaches of Han River for spawning, construction of hydro-junctions in middle and lower reaches of Han River also make aquatic habitats in such river sections greatly shrink and the environmental conditions are insufficient to make fish complete their life cycle. In addition, formation of Xinglong reservoir has inundated Maliang spawning ground and made Zhongxiang spawning grounds shrink and the flattening action of Xinglong reservoir is not good for breeding of fishes in Zekou spawning ground under the dam

On the whole, as the largest tributary of Yangtze River in the middle and lower reaches of Yangtze River, Han River is an important site for spawning and breeding of fishes living in middle and lower reaches of Yangtze River and feeding ground for some fishes.

Construction of Danjiangkou reservoir blocks out migration and communication between fishes in different reaches of Han River and Yangtze River, the original aquatic ecological function of Han River is shifted to water in middle and lower reaches of Han River. Particularly, low temperature of water discharged from Danjiangkou reservoir deferred the breeding of fishes in middle and lower reaches of Han River for about one month. But there are still many spawning grounds in lower reaches of Han River. These spawning grounds are important site for spawning and breeding of fishes in middle and lower reaches of Yangtze River. Construction of Wangfuzhou, Cuijiaying and Xinglong hydro-junction inundated some spawning grounds and migration of fishes is hindered, causing shrinking of spawning grounds both in light of area and fish species. Especially, in low flow years, small peak discharge and flattening of multiple hydro-junctions make function of the only Yicheng, Guanjiashan and Zhongxiang spawning grounds as well Zekou spawning ground under Xinglong dam significantly weaken. According to investigation results of 2014 on spawning grounds, no larval fish resources in Yicheng spawning grounds were found in low flow years. Zekou spawning ground under Xinglong dam is also unable to satisfy the demands of fishes spawning floating eggs for breeding due to unsatisfactory hydrological process, so no larval fish resources were found in low flow years. Larval fish resources in Guanjiashan and Zhongxiang spawning grounds were found but both the quantity and species reduce. Heightening of Danjiangkou dam in November 2014 will cause further reduction of water resources in middle and lower reaches of Han River and decrease in water temperature. This will further affect the above mentioned spawning grounds and fish resources in such areas will further decrease.

b) Cumulative impact of Yakou hydro-junction on aquatic ecosystem

Construction of Yakou Shipping Hub will further cut habitat of fishes into segment and further hinder the migration of fishes, especially the migration of eels and grass carp, black carp, silver carp and bighead towards upstream. Yakou Shipping Hub is low-head project and does not have regulation capacity. When the flow at the dam site equals to or is larger than 8,710m^3/s but is smaller than 13,500m^3/s, Yakou power station will stop power generation, sluice will operate normally and more water will be discharged to reduce water level of the reservoir until the normal water level are restored. When flow at the dam site is larger than 13,500m^3/s, Yakou power station will stop power generation, shipping will stop, water will be discharge openly and operation of the whole project is to control the flood. After that, water level rising in front of the dam will disappear quickly and waterway is basically in the natural state, exerting little impact on both the upstream and downstream hydrological regime.

According to prediction on hydrology, level of water at both sides of the sluice is basically the same at the time of open discharge and natural flow velocity in the water areas around sluice can be restored. Therefore, some fishes can migrate to the water above the dam. In other words, Yakou Shipping Hub does not completely hinder the migration of fishes. Construction of Yakou Shipping Hub will aggravate the adverse impact on fishes spawning floating eggs in middle and lower reaches of Han River. When the flow is smaller than 5,000m^3/s in low flow years, Yicheng spawning ground will be inundated and its function will lose. When the flow is between 5,000 and 8,000m^3/s, although pre-discharge measures are taken to reduce the water level and some hydrological conditions for spawning of Yicheng spawning ground is restored, mature breeder still find it difficult to migrate towards the upstream due to hindering of the dam and quantity of eggs is also limited. Only when the flow is larger than 8,000m^3/s, Yicheng spawning ground can play part of its function. Similarly, flattening action of Yakou reservoir area on flood peak, adverse impact will also be exerted on Guanjiashan and Zhongxiang spawning ground in low flow years. In conclusion, formation of hydro-junctions in middle and lower reaches of Han River will have significant impact on fishes spawning floating eggs. Particularly when the flow is smaller than 8,000m^3/s, not only function the three spawning grounds above Xinglong hydro-junction will be weakened but also Zekou spawning ground under Xinglong dam will be under adverse impact.

Therefore, due to hindering of built hydro-junctions in middle and lower reaches of Han River, the larval fish continuously migrate towards water under Xinglong dam but the mature breeder in lower reaches of Han River and middle and lower reaches of Yangtze River will find it difficult to migrate back, quantity of fish species spawning floating eggs will reduce and the function of current spawning ground will continuously be weakened. And construction of Yakou Shipping Hub will undoubtedly further aggravate such impact.

c) Mitigation measures

From the perspective of breeding habits of fishes in middle and lower reaches of Han River, the fishes in such reaches can be divided into two types: fishes spawning eggs on plants and fishes spawning floating eggs. The first type of fishes will be under limited impact owing to that aquatic plants are not greatly affected by formation of those hydro-junctions and that the water level does not fluctuate sharply since those hydro-junctions generate power on the basis of base-load flow. Due to changes of hydrological regime and hindering of the dams, breeding of the second type of fishes will be greatly affected and the quantity will be cut sharply. To restore the function of the spawning ground and protect the fish resources, hindering impact and hydrological regime changes need to be mitigated.

In accordance with studies of Institute of Hydroecology of the Ministry of Water Resources and Chinese Academy of Sciences on hydrological and hydraulic conditions for breeding of fishes spawning floating eggs in middle and lower reaches in Han River in 2004 to 2007, breeding of fishes spawning floating eggs in middle and lower reaches in Han River mainly relies on flood of Tangbai River and regional flood. Discharge of Danjiangkou reservoir also facilitates the breeding. Therefore, schedule Cuijiaying, Yakou and Xinglong hydro-junctions to discharge water openly at appropriate time in accordance with inflow from Tangbai River can not only restore the natural flow of river sections in middle and lower reaches of Han River in which fishes spawn, mitigate the adverse impact of hydrological regime changes on breeding of fishes spawning floating eggs; but also mitigate the hindering impact on migration and communication of fishes in different reaches. This is good for protecting and restoring the spawning grounds in middle and lower reaches, can effectively mitigate the adverse impact of Yakou Shipping Hub on fishes spawning floating eggs and also greatly mitigate the adverse impact of development of hydro-junctions in middle and lower reaches of Han River.

6.3 Impact assessment for terrestrial ecosystem

6.3.1 Impact on ecosystem

The Yakou Shipping Hub Project focuses on shipping, along with the overall benefits of power generation, irrigation, and tourism. Ecosystems to be assessed include forest ecosystem, wetland ecosystem, agricultural ecosystem, and town/village ecosystem. These ecosystems play an important role in sustaining habitat and biodiversity, as well as in purifying water sources and beautifying the environment. Construction and operation of Yakou Shipping Hub will affect local ecosystems as the inundation and land occupation caused by the project may lead to an increase of water area and a decrease of the biomass of vegetation. However, ecosystems are stable and resilient. They may rehabilitate themselves after a while. After the project is put into operation, the structures and functions of the ecosystems that are to be assessed will generally remain unchanged. Impact assessment for ecosystems focuses on wetland ecosystems and agricultural ecosystems.

a) Impact on wetland ecosystem

Wetland ecosystems to be assessed are generally found in the Han River between Xiangyang and Zhongxiang, the Han River tributaries such as Ying River and flood plains in the area. Implementation of the project affects wetland ecosystems both positively and negatively. On one hand, waste, wastewater, and domestic sewage produced during construction will contaminate water, which will indirectly disrupt wetland ecosystems for plants and animals. Such negative impact can be prevented by taking effective measures. During operation, inundation may turn natural flood plains and wetland into water area, which will submerge the original plants (such as poplar and brown willow) in the flood plains and thus reduce vegetation in the area. Moreover, inundation will turn shallow water into deep water, which may disrupt the habitat of wading birds. According to domestic and international studies on the impact of water level changes to the ecosystems of rivers, lakes, and wetlands, permanently raising the water level of a reservoir may lead to a decrease of the species and vegetation in the wetlands of the reservoir area in the short term. However, in the long term, wetland vegetation will adapt to the new water level and increase gradually. This project is a shipping hub project that focuses on shipping but also engages in power generation; no daily load regulation is entailed for the hub operation. Therefore, there is no obvious decrease in the quantity of water downstream from the dam after the project is put into operation, and thus the vegetation and animals in wetlands downstream from the dam will not be significantly affected by the project.

On the other hand, after Yakou Shipping Hub is put into operation, water area of the reservoir upstream from the dam will increase. By properly distributing water resources, impoundment capacity for wetland ecosystems will be increased, which may help change local climate in a positive way.

b) Impact on agricultural ecosystem

On one hand, implementation and operation of the project entails occupation and inundation of some farmlands, which will lead to lower crop yields. it may also lead to a decrease in the area of habitat for animals inhabiting these farmlands. According to statistics of Xiangyang Land and Resources Bureau, Yakou Shipping Hub will permanently occupy and inundate 3,059.65hm^2 of farmland, accounting for 27.49% of the area (11,130.39hm^2) of agro-ecosystem in the entire assessed area. It will disrupt agro-ecosystem structure and function.

On the other hand, Yakou Shipping Hub will benefit local agro-ecosystem. Implementation of the project may improve irrigation for the agro-ecosystem in the assessed area. In addition, areas along both banks of the Han River mid-and lower-reaches are grain, cotton, and oil production base. With construction of the hub, the water level of the project area will rise. The increased water may flow to irrigate a total of 80,000mu of farmland in Liushui Town, Zhengji Town, Yancheng, and Nanying, which will reduce the cost of transporting water. It is conducive to developing cost-effective agriculture. Moreover, the increase of the reservoir water area and effective irrigation area will help replenish underground water and increase moisture in the air, which will positively change the weather of the assessed area. An increase of humidity may help to the growth of crops in the river valleys along the Han River. Implementation of soil and water conservation measures can reduce the waste of water and soil resources, which will help to preserve important resources for agricultural development.

c) Impact on forest ecosystem

Land occupation and inundation caused by Yakou Hub project will lead to a decrease in the area of forest vegetation, cause the biomass and productivity of vegetation to fall, and disrupt the habitat of local animals.

With impoundment of the hub, all woodland having an altitude below 55.22m will be directly inundated. Woodland inundated due to this project covers an area of 114.69hm^2, accounting for 37.48% of the forest area (4,247.78 hm^2) in the entire assessed area. However, as the large area of woodland in the assessed area is artificial forest, the project has no big impact on the area's forest ecosystem. According to field surveys, plants in the occupied and inundated woodland are common species, including poplar, willow, paper mulberry, vitex, *Setaria viridis*, *Cynodon dactylon*, and *Artemisia lavandulaefolia*. These plants are widely growing in the assessed area. Land occupation and inundation will not lead to a decrease of these species. Construction, land occupation, and inundation after impoundment will impel the animals inhabiting the woodland to migrate to places far away from the construction area. It will change the distribution of animals in the assessed area's woodland, but it will not reduce the animal species.

d) Impact on town/village ecosystem

After Yakou Shipping Hub is built, the inundated areas will involve 8 townships (sub-districts) and 36 villages in Yicheng City, Xiangcheng District, and Xiangzhou District under the jurisdiction of Xiangyang. The inundated areas include land and a small number of farmhouses in the areas along both banks. Project construction and operation will help to boost the economy of relevant towns/villages. The project will improve waterways, making the Han River segment between Xiangyang and Yicheng navigable again. It will promote inland water shipping development. The hub will serve as a bridge between Hunan, Hubei, and Jiangxi provinces, ensuring energy supply security and fast economic and social development for these provinces. In addition, power generation will ensure sufficient and stable power supply, supporting local economic development. Construction of Yakou Shipping Hub may form a 52.67km waterway in the Han River, increasing the capacity of the waterway to 1000t from 500t and reducing the fuel consumption of ships. As a result, an increasing number of larger, standardized ships will be built, which will help to the development of the shipping industry. According to a survey of the current shipping industry, 8kg/kt.km of fuel has been consumed by the ships traveling in the Han River mid-and lower-reaches. After the waterway is formed, the fuel consumption will fall by 30-40%, leading to a decrease in the consumption of non-renewable resources such as petroleum and coal.

6.3.2 Impact assessment for landscape ecosystem

a) Change in the land use

The Yakou project entails the permanent occupation of land that covers 131.75hm^2 and the inundation of land that covers 8,494.12hm^2. See table 6.3.2-1 for the change in the use of land in the assessed area.

Table 6.3.2-1 Use, number, and area of plots before and after the project is completed

Types of land use	Before the completion		After the completion		Change	
	Number (plots)	Area (hm^2)	Number (plots)	Area (hm^2)	Number (plots)	Area (hm^2)
Woodland	942	3815.73	811	1987.78	-131	-1827.95
Grassland	17	151.62	12	134.89	-5	-16.73
Farmland	1005	11130.39	879	8070.74	-126	-3059.65
Water area	48	3701.81	39	8494.12	-9	4792.31
Construction land and land for other uses	513	3232.49	534	3344.51	21	112.02
Total	2525	22032.04	2275	22032.04	-250	0

According to the table, the reservoir construction and impoundment has changed the land use. The area of woodland, grassland, and farmland decreases due to inundation and land occupation. The area of woodland has decreased to 1,987.78hm^2 from 3,815.73hm^2; the area of grassland has decreased to 134.89hm^2 from 151.62hm^2; and the area of farmland has decreased from 11,130.39 hm^2 to 8,070.34hm^2 (including flood plains used for seasonally growing crops). Due to impoundment, water area has increased from 3,701.81 hm^2 to 8,494.12hm^2. Part of construction land is inundated due to the project, but construction of the dam and factory buildings entails land, so the area of construction land has actually increased from 3232.49hm^2 before impoundment to 3,344.51 hm^2.

The assessment of the project area focuses on wetlands. Permanently land occupation leads to decreases of woodland and farmland along both banks of the Han River. In conclusion, project construction and operation will change the use of land in the assessed area, but the change is not big.

b) Impact on biomass

See table 6.3.2-2 for the biomass losses of various vegetation types in the construction area. Construction will completely disrupt the original vegetation in the construction land. The biomass of vegetation will decrease; the biomass losses reaches 55540.77t, accounting for 3.56% of the total biomass in the assessed area. Scrubs and shrub herbosa lose more biomass than other vegetation types; their biomass losses account for 61.14% of the total biomass loss. The biomass loss of crops accounts for 33.05% of the total biomass loss. When construction ends, the biomass of relevant vegetation can be increased by artificially growing plants.

Table 6.3.2-2 Changes in the biomass of various vegetation types in the construction area

Change in the area		Average biomass (t/hm^2)	Biomass change(t)	Percentage of the total biomass loss (%)
Types	Area (hm^2)			
Coniferous forest	0.00	26.13	0.00	0.00
Broad-leaved forest	-97.56	89.11	-8693.57	15.65
Bamboo forest	0.00	24.00	0.00	0.00
Scrubs and shrub herbosa	-1718.44	19.76	-33956.37	61.14
Cash trees	-11.95	23.74	-283.69	0.51
Crops	-3059.65	6.00	-18357.90	33.05
Water area	4792.31	1.20	5750.77	
Total	-		-55540.77	

Notes: the “total” does not include the area (2,975.54hm^2) of construction land and land for other uses.

c) General assessment of landscape ecosystem

The landscape of the temporarily occupied land in the construction area can be recovered or improved by taking ecological compensation and restoration measures. In the permanently occupied area, structures will be built, which may disrupt the area’s natural landscape.

See table 6.3.2-3 for the dominance values of various plots after the project is implemented. After impoundment, parts of land will be inundated and the dam will be built, which will change the structure of local landscape ecosystem. However, most plots in the assessed area will remain unchanged, sustaining the ecosystem and ensuring that the ecosystem is resistant to external disruption. The basic components of landscape remain unchanged. In conclusion, project construction and operation will not significantly change the general natural landscape of the area.

Table 6.3.2-3 Dominance values of various plots before and after the project is implemented

Types	R_d(%)		R_f(%)		L_p(%)		D_o(%)	
	Before the implementation	After the implementation	Before the implementation	After the implementation	Before the implementation	After the implementation	Before the implementation	After the implementation
Woodland	26.95	26.31	8.94	8.75	9.07	9.02	13.51	13.28

Types	R_d(%)		R_f(%)		L_p(%)		D_o(%)	
	Before the implementation	After the implementation	Before the implementation	After the implementation	Before the implementation	After the implementation	Before the implementation	After the implementation
Grassland	28.24	26.86	12.81	9.62	10.22	9.73	15.37	13.99
Farmland	28.76	28.35	53.69	46.23	50.52	44.16	45.87	40.72
Water area	1.37	1.26	15.37	28.97	16.80	23.58	12.59	19.35
Construction land and land for other uses	14.68	17.22	10.53	13.19	13.39	13.51	13.00	14.36

According to the table, after the project is implemented, the land use has changed. The dominance values of woodland, grassland, farmland, construction land, and land for other uses have decreased due to inundation, while the dominance value of water area has increased from 12.59% before the project is implemented to 19.35% due to the increased importance of impoundment. Although the dominance value of farmland has decreased from 45.87% to 40.72%, it still far exceeds the dominance values of other plots. In conclusion, project construction and operation will not significantly change the natural landscape of the assessed area.

6.3.3 Estimation of impact on terrestrial plants

6.3.3.1 Impact of construction

The impact of Yakou Shipping Hub construction on terrestrial plants and vegetation comes in the following forms: land occupation and inundation, dust, and water contamination.

a) Impact of land occupation to plants

The construction site of the hub project covers an area of 377.08hm^2, accounting for 1.79% of the total area (211.07km^2) of the assessed area. Of 377.08hm^2, 131.75hm^2 is the area of permanently occupied land and 245.33hm^2 is the area of temporarily occupied land. Of 131.75hm^2, 29.48hm^2 is the area of dry land, 83.61hm^2 is the area of woodland, and 56.88hm^2 is the area of inland tidal flats; of 245.33hm^2, 99.51hm^2 is the area of dry land, 54.26hm^2 is the area of woodland, and 12.09hm^2 is the area of inland tidal flats. See table 6.3.1-4 for details. According to the table, the woodland temporarily and permanently occupied for the project covers a small area; the affected vegetation types are artificial forest, secondary scrub, and shrub herbosa. These types of vegetation are commonly seen in the assessed area. In conclusion, land occupation has no significant impact on plants.

Projects like gate dams, ship locks, and power plants entail permanent land occupation. Types of vegetation on the land that is permanently occupied for this project are corn, white gourd, and cotton; there is not much secondary vegetation on the permanently occupied land, so the impact on secondary vegetation is not big. A ships lock is arranged on the flood plains on the right bank of the main riverbed; the affected plant species are *Cynodon dactylon*, *Populus enramevicana cv*, and brown willows. A floodgate is arranged in the main channel of the river course on the left side of the ship lock, which will not impact terrestrial vegetation. A power plant is arranged near the beach in the middle of the riverbed; an erection bay is arranged to the left side of the plant, which will impact the shelter forest of *Populus enramevicana cv.* The diaphragm wall for this project extends to 50 meters from the levee, which will impact crops and *Cynodon dactylon*. Permanent land occupation will irreversibly disrupt the habitat of vegetation. Construction may damage vegetation and cause their biomass to decrease.

Land that is temporarily occupied is used for building a project management office, aggregate processing system, construction camps, various warehouses, processing plants, equipment maintenance workshops, quarries, waste dumps, and roads. Most of the vegetation on the temporarily occupied land is crop, such as corns, cotton, rice, and beans. Only 7.17% of the temporarily occupied land is woodland, which consists largely of the scrubs and shrub herbosa of paper mulberry, vitex, *Cynodon dactylon*, *Conyza canadensis*, and *Alternanthera philoxeroides*. Land occupation may also disrupt the habitat of *Populus enramevicana cv.* and *Pterocarya stenoptera*. Land occupation will directly damage vegetation, causing the number of plants and plant species in the affected area to decrease. However, after the project is completed, the restoration of vegetation will make up for some biomass losses.

b) Impact of dust to plants

Large amounts of dust (TSP, NOx, SO_2, CO, Pb, etc.) will be produced during construction. Such dust may rest on plant leaves, affecting their appearance and hindering their photosynthesis. It will stunt the growth of these plants.

c) Impact of water contamination to plants

Sewage produced by construction workers and waste produced by construction contain SS, oil, BOD5, COD, and ammonia nitrogen. These pollutants may contaminate the vegetation growing in the nearby water area. If they rest on plants, they may hinder the photosynthesis of plants. They may also permeate into soil, stunting the growth of plants.

6.3.3.2 Impact of operation

During its operation, the Yakou Shipping Hub Project may cause inundation, resettlement, and fluctuations in water levels, which will affect terrestrial plants and vegetation.

a) Biomass losses caused by inundation

The design water level for the Yakou Shipping Hub is 55.22m. The inundated area from Ruanjiapo on the right bank to the Yakou dam site averages 1,062m^2; the inundated area along the left bank of the Nanzhou-Nanying segment averages 367m^2; the inundated area long the right bank of the Zhangjiaju-Nanying segment averages 135m^2. According to the calculation of seepage, the inundated area along the right bank of the project area is 18.71km^2; the inundated area along the left bank of the project area is 9.01km^2.

During impoundment, the species and number of plants in the inundated areas will decrease. According to field surveys, most of the inundated areas are farmland; following farmland are the woodland of *Populus enramevicana cv* and the grassland of paper mulberry, *Hemarthria*, and *Conyza canadensis*. Plants in the inundated areas are locally common species and are widely growing in the reservoir surrounding areas. Only parts of farmland, short scrubs, and artificial forest are inundated, so inundation will not cause the species of inundated plants to die out. Crops in the inundated farmland will be damaged. If the water level of the reservoir rises, it may negatively affect agricultural ecosystem locally and the biodiversity of the wetland in the reservoir area. Plants in the inundated areas are not endemic, so during operation, the project will not have a big impact on local flora.

b) Impact on vegetation downstream from the dam

With regard to this project, the daily water inflow and outflow are balanced. If water flows into the reservoir at a rate of over 10000m^3/s, the natural river course will be restored for water discharge. In addition, the hub focuses on serving shipping, so the flow rate of water discharged downstream for base-load shipping shall be maintained at 450m^3/s to ensure sufficient water for shipping. Therefore, Project operation will not have a big impact on the terrestrial vegetation downstream from the dam.

c) Impact of fluctuations in water levels to wetland vegetation

Periodic inundation tends to change the physical property of soil. For instance, the oxidation-reduction potential of soil may decrease, the oxygen content of soil may decrease, and pressure on the root system may increase, which will slow the enzyme activity of plants for photosynthesis. Fluctuations in water levels will cause the decomposition of organic substances in soil to slow down, cause nutrient substances in soil to decrease, and slow the absorption of nutrient substances by wetland plants, stunting the growth of these plants. Fluctuations in water levels will also slow the exchange of nutrient substances between soil and water. Mr. Keeland and other scientists from the US believe that initial water levels play an important role in fluctuations in water levels. The same plant species in relatively dry places are susceptible to fluctuations in water levels, while plant species in wetlands tend to be immune to fluctuations in water levels. It may be because that initial water levels play a key role in a species' adaptability to changes of water levels. According to the analysis of hydrological regime, the water level of the Yakou Reservoir area falls by only 0.3m; the maximum fluctuation in level of water downstream from the dam averages 0.88m; the maximum fluctuation in water levels throughout wet seasons is only 0.84m. As the assessed area is a permanent river, soil in the area has high water content. Wetland plants in the reservoir area are more susceptible to fluctuations in water levels than plants in the river segments downstream from the dam (plants in the river segments downstream from the dam are susceptible to fluctuations in water level during wet seasons in particular). The change in the general properties of plant species in the areas where water levels are regulated is a response of plants to fluctuations in water levels. Whether a plant is adaptable to regulated water levels or not depends on its seed dispersal mechanism. Plants whose seeds are dispersed by wind or water tend to survive in areas where water levels are frequently regulated. The decrease of local species has provided living space for exotic species, causing the habitat of local species to shrink. Generally speaking, frequently regulating water levels tends to cause the number of species and the coverage of vegetation to fall. Although small changes of water levels also cause the number of species to fall, such impact is smaller than the impact of rising water levels to the number of species.

d) Impact on plants

The main types of vegetation in the Yakou Project area are farmland, shrubs, grassland, and the forest of *Populus enramevicana cv*. These types of vegetation are commonly seen in the Han River, so construction of power stations will not have a big impact on flora in the area.

According to relevant data and field surveys, there are no wild plant species under state protection in the assessed area. In the area, there is a 110-year-old tree (*Pistacia chinensis*). The tree is located along the Luojia River, northern latitude of 31°46'31.00" and east longitude of 112°10'32.00". It is 17m tall; its DBH (diameter at breast height) is 59cm and its crown diameter is 16m. The tree is not inundated. It is 500m upstream from the reservoir, 330m from the levee, and 9km from Yakou Dam; there is no road under construction near the tree, so the project will not affect the tree. In addition, some metasequoia trees and camphor trees are grown by man as border trees or in the surrounding areas of residences. Inundation and the construction of power stations will not have a big impact on these plants.

6.3.4 Impact on terrestrial animals

6.3.4.1 Impact of construction to terrestrial animals

Roads in the construction area for the Yakou Shipping Hub project will be expanded. Noise made by construction, stack yards for building stones and soil, as well as construction machinery and workers entering and leaving the site have disrupted the habitat of current wild animals, which will negatively affect their lives.

a) Impact on amphibians and reptiles

The industrial wastewater and domestic sewage produced during construction is not discharged. Soil erosion may affect water in the river course. Construction of levees along the river banks has disrupted the habitat of amphibians inhabiting still water and flowing water. For example, *Bufo gargarizans* and *Zaocys dhumnades* generally inhabit dark, damp tussocks, farmland, brooks, and cottages; they feed on insects. Saurian and snakes generally inhabit deciduous broad-leaved forests and mixed broadleaf-conifer forests in hills as well as dark, damp scrubs and farmland; they feed on insects, batrachia, birds, and mice. Construction may disrupt or even completely damage the habitat of these amphibians and reptiles. They can move to non-construction areas or the areas that have not been inundated for survival. Construction workers may eat frogs and snakes, which will reduce the number of local amphibians and reptiles, so measures shall be taken to prevent workers from eating local frogs and snakes.

b) Impact on birds

Terrestrial birds, birds of prey, and songbirds generally inhabit deciduous broad-leaved forests and mixed broadleaf-conifer forests in hills as well as in shrubberies and scrubs; they generally feed on insects and the seeds and fruit of plants, except birds of prey. Construction may disrupt the habitat of these birds, forcing them to leave the area. However, after vegetation is restored in the temporarily requisitioned land, they may return to their original habitat. Birds generally inhabit the areas along the right bank of the dam site where vegetation covers a large area, while the construction sites for the project are generally located on the left bank of the dam site, so the project will not have a big impact on these birds.

c) Impact on animals

Noise caused by blasts and machines during construction may drive animals away from their habitat. Animals in general tend to migrate to suitable habitat in order to avoid the noise and other harms caused by construction. After construction ends, they may return to their original habitat. Therefore, impact brought by construction to animals will not last long; it will disappear when construction ends.

The habitat of rodents such as sewer rats and *Cricetulus barabensis* largely overlaps with residential and working areas. In winter when food in the wild is in shortage, these rodents would inhabit residential areas, while in spring when food in the wild is increasing, they would inhabit the wild. They may also act as carriers of some natural-focal diseases. During construction, the population density of rodents will increase, so it is recommended that local health protection agency should pay closer attention to epidemic diseases and take measure to prevent natural-focal diseases.

6.3.4.2 Impact of operation to terrestrial animals

After the reservoir is built, the habitat of wild animals in the river valley and bank areas will shrink due to inundation. Reptiles such as saurian and snakes that generally inhabit the low-altitude areas may migrate to higher-altitude areas as their original habitat is disrupted, while animals that feed on these animals inhabiting the low-altitude areas will be indirectly affected. A small part of the habitat of birds and animals that inhabit low-altitude scrubs and tussocks will be disrupted. However, these birds and animals can migrate and they have multiple food sources, so construction of power stations will not have a big impact on them. On the other hand, after impoundment, the capacity of the reservoir and the wetland area of the reservoir area will increase, which will increase habitat for amphibians. This will help to the increase in the populations of amphibians.

After impoundment, the Han River water level will rise, which may inundate some beaches, tidal flats, and swamps that egrets, Chinese Pond Herons, and other wading birds inhabit. As their habitat shrinks, these wading birds will migrate to other suitable habitat. There are tributaries Nan River and Bei River as well as a large number of reservoirs, weirs, ponds, and paddy fields near the affected area, so the wading birds can easily find habitat similar to their original one. Moreover, as the Han River water level rises, the water area will increase and the quantity of fish in the reservoir area will increase, which can provide favorable habitat for waterfowls such as teal, *Ruddy shelduck*, and *Anser cygnoides*. As a result, the number of waterfowls in the area will increase.

As the water level of the reservoir rises, vegetation in areas along the banks of the reservoir area will be inundated; the habitat of amphibians and reptiles inhabiting the areas will be disrupted. As a result, these animals will have to look for suitable habitat and migrate there.

①Amphibian: the majority of amphibians in the assessed area are terrestrial animals. Inundation will force these animals to migrate to higher-altitude places. The water level does not rise much and the habitat of amphibians in the assessed area is widespread, so it will be easy for the amphibians to adapt to new habitat. As water flows more slowly due to impoundment, amphibians inhabiting flowing water areas will migrate to other flowing water areas (such as tributaries whose river courses are narrower). After the reservoir is built, still water or slow flowing water areas will increase, which will be conducive to the increase of the amphibians inhabiting still water.

②Reptile: reptiles in the assessed area generally inhabit scrubs and woodland near water. Impoundment will inundate parts of the habitat of these reptiles, forcing them to migrate to higher-altitude places. The water level does not rise much and the habitat of reptiles in the assessed area is widespread, so it will be easy for these reptiles to adapt to new habitat. Snakes will be indirectly affected by inundation because their potential food (amphibians) may have migrated to suitable habitat.

③Bird: birds can fly, so impoundment will not cause birds to die. The majority of birds in the assessed area are small birds that are suitable to inhabit plains. The habitat of these birds may shrink due to inundation. During impoundment and operation, slow flowing water creates a favorable habitat for waterfowls, which will be conducive to the increase of the populations of waterfowls. Birds of prey will be affected by inundation because their potential preys may have migrated to suitable habitat.

④Animal: the majority of animals in the assessed area are small animals. They will more or less be affected as their habitat is inundated. However, these animals have great vitality and their habitat in the assessed area is widespread, so it is easy for them to migrate to higher-altitude places or look for other habitat.

6.3.4.3 Impact on the animals that are under state and provincial protection

a) Impact on the wildlife that is under state protection

Among terrestrial vertebrates in the assessed area, no wildlife species under the Class I state protection category have been found; three wildlife species under the Class II state protection category have been found and they are *Buteo buteo*, *Milvus migrans*, and *Falco tinnunculus*. These three species are all birds of prey. They generally fly over woodland and the open ground near woodland. The habitat of these species have not been inundated or occupied for the project. Only human activities and the noise produced by construction affect these species as the areas where they fly and look for food are disrupted. In conclusion, the project has a small impact on the species.

b) Impact on the wildlife that is under provincial protection

There are 26 wildlife species under provincial protection inhabiting the assessed area. Of the 26 species, five are amphibians, including *Bufo gargarizans, Pelophylax nigromaculata, Fejervarya limnocharis, Microhyla ornata,* and *Pelophylax hubeiensis*; two are reptiles, including *Elaphe taeniura* and *Zaocys dhumnades*; eighteen are birds, including *Podiceps cristatus, Egretta garzetta, Anas platyrhynchos, Phasianus colchicus, Sterna hirundo, Streptopelia chinensis, Cuculus canorus, Upupa epops, Hirundo rustica, Hirundo daurica, Lanius cristatus, Lanius schach, Oriolus chinensis, Dicrurus macrocercus, Acridotheres cristatellus, Cyanopica cyana, Pica pica, and Turdus merula*; and one is *Meles meles*.

Of these species, *Bufo gargarizans, Fejervarya limnocharis,* and *Microhyla ornate* inhabit land near water. Temporary and permanent land occupation for the project will cause the habitat of these three species to shrink. During operation, impoundment will inundate a small part of the habitat. After impoundment, new habitat will form on the edge of the reservoir water area. *Pelophylax nigromaculata* and *Pelophylax hubeiensis* generally inhabit still water or slow flowing water. The solid waste generated during construction may contaminate the habitat of these two species, but after construction ends, their habitat can be restored. During operation, the number of ships traveling in the river will increase, which will indirectly pollute water, but such pollution will not be severe.

Elaphe taeniura and *Zaocys dhumnades* generally inhabit the woodland and scrubs near water. Temporary and permanent land occupation for the project will cause their habitat to shrink. During operation, the water level of the reservoir area will rise, forcing these two species to migrate out of the reservoir area. However, as the water level of the reservoir after impoundment does not rise much, it will have a limited impact on the species.

Of the birds, *Podiceps cristatus, Anas platyrhynchos,* and *Sterna hirundo* are swimming birds, while *Egretta garzetta* is wading bird. When the dam is being built and levees are being reinforced, the habitat of these four species will be occupied and disrupted. Their habitat may also be disrupted by shipping. However, as water area increases after impoundment, their habitat will increase.

Phasianus colchicus and *Streptopelia chinensis* are terrestrial birds; *Cuculus canorus* and *Upupa epops* are Scansores; *Hirundo rustica, Hirundo daurica, Lanius cristatus, Lanius schach, Oriolus chinensis, Dicrurus macrocercus, Acridotheres cristatellus, Cyanopica cyana, Pica pica, and Turdus merula* are songbirds. They generally inhabit woods. During construction, dust, noise and human activities may cause these birds to migrate out of the construction area. Temporary and permanent land occupation for the project will cause their habitat to shrink. During operation, after the impoundment of the reservoir, parts of the habitat of these birds will be inundated. However, the water level does not rise much, and most inundated woodland are paper mulberries and the shelter forests (forests of *Populus enramevicana cv* and brown willows) in the central shoal and flood plains, so inundation will not have a big impact on these birds.

Meles meles is found in woodlands, clearings, and scrub. Human activities and the noise produced during construction may startle this species and disrupt its habitat, forcing it to migrate out of the construction area. However, there is a large area of habitat similar to their original one near the construction area, so the project will not have a big impact on this species. *Meles meles* is good at digging holes, so it may ruin the embankment. Therefore, during operation authorities shall raise local residents' and organizations' awareness of environmental protection. On one hand, they shall prevent *Meles meles* from ruining the embankment; on the other hand, they shall prevent people from catching and killing *Meles meles*.

Pelophylax nigromaculata, *Elaphe taeniura*, and *Zaocys dhumnades* are edible and commercially important, so proper measures shall be taken to prevent construction workers from killing these species.

6.3.5 Soil erosion estimation

6.3.5.1 Scope and timeframe for estimation

The scope for the estimation of soil erosion is the regions disrupted by the project, including the Hub Project area and the protective works area of the reservoir. Soil erosion in the inundated area of the reservoir will not be estimated.

The project is a construction project. The timeframe for soil erosion estimation shall be arranged based on the construction progress of every construction crew and shall be determined based on the season when soil erosion tends to occur. Where construction time exceeds the rain season, the timeframe for soil erosion estimation shall be determined based on contingency. Where construction time is shorter than the rain season, the timeframe for soil erosion estimation shall be determined based on the percentage of construction time to the duration of the rain season. The timeframe for soil erosion estimation shall be divided into three stages: construction preparation, construction, and natural recovery. According to the information of the project area, the area has favorable natural conditions, sufficient sunlight, and abundant water. The natural recovery period is set to be one year. See table 6.3.5-1 for the timeframe and area for the estimation of the project subareas.

Table 6.3.5-1 Timeframe and area for the estimation of subareas

Project subareas	Timeframe (a)	Area (hm^2)

					Construction preparation	Construction	Natural recovery	Construction preparation	Construction	Natural recovery
Hub project area	Dam construction area	Earth-rock dam area		Side slope		1.0			6.10	
				Dam crest		1.0	1.0		14.07	11.42
		Cofferdam area	Phase II cofferdam	Outer slope		2.0			12.84	
				Weir crest		2.0			5.69	
			Phase III cofferdam	Outer slope		1.0			1.25	
				Weir crest		1.0			0.12	
		Open channel			1.0			82.08		
	PIU premise					1.0	1.0		7.50	7.50
	Borrow pit					1.0	1.0		6.75	6.75
	Temporary spoil ground				1.0	4.5	1.0	28.00	28.00	28.00
	Waste dump site					4.5	1.0		103.09	103.09
	Road construction area	Site-entry road area			1.0	4.5	1.0	0.70	0.08	0.08
		Construction detour area			1.0	4.5	1.0	2.20	2.20	2.20
	Living quarters for construction workers				1.0	4.5	1.0	21.15	15.99	21.15
	Subtotal							134.13	203.68	180.19

Table 6.3.5-1

Project subareas			Timeframe (a)			Area (hm²)		
			Construction preparation	Construction	Natural recovery	Construction preparation	Construction	Natural recovery
The protective works area of the reservoir area	Protective works area	Floodway area		1.0	1.0		82.80	12.00
		Inundation-free area		1.0			43.20	
	Waste dump site			1.0	1.0		125.31	125.31
	Construction detour area		0.5	1.0	1.0	3.27	3.27	3.27
	Living quarters for construction workers		0.5	1.0	1.0	0.40	0.40	0.40
	Subtotal					3.67	254.98	140.98
Total						137.80	458.66	321.17

Notes: Soil erosion in the inundated area will not be estimated during construction. After an open channel is built, gabion boxes shall be used to fence the slopes; soil erosion will not be estimated during construction and natural recovery. The estimated area of soil erosion during natural recovery is the non-hardened area along the side slopes of roads. Soil erosion in the PIU premises and the construction area within the cofferdam for the Hub Project-Phase II will not be estimated.

6.3.5.2 Estimation results

a) Area of disrupted surface

The project uses a total of 632.06hm² of land (the inundated area of the reservoir is excluded). According to the construction organization plan and filed survey, area of the requisitioned land that has not been disrupted by construction will not be included in the disrupted area. Area of the disrupted surface for the project is 607.72hm², of which 352.74hm² is the hub project area and 254.08hm² is the reservoir protection zone. See table 6.3.5-2 for more information.

Table 6.3.5-2 Area of disrupted surface Unit：hm²

Project subareas			Types of occupied land							Subtotal
			Farmland		woodland	Road	Water area and the land for water conservation facilities		Land for other uses	
			Paddy field	Dry land			River	Inland tidal flat	Idle land	
Hub project area	Dam construction area	Hub area					27.23	33.97		61.20
		Earth-rock dam area		3.18	3.20		1.08	7.37	5.34	20.17
		Cofferdam area		2.21	1.66		11.12	4.91		19.90
		Open channel area			76.32			5.76		82.08
	PIU premise			7.50						7.50
	Borrow pit			6.75						6.75
	Temporary spoil ground			7.00	21.00					28.00
	Waste dump site			66.71	32.04			4.34		103.09
	Road construction area	Site-entry road area			0.57	0.13				0.70
		Construction detour area		1.15				0.28	0.77	2.20
	Living quarters for construction workers			17.90	0.65			2.60		21.15
	Subtotal			112.40	135.44	0.13	39.43	59.23	6.11	352.74

Table 6.3.5-2

Project subareas	Types of occupied land	Subtota

			Farmland		Woodland	Road	Water area and the land for water conservation facilities		Land for other uses	l
			Paddy field	Dry land			River	Inland tidal flat	Idle land	
The protective works area of the reservoir area	Protective works area	Floodway area	27.58	20.11	31.40				3.71	82.80
		Inundation-free area	14.39	10.49	16.38				1.94	43.20
	Waste dump site		41.74	30.44	47.52				5.61	125.31
	Construction detour area			0.25	2.67				0.45	3.27
	Living quarters for construction workers			0.12					0.28	0.40
	Subtotal		83.71	61.41	97.87				11.99	254.98
Total			83.71	173.81	233.31	0.13	39.43	59.23	18.10	607.72

Notes: The inundated area of the reservoir is not included

b) Damaged soil and water conservation facilities

According to field surveys, there are no soil and water conservation facilities in the project area.

According to *Measures on the Standard and Use of Compensation and Prevention Payments for Soil Erosion* issued by the Hubei Provincial Government, *Reply on the Interpretation of Soil and Water Conservation Facilities* (SB [1996] No. 393) issued by Ministry of Water Resources, and *Reply of Hubei Provincial Department of Water Resources on the Interpretation of "Soil and Water Conservation Facilities"* (ESBF [2001] No.593), the area where soil is eroded due to this project includes occupied farmland, woodland, roads, and land for other uses, as well as water area and the inland tidal flats used for water conservancy facilities; the area totals 403.64hm². The area upstream from the dam construction area is part of the inundated area of the reservoir; it is not included in the area where soil is eroded.

c) Waste

An amount of spoil will be generated as a result of excavation in the subareas. According to earthwork balance in Chapter III, permanent spoil (6.4219 million m³) is the waste cleaned out of the dam construction area, the protective works area, and relevant living quarters. This waste will be transported to waste dumps for backfill. A total of 1.0968 million m^3 of topsoil stripped from the subareas will be used for vegetation and land rehabilitation. The topsoil will be temporarily piled up on the open grounds in the subareas.

In conclusion, the total amount of waste produced due to this project is 7.5187 million m^3, of which 1.0968 million m^3 is temporary waste and 6.4219 million m^3 is permanent waste. See table 6.3.5-3 for waste produced due to this project.

Table 6.3.5-3 Amount of waste produced due to the project Uni：10,000 m³

<table>
<tr><th colspan="4">Subareas</th><th>Subtotal</th><th>Temporary waste</th><th>Permanent waste</th><th>Notes</th></tr>
<tr><td rowspan="10">Hub project area</td><td colspan="2" rowspan="2">Dam construction area</td><td>Topsoil</td><td>14.60</td><td>14.60</td><td></td><td>Temporarily piled in stockyards; used for building the platform of the earth-rock dam</td></tr>
<tr><td>Foundation</td><td>482.64</td><td></td><td>482.64</td><td>Waste dump site</td></tr>
<tr><td colspan="2">PIU premise</td><td>Topsoil</td><td>2.25</td><td>2.25</td><td></td><td>Temporarily piled on the PIU premise; used later</td></tr>
<tr><td colspan="2">Borrow pit</td><td>Topsoil</td><td>2.03</td><td>2.03</td><td></td><td>Temporarily piled in borrow pits; used later</td></tr>
<tr><td colspan="2">Waste dump area</td><td>Topsoil</td><td>24.82</td><td>24.82</td><td></td><td>Temporarily piled at the waste dump site; used later</td></tr>
<tr><td colspan="2">Road construction area</td><td>Topsoil</td><td>0.56</td><td>0.56</td><td></td><td>Temporarily piled; used later</td></tr>
<tr><td colspan="2" rowspan="2">Living quarters for construction workers</td><td>Topsoil</td><td>5.47</td><td>5.47</td><td></td><td>Temporarily piled on the open ground of the living quarters for construction workers; used later</td></tr>
<tr><td>Hardened layer</td><td>2.64</td><td></td><td>2.64</td><td>Used for leveling tractor roads</td></tr>
<tr><td colspan="3">Subtotal</td><td>534.841</td><td>49.73</td><td>485.08</td><td></td></tr>
<tr><td colspan="3"></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="8">The protective works area of the reservoir area</td><td rowspan="2">Protective works area</td><td rowspan="2">Flood way area</td><td>Topsoil</td><td>29.78</td><td>29.78</td><td></td><td>Temporarily piled at the waste dump site; used later</td></tr>
<tr><td>Foundation</td><td>157.06</td><td></td><td>157.06</td><td>Waste dump site</td></tr>
<tr><td colspan="2">Waste dump site</td><td>Topsoil</td><td>29.62</td><td>29.62</td><td></td><td>Temporarily piled at the waste dump site; used later</td></tr>
<tr><td colspan="2">Construction detour area</td><td>Topsoil</td><td>0.46</td><td>0.46</td><td></td><td>Temporarily piled at the waste dump site; used for construction detour</td></tr>
<tr><td colspan="2" rowspan="2">Living quarters for construction workers</td><td>Topsoil</td><td>0.09</td><td>0.09</td><td></td><td>Open ground of the living quarters for construction workers</td></tr>
<tr><td>Hardened layer</td><td>0.05</td><td></td><td>0.05</td><td>Waste dump site</td></tr>
<tr><td colspan="3">Subtotal</td><td>217.06</td><td>59.95</td><td>157.11</td><td></td></tr>
<tr><td colspan="4">Total</td><td>751.87</td><td>109.68</td><td>642.19</td><td></td></tr>
</table>

d) Estimation of the amount of soil loss

The scope for the estimation of soil erosion for this project can be divided into the Hub project area and the protective works area of the reservoir. The amount of soil loss in the inundated area will not be estimated during construction. The timeframe for soil erosion estimation shall be divided into three stages: construction preparation, construction, and natural recovery.

According to estimation, the amount of soil loss occurring during construction is 109,724tons; an increased amount of soil loss is 96,015 tons. See table 6.3.5-4 for the amount of soil loss due to this project. There is a large amount of soil loss occurring in waste dumps and temporary soil grounds during construction, so soil and water conservation measures shall be taken to prevent and control soil erosion in these areas.

Table 6.3.5-4 Estimation of the amount of soil loss due to the project Unit：t

Subareas to be estimated					Amount of soil loss before the project begins	Estimated amount of soil loss	Increased amount of soil loss
Hub project area	Dam construction area	Earth-rock dam area		Side slope	74	427	353
				Dam crest	311	489	180
		Cofferdam area	Phase II cofferdam	Outer slope	169	1798	1629
				Weir crest	75	285	210
			Phase III cofferdam	Outer slope	37	394	357
				Weir crest	4	14	10
		Open channel			944	5335	4391
	PIU premise				136	226	120
	Borrow pit				122	608	486
	Temporary spoil ground				1911	15624	13783

Table 6.3.5-4

Subareas to be estimated			Amount of soil loss before the project begins	Estimated amount of soil loss	Increased amount of soil loss
Hub project area	Waste dump site		5670	58246	52576
	Road construction area	Site-entry road area	11	46	35
		Construction detour area	142	505	363
	Living quarters for construction		1166	2708	1589
	Subtotal		10772	86705	76082
The protective works area of the reservoir area	Protective works area	Floodway area	730	5940	5210
		Inundation-free area	333	3024	2691
	Waste dump site		1930	13784	11854
	Construction detour area		85	251	166

Subareas to be estimated		Amount of soil loss before the project begins	Estimated amount of soil loss	Increased amount of soil loss
	Living quarters for construction workers	8	20	12
	Subtotal	3086	23019	19933
Total		13858	109724	96015

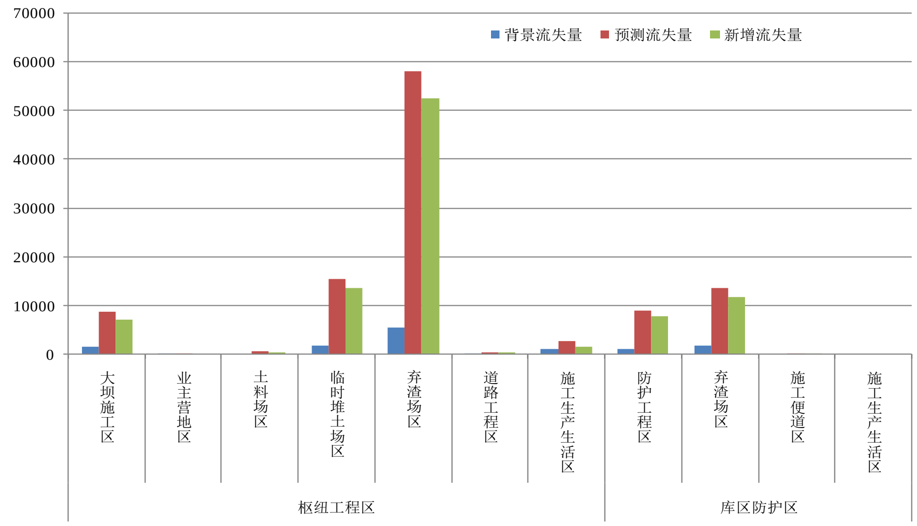


Fig 6.3.5-1 Amount of soil loss in the subareas

背景流失量	Amount of soil loss before the project begins
预测流失量	Estimated amount of soil loss
新增流失量	Increased amount of soil loss
大坝施工区	Dam construction area
业主营地区	PIU premise
土料场区	Borrow pit
临时堆土场区	Temporary spoil ground
弃渣场区	Spoil site
道路工程区	Road construction area
施工生产生活区	Living quarters for construction workers
防护工程区	Protective works area
施工便道区	Construction detour area
枢纽工程区	Hub project area

库区防护区	The protective works area of the reservoir area

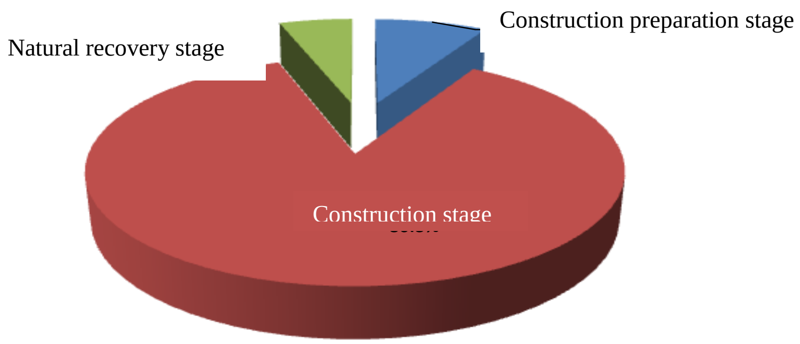


Chart 6.3.5-2 distribution of soil loss in different timeframes

6.3.5.3 Soil erosion hazard analysis

During construction, the surface of requisitioned land will be damaged to different degrees. If soil and water conservation measures fail to be taken, project construction may lead to 271,858 tons of soil loss in the project area. Soil loss will weaken the safety of the project itself, disrupt land resources in the project area, and change the scour and fill of the Han River course.

a) Impact on levee and reservoir bank

This project is generally a low-water head, runoff-pattern power station built on the riverbed. Along some levee segments, water levels may rise. As a result, the bank slope will permanently be submerged in water. Changes of hydrogeological condition may affect the solidness of the reservoir bank. In addition, some of the river islands in the areas near the dam are inundated, causing water area to widen; with the wind blowing, waves may erode the soil of the bank slope.

b) Impact on river courses and power stations

Most of the construction sites for the project are located along the Han River course. Spoil generated by construction will directly flow into the river, which may silt up the river course. As a result, the downstream river course may be silted. The silt may raise the riverbed and reduce the flood carrying capacity of the Han River. It may also silt the reservoir area of Cuijiaying hydropower station, lowering its efficiency.

c) Impact on soil fertility and land resources

Excavation and filling for the project ruin the area's original surface and vegetation. As a result, soil loss may occur when it is raining. Rain may take nutrient substances away from topsoil, thus soil fertility will be reduced. This may stunt the growth of trees and crops, harming land resources.

6.3.6 Impact on Hubei Yicheng Wanyangzhou National Wetland Park

6.3.6.1 Analysis of the influential factors

Main geomorphic type of Wanyangzhou National Wetland Park is alluvial plane and the soil type is yellow brown soil and sandy loam. The water source replenishment is comprehensive supply of atmospheric precipitation and surface runoff, etc. The water collection is permanently. The project construction will mainly change its hydrological regime, such as, increase of water amount, raise of water level, changes of water quality and reduction of flow velocity, and cause indirect impact to it through inundation of mudflat.

6.3.6.2 Analysis of impact on the protected objects in the Wetland Park

Wanyangzhou National Wetland Park is to maximize the conservation of wetland resources and wildlife resources and the wetland ecosystem within the park and the main object protected by the park is water quality of Han River, habitats of animals and plants and cultural resources of Han River.

Main types of wetland in Wanyangzhou National Wetland Park are permanent river wetland and flood plain. After rising of water level, part of the flood plain and artificial wetland will become into permanent river wetland and the area of permanent river wetland will increase but the area of flood plain will decrease. The natural wetland will still be the dominant land type within the park. Rising of the water level will change the water contents in and salinity of the soil and then change the material cycle and energy flow on such basis. These changes will affect the distribution of hygrophytes and hygrocoles within the park and the biodiversity and wetland ecosystem within the region.

In accordance with analysis of water environmental impact, the water quality at the preliminary stage of water storage will decrease, but the decrease only lasts for a short time.

On the whole, water quality of the reservoir area and the Wetland Park located section after completion of the project will remain basically unchanged.

In accordance with *Report on Local Resources of Wanyangzhou National Wetland Park*, the main plants in the Wetland Park are frequently-seen wetland plants and aquatic plants and artificial protective forest at both riversides. Upon rising of the water level, xerophyte on the mudflat will decay and die due to lack of oxygen caused by inundation and this is good for growth of wetland plants. This change will affect the quantity and distribution of migratory birds living in wetland. The increase in water area and decrease in mudflat owing to rising of water level will narrow down the habitats of part of amphibian and reptile animals (such as bufo bufogargarizans, microhyla ornate and eumeces chinensis, etc.) and small mammals (such as erinaceus amurensis and rodents) and force them to the riverside. This change will cause decrease of activity space and habitats of wading birds and increase of activity space and habitats of natatorial birds. The habitats of part of wetland plants and wetland animals will be inundated after completion of the project but rising of the water level will not significantly change the diversity of wetland plants and wetland animals. In addition, Rising of the water level of the reservoir area will provide wide space for activity and inhabiting of natatorial birds and aquatic plants.

Therefore, this project will exert certain adverse impact of the objected protected the Wetland Park.

6.3.6.3 Analysis of impact on structure and function of the Wetland Park

After implementation of the project, water level of the Wetland Park will be raised to 55.22m and it is predicted that the wetland conservation area will increase to 1,818.27 hm^2 (increasing by about 360hm^2), accounting for 73.73% of the total area of the Wetland Park; the restoration area will decrease to 391.72 hm^2, accounting for 15.88% of the total area of the Wetland Park; the reasonable used area will decrease by10hm^2; the scope of publicity and demonstration area and management area will remain unchanged. Increase of wetland conservation area is good for protection on wetland resources; inundation of the restoration area will reduce the pressure on ecosystem restoration of the wetland in the region.

On the whole, rising of water level will not exert big impact on protection of the

Wetland Park and structure and function of the Wetland Park.

Yakou Shipping Hub project is located downstream of the Wetland Park and the straight line distance is about 4.5km. The project construction will not exert any impact on the Wetland Park. After completion of the project, although rising of the water level within the Wetland Park and increase of water area in the Wetland Park will inundate habitats of part of wetland plants and wetland animals, it also provides broader habitats for natatorial birds and aquatic plants. On the whole, rising of the water level within the Wetland Park and increase of the water area are good for protection of the wetland resources and construction of this project will not have big influence on ecological function of the Wetland Park.

6.3.7 Impact of the project construction on ecosystem of the basin

6.3.7.1 Evolution of ecosystem in middle and lower reaches of Han River

In order to analyze impact of this project more objectively, we need to know the change tendency of ecosystem in recent years after development of hydro-junctions in middle and lower reaches of Han River. The impact of hydro-junctions is mainly reflected in damages to natural vegetation and landscape due to land occupation and inundation of the projects, thus decreasing or changing the habitats of animals and plants or directly causing loss to quantity of animal and plants. But on the whole, the impact is not simple addition of several projects. The biggest impact of Yakou Shipping Hub Project on the terrestrial ecosystem is reflected in the impact of inundation of the reservoir area on wetland ecosystem.

In order to objectively analyze the changes in wetland resources in middle and lower reaches of Han River caused by development of hydro-junctions, we have interpreted the satellite images of 1980, 1990, 2000 and 2014 and carried out comprehensive analysis on land utilization type on the basis of current data, with landscape method (namely, taking vegetation as the dominant factor) and by combining with the soil factor and topography factor. The assessed scope is main stream of Han River from Danjiangkou dam to estuary of Han River into Yangtze River, backwater end of Cuijiaying Hydro-junction in upper reaches of Tangbai River to estuary of Tangbai River into Han River and embankment at both sides of the river.

In consideration of compliance with wetland classification system as specified in *International Wetland Convention*, *Technical Specifications for National Wetland Survey (trial)* and *Implementation Rules of Hubei Province on Second Wetland Resource Survey* and characteristics of wetland in middle and lower reaches of Han River, the wetland in middle and lower reaches of Han River can be divided into two types: natural wetland and artificial wetland. Of which, the natural wetland includes permanent river wetland and flood plain and the artificial wetland includes reservoir, pool and paddy fields.

The statistical results: the total area of wetland in Han River has been decreasing since 1980 and it accounts only for 84.48% of the total wetland area in 1980. The changes may be caused by continuous small precipitation since end of 1990s, steadily increase of annual water consumption in upper reaches of Han River and regulation of the reservoirs in upper reaches of Han River.

Table 6.3.7-1 Changes in area of wetland in different periods

Type of wetland	Area of wetland in different periods (hm^2)			
	1980	1990	2000	2014
Permanent river	33894.36	33504.02	31939.33	34346.48
Floodplain	7410.24	11069.1	12626.46	3102.72
Reservoir and pools	1405.8	422.1	1032.75	83.39
Paddy fields	13676.56	10532.01	10432.06	10101.53
Total	56386.96	55527.23	56030.6	47634.12

The area of flood plain, paddy fields and reservoir and pool have reduced by 58.13%, 26.14% and 94.07% against that in 1980 (refer to Table 4.2.1-9 for details). Only the area of permanent river wetland has slightly increased by 1.33% against that in 1980. Apart from the above mentioned reasons, sharp fluctuation of water level of Han River in high and low flow years, uneven distribution of precipitation in the basin and relatively severe drought and flood hazards, especially the lack of irrigation in the dry season, may be one of the reasons causing significant reduction of area of flood plain and paddy fields.

The overall change tendency of wetland ecosystem in middle and lower reaches of Han River, part of flood plain, paddy fields and reservoir and pool will be transformed into permanent river wetland. And the main reason for this change may be the construction of hydro-junctions after 2000 (water storage of the reservoirs). This section will focus on impact of the project construction on wetland ecosystem in the basin from the perspective of the impact on wetland plants and the impact on wetland animals.

6.3.7.2 Impact on plants

a) Direct impact

Water demands and competition of wetland plants species caused transitional distribution difference of wetland plants along the riverbeds and construction of the hydro-junctions changed the water conditions in the assessment area and further changed the oxygen contents in soil. This will directly affect the distribution pattern of wetland plants along the riverbed. Hydrological conditions change is one of the major factors influencing wetland plants. The changes in hydrological conditions include change in water level, flow velocity and water quality and the impact of these changes on wetland plants is direct.

(1) Impact of water level change on wetland plant resources

Due to lack of oxygen, illumination intensity and heat caused by rising of water level, the inundated hygrophytes and hygrophilous vegetation in the reservoir area will gradually decay and disappear and be ultimately substituted by swamp plants and aquatic plants. Since the swamp plants are unable to fit in the deep water environment, has low germination rate and the rhizome does not tiller so much, the distribution of swamp plants will be gradually transferred to shallow water areas and mudflats. Due to lack of illumination and oxygen, the aquatic plants in the deep water areas will gradually die and even disappear. The aquatic plants in the shallow water areas will have good growth and will be gradually move to the shallow water areas. Owing to different life habits, rising of water level of the newly built reservoir will cause rising of water level in the distribution area of wetland plants. This plus the reduction of flood plain will cause decrease of the habitats area of wetland plants.

(2) Impact of flow velocity change on wetland plant resources

The impact of flow velocity change on wetland plant resources is mainly reflected in the impact on emergent aquatic plant, submerged plant, floating-leaved plant and floating plants. Water flow will impose shear force on aquatic plants and the action of the shear force will increase along with increase of the flow velocity. In rapidly flowing water, the flow will force aquatic plants to be in prostate state or approximately prostate state and tear the tissue structure of these aquatic plants. Meanwhile, action of the shear force will also change the substrate of aquatic plants and damage their living environment and ultimately make it disappear. In water with medium flow velocity, the aquatic plants are forced to bend and are even beaten down and only the part above the water is lightly hurt, in other words, the plants do not grow very well. In slowly flowing water, the habitats of aquatic plants are relatively stable and the aquatic plants can absorb adequate illumination and heat resources as well as organic matters. In one word, the slowly flowing water environment is good for growing of aquatic plants.

Water in river sections in reservoir area of the hydro-junctions (including Yakou hydro-junction) will be transformed from flowing state into static state and quantity of the submerged plants fitting in the static water environment, such as hornwort and watermilfoil, will enlarge. Since Yakou Shipping Hub Project has relatively bad runoff regulation capacity, it has limited impact on flow velocity under the dam and thus will not affect the wetland plants resources under the dam.

(3) Impact of water quality change on wetland plants resources

Blooms of phytoplankton will cause damages to structure and function of the aquatic ecosystem and reduction of the dissolved oxygen contents in and transparency of the water. Due to lack of oxygen and illumination, roots of the swamp plants, emergent aquatic plant and floating-leaved plant and submerged plants will have difficulties in breathing and further have damages in their physiological function. They will gradually decay and this will ultimately cause failure of aquatic vegetation. According to life cycle theory, the excessive emission of nitrogen and phosphorus is the fundamental reason causing changes of the water quality.

The hydro-junctions will slow the water flow, accelerate deposition of sediment and organic matters in the water and weaken the water exchange. According to studies on water quality of the middle and lower reaches of Han River, pollutants concentration at the typical cross-sections increased in varying degrees. This means the pollutants concentration will increase to some degree after formation of Yakou Shipping Hub Project.

b) Indirect impact

(1) Impact of mudflat substrate change on wetland plant resources

Due to interception of the dams against water, the substrate will rise and be transformed from cohesive soil into sandy soil and yellow soil and diverse substrate environment around the reservoir will form. More microhabitats in isolated island, peninsular and bay with many mudflats in the reservoir are will form after water storage of the reservoir due to different soil conditions and become environment suitable for growth of various aquatic plants. Owing to inundation, decay of vegetation and nutrient matters in the soil will gradually be released into the water. Therefore, in certain years, the nutrient matters in substrate of the reservoir will increase, which is conducive to growth of aquatic plants. But it is difficult to form regional small wetland with long-term water carrying capacity in mudflat with sharp gradient and the matter with bad water retention capacity, such coarse aggregate, as the main substrate, thus it is not good for growth of other hygrophytes.

(2) Impact of water content changes of mudflat on wetland plant resources

Water plays a dominant role in formation, development and evolution of wetland ecosystem. The rising or fall of water level may cause increase or decrease of water amount in different areas of the mudflat and further affect the distribution of wetland plants. Construction of the hydro-junctions makes the water level of the reservoir area rise and causes gradient increase of water contents in soil of the mudflat and gradual decrease of oxygen in the soil. Since the wetland plants have different adaptability to the water conditions, the distribution of wetland plants is gradually transited towards the areas near mudflats. Construction of the hydro-junctions makes the water level of the flowing water areas decrease and causes gradient decrease of water contents in the soil of the mudflat and gradual increase of oxygen in the soil. Due to different adaptability of wetland plants to water conditions, the distribution of wetland plants is gradually transited towards the water areas.

(3) Impact of formation of flood plain and microtopography on wetland plant resources

Flood plain refers to the lakes formed when the water in the depression in overflow lands is unable to flow back to the riverbed during the flood period. Wetland plants on the flood plain grow very well and are diverse. During the high flow years, most of the wetland plants are inundated and gradually disappear due to lack of oxygen and the aquatic plants have the opportunities to grow. In low flow years and normal flow years, the water with different depths in the river and ditches is important environment for survival of the aquatic plants in low flow years. Rising of the water level of the reservoir areas inundated some flood plain and the wetland plants originally growing on the flood plain then disappear. This is not good for wetland plants.

6.3.7.2 Impact on wetland animals

a) Impact on wetland birds

Change of water level will change the proportion of flood plain and the swing areas and then affect the carrying capacity of migratory birds in such areas. Construction of the hydro-junctions will change the water level of different river sections and then exert certain impact on the wetland birds.

Rising of the water level of the reservoir area will inundate some bushes, paddy fields and unused land and then cause some birds which inhabiting and feeding in these areas (such as, birds of timallidae, charadriidae, emberizidae and fringillidae) to migrate to other areas. Hence, the competition between species will be fierce and quantity will decrease. Meanwhile, the newly formed reservoir area will provide broader space for activities and will attract some birds living in water, such as birds of tachybapus ruficollis and anatidae and the quantity will increase. Hence, the project construction is good for this type of birds.

(1) Impact of flow velocity change

Flow velocity will mainly affect the selection of anatidae migratory birds on inhabiting water. Anatidae migratory birds will usually select water with slow flow velocity and more migratory birds will select wetland connecting with the static water as the habitats. Therefore, change of the flow velocity will not have big direct impact on birds of anatidae.

(2) Impact of water quality change

In accordance with prediction on water environment of water resource allocation project of north Hubei Province, the simultaneous operation of phase I of Han River-to-Wei River Water Transfer Project, Middle Route (Phase I) of South-to-North Water Transfer Project, Wangfuzhou, Xinji, Cuijiaying, Yakou, Nianpanshan and Xinglong hydro-junctions as well as the Yangtze River-to-Han River Water Transfer Project will deteriorate the water quality of Han River but can still meet the original water functional zoning requirement. Hence, implementation of this project will have limited cumulative impact on water environment.

From the distribution of eutrophication index we can see that the eutrophication index of the water increases along with discharge of pollutants into the water along the way. Agal bloom of different degrees will occur in river sections with high degree of eutrophication in lower reaches of Han River when the flow is small, the water level is low, the velocity is slow and the temperature is 10°C to 25°C. Agal boom will cause some changes in contents of dissolved oxygen in and light transmission of the water and thus cause significant changes in species and quantity of shrimps, fishes, zooplankton, zoobenthos and aquatic plants in Han River. These fishes, shrimps, phytoplankton and zoobenthos are food source of some birds and water quality changes will indirectly affect survival and diversity of the birds through influencing these aquatic creatures. Therefore, the project operation will have certain impact on water quality in lower reaches of Han River and then indirectly affect the quantity and diversity of wetland birds.

(3) Impact of changes in mudflat area on wetland animal resources

Annatidae migratory birds mainly feed on submerged plants and roots, stems and buds of wetland plants. Increase of mudflats and flood plain in the reservoir area will not only provide broader habitats for the submerged plants but also increase the food source of annatidae migratory birds. This is good for reproduction of annatidae migratory birds.

b) Impact on other terrestrial animals

Rising of water level of the reservoir area, increase of the water surface area of the reservoir area and reduction of habitats for reptiles will cause increase of the quantity in the given areas and aggravate the competition between species. The quantity of reptiles in the reservoir area will decrease and the distribution of mammals will also change. For example, rattus norvegicus liking water and snakes inhabiting in the junction between water and land will migrate along with change of the water level. The reduction of water amount and fall of the water level of the flowing river section outside the reservoir area will cause increase of the naked mudflat and transition of terrestrial vegetation into wetland vegetation. This provides broader habitats for rodents, amphibians and reptiles and is good for their reproduction.

(1) Impact of flow velocity change

The amphibians will usually choose the rivers with slow flow velocity or the static water area. But more amphibians will choose the wetland which is adjacent to the static water area as the habitats. Hence, the flow velocity will not have big impact on the amphibians. Causal relationship does not exist between mammals and the reptiles and the flow velocity. Hence, the impact of flow velocity on these animals is extremely tiny.

(2) Impact of water quality change

Change of water quality of the reservoir areas mainly indirectly influences the spawning, feeding and mating of the amphibians through slowly flowing river or the static water. But changes of water quality in different periods are different. In low flow years, the discharge volume is small, the velocity is slow and the capacity of the water to dilute the pollutants reduces. Then it will aggravate the pollution load in different river sections and the water quality will become worse. In the flood season, the discharge volume will increase and capacity of the water to dilute the pollutants increases. This is good for improving the water quality and mitigating pollution. By this way, distribution of the amphibians is indirectly affected. Meantime, according to the monitoring of the Institute of Soil and Water Conservation of Chinese Academy of Science and the Ministry of Water Resources on water quality in lower reaches of Han River, the water quality in lower reaches of the water sources will become worse due to the built or planned South-to-North Water Transfer Project and Han River-to-Wei River Water Transfer Project, etc. But the water quality can still meet the requirements of water functional zoning. The project has small cumulative impact on the water quality. Change of water quality will affect distribution of mammals and reptiles at the same time and worsening of the water quality may attract some rodents which will spread bacteria, thus causing adverse impact to human beings and other terrestrial animals.

(3) Impact of changes in mudflat area

The amphibians like to concentrate in shallow water areas in lakes and rivers and the temporary pool or forestland, bushes and grassland around the wetland are the activity space of the amphibians. The rising of water level and decrease of the mudflat areas due to water storage of the reservoir may lead to reduction of the quantity of terrestrial amphibians. The relatively static water will be formed after water storage and this is good for the amphibians loving static water. The fall of water level in the flowing river section will transform the permanent rivers in these sections into flood plain and mudflat and increase the inhabiting environment for the amphibians, thus changing the quantity and structures of the amphibians. For example, there are larger quantity of bufo gargarizans in dry land and abandoned dry pool and the positive correlation between the quantity and area of the naked land indicates that bufo gargarizans mainly moves around in dry terrestrial environment and its quantity has nothing to do with water surface area.

When the rising of water level and decrease of mudflat areas, construction areas and broad-leaved forest area lead to increase of the water area, the impact of reduction of land area on survival and quantity of the reptiles and mammals will be temporary. When dynamic balance of water amount within the hydro-junction is obtained, the dynamic balance of species quantity will gradually be obtained. On the whole, the project construction will have limited impact on other terrestrial animals.

6.4 Atmospheric and acoustic environmental impact prediction

6.4.1 Prediction and evaluation of environmental air impact

6.4.1.1 Prediction of environmental air impact in hub area

a) Environmental protection objectives

Environmental air sensitive objectives in the project hub area include sensitive receptors in waste dump, near stockyard, near blasting construction area and road within site. According to the general construction arrangement, sensitive objectives of the ambient air impact assessment include Yakou Village Group Three, Yakou Village Group Four, Yakou Village Group Five, Maocao Village Group Five, Maocao Village Group Six, Haoji Village Group Four, Heluo Village Group Ten, Nanzhou Village, etc., which are shown in Table 6.4.1-1 and Figure 6.4.1-1.

The access roads for the left bank and right bank are not part of the project, but vehicle traffic during the construction of the project will have some impact on the surrounding towns and villages, so environmental air impact of traffic in the access roads will also be considered in the prediction.

Table 6.4.1-1 List of environmental air sensitive objectives in the project

Sensitive objectives	Households within 200m	Impact categories	Generation areas	Nearest distance from pollution sources (m)
Yakou Village Group Three	First-second floor, about 6 households	Construction surface dust	No. 2 waste dump	About 200
		Traffic dust	No. 4 road within site	About 190
Yakou Village Group Four	First-second floor, about 4 households	Construction surface dust	No. 2 waste dump	About 180
		Traffic dust	No. 4 road within site	About 100
Yakou Village Group Five	First-second floor, about 18 households	Construction surface dust	No. 2 waste dump	About 150
		Traffic dust	No. 4 road within site	About 180
Nanzhou Village	First-second floor, about 33 households	Construction surface dust	No. 3 waste dump	About 140
		Traffic dust	No.8 road (to No. 3 waste dump road)	About 50
Maocao Village Group Six	First-second floor, about 24 households	Traffic dust	No. 1 road within site	About 200
			No. 3 road within site	About 295
		Concrete system dust	Concrete mixing system	About 200
Maocao	First-second	Traffic dust	No. 1 road within site	About 280

Village Group Five	floor, about 12 households	No. 1 temporary storage site dust	No. 1 temporary storage site	About 200
Yakou Village Group Eight	First-second floor, about 5 households	Borrow pit excavation dust	Yakou borrow pit	About 160
		Traffic dust	No. 7 road (to borrow pit road)	About 190
Haoji Village Group Four	First-second floor, about 17 households	Construction surface dust	No. 1 temporary storage site, topsoil storage area at right bank	About 170
Heluo Village Group Ten	First-second floor, about 9 households	Traffic dust	Access road	About 125

Note: 1. "Nearest distance" is the distance between the most unfavorable position in the environmental air sensitive objectives and dust pollution sources.

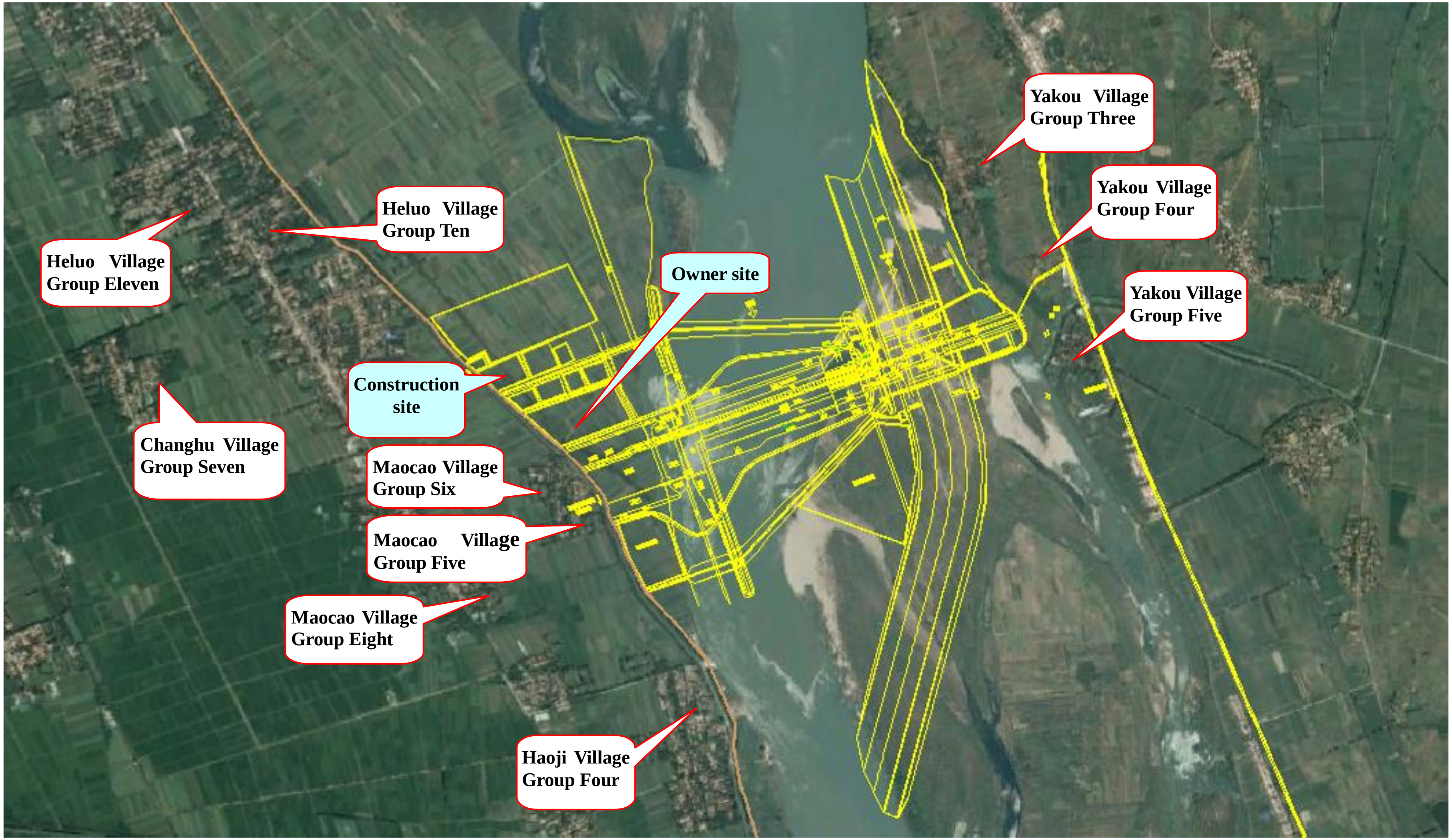


Figure 6.4.1-1 Distribution diagram of residential area surrounding the Yakou Shipping Hub Project

b) Pollution Sources

Project environmental air pollutions are mainly aggregate processing system dust, construction surface dust and traffic dust.

Two concrete mixing systems are set up in the project, with an area of about 58,000 m^2, a size of 185m×85m, dust emission intensity of 12.6kg/h, and dust emission rate of 0.06mg/s.m^2. Two temporary storage sites and three waste dumps are set up in the project. According to the relevant documents, construction surface dust emissions of the project are calculated with reference to the construction site dust emissions, and the dust emission rate in waste dumps and temporary storage sites is 0.194mg/s.m^2; dust emission factors in different types of roads are determined according to the relevant documents, and the calculation results of the dust emission rate in each sensitive road are shown in Table 6.4.1-2.

Table 6.4.1-2 List of dust emission rate in each sensitive road

Construction roads	Pavement materials	Roadbed width (m)	Dust emission rate	
			kg/km.h	mg/m.s
No. 1 road within site	Concrete	9	16.4	4.56
No. 2 road within site	Clay-bound macadam	10	25.4	7.07
No. 3 road within site	Clay-bound macadam	10	25.4	7.07
No. 4 road within site	Clay-bound macadam	10	25.4	7.07
No. 5 road within site	Clay-bound macadam	10	25.4	7.07
No. 6 road within site	Clay-bound macadam	8	25.4	7.07

c) Prediction mode

As the sensitive objectives are superimposed affected by concrete mixing system dust, waste dump and traffic dust, various types of air pollution contribution values and air background value should be superimposed predicted. Dam foundation excavation and concrete mixing system dust are regarded as point source pollutions, waste dump and temporary storage site are regarded as non-point source pollutions, and traffic dust is regarded as line source pollution. The contribution values are predicted with estimating modes (i.e., point source diffusion mode, non-point diffusion source mode and line source diffusion mode) recommended by the guidelines.

The average wind speed for many years in the project area is 1.4m/s, and the dominant wind direction is NW.

d) Prediction results analysis

The TSP background value in each sensitive receptor is 0.080mg/m^3. The pollution source emissions in waste dump and temporary storage site are predicted in accordance with simultaneous construction close to two sides of the sensitive receptor, and the size of the construction area is calculated by 5m×10m. The prediction results are shown in Table 6.4.1-3.

We can know from Table 6.4.1-3 that the TSP daily average concentrations of three environmental air sensitive objectives Yakou Village Group Five, Maocao Village Group Five and Maocao Village Group Six have exceeded standard, and the TSP daily average concentrations of other sensitive objectives meet the secondary standard requirements of "Environmental Air Quality Standards" (GB3095-1996). The reason that the TSP daily average concentration of Yakou Village Group Five exceeds the standard is mainly traffic dust in the access roads for the left bank, and the reason that the TSP daily average concentrations of Maocao Village Group Five and Group Six exceed the standard is mainly traffic dust in No. 2 waste dump, No. 1 temporary storage site and No. 1 road within site. It shows the environmental air is mainly affected by traffic dust, so that dust control measures should be taken against traffic dust.

Table 6.4.1-3 List of TSP prediction results of each sensitive objective Unit: mg/m^3

Sensitive objectives	Functional area	Evaluation standard	Impact categories	Generation areas	Nearest distance from pollution sources (m)	Contribution values	Background values	Prediction values	Exceeded values
Yakou Village Group Three	Second-class area	0.3	Construction surface dust	No. 2 waste dump	About 200	0.0101	0.08	0.2501	/
			Traffic dust	No. 4 road within site	About 190	0.16			
Yakou Village Group Four	Second-class area	0.3	Construction surface dust	No. 2 waste dump	About 180	0.0056	0.08	0.2136	/
			Traffic dust	No. 4 road within site	About 100	0.128			
Yakou Village Group Five	Second-class area	0.3	Construction surface dust	No. 2 waste dump	About 150	0.1466	0.08	0.3679	0.0679
			Traffic dust	No. 4 road within site	About 180	0.1413			
Nanzhou Village	Second-class area	0.3	Construction surface dust	No. 3 waste dump	About 140	0.0605	0.08	0.2245	/
			Traffic dust	No.8 road (to No. 3 waste dump road)	About 250	0.084			
Maocao Village Group Six	Second-class area	0.3	Traffic dust	No. 1 road within site	About 200	0.07	0.08	0.367	0.067
				No. 3 road within site	About 295	0.059			
			Concrete system dust	Concrete mixing system	About 200	0.158			
Maocao Village Group Five	Second-class area	0.3	Traffic dust	No. 1 road within site	About 280	0.152	0.08	0.3583	0.0583
			No. 1 temporary storage site dust	No. 1 temporary storage site	About 200	0.1263			
Yakou Village Group Eight	Second-class area	0.3	Borrow pit excavation dust	Yakou borrow pit	About 160	0.052	0.08	0.132	/
			Traffic dust	No. 7 road (to borrow pit road)	About 190	0.001			/

Haoji Village Group Four	Second-class area	0.3	Construction surface dust	No. 1 temporary storage site, topsoil storage area at right bank	About 125	0.0192	0.08	0.0992	/
Heluo Village Group Ten	Second-class area	0.3	Traffic dust	Access road	About 200	0.4878	0.08	0.1678	/

Note: “/” means no excess; TSP is daily average value.

6.4.1.2 Environmental air impact prediction in storage sites

a) Environmental protection objectives

According to field investigation, it’s mainly designed to outsource the stones and sandy gravels, as there are adequate stones and sandy gravels surrounding the project area. And Matoushan quarry is initially selected to provide stones and sandy gravels. By considering the principle of mining and processing nearby, aggregate processing system is arranged in Matoushan quarry. Environmental air sensitive objectives in storage sites are mainly sensitive receptors near the quarry and along the road within site, including Banqiaodian Town Shangwan Village Group Seven, Group Eight, and Group Nine, etc.

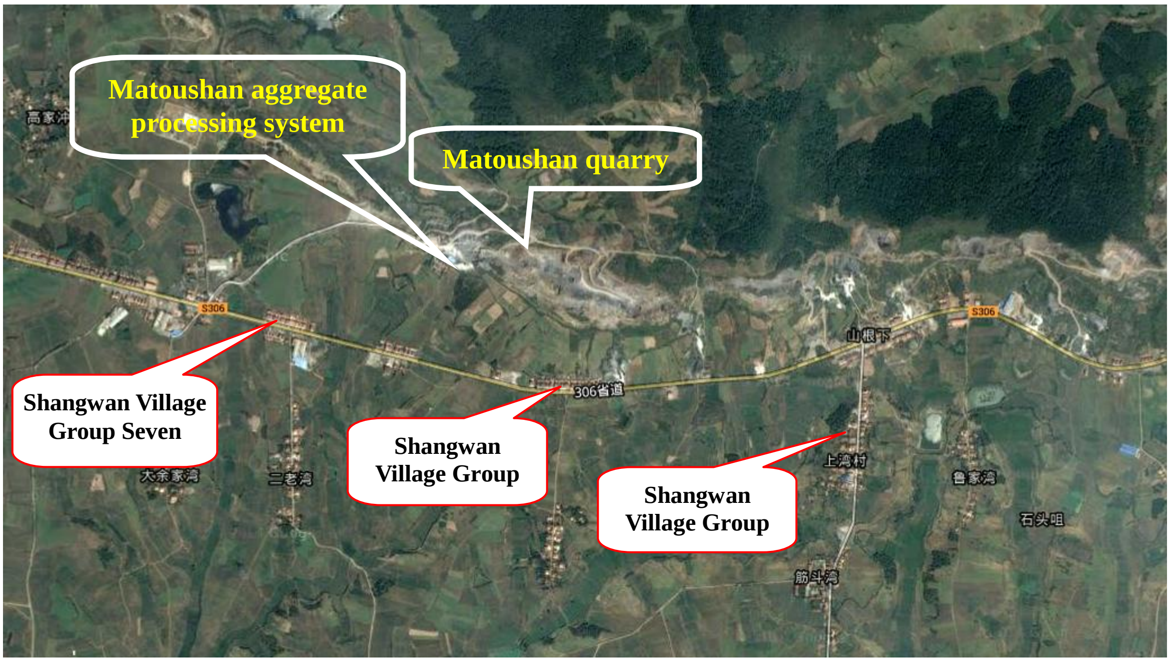


Figure 6.4.1-1 Distribution diagram of residential area surrounding the storage sites

b) Mining activities in Matoushan quarry

Matoushan quarry area is about 22.4km away from the dam site area, and village distributed around is mainly the Shangwan Village in the south. According to project analysis and environmental status investigation, the area's main air pollution is dust pollution, and the main pollution sources include: quarry blasting mining, aggregate processing system operation on the right bank, transportation road dust, etc., all of which are fugitive emissions.

Matoushan quarry will produce some dust pollution when blasting, which adopts medium-length hole blasting. The quarry has entered strip mining period, and the status investigation results show that as the nearest distance from the quarry blasting mining to Shangwan Village is 260m, quarry exploitation will not lead to excessive dust in Shangwan Village if effective measures are taken.

c) Aggregate processing system operation

The dust scope and extent in aggregate processing system are compared with dust monitoring data in the down bank stream aggregate processing system in the Three Gorges Dam Project, and the monitoring results are shown in Table 6.4.1-4. As can be seen from the monitoring table, environmental air quality surround the down bank stream aggregate processing system in the Three Gorges Dam Project meets the secondary standard requirements of "Environmental Quality Standards" (GB3095-1996) after taking measures such as dust reduction by sprinkling, bag filter installation, part sealing, etc.

It can be known from the analogy analysis that, the designed production capacity of aggregate processing system of the project is 170t/h, using the semi-dry production process. After taking measures such as collecting dust by installing dust catcher and bag filter, and reducing dust by sprinkling in coarse crushing plant-semi-finished products storage bin, intermediate crushing-secondary screening plant, fine crushing-third screening plant and coarse sand shaping plant proposed in the main design, the operation will have limited impact on the surrounding sensitive objectives.

Table 6.4.1-4 Statistical table of environmental air monitoring results of down bank stream aggregate processing system in the Three Gorges Dam Project

Monitoring spot	Monitoring indexes	Monitoring times	Monitoring mean value concentration (mg/m^3)	Evaluation	Secondary quality limit standard (mg/m^3)	Remarks
Down bank stream aggregate processing system	TSP	6	0.24	Attained	0.3	Coarse crushing processing capacity is 860 t/h; finished product

	PM10	6	0.023	Attained	0.15	production capacity is 810 t/h; semi-dry producing technology; main measures include reduction by sprinkling, part sealing, bag filter installation, etc.
	PM10	3	0.127	Attained	0.15	

6.4.1.3 Surface blasting dust prediction evaluation

a) Sensitive objectives

According to project analysis, the main air environmental sensitive objectives of dam blasting are Yakou Village Group Four and Group Five, the nearest distance of which from the dam construction area is about 400m.

b) Pollution sources

According to the construction plan, the blasting area of the project is mainly located at the hydropower station construction area, with a blasting period of 2 to 3 month. During the peak of construction, hydropower station blasting is conducted once 2 to 3 days, with an explosive usage of about 3t every time, a blasting operation size of 150m×15m, and a blasting time of about 5min. According to the relevant documents, about 54.2kg dust (TSP) is generated with one ton of explosives. It’s calculated that the one-time production of dam site blasting dust is 162.6kg.

c) Impact prediction analysis

The one-time production of hydropower station blasting dust is great, and the nearest residential areas from the hydropower station construction area are Yakou Village Group Four and Group five (about 900m), so the hydropower station blasting will have some impact on the environmental air quality of residential areas. However, as blasting dust is instantaneous non-point source, and the diameters of dust particles are large, which subside quickly, so its impact on sensitive receptors is short.

6.4.1.4 Lock exhausts emissions impact

The operation period of Yakou Shipping Hub Project does not produce air pollutants itself, but brings impact on the air environment mainly through exhausts emissions of the lock.

During the lock operation period, the exhausts emissions are mainly SO_2 and NO_2 emissions generated in the operation of marine power plant. However, as the ships get through the lock in very short time, so the impact of the air pollutants discharged from the ships is little. After the operation of the lock, the nearest sensitive receptor is hub management district. It’s recommended in the EIA that exhausts discharged from ships using oil-fired internal-combustion engines and automobile engines should be processed with exhaust gas purifier to minimize the impact of the ship exhausts on the external environment.

6.4.1.5 Air impact of waterway sailing on the coast

A lot of ships sail in the main stream of the Han River, and a small amount of exhaust gas discharged from their internal combustion engines will pollute environmental air. But with the completion of the hub and formation of kiloton waterway in the river, more and more large-tonnage ships will get through the waterway. The power equipment and anti-pollution facilities of large-tonnage ships are significantly better than those of the small ships. If the annual growth of total freight is kept at the same rate, the total amount of exhaust gas emissions from ships will be significantly reduced compared with previously. After waterway regulation, along with the implementation of waterway bank protection work and greening projects, the environmental air quality along the waterway will be greatly improved and environmental protection objectives along the waterway will not be affected basically.

6.4.2 Acoustic environmental impact prediction assessment

6.4.2.1 Acoustic environmental impact in hub area

The acoustic environment sensitive objectives are mainly superimposed affected by the construction noise, construction factory noise and traffic noise, therefore, comprehensive noise impact prediction assessment is conducted on sensitive receptors affected by the above noises. Since blasting noise is instantaneous point source, whose impact on the sensitive receptor is very limited and short, separate prediction assessment is conducted on the blasting noise.

a) Sensitive objectives

The acoustic environmental sensitive objectives of the project include the sensitive receptors near construction factory, waste dump, storage site, blasting construction area and along the road within site. According to the general construction arrangement, the sensitive objectives in the acoustic environmental impact assessment include Yakou Village (Group Three, Four and Five), Maocao village (Group Six and Five), Haoji Village Group Four, Heluo Village Group Ten, Nanzhou Village, Haoji Village Group Four, etc.

The detailed information about each sensitive objective is shown in Table 6.4.2-1. The access roads for the left bank and right bank are not part of the project, but vehicle traffic during the construction of the project will have some impact on the surrounding towns and villages, so environmental impact of traffic in the access roads will also be considered in the prediction.

Table 6.4.2-1 List of project noise prediction place and main noise sources

Sensitive objectives	Households within 200m	Noise categories	Generation areas	Impact period	Nearest distance from noise sources (m)
Yakou Village Group Three	First-second floor, about 6 households	Construction	No. 2 waste dump	24h	About 200
		Traffic	No. 4 road within site	24h	About 190
Yakou Village Group Four	First-second floor, about 4 households	Construction	No. 2 waste dump	24h	About 220
		Traffic	No. 4 road within site	24h	About 200
Yakou Village Group Five	First-second floor, about 18 households	Construction	No. 2 waste dump	24h	About 235
		Traffic	No. 4 road within site	24h	About 208
Nanzhou Village	First-second floor, about 33 households	Construction	No. 3 waste dump	24h	About 140
		Traffic	No.8 road (to No. 3 waste dump road)	24h	About 250
Maocao Village Group Six	First-second floor, about 34 households	Construction factory	Concrete system	8:00~22:00	About 200
			Concrete prefabricate factory	8:00~22:00	About 115
			Metal gate assembly plant	8:00~22:00	About 180
			Steel processing plant	8:00~22:00	About 215
			Template processing plant	8:00~22:00	About 270
		Traffic	No. 1 road within site	24h	About 270
Maocao Village Group Five	First-second floor, about 12 households	Construction factory	Metal gate assembly plant	8:00~22:00	About 250
			Steel processing plant	8:00~22:00	About 160
			Machinery and equipment parking area	8:00~22:00	About 185
			Template processing plant	8:00~22:00	About 160
		Traffic	No. 1 road within site	24h	About 220
Yakou Village	First-second floor,	Construction	Yakou borrow pit	8:00~22:00	About 255

Group Eight	about 5 households	Traffic	No. 7 road (to borrow pit road)	24h	About 120
Haji Village Group Four	First-second floor, about 17 households	Construction	No. 1 temporary storage site	24h	About 170
Heluo Village Group Ten	First-second floor, about 9 households	Traffic	Access road	24h	About 125

b) Noise source intensity

The main noise sources in the project include waste dump and storage site construction noise, concrete mixing system, other construction factories and traffic noise, etc. According to the actual situation of the construction, the noise sources of construction machine, concrete mixing system as well as other construction factories are mainly noises generated during the production process of construction machines or equipment, which can be predicted in accordance with point source. And the traffic noise can be predicted in accordance with line source.

The point source noise intensity is shown in Table 6.4.2-2, and the road construction design parameters are shown in Table 6.4.2-3. The designed speed and traffic volume of construction road design is in accordance with the design of third-class road within site, and the designed speed is 20km/h; No. 2, No. 4, No. 6, and No. 8 construction roads within site are on the left bank, which are the main construction area, with a daytime traffic volume of 40 vehicle/h, and nighttime traffic volume of 8 vehicle/h; No. 1, No. 3, and No. 7 construction roads within site are on the right bank, which have less construction area, with a daytime traffic volume of 30 vehicle/h, and nighttime traffic volume of 6 vehicle/h; there are a large number of large vehicles in construction road within site, and the large vehicles are predicted at a proportion of 80%; as construction intensity is less at night, daytime and nighttime traffic volume are calculated by 5:1. The designed speed of access road for the left bank is 20km/h; its daytime traffic volume is 20vehicle/h; nighttime traffic volume is 4vehicle/h; and the proportion of large vehicles in access road is predicted by 25%.

Table 6.4.2-2 List of point noise source intensity

Construction site	Noise source location	Measured source intensity at 1m (dB)	Predicted source intensity at 1m (dB)	Remarks
Concrete production system	Mixing plant	80~100	100	Predicted at the center

					of mixing plants
Construction factory	Template processing plant	Processing equipment	80~100	100	Predict by evenly setting up noise sources within site
	Steel processing plant				
	Metal gate assembly plant	Processing equipment	60~70	70	
	Concrete prefabricate factory				
	Machinery and equipment parking area				
Waste dump, deposit stockyard, topsoil storage site, storage site		Construction machine	70~90	90	Predict by simultaneous construction at two places near the sensitive receptor

Table 6.4.2-3 List of road construction design parameters

Road No./name		Class	Road surface (m)	Roadbed (m)	Road surface material	Designed speed (km/h)	Traffic volume (vehicle/h)	
							Daytime	Nighttime
Left bank	Access road for left bank	Third-class road	8.5	10	Concrete	20	20	4
	No. 2 road within site	Third-class road	8.5	10	Clay-bound macadam	20	40	8
	No. 4 road within site	Third-class road	8.5	10	Clay-bound macadam	20	40	8
	No. 6 road within site	Third-class road	8.5	10	Clay-bound macadam	20	40	8
	No. 8 road within site	Third-class road	7	8	Clay-bound macadam	20	40	8
Right bank	No. 1 road within site	Third-class road	7	9	Concrete	20	40	8
	No. 3 road within site	Third-class road	8.5	10	Clay-bound macadam	20	40	8

c) Prediction mode

Considering that the construction noise and construction factory noise are mainly construction machine noises, so point source mode is adopted in the prediction; and line source mode is adopted in the prediction of traffic noise; as the sensitive objectives are superimposed affected by construction noise, construction factory noise and traffic noise, therefore, superimposed prediction need to be conducted on various types of noise contribution values and noise background values.

The comprehensive superimposed impact prediction is conducted with Breeze Noise software of Trinity Consultants (Hangzhou).

1) Point source impact prediction mode

$$L_A(r) = L_A(r_0) - 20\lg(r/r_0)$$

Where: L_p (r)--A sound level from the sound source r;

L_p (r_0)--A sound level at the reference position r_0;

r--Distance between prediction point and sound source, m;

r_0--Distance between reference position and sound source, m.

2) Road traffic impact prediction mode

① Traffic noise source intensity

Noise $L_{m,E}$ generated in a vehicle is defined as:

$$L_{m,E} = L_m^{(25)} + D_v + D_{stro} + D_{stg}$$

Where: $L_m^{(25)}$ - average sound level at place with a horizontal distance of 25m from the center line of the lane, and a height of 2.25m in the free sound field;

$L_m^{(25)} = 37.3 + 10 \times \lg[M \times (1 + 0.082 \times p)]$, wherein: M is the average traffic volume per hour on a single lane road, as for a multilane road, the traffic volumes on the two outermost lanes are calculated, and the traffic volume of each lane is M/2; p is the percentage of vehicles over 2.8t;

D_V - Sound level correction of different speed;

D_{stro} - Sound level correction of different road surfaces;

D_{stro} - Sound level correction of different slopes.

② Sound level of traffic noise impact

When calculating the sound level of a multi-lane road, assume there are two line sources at the centerline with a height of 0.5m of two outermost lanes, and the average sound level of road noise L_m is calculated by calculating separately and adding together:

$$L_m = 10 \times \lg\left[10^{0.1 \times L_{m,n}} + 10^{0.1 \times L_{m,f}}\right]$$

Where $L_{m,n}$, $L_{m,f}$ are respectively the average sound levels of the nearest and farthest lanes from the prediction point. For a single lane road, the positions of the nearest and farthest lanes are the same. The sound level of a single lane is L_m:

$$L_{m,i} = L_{m,E} - D_l + D_s + D_{BM} + D_B$$

Where: $L_{m,E}$ -The noise generated by the vehicle;

D_l -Different sound levels due to different sound source segment lengths l in the calculation, Dl = 10×lg (l);

D_s -Different sound levels due to different distances and air absorption;

$D_s = 11.2 - 20 \times \lg(s) - s/200$, s is the distance between sound source and sound reception point;

D_{BM} -Different sound levels due to different ground absorption and meteorological factors;

$D_{BM} = (h_m / s) \times (34 - 600/s) - 4.8$;

D_B -Different sound levels due to different terrains and buildings.

3) Comprehensive superimposed prediction mode

The noise contribution values and noise background values of point source and line source are superimposed, and the calculation formula is as follows:

$$L_{Aeq} = 10 \times \lg\left[\sum_{i=1}^{n} 10^{0.1 \times L_i} + 10^{0.1 \times L_0}\right]$$

Where: L_{Aeq} -Comprehensive value superimposed;

L_i -Various noises impact contribution value;

L_0 -Noise background value.

d) Prediction Results Analysis

The prediction and output of sound value chart is conducted with Breeze Noise software of Trinity Consultants (Hangzhou). The software's prediction model and parameters adopt relevant calculation method recommended in "Technical Guidelines for Environmental Impact Assessment Acoustic Environment" (HT2.4-2009). The noise background value of each sensitive receptor is selected from acoustic environmental quality monitoring results of the project area in August 2013. The access road for the left bank and roads within site are third-class roads. The access road for the left bank connects Provincial Highway 218, and No. 1 road within site connects China National Highway 207. Class 4a standard will be executed within 50m outside the red line of Provincial Highway

218 and China National Highway 207. The "Acoustic Environmental Quality Standard" (GB3096-2008) provides that among 9 sensitive receptors in the project, Haoji Village Group Four and Heluo Village Group Ten are divided into two functional areas: 4a-class and second-class, and the remaining seven sensitive receptors are second-class functional areas.

The noise prediction background value of each sensitive receptor is shown in Table 6.4.2-4, and the calculation results are shown in Table 6.4.2-5.

Table 6.4.2-4 List of noise prediction background value of each sensitive receptor Unit: dB

Monitoring site	Functional area	Evaluation standard		Maximum noise		Exceeded value		Sensitive objectives nearby
		Daytime	Night time	Daytime	Night time	Daytime	Night time	
Yakou Village	Second-class	60	50	51	43	-	-	Yakou Village Group Three, Yakou Village Group Four, Yakou Village Group Five
Nanzhou Village	Second-class	60	50	56	45	-	-	Nanzhou Village
Maocao Village	Second-class	60	50	52	42	-	-	Maocao Village Group Six, Maocao Village Group Five
Yakou Village Group Eight	Second-class	60	50	54	41	-	-	Yakou Village Group Eight
Haoji Village Group Four	4a-class	70	55	67	52	-	-	Haoji Village Group Four (sensitive objectives within 50m outside the red line of China National Highway 207)
	Second-class	60	50	52	40	-	-	Haoji Village Group Four (except 4a-class)
Heluo Village Group Ten	4a-class	70	55	67	53	-	-	Heluo Village Group Ten (sensitive objectives within 50m outside the red line of China National Highway 207)
	Second-class	60	50	56	45	-	-	Heluo Village Group Ten (except 4a-class)

It can be known from Table 6.4.2-4 that, as for the acoustic environmental sensitive objectives mainly affected by construction factory, construction machine and road within site, the daytime and nighttime noises of the other acoustic environmental sensitive objectives all meet the requirements of second-class functional area in "Acoustic Environmental Quality Standard" (GB3096-2008), except the daytime noises of Maocao

Village Group Five and Group Six as well as Yakou Village Group Four. Maocao Village Group Five, Group Six, and Yakou Village Group Four respectively exceed 3.3dB, 5.1dB and 4.0dB. There is no operation in concrete production system and construction factory at night, and sensitive objectives exceed standard at night include Maocao Village Group Five, Group Six and Yakou Village Group Four, respectively exceed 2.4dB, 3.8dB and 2.6dB. The sensitive objectives exceed most at day and night are Maocao Village Group Five and Group Six, and the exceeding is mainly due to the combined effects of the concrete production system, template processing plants, steel processing plant and No. 1 road within site; the exceeding of Yakou Village Group Four is mainly due to the combined effects of metal structure assembly field and No. 4 road within site.

Table 6.4.2-5 List of noise prediction results of each sensitive receptor Unit: except households/a building, dB

Serial number	Sensitive receptor	Functional area	Households/ a building within 200m	Evaluation standard		Background value		Contribution value		Prediction value		Exceeded value		Exceeded households/a building (daytime/nighttime)	Remarks
				Daytime	Night time	Daytime	Night time	Daytime	Night time	Daytime	Night time	Daytime	Night time		
1	Yakou Village Group Three	Second-class	About 6	60	50	51	43	56	47.6	57	49	/	/	0	No operation in construction factory, concrete production system and borrow pit at night.
2	Yakou Village Group Four	Second-class	About 4	60	50	51	43	63	51.9	63	52.4	3.3	2.4	2	
3	Yakou Village Group Five	Second-class	About 18	60	50	51	43	52	46.7	55	47.5	/	/	0	
4	Nanzhou Village	Second-class	About 4	60	50	56	45	53	45.8	57	48	/	/	0	
5	Maocao Village Group Six	Second-class	About 6	60	50	52	42	64	52.9	65	53.8	5.1	3.8	2	

6	Maocao Village Group Five	Second-class	About 8	60	50	52	42	63	51.4	64	52.5	4	2.6	3
7	Yakou Village Group Eight	Second-class	About 4	60	50	54	41	54	43.8	57	45.9	/	/	
8	Haoji Village Group Four	4a-class	About 3	70	55	67	52	62	49.9	68	53.3	/	/	0
		Second-class	About 6	60	50	52	40	57	48.3	58	48.5	/	/	0
9	Heluo Village Group Ten	4a-class	About 3	70	55	67	53	62	49.9	69	53.3	/	/	0
		Second-class	About 17	60	50	56	45	56	47.4	58	48.3	/	/	0

Note: “/” means not exceeding standards, and the exceeded households/a building of sensitive receptors whose noise background values exceed the standard will be calculated according to the exceeding situation of the project’s noise contribution values.

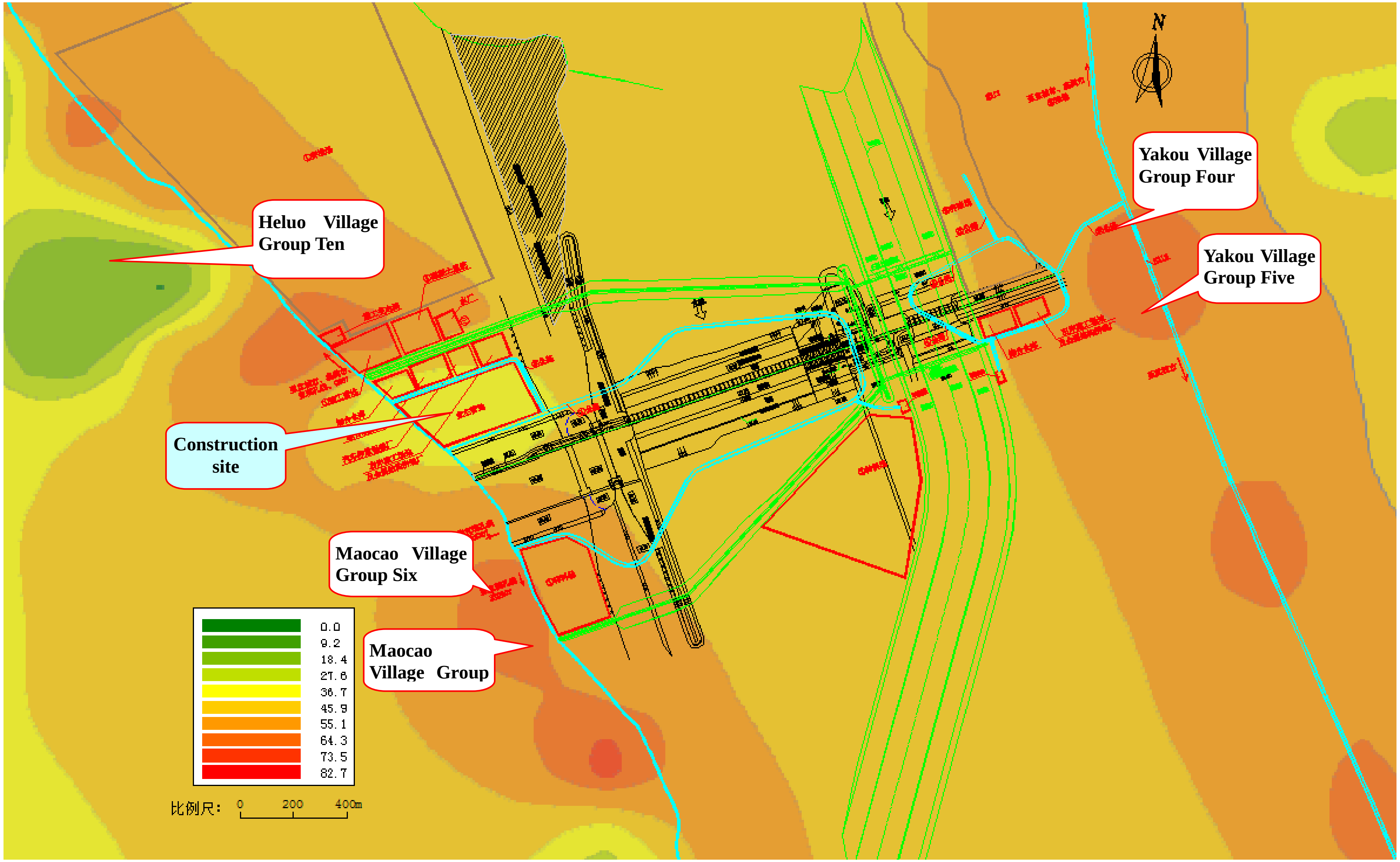


Figure 6.4.2 Sound value chart for noise prediction contribution value of each sensitive receptor in hub area

6.4.2.2 Quarry blasting noise impact analysis

According to the general construction arrangement, the blasting source in the blasting excavation site in the construction of Yakou Shipping Hub that is close to the sensitive objectives outside the construction site is mainly Matoushan quarry blasting excavation, and the nearest distance between the blasting site and Shangwan Village is 650m. The blasting excavation in Matoushan quarry will bring some impacts on Shangwan Village, such as blasting noise, blasting vibration, blasting flying rocks, etc.

(1) Impact of blasting noise

There is no mode for blasting noise prediction at present. The Xiangjiaba Hydropower Station designed by our institute has carried out field monitoring according to the blasting explosive usage in the project dam site area, and noise at different distance in the same direction with the blasting source. The specific monitoring results are shown in Table 6.4 .2-6.

Table 6.4.2-6 Xiangjiaba Hydropower Station blasting noise monitoring results table

Blasting source names	Explosive charge (kg)	Monitoring results L_{max} dB(A)			
		40m	70m	120m	450m
Fossil river course Group one	30	95.8	90.5	97.6	67.6
Fossil river course Group two	60	92	84.6	88	64
Benchland Group one	5	88.8	90.4	-	66.9
Benchland Group three	10	105.9	90.8	110.8	69.7
Benchland Group five	15	107	106.9	-	72.8

The explosive charge in Matoushan quarry is 30kg-60kg. Calculating by analogy, the noise intensity is about 62.9 dB (A) when the blasting arrive at the nearest household in Shangwan Village Group Five. The noise standard distance is about 850m, and households affected by noise totaled about 13 households.

(2) Impact of blasting vibration

According to the national GB6722-2003 "Blasting Safety Regulations", the safety allowed standard of blasting vibration on the buildings is shown in Table 6.4.2-

7.

Table 6.4.2-7 Safety allowed standard of blasting vibration’s impact on buildings

Serial number	Protection object types	Safety allowed velocity (cm/s)		
		<10Hz	10-50Hz	50-100Hz
1	Adobe house, rubble house, loess cave dwelling	0.5-1.0	0.7-1.2	1.1-1.5
2	Ordinary brick house	2.0-2.5	2.3-2.8	2.7-3.0
3	Reinforced concrete structure house	3.0-4.0	3.5-4.5	4.2-5.0

The standard 0.5cm/s is adopted in the evaluation of impact on Shangwan Village. According to the research results, explosive charge and distance from the explosion are important parameters to determine the ground vibration levels. According to the relevant conversion between particle velocity and distance function (see "Blasting and Vibration Control" in No. 5, October 1993), the converted distance of 0.5cm/s is 9m/kg. The safety limit curve is obtained, and the safety distances under charges at all levels are calculated. According to the calculation, the safety distance is 69.7m when the charge of the project is 30~60kg.

The Xiangjiaba Hydropower Station has conducted field test on blasting vibration. According to the test results of earthwork excavation blasting: at 250m from the diversion channel at the left bank, when the explosive charge is 300kg, the vibration velocity is 0.094cm/s; at 1000m, when the explosive charge is 300kg, the vibration velocity is 0.005cm/s. Evaluated by the 0.5cm/s standard, Matoushan quarry blasting has little safety impact on vibration of houses and buildings in Shangwan Village.

In the implementation phase, the construction unit should conduct real-time monitoring on the actual explosive charge’s impact on field vibration, and determine the specific blasting program that has no effect on the buildings in Shangwan Village, which can be implemented after being reported to the supervisor. The specific measures can be seen in section 7.6.2.

(3) Impact of blasting flying rocks

During the blasting process of quarry bench, the vast majority of blasting rocks will become muck pile in the air, and a small amount of rocks will become flying rocks by breaking way from muck pile. According to GB6722-86 "Blasting Safety Regulations", the safety distance between individual flying rocks and people is 300m.

According to site survey, the nearest distance between the lowest excavation of the quarry and surrounding farmland is about 370m. The flying rocks have little impact on farmland, but blocking need to be done. What's more, since the existing road in the south of the quarry is one of the external accesses for students and villagers in Shangwan Village, which is the only way for the students to go home especially at 6:00-7:00 a.m. and 4:00-6:00 p.m., and the nearest distance between the road and the quarry is only 310m, so blasting flying rocks in the quarry may have some impact on the safety of people walking on the road.

In addition, since the place outside the land acquisition line at the south and west of the quarry are farmland, and blasting rolling rocks will have some impact on farmland vegetation, therefore, certain measures need to be taken to prevent the scattering of rolling rocks.

6.4.2.3 Surface blasting noise prediction evaluation

a) Sensitive objectives

The main blasting location of the project is hydropower station construction area. The impact range of surface blasting noise is relatively large, and the residential areas within 500m of the blasting construction area are regarded as blasting noise sensitive protection objectives according to the actual impact situation. According to the construction plan, there is no acoustic environmental sensitive objective within 500m of the hydropower station construction area, and the acoustic environmental sensitive objectives closest to the hydropower station construction area are Yakou Village Group Four and Group Five, and the closest distance is about 800m.

b) Prediction mode

The surface blasting noise is stationary noise source. According to the construction arrangement and relative positions of the surrounding sensitive receptors, the recommended mode in "Technical Guidelines for Environmental Impact Assessment Acoustic Environment" (HJ2.4-2009) is adopted, and the valley reflection, air absorption and ground effect are considered.

The prediction formula is as follows:

$$L_w(r) = L_A(r_0) - 20\lg(r / r_0) - a \times (r - r_0)$$

Where: $L_w(r)$ --Noise A sound pressure level at the prediction point (dB);

$L_A(r_0)$ --Noise A sound pressure level at the reference base point (dB);

$20\lg(r / r_0)$ --Geometric divergence attenuation (dB);

r --Distance between the prediction point and noise source (m);

r_0 --Distance between the reference base point and noise source (m);

a --Additional attenuation coefficient of air absorption (take 1dB/100m).

c) Prediction results evaluation

The comprehensive superimposed impact prediction on sensitive objectives is conducted with Breeze Noise software of Trinity Consultants (Hangzhou).

During the peak of the construction, the explosive usage is about 3t every time. According to the relevant documents, when the deep-hole blasting is conducted with 3t explosives, the maximum noise level at 200m away from the blasting point is about 130dB. The surface blasting noise attenuation prediction results are shown in Table 6.4.2-8.

Table 6.4.2-8 Surface blasting noise attenuation prediction results

Distance from noise source (m)	Noise prediction value (dB)		Distance from noise source (m)	Noise prediction value (dB)
100	137		2000	92
200	130		2500	85.1
500	119		3000	78.5
1000	108		3500	72.1
1500	99.5		4000	66

Surface blasting's noise intensity is great, and its sound transmission distance is far. It can be known from Table 6.4.2-6 that, only when the distance from blasting point is above 2800m will the acoustic environmental quality meet the second-class standard of "Acoustic Environmental Quality Standard" (GB3096-2008). Blasting noise will have impact on acoustic environmental sensitive objectives such as Yakou Village Group Four and Group Five near the dam. Since the blasting noise is instantaneous point source, its impact time on the sensitive receptors is short.

6.4.2.4 Acoustic environmental impact of lock operation

The noises during the lock operation are ship noises, mainly engine noise (including exhaust sound) and honking noise. The noise can reach up to 90dB (A) at 5m away from the noise source during the operation. The noise production equipment is continuous and steady line noise source, which will adversely affect the residents within 30m of shore. Since the lock is located at the right bank of the hub, after the operation, the sensitive receptors within 30m are office operation personnel in the hub management area, who are far away from the right bank of Maocao residential area, the EIA recommends that silencer and insulating layer should be installed in intake and exhaust ports and tube wall of ships to minimize the noises' impact on external environment.

With the development of science and technology and the promotion of high-tech, the inland ships will be environment-friendly and energy-saving in the future, especially the suspended screw boat will be phased out in inland shipping, which will greatly reduce the noise.

6.4.2.5 Noise impact analysis on waterway sailing

With the enhancing of navigation ability of the waterway, the tonnage of sailing ships gradually increases. Most of the design representative fleets are kiloton fleets in the main stream, and the largest navigable ship is 5000t. According to the measured data of waterways, the exposure sound level of a kiloton ship is about 73dB (A) at 15m, attenuating to 70dB (A) at 21m, and attenuating to 55dB (A) at 120m. The waterway width in Yakou Reservoir is generally about 800m~1200m, and the narrowest width is 480m. The distance between the main waterway and bank of the Han River is more than 200m. In addition, ships whistling may affect densely populated areas, so it needs to be banned. It is thus obvious that for the ships sail normally on the water during the operation, their noise impact is mainly on the Han River, and will hardly have impact on residential area on both sides of the reservoir area.

6.5 Analysis of impact on resettlement environment

6.5.1 Analysis of environmental capacity of the resettlement area

6.5.1.1 Analysis of resettlement mode

Construction of Yakou Shipping Hub Project will altogether acquire cultivated land of 24 administrative villages which are all located in Yicheng city.

In this phase, environmental capacity analysis of the project-affected administrative villages is carried out mainly according to the average area of cultivated land per person. After reclamation and regulation, if the average area of cultivated land per person in those villages reaches the production and resettlement standard of 2mu, then environmental capacity of such village is deemed as adequate and those villagers can be resettled within their village. Or else, they have to be resettled elsewhere.

6.5.1.2 Analysis of land resources carrying capacity

According to the inventory survey, inundation areas and construction of Yakou Shipping Hub Project will altogether occupy land of 2,496mu, accounting for 1.72% of the total area of cultivated land in four project-affected districts (cities or counties). The land resources in these regions are abundant. Therefore, the combined method of resettlement in nearby areas, scattered resettlement and centralized resettlement is adopted. In accordance with the RAP:

For villages whose lands are to be acquired: (1) if the average area of cultivated land after inundation is less than 1mu, the villagers will be resettled in nearby areas through land regulation; (2) if the average area of cultivated land is more than 1mu before inundation but less than 1mu after inundation, then part of the villagers will be resettled in other place to make the average area of cultivated land after inundation not be less than 1mu; (3) if the average area of cultivated land before inundation is less than 1mu, such villages are usually located around cities and towns and does not much rely on the land; therefore, only part of the villagers will be resettled in other place to maintain the original level of cultivated land; (4) villagers from villages whose cultivated land are not inundated will be resettled within the villages. According to the above principles, the total environmental capacity of those villages involved in land acquisition is 3,979 persons.

For villages whose lands are not to be acquired: environmental capacity analysis is carried out according to standard that the average area of cultivated land is 1.5mu and the village is the analysis unit. Resettlement capacity of the villages is determined according to 50% of the environmental capacity on the basis of the economic conditions of the villages. Then those three districts (cities or counties) can altogether accept 11,102 persons.

In conclusion, in accordance with the above environmental capacity calculation and analysis of population needs to be resettled in the project area, the majority of villagers can be resettled within the villages and only a few of them needs to be resettled in nearby villages or other places within the town.

6.5.1.3 Analysis of water resources carrying capacity

Domestic water of residents: most of the villagers are to be resettled within the villages or other places within the town, new water supply lines will be built for those centralized resettlement areas. But the total water supply remains unchanged and mainly comes from surface water of Han River which is of good quality. So both the water amount and water quality can meet the demands for living.

Water for irrigation: after reservoir of Yakou Shipping Hub Project inundates part of the lands, the demands for irrigation in the areas will reduce and the project construction will not bring about demands on large amount of water for irrigation. Therefore, the current irrigation facilities can meet the requirements.

6.5.2 Environmental suitability analysis of resettlement

6.5.2.1 Environmental suitability analysis of the resettlement location

Resettlement of this project revolves about agricultural production and is implemented through scattered resettlement within the village and centralized resettlement in other place of the town. Centralized resettlement areas are not set up in the project-affected areas. When selecting the resettlement areas, we mainly consider the following factors：

(1) Topography and geological stability

In accordance with relevant regulations of China, slope wasteland with gradient of above 25° is prohibited from reclamation. So selection of new resettlement areas should avoid the slope wasteland with gradient of above 25° and geological stability should also be taken into consideration. Upon investigation, unfavorable geological conditions in those resettlement areas, such as, landslide, collapse and debris flow, do not exist and the gradient is below 15°. Meanwhile, the bearing stratum has even thickness and stable horizon. These conditions are suitable for residence.

(2) Ecological conditions

The ecological environment in each resettlement area is similar to that of the project-affected areas. According to the inventory survey, vegetation in the resettlement areas is mainly agricultural vegetation. Most of the lands are dry land and a few of them are garden and forest land. The remaining is land for construction (old house). There are no ecological sensitive areas in those resettlement areas and construction of those resettlement areas exert limited impact on biodiversity and stability of ecosystem.

(3) Water source

The resettlement areas are located in the original villages or towns and there are water supply projects in those administrative villages. Water source is determined according to the existing water intake facilities. In accordance with “section 6.5.1.3 analysis of water resources carrying capacity”, the demands for domestic water consumption and irrigation in those resettlement areas can also be met. After resettlement, the domestic water is supplied in a centralized way other than in a scattered way, the water quality and amount can be better guaranteed and the water for irrigation is not affected.

(4) Power supply

According to current living conditions and economic development of local villagers, the power is still supplied by the grid of their towns and the power supply capacity does not increase. Therefore, the demands of those resettlement areas for power supply can be met.

(5) Communication conditions

According to the RAP, connections project for communications in each resettlement area have been considered and the communication will not be affected.

(6) Transportation conditions

Part of roads within the construction site needs rebuilding or reforming for the project construction and roads connecting the resettlement areas with the outside world will also be built. Therefore, the transportation conditions after resettlement will be better.

(7) Production and living conditions

In accordance with RAP and “section 6.5.1.2 analysis of land resource carrying capacity”, there are adequate land resources for agricultural production after resettlement and the maximum radius of farming in the living areas and production areas should not be longer than 2km. After reasonable planning, the transportation conditions in the resettlement areas will be better. Meanwhile, the medical service, education and trade of the resettlement areas will basically not be affected since the resettlement is within the original towns. After centralized resettlement, the construction of supporting facilities will provide more convenience for production and life of the villagers.

(8) Customs

Since the resettlement is within the original towns and we have repeatedly solicit opinions from villagers to be resettled, the issues of conflicts on customs and culture does not exist.

In conclusion, the construction of resettlement houses is in the location with better transportation, power supply and water supply conditions on the basis of the existing infrastructures and social service system of the resettlement areas and it is unnecessary to specially plan the construction of infrastructure. There are no natural reserves, scenic spots, water source protection area, geological hazards, areas with concentrated distribution of valuable but rare animals and plants in the scattered resettlement areas. From the perspective of geology, ecological environment, water sources, land, transportation, production and life and customs, the resettlement areas have good environmental conditions.

6.5.2.2 Environmental suitability analysis of production and resettlement

Since the villagers to be resettled mainly engage in planting which relies significantly on local environment. The villagers are mainly to be resettled within the villages. Meanwhile, we will actively develop the secondary and tertiary industries according to local urbanization, provide training to improve their employment skills and expand their income sources.

According to the impact of land acquisition, conditions of exploitable resources and opinions of the villagers to be resettled, the development items include paddy field regulation, transformation of dry land into paddy field, improvement of low-yield fields, vegetable cultivation in greenhouse and development of secondary and tertiary industries. The secondary and tertiary industries mainly refer to doing business and transportation. At the same time, provide labor service by taking advantage of the local geological advantages and industrial and commercial development. The production and resettlement plan complies with the principles of “taking agriculture as the basis, properly arranging the villagers to be resettled through multiple channels and by multiple means and developing secondary and tertiary industries according to the local actual conditions”, can guarantee the restoration of life quality of the villagers and the development items will exert limited impact on environment.

Zhengji Town, one of the resettlement areas, is under expansion and business, trading and processing market will be gradually built in the town, providing good opportunities for employment of the villagers to be resettlement. The planning has avoided soil erosion and increase of pollutants discharge (including solid wastes, noise, smoke, dust and sewage) due to construction of new towns and infrastructures.

Detailed resettlement management scheme is described in the RAP, including training, resettlement monitoring and supervising and other specific systems, guaranteeing the implementation of various mitigation measures.

In conclusion, the environmental suitability of resettlement is satisfactory.

6.5.3 Impact on life quality

The resettlement is within the original towns and villages, revolves about agricultural production and on the basis of “long-term compensation”. Appropriate amount of cultivated land and garden plot will be allocated according to the actual conditions of each village and the remaining garden plot, forest land and grassland of the village will continue to be used. After resettlement, the economic benefits of the villages mainly include income from long-term compensation, income from planting and income of other industries. We will allocate certain amount of cultivated land to the villagers to guarantee their basic needs for grain and make them have production materials with quantity and quality equivalent to the original level; take measures to make the average income per each villager not be lower than the original level. We predict on the basis of current living standard and development plan of national economy that the average income per each villager to be resettled within the project-affected area will be 10,420 Yuan by 2018, surpassing the formulated resettlement goal.

In conclusion, living conditions and the average income per each person after the resettlement will be greatly improved. In other words, the resettlement can improve the living standard of the villagers.

6.5.4 Impact of resettlement on the resettlement area

6.5.4.1 Impact on ecological environment

For resettlement, construction of residential buildings and infrastructures is required. This may exert certain impact on the resettlement areas and the surrounding ecological environment.

(1) Impact on vegetation

Most of the lands in the resettlement areas are cultivated land and some of the lands are land for construction and forest land. Of which, the cultivated land is mainly comprised of dry land. We have considered utilization of current land for construction and the unused land during location selection of resettlement areas. Impact of resettlement on ecological environment is mainly reflected in damages to part of the artificial forest and cultivated land, causing loss of certain biomass.

(2) Impact on plants

Most of the lands occupied by the resettlement areas are artificial forest and agricultural fields.

Inundation of Yakou reservoir and the project construction will affect eight towns (sub-district offices) and 36 villages in Yicheng city, Xiangcheng district and Xiangzhou district under administration of Xiangyang, two industrial enterprises ad 27 individually-run business and part of special facilities. The resettlement includes production resettlement and resettlement of the affected villagers.

Production resettlement revolves about the planting industry and is appropriately regulated between villages through paid land transfer, thus making the average area of cultivated land owned by each person for who the production resettlement is required not be less than the original level.

For house relocation, centralized and scattered house construction methods are adopted. The area of land for construction of residential house is calculated according to 80m^2 per person and altogether 216.6 mu house-building plot are to be acquired. Most of the non-agricultural people who have to move are company staff and will be arranged in a centralized way in newly built residential area within main embankment of Han River and the land occupied is dry land. The plants to be damaged are mainly cotton, corn, fruit and vegetables. The agricultural population who has to move is small and will be arranged in a scattered way within the villages and the plants to be affected is frequently-seen brushes in the local areas.

The plants which may be affected by the resettlement will be broussonetia papyrifera, vitex, cynodon dactylon l., alternanthera philoxeroides (mart.) griseb and artemisia lavandulaefolia. Such plants are widely distributed in the region. Hence, construction of the resettlement area will not exert big impact on such plants. We suggest that the governmental departments should formulate resettlement plan to ensure the life quality of the people to be resettled.

(3) Impact on animals

Since the production resettlement is mainly through regulation of land between villages, the production resettlement will not exert obvious impact on terrestrial animals. The impact on terrestrial animals is mainly reflected in occupation of construction of the centralized and scattered resettlement houses on habitats of animals. However, the centralized resettlement houses are mainly located within main embankment of Han River and the scattered resettlement houses are mainly within the original villages, there areas are disturbed by human beings greatly and the affected animals are species living near human beings, such as, gekko japonicus; hirundo rustica, hirundo striolata, motacilla alba, sparrow and magpie; ordinary pipistrelle, mustela sibirica, apodemus agrarius, house mouse and emberiza aureola, etc. These animals are accustomed to live near human beings and some even build their nests in houses of rural residents (such as hirundo rustica, hirundo striolata and sparrow). Although the newly built houses occupy part of their room for activities or feeding grounds, the area of new house-building plots is not big and the newly built houses also provide new food sources (grain and domestic wastes) and sanctuary (their natural enemy is not bold enough to approach the human activities areas). On the whole, the impact on survival of these animals is limited.

6.5.4.2 Assessment of impact on land utilization

The resettlement will occupy certain area of land which will be small against the land occupied by inundation of Yakou reservoir and the project. In addition, the cultivated land resources in the region are relatively rich. Therefore, the impact on local agricultural production is limited upon regulation of land resources. The land temporary occupied by construction will be restored upon completion of the construction and the impact on yield of agricultural crops is limited. Meanwhile, the cultivated land resources of the region are rich, and the land permanently and temporarily occupied only accounts for 0.16% and 0.7% of the cultivated land of the designed counties and cities.

6.5.4.3 Impact on sound environment and ambient air

The resettlement and house and road construction will cause noise and dust pollution to the nearby schools and villages and the construction vehicles and machines will cause waste gas pollution. But the construction period is short and the construction scale is small, the pollution intensity caused by machinery equipment is also small, so it will not exert big impact on nearby residents and the impact will disappear along with completion of the construction.

6.5.5 Impact of protective works and inundation treatment works on the environment

Protective works and inundation treatment works mainly include construction of the dyke and drainage facilities, including regulating lock, pump station, channel, and construction, reform and expansion of some of the channels. Construction of these works basically does not exert impact on hydrological regime of main stream of Han River. Soil erosion and increase of concentration of suspended matters in the water may be caused during the construction period. No wastewater will be generated during the operation period, basically not affecting the water quality of Han River.

The land used and occupied by the project construction is mainly mudflat, dry land and artificial forest (populus) and some bushes and house-building plots. Dryland crops and populus are frequently-sees artificial species and are widely distributed in the project area. The inventory survey found out that the regionally protected animals are mainly the birds. Therefore, construction of the protective works will have limited impact on terrestrial ecosystem. The protective works will also narrow down the scope of areas affected by inundation of Yakou reservoir and mitigate the impact of inundation of terrestrial animals.

Meanwhile, construction of protective works will reduce the population who have been resettled and mitigate the impact on local agricultural production. The rebuilt drainage facilities will increase the regional drainage and water logging capacity and is of positive meaning.

Discharge of flushing wastewater concrete mixing system, wastewater from repair of machine and domestic sewage of construction personnel during the construction period without treatment will affect the water quality of part of Han River. This type of wastewater has to be reused upon treatment. This has been illustrated in the special report on protection of the reservoir areas. The construction will also cause dust, exhaust and noise pollution to the nearby residential areas. Since the construction period is short, such impact will disappear along with completion of the construction.

6.5.6 Impact of reconstruction of special facilities

Reform and reconstruction of small-scale transportation and communication facilities will inevitably do harm to vegetation on some areas. Arbitrary dumping of wastes due to excavation of infrastructure will cause soil erosion. But the construction scale is small and construction period is short, the impact will end along with completion of those special facilities.

6.6 Project impact on social environment

6.6.1 Impact on water intake & drainage

a) Water intake & drainage facilities

After the reservoir is impounded, five pump stations at Zhangjiazui (for irrigation), the thermal power station, Nanying (for irrigation), the water works at town of Yicheng City and the water works of Xiangnan Chemical Plant will be affected. Some water pumps will be submerged by the rising water level and can't work normally. Water intake renovation is proposed in the RAP, mainly for the two pump stations at Zhangjiazui and at the water works at town of Yicheng City, to elevate the position of water intake and pump room.

The culverts and sluices at the reservoir area are opened for drainage at low flow season and closed for water retaining at flood season. At pump stations, water is drawn from Han River for irrigation or other purposes. Protection works and drainage renovation have been proposed for the reservoir area. The nine culverts and sluices to be submerged are included in restoration and reconstruction of special facilities and they may be blocked, expanded or reconstructed. Therefore, the project won't affect water intake & drainage.

b) Water quality

The water of this section of Han River is good in quality now, and it is forecast that the water quality at this section won't be greatly impaired by the project. Since the tail part of the reservoir locates downstream from the mouth where Nan River (Gucheng County) feeds into Han River, the inflowing water of the reservoir will get slower. This is not good for diffusion, dilution and degradation of pollutants in water and may impair the water quality of the water intakes along the mainstream for domestic use of Yicheng City. Details are provided in Section 5.1.2.3 "Forecast and evaluation of project impact on water quality at water intakes". So pollution prevention and control should be enhanced at mainstream and tributaries of Han River to guarantee the water quality at water intakes.

6.6.2 Analysis of economic and social impacts

6.6.2.1 Analysis of economic impacts

This is a comprehensive water resource utilization and development project. A waterway will be formed and a dam will be constructed for power generation. Although the profitability of the project to a large extent is restricted by the feed-in tariff and debts must be paid during project construction and operation, this project, as a large public infrastructure project, will promote waterway upgrade and local economic development and therefore create huge social benefits.

(1) Han River is an important part of the main waterway network of Yangtze River. The development of Han River is of great significance to national inland river shipping industry. After the project is completed, the backwater of the reservoir will join to Cuijiaying hydro-junction, five mudflat areas will be submerged, and the shipping capacity of the river section upstream from the dam with length of 52.67km

will be promoted from 500t to 1000t. On one hand, the cost of waterway improvement and maintenance is decreased, and on the other hand, this project lays a foundation for the formation of Danjiangkou-Xinglong waterway and helps to realize the 2020 waterway planning target of the mainstream of Han River.

(2) Water transport is an environment-friendly, energy-saving and low-carbon mode of transportation. The unit energy consumption of water transport is only half of railway transport and one tenth of road transport. After the project is completed, the shipping capacity of Han River will be greatly improved, and due to the advantages of water transport i.e. low cost, small coverage of land, large transport capacity and low energy consumption, part of bulk cargos such as coal and minerals may be transferred from land transport to water transport. As a result, the energy consumption will be decreased and the emission of harmful substances will be reduced. At the same time, a 52.67km waterway upstream from the project site will be formed and large ships are allowed to go through Han River. Total fuel consumption of ships will decrease by 30-40% and cost saving of water transport will create more economic benefits.

(3) Xiangyang City is a hub of the power grid of Hubei province. With the rapid growth of economy, power consumption is increasing fast and power shortage is getting heavier. Local power supply already can't meet the growing power load. Yakou shipping hub has an installed capacity of 74.2 MW, a guaranteed output of 19.0 MW and an average annual energy output of 263 million kW·h. The project site is near to Xiangyang and Yicheng. After completed, it will mitigate power shortage in this area and facilitate urban construction and economic development of the two cities. In addition, it is a hydropower station in replacement of a thermal power station. The consumption of standard coal will decrease by 80,960t every year, that is to say, CO_2 emission will be reduced by 212,100t (equivalent to 73,800t carbon) and SO_2 emission will be reduced by 690t. So this project follows the trend of developing low-carbon clean energy. It will play a great role in energy saving and emission reduction and facilitate the protection of biological environment.

(4) In respect of agricultural production, after the hub is built, normal water level

of this section of Han River will be raised and the reservoir water can be used for irrigation for 80,000mu farmland at Liushui, Zhengji, Yancheng and Nanying. The insurances probability of irrigation water will get higher and irrigation cost will be decreased to facilitate the development of high-efficiency eco-agriculture. Local residents also can develop aquaculture to increase family income.

(5) This project will accelerate urban construction of Yicheng City, improve its investment environment and greatly promote the economic development of Xiangyang City and even the upstream area. After the project is completed, the width of river course in this section will increase to 2-5km, water surface of the reservoir will reach 12,700 hectares, and the reservoir will join to Cuijiaying hydro-junction to form a beautiful natural scenery belt. Tourism and other related industries will be boosted and living quality of the residents on both banks will be improved.

(6) The south Shaanxi province is rich in water, mineral and biological resources but Hubei province has to import iron ore, petroleum and coal from other places, so they depend on the water transportation of Han River. Yakou shipping hub will improve the conditions of Yujiahu port and Yicheng port, facilitate the formation of the waterway from Wuhan to southwest Hubei province, promote the north-to-south coal transfer, and stimulate the economic development of Xiangyang City, Shiyan City and even south Shaanxi province and west Henan Province.

6.6.2.2 Analysis of social impacts

a) Positive impacts

After the project is completed, a 52.67km waterway will be formed. The shipping capacity of Han River will be greatly improved and the multi-modal transportation structure at this area will be more complete. For a long time, low shipping capacity of Han River led to low competitiveness and poor performance of shipping enterprises in this area, and most of their employees had a poor life. Yakou shipping hub will promote the development of shipping industry in Hubei province and bring new hope to the shipping enterprises in distress and their staff.

From the perspective of social harmony and stability, the construction and operation of this project and the development of related service industries will bring new jobs to local residents and attract some migrant workers back home. As a result, the incomes of local residents will be increased and local educational, cultural and health conditions will be improved.

b) Adverse impacts and risks

(1) During project construction, the upstream water level may be raised by the backwater due to the cofferdam. Floods may occur and losses may be incurred from flood inundation.

(2) During project construction, the noise emitted by mechanical machinery will produce adverse effect to the surrounding residents, transport vehicles may bring a certain pressure on surrounding traffic, and automobile exhaust and dust may exacerbate air pollution. At the same time, project construction may also cause influence on the water environment of the reservoir area, so strict water environment monitoring is suggested.

(3) The farmland, dry land and housing at low positions inside the levees may be inundated by water, so operation and maintenance cost should be increased to enhance drainage and anti-seepage. Land reclamation by field-lifting may be necessary or the farmers may have to plant other crops. Some houses must be reinforced or dismantled. The government should make solutions to address this problem.

6.6.3 Impact on local shipping industry

Currently only the ships with a maximum load of 500t are admitted to the Danjiangkou-Xiangyang section of Han River. However, after the hub is built, the shipping capacity of Yakou-Wangfuzhou section of Han River will be greatly improved. A ship lock that give access to 2×1000t ships will be built to ensure the smooth navigation between upstream and downstream of the power station. In a word, the project will promote the development of local water transportation.

6.6.4 Impact on local land use structure

a) Impact on local land use

This project is expected to cover an area of 6,996.62hm^2 in total, of which the dam area occupies 130.33hm^2, the hub management area occupies 13.69hm^2 and the reservoir inundated area occupies 6852.61hm^2.

The dam area and the hub management area belong to construction land, with total area of 144.02hm^2. But in the project, some land belongs to non-construction land, with total area of 143.18hm^2, distributed at Zhengji, Liushui, Kongwan, Liuhou, Nanying, Wangji and Xiaohe. This is inconsistent with the general land use planning of Yicheng City and adjustment should be made.

Land reclamation from residential area is necessary to ensure zero increase of total quantity of construction land. Overall, after adjustment, the total quantity of construction land of Yicheng City won't be influenced by the project.

Land use structure should be adjusted based on land characteristics and current land use status in accordance with Yicheng municipal social and economic development strategy. This will promote the reasonable and intensive use of land, prevent redundant construction and industrial structure convergence, coordinate urban and rural economic development, and promote industrial agglomeration.

b) Impact on basic farmland

This project is expected to cover an area of 6,996.62hm^2 in total, of which the cultivated land is 317.81hm^2, including 270.31hm^2 basic farmland. The quantity of basic farmland won't exceed the quota of over-designated basic farmland of the city and will be deducted from the quota. Article 31 of *Land Administration Law of the People's Republic of China* stipulates that in the case of occupying cultivated land for non-agricultural construction, the units occupying the cultivated land should be responsible for reclaiming the same amount of land in the same quality as that occupied according to the principle of "reclaiming the same amount of land occupied". The PIU has paid the cultivated land reclamation fee and has reclaimed proper quantity of land to make up for the cultivated land occupied.

According to the Overall Planning for Land Use of Yicheng City (2006-2020), the protected basic farmland is 62,226hm^2, of which the existing over-designated basic farmland is 3,696.2638 hm^2. According to the *Notice of the Ministry of Land and Resources on Strict Implementation of Overall Land Use Planning* (G.T.Z.F. [2012] No.2), in case of occupying the over-designated basic farmland for traffic corridor stipulated in the overall land use planning of a county or town or for key construction projects such as livelihood related projects, environmental protection projects and other special projects stipulated in overall land use planning, the over-designated basic farmland should be deemed as common cultivated land when handling approval procedures, without the need of designating new basic farmland. This project will occupy 270.3113hm^2 basic farmland, which doesn't exceed the quota of over-designated basic farmland of the city and will be deducted from the quota.

6.6.5 Impact on tourism & landscape

a) Impact of land occupation on regional tourism & landscape

Permanent and temporary land occupation will damage vegetation and change the natural landscape. During project construction, most of the land occupied is bare. Grass and trees will be planted after completion of the project, but vegetation restoration needs some time. So project construction will have some adverse impacts on the landscape.

Investigation shows that there is no tourism attractions on the land occupied, so the project has no impact on local tourism.

b) Impact on development of tourism & landscape

The reservoir is regulated on daily basis. The inflowing water is used for power generation in addition to shipping and fishways. A minimum discharge flow will be guaranteed so that the downstream water flow is not too small or cut off. The reservoir will join to Nianpanshan reservoir at downstream and to Cuijiaying provincial wetland park at upstream to largely expand regional tourism resources. Roads built inside and outside of construction site will improve local traffic facilities. The broad water area of this project, together with Wolong area and Lihua Lake, will form a tourism cluster to boost local tourism industry.

6.6.6 Impact on cultural relics and historical sites

Hubei Provincial Institute of Cultural Relics and Archaeology carried on investigation and exploration in the project affected area and compiled the *Cultural Relics Protection Plan of Han River Yakou Shipping Hub Project*. This plan has been reviewed and approved by Hubei Provincial Cultural Relics Bureau.

No state, provincial or municipal cultural relic protection sites are involved in this project. But 12 ancient tombs and sites including one county-level protection site - Wangjiagang tomb will be submerged by the reservoir water. The project impact on cultural relics and historical sites will be decreased to the largest extent by unearthing and data archiving.

6.6.7 Impact on human health

A great number of migrant workers will work here for the project and this may be a hazard to the health of local residents. Local incidences of infectious diseases should be investigated, necessary hygiene and medical facilities should be provided at the temporary living area and analyses should be conducted to find out the impact of migrant workers on the health of local residents and also the impact of local diseases on these workers.

6.6.7.1 Overall evaluation of sanitary conditions

a) Sanitary conditions

The project site is 28km from the urban area of Yicheng City. Here, transportation is convenient and the economy develops rapidly. However, urban and rural gap is big. In the urban area, the economy is more developed with good sanitary conditions, while in the rural area, most of the residents are farmers with poor sanitary conditions. In recent years, housing conditions of rural residents have been greatly improved, but their long-term bad habits are still detrimental to their health. For example, the house is too close to pens, excrement management is poor and wastes are thrown everywhere. This attracts mosquitos and flies and facilitates the spreading of infectious diseases.

b) Medical technology

Medical technology is closely related to the incidence of diseases, especially prevalence of infectious diseases. Currently most of nearby hospitals or clinics are comprehensive medical institutions covering all basic specialties and equipped with basic medical equipment. The medical technology of these institutions has been greatly improved and a large proportion of their staff have junior college degree or higher degree. During project construction, the influx of a great number of workers may bring disease and the risk of transmission or prevalence of some diseases will be increased. This is a hazard to the health of the workers and local residents.

c) Quality of drinking water

In surrounding villages, drinking water is from tap water with good quality. According to the construction plan, the water used at project site is from the water works upstream from the earth dam. The water in this section of Han River is good in quality and can be used as the drinking water source. Unified management of water for construction and domestic use will guarantee the quality and safety of drinking water.

6.6.7.2 Forecast of population health

a) Natural focal disease

There is no incidence of plague in this area in history, but schistosomiasis ever spread in Xiangcheng and Gucheng. With great efforts, the schistosomiasis was eliminated in 1986. No patient suffering from schistosomiasis was found in recent years. This hydropower station is built on riverbed, so water level rise is small and the inundated area won't be large. So the project won't cause large-scale breeding of oncomelania or great change in density and species of rats. In other words, the project won't largely expand natural epidemic foci and won't cause the spreading of natural focal diseases.

b) Water-borne infectious diseases

Investigation shows that almost all of rural residents have used tap water, the water quality is guaranteed and their bad habits have been greatly changed, so the incidence of water-borne infectious diseases is low. But the influx of a great number of works will increase the risk of the water-borne infectious diseases such as dysentery, hepatitis A and typhoid fever. This may threaten the health of local residents and the workers. So, great attention should be paid to drinking water quality, foods hygiene & safety and management of workers to prevent prevalence of infectious diseases.

c) Insect-borne infectious diseases

The incidence of insect-borne infectious diseases has close relationship with the species and density of the insects and the season. Main vector of insect-borne infectious diseases is mosquito. Malaria is common in this area. The vectors of malaria usually are anopheles sinensis and anopheles lesteri anthropophagus. According to the investigation of Xiangyang Municipal Disease Control Center, the vector of malaria in Xiangcheng, Fancheng, Laohekou and Gucheng is anopheles sinensis, and the peak incidence is from May to September every year.

The influx of a large number of workers will increase the risk of malaria. So, during project construction, prevention measures should be taken and malaria prevention knowledge should be disseminated to local residents and the workers. Getting rid of bad habits is very important to eliminate breeding environment of mosquitos and bed net, window screening and coils can be used. Sleeping in the open should be prohibited. Once malaria epidemic is found, it must be reported to relevant authority and the patient should be transferred to medical institution. Measures should be taken to prevent spreading and prevalence of malaria.

d) Endemic diseases and other infectious diseases

There are no endemic diseases in this area, but HIV/AIDS and tuberculosis have high incidence in Xiangyang City.

In 2008, 101 AIDS cases (including the hidden AIDS patients) were reported in Xiangyang City, including 59 males and 42 females, ranking the highest in Hubei province. Cases were reported in each of Xiangcheng, Fancheng, Gucheng and Laohekou. Most of the patients are young adults aged 20~54 (86 cases) and most of them are farmers. The statistics of the AIDS cases in 2008 indicate that in most of the cases, AIDS was spread through sexual contact, accounting for 47.6%. The number of AIDS cases reported has an increase this year. During project construction, a large number of workers will pour in. This will increase the difficulty of AIDS prevention and the risk of AIDS spread among the workers and local residents. During the period of construction, knowledge dissemination about the spread and prevention of AIDS should be enhanced among the workers and local residents and good conditions should be created for the family life of the workers.

The incidence of tuberculosis in Xiangyang City is one the rise in recent years. In 2008, 5788 cases were reported and 3 patients died. The influx of a large number of workers will increase the risk of tuberculosis infection. Thus, tuberculosis prevention and knowledge dissemination should be further enhanced. Once tuberculosis infection is found, the patient should be taken to the hospital and all persons having contact with the patient should be placed in isolation.

6.6.8 Impact on fishermen

The area in the middle and lower reaches of Han River is an important freshwater aquaculture base. The aquatic products here account for 32.93% of the total production of the province. Xiangyang section of Han River covers the water area of 758,000mu, accounting for 25.4% of the total water surface of the city, and this section of Han River accommodates 73 species of economic fishes, accounting for 74.5% of the total number of fish species of the city. The natural fish production in this section ever amounted to more than 15,000t, but it decreased gradually in recent years. The analysis of section 6.2.2 indicates that after the project is completed, the hydrological conditions will change and fish species in this section will also change: specifically, the demersal fishes laying adhesive and demersal eggs and adapted to sediment environment (rapids, gravels, caves and rocks) such as lepturichthys fimbriata, glyptothorax sinensis regan and leiobagrus marginatus will decrease and may disappear; the fishes adapted to slow or static water will increase and become the main aquatic products here; the fishes laying pelagic eggs such as the four Chinese carps , xenocypris argentea gunther, parabramis pekinensis, saurogobio dabryi, pseudolaubuca sinensis and brass gudgeon will decrease sharply and even disappear.

In a word, after the project is completed, fish breeding and growth speed will get slow, fish quantity and quality will be impaired and the fishermen will suffer great loss. Thus, compensation measures should be taken.

6.7 Analysis of other environmental impacts

6.7.1 Impact on geological environment

6.7.1.1 Stability of bank slope

a) Classification of reservoir bank

Kongjiaying-Gaojiage section and Nanzhou-dam section have rock bank slope, with total length of 10km and all the rest has earth bank slope. The stability of earth bank slope depends on the geological structure. The bank slope will be influenced by the reservoir water in two aspects: the impact from waves and water level fluctuation and the impact from river erosion, especially in flood season.

The influencing factors of bank slope stability can be divided into internal cause and external cause, the former means the material and geological structure of bank slope and the latter mainly includes distribution features of groundwater seepage field, river regime, water level fluctuation, ships, wind and waves etc. Bank slope is made of sandy soil, with smaller natural angle of repose and more easily suffer erosion than the bank slope made of cohesive soil. The bank slope stability will be better in water rising period (than water recession period), or if the bank slope is convex type rather than concave type, or if river regime is under control (e.g. revetment, riprapping and spur).

Bank slope is divided into two types: artificial bank (I) and natural bank (II).Artificial bank (I) means the bank with artificial levee, which is subdivided into two subtypes: the bank temporarily used against the flood with a recurrence interval of 20 years (I1) and the bank used against the normal water level of the reservoir (I2). The two subtypes generally cover the entire bank with artificial levee. Natural bank

(II) is also subdivided into two subtypes: earth bank (II1) and bedrock bank (II2).Details about bank classification are shown in Table 6.7.1-1.

Table 6.7.1-1 Classification of bank slope

Types of bank slope		L or R	Location	Length (km)	Proportion (%)	Features
Artificial bank (I)	I_1	Left	Gaojiage-Nanying	36.9	34.2	Temporarily used against the flood with recurrence interval of 20 years
		Right	Shuiwa-Xiaohe Town			
	I_2	Left	Nanying-Nanzhou	34.3	31.7	Used against the normal water level of the reservoir
		Right	Ruanjiapo-Yakou dam			
Natural bank (II)	Earth bank (II)	Left	Reservoir tail - Kongjiaying	26.8	24.8	Bank formed from terrace or high flood plain
		Right	Cuijiaying dam - Shuiwa; Xiaohe Town - Ruanjiapo			
	Bedrock bank (II2)	Left	Kongjiaying-Gaojiage; Nanzhou-dam	10.0	9.3	Slope made of bedrock

Bank of the reservoir has a total length of 108km, of which artificial bank is 71.2km long, accounting of 65.9% and natural bank is 36.8km long, accounting for 34.1%.

Usually, the natural bank has the problem of slope stability while the artifical bank may have the problems of levee foundation seepage and seepage deformation in addition to slope stability.

On the basis of bank material, current status, revetment and river regime, bank slope stability is classified into four types, i.e. good stability, average stability, poor stability and instability.

b) Evaluation of bank slope stability

1) Natural bank

Details are shown in Table 6.7.1-2.

Table 6.7.1-2 Engineering geological evaluation of natural bank slope

Subtypes	L or R	Location	Length (km)	Proportion (%)	Geological features	Stability evaluation	
						Before impoundment	After impoundment
(II1)	Right	Cuijiaying dam - Shuiwa	3.5	24.8	Slope is formed from the 2nd grade terrace, elevation of terrace surface: 65 ~ 72m;Slope gradient: 45° and slope height: 10m; Slope material: silty clay; Without outer mudflat, this segment is at scouring position and is slightly	Average stability after building revetment	Average stability

Subtypes	L or R	Location	Length (km)	Proportion (%)	Geological features	Stability evaluation	
						Before impoundment	After impoundment
647					concave; Investigation shows that riprapping and stone revetment were provided before 1975 and the revetment is 5.0m high. No slope instability is found.		
	Right	Xiaohe Town - Ruanjiapo	12.9		Slope is formed from the 2nd grade terrace, elevation of terrace surface: 68 ~ 71m;Slope gradient: about 50°~60°and slope height: about 18m; Slope material: silty clay; This segment is basically straight and riprapping is provided at scouring position. The slope has many gullies, so slope stability is poor and bank collapse is serious in some positions.	Instability	Instability
	Left	Reservoir tail - Kongjiaying	10.4		Slope is formed from high floodplain, elevation of floodplain surface: 61m; Slope materials: sandy loam and fine sand; Located at convex bank, with broad mudflat outside and small amount of bank collapse.	Average stability	Average stability
II2	Left	Kongjiaying -Gaojiage	5.2	9.3	Slope is made from bedrock and a small amount of the 2nd grade alluvial terrace and slope is steep; At scouring position, without outer mudflat.	Good stability	Good stability
	Left	Nanzhou-dam	4.8		Slope made from bedrock of tertiary stratum.	Good stability	Good stability

Table 6.7.1-2 shows that total length of natural bank is 36.8km, of which the length of subtype II1 is 26.8km, accounting for 24.8% of total bank length of the reservoir, and the length of subtype II2 is 10km, accounting for 9.3% of the total bank length of the reservoir. The stability of natural bank has no change before and after impoundment. Xiaohe Town - Ruanjiapo section is classified into "instability" type, with length of 12.9km, accounting for 11.9% of the total bank length of the reservoir, and the rest of natural bank is classified into "average stability" or "good stability".

2) Artificial bank

Before water impoundment, the artificial levee is not in contact with water and it is used to retain water only in flood season. After water impoundment, the artificial levee may be influenced from two aspects: first, the bank slope will be submerged and underwater reformation of bank slope may occur this may impair the stability of the levee; second, water impoundment may directly impair the stability of the levee.

Therefore, the engineering geological conditions of bank slope and the levee itself should be evaluated respectively.

(1) Engineering geological evaluation of water-side bank slope

Table 6.7.1-3 shows that the artificial bank rated with "average stability" is 22.9km long, accounting for 21.2% of the total length of bank slope, and the artificial bank rated with "instability" is 14km long, accounting for 13% of the total length of bank slope. Bank slope reformation has appeared at subtype I2 sections (used against normal water level of the reservoir), with total length of 34.3km, accounting for 31.7% of the total length of bank slope.

Table 6.7.1-3 Engineering geological evaluation of water-side bank slope

Subtypes	L or R	Location	Length (km)	Proportion (%)	Geological features	Stability evaluation	
						Before impoundment	After impoundment
I1	Right	Shuiwa - Daying	9.0	17.5	Slope is formed from the 1st grade terrace, elevation of terrace surface: 59.8 ~ 62m; Slope gradient: 35°~40° and slope height: 8m; Slope materials: sandy loam and silt loam; Without outer mudflat, this segment is straight or slightly concave, partially at scouring position; Investigation shows that riprapping and stone revetment were provided before 1975 and the revetment is 5.0m high. No slope instability is found.	Average stability after building revetment	Average stability
	Right	Daying - Xiaohe Town	9.9		Slope is formed from the 1st grade terrace, elevation of terrace surface: 57 ~ 59.8m; Slope gradient: 35° or so and slope height: 4m; Slope materials: sandy loam and silt loam; Width of outer mudflat > 200m, this segment is nearly straight, partially at scouring position; Investigation shows that riprapping and stone revetment were provided before 1975. No slope instability is found.	Average stability after building revetment	Average stability
I2	Right	Ruanjiapo - Yejicheng Sluice	6.5	16.6	Slope is formed from the 1st grade terrace, elevation: 55-56m; Slope gradient: 60°; Slope materials: silt loam and sandy soil; There is no outer mudflat or the outer mudflat is narrow; This segment is nearly straight, so water flows along the slope; Riprapping is provided at some scouring positions and there is collapse.	Poor stability	Bank slope is submerged and underwater reformation appears
	Right	Yejicheng sluice - Yakou dam	11.5		Slope is formed from the 1st grade terrace or high floodplain, elevation: 52-54m; Slope gradient: almost 90° and slope height: 2-3m; Slope materials: silt loam mixed with sandy soil; Width of outer mudflat > 200m, this segment is slightly convex, with serious collapse.	Instability	Bank slope is submerged and underwater reformation appears

Subtypes	L or R	Location	Length (km)	Proportion (%)	Geological features	Stability evaluation	
						Before impoundment	After impoundment
I1	Left	Gaojiage - Zhangjiazui	4.0	3.7	Slope is formed from the 1st grade terrace, elevation of terrace surface: 59.6m, slope height: 3~4m; Slope materials: silt loam and sandy soil; This segment is straight, there is no outer mudflat or the outer mudflat is narrow, stone revetment is built.	Average stability after building revetment	Average stability
	Left	Zhangjiazui -Nanying	14.0	13.0	Slope is formed from high floodplain, elevation: 56.7m; Slope materials: sandy loam and fine sand; This segment is at convex bank, with broad outer mudflat; there is no revetment and slope collapse appears.	Instability	Instability
I2	649 Left	Nanying-Nanzhou	16.3	15.1	Slope is formed from the 1st grade terrace, elevation of terrace surface: 54-56m; Slope gradient: 35° or so and slope height: 4m; Slope materials: sandy loam and silt loam; There is no outer mudflat in most part of this segment, with wide outer mudflat at several positions. This segment is nearly straight; Riprapping and stone revetment has been provided; No slope instability is found.	Average stability after building revetment	Bank slope is submerged and underwater reformation appears

(2) Engineering geological evaluation of artificial levee

There are three sections of artificial levee, namely Yidong, Yixi and Oumiao, with total length of 71.223 km. In the total length of artificial levee, a length of 34.3km is used against normal water level of the reservoir and the rest is temporarily used against the floods with a recurrence interval of 20 years.

A. Engineering geological evaluation of levee foundation

Based on the geological structure and major engineering geological problems of levee foundation, the boundary conditions of seepage flow inside and outside the levee such as width of outer mudflat, ponds and gullies inside the levee, and bursts and scour pits, and the floods in history, the engineering geological conditions of levee foundation is classified into four types: good (A), average (B), poor (C) and worse (D). The outer mudflat is also classified into four types by the width: wide outer mudflat (width >200m), common outer mudflat (width: 100~200m), narrow outer mudflat (width: 50~100m), without outer mudflat (width<50m). The length of types A and B is 30.323km, accounting for 42.6% of the total length, and the length of types C and D is 40.9km, accounting for 57.4% of the total length. The major engineering ecological problems are levee foundation seepage and seepage deformation.

B. Engineering geological evaluation of levee body

Yidong section consists of two parts: one part with length of 12.811km is good, while the other part with length of 21.49km has too strong permeability and sloughing ever happened on land-side slope; Yixi section is good generally, but small amount of seepage ever appeared in the section from stake number 8+500 - 10+500 and some part of the levee body built with sandy soil has poor performance; in Oumiao section, the part from stake number 32+080 ~ 35+663 is good, but the remaining part has small amount of seepage in flood season, especially the part built with sandy soil.

In a word, the good part of the three sections of artificial levee has a length of 30.9km, accounting for 43.4% of the total length of the artificial levee, while the remaining part, with a length of 40.323km, has poor performance and has the problems such as too strong permeability, small amount of seepage and local sloughing. After the reservoir is impounded, these problems will get more serious. Especially in the section in permanent contact with reservoir water, slope failure may occur, so much attention should be paid to it.

c) Preliminary conclusion

Statistics of geological problems of bank slope is shown in Table 6.7.1-4.

Table 6.7.1-4 Statistics of geological problems of bank slope

<table>
<tr><th>Bank type</th><th colspan="2">Location</th><th>Name, stake number or length (km)</th><th>Major geological problems</th></tr>
<tr><td>Natural bank</td><td colspan="2">Right</td><td>Xiaohe Town – Ruanjiapo, length: 12.9km.</td><td>Slope failure</td></tr>
<tr><td rowspan="3">Artificial bank</td><td colspan="2" rowspan="2">Water-side slope</td><td>Ruanjiapo – Yejicheng sluice, length; 6.5km;
Yejicheng sluice – Yakou dam, length: 11.5km;
Nanying – Nanzhou, length: 16.3km</td><td>Bank slope is submerged and underwater reformation appears</td></tr>
<tr><td>Zhangjiazui – Nanying, 14km</td><td>Slope failure</td></tr>
<tr><td>Level foundation</td><td>Yidong section</td><td>5+550~8+300; 8+800~18+200; 19+800~25+500; 26+200~28+200; 30+000~31+200</td><td>Levee foundation seepage and seepage deformation may appear after water impoundment</td></tr>
</table>

Table 6.7.1-4 (Continued)

Bank type	Location		Name, stake number or length (km)	Major geological problems
Artificial bank	Levee foundation	Yixi section	1+500~3+000; 7+500~12+100; 13+200~15+400	
		Oumiao section	19+500~20+250; 22+200~24+800; 25+500~32+600; 33+800~34+900	
	Levee body	Yidong section	0+000~18+000; 21+110~24+600	The permeability is too strong, and slope failure may occur after water impoundment
		Yixi section	6+000~7+000; 8+500~10+500	
		Oumiao section	21+500~23+000; 22+200~32+200	Serious seepage in flood season
	Culverts and gates	Oumiao section	Hujiatao sluice, stake number: 33+283	Seepage deformation of sluice foundation may appear
		Yidong section	Baijiatao sluice, stake number: 15+627	Seepage deformation of sluice foundation may appear

The following measures should be taken to solve the geological problems:

(1) The Xiaohe Town–Ruanjiapo section of the natural bank has poor stability. Slope failure has appeared and will get serious after the reservoir is impounded. Above the slope is grade II terrace, most of which is used as cultivated land. There is no residential house. So, the hazard of slope failure is small and we suggest having continuous monitoring on slope stability.

(2) As for artificial bank, the stability of water-side slope is very important; especially the part where there is no outer mudflat or the outer mudflat is narrow. For example, at the part from Ruanjiapo to Yejicheng sluice (of Yixi section), there is no outer mudflat or the outer mudflat is narrow, most of the bank is straight so water flows along the bank, but some part of the bank just faces water flow and is heavily scoured by water. Slope collapse still happened in spite of riprapping and stone revetment and it will get worse after water impoundment, so slope protection is needed.

(3) After the reservoir is impounded, some part of Yidong section, Yixi section and Oumiao section may have problems such as levee foundation seepage and seepage deformation. The total length of these parts is 40.9km. Such problems may more occur at the part which is in permanent contact with reservoir water. This part has a length of 19km. Measures should be taken for the length of 40.9km to prevent

and control levee foundation seepage and seepage deformation.

(4) After the reservoir is impounded, some part of Yidong section and Yixi section may have the problem of slope failure. The total length of these parts is 24.5km and measures should be taken. Among these parts, a length of 16km is only temporarily used against the floods with a recurrence interval of 20 years, so slope failure is not likely to happen in this part. But the remaining length of 8.5km is used against the normal water level of the reservoir, so slope failure probability is large. In Oumiao section of the levee, a length of 11.5km may have serious seepage in flood season, so measures must be taken.

(5) Bank of the reservoir is long and has complicated geological structure. Especially, the problems of artificial bank, such as levee foundation seepage, seepage deformation and slope failure, are very critical. We suggest conducting a research focusing on this aspect.

6.7.1.2 Reservoir leakage

This reservoir is built on riverbed and the water area is wide and shallow. It has no natural opening. The sources of all streams and tributaries on both banks have an elevation higher than the normal water level of the reservoir. There is no carbonate rock formation between the reservoir and the adjacent valley, and large-area water-transmissible fault in connection with adjacent valley is not found. So the reservoir doesn’t have the problem of water leakage. No valuable minerals are discovered except gypsum and small amount of gold at Cihe town. So, no mineral resources will be submerged.

As mentioned, this reservoir is built on riverbed. After water impoundment, the water is retained inside the levees and the rise of water level is not large.

Left bank: In Yakou dam – Nanzhou section, the bank slope is formed from ridges, very broad, with ground elevation larger than 80m. The material of bank slope is bedrock, mainly clay rock. So, the bank slope has good water-resisting property and won’t have the problem of water leakage. In Nanzhou–Gongnao section, the bank slope is formed from the 1st grade terrace, with ground elevation below the normal water level (55.22m) of the reservoir. The materials of levee foundation and levee body mainly are silt loam and sandy loam, and also sandy soil at some positions. So water leakage into the levee may occur. In Gongnao – Gaojiage section, the bank slope is formed from the 1st grade terrace, flat and broad, with ground elevation of 56~61m. The groundwater discharges from the terrace into Han River. After the reservoir is impounded, the groundwater level in some areas will be raised, but permanent water leakage won't happen. In Gaojiage–Kongjiaying section, the bank slope is formed from bedrock, with ground elevation larger than 90m. The mountain is thick and therefore water leakage won't happen. In Kongjiaying – reservoir tail section, the bank slope is formed from broad and high floodplain, with ground elevation larger than 60m. This section is inside the current waterway. After the reservoir is impounded, the rise of water level is not large. So this section won't have the problem of water leakage.

Right bank: in the section from Yakou dam to stake no. 3+000 (at Yixi section), the bank slope is formed from the 1st grade terrace, with ground elevation below the normal water level (55.22m) of the reservoir. The materials of levee foundation and levee body are silt loam, sandy loam and sandy soil. So water leakage into the levee may occur. In the section from stake no. 3+000 (at Yixi section) to Ruanjiapo, the bank slope is formed from the 1st grade terrace, with ground elevation of 56~57m. The materials of levee foundation are sandy loam and silt loam. The terrace is 1.2 ~ 1.5km wide. Water leakage may happen, but not serious. In the section from Ruanjiapo to reservoir tail, the bank slope is formed from mainly the 2nd grade terrace, with ground elevation larger than 58m. After the reservoir is impounded, the rise of water level is not large and the groundwater recharge and discharge won't be changed. So this section won't have the problem of water leakage.

In conclusion, the Nanzhou–Gongnao section on left side and the section from Yakou dam to stake no. 3+000 (at Yixi section) on right side may have the problem of water leakage, which may aggravate existing inundation or cause new inundation and may threaten the safety of the levee. The remaining part of the bank has no water leakage or the water leakage is not serious.

6.7.1.3 Reservoir inundation and bank collapse

On left bank, the section upstream from Zhangjiazui and the Nanzhou–Yakou dam section won’t cause inundation; on right bank, the section upstream from Ruanjiapo won’t cause inundation except for Zhangjiazui–Lijiadian section. Inundation mainly appears in the Zhangjiazui–Nanzhou section on left bank, and the Zhangjiazui–Lijiadian section and the Ruanjiapo–Yakou dam section on right bank. Since the designed normal water level of the reservoir is 55.22m, the inundation distance is 1062m on average in the Ruanjiapo– Yakou dam section on right bank, 367m on average in the Nanzhou–Nanying section on left bank, and 135m on average in the Zhangjiazui–Nanying section on right bank. Based on seepage calculation, the inundation area on right bank totals up to 18.71km^2 and that on left bank totals up to 9.01km^2.

At the seriously inundated areas, more drainage ditches may be excavated to lower groundwater level and mitigate inundation. But the engineering measures carried out for this purpose should not cause instability or seepage deformation of the levee. At the slightly inundated areas, inundation may be mitigated by adjusting crop planting structure.

6.7.1.4 Reservoir induced earthquake

This project is located to the north of upper Yangtze platform (II) - a secondary tectonic unit of Yangtze paraplatform (I). This area is a relatively stable tectonic unit formed based on previous sinian system fold belt, without intensive settlement. Major faults within 50km around the project site include: Nanzhang-Jingmen fault, Wu'an-Shiqiao fault, Huji-Shayang fault and Yonglonghe fault. The four faults extend northward or northwestward in parallel, forming graben or horst, connecting to Xiangfan-Guangji fault in the north.

The project site is near the border of Qinling fold system and Yangtze paraplatform, at the south margin of Qinling fold system. Generally, the project site was superposition-based rifting structure and later changed to depression structure.

Currently, the dam site is at the south margin of the rifting area of Nanxiang basin, at settlement status in a long time. There is a regional great fault near the project site. It has features of seismic structure but it's far from the dam site or the seismic activity is weak, thus having little effect on dam stability. There is a microtremor concentrate area near the dam site, but it is more than 30km away from the dam site and the seismic intensity will attenuate to IV or lower degree at the dam site. So, it has little effect on the dam and the regional crust is basically stable. Major regional faults within 300km around the dam site include: Xiangfan-Guangji fault, Ankang fault, Danfeng-shangnan fault, Tongbai fault, Nanzhang-Jingmen fault, Wu'an-Shiqiao fault, Huji-Shayang fault, Yonglonghe fault, Tongchenghe fault, Wuduhe fault, Jiuxiwan fault, Yuan'an fault, Xiannvshan fault and Xinhua fault.

Generally, these faults are better developed, most of them extend northward or northwestward, but they don’t' have strong activity and earthquakes along these faults are far from the project site. So these faults have little impact on the project.

6.7.1.5 Comprehensive assessment of geological hazards

The project site is near the border of Qinling fold system and Yangtze paraplatform, at the south margin of Qinling fold system. Generally, the project site was superposition-based rifting structure and later changed to depression structure. Currently, the dam site is at the south margin of the rifting area of Nanxiang basin, at settlement status in a long time. There is a regional great fault near the project site. It has features of seismic structure but it's far from the dam site or the seismic activity is weak, thus having little effect on dam stability. There is a microtremor concentrate area near the dam site, but it is more than 30km away from the dam site and the seismic intensity will attenuate to IV or lower degree at the dam site. So, it has little effect on the dam and the regional crust is basically stable.

Main types of geological disaster at the assessed area on both banks of the backwater section from dam to reservoir include: landslide and collapse. In addition, there are many bank failures, sliding masses, dangerous rocks and instable slopes on both banks.

The dam structure may suffer from geological hazards such as uneven settlement of foundation, karst collapse and etc. At the same time, inundation-caused wetland may appear at the two villages Yakou (left bank) and Baima (right bank) which locate at low-lying positions of the 1st grade terrace, because the flow direction and recharge-discharge relation will change after water level of Han River is raised. Construction of the dam, hydropower station and ship lock may cause the collapse of foundation pit, therefore causing geological disaster. So, proper prevention measures should be taken.

6.7.2 Forecast and evaluation of the impact from solid wastes

During project implementation, solid wastes mainly include domestic garbage, spoil and construction wastes.

a) Domestic garbage

Domestic garbage is mainly produced at the office area and living area of the construction team, mainly include organic kitchen wastes and also woods, plastic bags, paper wastes and brick slags etc. According to the expected number of construction personnel and workers, it's estimated that the maximum production of domestic garbage will amount to 1.50t each day, and total amount of domestic garbage produced during project implementation will reach 2190t.

To protect environmental sanitation and avoid water pollution, domestic garbage collection place should be set at the living area and the domestic garbage should be transported out on a regular basis. Measures should be taken to prevent scattering of garbage, breeding of flies and diffusion of foul smell. The garbage leachate should be properly treated to avoid air pollution and water pollution.

b) Spoil

The earth and stone works mainly include earth dam, hydropower station, ship lock, water diversion works, temporary facilities, roads at the site, stock yard and cofferdam etc. According to earthwork and stonework balance, total amount of excavation (of earth and stone) is 14.1375 million cubic meters, total amount of fill is 6.8538 million cubic meters, total amount of useful earth and stone is 6.6188 million cubic meters, total amount of borrowed earth and stone is 235,000 cubic meters, and total amount of spoil is 7.5187 million cubic meters. The spoil will be stored at the designated waste dump according to the requirements of soil and water conservation and proper engineering measures should be taken and plants should be grew to prevent soil and water loss. The earth and stone produced from excavation will be used as material of concrete system, or used for earth dam, or stored at waste dump as spoil. If treated in strict accordance with the requirements of soil and water conservation, the spoil won't damage the environment.

The backfill stored at the site may be washed away by rainwater or raised by wind, so proper measures should be taken to prevent environmental pollution.

c) Construction wastes

There will be all kinds of scraps during construction process, such as metal and plastic wastes, scrap steel, oil drum, packages, timbers and batteries etc. Improper treatment may damage surrounding environment. If the abandoned materials are stored in the open air, they may rust or rot. This will cause loss of property and also pollute water and soil. So, the abandoned materials should be managed and recycled. Especially, the batteries should not be stored in the open air because battery corrosion will cause serious pollution.

7 Mitigation measures

7.1 Design principles

We will develop mitigation measures that aim to prevent environmental pollution, based on the evaluation of various environmental factors, the environmental impact estimation, and the project's adverse impact on the environment. We will develop mitigation measures for Yakou Shipping Hub Project in accordance with the following principles:

a) Environmental impact shall be prevented or minimized. In order to better protect the environment, we request that the overall arrangement of the project should be optimized, quantities should be reduced, and the construction site should be closed off.

b) The environment shall be rehabilitated. Soil and water conservation measures shall be taken to further rehabilitate land and vegetation.

c) A combination of measures shall be taken to manage the project. Measures will be taken to prevent and treat the wastewater produced by construction and to prevent and reduce the noise produced by construction. Meanwhile, efforts will be doubled to manage the environment of the construction area so as to minimize the harm of construction to human health.

d) Different proposals shall be compared so that the most suitable one can be selected from them. Proposals for wastewater treatment shall be compared based on the environment and the features of the project so that the most suitable proposal can be selected and adopted.

e) The selected proposal shall be economical, feasible, and effective. Relevant parties shall compare different proposals and select the best one that suits local conditions. In addition, the feasibility and effectiveness of the selected proposal shall be analyzed.

f) The proposal shall be sustainable. The selected proposal must be sustainable in order to ensure that the environment can be rehabilitated over time.

g) The main works shall be harmonious with its surrounding environment. Both the project’s and the resettlement plan’s roles in environmental protection and water & soil conservation should be fully played. Water and soil conservation measures should suit local conditions and go hand in hand with environmental greening and beautifying measures.

7.2 Tasks and objectives

7.2.1 Tasks

A plan for preventing and reducing the impact of the project to local residents and the ecological environment shall be designed based on the environmental impact estimation and in accordance with China and Hubei environmental protection laws and regulations.

See table 7.2.1 for mitigation measures for the Yakou Shipping Hub Project.

See attached map 24 for mitigation measures for the construction area of Yakou Shipping Hub Project.

Table 7.2.1 Mitigation measures for Yakou Shipping Hub Project

No.	Project	Mitigation measures
1	Water quality protection	
1.1	Treatment of wastewater produced by the aggregate processing system	Precipitation of fines by using flocculates
1.2	Treatment of wastewater produced by the concrete mixing system	Holding the sewage in a quiescent basin
1.3	Oily wastewater treatment	Oil separator having the co-current flow pattern
1.4	Treatment of domestic sewage in the construction area	Anaerobe/aerobe purification tank, a complete set of water treatment equipment
1.5	Reservoir cleaning	Clean up the bottom of the reservoir as required
2	Ecological environment protection measures	
2.1	Plant resources protection measures	Raise the public awareness of plant resources protection in accordance with relevant policies; restore vegetation in the construction area; plant evergreen trees at the foot of a mountain and along the road in the area where vegetation remains relatively intact; built fire barriers
2.2	Animal resources protection measures	Eradicate poaching, put more efforts into monitoring and protecting the environment, reduce pollution, raise construction workers' awareness of environmental protection, and strive to develop a harmonious relationship between humans and animals.
2.3	Aquatic life protection measures	Strengthen environmental management, reduce pollution, impose a ban on devastating fishing methods; implement ecological regulation for this project and other hydro-power development projects from May to August every year, rehabilitate Yicheng spawning area in the reservoir area; use power generation or open the floodgate to ensure ecological flow; build a fishway that imitates natural fishways when the hub project is underway; build a station to increase fish spawning, artificially increase and release fish spawns
3	Water and soil conservation plan	
3.1	Main works area	Allocate and transport earth and rocks, optimize construction process, minimize wastes, ensure that the drains of factory buildings work well; green the open space on both banks of the hub, excavation slopes of factory buildings, and open space in factory buildings; recover and improve ecological landscape; build temporary drains and barriers for the lifted/filled area and the stripped topsoil
3.2	Construction road area	Ensure drains and barriers work well, green slopes, and plant street trees

3.3	Temporary construction area	Ensure drains and barriers in the temporary construction area work well, strip topsoil, clean up and level the slash, resume land reclamation or grow trees and grass
3.4	Stockyard area	Ensure drains and barriers work well, build sand basins, strip topsoil, set up temporary boundary walls around the topsoil stockyard area, re-plough and re-green slopes
3.5	dump area	Build a system of drains and barriers, build boundary walls around wastes, maintain slopes after wastes are dumped, level the wastes, cover wastes with soil for reclamation or grow trees and grass to green the area of wastes
3.6	Resettlement area	Ensure drains and barriers work effectively, green the resettlement area, green slopes and the open space in the specialized facilities reconstruction area
4	Domestic waste treatment	Safely stockpile wastes, transport wastes to Yicheng landfill for disposal
5	Atmospheric environment protection	Prepare dust removal equipment, improve construction process, reduce or prevent dust
6	Acoustic environment protection	Built soundproofing walls, use the terrain of the construction area to reduce noise, use the construction machinery that meets the requirements for environmental protection, use proper equipment to reduce or prevent noise, supervise construction.
7	Population health	Implement disease control and prevention, arrange for local residents to take physical examination

7.2.2 Objectives

Goals that mitigation measures are taken to achieve are set based on the environmental functions achieved in the project area and the features and requirements of main works. See table 7.2.2.

Table 7.2.2 Design goals of environmental protection for Yakou Shipping Hub Project

Project	Design goals
Ecological water use	Ensure water is discharged downstream at a flow rate of $450m^3/s$
Wastewater (sewage) treatment	Treat industrial wastewater and return it to the water cycle, treated wastewater to be reused shall meet the standard that SS≤300mg/L, pH6-9; treat domestic wastewater and reuse it for greening by following the Standard A under Standard Class I of the *Discharge Standard of Pollutants for Municipal Wastewater Treatment Plant* (GB18918-2002). According to the standard, the concentrations of COD, BOD_5, SS, oil, total nitrogen, and total phosphorus in domestic wastewater shall be 50mg/L, 10 mg/L, 10 mg/L, 1 mg/L, 15 mg/L, and 0.5mg/L respectively.
Terrestrial ecology and landscape protection	Keep the ecosystem of the project construction area intact and stable so that the state-level endangered animal species will not become extinct due to the impact of the project; properly arrange the construction site, control the area of land used for construction, strengthen construction management, reduce the project's adverse impact on animals and plants in the construction area; protect the original vegetation and landscape resources in the reservoir's surrounding area.
Aquatic ecology protection	Build fishways within the dam, artificially increase and release fish spawns to protect fish species.
Waste gas control and prevention	Under *Integrated Emission Standard of Air Pollutants* (GB16297-96), TSP concentration of fugitive emissions shall be kept under TSP1.0 mg/Nm^3

Noise control	According to *Noise Limits for Construction Site* (GB12523-90), noise produced during daytime shall not exceed 85dB, noise produced during nighttime shall not exceed 55dB
Water and soil conservation	Prevent and treat soil erosion in the construction area, ensure the project operates safely, properly dispose of the wastes produced by construction, at least 95% of wastes shall be enclosed; rehabilitate at least 95% of the affected land in the construction area, treat at least 97% of the eroded soil; the soil erosion control degree shall be 1.0; restore at least 99% of the vegetation in the area that becomes bare due to construction, ensure the trees and grass that are grown covers at least 17% of the area to be treated.
Resettlement	Improve the quality of the work and life of the displaced persons and residents in the project area; develop a proper industrial structure, ensure the economy of the resettlement area grows as fast as or faster than that of the project area.
Population health	Keep the incidence of endemic and infectious diseases in the construction and resettlement areas under the current level

7.3 Water quality protection measures

7.3.1 Measures for ensuring minimum discharge volume

a) Initial impoundment period

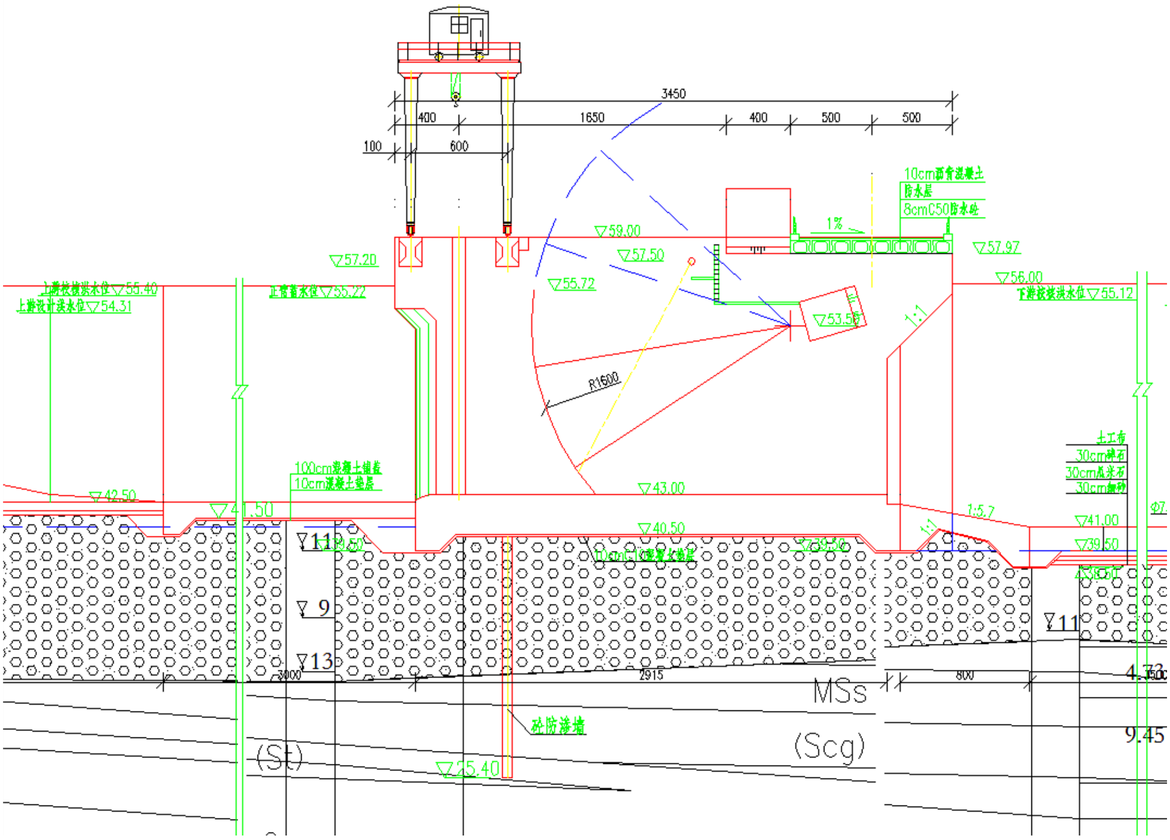
The river diversion plan for the Yakou Shipping Hub includes three phases. Cofferdams built at all three phases are earth-rock cofferdams. At phase I, an open channel will be excavated on the left overflow lands for river diversion, while the main riverbed on the right bank will be used for drainage and navigation. Flood diversion will be carried out every five years and the peak discharge is 12,000 m^3/s. At phase II, a cofferdam will be built around the main riverbed on the right side, while the open channel on the left bank will be used for overflowing and navigation. Flood diversion will be carried out every ten years and the peak discharge is 13,500m^3/s. At phase III, a cofferdam will be built around the open channel used for river diversion, while the 36-hole sluice gate built on the right bank will be used for drainage and navigation. Flood diversion will be carried out every ten years and the peak discharge is 13,500m^3/s. From October of the fifth year and January of the sixth year, the cofferdams built at three phases will be used to retain water for power generation.

We can see that river diversion at phase I and II does not involve impoundment. At the end of the phase III river diversion, the reservoir will begin to store water in early October of the fifth year. If the design dependability of initial impoundment is 85% and the minimum volume of discharge from the sluice gate is maintained at 450m^3/s, storing water to a dead water level of 54.72m takes 20.2 days on average, while storing water to a normal level of 55.22m from the dead water level takes 2.69 days on average.

b) Normal operation period

According to the design of the Yakou Hub power station, during the normal operation period, the power station operates as a baseload plant. Seven hydraulic turbines, each having a rated discharge of $327m^3/s$, have been set up. The seven turbines have a total rated discharge of $2,291m^3/s$. Therefore, a minimum discharge volume of $450m^3/s$ can be guaranteed by a set of two or more power generators.

Various accidents may occur during operation, for instance, the power system fails, the electricity generated by the power station cannot be transmitted outside, or all power generators shut down. In these cases, baseload discharge patterns may cause fish migration difficulties due to sustained high flow releases. Although the chances of the aforesaid accidents occurring are tiny, once such an accident occurs, it may disrupt the aquatic ecosystem of the Han River lower reaches. Therefore, water should be discharged from sluice structures and other emergency measures shall be taken in order to ensure that water supply of the Han River lower reaches is sufficient. 12-hole sluice gates are set up on the left bank of the Yakou Shipping Hub and 36-hole sluice gates are set up on the right bank. The sluice gates can operate separately and jointly. Opening some sluice gates (the 12 adjacent sluice gates on the right side of the power station) or controlling the sluice gate opening (10°, 20°, 30°, etc) controls the amount of water being discharged. See map 7.3.1 for the side view of a sluice gate.



Map 7.3.1 Side view of a sluice gate

c) Reliability analysis

According to the aforesaid analysis, during the initial impoundment period, the sluice gate can discharge water of a minimum volume of 450m^3/s. During the normal operation period, in general, overflow may occur when electricity is being generated; in case of an accident, overflow may occur by controlling the sluice gate. So the minimum discharge volume can be guaranteed.

d) Ecological flow monitoring proposal

It is advised that a monitoring system should be established between the water administration department and the power plant so that this system and the automatic system of hydrologic data collection and transmission can monitor ecological flows online. Read section 9.1.4.1for the details. During the initial impoundment period, relevant parties will ensure that the discharge volume meets the need by monitoring and controlling the sluice gate opening. In the case of normal operation, relevant parties will monitor power generation; in the case of power generators being overhauled, relevant parties will ensure that the minimum discharge volume meets the needs for the water supply and ecological flows of the Han River lower reaches.

7.3.2 Treatment of wastewater (sewage) in the construction area

7.3.2.1 Treatment of wastewater produced by aggregate processing

a) Objectives

The wastewater produced by aggregate processing contains SS; it does not contain other toxic or hazardous substances. To prevent wastewater from contaminating the water of the Han River lower reaches, the wastewater produced by aggregate processing shall not be discharged to the downstream river course. The wastewater produced by aggregate processing should be treated and reused. Only when SS≤300mg/L can the wastewater be treated with the current treatment technology and be reused.

b) Sources and characteristics of wastewater

An aggregate processing system is set up near Matoushan quarry for the project.

The system processes 500 tons of solids per hour, produces 400tons of solids per hour, and consumes $400m^3$ of water per hour. Given that the surface of solids contains water and that evaporation or leakage may cause water loss of 10 percent, the remaining 90 percent forms wastewater. The aggregate processing system produces $360m^3$ of wastewater per hour with a rate of flow of $0.10m^3/s$ during the peak hours of operation. During the peak hours, wastewater will be discharged 18 hours a day.

The aggregate processing system produces a large amount of wastewater that contains a high SS concentration. Based on the characteristics of solids, the aggregate processing method, and the survey sampling data regarding the completed and under-construction hydropower projects, the SS concentration in wastewater produced by the aggregate processing system is determined to be $25000m^3/L$. In wastewater, the SS whose diameters range between 0.15mm and 5mm account for 15% of the total; the SS whose diameter is about 0.1mm account for 79% of the total; the SS whose diameters are less than 0.1mm account for 6% of the total.

c) Recommended process design

It is recommended that flocculants can be used to get rid of the fine particles in wastewater produced by the aggregate processing system as a way to treat the wastewater. The wastewater flows from a screening building to a pump sump. A mortar pump pumps the wastewater up to such a level that it flows to a fines recovery system where larger SS will be removed. The mixture of filtered water and flocculants flows into the settling ponds having co-current flow patterns where solid substances in suspension are precipitated. Then supernatant flows into a reservoir and it is reused by the screening building. Slurry in the settling pond is pumped out of the tank by a suction dredge and treated by a filter press. The filter cake discharged from the filter press will be transported to a nearby dump. See chart 7.3.2-1 for treatment steps. See attached map 25 for wastewater treatment facilities for Yakou Shipping Hub Project.

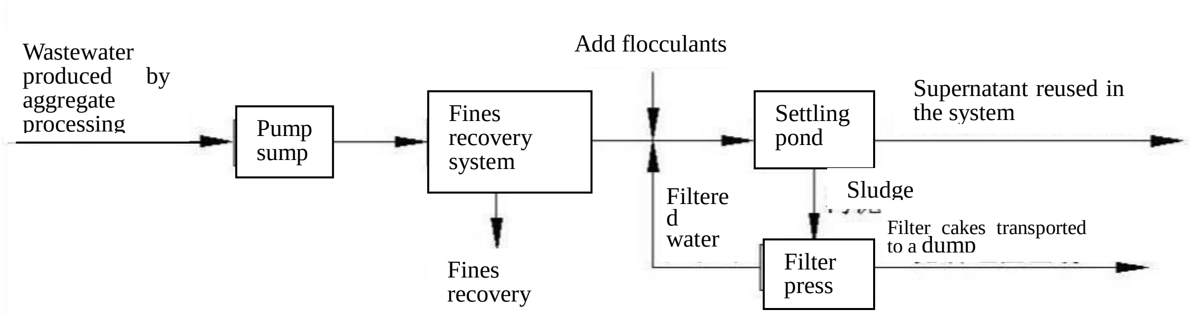


Chart 7.3.2-1 Steps for precipitation of fines by using flocculates

Fine solids are pre-handled through a recovery system so that larger particles are removed from solids. The DERRICK HI-G Dryer Fines Recovery System will be used to handle fines. The system consists of a high G-force linear motion vibratory screen and a radial design cluster of unibody hydrocyclones (a diameter of 100mm), which can remove larger particles from the solids contained in wastewater. The system can recover up to 80% of the solids currently reporting to the settling pond facility and greatly reduce pond cleaning efforts. All recovered solids can be reused for the project.

As precipitated slurry tends to form into small clumps in a settling pond, it needs to be promptly discharged from the bottom of the settling pond. It is preferable that a sludge pump is used with a mixer so that sludge can be promptly pumped out of the pond. The settling pond can also be equipped with a sludge scraper so that the pond can be cleaned on a regular basis. According to this proposal, the settling pond will be equipped with a sludge scraper.

According to this proposal, a small area of land will be used, flocculants will be used in a cost-effective way, and the fines recovery system can be used in a dewatering equipment room and used for the next project.

d) Sludge treatment

The slurry directly discharged from the settling pond contains a large quantity of water. If it is dried naturally, a large area will be needed; precipitated solids and slurry will be filtered and dewatered using gravity. If a filter press is used to filter wastewater, a proportion of wastewater will be reused and the other proportion of wastewater will be transported to a dump nearby. In this case, water content will fall to less than 30%, the quantity of wastes will greatly reduce, transport costs will reduce, and the filter press can be reused for the next project. For this project, slurry will be dewatered through a filter press. A vacuum belt filter can be used to dewater slurry, because it is efficient and highly automatic. In addition, it has a large production capacity and can be simply operated. After slurry is dewatered, it will be transported to a dump. Transport of slurry should be managed in accordance with the transport management requirement for protection of atmospheric and acoustic environment. In this way, air and noise pollution in the construction area can be effectively reduced.

Sludge treatment is a key part of this treatment system. The aggregate production system for this project produces a total of 2.163 million tons of sandy gravels, of which 1.1392 million tons are needed for the left bank and 1.0238 million tons are needed for the right bank. SS concentration in industrial wastewater is 25000mg/L. After the wastewater is treated, its SS concentration should reduce to 300mg/L. If water is consumed at a rate of 1.0t/m^3 for washing sandy gravels, the system will produce a total of 53,400 tons of silt, about 26,700 m^3. Depending on the situation, some silt can be recycled, and the maximum quantity of recycled silt available is 24,000 m^3. The quantity of sediment to be dumped is 2,700 – 26,700 m^3. The capacity of dumps on both left and right banks is 850,000 m^3 each, while 760,000 m^3 of wastes will be dumped as planned, so the remaining capacity of a dump is sufficient for sediment to be stockpiled.

e) Structure design

The aggregate processing produces 360m^3 of wastewater per hour, i.e. 0.10m^3 of wastewater per second. In flood seasons, rainfall tends to raise the water level of a river. Based on this fact, the maximum design discharge is set at 0.14m^3/s. Based on the local topography, wastewater treatment systems will be generally set up downstream from the aggregate processing system, and each of these systems covers 1800m^2.

Settling pond: two settling ponds (one is for use and the other is a standby) that have co-current flow patterns will be prepared; the horizontal flow velocity is designed to be 0.05m/s; the settling process lasts 1.5 hours; the ponds are cleaned every two days; the pond is 30m long, 15m wide, and 4.0m high.

Reservoir: one rectangular reservoir will be used. It is 15m long, 10m wide, and 3.2m high.

Sludge dewatering system: sludge treatment is a key part of this system. According to the proposal, a set of screw press dehydrators for sludge dewatering will be used. The dehydrator produces 6m^3 of sludge per hour; sludge's water content accounts for 33%-40% of the total.

f) Analysis of the effect of operation and treatment

For Yakou Shipping Hub Project, the treatment system for wastewater produced by the aggregate processing system treats a large amount of wastewater (the maximum capacity is 320m^3/h). The wastewater treatment system covers a small area (only 1/8-1/10 of the area covered by traditional treatment system, for instance, a piece of equipment that treats wastewater at a rate of 200m^3/h covers only 15m^2). It consumes only a small amount of power (only needs to be upgraded once throughout its operation), treats wastewater efficiently and effectively (water produced reaches 5mg/L-70mg/L), and operates at a low cost. In addition, this system operates in a simple way with high investment performance, and its operation does not require human intervention.

g) Feasibility of multipurpose use of wastewater

This proposal has environmental and economic benefits. It has taken into account the terrain of the project area and the following facts: the construction site is strictly limited, the concentration of SS in wastewater is high, and the quantity of sludge is huge. Not only will wastewater be treated, but solids will also be recycled.

The wastewater treatment process focuses on cleaning the wastewater produced by the aggregate processing system for the hydropower project. The process is simple. Precipitation of solids is cost-effective. Treated wastewater can generally be recycled. To ensure that the system operates normally, sand, silt, and mud should be promptly dredged. Quantity of reagents used for wastewater treatment should be controlled in order to ensure the water quality. Efforts should be doubled to monitor the effluent.

7.3.2.2 Treatment of wastewater produced when the batching plant is being rinsed

a) Objectives

Throughout project construction, wastewater produced by the concrete batching system is the water used to flush the batching plant. The wastewater is intermittently discharged from the plant. It contains a high concentration of SS and PH. Wastewater produced when concrete is being mixed with water for this project shall be recycled.

b) Source of wastewater

The concrete batching system consumes 60m^3 of water a day during the peak hours of operation. Wastewater produced by the concrete batching system is the water used to rinse the batching plant during shift changes. The rinse is intermittent and it takes only a few minutes.

c) Recommended process design

As the amount of the aforesaid wastewater is small and the rinse takes only a short time, it is proposed that a rectangular settling pond should be used for treating wastewater. Wastewater should be discharged into a quiescent basin during a shift change and should not be discharged from the basin until the next shift change. The settling process is simple and the settling pond is built as a low cost. Sludge can be cleaned out on a regular basis. See chart 7.3.2-2 for treatment steps for wastewater produced by the concrete production system.

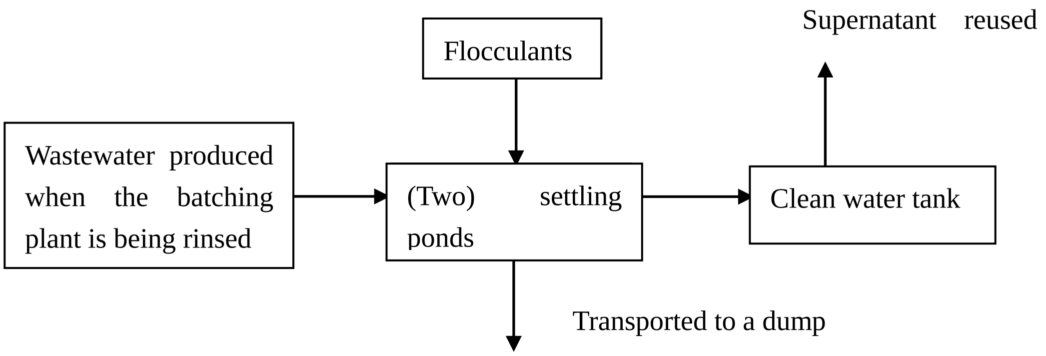


Chart 7.3.2-2 Treatment proposal for wastewater produced when the batching plant is

being rinsed

The continuous working time of a settling pond in the batching plant is not set. Wastewater produced when the batching plant is being rinsed is discharged into a settling pond (the other settling pond is a standby). Wastewater will stay precipitated for 7hours -8hours in the pond. After precipitation, it will be discharged outside the pond. If necessary, flocculants will be used. The settling pond's outlet is set movable so that the pond can be cleaned and the water level of the pond can be regulated. The standby pond will be used when sediment in the first settling pond reaches a certain level. The sludge in the first pond will be naturally dried, following which, the sludge can be scooped out by a grab machine and transported to a dump. After wastewater is precipitated by using flocculants, it can be pumped out of the pond to a clean water tank by a clean water pump.

d) Structure design

The treatment system for wastewater produced by the concrete batching system flows at a rate of $60m^3/d$. If wastewater is discharged for 10 minutes at the end of working time of a settling pond, and the working time of a settling pond is divided into three shifts, wastewater will be discharged at a rate of $0.005m^3/s$. If wastewater stays in the treatment system for two days, supernatant will be pumped to a clean water tank at the beginning of the third shift. The design size of a settling pond is 4m×3m×3m, exceeding the actual height by 0.3m. The design size of a clean water tank is 4m×3m×3m. Two settling ponds are alternately used every five days. Sludge in the ponds can be scooped out by a grab machine and transported to a dump nearby.

e) Feasibility analysis and safeguard measures

According to this proposal, relevant workers need to put the mixture of copperas and PAM (polyacrylamide) into resettling ponds as a way to reduce the concentration of SS and the alkalinity of water in the ponds. After wastewater is treated, supernatant will be pumped to a clean water tank in an attempt to ensure the water quality. The water level of the water pump should be maintained at the supernatant level when water is being pumped. Efforts should be doubled to control the quantity of reagents and monitor the effluent in order to ensure its quality.

7.3.2.3 Treatment of wastewater produced by the maintenance system

a) Objectives

The main pollutants in wastewater produced by machinery maintenance in the construction area are SS and petroleum. Such wastewater is known as oily wastewater; its oil concentration is 20mg/L ~ 40mg/L. The river segment where the construction area for this project is located lies upstream from the Yicheng Drinking Water Source Reserve. After oily wastewater is treated, it will be reused by businesses. The general processing plant for the project produces 20m^3 of wastewater per day.

b) Recommended process design

Oily wastewater produced by the maintenance system for this project can be treated through an oil separator. See chart 7.3.2-3 for the treatment steps. Oily wastewater produced in the construction area is intermittently discharged. The oil separator is designed to treat 20m^3 of oily wastewater per day; the horizontal flow velocity is designed to be 0.055m/s; oily wastewater stays in the oil separator for 10 minutes; oil and sludge in the oil separator should be cleaned out every 7 days. The whole set of the oil separator, covering 100m^2, is set up beside the processing plant.

Oily wastewater → Small oil separator → Clean water tank → Supernatant recycled

Chart 7.3.2-3 Designed steps for oily wastewater treatment

See figure 7.3.2-4 for the structure of a small oil separator. Waste oil is removed from water by an oil skimmer floating in the oil separator; wastewater is then further deoiled through a coke filter. This treatment is simple, cost-effective, and practical.

c) Treatment effect analysis

The main equipment of this treatment system is a small oil separator. It can operate whenever pipes are well connected. The design of the separator is based on the specific gravity difference between the oil and the wastewater. The equipment's inlet, outlet, and oil discharge work automatically; the equipment can operate without human intervention; generally, it can be controlled by only one person. The quantity of oily wastewater is small; after oily wastewater is treated, it can be used to wash vehicles.

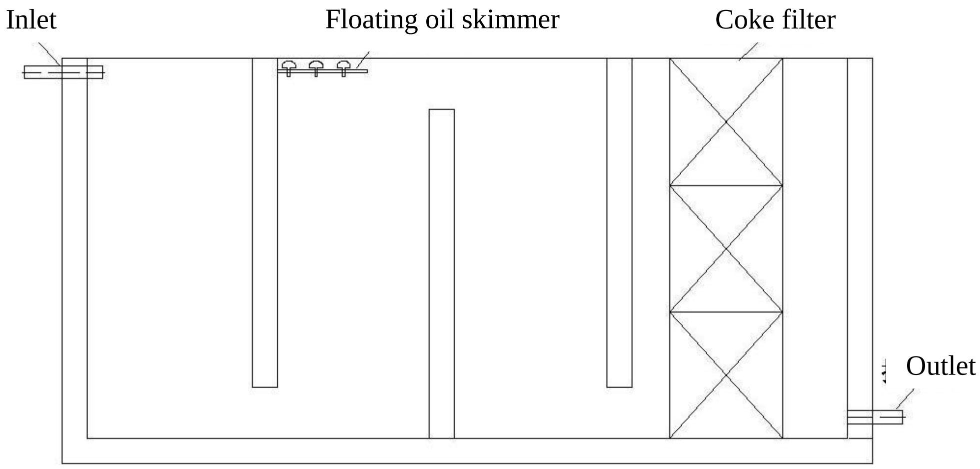


Fig. 7.3.2-4 Small oil separator

7.3.2.4 Treatment of water in foundation pit

a) Water in foundation pit

Water in the dam's foundation pit consists of rainfall and water seepage; its main pollutant is SS. According to data on monitoring of wastewater in foundation pits for other hydropower projects in China, the SS concentration and pH of wastewater in foundation pits are 2000mg/L and 11-12 respectively. Affected by mechanical fuel oil, transport by road, blasting, and construction activities, the wastewater in foundation pits contain a small quantity of mineral oil.

b) Treatment design proposal

The wastewater in foundation pits is alkaline; it contains a high concentration of SS. According to treatment of wastewater in foundation pits for other hydropower projects in China, wastewater in foundation pits is generally treated with the flocculants put into foundation pits. The wastewater stays in the pits for 2 hours for precipitation. After settling, the supernatant can be reused and the remaining sludge will be removed from the pits on a regular basis. Such wastewater treatment techniques are effective and economical. See chart 7.3.2-5 for the treatment steps. This proposal only entails that flocculants should be put into foundation pits on a regular basis, but it does not entail any investment in infrastructure construction.

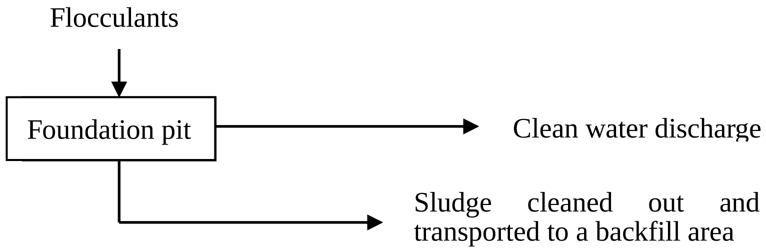


Chart 7.3.2-5 Designed steps for treatment of water in foundation pits

c) Treatment effect evaluation

Based on the results on effective monitoring of water quality, flocculants should be added properly at the right time so that wastewater in foundation pits can be effectively treated as required.

7.3.2.5 Domestic wastewater treatment

a) Objectives

The main pollutants of domestic wastewater in the construction area are BOD_5 and COD. After domestic wastewater is treated, the effluent should meet the Standard A under Standard Class I of the *Discharge Standard of Pollutants for Municipal Wastewater Treatment Plant* (GB18918-2002), which will be used to watering the construction area and reducing dust. The concentrations of COD, BOD_5, SS, oil, total nitrogen, and total phosphorus in domestic wastewater are 50mg/L, 10 mg/L, 10 mg/L, 1 mg/L, 15 mg/L, and 0.5mg/L respectively.

b) Sources of wastewater

According to the construction plan for the Yakou Shipping Hub, during construction peak periods, the number of construction workers is 1,500. If wastewater produced by construction workers is 80% of 250 liters per person per day (average water use per person per day), wastewater produced by every construction worker will average 200L a day; domestic wastewater produced in the construction area will be 300m^3 a day. Domestic wastewater produced during hydropower project construction comes primarily from washing and the discharge from bathrooms and canteens. A large quantity of domestic water is used during construction. Pollutant concentrations in domestic wastewater produced in the construction area are lower than those produced in urban areas.

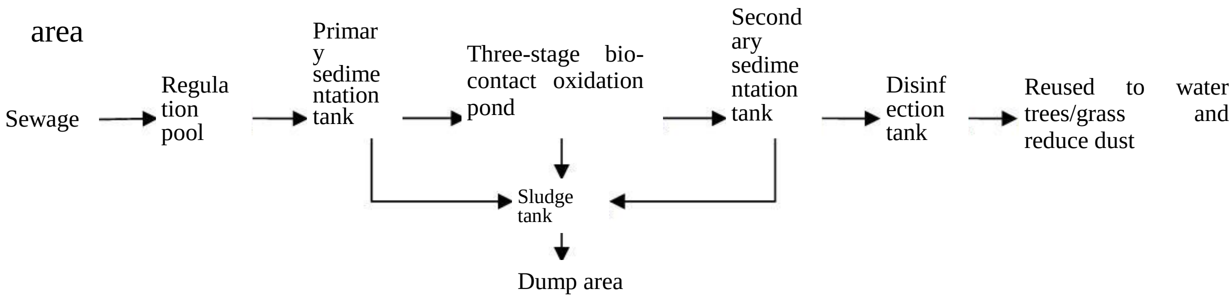
c) Recommended process design

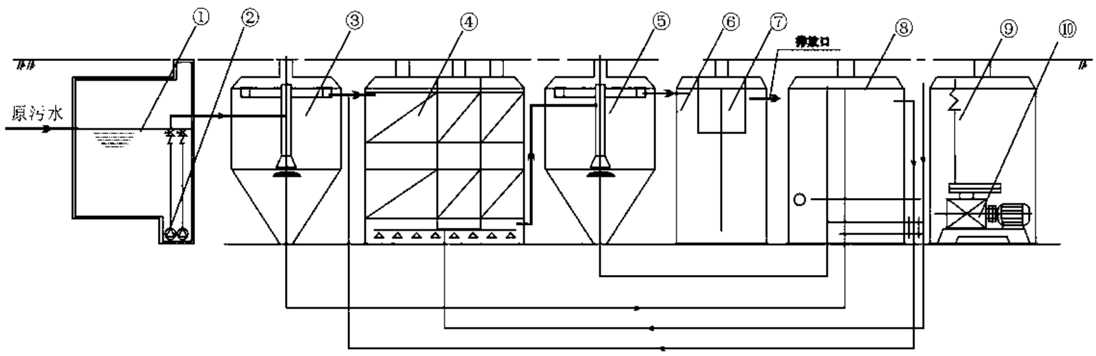
It is recommended that a complete set of domestic wastewater treatment equipment should be used to treat wastewater produced in the living quarters during project construction. Comparing with a septic tank, a complete set of the equipment costs more, but it is more efficient and effective. It covers a smaller area and operates simply, and it can be reused.

As low-concentration organic wastewater, domestic wastewater has a strong biodegradability and a wide variety of nutrient elements. Moreover, it is less likely to be contaminated by heavy metal ions. Three-stage bio-contact oxidation pond is used in the integrated treatment equipment. An equalizing basin is installed to regulate the quality and flow of water. The aerating system uses jet aerators.

Construction camps are arranged on both left and right banks according to the construction layout, so two sets of domestic wastewater treatment systems need to be installed. On the left bank, the domestic wastewater treatment facilities are built within the campsite. Wastewater produced by construction supervisors and workers as well as by PIU is treated at a rate of 200 m^3/d and 150m^3/d respectively. WSZ-AO series of sewage treatment equipment will be used to treat domestic wastewater. The equipment contains a pool body having steel structure that can be buried underground. Based on the quantity of wastewater to be treated, WSZ-A-20 equipment will be used. The capacity of a biological pool is set at 800m^3. According to analysis of relevant data, the treated domestic sewage can meet the Standard A under Standard Class I of the *Discharge Standard of Pollutants for Municipal Wastewater Treatment Plant*.

See diagram 7.3.2-6 for the treatment steps for domestic sewage in the construction area





① Regulation pool ②submersible sewage pump ③ primary sedimentation tank ④ three-stage bio-contact oxidation pond ⑤ secondary sedimentation tank

⑥disinfection tank ⑦ disinfection device ⑧ sludge tank ⑨ ventilator room ⑩ fan

Diagram 7.3.2-6 Treatment steps for domestic wastewater in the construction area and Treatment process through WSZ-A equipment

The equipment’s primary sedimentation tank is a vertical-flow settling pond. After wastewater is treated, it automatically flows to a bio-contact oxidation pond, where it will be further treated. The pond involves three stages; wastewater stays in the pond for at least 4 hours in total. Wastewater that has gone through biochemical process flows to the secondary sedimentation tank that consists of two vertical-flow settling ponds operating in parallel; the ascending flow rate is 0.3mm/s-0.4mm/s. Sludge is pumped up to a and it is discharged from the tank. Wastewater goes through the secondary sedimentation tank and then enters a disinfection tank, where it stays for 30 minutes to be disinfected. After it, disinfected wastewater is discharged to a clean water tank. Before wastewater enters a complete set of treatment equipment, the set of equipment needs to be equipped with an additional sewage regulation pool to regulate the quality and quantity of domestic sewage. Based on the quantity of sewage, the regulation pool is designed to be 5m×4m×3m.

The equipment can be easily operated and maintained. It has a long service life. The equipment treats wastewater in a sludge-free way, so it will not pollute the environment. Water in the clean water tank can be used to water the construction area and reduce dust in the area.

d) WSZ-A equipment management

After the equipment is installed, it shall be filled up. Tests should be carried out to ensure that pipes are leakproof. The sinks of the two secondary sedimentation tanks should be adjusted to be at the same level. After it, soil can be used to fill the space between equipment and then be leveled. A regular maintenance system must be established for the equipment, especially for the fans and water pumps that are susceptible to damage. For instance, if sewage enters the equipment, the equipment must be cleaned up and its engine oil must be replaced before it operates again; before a fan is turned on, workers must check if the air lock is open. Wastewater should be pumped into the equipment at rated flow. Workers need to turn on the fan for aeration and keep track of the fillings in the bio-contact oxidation pond on a daily basis. A fan shall be maintained every 10,000 hours for which it operates; a water pump shall be maintained every 5,000 hours-8000 hours for which it operates.

e) Operation and treatment effect analysis

Using a complete set of equipment to treat domestic sewage can be effective. The treated wastewater is expected to meet the Standard A under Standard Class I of the *Discharge Standard of Pollutants for Municipal Wastewater Treatment Plant*; it can be used to water the construction area and reduce dust in the area. The set of equipment covers a small area of land; it is highly automatic and controllable.

7.3.2.6 Wastewater treatment system operation management

a) Water treatment system operation management in the construction area

Wastewater treatment system workers shall have expertise in the field. They shall receive relevant technology and management training provided by the equipment manufacturer before their work begins. To ensure that all wastewater treatment systems operate normally and stably, operators shall strictly follow the SOP (standard operating procedure) to correctly operation the equipment and regularly maintain it.

Should any problem be identified, operators shall promptly report it to environmental authorities so as to have it fixed.

① To ensure wastewater treatment system operates effectively, relevant parties may as well include the building and effective operation of wastewater treatment systems in the project contract as one of its articles.

② Environmental supervision organizations for this project shall regularly inspect the operation of wastewater treatment systems so as to keep track of the operation and provide oral or written rectification advice should any problem arise.

③ Wastewater treatment system workers shall receive relevant technology and management training before their work begins. Operators shall strictly follow the SOP to correctly operation the equipment and regularly maintain it. Should any problem be identified, operators shall promptly report it to supervisors and construction contractors so as to have it fixed.

④ The set of equipment shall be debugged before its operation officially begins. Optimum amount of agents to be put into water shall be determined, so as to ensure that the quality of an effluent meets the standard and the equipment operates at a minimum cost.

⑤ Promptly removing sediment and sludge away from the equipment is a key to ensure that wastewater treatment systems operate normally, so importance shall be attached to system operation management.

⑥ Funds earmarked for operating and managing wastewater treatment systems shall be used for this purpose only, so as to ensure normal operation of the systems.

b) Balance of water supply and drainage in the construction area

During project construction, the total quantity of wastewater discharged from the construction area is 4700m^3 per day. Contaminated water consists of domestic sewage oily wastewater, and wastewater produced when sand-gravel aggregate is being processed or when concrete is being mixed. Main contaminants in wastewater (sewage) are SS and pH. Industrial and domestic wastewater produced in the construction area has been treated (the treated wastewater meets the relevant standard) and reused. The treated water can be used for watering construction sites and roads and reducing dust in these areas; it can also be used to water trees/grass in these areas and wash the batching plant and vehicles. See table 7.3.2 for balance of daily wastewater supply and drainage.

Table 7.3.2 Balance of daily wastewater supply and drainage for Yakou Shipping Hub Project construction

Wastewater categories	Quantity of water supply (m^3/d)	Quantity of water used or consumed (m^3/d)	Wastewater quantity (m^3/d)	Quantity of reused water (m^3/d)	Quantity of remaining wastewater (m^3/d)
Wastewater produced during aggregate processing	4320	432	3888	3888	0
Wastewater produced when concrete is being mixed	60	6	54	54	0
Oily wastewater	20	2	18	18	0
Domestic sewage	300	20	280	280	0
Total	4700	460	4240	4240	0

After wastewater produced during aggregate processing and when concrete is being mixed is treated, it can be reused for washing the aggregate processing system and the batching plant if it meets the quality standard of water to be reused. The quantity of treated oily wastewater is small. There is a lot of equipment in a construction machine works, so the treated oily wastewater can be used to reduce dust in the machine works, and the remaining water can be used to wash vehicles. A large quantity of the treated domestic sewage can be used to reduce dust on roads. If the quantity of the treated domestic sewage exceeds the quantity of water used for watering roads, the exceeded quantity can be used to wash vehicles and water trees/grass; the treated domestic sewage can generally be used up.

7.3.3 Water quality protection measures for operation period

7.3.3.1 Measures for treating wastewater (sewage) in the hub area

a) Domestic sewage treatment

The PIU premises will serve as permanent living quarters for workers responsible for operation of power stations. Workers staying in the living quarters during operation will not outnumber those working during construction. Therefore, the domestic sewage treatment facilities built during construction can be also used to treat domestic sewage produced during operation. It is recommended that the WSZ-A equipment should still be used to treat domestic sewage. The regulation pool needs to be properly renovated.

After domestic wastewater is treated, the effluent should meet the Standard A under Standard Class I of the *Discharge Standard of Pollutants for Municipal Wastewater Treatment Plant* (GB18918-2002), which will be used to watering the construction area and reducing dust. The concentrations of COD, BOD_5, SS, oil, total nitrogen, and total phosphorus in domestic wastewater are 50mg/L, 10 mg/L, 10 mg/L, 1 mg/L, 15 mg/L, and 0.5mg/L respectively. The remaining sludge will be dried; the dried sludge and domestic waste will be treated together. As the plant area is large, water demand of the project can be met. Therefore, it is feasible for the treated domestic sewage to be used for watering tree/grass and reducing dust in the plant area.

b) Oil contamination prevention and control measures

Oil used by power stations when they are operating can be divided into turbine oil and insulating oil, which are stored in turbine oil tanks and insulating oil tanks respectively. When power generators and transformers are being examined and repaired, dirty oil in oil pipes and bearings shall be collected and stored in dirty oil tanks. Oil systems have all been equipped with oil treatment equipment. Recyclable dirty oil can be reused after it is treated through turbine oil treatment equipment, while unrecyclable dirty oil should be collected and disposed of by qualified organizations. In case of an explosion or leakage, waste oil will be retained in the chamber of an oil tank that has oil baffles, thus it will not be leaked.

Oily wastewater produced during the operation of power stations is water used for washing the ground onto which oil leaks from turbine oil or insulating oil treatment equipment and pipes when they are being examined and repaired. To prevent and control oil pollution, relevant parties shall strengthen management to prevent oil leaks and ensure cleaner production. In addition, they shall also build a sump pit in the oil treatment chamber to collect oily wastewater which will be treated through oil-water separators and then be reused to water roads, flowers, and trees. Two oil-water separators, each having a capacity of $10m^3/h$, will be used. Oil contained in the wastewater treated through the oil-water separators may fall to below 5mg/L.

7.3.3.2 Cleaning up the reservoir zone

a) Area to be cleaned up

To ensure that the Yakou Shipping Hub operates safely and to prevent water contamination, the reservoir zone must be cleaned up before impoundment begins. Relevant parties shall follow the *Design Specifications for Cleaning of Reservoir Zone of Hydroelectric Project* (DL/T 5381-2007) when cleaning the reservoir zone. Cleaning of the reservoir zone includes sanitation, the demolition of structures, and the cleaning of woodland. The reservoir zone within its backwater line shall be cleaned up.

b) Technical requirements

With regard to demolition of buildings and structures, buildings and outbuildings within the area to be cleaned shall be demolished; boundary walls, chimneys, walls (except cob walls) shall be demolished; waste materials that tend to float and cannot be reused shall be removed from the reservoir and burned down.

With regard to sanitation, the sources of pollution to the area that is to be cleaned shall be sanitized. Contaminants from livestock enclosures, toilets, cesspools, biogas digesters, and dumps shall be removed to a proper location outside the reservoir. If contaminants are hard to be removed, the livestock enclosures, toilets, cesspools, biogas digesters, and dumps shall be exposed to the sun and sanitized with 0.5-1.0kg of quick lime per square meter. Sump pits shall be filled up with uncontaminated soil. Graves in the area shall be relocated by local residents in accordance with their own will. Pits that remain after graves are removed shall be sanitized with bleaching powder. The graves that no one has claimed can be disposed of in other ways. The reservoir zone shall be cleaned under the guidance of the local health and epidemic prevention department.

With regard to cleaning of woodland, trees, shrubs, and remaining floats in the gardens and woodland that are to be cleaned shall be felled, transplanted, or transported elsewhere. The amount of work entailed in cleaning gardens and woodland shall be determined based on the area to be cleaned; the amount of work entailed in removing scattered trees shall be determined based on the number of trees to be removed.

7.3.3.3 Water pollution control for the reservoir area

To tighten water pollution control for the reservoir area, Xiangyang Municipal Government has developed a *Han River (Xiangyang Segment) Water Pollution Prevention and Control Plan*. The plan, covering the Yakou Shipping Hub reservoir area and Tangbai River segment in Hubei, is designed to ensure that the water quality of the Han River segment in Xiangyang meets the water functional zoning requirement. It guarantees a favorable environment for the Yakou Shipping Hub Project development. See appendix 19 for details.

The plan aims to ensure that water pollutants discharged from key industrial enterprises meet pollutant discharge standards. It also aims to achieve the following goals: key industrial pollutants (COD (chemical oxygen demand), ammonia nitrogen) are decreasingly discharged year by year; COD and ammonia nitrogen in industrial wastewater in the Yakou Shipping Hub reservoir decrease by 70%; the quality of water in the reservoir area is expected to improve. The quality of water in Xiangyang municipal districts shall meet the water environmental functional requirement. The quality of eighty percent of water (excluding the border of water between Xiangyang and Henan) in Xiangyang under national and provincial monitoring shall be better than water quality Class III and shall not be worse than water quality Class V. Both one hundred percent of water flowing from Xiangyang and one hundred percent of water flowing from Xiangyang's concentrated drinking water sources shall meet relevant quality standards.

a) Industrial pollution source control

1) Industrial park wastewater treatment project

Priority will be given to the implementation of the Laohekou Chenbu Science Park Project, Yicheng Leida Industrial Park Project, and Gucheng Jiangkai-district Niejiatan Sewage Treatment Plant and Sewage Interception Pipe Network Construction Project. Other counties (cities) shall also step up sewage treatment facility construction for industrial parks within counties, so that all industrial parks at county level or above will be equipped with sewage treatment facilities by 2016.

According to surveys, Yujiahu sewage treatment plant has been built in the upper reaches of Wangjia dagou, a primary pollution source of the Yakou reservoir area. Yujiahu sewage treatment plant, located in Xiangcheng economic development zone in Xiangyang, is infrastructure supporting the development zone. The total scale of plant construction is 50,000 tons a day, and the phase I scale of construction is 25,000 tons a day. The plant is designed to treat the industrial wastewater produced in the economic development zone and domestic sewage produced in Oumiao Town by using A^2O oxidation ditch. Commercial operation of the plant began in April of 2012. Currently, the plant generally treats industrial wastewater discharged from the Yujiahu and Baokang Industrial Parks.

2) Key industrial pollution source control projects

Environmental pollution control will focus on enterprises involving lead that are located in Gucheng and Laohekou along the Han River, the phosphate mining and processing enterprises along the south Baokang river, Hubei Denglin Farm Chemical Fertilizer Plant, and other nitrogen and phosphate fertilizer producers, so as to remove the hidden risk that heavy metal and phoschemical industry may contaminate water. Dangerous wastes, hazardous chemicals, and tailings ponds shall be strictly managed, and a pre-emergency prevention and emergency response system shall be established for emergencies caused by the aforesaid items. Industrial wastewater produced by the chemical, chemical fiber, medicine, papermaking, printing and dyeing, electroplating, brewing, and meat processing industries shall be treated, so as to ensure that industrial enterprises along the river meet wastewater discharge standards. Enterprises that tend to pollute the environment, such as small electroplating enterprises and small chemical enterprises, shall be banned from conduction business. In addition, efforts shall be made to ensure that these closed-down enterprises will not operate again.

(1) Tightening key pollution source control

In 2015, the special pulp production line and wastewater treatment facilities of Hubei Golden Ring Co., Ltd were upgraded. The industrial wastewater treatment facilities and technologies of the following companies/organizations were upgraded: Huazhong Medicine Industrial Park, Baokang Yaozhihe Chemical Co., Ltd. Hubei Shierjia Fertilizer Co., Ltd. Sanhui Electric Co., Ltd. Hubei Fengli Chemical Co., Ltd. and Hubei Denglin Farm Xiangdeng Chemical Fertilizer Plant. Wastewater treatment facilities and technologies of the following companies were upgraded: Hubei Jinyang Metallurgical Incorporated Co., Ltd. Hubei Chukai Metallurgy Co., Ltd. Xiangfan Dongfeng Tianshen Storagebattery Co., Ltd. and Hubei Runyang New Energy Co., Ltd. Water reuse projects for these companies were completed.

In 2016, pollution control and the ecological restoration projects will be completed for the following mining areas: Liuzhuya phosphate mine of Xiangyang Fengrong Phosphorization Co., Ltd. Baizhu phosphate mine of Baokang Yaozhihe Phosphorization Co., Ltd. Jiulichuan phosphate mine of Baokang Yaozhihe Mining Co., Ltd. and Chufeng phosphate mine of Baokang Chufeng Chemical Co., Ltd.

According to surveys, Hubei Denglin Farm Chemical Fertilizer Plant which is located in the Yakou Shipping Hub reservoir area has not been equipped with an effective wastewater treatment system because the plant’s current water cycling system has yet to be improved. Industrial wastewater produced by the plant is being treated. The wastewater containing ammonia nitrogen has been treated through A-O/SBR system.

It is proposed that the gas desulfurization wastewater treatment system adopts the micro-vortex coagulation process owned by Xuzhou Research Institute of Water Treatment. The investment entailed for the wastewater treatment system, totaling 4.1326 million Yuan, will be jointly made through BT cooperation by Hubei Denglin Farm Chemical Fertilizer Plant and Hangzhou Worun Energy-saving Technology Co., Ltd. The system was expected to be put into operation by the end of 2015.

(2) Main pollutant emissions reduction

In 2017, pollutant emissions reduction projects for the following companies will be completed: Hubei Landai Beer Co., Ltd. Xiangfan Chutian Chemical Fiber Co., Ltd. Hubei Dongfang Chemical Industry Co., Ltd. Xiangfan Wanbao Cereals. & Oil Co.,Ltd. and Wuhan Railway Bureau-Jiang'an Xiangyang Vehicle Accessories Factory. Main pollutant emissions reduction projects will be completed for the following organizations: Chenbu Wastewater Treatment Plant in Laohekou City, Niejiatan Wastewater Treatment Plant in Gucheng County, Wastewater Treatment Plant of Baokang County (increasing 10,000t/d). In addition, Zaoyang's East Xinglong River wastewater treatment project and the wastewater treatment plant upgrading project for the Xiangyang Thermal Power Plant of Dongfeng Company will also be completed.

(3) Closing down "new five small" and "fifteen small" enterprises

By the end of 2015, all "new five small" and "fifteen small" enterprises that pollute the environment will be closed down. These enterprises include Lü Zhaoliang's small plating factory (Lü Zhaoliang is from Luzhai Village of Tuanshan Town in the high-tech zone), the small plating production line of Junhaoxing Machine Shop in Mizhuang Town in the high-tech zone, the small plating production line of Zhongxinghe Machine Shop in the high-tech zone, Wang Chuanying's small plating factory in the high-tech zone, and Hu Kui's small plating factory in the high-tech zone.

b) Domestic pollution source control

1) Downtown sewage treatment plant upgrading project and pipe network building project

Taipingdian sewage treatment plant shall be built within the deadline and put into operation; the sewage treatment plant in the Yujiahu Industrial Park shall be upgraded and put into operation; the sewage treatment plant construction project in the New Dongjin district shall be implemented without delay; sewage treatment projects for all industrial parks in downtown areas shall be implemented.

(1) In 2015, Taipingdian sewage treatment plant construction project, Yujiahu Industrial Park sewage treatment plant upgrading project, and Longzhong area-Xiangcheng sewage interception pipe project shall be completed; the sewage interception pipe project for the area from New Xiangnan District to the south inner ring road shall be completed.

(2) In 2016, west Zhangwan urban sewage interception main pipe project, Oumiao Town-Yujiahu Sewage Treatment Plant sewage interception main pipe project, and New Dongjin District sewage network project-phase I will be completed; New Dongjin District sewage treatment plant construction will start.

(3) In 2017, sewage inception main pipe project for the area in the north to Dengcheng road, Oumiao Town-Yujiahu Sewage Treatment Plant sewage interception main pipe project, Mizhuang-Mingcheng Road sewage interception main pipe project, and New Dongjin District sewage treatment plant project will be completed. Meanwhile, the rain sewage diversion system reconstruction project will be implemented for old quarters so that urban sewage treatment plants collect over 90% of urban sewage.

According to the above information, Yujiahu wastewater treatment plant focuses on the treatment of the industrial wastewater produced in the Xiangcheng economic development zone and the domestic sewage produced in Oumiao Town. Construction of Yujiahu wastewater treatment plant began in October of 2009. Yujiahu Wastewater Treatment Plant Project-Phase I was completed in July of 2011. However, construction of domestic sewage network for the area between Oumiao Town and Yujiahu wastewater treatment plant has yet to begin.

2) County-level wastewater treatment plant upgrading and sewage network project

Expansion of county (city)-level urban sewage treatment plants and construction of supporting sewage network shall be accelerated, so as to form a sewage network that covers all built-up areas. By the end of 2016, Laohekou Open Channel Project, Zaoyang Shahe Project, and Yicheng Yidao Ditch Project, as well as Rain Sewage Diversion System Project shall be implemented. These projects are designed to increase the efficiency of the current urban sewage treatment facilities and ensure that county (city)-level sewage treatment plants collect over 90% of sewage by the end of 2016.

According to surveys, Yakou Reservoir Yicheng Sewage Treatment Plant Project-Phase I has been completed; the Phase I plant treats 20,000tons of sewage per day on average. The Project-Phase II has been included in the urban development plan. The Phase II construction site is located in the west to the Phase I construction site. The Phase II plan will treat 20,000 tons of sewage per day on average. An additional ￥44.6 million investment is expected to make. The project will serve 160,000 people over an area of 25km^2. A main urban sewage pipeline that is 8.1km long is being built for the urban sewage network project.

3) Township sewage treatment plant construction and sewage pipeline construction project

Construction of sewage treatment plants and supporting sewage network for the villages and towns along the Han River began in 2015 and will be completed by the end of 2017, which will form a sewage network that covers all built-up areas.

c) Control for non-point sources of agricultural pollution

1) Animal husbandry

The arrangement of farms shall be optimized, the number of animals to be bred and raised shall be properly controlled, and breeding methods shall be improved. Environment-friendly breeding methods shall be promoted. Excrement and wastewater produced by livestock shall be collected and treated. Efforts shall be taken to prevent and control pollution caused by animal husbandry. Emission standards for animal husbandry shall be strictly followed in order to ensure that the annual target of emission reduction for farming can be achieved.

(1) In 2015, Hubei Liangyou Jinniu Animal Husbandry Technology Co., Ltd. and seven other large-scale animal husbandry businesses closed down their farms in the areas where livestock breeding and raising is banned.

(2) In 2016, Xiangcheng Guanshan Animal Husbandry Cooperative and twelve other farms where large-scale animal husbandry is carried out shall meet the total discharge reduction target. The farms in the areas where livestock breeding and raising is restricted shall meet the emission standards, or resources on these farms are generally recycled.

2) Crop farming

Pollutants produced by crop farming can be reduced by properly using pesticides and chemical fertilizers, by testing soil for formulated fertilization, and by changing the method of fertilization. These measures can increase the chemical fertilizer use efficiency. Crop farming system shall be adjusted in order to prevent and control pollution. The use of a recycling agricultural production system shall be promoted so that pollutants can be recycled through the system and thus pollutant emissions will be reduced. Relevant parties shall tighten pesticide-market regulation and encourage the use of highly effective and safe pesticide products whose toxicity is low. New types of crop protection machinery and technologies shall be promoted. The pesticide use efficiency shall be improved.

3) Aquaculture

Both pollution and eutrophication of some river basins and segments come primarily from aquaculture. Aquaculture activities shall be carried out in such a way that aquatic ecosystem will not be disrupted. The amount of baits put into water shall be minimized. The use of recycled pond water shall be promoted for aquaculture and a wetland system shall be built in order to recycle the water that has been used for aquaculture.

7.3.3.4 Protection measures for drinking water sources

a) Protection measures for drinking water sources

The following measures shall be taken to protect the water intakes of various water works: water quality monitoring shall be strengthened and the information of water quality shall be reported to authorities in a timely manner; reservoir water quality monitoring and study shall be intensified in order to keep track of the change in distribution of main pollutants in water bodies, so that measures can be taken to prevent water contamination.

Water works generally use activated carbon adsorption to remove nitrogen from water flowing out of the intakes of water works in the reservoir area as a way to ensure the quality of drinking water. It is recommended that drinking water should go through advanced treatment in order to ensure its quality. Advanced treatment refers to treatment of macromolecular organic substances in drinking water, in addition to the traditional water treatment steps including coagulation, precipitation, filtration, and disinfection. In general, advanced treatment of drinking water entails ozone-activated carbon, membrane separation, biological activated carbon, and stripping.

In addition, relevant parties shall develop an emergency plan and system for responding to water contamination in the Han River in order to prevent any accidents from contaminating the source of drinking water. Pollution levels, the details of establishing an emergency center, and emergency measures shall all be explicitly stated in the emergency plan.

b) Yicheng water source reserve

1) In the drinking water source reserve, relevant parties can dredge the reservoir zone several times, green the banks of the reservoir area, build revetments, turn reclaimed farmland into forests, reduce the impact of pesticides and chemical fertilizers to water quality, and conserve water and soil along the banks of the reservoir area, so as to ensure the quality of water sources while beautifying the environment of the reservoir area.

2) A drinking water source protection plan shall be developed and improved. Fishing, berthing, swimming, and any other activities that may contaminate water

sources are banned in the water area that is no more than 100 meters from a water source. Water suppliers shall put up signs for the aforesaid water area and the bans.

3) Pollution sources in the water source reserve shall be thoroughly inspected. The focuses of pollution prevention and control shall be determined based on the emissions of various pollution sources.

4) The arrangement of and pollution prevention and control for the drinking water source reserve shall be included in the Yicheng economic and social development plan and water pollution prevention and control plan.

5) Relevant parties shall strictly follow the regulations on drinking water source pollution prevention and control in order to prevent water contamination and ensure the quality of drinking water. Water pollution incidents are increasing, so water authorities shall take proactive measures to prevent pollution incidents, strictly enforce the regulations on pollution prevention and control for the water source reserve, and intensify supervision over enterprises that fail to meet the emission standards.

6) A water environment monitoring network shall be established for dynamic monitoring of the quality of the Han River water. Relevant parties shall improve the water quality monitoring network and properly set up water quality monitoring stations for drinking water sources, so as to keep track of dynamic changes in the quality of urban water sources. They shall also regularly publicize information regarding the quality of drinking water sources.

7) A system of total discharge control and emission permits shall be implemented. A system of emissions reporting, registration, and permits shall be implemented in the water source reserve in order to review, approve, and limit total discharge. Wastewater (sewage) discharge must be strictly controlled, so that the water environment can be effectively protected, ecological balance can be maintained, and harmony between man and nature can be achieved.

7.3.3.5 Eutrophication prevention and control

Eutrophication of the reservoir water is generally caused by the following factors:

nutrient substances, climate, reservoir operation methods, and the chemical property and biological property of the reservoir water. Eutrophication prevention measures, such as controlling pollution sources, shall be taken to protect water quality.

a) Relevant parties shall strengthen water resource protection publicity and dissemination by intensifying the publicity of *Water Law*, *Environmental Protection Law*, *River Regulations*, and *Regulation on Water Pollution Prevention and Control*. They shall raise public awareness of the importance of reservoirs to the living environment.

b) The reservoir water quality and quantity shall be effectively monitored and assessed. The cross section of the major river courses upstream from the reservoir shall be regularly monitored. The people's governments at various levels shall prevent and control water pollution and protect the water environment by developing water environmental protection policies and intensifying supervision over the enforcement of environmental protection laws. By establishing a strict accountability system, governments can ensure that water pollution will be prevented or controlled. A legal system and a law enforcement agency shall be established to help motivate enterprises to double their efforts in preventing and controlling water pollution.

c) Efforts shall be doubled to conserve water and soil in order to reduce soil erosion. Soil erosion is particularly bad in the reservoir surrounding area, so soil erosion shall be prevented or controlled by using a combination of tillage, engineering measures, and mitigation measures. By treating small river basins, a new pattern of water and soil conservation will take shape. Increasing the area covered by vegetation in the reservoir surrounding area and along the river upper reaches will greatly reduce nutrient substances entering the reservoir area.

d) Improving soil fertility and promoting environment-friendly fertilization are measures required for increasing agricultural output. However, overuse of chemical fertilizers will not only increase the cost of farming, but it will also cause the loss of nutrient substances, causing eutrophication to occur in the downstream reservoir water bodies. Therefore, an environment-friendly farming project should be launched in the river upper reaches, and new agricultural technologies shall be promoted. Oversupply of nitrogen fertilizers can be avoided by changing the method of fertilization. Such measures as implementing a irrigation system, properly growing crops, promoting the use of new compound fertilizers and controlled-release fertilizers can effectively control the use of fertilizers and thus reduce the non-point sources of agricultural pollution. Nitrogen and phosphorus losses from agricultural runoff can be reduced by conservation tillage, crop rotation, and water saving irrigation. Eutrophication of the reservoir water can be prevented and controlled by adjusting the agricultural structures and limiting the use of chemical fertilizers such as nitrogen and phosphorus fertilizers.

e) Phosphorus-free synthetic detergents will be used. Nitrogen and phosphorus shall be removed from wastewater. Detergents used in households contain a relatively large amount of phosphorus, which accounts for 9.2%-15.5% of a detergent. Fifty percent to seventy percent of phosphorus in urban domestic sewage comes from detergents, so detergents constitute a main source of nutrient substances in water bodies. Therefore, authorities shall strictly restrict the phosphorus content of synthetic detergents, prohibit the sale and use of detergents containing phosphorus, and promote the use of phosphorus-free detergents. These measures can help prevent phosphorus pollution and the eutrophication of the reservoir water. Nitrogen and phosphorus can be removed from wastewater through a wastewater treatment system. An oxygen-deficient/anaerobic environment can either be formed by the wastewater treatment system or independently created; when oxygenation capacity is changed, the oxygen-deficient/anaerobic environment may become favorable for nitration/denitrification and dephosphorization, thus nitrogen and phosphorus can be removed from wastewater.

7.3.3.6 Total discharge control and environmental management measures

a) Total pollutant discharge control for the reservoir area

1) Industrial restructuring and upgrading shall be pushed ahead; increased pollutant discharge shall be strictly controlled.

Reducing pollutants discharged by key industries remains the focus of total discharge control. Increases of pollutants shall be reduced from their sources. Relevant parties shall tighten pollution control and prevent increases of industrial pollutant discharge.

(1) Authorities shall double their efforts to push ahead industrial restructuring and upgrading, impose high standards on industry access, and renew the discharge and capacity standards for key industries under the condition that these standards are feasible. These measures may in turn press papermaking, textile printing and dyeing, brewing, chemical, and fertilizer industries to upgrade their technologies, improve their development patterns, and reduce the increase of pollutants.

(2) Businesses shall double their efforts to prevent and control industrial pollution, improve pollution control techniques, strictly enforce industrial pollutant discharge standards, ensure their production is environment friendly, and reduce pollutant sources and discharge.

2) Counties and key towns shall accelerate construction of wastewater treatment facilities and improve the environmental performance of these facilities.

(1) The wastewater load of treatment plants and the coverage of urban sewage network shall be increased.

(2) Proper steps shall be taken to facilitate the construction and operation of industrial wastewater treatment plants.

(3) Urban wastewater treatment facilities' performance on removing nitrogen and phosphorus from wastewater shall be improved. Urban wastewater treatment plants shall meet pollutant discharge standards as required.

(4) Emission reduction efforts shall include construction of sludge treatment facilities.

(5) Recycled wastewater shall be continuously increased; wastewater recycling methods shall be determined.

3) Sources of agricultural pollution shall be included in the total discharge control system; pollution caused by animal husbandry shall be prevented or controlled.

Sources of agricultural pollution will be included in the total emission reduction system for the farms and communities where large-scale animal husbandry is carried out.

(1) Biogas engineering project and animal excrement recycling project shall be launched at a faster pace for the farms and communities where large-scale animal husbandry is carried out, in order to prevent and control pollution caused by animal husbandry. Facilities shall be built for treating organic waste, such as crop stalks, excrement, and domestic waste. Human and animal excrement and domestic waste shall be recycled and used as fertilizers, forage, and fuel.

(2) Energy-saving agricultural technology, the technique of testing soil for formulated fertilization, and the use of organic fertilizers shall be promoted. Highly effective, lowly toxic, less-persistent pesticides shall be properly used.

(3) Discharge from rural domestic pollution sources shall be controlled. Wastewater treatment technology shall be widely promoted and used. Rewards shall be granted for effective prevention and control of pollution as a way to encourage people to control environmental pollution in the rural area and protect the environment.

b) Environmental management measures

Building, renovating, and expanding a reservoir must strictly follow the industrial policy and environmental protection laws. Cleaner production and the use of advanced equipment will be promoted in an effort to reduce pollution while increasing production. As the river segment in Xiaohe Town is heavily contaminated, new projects that will cause water pollutants to increase are banned. Authorities shall follow environmental protection policies when developing a project plan. The production techniques and equipment that consumes a lot of energy, cause heavy pollution, and lack cost-effectiveness shall be eliminated in accordance with the law. According to environmental protection laws and regulations, authorities shall grant pollutant discharge permits to the organizations that have met the discharge standards and shall inspect and supervise these organizations for pollutant discharge. Pollutants from every pollution source shall be reduced. Authorities shall improve the method of discharge permit management so as to prevent the organizations that have no discharge permits from discharging pollutants.

7.3.4 Treatment measures for wastewater from ships

7.3.4.1 Prevention and control of pollution caused by wastewater from ships

a) Treatment measures for domestic sewage from ships

Ships shall be equipped with wastewater treatment equipment or wastewater container that has a capacity large enough to treat or store domestic sewage produced on a vessel. Domestic sewage produced on a vessel shall not be discharged in port, but it shall be collected by the vessels designated by maritime authorities.

b) Treatment measures for pollutants discharged from ships

According to MARPOL (International Convention for the Prevention of Pollution from Ships) 73-78, the bilge water discharged from any ship having a gross tonnage of at least 400 shall go through oil-water separators. Register of Fishing Vessel of the People's Republic of China has enacted *Rules for Pollution Prevention Structures and Equipment of Seagoing Ships* and *Rules for Pollution Prevention Structures and Equipment of Inland Waterways Ships*. Based on these Rules, any ship having a gross tonnage of at least 400 shall be equipped with oil-water separators.

According to *Provisions of the People's Republic of China on the Prevention and Control of Vessel Pollution of the Inland Water Environment*, vessels docked in port shall not discharge their bilge water into the wharf's water area. Bilge water shall be collected by the vessels designated by maritime authorities.

Maritime authorities shall inspect a ship's bilge water when the ship is entering and leaving a port. When a ship berths, maritime authorities shall examine and record the amount of oily wastewater on board of the ships; when the ship leaves, they shall review the amount of oily wastewater on board of the ship so as to keep track of the change of the amount. These measures aim to effectively control and prevent ships from illegitimately discharging their bilge water into water when they are docked in port, ensuring that ships arriving in port do not discharge their bilge water into the wharf's water area.

Ships shall not discharge industrial wastewater into a wharf's water area. If wastewater has to be discharged into water, persons in charge of the ship shall apply to maritime authorities for the permission; the wastewater shall be shipped to a place designated by maritime authorities for disposal.

7.3.4.2 Bilge water of ships passing through a lock

The quantity of bilge water of ships traveling in the reservoir area is estimated to reach 55.66 tons a year by 2020 and the bilge water's oil concentration will average 500-1000mg/L. If the bilge water is directly discharged into water without being treated, it will contaminate water. Bilge water is forbidden to be directly discharged into waterways. Bilge water shall be collected by wastewater collection devices with which a ship is equipped and shall then be shipped to oily wastewater treatment facilities on land for treatment. Wastewater treatment facilities at port shall be upgraded so as to effectively treat wastewater from ships. The treated wastewater shall meet the *Integrated Wastewater Discharge Standard* (GB8978-1996) Class I before it is discharged.

Based on the current wharf (about 23km upstream from the Yakou Shipping Hub dam site) in the Xiaohe port area of Xiangyang Port, an oily wastewater treatment system will be built on land. This system includes an oily wastewater treatment station and wastewater collection pipelines. Wastewater collection vessels dock at the current wharf. The wharf where wastewater collection vessels dock shall be equipped with a DN80 pipeline for collecting domestic sewage from ships and a DN80 pipeline for collecting oily wastewater from ships. Wastewater collection and treatment facilities on land are located at the current ferry crossing. The facilities are equipped with oil-water separators (having a capacity of 1.0t/h), oil separators, and oily water treatment equipment. The treated wastewater shall meet the *Integrated Wastewater Discharge Standard* (GB8978-1996) Class I (its oil concentration shall be less than 5mg/L) before it is discharged.

See chart 7.3.2 for the collection and treatment steps for the domestic sewage and bilge water from ships passing through a lock.

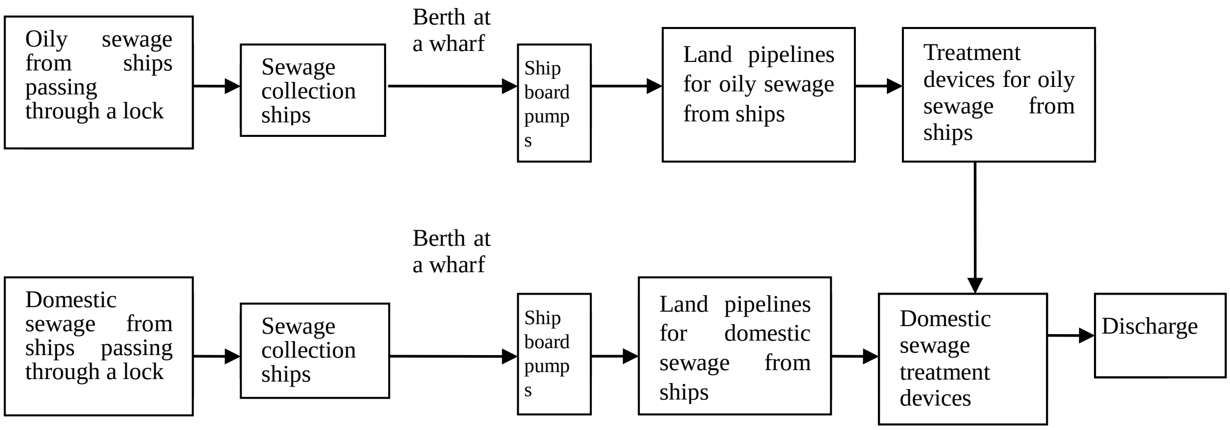


Chart 7.3.2 collection and treatment steps for the domestic sewage and bilge water from ships passing through a lock

7.3.5 Reservoir inundation treatment

Normal water level of the Yakou Shipping Hub is designed to be 55.22m. Based on this, the inundated area on the right bank of the project area is estimated to be 18.71km^2, and the inundated area on the left bank of the project area is estimated to be 9.01km^2.

For urban areas that may be inundated, as underground water level rises, water in soil increases, which will affect urban living environment. The inundation's effects can be mitigated by rebuilding the surface water drainage system, increasing drains, lowering the underground water level, installing a damp proof course for the ground floor of a building, and intensifying underground water monitoring. To mitigate the inundation's effects on farmland, it is recommended that drains should be excavated, underground water level should be lowered, and the mix of crops planted should be changed.

The inundation's effects can be mitigated by taking the following measures:

Right bank: Relief wells shall be excavated in the area along the levee toe between cross section 2-2 and the dam site. The water level in the relief well is 3m; the bottom of catchment pipes is buried at a depth of 3.3m underground; the well spacing is 80m.

The function of the catchment pipes is the same as that stated in Plan I. Water in catchment pipes is discharged from the underground culvert excavated parallel to the dam axis at the dam site. Relief wells will be excavated in the area between Tannao Village and Yejicheng Lock. The well spacing is 80m; the water level in the relief well is 3m; the bottom of catchment pipes is buried at a depth of 3.3m underground. Water in catchment pipes flows into Yejicheng Lock, passes through a small pump station, and then discharges into the Han River. Relief wells will be excavated in the area along the levee toe between cross section 4-4′ and cross section 5-5′. The water level in the relief well is 3m; the bottom of catchment pipes is buried at a depth of 3.3m underground. Water in catchment pipes flows into Yejicheng Lock, passes through a small pump station, and then discharges into the Han River. An open Ditch will be excavated in the area between Tannao Village and Zhoujiazhuang for drainage. The Ditch is 3.5m deep; its water level is 0.2m. Water flows from both Tannao Village and Zhoujiazhuang into Huangjia Trench.

Left bank: It is recommended that an additional drain should be excavated in the area between cross section 9-9′ and 10-10′ of Nanzhou-Nanying. The drain is 4m deep; its normal water level is 0.2m. The drain shall be excavated along its original track and farmland. The part of the drain that goes through a village shall be buried underground. This underdrain is about 250m from the levee toe. Relief wells shall be excavated in the village area along the levee toe. The well spacing is 80m; the water level in the relief well is 3m. Catchment pipes shall be installed to collect water discharged from relief wells and then discharge water into the drain. An additional drain shall be excavated in the area between cross section 11-11′ and 12-12′. The drain extends to Gongnao Village. The drain is 3m deep; its normal water level is 0.2m. It shall be arranged along roads, about 350m from the levee toe. The part of the drain that goes through a village shall be buried underground. Zhangjiaju-Nanying section is generally free from the impact of inundation, so no relief wells or drains are needed.

7.4 Fish species protection

7.4.1 Identification of the species to be protected

Fish species to be protected can be identified based on their importance: state-or provincial-level endangered fish species, endemic fish species, key species in aquatic ecosystem (e.g. rare species), and commercially important fish species. Fish species to be protected can be identified based on their susceptibility to the impact of the project: species that lack resilience, species whose habitats are severely disrupted by the project, and species that are adaptable to the environment disrupted by the project. Fish species to be protected can be identified based on their current state: endangered species, vulnerable species, rare species, and species that rely on protection. Fish species to be protected can be identified based on their lives: species that migrate far, species that are picky about spawning environment, and species that grow, breed, and mature slowly.

A total of 93 fish species will be evaluated. None of the 93 species are under state protection. Of the 93 fish species, five are under provincial protection, namely *Saurogobio gracilicaudatus*, *Onychostoma macrolepis* (*Varicorhinus macrolepis*), *Leiocassis longirostris*, *Luciobrama macrocephalus*, and *Ochetobius elongates*; *Liobagrus marginatus* is the only endangered species. Therefore, these fish species should be specially protected throughout the project.

The commercially important fish species in the Han River mid-and lower-reaches that release pelagic eggs are silver carp, bighead carp, grass carp, black carp, *Parabramis pekinensis*, *Elopichthys bambus*a, *Luciobrama macrocephalus*, *Xenocypris argentea Gunther*, *Coreius heterodon*, *Rhinogobio typus*, and *Rhinogobio cylindricus*. These species play an important role in the aquatic ecosystem of the Han River flowing water segment. Moreover, these species account for a large percent of fish caught from the Han River. The populations of silver carp, bighead carp, *Elopichthys bambus*a, and *Luciobrama macrocephalus* may indicate whether the quality of the reservoir water is good or not, so close attention should be paid to these four species.

Different measures shall be taken to protect different fish species based on their habits and biological characteristics. As *Saurogobio gracilicaudatus* and *Onychostoma macrolepis* are small, it is difficult to take measures for fish stock propagation. Moreover, the living space needed by these small fish species is small, so the way to protect the species is to protect their habitats. To protect species like silver carp, bighead carp, *Elopichthys bambus*a, and *Parabramis pekinensis* that release pelagic eggs, fish ladders should be built and biological regulation should be implemented. In order to protect species like *Luciobrama macrocephalus* and *Ochetobius elongates* whose populations are small and difficult to increase, measures shall be taken to protect and restore their habitats, while research on fish farming shall be conducted to provide technical support for fish stock propagation.

7.4.2 Habitat protection

Habitat protection is a major method to protect fish stocks and mitigate the impact of hydro-power development projects to fish species. After Yakou Shipping Hub is put into operation, the quantity of the Han River downstream water will inevitably decrease, which will negatively affect local fish stocks and disrupt the hatching of fish species that release pelagic eggs. Therefore, fish habitats in the Han River and tributaries shall be protected as a way to mitigate the project’s impact on fish stocks.

a) Protection of habitats in the main stream

According to a survey, a majority of fish has been found in the rear section of the reservoir after the reservoir is built. Therefore, it is safe to say that the rear section of the reservoir is a habit to which fish in the reservoir area can adapt after the hydropower station is built. As the Han River segment upstream from the Yakou Shipping Hub joints Cuijiaying hydro-junction, the rear section of the reservoir may form a water area when Cuijiaying hydro-junction discharges flood downstream during flood seasons.

In addition, Yakou Shipping Hub discharges flood during flood seasons, so flowing water area downstream from the Yakou dam can be generally maintained, which is generally conducive to the spawning of fish species that release pelagic eggs.

Therefore, it is recommended that during flood seasons, the river segments (between the area downstream from Cuijiaying dam and the rear section of the Yakou reservoir, and between the area downstream from Cuijiaying dam and Nianpanshan Reservoir) with a flow rate of 0.2m/s should be protected as fish habitats in the main stream. It is estimated that the river segments downstream from Cuijiaying dam and Yakou dam respectively that have a flow rate of at least 0.2m/s are 5km long and 7km long respectively. It is recommended that fishing should be banned in the aforesaid river segments.

① Fishing in the river segments under protection shall be banned. During the breeding season (from March to August), fishing, sand mining, and other activities that may disrupt the aquatic habitat in the aforesaid areas shall be banned; warning signs shall be put up near these areas.

② Environmental flows discharged at a rate of 450m^3/s from the Yakou Shipping Hub shall be guaranteed; an online monitoring system for environmental flows shall be established.

③ Environmental flows shall be properly increased during the fish breeding seasons in order to ensure the ecosystem quality of the aforesaid areas for fish spawning and inhabiting. Biological regulation plans for the spawning period shall be carefully developed so that hydrological regime is favorable for spawning.

④ Pebbles and stumps can be placed in the aforesaid areas to create a favorable habitat for fish.

⑤ Water quality, fish, and aquatic life should be continuously monitored.

⑥ Fishery administration shall be intensified.

b) Protection of habitats in tributaries

1) Importance

Tributaries, an integral part of the river ecosystem, plan an important role in the biodiversity of rivers. According to surveys, most fish species swim to and fro between the main stream and tributaries of a river for ingestion and spawning or hibernation. After the Yakou Shipping Hub is built, aquatic habitats in the evaluated area shrink, while aquatic habitats in the tributaries are sustained. With the implementation of plans for hydro-power development in the Han River mid-and lower-reaches, aquatic habitats in the main stream will further dwindle. Therefore, aquatic habitats in the tributaries are very important for fish species in the Han River mid-and lower-reaches and for fish species whose spawning needs flowing water.

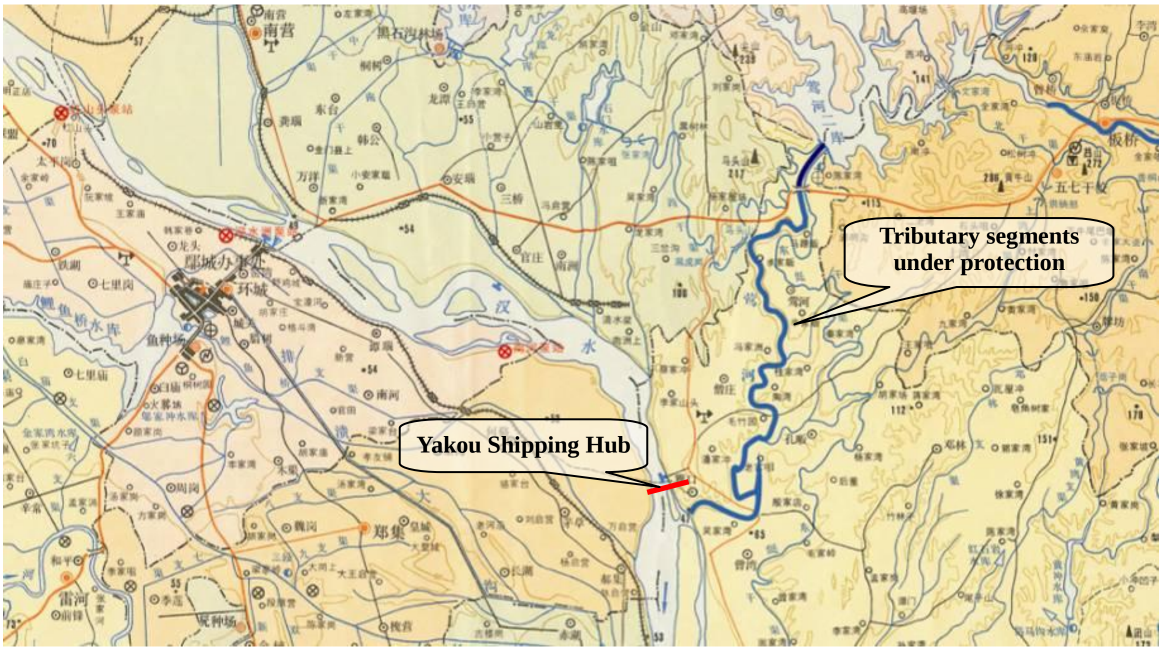
2) Tributaries selected to be protected

The following tributaries shall be selected: ① tributaries that have already been identified to be protected; ② tributaries that have good water quality and have rarely been disrupted by human activities. ③ tributaries that have a large quantity of flows, good water quality, and rich fish stocks

After the Yakou reservoir is built, tributaries Weishui and Chunhe will be in the reservoir area, while tributary Yinghe is in the area downstream from the dam. According to survey data and field surveys, Weishui, also known as Xiaohe, along which there are a large number of chemical plants, has poor water quality and few fish stocks. Chunhe River covers a small area and has poor water quality. Most fish in Chunhe are small. There is no tributary in the Yakou Shipping Hub reservoir that can serve as a habitat for fish.

The tributary downstream from the dam is Yinghe River (left bank), which was called Rushui in ancient times. Yinghe River, originating from Qingfengling in Zaoyang of Hubei province and flowing southwestward to Yicheng County, is 63km long and covers an area of 403.9km^2. The Yinghe estuary water flows at a rate of 5.35m^3/s on average for years. Two reservoirs have been built in the Yinghe River. The total capacities of the first Yinghe reservoir and the second Yinghe reservoir are 119.50 million m^3 and 82.40 million m^3 respectively. Yinghe River, abounding in pools and flood plains, has both bends and straight parts as well as rapid and slow flows. The Yinghe riverbed consists of pebbles, gravels, sand and mud. The habitat of Yinghe River is similar to that of the Han River main stream. Yinghe River provides habitats for fish species inhabiting flowing waters, including *Botia superciliaris, Xenocypris* *argentea Gunther, black carp, grass carp, silver carp, bighead carp, Distoechodon tumirostris, Parabramis pekinensis, Opsariichthys bidens, Rhinogobio typus, Saurogobio dabryi, Bagrus bajad, Squalidus argentatus, and Pseudolaubuca sinensis*. It also provides spawning grounds for fish species that release viscid eggs and inhabit slowly flowing water and still water, including common carp, crucian carp, catfish, *Squaliobarbus curriculus, Monopterus albus, Rhodeus sericeus*, loach, and shellfish. According to ecological surveys, Yinghe River serves as the spawning ground for fish species that release viscid eggs in the evaluated area, including *Cyprinus carpio, Carassius auratus, Pelteobagrus fulvidraco, Pelteobagrus vachelli, Silurus asotus, Xenocypris davidi*, and *Misgurnus anguillicaudatus*. No spawning grounds for Asian carps and other fish species that release pelagic eggs have been found.

Based on surveys of these tributaries, by comparing such indicators as the quantity of water, water quality, landform, river regime, hydrological regime, fish stocks, and river development, Yinghe River is selected to be protected as a tributary habitat for fish. The river segment under protection is between the area downstream from the second Yinghe Reservoir and the Yinghe estuary, which is about 18km long. See map 7.4.2-1 for the protected river segment.



Map 7.4.2-1 Protected river segment

3) **Similarities of the protected habitats in the tributary Yinghe**

(1) Similar species

According to field surveys, fish species inhabiting Yinghe River include *Xenocypris, Parabramis pekinensis, Paracanthobrama guichenoti, Pseudolaubuca sinensis, Cyprinus carpio, Carassius auratus,, Pelteobagrus fulvidraco, Pelteobagrus vachelli, Silurus asotus, Xenocypris davidi,* and *Misgurnus anguillicaudatus*. These species are identical to some of the species in the Han River main stream.

(2) Similar aquatic habitats

The river bed of the Han River mid-and lower-reaches contains grits, silt, and even sludge. There are many overflow lands, sand beaches, and forks within the Han River course. Generally, water in the front part of a shoal tends to flow rapidly. The bottom of a shoal consists largely of grits. Aquatic vegetation lacks in the front part of a shoal. Water in the rear part of a shoal tends to flow slowly; aquatic vegetation abounds in the rear part of a shoal. Both terrestrial vegetation and hygrophyte generally abounds on overflow lands. Water in the overflow lands, river bends, and pools that have many forks tends to flow slowly; aquatic vegetation in these water areas generally abounds.

According to field surveys, Yinghe River, abounding in pools and flood plains, has both bends and straight parts as well as rapid and slow flows. The Yinghe riverbed consists of pebbles, gravels, sand and mud. Near the Yinghe estuary, submerged plants, aquatic plants, hygrophyte abound. Aquatic habitats in Yinghe River are similar to those in the overflow lands and river bends of some of the Han River segments, which are suitable for the spawning of *Cyprinus carpio, Carassius auratus*, and other fish species that release viscid eggs.

Most Yinghe River segments have gravel riverbeds, whereas only a few segments of the Han River have gravel riverbeds. After impoundment, the few gravel riverbeds will further shrink. The Yinghe River segments make up for the shortage of the Han River segments that have gravel riverbeds. The Yinghe River segments may serve as spawning grounds for fish species that release viscid eggs. Moreover, the Yinghe estuary, which is rich in aquatic vegetation, may serve as spawning grounds for fish species that release viscid eggs in slowly flowing water or still water. In addition, the Yinghe River lower reaches abound in flood plains and pools, making favorable habitats for small fish species that swim in flowing water.

4) Protected fish species

Protected fish species in the tributary habitats are commercially important species and species endemic to the area, including *Culter alburnus, Rhinogobio typus, Squaliobarbus curriculus, Xenocypris argentea Gunther, silver carp, bighead carp, black carp, grass carp, Distoechodon tumirostris, Parabramis pekinensis, Squalidus argentatus,* and *Saurogobio gracilicaudatus*.

5) Protection measures

Measures and requirements:

① Creating habitats

Habitats for fish can be created by placing pebbles and gravels in an area and transplanting water plants to the area. Artificial spawning grounds can be built for fish. Pebbles (60%) having a diameter of 4-8cm each and gravels (40%) having a diameter of 1-3cm each can be used to pave the surrounding area or the beach of the river island. Area of pebble beach and gravel beach can be increased. These areas can serve as spawning grounds for fish. Spawning grounds for fish can also be created by transplanting hygrophyte to the river beach. Eight to ten plant species can be planted on the man-made river beach, with each species covering an area of 3~5m^2.

Figure 7.4.2-2 Created habitats

② Fishing in the protected tributary segments shall be banned; these segments shall be marked with “no fishing” signs.

③ Long-term monitoring of fish species, aquatic life, and water quality shall be implemented.

④ Fishery administration shall be intensified. Fishery regulations shall be strictly enforced. Illegal fishing practices such as using electric shock, explosion, and poison to catch fish shall be prohibited.

⑤ During the breeding season (from March to August), fishing and any other activities that may disrupt aquatic habits in the aforesaid areas are banned. These areas shall be marked with “no-fishing” sings.

7.4.3 Fish ladder construction

7.4.3.1 Fish ladders

a) Purposes

Construction and operation of Yakou Shipping Hub has remarkably changed the hydrological regime and fish habitats of the river segment where the hub project is located. Moreover, upstream hydro-power development projects have disrupted fish’s habitats in the reservoir area. In this context, fish ladders shall be built for the following purposes:

1) Bridging fish species upstream and downstream from the dam

Most of the fish species inhabiting the dam site do not migrate. However, these species may breed with other species, which will enrich their gene pool. This is very important to a stable evolvement of fish species.

The dam reduces the habitat of diadromous fish species, which hinders the evolvement of these fish species in the dam site. By building fish ladders, the habitat for fish in the dam site can be increased, which may help increase fish species.

Therefore, fish ladders are built for fish species to swim freely upstream and downstream from the dam.

2) Preserving migration passings

Of the fish species inhabiting the dam site, black carp, grass carp, silver carp, and bighead carp are diadromous species. These carps need to migrate far in order to find suitable habitats for spawning. Fish ladders are built to ensure that migration passings are free of obstacles for these carps.

b) The fish for which fish ladders are built

Fish ladders are built for fish to swim freely upstream and downstream from the dam. With regard to this project, fish ladders are built for all fish species inhabiting the dam site.

When designing fish ladders, the designer shall take into account the characteristics and habits of the fish species. Fish that will use fish ladders is identified in this report based on its quantity.

To ensure fish swims freely upstream and downstream from the dam through fish ladders, relevant parties will pay close attention to silver carp, grass carp, black carp, bighead carp, *Squaliobarbus curriculus*, and *Leiocassis longirostris*.

c) Season

Fish ladders are built for fish to swim freely upstream and downstream from the dam, so in principle, fish can use fish ladders all year round. Close attention shall be paid to the quantity of fish passing the dam through fish ladders during the breeding season. So the main season for fish to use fish ladders can be determined as a period from March to September based on the breeding season. See table 7.4.3-1for more information.

Table 7.4.3-1 Season during which fish uses fish ladders

Fish species that use fish ladders	**Month**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Silver carp												
Grass carp												
Black carp												
Bighead carp												
Squaliobarbus curriculus												

Leiocassis longirostris												
Season	1	2	3	4	5	6	7	8	9	10	11	12

Notes:

Main season General season Breeding season

7.4.3.2 Types of fish ladders

a) Main types of fish ladders

Fish ladders can be divided into upstream fish ladders and downstream fish ladders. See table 7.4.3-2 for the main types of fish ladders.

Table 7.4.3-2 Main types of fish ladders

Upstream fish ladder	Downstream fish ladder
Baffle fishway	Physical fence with bypass Immaterial Fence with bypass Fish pump
Rock-ramp fishway	
Fish elevator	
Fish lock	
Fish collection and transport facility	

As fish is generally hindered from swimming upstream, upstream fish ladders are relatively common. Fish ladders for this project focus on restoring upstream passageways for fish. Details about the main types of upstream fish ladders are as follows:

(1) Baffle fishway

A fishway, also known as a fish ladder or fish pass, is widely used. It has a long history. In the 19th century, over 100 fishways were built in France. A baffle fishway, consisting of inlet, slot, and outlet, uses a series of symmetrical close-spaced baffles in a channel to redirect the flow of water, allowing fish to swim around the barrier. Baffle fishways need not have resting areas, although pools can be included to provide a resting area or to reduce the velocity of the flow. Such fishways can be built with switchbacks to minimize the space needed for their construction. As baffles come in variety of designs, baffle fishways can be divided into Denil fishways, Larinier fishways, and Alaskan Steeppass.

(2) Rock-ramp fishway

A rock-ramp fishway uses large rocks and timbers to create pools and small falls that mimic natural structures. Because of the length of the channel needed for the ladder, such structures are most appropriate for relatively short barriers. As the ramp is not steep, such fishway is generally used for the projects in water areas where upstream and downstream water level difference is small.

(3) Fish elevator

A fish elevator, as its name implies, breaks with the ladder design by providing a sort of elevator to carry fish over a barrier. It consists of flume, hopper, and effluent flume. With a fish elevator, fish swim into a collection area at the base of the obstruction. When enough fish accumulate in the collection area, they are nudged into a hopper that carries them into a flume that empties into the river above the barrier. As a fish elevator covers a small area of land, it is generally used for the projects in water areas where water head have large flows.

(4) Fish lock

The design of a fish lock is similar to that of a ship lock. Consisting of upper flume, lock chamber, and lower flume, a fish lock uses the upper and lower lock gates to regulate the water level in the lock chamber for fish to pass. With the upper lock gate being slightly open and the lower lock gate being widely open, a current forms at the lower lock gate, which draws downstream fish species into the lock chamber through the flume. Then the lower lock gate shall be closed. When the water level in the lock chamber rises to the upstream water level, the upper lock gate shall be opened; fish can be drawn out of the chamber into the upper reaches by making water in the chamber to flow. Then the operator of the fish lock shall close the upper lock gate and open the lower lock gate, drawing fish in again. Fish may pass the lock effortlessly, so fish lock is generally favorable for fish species that swim poorly.

(5) Fish collection and transport facility

With fish collection and transport facility, downstream fish species are drawn to a hull or a box. They then pass through a ship lock or be transported by vehicles to the area upstream from the dam, where they may cross the dam. The facility is well suited to tall dams. It also serves as a preparation for building upstream fish ladders. Its drawback is that fish may get injured in transit.

b) Strengths, weaknesses, and application

A fish ladder comes in many types. These types of fish ladders are designed to suit different projects and fish species, so they have different features. See table 7.4.3-3 for features of different fish ladders.

Table 7.4.3-3 Strengths and drawbacks of different fish ladders

Type	Strength	Drawback	Application
Baffle fishway	✓ Good energy dissipation ✓ Stable structure ✓ Covering a small area ✓ Fish passing around barriers continuously	× Artificial structure × Difficult to upgrade	Mid-and low-water head projects
Rock-ramp fishway	✓ Adaptable for fish ✓ Fish passing around barriers continuously ✓ Easy to upgrade	× Poor energy dissipation × Unstable structure × Poorly adaptable to water level changes × Covering a large area	Low-water head projects
Fish elevator	✓ Covering a small area ✓ Suited to high water head	× Difficult for fish collection × Complex operation × High operation cost	Mid-and high-water head projects
Fish lock	✓ Covering a small area ✓ Suited to high water head	× Difficult for fish collection × Complex operation × High operation cost	Mid-and high-water head projects
Fish collection and transport facility	✓ Flexible ✓ Suited to high water head	× Complex operation × High operation cost	Mid-and high-water head projects Building additional fish ladders

c) Recommended types of fish ladders

Fish elevators, fish collection and transport facilities, and fish locks are generally suited to mid-and high-water head dams. This hub is a low-water head shipping hub; the highest water head involved in this hub is only 10m. Therefore, it is not recommended that these three types of fish ladders should be used for this project.

Baffle fishways and rock-ramp fishways are widely used for low-water head hydraulic and hydro-power engineering. They are feasible in that they are stable and they meet the flow regime and velocity needed by fish. Therefore, it is recommended that these two types of fish ladders should be used for the project. A few feasible arrangement plans for baffle fishways and rock-ramp fishways will be compared below.

7.4.3.3 Comparison and selection of fish-passing plans

a) Location selection reasoning

According to engineering layout of Yakou hub, fishway or nature-like fish passage can be situated following four layout plans, namely on central bar between power station and left sluice, in between power station and right sluice, in between right sluice and ship lock, and on right bank, as shown in Figure 7.4.3-1.

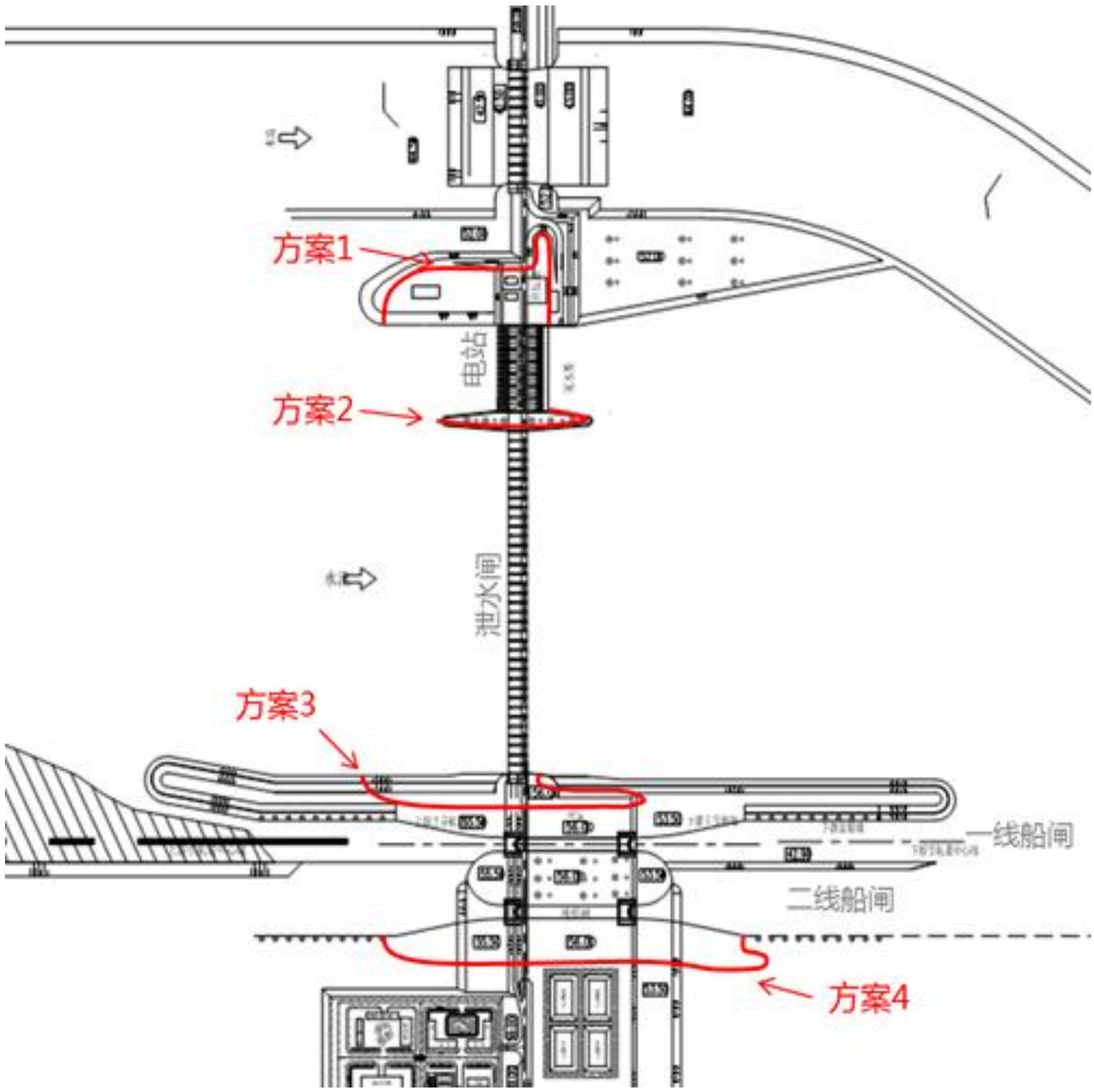


Figure 7.4.3-1Plan comparison and selection of fish pass location selection

原文	English
方案 1	Plan 1
电站	Power station
方案 2	Plan 2
泄水闸	Sluice
水流	Water flow
方案 3	Plan 3
一线船闸	First-line ship lock
二线船闸	Second-line ship lock
方案 4	Plan 4

Table 7.4.3-4 Strength and weakness comparison of fish pass location selection plans

Plan location selection		Main strength and weakness
Plan1	Central bar between power station and left sluice	✓ Close to hydropower station, with frequent discharged water, good for fish luring; ✓ Close to central bar, good for fish swimming upstream.
Plan2	Between power station and right sluice	✓ Close to hydropower station, with frequent discharged water, good for fish luring; × Limited layout space; × Close to riverway center, bad for fish swimming upstream.
Plan3	Between right sluice and ship lock	× Without frequent discharged water, bad for fish luring; × Not close to bank, bad for some fish swimming upstream.
Plan4	On right bank	✓ Close to bank, good for fish swimming upstream; × Without frequent discharged water, bad for fish luring.

Out of the four layout plans, the central bar layout plan has frequent discharged water which is good for fish luring. In addition inlet is close to central bar which can be relatively easily found by fish swimming upstream along the bank. Therefore, the project fish pass adopts **Plan 1: central bar layout between power station and left sluice**. See Table 7.4.3-4 for comparisons of major strengths and weaknesses of the four plans.

b) Plan comparison and selection

After the left bank location selection is determined, two feasible plans of fishway and nature-like fish passage are compared in detail:

Plan1—left-bankfishway

Fishway can be built along the left bank of the power station, with inlet situated at waterfront area in front of the plant downstream of the left-bank hydropower station circling the area in front of the plant below the dam and extending upwards to riverway upstream. See Figure 7.4.3-2 for sketch map of Plan 1 layout.

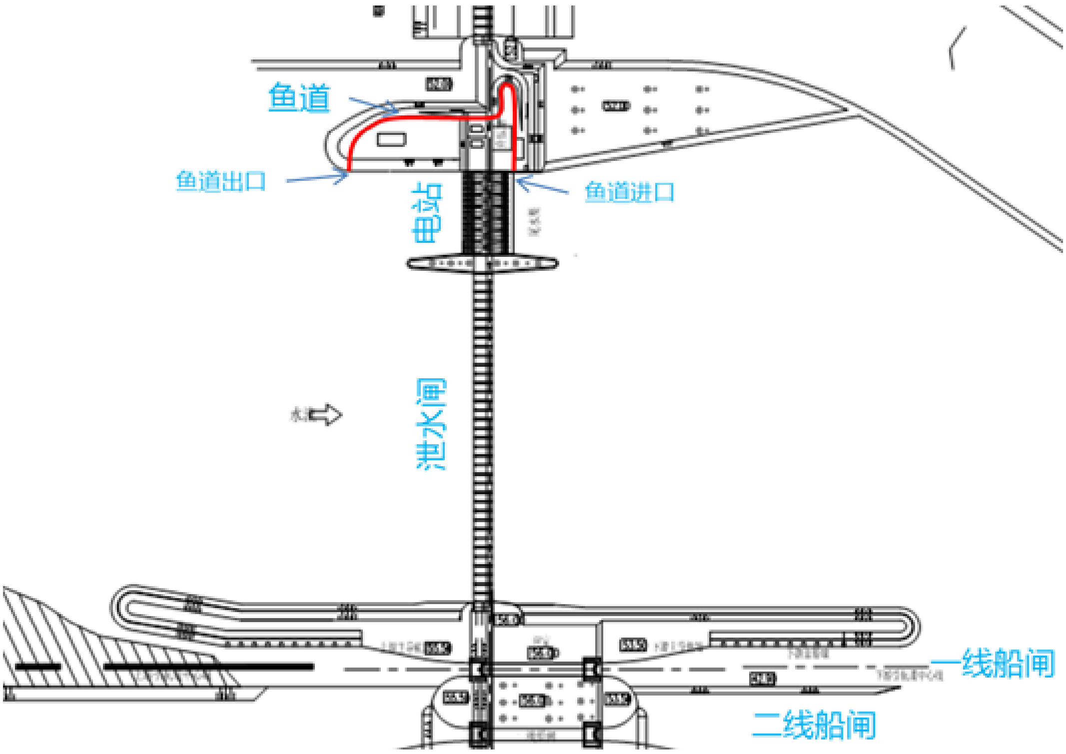


Figure 7.4.3-2 Sketch map of right-bank fishway plan

原文	English
鱼道	Fishway
鱼道出口	Fishway outlet
电站	Power station
鱼道进口	Fishway inlet

泄水闸	Sluice
一线船闸	First-line ship lock
二线船闸	Second-line ship lock

Plan 2—left-banknature-like fish passage

Similar to the fishway plan, nature-like fish passage can be built on the left bank with inlet situated in front of the left-bank installation room, circling downstream of the dam and extending upwards to reservoir area upstream of the dam. See Figure 7.4.3-3 for sketch map of Plan 2 layout.

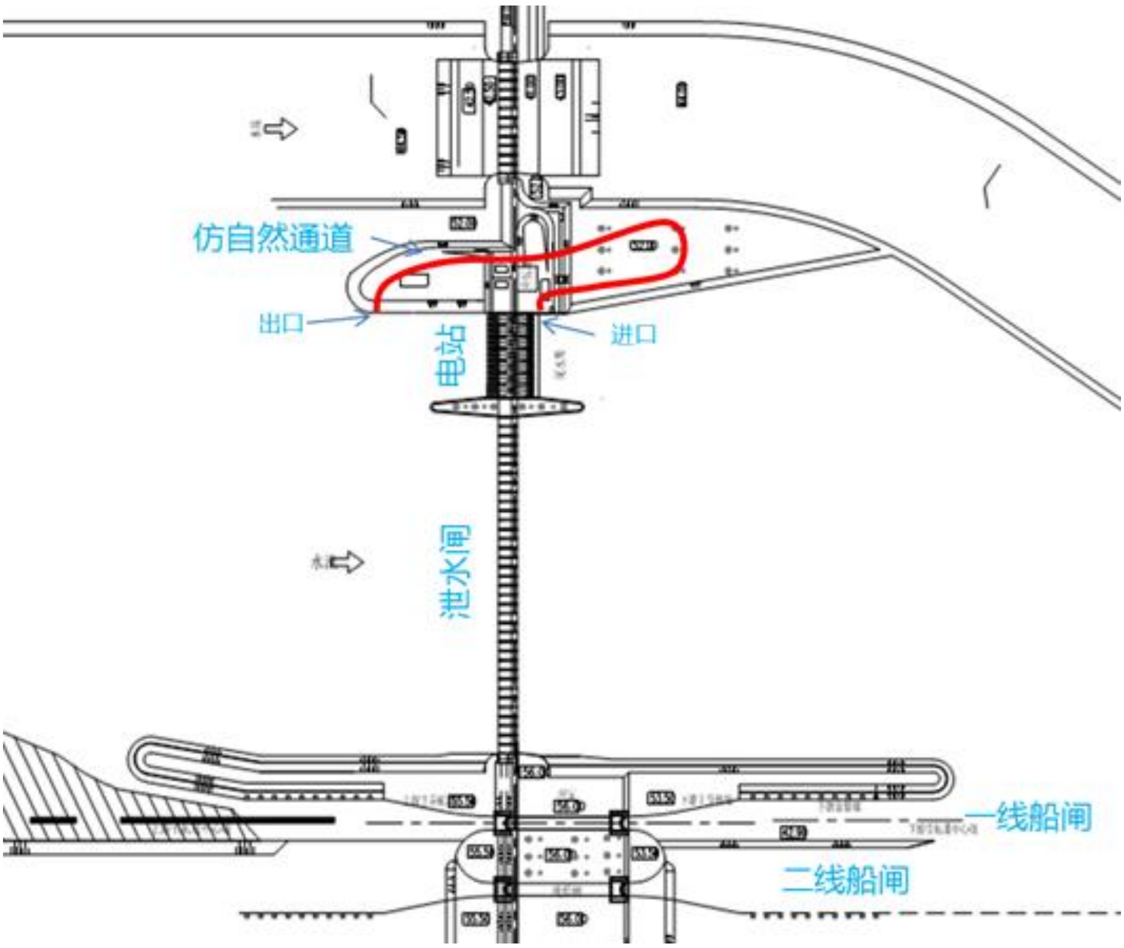


Figure 7.4.3-3 Sketch map of right-bank nature-like fish passage plan

原文	English
仿自然通道	Nature-like fish passage
出口	Outlet

电站	Power station
进口	Inlet
泄水闸	Sluice
一线船闸	First-line ship lock
二线船闸	Second-line ship lock

Plan 3—left-bank nature-like fish passage

Nature-like fish passage shares similar internal diaphragm structure with fishway, and has rock pavement on side wall and bottom at the same time forming a substratum structure similar to that of a natural creek. However, different from traditional nature-like fish passage, its side walls can be upright without the need of high slope excavation required by nature-like fish passage.

Nature-like fish passage on central bar can have inlet situated at waterfront area in front of the plant downstream of the left-bank hydropower station circling the area in front of the plant below the dam and extending upwards to riverway upstream. After the completion and water storage of Nianpanshan project in the downstream, water level below the Yakou hub will be relatively stable meeting the work requirement of nature-like fish passage. However, prior Nianpanshan project completion, given the relatively large water level amplitude, it is considered to build an extra project fishway in addition to nature-like fish passage so as to meet immediate fish-passing demand. Therefore, fish pass design includes inlet, outlet, Nature-like fish passage, assembling pool and a project fishway section. See Figure 7.4.3-3 for sketch map of Plan 3 layout.

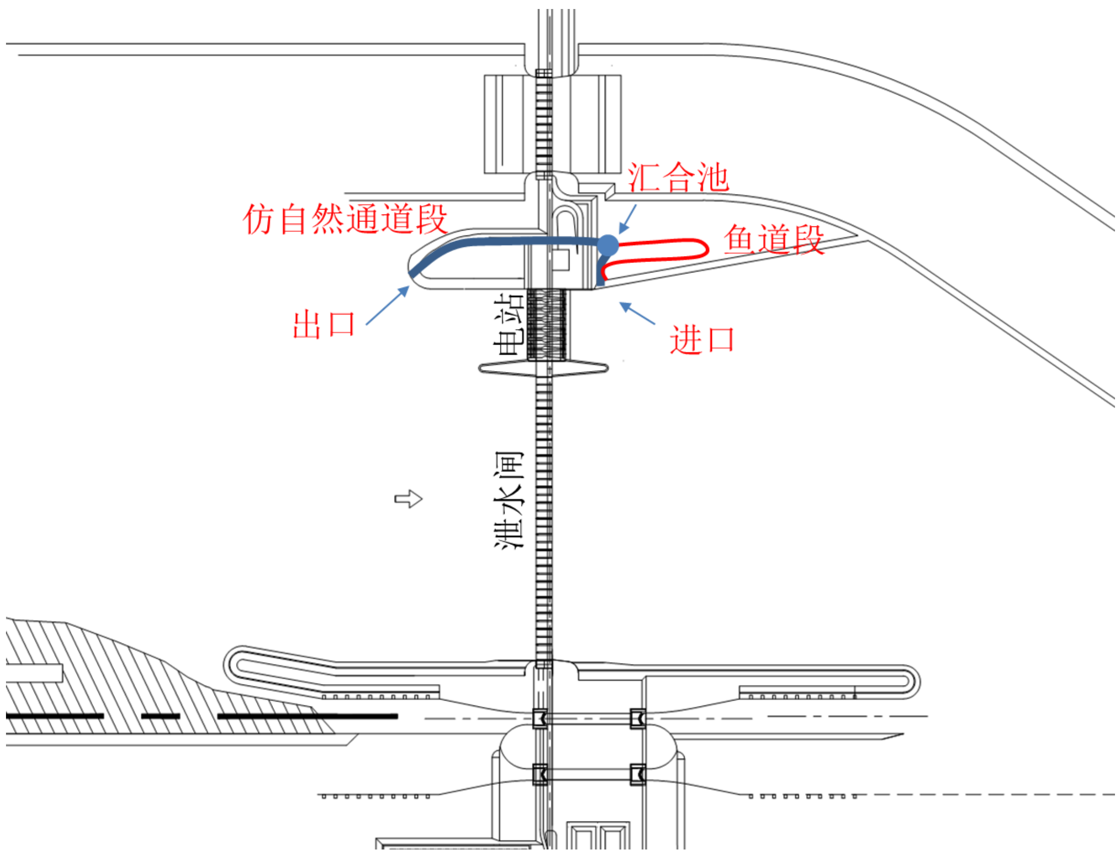


Figure 7.4.3-4Sketch map of left-bank nature-like fish passage plan

原文	English
仿自然通通道段	Nature-like fish passage
出口	Outlet
电站	Power station
汇合池	Assembling pool
鱼道段	Fishway section
进口	Inlet
泄水闸	Sluice

c) Analysis of strength and weakness

See Table 7.4.3-5 for detailed analyses of strength and weakness of the three plans discussed above.

Table 7.4.3-5 Strength and weakness comparison of comparison and selection plans

Plan	Strength	Weakness

Plan1: left-bank fishway	Fishway length relatively short with relatively small work amount; strong adaptability to water level amplitude in the downstream	Artificial structure, not close to nature
Plan2: left-bank nature-like fish passage	Structurally close to nature	Difficult to adapt for water level amplitude in the downstream; Relatively long passageway with relatively large work amount
Plan 3: left-bank natural fishway simulation	Complicated internal structure and flow regime; relatively close to nature and suitable for passing many fish species; effective energy dissipation with relatively short length; strong adaptability to water level amplitude in the downstream	Complicated construction technique

d) Comparison and selection result

Given that the three plans discussed above all have strengths and weaknesses and all are feasible, a scoring table is adopted for comprehensive consideration of fishway and nature-like fish passage in terms of factors such as fish-luring capacity, fish-passing capacity, fish adaptability, construction cost and operating maintenance, so as to compare and select a fish pass type suitable to the project, as shown in Table 7.4.3-6.

Table 7.4.3-6Scoring criteria of fish pass plan comparison and selection

c	Indicator	Scoring criteria		
		3	2	1
Fish-luring capacity	Inlet location	Multiple locations, easy to find	Close to power station tail water or discharged water	Difficult to find
	Water flow attraction	Large water flow volume	Medium water flow volume	Small water flow volume
	Adaptability to water level variation	Strong	Medium	Weak
Fish-passing capacity	Fish-passing species	Various sizes, many fish species	Most targeted fish species	Few targeted fish species
	Fish-passing number	Relatively large	Relatively small	Very small
	Fish-passing timing	Continuous	Incontinuous, short cycle	Incontinuous, long cycle
	Solution to going upstream and downstream	Combined	Partially combined	Cannot combine
Fish adaptability	Natural level	Similar	Natural simulation	Artificial
	Flow velocity control	Effectiveenergy dissipation	Medium-level energy dissipation	Poor energy dissipation
	Flow regime control	Flow regime of Simple direction	Flow regime of relatively complicated directions	Chaotic flow regime of complicated directions
	Level of water quality difference in the upstream and downstream	Consistent	Continuously changing	Abrupt changes with large differences
Work amount	Land occupation	Small	Medium	Large
	Construction cost	Low	Medium	High
Operating maintenance	Operation cost	Low	Medium	Large human, material and financial cost
	Structuralstability	Structurally stable	Relatively stable	Instable
	Later reconstruction	Easy to reconstruct	Relatively easy to reconstruct	Difficult to reconstruct
	Equipmentmaintenance	Difficult to malfunction, easy maintenance	Requires periodicalmaintenance	Easy to malfunction, high maintenance fee

Note: weight coefficients are allocated according to the level of significance of various factors: weight coefficient=5 weight coefficient=3 weight coefficient=2 weight coefficient=1

Comparison and selection results are compared in terms of total scores by multiplying scores obtained according to scoring of various indicators and the corresponding weight coefficients, as shown in Table 7.4.3-7.

Table 7.4.3-7Scoring results of comparison and selection plans

Consideration	Indicator	Plan1 Left-bank	Plan2 Left-bank nature-	Plan3 Left-bank nature-like

		fishway	like fish passage	fish passage
Fish-luring capacity	Inlet location	15	15	15
	Water flow attraction	10	15	10
	Adaptability to water level variation	15	5	15
Fish-passing capacity	Fish-passing species	6	9	9
	Fish-passing number	6	9	6
	Fish-passing timing	9	9	9
	Solution to going upstream and downstream	6	6	6
Fish adaptability	Natural level	4	6	6
	Flow velocity control	6	2	6
	Flow regime control	4	6	6
work amount	Land occupation	6	4	6
	Construction cost	6	4	4
Operating maintenance	Operation cost	3	2	3
	Publicity and exhibition effect	3	3	3
	Structural stability	3	1	2
	Later reconstruction	1	3	1
	Equipment maintenance	3	2	3
Total		106	101	110

According to comparison and selection of listed scores, fishway plan, nature-like fish passage plan and nature-like fish passage plan score 106, 101 and 110 respectively, therefore integration of nature-like fish passage with fishway plan is advantageous to a certain extent. See Figure 7.4.3-5 for comparison of various comprehensive features.

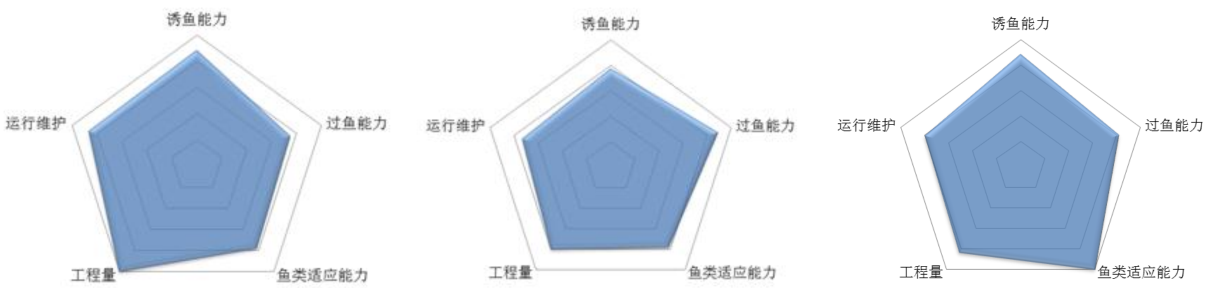


Figure7.4.3-5Comparison of plan features

(Left: fishway plan; center: nature-like fish passage plan; right: nature-like fish passage plan)

原文	English
诱鱼能力	Fish-luring capacity

过鱼能力	Fish-passing capacity
鱼类适应能力	Fish adaptability
工程量	Work amount
运行维护	Operating maintenance

As to specific indicators, in terms of fish-luring capacity, three plans all have good fish luring conditions regarding inlet location and fish luring water flow. However given the relatively large amplitude of operating water level downstream of the project, nature-like fish passage has relatively weak adaptability towards water level amplitude because generally it has a 1.0m~2.0m depth and an about 1:2 side slope with a trapezoid cross section, which experiences non-linear flow variation during changes of water depth. In addition, water flow condition within the passageway is heavily affected by changes of water level. The adoption of nature-like fish passage plan would require the construction of an additional inlet, otherwise it could not adapt to water level changes in the downstream. Moreover, frequent alternating operation between different inlets and changes of hydraulic conditions may affect fish. Therefore, water level amplitude in the downstream may greatly affect inlet working efficiency of nature-like fish passage of the project.

In terms of fish-passing capacity, nature-like fish passage and nature-like fish passage are of certain advantages given that they have substrata and water flow conditions similar to that of a natural river. However, nature-like fish passage requires a relatively large excavation amount and a relatively high project cost, given its relatively flat gradient and relatively long and wide passageway. In terms of operating maintenance nature-like fish passage requires much maintenance work because it is mainly piled up by rock blocks which easily change positions due to frequent water level changes and water flow blast during daily operation affecting hydraulic conditions of the passageway.

By comprehensively comparing the three plans, nature-like fish passage combines advantages of fishway and nature-like fish passage, including a substratum similar to natural creek, diverse flow regime suitable for the passing of many fish species, and adaptability towards water level changes. In conclusion, **at this stage it is recommended that the project fish pass adopts nature-like fish passage plan.**

7.4.3.4 Fishway preliminary design

a) Fish pass operating water level

1) Inlet operating water level

Short term: prior Nianpanshan construction, fishway minimum operating water level follows the downstream minimum tail water level of 45.76m. Except for extreme conditions, downstream water level mainly varies between minimum tail water level and the water level under full unit operation during normal operation of the junction.

Sluice opens to near unrestricted level when dam site discharge equals or exceeds 8710m3/s, and fish can swim upstream from the sluice over the dam as river basically restores its natural regime.

So, when inlet design water level is between 50.32m(unit shutdown, sluice open unrestricted) and 45.76m(minimum tail water level), downstream operating water level amplitude is 4.56m.

Long term: after Nianpanshan construction, downstream water level will vary between the normal Nianpanshan water level of 50.72m and the dead pool level of 50.32m, with downstream operating water level being relatively stable.

2) Outlet operating water level

Water level upstream of the project is relatively stable, being the normal water level of 55.22m most of the time. So outlet design water level is between 55.22m(maximum operating water level) and 54.72m (dead pool level); fishway flood prevention sluice gate will be closed and fishway will have no fish passing when extreme flood comes.

See Figure 7.4.3-6 for operating water levels in the upstream and downstream.

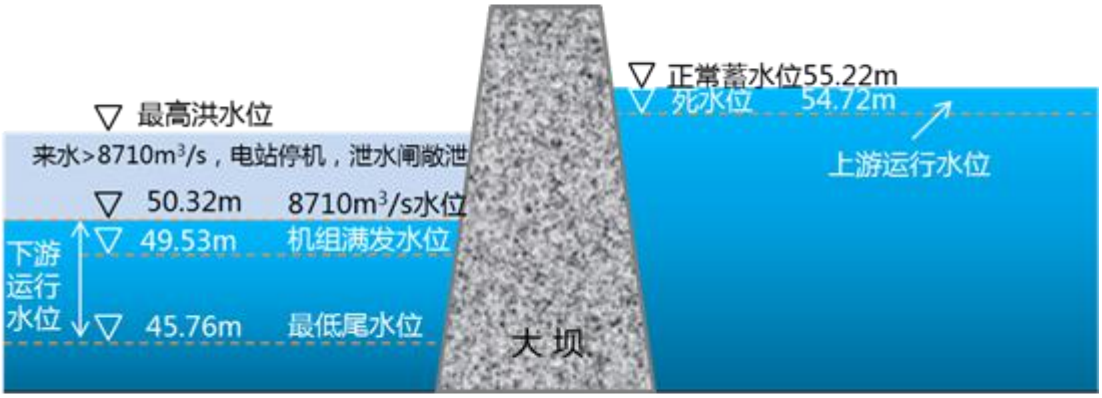


Figure7.4.3-6Sketch map of upstream and downstream operating water levels

原文	English
最高洪水位	Maximum flood level
来水>8710m^3/s，电站停机，泄水闸敞泄	Water inflow>8710m^3/s, power station shutdown, sluice open for unrestricted discharge
水位	Water level
下游运行水位	Downstream operating water level
机组满发水位	Unit maximum power generation water level
最低水位	Minimum water level
正常蓄水位	Normal storage level
死水位	Dead pool level
上游运行水位	Upstream operating water level
大坝	Dam

3) Water head difference

The maximum design water head difference of the project fishway is 55.22-45.76=9.46m; minimum operating water head difference=55.22-50.72=4.5m; water head difference amplitude is 4.96m.

b) Flow velocity

1) Fish flow resistance ability analysis

Main fish-passing subjects of the project include four major domestic fishes, therefore internal design flow velocity of the fish pass is determined by taking into account the flow resistance abilities of these fish species.

There were some tests done on the flow resistance abilities of four Chinese carps in China, accumulating relevant conclusions and materials. Institute of Hydro ecology conducted an additional test on existing data. See Table 7.4.3-8 for test result.

Table 7.4.3-8 Test result of flow resistance ability of four major domestic fishes

Species	body length(cm)	Inductive flow velocity (m/s)	Preferred flow velocity (m/s)	Critical swimming speed(m/s)	Extreme flow velocity (m/s)	Note
Mylopharyngodon piceus	26~30			0.6~0.94		Indoor test result of Institute of Hydrobiology of Chinese Academy of Sciences. Critical swimming speed refers to the swimming speed of fish after swimming against current for 30 minutes.
	40~50			1.25~1.31		
	64.1			1.06		
Ctenopharyngodon idellus	24~27			1.02		
	30~40			1.27		
	40~50			1.03		
Hypophthalmichthys molitrix	40~50			0.9~1.0		
Aristichthys nobilis	40~50			<0.8		
Ctenopharyngodon idellus	15~18	0.2	0.3~0.5		0.7	Test result of Survey and Design Institute of Hebei Provincial Hai River Treatment Headquarters, and Hebei Provincial Bureau of Aquatic Products. (fish tested have less physical strength after transportation)
	18~20	0.2	0.2~0.6		0.8	
Hypophthalmichthys molitrix	10~15	0.2	0.3~0.5		0.7	
	23~25	0.2	0.2~0.6		0.9	
Mylopharyngodon piceus	50~60				1.3	High-range model test result of Fuchun River fisway (1:1.5)
Ctenopharyngodon idellus	30~40				1.2	
Hypophthalmichthys molitrix	30~40				1.2~1.9	
	70~80				1.2~1.9	

Aristichthys nobilis	80~90				1.2~1.9	
Mylopharyngodon piceus	12~41	0.08		0.97	1.25	Institute of Hydro ecology test result of Ministry of Water Resources and Chinese Academy of Sciences
Ctenopharyngodon idellus	9~36	0.09		0.95	1.10	
Hypophthalmichthys molitrix	7~32	0.12		0.99	0.98	
Aristichthys nobilis	15~21	0.06		0.83	1.10	

2) Design flow velocity evaluation

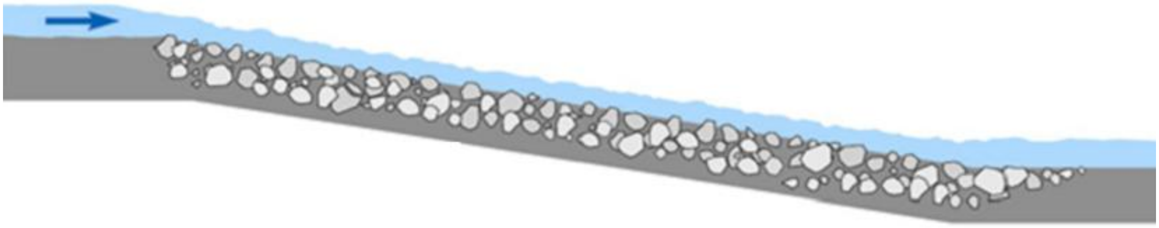
Combining historical research data and test data, recommended flow velocity value of fish-passing orifice/perps of this fishway is 1.1m/s; fishway inlet fish-luring flow velocity is controlled at 0.48~0.96m/s and determined to be 0.88~1.10 m/s after correction; recommended value of minimum inductive flow velocity is 0.2 m/s.

c) Fishway structure

1) Nature-like fish passage

(1)Pool-type structural type

Both fishway and nature-like fish passage are comprised of levels of water pools which achieve the purpose of flow velocity reduction by energy dissipation through diaphragm within the water pool. According to different forms of internal diaphragm, nature-like fish passage can be of different structural types. Currently, commonly seen fishway structure includes the three types of evenly-paved rock type, alternating rock type and weir type.



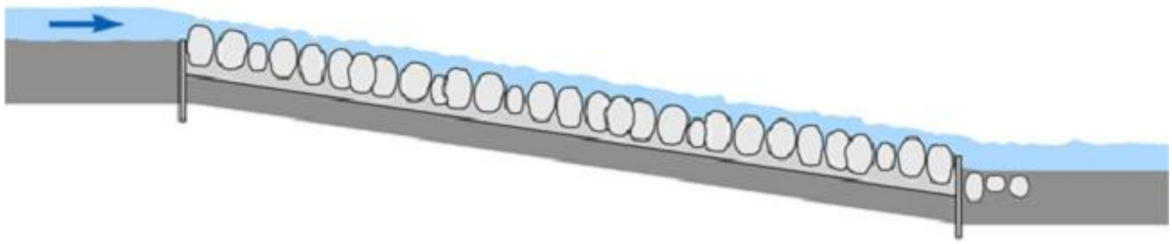


Figure 7.4.3-7 Sketch maps of nature-like fish passage with two types of even rock pavement

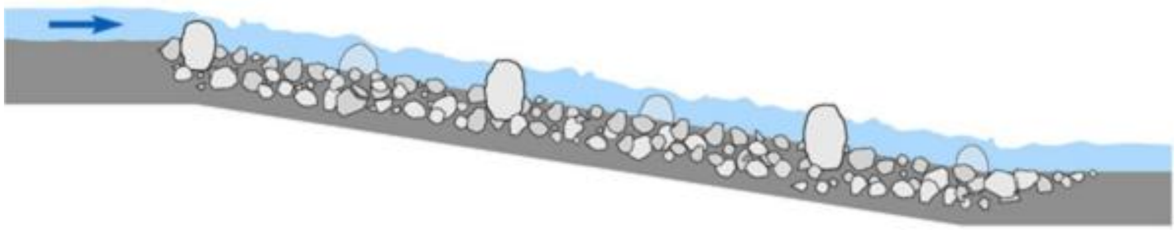


Figure 7.4.3-8 Sketch map of nature-like fish passage with alternating rock

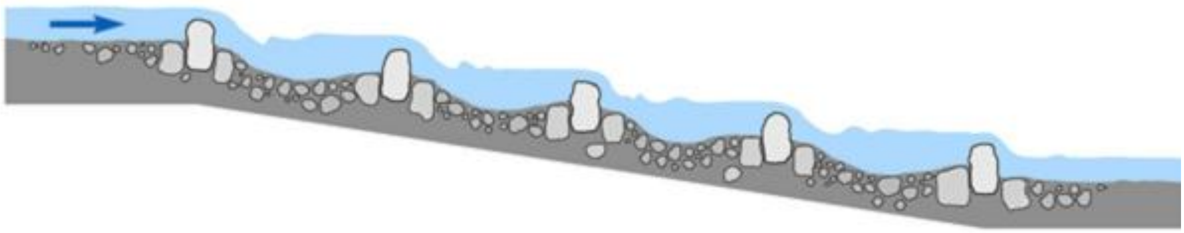


Figure 7.4.3-9 Sketch map of weir-type nature-like fish passage

Main fish-passing purpose of the project is to ensure as much as possible that fish migratory passageway is unobstructed including more fish species both surface and demersal fishes. Similar to fishway fish-passing orifice and perps-type fishway, alternating rock type can basically achieve linkage of the upstream and the downstream allowing both surface and demersal fishes to find and pass, thus further facilitating exchanges between various fish species in the upstream and downstream.

Meanwhile, given that downstream water level variation amplitude is close to 5m, out of the three structural types, evenly-paved rock type nature-like fish passage cannot adapt to such water level amplitude; weir type is also not recommended as rise or drop affecting fish passing may occur due to large variations of flow velocity along the pools in the upstream and downstream during water level variations. Out of the three plans, only alternating rock type nature-like fish passage can adapt to such water level changes.

Therefore, after comprehensive consideration of engineering characteristics and fish biological habits alternating rock type is the recommended structural type of nature-like fish passage.

(2) Passageway material

Nature-like fish passage uses different materials than fishway normally structured with steel reinforcement concrete, and usually include the following types:

A Enrockment

Main structure of enrockment type nature-like fish passage is usually structured by large rocks piling up with water flow protective screen forming by large rocks piling up internally according to certain requirements. Given its instable structure, enrockment type nature-like fish passage usually has a relatively shallow depth mainly between 0.5m~1.5m.

B Grouted rubble

Grouted rubble is rock-block brickwork using cementitious material. Rock keeps its side-wall stability by adhesiveness of the cementitious material, friction and its own weight. Given that interspace between rocks is densely filled, it has better integrality, compatibility and hardness which prevents leakage and increases erosion resistance. Fishway with grouted rubble materials can have increased side wall roughness and reduced flow velocity around side walls.

C Gabion

Gabion is cage woven by low-carbon high-galvanized steel wire strand filled with stoppings such as rock blocks. As an integrated structure with relatively stable structure, Gabion is generally used in flat river banks with high flow velocity, severe erosion and much slope leakage. Therefore, it is used in fishway with relatively large water flow velocity.

D Reinforced grouted rubble

Follows the same principle as normal grouted rubble, reinforced grouted rubble is stable rock-block brickwork of rocks connected by cementitious material. While normal grouted rubble usually uses rubble and has some surface reformation keeping a bright and clean surface, reinforced grouted rubble uses rock blocks of various sizes and shapes with cementitious material forming an uneven surface of larger roughness than that of normal grouted rubble.

Strengths and weaknesses of the following nature-like fish passage materials are compared as follows:

Table 7.4.3-9 Strength and weakness comparison of several nature-like fish passage materials

Fishway type	Enrockment	Grouted rubble	Gabion	Reinforced grouted rubble
Strength	Easy construction; complicated water flow conditions	Clean appearance; stable structure	Easy construction	Stable structure; complicated water flow conditions relatively large roughness; effective energy dissipation
Weakness	Water leakage and seepage; instable structure; difficult maintenance	Relatively small roughness; water flow relatively smooth	Gabion may harm fish body; Inaesthetic appearance	Relatively complicated construction

Enrockment-type nature-like fish passage

Fishway side wall with grouted rubble material

Gabion-type fishway

Reinforced grouted rubble nature-like fish passage

According to comparison above, **reinforced grouted rubble is the recommended flume material** for it ensures upright side wall like the fishway, saves land, avoids high slope excavation, ensures structural stability, increases side-wall and bottom roughness in addition to fishway structure, improves energy dissipation efficiency and further reduces flow velocity of the passageway allowing more fish passing in terms of species and sizes.

(3) Scale dimension

Nature-like fish passage of the nature-like fish passage adopts alternating rock type using rock barrier within the passageway for flow velocity reduction by energy dissipation, with a bottom width about 2.0m, a side slope of 1:2.5, water depth of about 2.0m, surface water width of 12.0m under normal operating water depth, and a passageway longitudinal gradient of 1%.

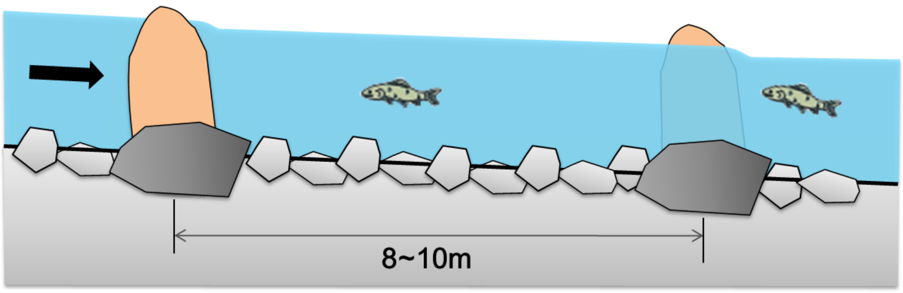


Table 7.4.3-10 vertical section of nature-like fish passage

2)Project fishway section

To meet the relatively large requirement of Yakou fish pass inlet water level amplitude prior the construction of Nianpanshan junction, a project fishway is to be built in addition to nature-like fish passage so as to meet the short-term fish-passing demand.

(1)Structural type

Fishway comprises levels of water pools achieving the purpose of flow velocity reduction by energy dissipation through diaphragm within the water pool. According to different forms of internal diaphragm, nature-like fish passage can be of different structural types. Currently, commonly seen fishway structures include the three types of Daniel type, downflow weir type and perps type. Main purpose of the project fishway section is to adapt to large water level variations prior Nianpanshan completion, therefore it can only use the vertical perps type.

Perps type fishway also includes various diaphragm design patterns with different hydraulic features for different applicable subjects, for instance unilateral perps type, opposite-side perps type and bilateral perps type. To meet the demand of exchanges between the upstream and downstream of small-sized fish species and fish species with relatively weak swimming abilities, opposite-side perps type and bilateral perps type fishway are not recommended. It is recommended that pool chamber structure adopts unilateral perps type.

(2)Scale dimension

Mature four Chinese carps are of relatively large sizes among major fish-passing subjects of Yakou shipping hub fishway, therefore their sizes are taken as a restrictive indicator. Maximum body length of four Chinese carps generally are between 100~120cm, considering fish-passing scale, fish-passing subject, chamber flow regime and total fishway body length of this fishway, chamber length of this fishway is determined to be 3.6m.

Fishway width is mainly related to perps width, fish-passing quantity, fish-passing species and individual sizes. The larger the fish-passing quantity is, the larger the fish-passing individual is, the larger the fishway width is. Given that fish-passing subjects are relatively many, local fishery resources are relatively plentiful, and fishway building land intensity and construction difficulty are not high, after overall consideration, fishway width is determined to be 3.0m.

Fishway water depth is mainly determined by habits of the fish-passing subjects, for instance demersal fish and large-sized mature fish may require deeper water depth, combined with variations of fishway operating water level. The project fishway needs to accommodate both surface and demersal fishes, and adapt to relatively large water level amplitude in the downstream. Relatively shallow water depth cannot adapt to relatively large water level amplitude and would require increases inlet numbers. Therefore, fishway normal operating water depth is designed to be 3.0m, and the depth can be accordingly increased as it gets closer to downstream chamber so as to prevent overflow due to water flow fluctuations of fishway during operation.

Design of fish-passing orifice is directly related to energy dissipation effect and fish possibility of the fishway. After overall consideration of body sizes of fish-passing subject, fishway dimension, and energy dissipation requirement of the fishway, minimum width of fish-passing orifice of this fishway is determined to be 45cm.

Flow velocity V of perps is determined by upstream and downstream water head difference Δh of perps: Vmax ≈(2gΔh)0.5;

Vmax is1.1m/s, so inter-pool drop: Δh ≈ (Vmax)2 /2g =0.06m;

Fishway base slope=Δh/L=0.06/3.6 ≈ 1/60;

Technically, one resting chamber should be built for every 1m elevation of this fishway. Resting pool has no base slope and is usually at least two times the chamber length. In addition, resting pool must be built in fishway turning corner with resting pools being long enough to prevent excessively forceful runs from the upstream blasting the opposite wall (in particular location of 180° turn) or prevent runs from obstructing water flow in the downstream runs (for instance, preventing swirling water flow formation). Therefore, resting pools are to be built in turning corners of the fishway.

(3)Natural simulation design

To reduce bottom flow velocity, fishway bottom is paved with pebble or gravel stone, using rock particles of a 10-30cm diameter in alternating layout of big and small rocks. See Figure 7.4.3-11 for specific requirements and design sketch. With reduced fishway bottom flow velocity, some fish species with weak swimming abilities can swim upstream along rock intervals on fishway bottom, meanwhile also providing locations for temporary rest and regaining strength.

To ensure rock stability under water flow blast, and prevent fishway from clogging, bottom rock also adapts grouted type.

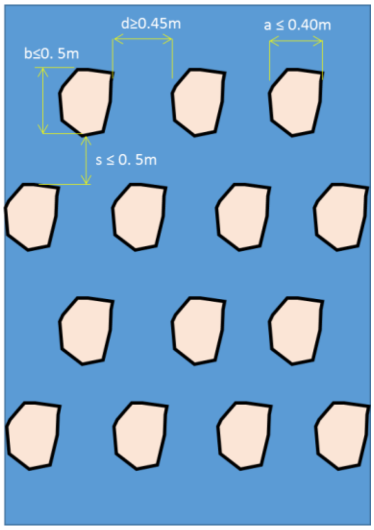


Figure 7.4.3-11 Sketch map and design sketch of rock layout on fishway bottom

d) Design of fishway inlet, outlet and fish collection system

1) Inlet design

(1) Analysis of flow field below the dam

According to *Han RiverYakou Shipping Hub Project Overall Water Engineering Model Test Research* Report drafted by Tianjin Research Institute for Water Transport Engineering of Ministry of Transport, under natural conditions prior hydropower development, during dry flow season dam site river section has water flow contracted to the center of its river channel in smooth and straight sections and water flow close to concave bank in curving river sections. Riverway flow velocity increases as flow volume increases, with a maximum flow velocity of average annual discharge being 1.6 m/s occurred in downstream concave bank area of an “S” curve. During main fish-passing season, main discharge is tail water of power generation from power station during normal fish pass operation. Therefore, mainstream is on the left bank closing to thalweg under the influence of left-bank guide wall.

(2) Analyses of fish migration route and concentration water area

When hydropower station generates power, flow velocity of tail water channel is about 1~2.5m/s, with an average flow velocity may be surpassing flow resistance abilities of some fish species. However, hydropower station tail water is not consistent and it is dynamic and instable that most fish species can reach water gap area by swings in the water areas on the bottom or alongside walls where friction is relatively large and flow velocity is relatively little, or riding on swirling water flow. Therefore, according to major flow fieldflow regime downstream of the dam, major fish concentration water areas below the dam are determined as shown in the picture below.

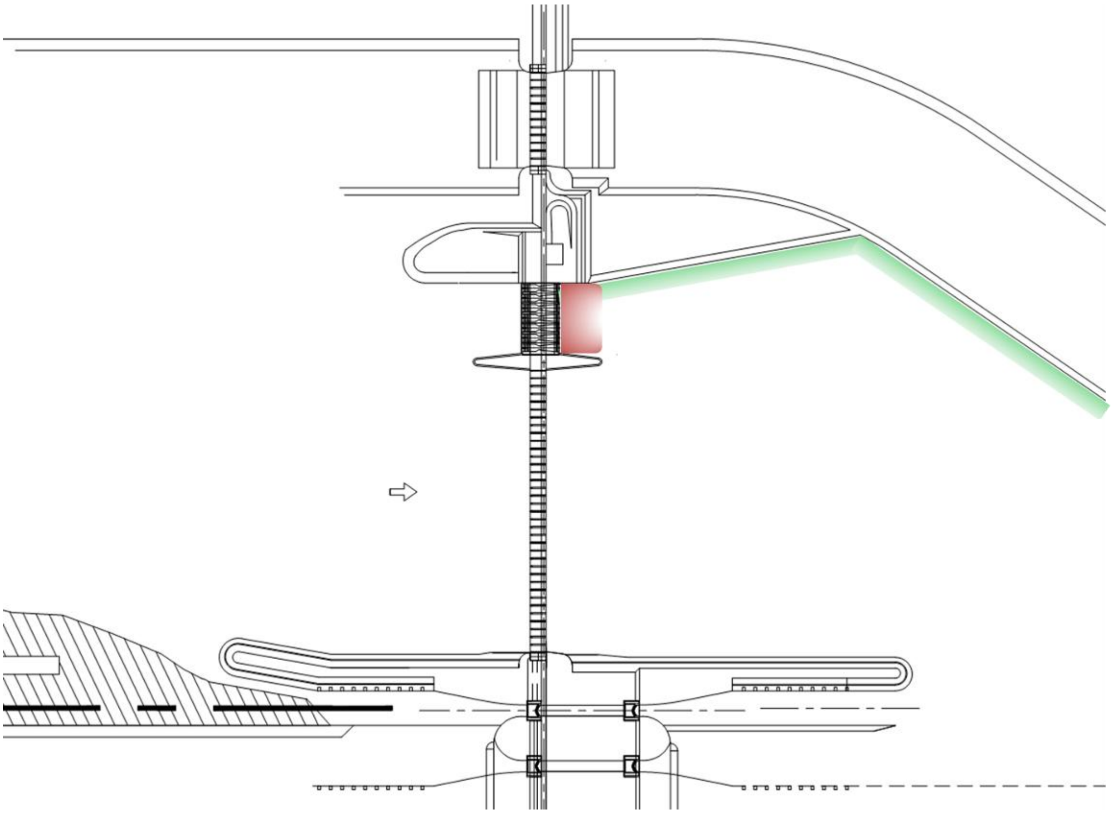


Figure 7.4.3-12Analysis of fish concentration water area downstream of the dam (red being main concentration area; green being main migration route)

(3) Fish pass inlet location selection

To improve fish-luring efficiency of fish pass inlet, fish pass inlet should be built in the water area with densest fish species. According to analyses of flow field flow regime below the dam and major fish concentration water areas, fish pass inlet should be built near hydropower station tail water as much as possible, and meanwhile also close to fish migration route as much as possible.

After overall consideration, to improve fish entering efficiency of fish pass inlet, fish pass inlet is to build in a location close to central bar on the left side of the hydropower station.

(4) Operating water level and elevation

Given that inlet water level changes between45.76m to 50.72m with water level amplitude reaching 4.96m, building one inlet would be difficult to meet such water level amplitude requirement affecting inlet fish-luring effect. Considering that the project is of daily adjusting effect, building too many inlets would require frequent water level changes involving the opening and closing of various inlets, which may be of certain interference to fish entering fish pass. After overall consideration, inlet elevation is determined according to water level features prior and after Nianpanshan project completion in the downstream. Two inlets of high and low water levels of 48.72m and 44.26m are determined as shown in Figure 7.4.3-13.

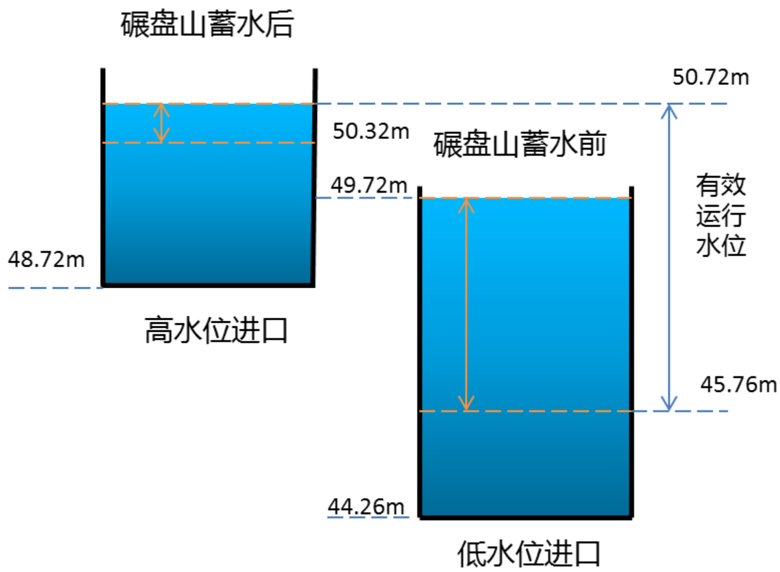


Figure 7.4.3-13Fish pass inlet operating water level and elevation

原文	English
碾盘山蓄水后	After Nianpanshan water storage
高水位进口	High water level inlet
碾盘山蓄水前	Prior Nianpanshan water storage
低水位进口	Low water level inlet
有效运行水位	Effective operating water level

Prior Nianpanshan construction:

When water level is between 45.76m and 49.72m, low water level inlet will be used and the corresponding operating water depth of low water level inlet is between 1.5m and 5.46m;

After Nianpanshan construction:

Downstream water level will be stably between 50.32m and 50.72m and the high water level inlet will then be used, with the corresponding operating water depth of high water level inlet being between 1.6m and 2.0m, capable of a relatively stable operation condition;

When flood is approaching with $Q>8710m^3/s$:

Fish pass will be closed; units shutdown and sluice open to unrestricted discharge allowing fish species to swim pass the dam through sluice.

(5) Inlet layout

According to relevant specifications, fish pass inlet should be built in flow field tail water location, which is good for fish luring using tail water from power generation from power station. Inlet of this fish pass is below the tail water on the left bank of hydropower station, a relatively ideal inlet location.

(6) Recharge facility

Prior Nianpanshan completion, water level amplitude below the dam is relatively large, during high water level operation, to avoid unfavorable situation in terms of fish luring such as relatively small inlet flow velocity, water recharge is necessary.

Water recharge is mainly for the purpose of improving inlet fish-luring flow velocity when water level exceeds normal operating water depth. Water recharge volume is $Q_{recharge}=(49.72m-46.76m)\times0.45m\times1.1m/s=1.47m^3/s$.

Through 1.8m-diameter steel guidepipe from upstream of the dam, water recharge enters fish pass via stilling pool for energy dissipation. The total length of water recharge pipe is 204.30m.

2) Hydropower station fish collection system design

Under normal power generating condition of the power station, most fish species swimming upstream will be attracted by tail water and concentrate along hydropower station tail water. Under full unit operation, it could be difficult for some fish species far away from right-bank fishway inlet to find the inlet. To improve fish-luring efficiency of fishway inlet regarding fish species concentrated on the other side of the hydropower station, hydropower station fish collection system is built on tail water platform, including water recharge channel, fish collection channel, fish inlet, water recharge pipeline and stilling pool. See picture below for its operating principle.

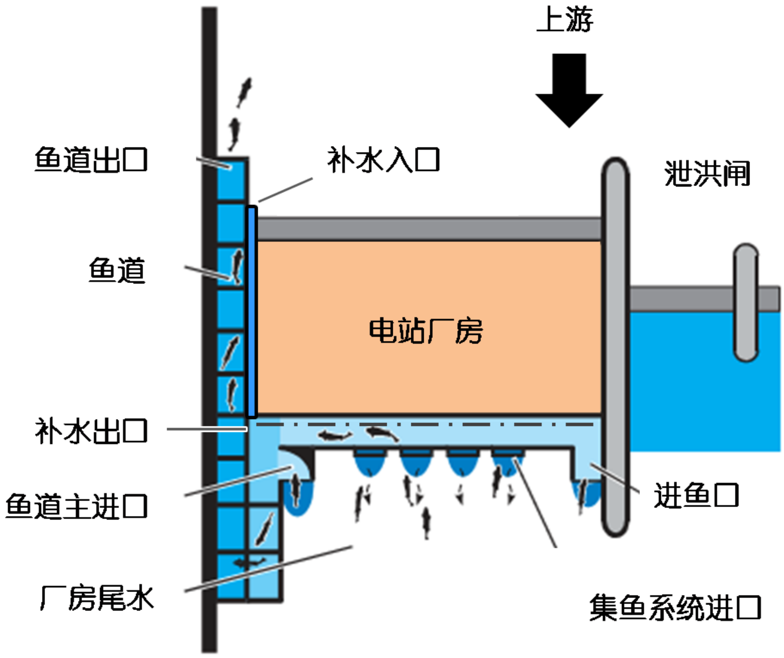


Figure 7.4.3-14Sketch map inlet fish-luring fish collection system and its operating principle

原文	English
鱼道出口	Fishway outlet
鱼道	Fishway
补水出口	Water recharge outlet
鱼道主进口	Fishway main entrance
厂房尾水	Hydropower station tail water
补水入口	Water recharge inlet

电站厂房	Station hydropower station
上游	Upstream
泄洪闸	Sluice
进鱼口	Fish inlet
集鱼系统进口	Fish collection system entrance

Fish collection system stretches across the front part of hydropower station tail water like a corridor with a total length about 59m, mainly including fish collection channel, water recharge channel, stilling chamber, grille and controlling sluice gate, among which fish collection channel is of a 2m wide U shape structure and fish collection channel floor has an elevation of 48.68m. Water recharge channel is of a cage structure with a width of 1.0m. Fish inlets are situated at the upper side of downstream side wall of fish collection channel, and each fish inlet has a rectangular orifice of 1m long and 0.5m wide. Preliminarily it is recommended to build 8 fish inlets with orifices evenly distributed in various unit sections with orifice bottom on the upper part of tail water pipe of different elevations so as to meet fish entering demands under different downstream water levels.

Various inlets have sluice gates. According to downstream water level changes, appropriate water depth is controlled by adjusting orifice opening and closing, opening size and opening elevation, as well as water flow volume and flow velocity of the controlled channel. Discharge flow velocity of various inlets of the fish collection system should be controlled within 0.48m/s to 0.96m/s.

The 2m wide fish collection channel gathers fish entered from various supporting inlets and guides them by water flow within the channel to inlet pool situated next to the fish collection system, and then into fishway to swim upstream. Fish collection channel keeps a certain horizontal flow velocity so as to attract fish species to swim towards the assembling pool, and horizontal flow velocity should be controlled within 0.4m/s to 0.5m/s for such flow velocity provides directional guidance to fish species without causing large water surface gradient within the channel, thus ensuring various fish inlets on the channel side will have roughly the same water level drop and orifice flow velocity in and out of the channel.

Stilling chamber (pool) is situated at the bottom of fish collection channel. Stilling chamber disperses water flow coming from water recharge channel for energy dissipation, which then slowly enters fish channel under relatively low flow velocity avoiding water surface fluctuations of fish collection channel and interference with fish going forward. Flow velocity from stilling chamber to fish collection channel should not be realized by fish species, otherwise fish species may stop at outflow grille. It is recommended that stilling chamber should have a flow velocity <0.15m/s, and an outflow grille flow velocity around 0.07m/s.

Various hydraulic conditions are relatively complicated in the fish collection system, so it is recommended that the validity of the design result should be verified and optimized by partial physical modeling test in the next phase.

3) Outlet

Outlet operating water level of this fishway is relatively stable, with most of the time being the normal water level of 55.22m. Therefore, elevation of the fishway outlet floor is determined to be 52.22m.

Outlet of this fishway is situated at a location about 330m from dam axis upstream of hydropower station on the left bank. The location is relatively far from hydropower station water inlet and fish species succeeded in swimming upstream will not be brought downstream by water flow.

e) General layout and parameter

1) Plane layout

Yakou shipping hub fish pass is situated in the waterfront area of central bar on the left side of left-bank flow field, with inlets situated below tail water area including a high water level inlet (bottom elevation of 48.72m) and a low water level inlet (bottom elevation of 44.26m). Low water level inlet after circling around once joins high water level inlet in the assembling pool (bottom elevation of 49.22m). Assembling pool is 30m long with sluice gate using a both manual and electronic screw headstock gear for opening and closing high or low water level inlets according to water level changes. Fish-passing passageway circles booster station, extends to the upstream after crossing dam structures, and further extends to the upstream reservoir area about 330m from dam axis.

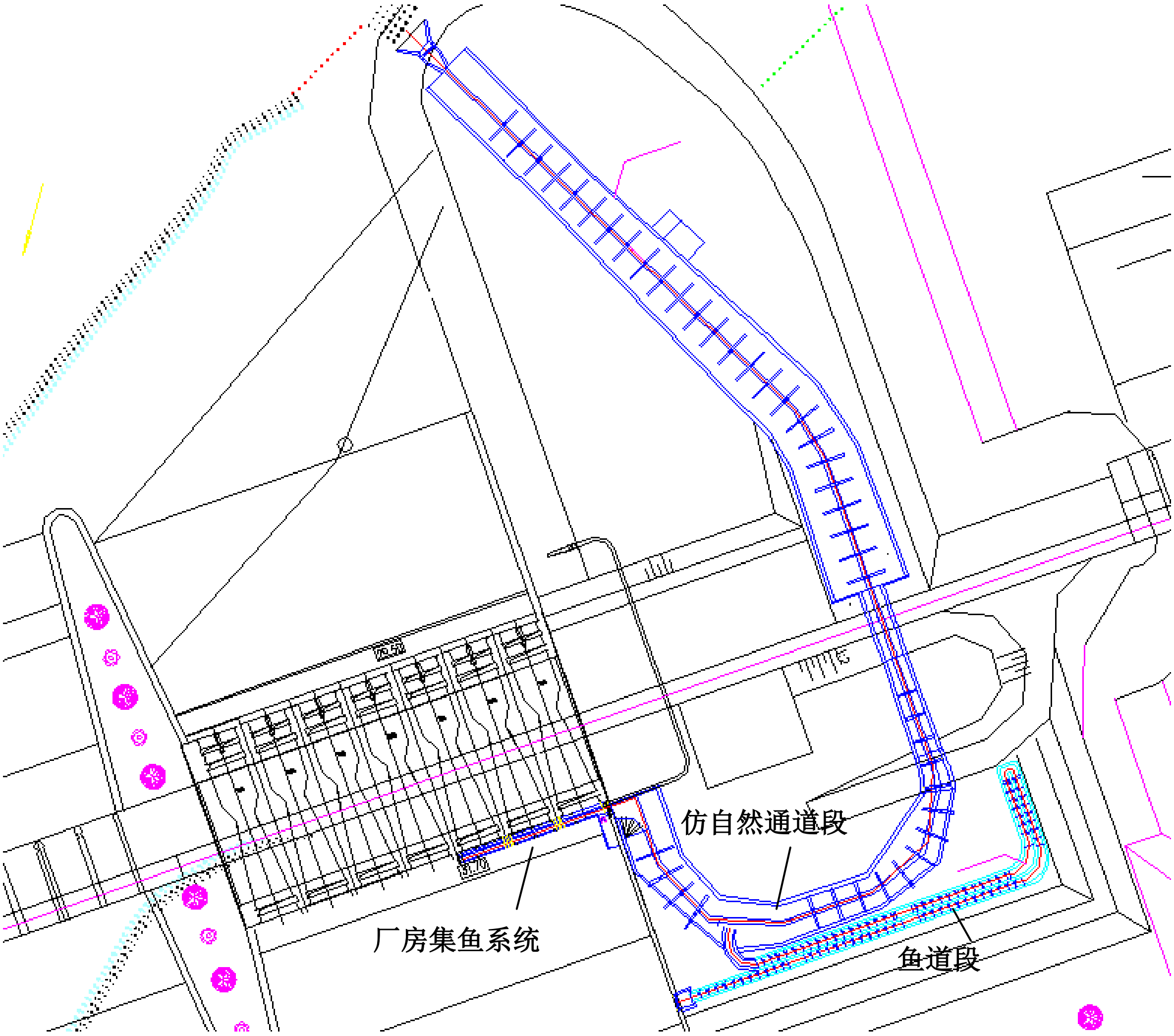


Figure 7.4.3-15 Fish pass general layout

原文	English
厂房集鱼系统	Hydropower station fish collection system
仿自然通道段	Nature-like fish passage
鱼道段	Fishway section

Total length of fish pass is 951.08m, among which ecological passageway simulation is 560.58m and the project fishway section is 390.5m. Ecological passageway simulation has a trapezoid cross section, a 2.0m bottom width, a 1:2.5side slope, a water depth of 2.0m, surface water width of 12.0m under normal operating water depth, and a passageway longitudinal gradient of 1%, including altogether 45 sections (section length 10m, divided by 200mm grouted rubble diaphragm) and 2 resting sections (total length 60m), with side slope using reinforced grouted rubble and bottom paved by pebble or gravel stone. Fishway adapts a rectangle cross section, with a chamber length determined as 3.6m and a water depth determined as 3m. Fishway has 7 resting pool sections among which 4 are in curved sections with 200mm diaphragm and minimum fish-passing orifice width determined as 45cm. fishway floor and side walls adopt on-site concrete with an average fishway floor gradient of 1/60. Fishway floor is paved by pebble or gravel stone.

Upstream outlet of ecological passageway simulation will have a bulkhead sluice gate for maintenance and passageway flow volume adjustment using a both manual and electronic screw headstock gear for opening and closing. At the front part of the culvert section connecting the dam area, a bulkhead sluice gate will be built for flood prevention, using a both manual and electronic screw headstock gear for opening and closing. Ecological passageway simulation and downstream inlet of the project fishway all have bulkhead sluice gates for maintenance and flood prevention, using both manual and electronic screw headstock gears for opening and closing.

Upstream water recharge pipeline inlet has a floor elevation of 51.72m and a bulkhead sluice gate for maintenance and water recharge adjustment using a both manual and electronic screw headstock gear for opening and closing. Sluice gate is connected in the back to a prefabricated concrete pipe of 1.8m in diameter and concrete foundation is built below water recharge pipe. With a water recharge pipeline outlet elevation of 47.82m, discharged water hits the surface of downstream water recharge system and enters into fish collection system from water recharge orifice of 800mm×400mm (width×height) on the wall between water recharge channel and fish collection channel. Water recharge pipeline is water recharge pipeline, with water recharge channel and fish collection channel width being 1.0m and 2.0m respectively and length both being 63.64m, hanging over flow field tail water gate pier, with the top elevation being 51.70m. Water recharge channel bottom elevation is 47.82m. Bottom elevations of fish collection channel, assembling pool, main fish entrance all are all 48.72m. Fish collection channel has fish orifice (dimension 1000mm×1000mm) built with an elevation of 49.46m.

Fishway outlet is equipped with observation chamber and sampling pool to count the number and species of passing fish.

2) Parameter summary

See Table 7.4.3-10 for major design parameters of Yakou shipping hub fishway.

Table 7.4.3-10 List of major fishway parameters

	Item	**Unit**	**Indicator**	**Note**
Nature-like fish passage	Structural type		Alternating rock type	
	Bottom width	m	2.0	
	Water depth	m	2.0	
	Side slope		1:2.5	
	Chamber length	m	10	
	Total width	m	12.0	Normal operating water depth
	Base slope		1:100	
	Total length	m	510	Effective dimension, including assembling pool
	Inlet elevation	m	48.72	
	Outlet elevation	m	53.22	
	Operating discharge	m^3	1.23	
Project fishway section	Diaphragm type		Vertical perps type	
	Chamber length	m	3.60	Effective dimension
	Chamber width	m	3.00	Effective dimension

Table 7.4.3-10(continued)

	Item	**Unit**	**Indicator**	**Note**
Project fishway section	Perps width	m	0.45	Effective dimension
	Inter-pool drop	m	0.06	
	Fishway base slope		1/60	
	Resting pool length	m	7.20	Effective dimension
	Resting pool number	unit	7	
	Inlet elevation	m	44.26	

	Item	Unit	Indicator	Note
	Outlet elevation		49.22	Same assembling pool
	Fishway total length	m	390.5	Effective total length excluding special structures such as curve or sluice gate
Assembling pool	Length	m	30.00	
	Bottom width	m	2	
	Side slope		1: 2.5	
	Water depth	m	2.00	
	Base slope		0	assembling pool has no base slope
	Elevation	m	49.22	

f) Subsidiary facility

1) Observation chamber

Fish pass is equipped with observation chamber situated near fishway outlet to count fish species and numbers successful of swimming upstream, evaluate fish-passing effect of the fishway, prepare for future fishway structural improvement and improve fish-passing effect, with publicity and exhibition functions at the same time. Observation chamber is a two-story building with one ground floor and one underground floor. The ground floor is a show room where tourists can watch live fish migration in the fishway on projection TV, with introductions of major migratory fish species exhibited on the walls. The underground floor is the fish pass observation chamber which is mainly used for storing equipment such as camera and electronic counter. Underwater cameras are set within the passageway for number counting, observing postures of fish in the passageway and judging adaptability and level of fatigue of fish towards the passageway.

2)Fish collection pool

To monitoring the operating effect of the fishway, and record detailed parameters including number counting, species verification and size measurement of passing fish, collection of fish from the fishway is necessary. Fish collection pool built next to the fishway can be used for fish collection.

7.4.3.5 Fishway work amount and investment

See Table 7.4.3-11 for work amount of main fishway structures of Yakou shipping hub.

Project investment estimate is 18.0776 million Yuan and see Table 7.4.3-12 for details.

Table 7.4.3-11 Work amount of main fishway structures of Yakou shipping hub

Serial No.	Compartmentalized project name	Unit	Project number
1	Water recharge channel fish inlet tank C25	m³	1130
2	Floor, thickness (within m) 2 C20	m³	1276
3	On-site concrete steel reinforcement processing floor	T steel reinforcement	56.5
4	water recharge channel, C25	m³	508.2
5	On-site concrete steel reinforcement processing, others	T steel reinforcement	29.11
6	Grouted rock blocks, bottom protection M25	m³	2215.98
7	Grouted pebble bottom protection M25	m³	222
8	Grouted rock blocks, flat protection slope M25	m³	6158.38
9	Grouted pebble, flat protection slope M25	m³	616
10	Ground paving project of inverted filter geotechnical cloth	㎡ paving area	16049.41
11	Retaining wall, average thickness (within m) 1.0 C20	m³	314.51
12	Slab with bottom membrane, thickness(within m) 0.5 C25	m³	77
13	On-site concrete steel reinforcement processing, land transportation and installation, others	T steel reinforcement	6.62
14	Grouted rock-block embankment M25	m³	4785.92
15	Grouted pebble embankment M25	m³	479
16	Cushion M10	m³	802.47
17	Floor, thickness (within m) 1 C20	m³	610.21
18	Others, caping, pier C25	m³	22
19	Ground paving project, on-site backfill, bulldozer rolling	m³paving area	2200
20	cushion C20	m³	110
21	Apron C25	m³	30
22	Floor, thickness (within m) 1 C20	m³	10562.8
23	Vertical plate, thickness (within m) 0.5 C20	m³	184.47
24	on-site concrete steel reinforcement processing, others	T steel reinforcement	11.07
25	Ground paving project, laying cushion pebble	m³paving area	247.5
26	Ground paving project, on-site backfill, bulldozer rolling	m³paving area	21919.92
27	Water stopping copper sheet width 30cm	Linear meter	777.17

28	retaining wall (average thickness (within m) 1.0 C20	m³	137.46
29	retaining wall (average thickness (within m) 1.0 C20	m³	120.27
30	Steel pipe scaffold plate, flat plate: thickness (within m) 2	m³concrete	12448.21
31	steel pipe scaffold steel reinforcement concrete wall, gravity type	m³concrete	572.24
32	steel pipe scaffold grouted rubble wall, gravity type	m³concrete	13160.28

Table 7.4.3-12 Project cost summarization of Yakou hub fishway

Serial No.	Item name	Price (ten thousand Yuan)
1	Civil engineering project	14.74
1.1	Observation chamber	7.04
1.2	Sampling chamber	7.70
2	Water works	1511.85
2.1	Total roughly estimated direct expense	1254.55
	Among which labor cost :	240.26
	material cost:	947.85
	mechanical cost :	66.44
2.2	Total construction expense	257.30
3	Metal structure	81.17
3.1	Total roughly estimated direct expense	71.2316.97
	Among which labor cost :	13.78
	material cost:	43.86
	mechanical cost :	13.58
3.2	Total construction expense	9.94
4	Observation chamber equipment	200.00
5	Total	1807.76

Note: see detailed investment estimate in *Hubei Provincial Han River Yakou Shipping Hub Project Fish Pass Technique and Plan Comparison and Selection Report*.

7.4.3.6 Fishway operation plan

For the project, the main purpose of fish pass is to facilitate fish exchanges of upstream and downstream of the dam. Main fish-passing season is determined to be from March to September based on the reproduction season of major fish-passing subjects. According to *Reply to Joint Ecological Operation Plan (trial) of Han River Hydro-junctions Downstream of Danjiangkou* (EZH [2015] No. 235, during the Han River peach blossom flood season from March to early May, the main objective of ecological operation is to ensure that parent fish downstream of the dam are able to swim upstream of the dam as river water temperature is relatively low and large numbers of matured parent fish are gathered below various junction dams to swim further upstream. Therefore, fishway operation plan of the project:

Fishway is mainly for parent fish gathered below the dam during March to August to swim upstream. In Han River, fish going downstream is mainly dependent upon unrestricted sluice discharges during large-scale flood periods according to project dispatching and joint ecological operation of hydropower development projects. When the number of unrestricted discharge is limited, hydro-turbine and sluice are used. Fish-passing subjects are mainly fish with pelagic eggs and juvenile fish mainly drifting with water inactively due to weak swimming ability. According to survey, with ordinary axial-flow and cross-flow hydro-turbines, survival rate of fish going downstream can reach 90%. Therefore, during August and September every year natural simulation fishway can be used as a part of fish habitat which also allows fish going downstream.

7.4.4 Artificial stock enhancement and releasing

7.4.4.1 Releasing species

The determination of enhancement and releasing species requires overall planning while highlighting priority. For already determined protection subjects, comprehensive analysis need to be conducted for combination of the near and the far as well as reasonable optimization according to resources situation and biological features of the protected fish species, as well as changing trend of ecological environment, and technical and economic feasibility. In actual operation, determination of enhancement and releasing species is similar to the determination of protection subjects in terms of factors considered. However, the following issues need to be noticed.

From a technical prospective, considering that fry breeding technology is relatively well-developed, priority should be given to species with certain productive scale. For breeding technologies that are not yet successful but have matured artificial reproduction technology of similar species to learn from, artificial egg collection and parent releasing can be adopted before achieving breakthrough and carrying out artificial reproduction releasing as the result of strengthening research on enhancement and releasing technology. For fish species whose proper habitats are severely damaged and can only be stock species because they can no longer form natural population, they are not suitable for being enhancement and releasing subjects. For species with extremely rare stock and are difficult to collect eggs or parent fish, they are not suitable for being enhancement and releasing subjects for now, and may carry out enhancement and releasing after resources are restored.

As for the selection of releasing subjects, given that protection fish species and special fish species are few in population number, difficult to recover once damaged, and have special requirements for habitats, weak self-adjusting abilities and weak resistance towards outside interference, therefore enhancement and releasing subjects are mainly rare protected fish species and special fish species, followed by major economic fish species. Meanwhile, the selection of enhancement and releasing subjects also needs consider factors such level of being affected by the project, protection requirements, current resources amount and artificial reproduction technology.

According to key protection subjects of the lower reach of Han River, combined with features of fish resources and requirements of fishery development, enhancement and releasing species given key considerations include *Leiocassis longirostris*,*Megalobrama skolkovii*,*Parabramis pekinensis*,*Squaliobarbus curriculus*, *Distoechodon tumirostris*, *Luciobrama macrocephalus*, *Ochetobibus elongatus*, *Hypophthalmichthys molitrix*, *Aristichthys nobilis*, *Ctenopharyngodon idellus*, *Mylopharyngodon piceus*, *Elopichthys bambusa* and *Leiocassis crassilabris*. Given that fish species such as *Luciobrama macrocephalus* and *Ochetobibus elongatus* have not been seen in the reservoir area for many years and thus cannot carry out domestication or reproduction research or practice, they can only be key observatory subjects needing survey on resources situation. *Hypophthalmichthys molitrix*, *Aristichthys nobilis* ,*Ctenopharyngodon idellus* and *Mylopharyngodon piceus* are proposed to be sub-contracted as they have developed systems of protospecies and fine breed and Hubei province can provide enough quality fries on its own.*Elopichthys bambusa*, being a ferocious fish of relatively great impact to fish populations, is not suitable for releasing at the moment and may be suitable for enhancement and releasing based on further resources monitoring situations. *Leiocassis crassilabris* is currently not yet successful in artificial domestication and reproduction, and may be suitable for enhancement and releasing when with matured technology resulting from the recently started research on domestication and reproduction technologies.

Therefore, immediate key releasing species include *Hypophthalmichthys molitrix, Aristichthys nobilis, Ctenopharyngodon idellus, Mylopharyngodon piceus, Leiocassis longirostris, Megalobrama skolkovii, Parabramis pekinensis, Squaliobarbus curriculus*and *Distoechodon tumirostris*; enhancement and releasing subject added in the long term include *Leiocassis crassilabris*.

7.4.4.2 Releasing standard

Fry released must be first filial generation of artificial reproduction from wild parents. Some Han River fish eggs collected by aid station can be incubated and cultivated as parent fish for the purpose of reproduction, however, over 60% shall be wild parents introduced from Yangtze River. Fry released must not have disabilities or diseases and must be physically strong. It is recommended that releasing fry species technical specification should be formulated by national fishery administrative authorities.

7.4.4.3 Releasing number and specification

Releasing number: number of enhancement and releasing is generally related to the objective of enhancement and releasing, as well as factors such as natural environment of releasing water body, hydrological climate, physicochemical property, food organism resources, current fishery resources, population structural feature, biological feature, size and quality of the subject released, releasing frequency and timing. Given that factors needing consideration are relatively complicated regarding the determination of enhancement and releasing number with many uncertain factors added, it is very difficult to determine the reasonable releasing number for an open natural water body, and there is no unified standard calculation method till this day.

According to monitoring situations of fish resources populations after reservoir construction, number of releasing fry can be properly adjusted.

Fry releasing standard: size of individual fry released is of great impact on releasing effect. Fry released being too small directly impacts releasing effect due to low survival rate resulting from weak resistance to natural environment such as wind and wave resistance, low energy and easiness to be captured and eaten by ferocious fish. However, fish fry being too large may require more economic input. Generally speaking, releasing fingerling should follow the standard of starting scale formation, because at this stage fingerling will have its eye, fin, mouth and digestive functions fully developed, and has turned from endogenous nutrients to active foraging in the outside world, forming its own way of life. Meanwhile, scale formation improves various functions of surface skin, including mucus secreted by the skin which reduces friction on fish in water body, ensures swimming speed of fish in water, and helps the fish to forage more effectively while be better at avoiding been captured by other fish species. Mucus secreted by the skin forms a protection membrane outside of the body, which effectively prevents penetrations of various bacteria in the water body and maintains water body stability of its whereabouts. In addition, most fish species have epidermis cell pigment formed during scale formation period, and have adapted to water body backgrounds of where they are, making them better at hiding themselves in water body environments and more effective in foraging and avoiding been captured by other fish species.

Fishery production is highly seasonal, so is the buying and selling of fish fry. For general production, “Shuihua”, “Xiahua” and “Dongpian” are sold. “Shuihua” refers to fry without mouth opening for food; “Xiahua” refers to small-sized fingerling with fresh scale; “Dongpian” refers to large-sized fingerling after one year cultivation. Their sizes are respectively 0.8-1.0cm, 3cm and 10-15cm. Sizes of fry released should be according to the actual situation of fry production.

In actual enhancement and releasing operation, sizes should be flexibly adjusted according to fry growth, fry source, water area eco-environmental situation and ferocious fish resources. Generally, releasing size can be based on the cultivated sizes of the year, and releasing after wintering due to the blind pursuit of larger size is not encouraged.

The larger the size of fingerling released, the stronger adaptability to environment and ability to avoid enemy organism, the higher the survival rate. However the larger the fingerling size, the higher the cultivation cost and the more production facilities required. In conclusion, size of artificial enhancement and releasing should be within a total length of 4-10cm; releasing size of the aid station from the period of incubation to smooth swimming should be around 3cm.

Number of enhancement and releasing require overall consideration of current resources situation, fishery development planning and water quality management, and is generally related to natural environment of releasing water body, hydrological climate, physicochemical property, food organism resources, current fishery resources, population structural feature, biological feature, size and quality of the subject released, releasing frequency and timing. Enhancing and releasing protection measures taken after hydropower project construction are compensational releasing, therefore, determination of enhancement and releasing number is also closely related to the range and level of impact on fish resources from project construction and operation. Given that factors needing consideration are relatively complicated regarding the determination of enhancement and releasing number with many uncertain factors added, it is very difficult to determine the reasonable releasing number for an open natural water body, and there is no unified standard calculation method till this day. Estimate based on area after reservoir completion is listed below:

For releasing number, fishery resources situation of the river section surveyed and length and area of water area after operation are considered, combined with *Reservoir Fishery Facility Supporting Specification* (SL95-94, Ministry of Water Resources, 1994) published by the Ministry of Water Resources, Yakou reservoir area is 52.67km long, with a reservoir area of 853.8hm^{2}under normal water level. For river, according to *Reservoir Fishery Facility Supporting Specification* (SL95-94, Ministry of Water Resources, 1994) published by the Ministry of Water Resources, it is Class Two water body with a fishery yield of 150-300kg/hm^2. Given that there are few carnivorous fish, fingerling stock should be 3 and releasing fingerling body length should be between 4-8cm of about 250-300 fish/kg, and releasing number is calculated to be 5% of reservoir fish number. Therefore, releasing number should be 853.8×(150 ~ 300)/3×(250 ~ 300)×5%= 85.38-204.91 ten thousand fish/year, with an average releasing fish number being (64.03+153..68)/2=1088.6thousand fish, and the actual releasing number should 4354.4 thousand fish as calculated by a 25% fry survival rate. Preliminary releasing number is 4 million fish per year; among 4 million fish, 3.5 million are to be subcontracted for cultivation and 500 thousand fish are to be reproduced and cultivated by the enhancement and releasing station. See Table 7.4.4-1 for details.

Table 7.4.4-1Fish stock enhancement and releasing scale (ten thousand) of Yakou shipping hub project

Serial No.	Species	Releasing standard and number (ten thousand) of Yakou Project			Source
		total length4-6cm	total length6-8cm	total length8-10cm	
1	*Ctenopharyngodon idellus*			40.0	Sub-contract production
2	*Mylopharyngodon piceus*			10.0	
3	*Hypophthalmichthys molitrix*			200.0	
4	*Aristichthys nobilis*			100.0	
5	*Leiocassis longirostris*	3.0	12.0		Build enhancement and releasing station for production
6	*Megalobrama skolkovii*		17.0		
7	*Parabramis pekinensis*		8.0		
8	*Squaliobarbus curriculus*	3.0	3.0		
9	*Distoechodon tumirostris*	4.0			
	Total	10.0	40.0	350.0	400.0

7.4.4.4 Releasing cycle and releasing location

a) Releasing cycle

According to compensation of biological resources loss and compensation term (multiple) of Clause 7.2 of *Technical Specification of Impact Evaluation of Construction Project on Marine Biological Resources*: biological resources loss by occupying fishery water area shall be compensated for 3 years should the term of occupation be less than 3 years; shall be compensated for the actual term of occupation should the term of occupation be from 3 to 20 years; shall be compensated for no less than 20 years should the term of occupation exceed 20 years. The project has planned for a 20-year fish releasing cycle. After 20 years, releasing plan will be adjusted according to the restoration situation of fish resources.

b) Releasing location

Selection of releasing location need to meet the following requirements: ① convenient transport; ②reservoir bay with relatively open water area or riverway backwater bay, featuring stable and slow water flow; ③water depth within 5m and few ferocious fish; ④ relatively plentiful food organism. According result survey of current aquatic organism situation, combined with water regime of Yakou reservoir area and downstream of the dam, as well as flow field distribution situation, 3 releasing locations were proposed, namely Tangbai River estuary of Cuijiaying reservoir area, Wei River estuary of Yakou reservoir area, and Ying River estuary downstream of the dam.

7.4.4.5Comparison and selection of construction plans of enhancement and releasing station

According to technical and management requirements of location selection regarding fish stock enhancement and releasing station, based on site survey altogether 2 site plans are proposed, namely reconstruction and expansion of fish stock enhancement and releasing station of Cuijiaying hydro-junction project, and new construction of proposed site of Yakou shipping hub.

a) Reconstruction and expansion of fish stock enhancement and releasing station of Cuijiaying hydro-junction project

Han River Cuijiaying hydro-junction project EIA Report requires 14 species of releasing fish and altogether 226 thousand fishes. Fish stock enhancement and releasing station project of Cuijiaying hydro-junction project started on January 17 of 2011 and completed on July 2 of 2011. Previous design incorporates impounding reservoir, incubation facility, power facility, aeration facility, office building, road, fishing facility, parent fish breeding pool, fry breeding pool and stock breeding pool and drainage and irrigation system, including (1) 8 parent fish pools of 5 mu each; (2)

one protospecies ecological pool of 15 mu; (3)fry breeding pool, 1-2 mu; (4) impounding reservoir of 4-5 mu and 3m depth; (5) two 5m-radius spawning pools; (6) water tower of $100m^2$and 3m depth; (7) incubation tank: length*width*depth=2m*1.5m*1.2m; (8) supporting facilities.

Currently, facilities that are completed and can be operated include: (1) protospecies ecological pool of $6{,}000m^2$; (2) parent fish pool of $6300m^2$; (3) fry breeding pool of $2600m^2$; (4) two 5m-radius spawning induction pools; (5) water diverting pipeline: automatic flow diversion from reservoir area; (6) roads. Incubation facility and fry pool supporting facilities are not completed and cannot operate. Reconstruction is needed to meet original design functions. There is a 20 mu opening near the station site that can be used as expansion land; water source is artesian water of the reservoir area and 0.5 km apart, facilitating operating cost decrease and convenient management.

b) New construction of proposed site of Yakou shipping hub

Fish stock enhancement and releasing station on the right bank overflow lands was planned to about 86.7 mu, including parent fish pool, fry pool, fry breeding plant and incubation pool. Key construction conditions according to site survey are: proposed location on the right bank overflow lands is downstream of the management office camp which needs water supply for production as it has an elevation of 56.00m whereas reservoir maintains an operating water level of 55.22m; straight-line distance between overflow lands station site and Han River is about 500m; close to and can be integrated with the management camp dividing by center line of the dam; relatively abundant land area.

c) Analysis and comparison

There is a nearly 20-Mu spacing that can be used downstream of Cuijiaying fish stock enhancement and releasing station, where 10 mu can be used as reconstruction and expansion land after keeping enough riverfront area. Soil property of the land is prone to leakage which requires for anti-leakage treatment. The proposed station site of Yakou shipping hub fish stock enhancement and releasing station has abundant proposed area of 80 mu and may not need anti-leakage treatment for its soil property.

Cuijiaying fish stock enhancement and releasing station is capable of automatic water diversion greatly benefitting future operation; Yakou proposed station need pump station for water supply. Artesian water supply can greatly improve water quality and operational convenience, and is conducive to reproduction efficiency and success rate of releasing fish; reconstruction and expansion can take full advantage of existing facilities.

However, reconstruction and expansion involves issues including construction cost apportionment, operation cost apportionment, operating management, and sci-tech research investment, which require coordination of multiple sides for solution.

In conclusion, construction plan of a new fish stock enhancement and releasing station nearby Yakou shipping hub camp is recommended and adopted.

7.4.4.6Process design of the recommended plan

a) Design objective

1) Meeting immediate scale requirement of fish stock enhancement and releasing

Immediate releasing species of Yakou shipping hub project are *Leiocassis longirostris, Megalobrama skolkovii, Parabramis pekinensis, Squaliobarbus curriculus* and *Distoechodon tumirostris*, with an annual releasing amount of 500 thousand fish. Releasing of *Mylopharyngodon piceus, Ctenopharyngodon idellus, Hypophthalmichthys molitrix* and *Aristichthys nobilis* will be subcontracted.

2) Medium and long term fish stock enhancement and releasing requirement

The purpose of carrying out fish stock enhancement and releasing is to protect and restore fish resources of the project involved river section and maintain a stable water ecosystem. In designing a fish stock enhancement and releasing station, considerations need to be given to research platform and facility of fish stock enhancement and releasing technology, which carry out medium and long-term research on fish stock enhancement and releasing technology regarding fish in the lower reach of Han River, so as to realize medium and long-term fish stock enhancement and releasing for the protection of basin fish resources.

(3) Han River basin fish protection demonstration project construction

Fish stock enhancement and releasing station is an important environmental protection project of water-related project. Focusing on environmental protection, it will be developed into an ecological zone of certain scale, publicity and educational point for environmental protection, and an environmental protection demonstration project.

b) Technical work procedures

Technical work procedures of the enhancement and releasing station include mainly: collection and purchase of parent fish, domestication and cultivation of parent fish, artificial spawning induction and insemination, artificial incubation, fry cultivation, releasing, releasing effect monitoring, production scale and method adjustment, with structures designed meeting corresponding production procedures. See Figure 7.4.4-1 for details.

c) Productive plan

Fish stock enhancement and releasing station can be divided into the three stages: parent fish cultivation; spawning induction and incubation as well as cultivation of freshly incubated fry; fry cultivation.

Parent fish cultivation: earth-pool still water cultivation and flowing water cultivation. Circulating water cultivation belongs to flowing water cultivation adding water treatment system and recycling of wastewater from cultivation. According to living habits of releasing fish species, the cultivation method of outdoor parent breeding pool refilled regularly with new water is adopted given that releasing fish originally live in river section of Han River basin where soil is generally adhesive.

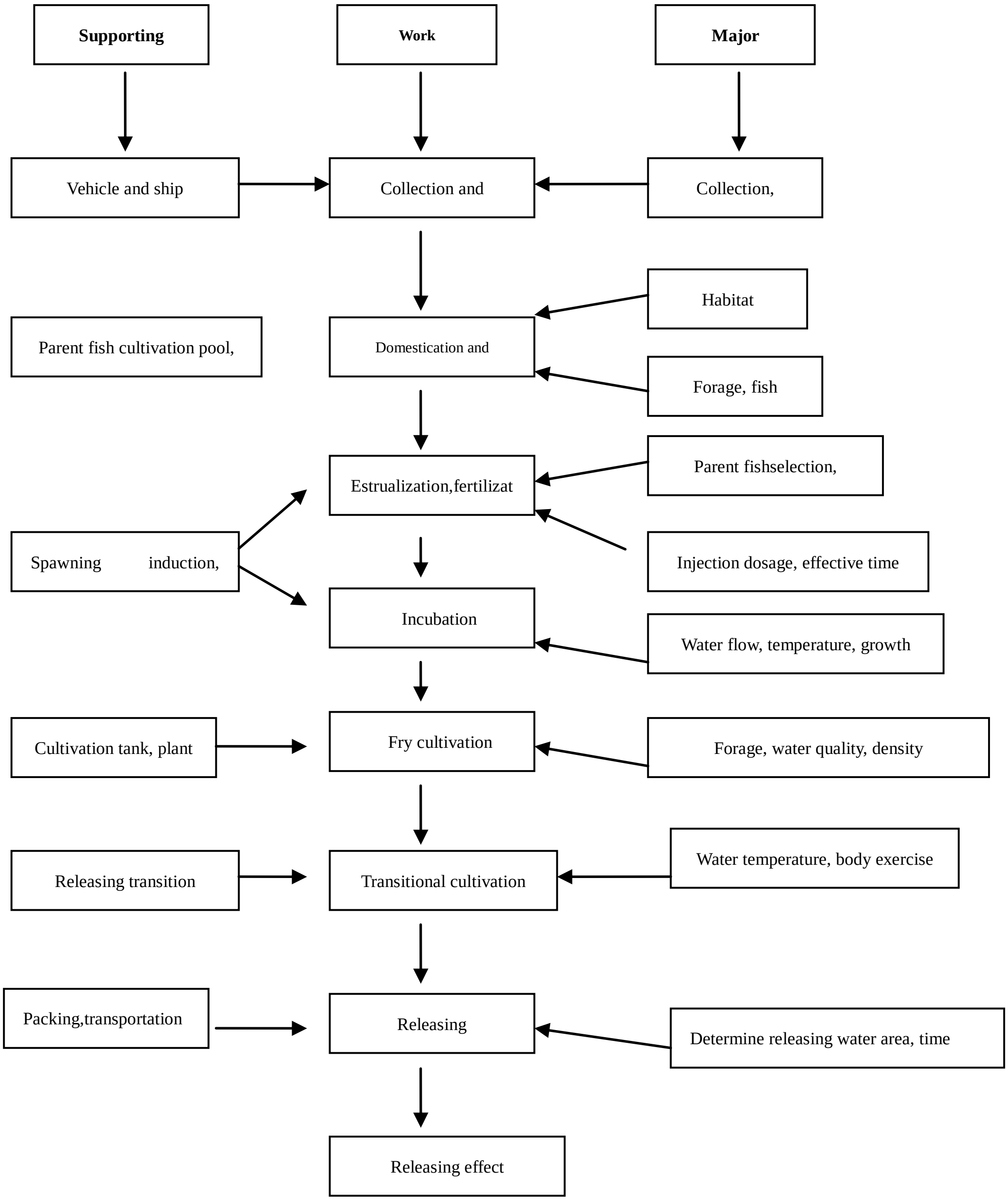


Figure 7.4.4-1 Flow chart of enhancement station technical work

Spawning induction, incubation and cultivation of freshly incubated fry: these three production links feature short time and large impact on annual production, and are essential links to aquacultural fry production as well as releasing fry production of fish stock enhancement and releasing station. In aquacultural fry production, spawning induction and incubation both use clear water and are mostly carried out indoor; cultivation of freshly incubated fry is also generally carried out in fry mesh cage (referred to as “water flower cage” in the aquaculture industry) by yolk feeding.

Aquacultural fry ground is generally equipped with water storage tank of relatively large size and depth (generally over 20 mu in size) to be used for one production cycle. The tank will completed disinfected and kept 10 to 15 days prior fish reproduction. Two settling and impounding reservoirs will be used alternatively with circulating water treatment equipment for clear water supply for links of spawning induction, incubation and cultivation of freshly incubated fry.

Fry cultivation: earth-pool still water cultivation, flowing water cultivation and mesh cage cultivation. According to living habits of releasing fish fries, slightly flowing water cultivation can be adopted with cement protection slope and anti-leakage treatment of the pool bottom.

d) General layout and building structure

Yakou shipping hub fish stock enhancement and releasing station is situated on the south side of PIU camp. Breeding functional area site has a design elevation of 56.0m, covering 86.7 mu. Water intake pump house is situated near the second-line ship lock on the east side of the camp.

According to releasing subject, releasing scale, construction condition, production technique and production scale, preliminary design includes structures such as: ①one spawning induction incubation and freshly incubated fry breeding plant, internally equipped with two spawning induction pools, three GFRP incubation tanks, three Yushchenko incubator, two conical incubation barrels, 30 1m-diameter cultivating pots and one set of circulating water treatment system; ② one fry cultivating plant, internally equipped with 40 2m-diameter cultivating pots; ③ 13 outdoor fry breeding pools covering 8.13 mu; ④ 9 parent fish cultivation pools covering 8.97 mu; ⑤ one stock transition pool and live food breeding pool, covering 5.79 mu; ⑥ 2 quarantine pools; ⑦ two impounding reservoirs; ⑧ two backup parent fish pools, covering 2.22 mu; ⑨ 6 large-scale fry breeding pools covering 7.28 mu; ⑩complex building of 1059.64m^2, with exhibition room, warehouse, lab and office quarter.

One set of circulating water treatment system is shared by spawning induction incubation plant, fry breeding plant and parent fish breeding plant, so as to ensure water temperature and water quality during fish reproduction season. See Table 7.4.4-2 for detailed construction contents, and Table 7.4.4-3 for main civil engineering work amount.

Table 7.4.4-2 Building Specifications of the proposed Yakou fish stock enhancement and releasing station

Serial No.	Fishpond name	Aquaculture water body dimension			Number	Area (m^2)	Location	Water supply situation
		Length (m)	Width (m)	Depth (m)				
1	Spawning induction pool	1.5	1.5	1	2		Spawning induction incubation plant	impounding reservoir
2	GFRP incubation tank	2	0.8	0.6	3	4.8	Spawning induction incubation plant	
3	Yushchenko incubator	3.26	0.85	0.89	3	8.313	Spawning induction incubation plant	
4	Conical incubation barrel	0.43	0.43	1.1	2	1.16	Spawning induction incubation plant	
5	1m-diameter cultivating pot	0.5	0.5	0.8	30	23.55	Spawning induction incubation plant	
6	2m-diametercultivating pot	1	1	0.8	40	125.6	Fry breeding plant	
7	Outdoor fry breeding pool	/	/	1.5	20	10633		Direct water supply from pump station
8	Parent fish breeding pool	/	/	1.5	8	6399		
9	Spawning induction incubation and breeding plantof freshly incubated fry	36	12		1	432		Circulating water treatment system
10	Fry breeding plant	35	12		1	420		

Table 7.4.4-2(continued)

Serial No.	Fishpond name	Aquaculture water body dimension			Number	Area (m^2)	Location	Water supply situation
		Length (m)	Width (m)	Depth (m)				

11	Complex building 2F	36	15.3		1	1059.64		
12	Ecological purification pool	48	25	1.5	1	1200		Direct water supply from pump station
13	Quarantine pool	15	10	1.2	2	300		
14	Impounding reservoir	20	10	2.5	2	400		
15	Pump station and water diversion pipeline							
	Structures area					21007.06		

Table 7.4.4-3 Main civil engineering work amount of Yakou fish stock enhancement and releasing station

Serial No.	Project item	Unit	Impounding reservoir	Parent fish breeding pool	Quarantine pool	chum breeding pool	Outdoor fry breeding pool	pump house	Road and others
1	Earthwork excavation	m^3	335.13	1958.30	129.64	196.58	3797.31	700.00	
2	Earthwork backfill	m^3	43.55	783.32	51.85	78.63	1518.92	490.00	70435.20
3	C25concrete	m^3	432.79	1826.19	102.64	182.82	3275.89	52.06	624.36
4	C15cushion	m^3	52.78	305.61	20.23	36.81	711.13	3.53	66.66
5	Steel reinforcement	t	30.30	127.83	7.18	12.80	229.31	7.00	

Table 7.4.4-4 Main work amount of water supply and discharge of Yakou fish stock enhancement and releasing station

Serial No.	Item name	Specification	Unit	Project number	Note
1	Butterfly valve	DN100	Unit	68.00	
2	Butterfly valve	DN300	Unit	4.00	
3	Water supply pipe	DN100 PE piping	Mete	500.00	

			r		
4	Water supply pipe	DN200 PE piping	Meter	300.00	
5	Water supply pipe	DN300 steel piping	Meter	100.00	
6	Water discharge pipe	DN100 PE piping	Meter	170.00	
7	Water discharge pipe	DN300 HDPE piping	Meter	680.00	
8	Backflow preventer	DN100	Unit	1.00	
9	Water meter	DN100	Unit	1.00	
10	Outdoor ground fire hydrant	SS150/80-1.6	Set	1.00	
11	Round discharge inspection well	Φ700	Unit	80.00	Brick
12	Valve well	Φ700	Unit	68.00	Brick
13	Valve well	Φ1500	Unit	4.00	Brick
14	Water meter chamber		Unit	1.00	Brick
15	Submersible pump	250QGW500-13-30	Set	2.00	
16	Installation fee			15%	
17	Total				

e) Parent fish and fry breeding production arrangement

According to species and scale of fish releasing of Yakou shipping hub project, combined with conditions of water supply and land utilization, an integrated technique combining outdoor cultivation in slightly flowing water and indoor cultivation in circulating water will be adopted. See Table 7.4.4-4 and 7.4.4-5 for production arrangements of parent fish cultivation and fry cultivation production respectively.

Table 7.4.4-4 Parent fish production arrangement of the proposed Yakou fish stock enhancement and releasing station

Serial No.	Fishpond name	Fish stocking	Aquaculture water body dimension		Number	Area (m^2)	Regular stocking density (kg/m^2)	Actual stocking density (kg/m^2)	Actual stocking amount of parent fish (kg)
			Unit area (m^2)	water depth (m)					
1	Outdoor parent fish breeding pool	Parent fish	/	1.2	7	6399	0.225	0.21	448.49
2	Backup parent fish breeding pool	Backup parent fish	/	1.2	1	300	0.225	0.45	134.55
	Parent fishpool subtotal				8	6699			

Quantity of parent fish is 448.49kg and quantity of backup parent fish is calculated to be 134.55kg, 30% of the parent fish quantity, totaling583.04kg. Actual stocking amount of parent fish is 0.949 times that of the regular stocking density. To maintain good water quality and water temperature, new water is regularly added according to the preliminary design to maintain good water quality.

Table 7.4.4-5 Fish releasing production arrangement of the proposed Yakou fish stock enhancement and releasing station

Breeding period	Name of cultivating facility	Fish pool area (m^2)	Number	Area	Stocking density(ten thousand/m^2)	Stocking amount (ten thousand)	Output (ten thousand)	Production feature
1.5cmfry cultivation	1m-diameter cultivating pot	0.785	30	23.55	0.7549	17.78	13.33	Cultivate 844.4 thousand 1.5cm fries; transfer some to outdoor fish stock breeding pool; continue cultivation after attenuation.
	2m-diameter cultivating pot	3.14	40	125.6	0.7549	94.81	71.11	
	Subtotal		30	149.15	0.755	112.59	84.44	
4-6cmfry cultivation	1m-diameter cultivating pot	0.785	30	23.55	0.2000	4.71	3.53	Cultivate 633.3 thousand 4-6cmfries; release 100 thousand fries; continue cultivation after attenuation.
	2m-diameter cultivating pot	3.14	40	125.6	0.2000	25.12	18.84	
	Outdoor fry breeding pool1	140	40	5600	0.0068	38.23	28.67	
	Outdoor fry breeding pool2	300	8	2400	0.0068	16.38	12.29	
	Subtotal			8149.15		84.44	63.33	
8cmfry cultivation	1m-diameter cultivating pot	0.785	30	23.55	0.1000	2.36	1.77	Cultivate fish needing difficult breeding technology; Cultivate 400 thousand 8cmfries; release 400 thousand fries.
	2m-diameter cultivating pot	3.14	40	125.6	0.1000	12.56	9.42	
	Outdoor fish stock breeding pool 1	140	40	5600	0.0048	26.89	20.17	
	Outdoor fish stock breeding pool 2	300	8	2400	0.0048	11.53	8.64	
	Subtotal			5749.15		53.33	40.00	

7.4.4.7 Process design of comparison scheme

a) Design objectives

1) To meet the recent requirements of fish proliferation and releasing scale

The original design task of fish proliferation station for Han river Cuijiaying shipping hub project is to meet the recent requirements of fish proliferation and releasing scale of Cuijiaying shipping hub project. Recent releasing objects are black carp, grass carp, silver carp, bighead carp, bluntnose black bream, coreius heterodon, silurus meridionalis Chen, pelteobagrus fulvidraco and other 6 kinds of fish (Mongolian culter, culter alburnus, carp and mandarin fish, etc.), with annual releasing quantity of 215,000 fish (including 10,000 silurus meridionalis Chen required releasing. Considering the silurus meridionalis Chen is a ferocious fish, laying viscid eggs, and no effect by the project, it is to be subtracted the silurus meridionalis Chen releasing). It meets the recent requirements of releasing objects of 2 shipping hubs of Cuijiaying and Yakou project after Cuijiaying's expansion and reconstruction, increasing leiocassis longirostris, megalobrama skolkovii, parabramis pekinensis, squaliobarbus curriculus and distoechodon tumirostris on the former basis of Cuijiaying. The annual releasing quantity is 665,000, see Table 7.4.4-6. Cancel the releasing of silurus meridionalis Chen, and consign production and releasing for black carp, grass carp, carp, silver carp, bighead carp. Long-term releasing species: Leiocassis crassilabris.

Table 7.4.4-6 Total releasing scale of Cuijiaying and Yakou shipping hub project

No.	Species	Releasing scale and quantity of Yakou project (10,000)			Releasing scale and quantity of Cuijiaying project (10,000)		Sources
		Total length 4-6 cm	Total length 6-8 cm	Total length 8-10cm	Total length 4-6 cm	Total length 12-14cm	
1	Grass Carp			40		1	Consigned production
2	Black carp			10		1	
3	Silver carp			200		1	
4	Bighead carp			100		1	
5	Leiocassis longirostris	3	12.0				To build proliferation and releasing stations for production
6	Megalobrama skolkovii		17.0				
7	Parabramis		8.0				

No.	Species	Releasing scale and quantity of Yakou project (10,000)			Releasing scale and quantity of Cuijiaying project (10,000)		Sources
		Total length 4-6 cm	Total length 6-8 cm	Total length 8-10cm	Total length 4-6 cm	Total length 12-14cm	
	pekinensis						
8	Squaliobarbus curriculus	3	3.0				
9	Distoechodon tumirostris	4					
10	Bluntnose black bream				2.5		
11	Coreius heterodon				2.5		
12	Silurus meridionalis Chen						
13	Pelteobagrus fulvidraco				2.5		
14	6 other species of fish				9.0		
	Total	10.0	40.0	350.0	16.5	4.0	420.5

(2) Medium-term and long-term requirements on proliferation and releasing

The main purpose of carrying out fish proliferation and releasing is to protect and recover fish resources of the project involving river section, and to maintain the stability of water ecosystem. The design for fish proliferation stations needs to consider technology research platform and facilities of medium and long term fish proliferation and releasing, to carry out technology research on medium and long term proliferation and releasing for Han river downstream fish, so as to achieve medium and long term fish proliferation and releasing and to protect fish resources in a river basin.

(3) To establish a demonstration project of fish protection in Han river basin

Same as new program.

b) Technology work flow

Same as new program.

c) To build structures

According to releasing objects, releasing scale and production technology, production scale, combined with the constructed items and with improving the breeding function of releasing fish as purpose, it will execute preliminary design of structures construction and expansion and reconstruction scale, with new built facilities land area of 0.23 hm^2 and a total area for proliferation station after expansion and reconstruction renovation of 3.75 hm^2, for details see Table 7.4.4-7.

Table 7.4.4-7 Building specifications for expansion and reconstruction of fish proliferation and releasing station

No.	Fish pond name	Specification for breeding water			Quantity	Area (m^2)	Treatment location	Construction situation
		Length (m)	Width (m)	Depth (m)				
1	Spawning pool	1.5	1.5	1	2	14.13	Spawning and incubation workshop	New built
2	Glass fiber reinforced plastics hatchery	2	0.8	0.6	4	6.4	Spawning and incubation workshop	New built
3	Yushchenko incubator	3.26	0.85	0.89	4	11.084	Spawning and incubation workshop	New built
4	Coniform hatching barrel	0.43	0.43	1.1	4	2.322344	Spawning and incubation workshop	New built
5	Incubating cylinder with diameter of 1 m	0.5	0.5	0.8	30	23.55	Spawning and incubation workshop	New built
8	Pond for parent fish with diameter of 4 m	2.0	2.0	1.2	10	125.6	New built workshop of pond for parent fish	New built
9	Outdoor pond for parent fish	81	75	1.5	1	6075	Pond for parent fish breeding	Original
10	Spawning pool	5	5	1.5	2	157	Changed for pond for parent fish breeding before spawning	Reconstructed
11	Outdoor hatchery	2	1.5	1.2	12	36	Pond for fry rearing after re[illegible] Time sequence	Reconstructed

12	Outdoor ecological pond for original species	75	51	1.5	1	3825	Changed for pond for fry rearing	Original
		53	35	1.5	1	1855	Changed for pond for fry rearing	Original
13	Outdoor pond for fry rearing	61	40	1.5	1	2440	Pond for fry rearing	Original
14	Outdoor pond for fry rearing in flowing water	15	2	1.3	15	450	Pond for fry rearing after reconstruction	Reconstructed
15	New built workshop for spawning, hatching and fry rearing breeding	36	12		1	432		New built
16	New built workshop of pond for parent fish	40	16		1	640		New built
17	New built display room, warehouse, laboratory room	32	12			384		New built
18	Live bait breeding pond	15	10	1.5	2	300		New built
19	Isolation pond for prevention	15	5	1.2	2	150		New built
20	New built reservoir	20	10	2.6	2	400		New built
	Area of new built facility land (M2)					2306		

7.4.4.8 Scientific research and design

In order to ensure successful completion of the task of proliferation and releasing, and achieve the purpose of species conservation, it is necessary to carry out scientific and technological research on appropriate technology. Research projects mainly include four aspects of wild parent fish of fish conservation: collection and breeding technology, artificial breeding technology, technology of large-scale fry rearing, releasing technology.

The collection and breeding technology for wild parent fish mainly includes collection location of parent fish, domestication conditions, breeding management methods, disease control, etc. The research content of this part is to mainly ensure that a sufficient number of wild parent fish can be collected, and to ensure them alive in the base until artificial breeding completed.

Artificial breeding technology of parent fish includes selection criteria, artificial spawning, fertilization methods, research on incubation conditions, etc. The research of this part is to mainly ensure to obtain fertilized eggs of releasing species and hatch them.

Technology of fry rearing includes breeding method, disease control, and appropriate specifications of releasing, etc. The technology is to ensure rapid and efficient breeding of larvae until suitable specifications.

Releasing technology includes mark method selection, suitable releasing specifications, location and time, etc. The project is mainly to evaluate the effect of proliferation and releasing. In study on releasing technology, it should also establish standardized procedures, such as temporary rearing time and location in Jinsha river before releasing.

There exists differences and similarities among different fishes of related content in these four aspects of technology, so it can combine actual situation for bundled tender or separate tender. As guarantee of task completion in proliferation and releasing at proliferation and releasing station, the units in charge of the project should not only ensure to complete releasing task of the current year but also to present a series of operation norms and standards as a basis for subsequent production.

7.4.4.9 Operation management and effect evaluation

a) Operation management

Considering the actual situation of fish proliferation station, it divides proliferation and releasing work into two parts: technology research and production operation respectively. Project of technical research can be applied in way of project tender, distributing to units with considerable capacity to implement. Production and operation will be completed by fixed staff at releasing station.

It sets 1 director and 1 deputy director of production for proliferation station, responsible for the specific management of breeding production at proliferation station, and parent fish breeding group and artificial breeding group, with 1 group leader respectively. Parent fish breeding group will be responsible for collection, rearing and large-scale size breeding production of fingerling and adult fish, and artificial breeding group will be responsible for spawning, hatching, early fry rearing and production. It sets 1 group leader respectively, who should have a bachelor's degree or above in aquaculture breeding specialty.

b) Effect evaluation (establishment of marking and genetic records)

In order to make artificial proliferation and releasing to achieve the desired effect, it must carry out evaluation on releasing effect: it should establish corresponding genetic records to all species of artificial proliferation and releasing, and execute marking and releasing. Combined with environment monitoring of aquatic ecology in main stream river cascade development along upstream of Han river, according to the effect evaluation of recovery situation of fish resources to releasing, so as to timely adjust releasing scheme, and make releasing achieve maximum effectiveness.

7.4.4.10 Project investment and operation cost

a) Investment on project construction

Investment estimation for the project of Yakou proliferation and releasing station is 17,108,600 yuan, for details see Table 7.4.4-8.

Table 7.4.4-8 Summary table for project cost of Yakou proliferation and releasing station

No.	Name of project or cost	Cost (ten thousand yuan)			
		Construction works	Installation engineering	Equipment purchase	Total
1	Civil engineering	1249.70	10.00	226.50	1486.20
1.1	Releasing station	176.44	10	226.5	412.94
1.2	Reservoir	35.46			35.46
1.	Pond for parent fish breeding	153.08			153.

3					08
1.4	Isolation pond for prevention	8.72			8.72
1.5	Live bait breeding pond	15.52			15.52
1.6	Outdoor pond for fry rearing	280.06			280.06
1.7	Workshop for spawning, hatching and fry rearing breeding	133.06			133.06
1.8	Workshop for fry rearing	129.36			129.36
1.9	Multi-functional building	318.00			318.00
2	Drainage works		7.58	50.53	58.10
3	Electric engineering		21.72	144.83	166.55
4	Total	1249.70	39.30	421.86	1710.86

Note: For budgetary estimate of proliferation station project, see "Design report on fish proliferation and releasing station of Yakou shipping hub project".

b) Operation cost of fish proliferation and releasing station

Operation costs of parent fish proliferation and releasing station include fees on purchase, feed, staff salaries, electricity, releasing, transportation, management fees, monitoring and research on releasing effect, etc. It's estimated for the proliferation and releasing station to achieve the designed releasing scale in 4 years, for operating costs of each year, see Table 7.4.4-9. From the fifth year, the operating costs of proliferation and releasing station will be included in generation operating cost of power plant.

Table 7.4.4-9 Operating costs required for each year

Item	Calculation standard	Calculation basis	Operating costs required for each year (ten thousand yuan)				
			First year	Second year	Third year	Fourth year	Fifth year
I. Salaries and benefits		Persons	52.8	52.8	52.8	52.8	52.8
1. Management and professional personnel	8000 yuan a month per person	4	38.4	38.4	38.4	38.4	38.4
2. Workers	3000 yuan a month	4	14.4	14.4	14.4	14.4	14.4

	per person						
II. Material costs			12.88	19.24	26.25	33.74	29.97
1. Purchase fees for parent fish	Calculated respectively for each year		7.00	7.48	8.61	10.23	6.46
2. Feed costs of parent fish	Calculated respectively for each year		4.44	8.88	13.31	17.75	17.75
3. Feed costs of fingerling	Calculated respectively for each year		1.44	2.88	4.32	5.76	5.76
III. Fuel costs			30	30	30	30	30
1. Electricity fee	1 year	200 thousand yuan	20	20	20	20	20
IV. Transport charge	1 year	100 thousand yuan	10	10	10	10	10
V. Releasing fee	1 year	100 thousand yuan	10	10	10	10	10

Table 7.4.4-9 (Continued)

Item	Calculation standard	Calculation basis	Operating costs required for each year (ten thousand yuan)				
			First year	Second year	Third year	Fourth year	Fifth year
VI. Management fees	1 year	300 thousand yuan	30	30	30	30	30
VII. Monitoring fees	1 year	600 thousand yuan	60	60	60	60	60
VIII. Scientific research fees	1 year	600 thousand yuan	60	60	60	60	60
Total			265.68	272.04	279.05	286.54	282.77

7.4.5 Ecological regulation

7.4.5.1 Objectives of ecological regulation

Due to reservoir regulation, the hydrological regime and physical and chemical properties of water of river section under the dam will both present a series of changes, such as frequent fluctuation of water level, flood process weakening, water discharging to change downstream riverbed bottom sediment, etc. At the same time, it forms a water reduction river section of a long distance for water regulating, channel water diversion and power generation, so it needs to discharge appropriate ecological flow. In addition, the peak period of agricultural irrigation water is often overlapped with fish breeding period, so it needs to consider different water demand. Therefore, it needs to combine with reservoir operation for reasonable utilization in adjusting flow reservoir capacity based on reproductive biology of downstream fish, coordinate the relations among taking and regulating water, power generation, flood control and ecological water demand, and optimize scheduling scheme. Especially during the period of fish breeding, according to the ecological needs of fish breeding, it needs artificial scheduling to form a suitable flood process, so as to create conditions for fish reproduction.

The main economic fishes with typical pelagic eggs in this river section: Silver carp, bighead carp, grass carp, black carp, parabramis pekinensis, elopichthys bambus, luciobrama macrocephalus, xenocypris argentea, coreius heterodon, rhinogobio typus, rhinogobio cylindricus, these fish need certain flow stimulation when spawning, so they can hatch successfully in constant flow impulse. Therefore, it is suggested that during the spawning period, it should guarantee a certain running water conditions.

7.4.5.2 Retrospective assessment and its issued ecological regulation scheme

In "Research report on retrospective environmental impact assessment of main stream river cascade development in the middle and lower reaches of Han river", with Nianpanshan hub which has the biggest change to hydrological regime as an example, it analyzes the changing situation of hydrological parameters in normal operation and after opening all sluice gates. The analysis shows that: Under the conditions of normal operation, the water level increasing range caused by inflow increase in Nianpanshan reservoir area is almost negligible, for the slow flow rate, it cannot be up to the breeding requirements of four domestic fishes; and after the implementation of ecological regulation, the inflow is increased from 800 m^3/s to 1200 m^3/s, which can cause significant rising of water level, with average velocity of each section of reservoir area > 0.5 m/s, so it meets the basic hydrological conditions of four domestic fishes, also it is consistent with the historical hydrological conditions necessary for four domestic fishes spawning. Therefore, during June to August of each year, it should implement ecological regulation of Han river middle and lower reaches according to the situation of upstream and tributary inflow, with the discharged flow in Danjiang reservoir up to more than 800 m^3/s, and flow in Huangzhuang up more than 1200 m^3/s, and open all gates of three steps (Yakou, Nianpanshan, Xinglong) at the same time so as to make hydrological conditions to meet the breeding requirements of four domestic fishes and other rare fishes such as elopichthys bambus, ochetobius elongatus, luciobrama macrocephalus, etc.

Approval for retrospective assessment (Letter from epb [2013] No. 1273) will further clarify: "During fish reproduction season of pelagic eggs (May to August), when the discharged flow of Danjiangkou reservoir is up to more than 800 m^3/s, it should increase the discharged flow of cascade in fish spawning grounds of downstream or aquatic germ plasm resources protective area......" It analyses according to the flood peak of Han river middle and lower reaches in historical spawning and breeding period, the breeding of four domestic fishes mainly depends on Tangbai river flood, and Danjiangkou discharge has positive promotion on its spawning scale, with significant reduce of discharged flow after Danjiangkou reservoir's heightening, so it needs adjust ecological regulation scheme proposed by retrospective assessment.

7.4.5.3 Ecological regulation scheme

a) Hub discharge and flood control regulation to meet the requirements of fish reproduction

Because the regulation performance of Yakou shipping hub is not strong, it should take method of baseload power generation, which has no significant adverse impact to fish reproduction of sticky larval during the period of March to May at Han river middle and lower reaches, so it doesn't need to implement ecological regulation, mainly to maintain the stability of water level.

During the flood, the hub cannot regulate runoff process , but have fading effect to small flood process; it has limited impact to fish reproduction of pelagic eggs in the downstream, but has effects of inundation to spawning grounds of fish with pelagic eggs. According to hydrological forecasting results, only in the situation of hub discharge spawning grounds in reservoir area can play a role; at the same time, when breeding in discharge, parent fish can enter spawning grounds in reservoir area through sluice to participate in breeding, which is very beneficial to protect and restore spawning grounds in reservoir area; but even part of mature parent fish can enter the middle and lower reaches of Han river for spawning, with the construction of Danjiangkou reservoir and hydraulic and hydroelectric complex at middle and lower reaches of Han river, it causes water habitats at middle and lower reaches of Han river in dramatically shrinking, drifting reproduction process of fish eggs is not enough and unable to complete life course.

At present, Yakou shipping hub has developed a regulation scheme of discharge and flood control. In the case of flood control flow up to discharge regulation quantity, it needs regulate according to the established regulation scheme of discharge. Specifically: When the flow reaches 5,000m^3/s, gate will be gradually opened, it needs control discharge to maintain the connecting between upstream and downstream; when dam site discharge is greater than 13,500 m^3/s, power plant will stop generating, ship lock will suspend, and sluice gate will discharge to meet hydrological requirements of fish drifting breeding. In order to be beneficial to breed parent fish tracing and early resources crossing dam, it needs open gates in 24 hours before peak discharge coming, and delayed 24 hours to close gates after the end of flood for impoundment.

b) Ecological regulation scheme of cascade joint

During the spawning period of "four domestic fishes" in Han river every year, it can make sure a certain ecological flow of discharge through Danjiangkou, and implement the discharge and regulation in cascade joint combined with a certain scale of Tangbai river flood at least for 2 times. Ensure the smoothing in spawning of existing spawning grounds, drifting hatching of fertilized eggs and fertilized fish migration channels to finish the reproduction.

It analyses peak process of four domestic fishes spawning monitored by water engineering ecology over the years, for breeding of four domestic fishes in the middle and lower reaches of Han river, although Danjiangkou discharge has positive effect on the spawning scale, mainly relying on the Tangbai river flood, during the period of the flood, in case of the flow in Huangzhuang hydrological station of Han river (located under Yakou dam about 75KM) up to 1200 m^3/s, all the early four domestic fishes resource were monitored (in 2014 survey the flow of pelagic eggs in fish spawning of Han river is 1040 m^3/s, which is coordinated with the demands that Huangzhuang hydrological station flow is up to 1200 m^3/s when it is proposed ecological regulation in cascade joint in the report of retrospective assessment, so as to meet hydrological requirements of ecological regulation.

Therefore, the ecological regulation will take Tangbai river flood as the basis, combined with the interval inflow, every year from May to August, combined with tributary Tangbai river flood process at least for 2 times of ecological regulation in cascade joint of Danjiangkou of Han river, specifically: In the second half of May to August of high flow years and normal flow years, when Tangbai river Dongpo flood control stations forecast flood flow quantity equal or above 600 m^3/s 24 hours in advance, or forecast flood equal or above 300 m^3/s 24 hours in advance in low flow years, it should immediately start ecological regulation scheme, namely it starts ecological regulation when Tangbai river forecasts flood quantity equal or above 600 m^3/s in the second half of May to July; in case of no flood of 600 m^3/s in the second half of May to July, it can be judged the year as low flow year, and it will immediately start ecological regulation when Tangbai river forecasts the flood flow quantity up to 300 m^3/s in August. At this time, Danjiangkou will discharge ecological flow of 400 m^3/s according to regulation requirements, which can ensure the flow of Huangzhuang hydrological station up to 1200 m^3/s (i.e. meeting flow requirements of ecological regulation in cascade joint proposed by retrospective assessment). Wangfuzhou cascade has no water storage, but discharges according to inflow; for 3 cascades in Cuijiaying, Yakou and Xinglong, it needs to start gates for pre-discharge 24 hours in advance, reduces water level of the reservoir, and implement joint discharge in Cuijiaying, Yakou and Xinglong when the actual flow monitored by Tangbai river Dongpo flood control station is up to start flow of ecological regulation, with discharge time of 5 to 7 days, until the end of flood peak, in order to facilitate eggs and fry drifting down dam.

In special low flow years, when Tangbai river Dongpo flood control station has not occurred flood equal or greater than 600 m^3/s in the second half of May to August, and has not occurred flood equal or greater than 300 m^3/s, in the early and mid September of autumn season, Tangbai river or Han river occur flood in any scale, it needs start an ecological regulation in joint according to the way above mentioned.

At present, Hubei Provincial People's Government in Hubei government letter [2015] No. 235 issued an approval to "Scheme of ecological regulation in cascade joint in Danjiangkou downstream of Han river stream in Hubei province", see Annex 2.

7.4.5.3 Feasibility analysis on ecological regulation scheme

a) Guarantee rate analysis on Tangbai river flood

Due to the ecological regulation of the project with Tangbai river floods as prerequisite, so it is necessary to do further investigation on basic situation of guarantee rate of Tangbai river and its flood peak flow.

1) Introduction of Tangbai river basin

Tangbai river is a tributary in the middle reaches of Han river left bank, it is also a tributary of the largest area in Han river basin area, the two branches upstream both originate in Henan province. East branch Tang river is originated in south Qifengshan of Fangcheng County, and into Hubei through Shitai temple of Xiangzhou district, with full-length of 286 km, and catchment area of 8,685 km^2. West branch, as a mains stream, is originated Yuhuang top east of Funiu mountain peak in Song County, and into Hubei through Zhaiwan of Xiangzhou district (river sections belonging to Tang river are habitually called Bai river, with catchment area of 12,224 km^2), flowing into Han river through Xiangyang city. Channel longitudinal ratio is reduced to 1/1,500-1/4,000.

Tangbai river's main stream is in length of 352 km (48.6km in Hubei province), with its catchment area of 24,500 km^2 (4,439 km^2 in Hubei).The width of Tangbai river is generally about 1000 m, and more than 2000 m in larger width. East branch of Tang river is of 48 km in Hubei province, with two larger tributaries Xiaohuang river and Heiqing river. Xiaohuang river originates from Tanghe county in Henan province, flowing through Xiangzhou district in Hubei province into Tang river, with length in provincial inland river of 50.2 km, and catchment area of 247 km²; Heiqing river originates from Zaoyang city, flowing through Xiangzhou district into Tang river, with length of 61.5 km, and catchment area of 448k km².

As Tangbai river's largest tributary in Hubei province, Gun river originates from saddle section between Tongbo mountain and Dahong mountain, flowing through Sui county, Zaoyang city, Xiangzhou district, in Tangjiadian of Xiangzhou district into Tangbai river, with full-length of 134 km, and catchment area of 2,824 km².

In the 1960s and 1970s, there are a series of large and medium-sized reservoirs in upstream of Tangbai river, such as: Yahekou reservoir (large-sized I) in Henan Nanzhao county in the upstream of Bai river, Huashan reservoir (medium-sized) along Tang river tributary (Bi river) in Biyang county, Zhaowan reservoir (medium-sized) along upstream of Tuan river tributary (Zhao river) in Zhenping county, Hushan reservoir (medium-sized) along upstream of Sanjia river tributary (Chou river) in Mazhenfu village of Tanhe county, Guangou reservoir (large-sized II) along Gun river tributary in Shuanggou town of Xiangyang County, and Fanzhuang reservoir (medium-sized) along upstream of Tangbai river tributary (Ganggou) in Xiangyang County. In recent years 4 overflow dams were built in Bai river section of Nanyang city. But up to now, Tangbai River has no related planning in water conservancy and hydropower. Among the built water conservancy projects, only Yahekou reservoir may effect on flood scale of Tangbai River. The reservoir has catchment area of 3,025 km², a total capacity of 1.316 billion m^3, including flood control capacity of 521 million m^3. The water surface area of the reservoir is about 120 km², which is a large-scale water control project of comprehensive utilization combined with flood control, irrigation as main project, taking power generation, aquaculture, urban water supply and tourism into consideration. Built in November 1958, completed in June 1960, first reinforcement from 1988 to 1992, and second reinforcement from 2009 to 2011. The design area for reservoir irrigation is of 2.1 million acres, including 1.27 million acres that has been supporting the effectiveness. The installed capacity of hydropower station is 11,720 kW, its average annual power generation capacity is 33.9 million kW.h.

2) Hydrometeorology and hydrologic station network of Tangbai River

Tangbai river basin is in north subtropical monsoon climate zone, with four distinct seasons. It is controlled by Pacific Subtropical High in summer and autumn seasons, hot and rainy; and controlled by Lilium siberia and Mongolia high-pressure in winter and spring season, dry and rainless. Average temperature for many years is 15°C. Average precipitation in river basin for many years is 812.4 mm, the maximum precipitation is 1,294.6 mm, and the minimum precipitation is 551.4 mm. Affected by topography, the distribution trend of precipitation in the area is that the edge hill of river basin is larger than central basin, with average water surface evaporation for many years is 1,714.6 mm, and the maximum annual amount of 1,986.4 mm.

Tangbai river basin hydrological station was first established in 1936. For Tang river main stream, there are 3 hydrological stations: Sheqi, Tanghe, Guotan, with control area respectively 1,044 km^2, 4,771km^2, 6,877 km^2; For Bai river main stream, there are mainly 4 hydrological stations: Baitugang, Yahekou reservoir, Nanyang, Xindianpu, with control area respectively 1,134km^2, 3,025km^2, 3,896km^2, 10,958km^2; For Tangbai river main stream, there set Dongpo flood prevention special station, located in downstream of Tang river and Bai river confluence, with distance of Han river bayou of about 15 km and catchment area of 20,909 km^2.

Distribution map for hydrologic station network of Tangbai River and Han river middle and lower reaches will be shown in Figure 7.4.5-1.

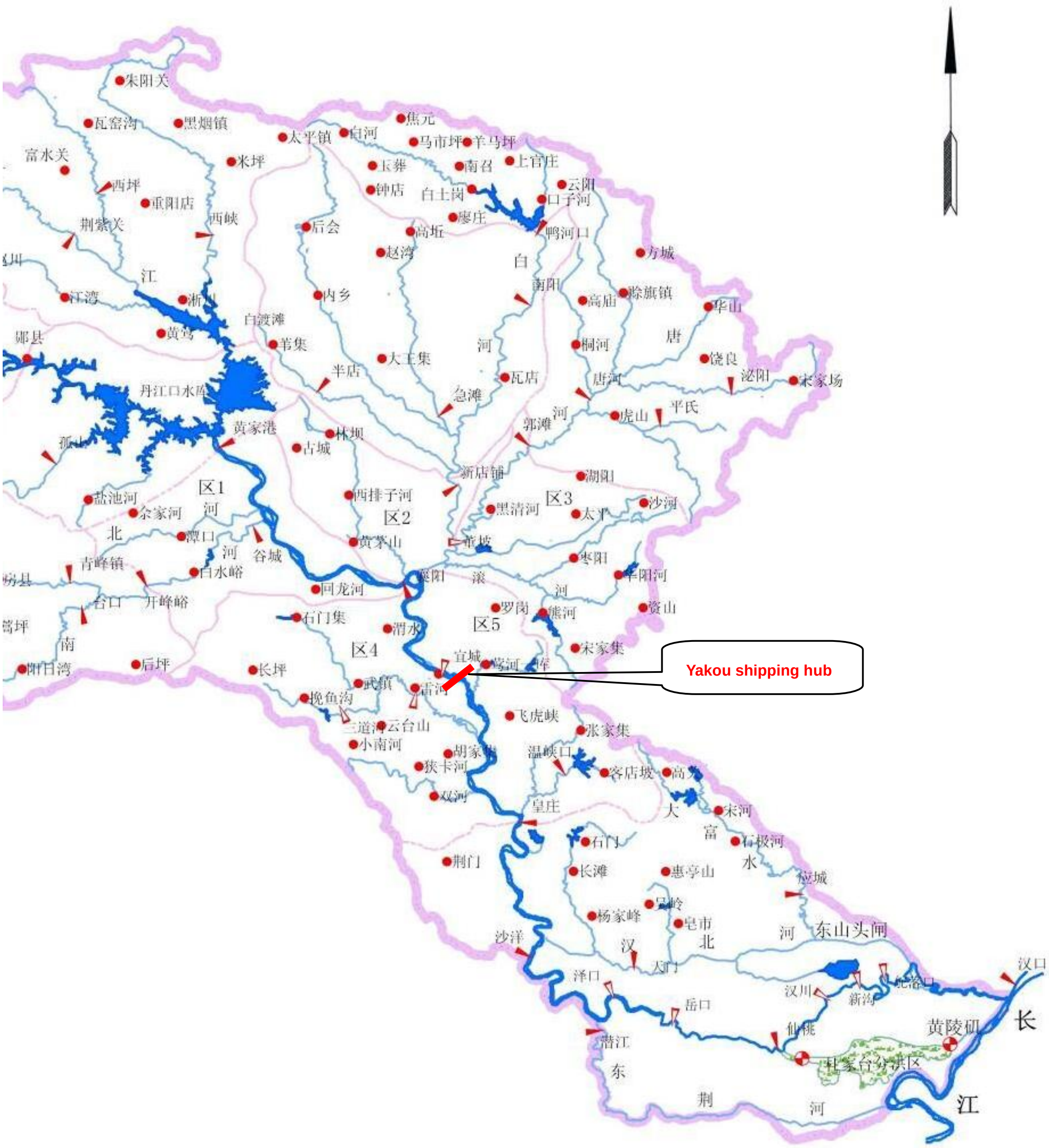


Figure 7.4.5-1 Distribution map for hydrologic station network of Tangbai River and Han River middle and lower reaches

3) Related analysis on flood peak discharge for Tangbai River and Han river main stream

According to flood data of Tangbai River Dongpo and Huangzhuang station 2 of Han river in May to August from 1985 to 2014, when it analyses and calculate the maximum flow of Dongpo, Huangzhuang flow in corresponding period and analysis for corresponding weight see Table 7.4.5-1. Related schematic diagram of

Huangzhuang and Dongpo station 2 is as shown in Figure 7.4.5-2. It is known from the analysis of figure: When a certain scale of flood occurred in Tangbai river, a certain scale peak will form in Han river, the two correlation coefficient is 0.87.

Table 7.4.5-1 Statistical table of the maximum flow corresponding weight for Dongpo station accounting for Huangzhuang

Year	Maximum flood peak flow of Dongpo (m^3/s)	Corresponding flow of Huangzhuang (m^3/s)	Weight (%)	Year	Maximum flood peak flow of Dongpo (m^3/s)	Corresponding flow of Huangzhuang (m^3/s)	Weight (%)
2000	7200	8290	86.9	2004	1573	3285	47.9
1998	6050	8730	69.3	2006	1427	2280	62.6
2010	5942	12200	48.7	1988	1339	2960	45.2
1991	4355	6253	69.6	1993	1234	1958	63.0
2005	4137	4715	87.7	2012	1198	1930	62.1
2008	3735	7140	52.3	1985	1154	2480	46.5
2003	3732	4230	88.2	1994	950	1490	63.8
1996	3121	7098	44.0	1995	878	973	90.2
2007	2842	8443	33.7	1986	751	2169	34.6
1989	2617	6651	39.3	1997	701	1567	44.7
2002	2610	2670	97.8	1999	558	964	57.9
1990	2310	4540	50.9	1992	462	2065	22.4
2009	2196	4320	50.8	2011	398	1933	20.6
1987	1810	2650	68.3	2013	340	1910	17.8
2001	1634	1720	95.0	2014	32	697	4.6

Corresponding flow of

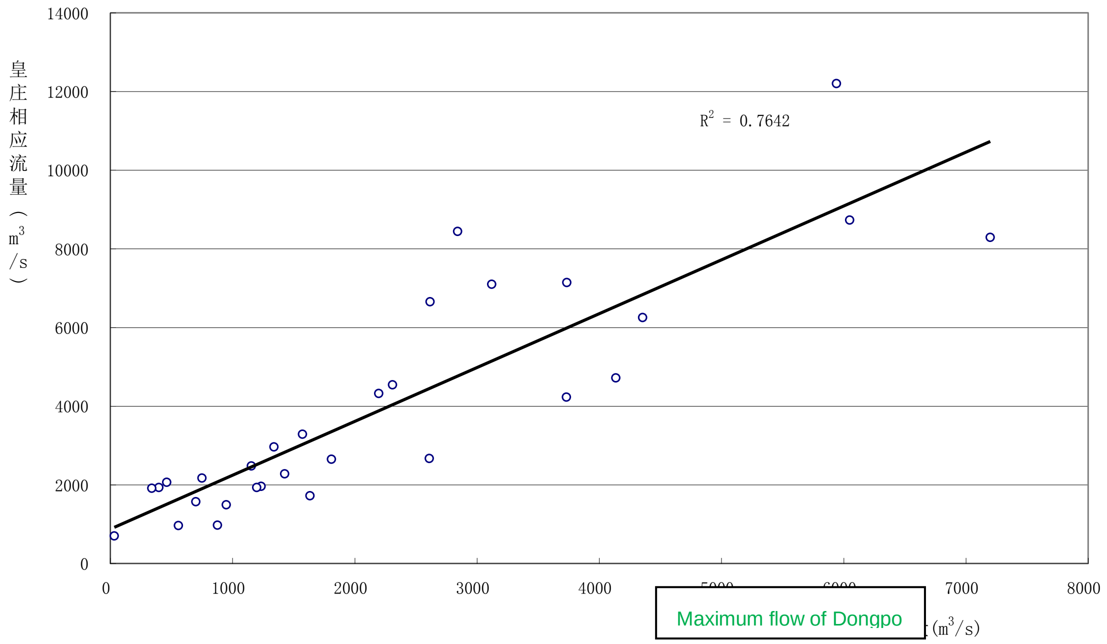


Figure 7.4.5-2 Related schematic diagram for maximum flow of Dongpo and corresponding flow of Huangzhuang

4) Guarantee rate analysis on Tangbai river flood of different magnitude

Considering meeting requirements of fish reproduction of Han River, it needs a large scale flood in Tangbai river. According to flood data of Tangbai river Dongpo and Huangzhuang station 2 of Han river in May to August from 1985 to 2014, in case of Huangzhuang flow >1200m³/s, Dongpo flow in boundary conditions respectively 1000m³/s, >800m³/s, >700m³/s, >600m³/s, >300m³/s, the analysis assumes different guarantee rate meeting two kinds of boundary conditions.

The flood guarantee rate meeting boundary conditions Huangzhuang >1200 m³/s and Dongpo >1000 m³/s is 70%;

The flood guarantee rate meeting boundary conditions Huangzhuang >1200 m³/s, Dongpo >800 m³/s is 73.3%;

The flood guarantee rate meeting boundary conditions Huangzhuang >1200 m³/s, Dongpo >700 m³/s is 76.7%;

The flood guarantee rate meeting boundary conditions Huangzhuang >1200 m³/s, Dongpo >600 m³/s is 86.7%;

The flood guarantee rate meeting boundary conditions Huangzhuang >300 m³/s, Dongpo >800 m^3/s is 93.3%;

It can be seen over the same period of Tangbai river flood, Han River can also form a medium or small scale flood, that is as flood peak discharge of Han river of 1200 m^3/s, Tangbai river's contribution value is limited. So guarantee rate of 86.7% of Tangbai river inflow in general years will be chosen, with boundary conditions of Huangzhuang > 1200 m^3/s and Dongpo > 600m^3/s; and guarantee rate of Tangbai river in lower flow years is 93.3%, with boundary conditions of Huangzhuang >1200 m^3/s and Dongpo >300 m^3/s proposed as requirements on peak discharge to implement ecological regulation per year.

The detailed statistical process of Dongpo > 600m^3/s and > 300m^3/s is shown in Table 7.4.5-2 and Table 7.4.5-3.

Table 7.4.5-2 Statistical table of the minimum flow rate above 600 m^3/s in Dongpo station over the years

Year	Boundary conditions of Huangzhuang	Boundary conditions of Dongpo	Flood characteristics	Maximum flood peak flow (m^3/s)	Total duration of flood (1h)	Frequency of floods	Remarks
2000	Q-Huangzhuang > 1200	Q-Dongpo >600	Single, multiple	7200	556	6	High
2010	Q-Huangzhuang > 1200	Q-Dongpo >600	Multiple	5942	552	3	High
1998	Q-Huangzhuang > 1200	Q-Dongpo >600	Single, multiple	6050	260	7	High
2005	Q-Huangzhuang > 1200	Q-Dongpo >600	Single, multiple	4137	475	7	High
1989	Q-Huangzhuang > 1200	Q-Dongpo >600	Single, multiple	2617	218	3	High
2007	Q-Huangzhuang > 1200	Q-Dongpo >600	Single, multiple	2842	346	6	High
1990	Q-Huangzhuang > 1200	Q-Dongpo >600	Single	2310	53	2	High
1996	Q-Huangzhuang > 1200	Q-Dongpo >600	Single, multiple	3121	156	2	Medium high

Year	Boundary conditions of Huangzhuang	Boundary conditions of Dongpo	Flood characteristics	Maximum flood peak flow (m^3/s)	Total duration of flood (1h)	Frequency of floods	Remarks
1991	Q-Huangzhuang > 1200	Q-Dongpo >600	Single	4355	102	1	Medium high
1987	Q-Huangzhuang > 1200	Q-Dongpo >600	Single	1810	105	2	Medium high
2009	Q-Huangzhuang > 1200	Q-Dongpo >600	Single	2196	154	4	Medium high
2004	Q-Huangzhuang > 1200	Q-Dongpo >600	Single, multiple	1573	166	4	Medium high
1985	Q-Huangzhuang > 1200	Q-Dongpo >600	Single	1154	45	2	Medium
2003	Q-Huangzhuang > 1200	Q-Dongpo >600	Single	3732.4	170	4	Medium
2008	Q-Huangzhuang > 1200	Q-Dongpo >600	Single	3735	90	1	Medium
2006	Q-Huangzhuang > 1200	Q-Dongpo >600	Single	1426.9	79	3	Medium
2002	Q-Huangzhuang > 1200	Q-Dongpo >600	Single	2610.0	80	2	Medium
1995	Q-Huangzhuang > 1200	Q-Dongpo >600		0	0	0	Medium low

Table 7.4.5-2 (Continued)

Year	Boundary conditions of Huangzhuang	Boundary conditions of Dongpo	Flood characteristics	Maximum flood peak flow (m^3/s)	Total duration of flood (1h)	Frequency of floods	Remarks
1988	Q-Huangzhuang > 1200	Q-Dongpo >600	Single	1339	72	2	Medium low
2001	Q-Huangzhuang > 1200	Q-Dongpo >600	Single	1324.5	50	2	Medium low
2012	Q-Huangzhuang > 1200	Q-Dongpo >600	Single	1198	23	1	Medium low
1993	Q-Huangzhuang > 1200	Q-Dongpo >600	Single	1234	23	1	Medium low

Year	Boundary conditions of Huangzhuang	Boundary conditions of Dongpo	Flood characteristics	Maximum flood peak flow (m^3/s)	Total duration of flood (1h)	Frequency of floods	Remarks
1997	Q-Huangzhuang > 1200	Q-Dongpo >600	Single	701.0	9	1	Medium low
1986	Q-Huangzhuang > 1200	Q-Dongpo >600	Single	676.4	35	1	Low
1994	Q-Huangzhuang > 1200	Q-Dongpo >600	Single	950	19	1	Low
1992	Q-Huangzhuang > 1200	Q-Dongpo >600		0	0	0	Low
1999	Q-Huangzhuang > 1200	Q-Dongpo >600		0	0	0	Low
2014	Q-Huangzhuang > 1200	Q-Dongpo >600		0	0	0	Low

Table 7.4.5-3 Statistical table of the minimum flow rate above 300 m^3/s in Dongpo station over the years

Year	Boundary conditions of Huangzhuang	Boundary conditions of Dongpo	Flood characteristics	Maximum flood peak flow (m^3/s)	Total duration of flood (1h)	Frequency of floods	Remarks
2000	Q-Huangzhuang > 1200	Q-Dongpo >300	Single, multiple	7200	875	7	High
2010	Q-Huangzhuang > 1200	Q-Dongpo >300	Multiple	5942	702	4	High
1998	Q-Huangzhuang > 1200	Q-Dongpo >300	Single, multiple	6050	442	7	High
2005	Q-Huangzhuang > 1200	Q-Dongpo >300	Single, multiple	4137	969	8	High
1989	Q-Huangzhuang > 1200	Q-Dongpo >300	Multiple	2617	267	2	High
2007	Q-Huangzhuang > 1200	Q-Dongpo >300	Single, multiple	2842	757	6	High
1990	Q-Huangzhuang > 1200	Q-Dongpo >300	Single, multiple	2310	205	4	High
1996	Q-Huangzhuang >	Q-Dongpo >3	Multiple	3121	282	1	Medium high

Year	Boundary conditions of Huangzhuang	Boundary conditions of Dongpo	Flood characteristics	Maximum flood peak flow (m^3/s)	Total duration of flood (1h)	Frequency of floods	Remarks
	1200	00					
1991	Q-Huangzhuang > 1200	Q-Dongpo >300	Single	4355	158	1	Medium high
1987	Q-Huangzhuang > 1200	Q-Dongpo >300	Single	1810	216	2	Medium high
2009	Q-Huangzhuang > 1200	Q-Dongpo >300	Single	2196	500	6	Medium high
2004	Q-Huangzhuang > 1200	Q-Dongpo >300	Single, multiple	1573	432	3	Medium high
1985	Q-Huangzhuang > 1200	Q-Dongpo >300	Single, multiple	1154	146	2	Medium
2003	Q-Huangzhuang > 1200	Q-Dongpo >300	Single, multiple	3732.4	344	4	Medium
2008	Q-Huangzhuang > 1200	Q-Dongpo >300	Single, multiple	3735	261	7	Medium
2006	Q-Huangzhuang > 1200	Q-Dongpo >300	Single, multiple	1426.9	345	4	Medium
2002	Q-Huangzhuang > 1200	Q-Dongpo >300	Single, multiple	2610.0	180	3	Medium
1995	Q-Huangzhuang > 1200	Q-Dongpo >300	Single	302	2	1	Medium low
1988	Q-Huangzhuang > 1200	Q-Dongpo >300	Single, multiple	1339	213	2	Medium low
2001	Q-Huangzhuang > 1200	Q-Dongpo >300	Single	1324.5	84	2	Medium low
2012	Q-Huangzhuang > 1200	Q-Dongpo >300	Single	1198	77	3	Medium low
1993	Q-Huangzhuang > 1200	Q-Dongpo >300	Single	1234	45	1	Medium low
1997	Q-Huangzhuang > 1200	Q-Dongpo >300	Single	701.0	57	2	Medium low
1986	Q-Huangzhuang > 1200	Q-Dongpo >300	Single	676.4	6	1	Low

Table 7.4.5-3 (Continued)

Year	Boundary conditions of Huangzhuang	Boundary conditions of Dongpo	Flood characteristics	Maximum flood peak flow (m^3/s)	Total duration of flood (1h)	Frequency of floods	Remarks
1994	Q-Huangzhuang >1200	Q-Dongpo >300	Single	950	35	1	Low
1992	Q-Huangzhuang >1200	Q-Dongpo >300	Multiple	462	61	1	Low
1999	Q-Huangzhuang >1200	Q-Dongpo >300		0	0	0	Low
2014	Q-Huangzhuang >1200	Q-Dongpo >300		0	0	0	Low

(5) Statistical analysis on flood process in typical years (May to August)

(1) Analysis on high, medium and low flow of Tangbai river in the past 30 years (May to August)

a. Definition of high, medium and low flow year of runoff from May to August

In the time section of a series of data and experience, the analysis and definition take frequency P<20% as high low years, taking frequency P>80% as low years, and taking frequency P=50% as medium flow year; and among them will be respectively named medium high year or medium low year.

b. Analysis on high, medium and low flow of Tangbai river in the past 30 years (May to August)

According to Xindianpu and Guotan data calculation and analysis on Dongpo (Tangbai river) runoff in May to August from 1985 to 2014, and the size of calculation experience, the frequency is shown in Table 7.4.5-4, it is to be known according to empirical frequency: In 2007 typical empirical frequency P=19.4% as high flow years; in 2008 typical empirical frequency P=48.4% as medium flow years; in 1994 typical experience frequency P=80.6% as low flow years.

Table 7.4.5-4 Runoff series of Dongpo station in May to August from 1985 to 2014

Year	Runoff (100 million m^3)	No.	Year	Runoff (100 million m^3)	Experience P (%)	Year	Runoff (100 million m^3)	No.	Year	Runoff (100 million m^3)	Experience P (%)

1985	19.7	1	2000	61.0	3.2	2000	61.0	16	2006	15.6	51.6
1986	6.6	2	2010	54.2	6.5	2001	10.4	17	2002	12.7	54.8
1987	25.9	3	1998	44.9	9.7	2002	12.7	18	1995	11.9	58.1
1988	11.8	4	2005	38.7	12.9	2003	19.3	19	1988	11.8	61.3
1989	35.3	5	1989	35.3	16.1	2004	21.2	20	2001	10.4	64.5
1990	28.4	6	2007	30.8	19.4	2005	38.7	21	2012	10.4	67.7
1991	27.1	7	1990	28.4	22.6	2006	15.6	22	1993	9.4	71.0
1992	6.0	8	1996	27.2	25.8	2007	30.8	23	1997	8.8	74.2
1993	9.4	9	1991	27.1	29.0	2008	17.9	24	1986	6.6	77.4
1994	6.2	10	1987	25.9	32.3	2009	22.2	25	1994	6.2	80.6
1995	11.9	11	2009	22.2	35.5	2010	54.2	26	1992	6.0	83.9
1996	27.2	12	2004	21.2	38.7	2011	4.8	27	1999	5.8	87.1
1997	8.8	13	1985	19.7	41.9	2012	10.4	28	2013	5.7	90.3
1998	44.9	14	2003	19.3	45.2	2013	5.7	29	2011	4.8	93.5
1999	5.8	15	2008	17.9	48.4	2014	1.4	30	2014	1.4	96.8

(2) Analysis on typical flood process in the high flow year of 2007

According to the flood data of four stations (Huangzhuang, Dongpo, Guotan and Xindianpu) in May to August in 2007, with hourly flood process, flood hydrograph drawing is shown in Figure 7.4.5-3; according to boundary conditions of Huangzhuang >1,040 m³/s, Dongpo >300 m³/s, flood hydrograph drawing is shown in Figure 7.4.5-4.

Characteristics of greater flood and peak of Tangbai river in 2007, peak flow and duration are shown in Table 7.4.5-5. It is known that there are more than 6 greater floods in Tangbai River in 2007 shown from the chart analysis, with the maximum peak flow of 2,842 m³/s, mostly are single peaks, floods mainly occurred in June and July.

Table 7.4.5-5 Statistical table of flood characteristics in typical year of 2007

Year	Boundary conditions		Flood peak Characteristic	Peak flow (m³/s)	Flood duration (1h)	Flood frequency	Remarks
2007	Q-Huangzhuang >1040	Q-Dongpo >600	Single	1341	31	1	High
			Single	725	15	2	
			Multiple	1287	64	3	
			Single	1231	24	4	
			Single	2705	94	5	
			Single	2842	118	6	
			Total	2842	346	6	
		Q-Dongpo >300	Single	1341	57	1	
			Multiple	1287	188	2	
			Multiple	2842	374	3	
			Multiple	525	72	4	
			Single	591	61	5	
			Single	304	5	6	
			Total	2842	757	6	
	Q-Huangzhuang >1200	Q-Dongpo >600	Single	1341	31	1	
			Single	725	15	2	
			Multiple	1287	64	3	
			Single	1231	24	4	
			Single	2705	94	5	
			Single	2842	118	6	
			Total	2842	346	6	
		Q-Dongpo >300	Single	1341	57	1	
			Multiple	1287	188	2	
			Multiple	2842	374	3	
			Multiple	525	72	4	
			Single	591	61	5	
			Single	304	5	6	
			Total	2842	757	6	

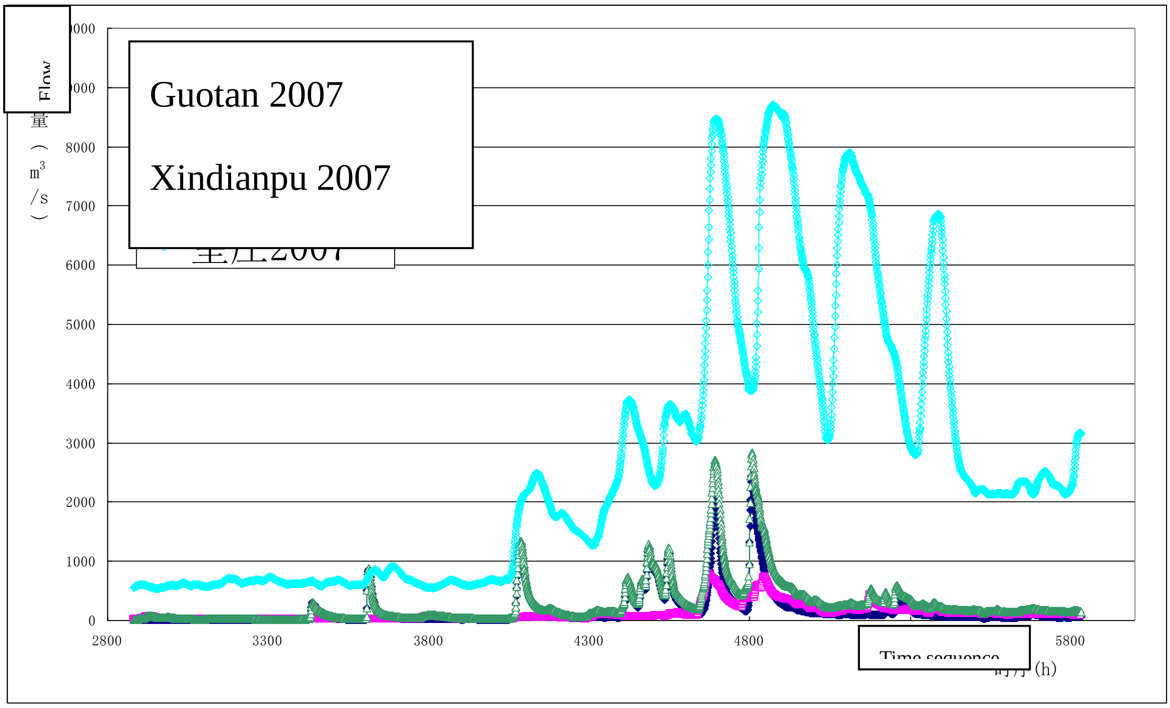


Figure 7.4.5-3 Schematic diagram of flood process in the typical year (May to August) of 2007

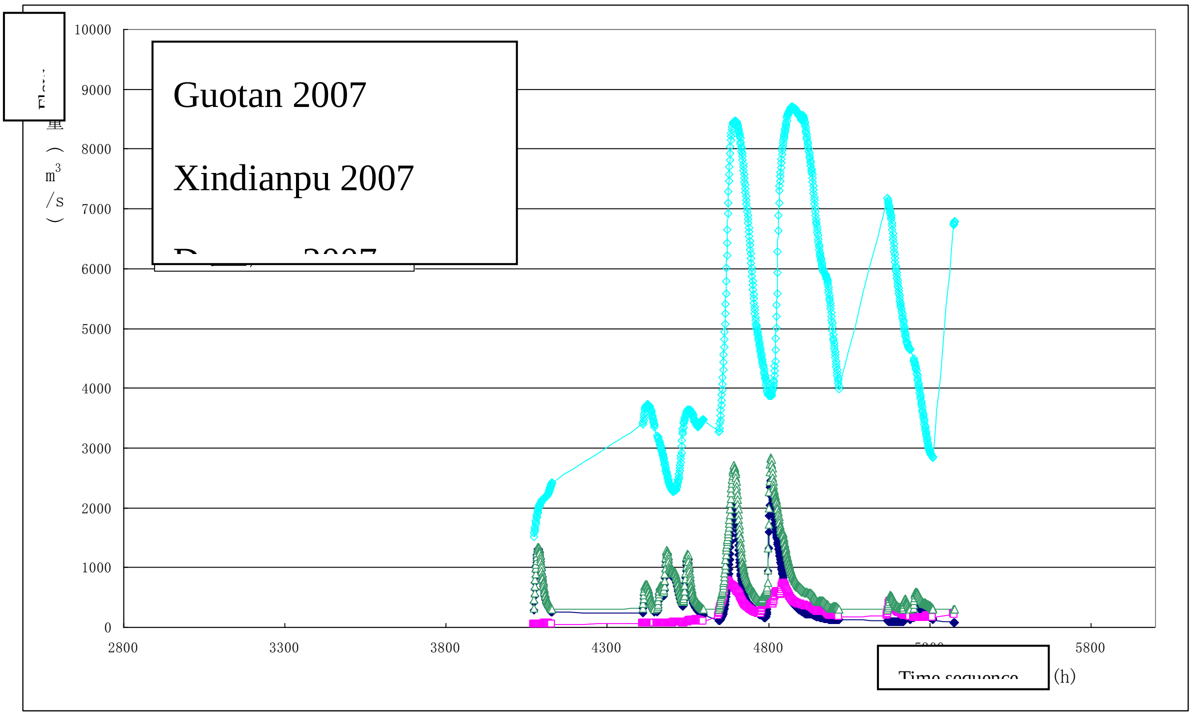


Figure 7.4.5-4 Schematic diagram of flood process of Huangzhuang and Dongpo in the typical year of 2007 (May to August)

(3) Analysis on typical flood process in the medium flow year of 2007

According to the flood data of four stations (Huangzhuang, Dongpo, Guotan and Xindianpu) in May to August in 2008, with hourly flood process, flood hydrograph drawing is shown in Figure 7.4.5-5; according to boundary conditions of Huangzhuang >1,040 m³/s, Dongpo >300 m³/s, flood hydrograph drawing is shown in Figure 7.4.5-6.

Characteristics of greater flood and peak of Tangbai river in 2008, peak flow and duration are shown in Table 7.4.5-6. It is known that there are more than 8 greater floods in Tangbai river in high flow year of 2008 shown from the chart analysis, with only one flood more than 600 m³/s, and maximum peak flow of 3,735 m³/s, mostly are single peaks, floods mainly occurred in July and August.

Table 7.4.5-6 Statistical table of flood characteristics in typical year of 2008

Ye	Boundary conditions		Flood	Maximu	Total	Frequen	Remar
2008	Q-Huangzhuang >1040	Q-Dongpo >6	Multiple	3735	90	1	Medium
			Total	3735	90	1	
		Q-Dongpo >300	Single	320	6	1	
			Multiple	3735	118	2	
			Single	383	25	3	
			Single	335	11	4	
			Single	462	31	5	
			Multiple	387	50	6	
			Single	514	31	7	
			Single	333	17	8	
			Total	3735	289	8	
	Q-Huangzhuang >1200	Q-Dongpo >6	Multiple	3735	90	1	
			Total	3735	90	1	
		Q-Dongpo >300	Multiple	3735	118	1	
			Single	383	25	2	
			Single	335	11	3	
			Single	349	9	4	
			Multiple	387	50	5	
			Single	514	31	6	
			Single	333	17	7	
			Total	3735	261	7	

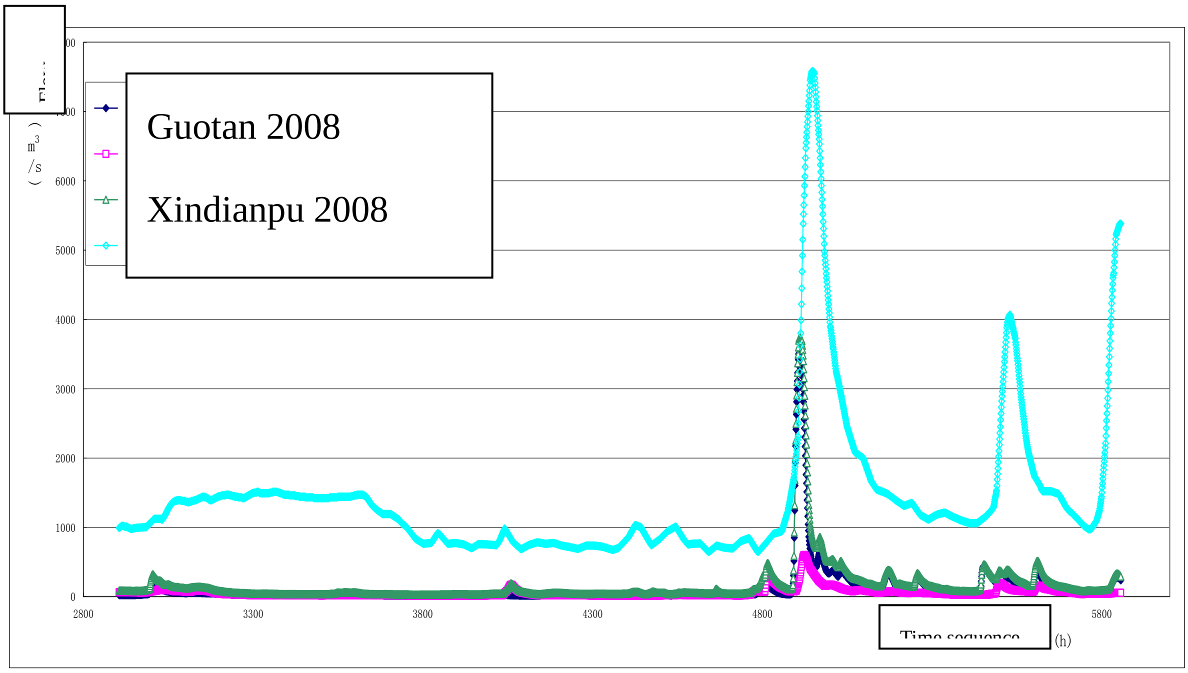


Figure 7.4.5-5 Schematic diagram of flood process in the typical year (May to August) of 2008

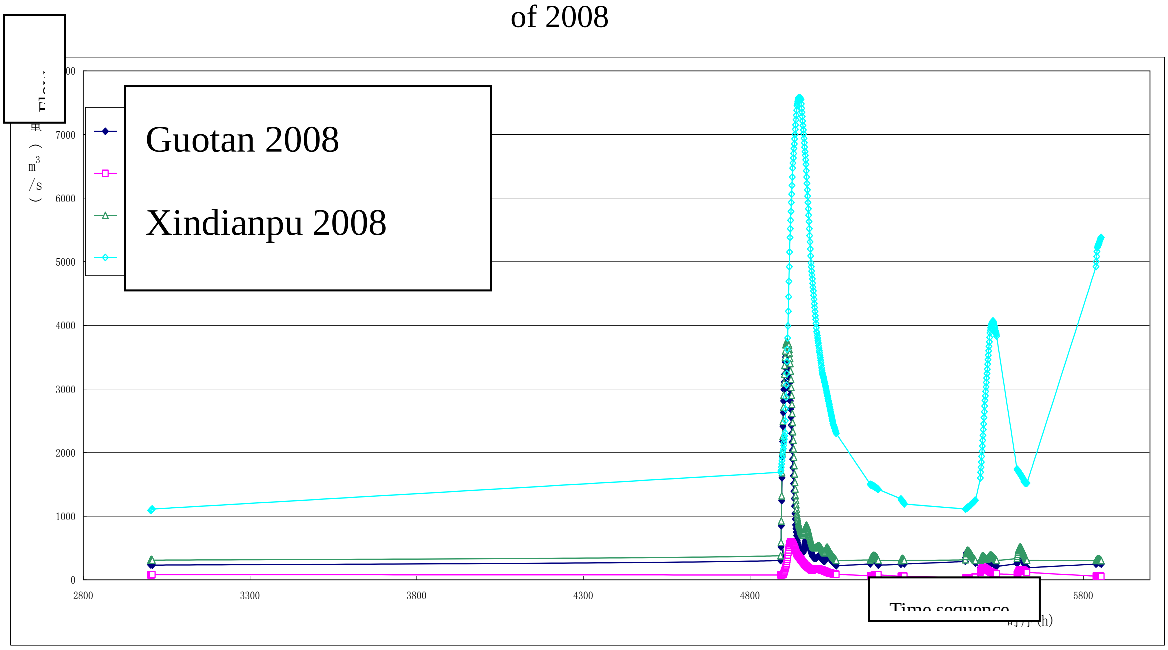


Figure 7.4.5-6 Schematic diagram of flood process of Huangzhuang and Dongpo in the typical year of 2008 (May to August)

(4) Analysis on typical flood process in the low flow year of 1994

According to the flood data of four stations (Huangzhuang, Dongpo, Guotan and Xindianpu) in May to August in 1994, with hourly flood process, flood hydrograph drawing is shown in Figure 7.4.5-7; according to boundary conditions of Huangzhuang >1,040 m³/s, Dongpo >300 m³/s, flood hydrograph drawing is shown in

Figure 7.4.5-8.

Characteristics of greater flood and peak of Tangbai river in 1994, peak flow and duration are shown in Table 7.4.5-7. It is known that the flood occurring in Tangbai River in 1994 was greater than other floods according to the chart analysis, with the peak flow of 950 m³/s, single peak, the flood mainly occurred in late July.

Table 7.4.5-7 Statistical table of flood characteristics in typical year of 1994

Year	Boundary conditions		Flood peak Characteristic	Maximum flood peak flow (m³/s)	Total duration of flood (1h)	Frequency of floods	Remarks
1994	Q-Huangzhuang >1040	Q-Dongpo >600	Single	950	19	1	Low
			Total	950	19	1	
		Q-Dongpo >300	Single	950	35	1	
			Total	950	35	1	
	Q-Huangzhuang >1200	Q-Dongpo >600	Single	950	19	1	
			Total	950	19	1	
		Q-Dongpo >300	Single	950	35	1	
			Total	950	35	1	

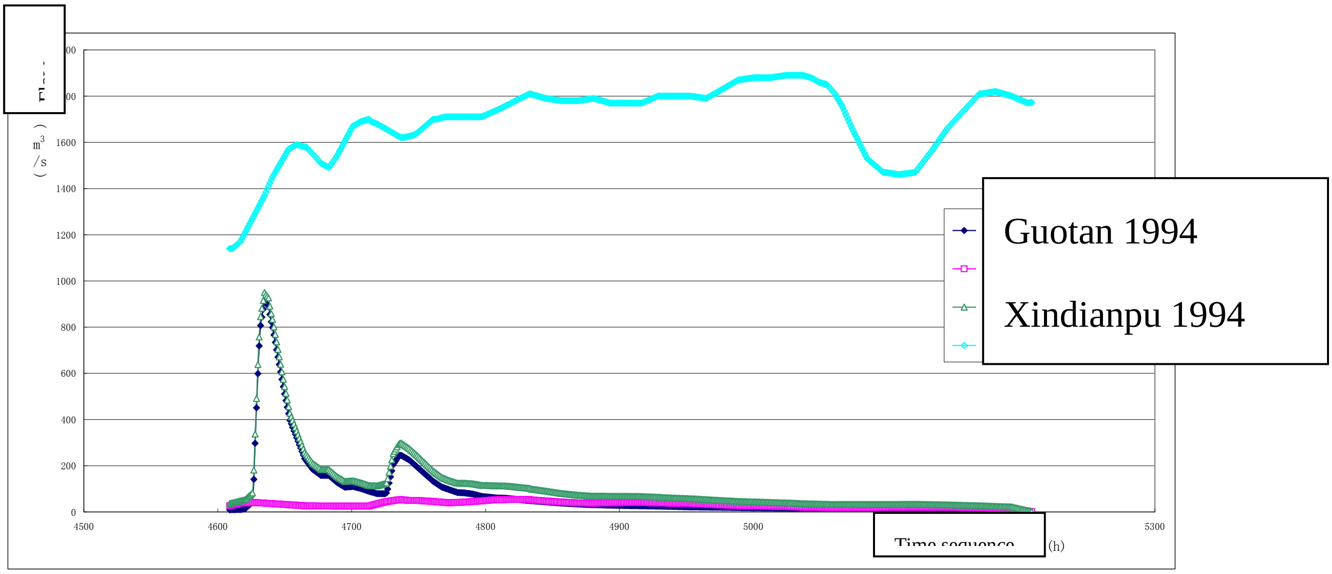


Figure 7.4.5-7 Schematic diagram of flood process in the typical year of 1994 (May to August)

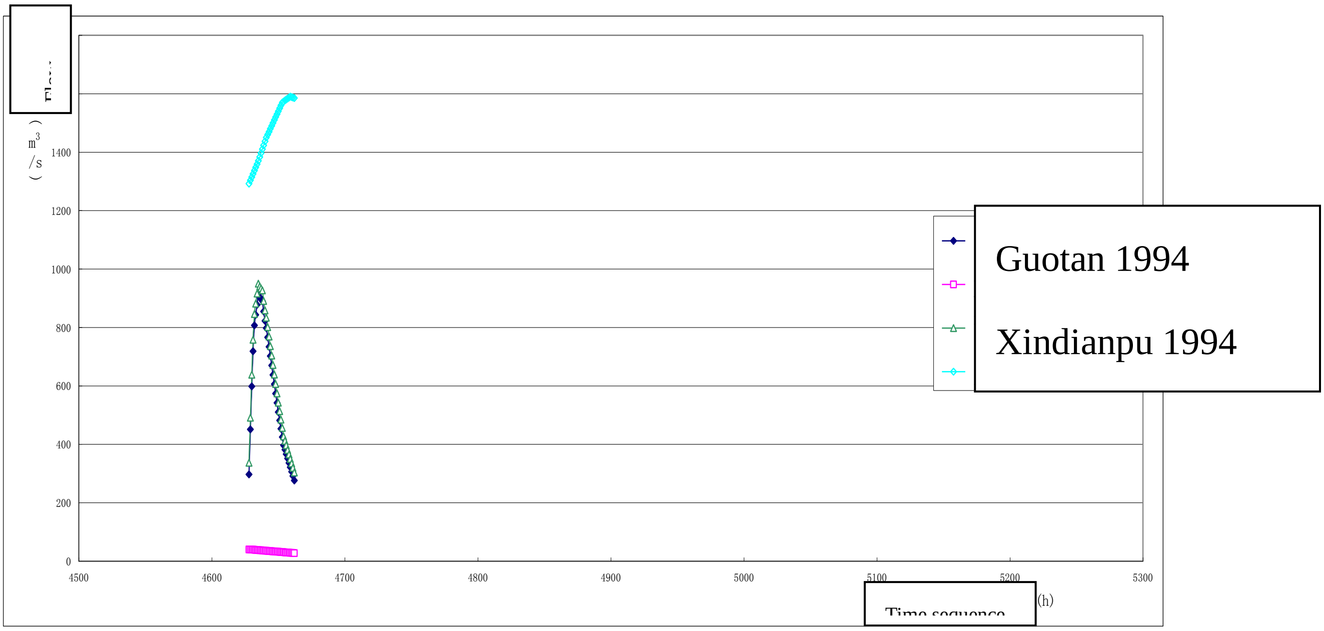


Figure 7.4.5-8 Schematic diagram of current-limiting flood process of Huangzhuang and Dongpo in the typical year of 1994 (May to August)

b) Analysis on Tangbai river water quality

Tangbai River is the main source of water and industrial water for people along the river, its better section in water quality is in the upper stream, but with the development of mountain economy, it is also facing the threat of pollution. The main pollutants of river pollution are industrial waste water and urban domestic water, especially industrial wastewater, and wastewater from chemical, brewing, paper, pharmaceutical, textile and dyeing is a key source of pollution. According to "Environmental function category of surface water in Hubei province" (Hubei government office 2000 No. 10), the water environment function of Tangbai River belongs to general industrial water zone, in implementation of class IV standard.

Shown from monitoring data of water quality in river boundary section of Tangbai river basin, from August 2005, the Tangbai river water quality has been improved slightly, data shows its water quality is class III; Bai river water quality is class IV. From January 2006 to June 2007 Bai river has been classified as inferior class V, heavily polluted; Tang river belongs to class III. From 2007, in addition to occasional improved water quality, Bai river has been classified as inferior class V; from 2011, Tang river water quality became poor, further polluted. The serious pollution section of Tangbai river belongs to organic pollution, such as BOD, ammoniacal nitrogen, P. From 2011, due to increment of governance intensity, urban sewage and industrial wastewater were processed, with significant improvement in water quality, river boundary section data shows Tang river water quality as class III. According to "Xiangyang bulletins on environmental situations" about surveillance results in Tangbai river routine surveillance section in 2012 to 2014, it is calculated to obtain Tangbai river water quality class from 2012 to 2014, see Table 7.4.5-9.Tang river is a section of Fukou, Bai river is a section of Zhaiwan, and Tangbai river is a section of Zhangwan. In 2014, the Fukou section water quality of Tang river junction section is good, similar with the previous year (class IV only in May); the Zhaiwan section water quality of Bai river junction section is good, similar with the previous year class III (class IV only in February and March); Tangbai river water quality was a little polluted, similar with the previous year class (class III from June to November).

Table 7.4.5-9 Evaluation table of Tangbai river water quality from 2012 to 2014

Rivers	Sections	Section types	Year	Water quality class											
				Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Tang river	Fukou (III)	Hubei Henan cross-border section	2012	IV	III	IV	V	V	III	IV	III	IV	III	IV	IV
			2013	III	III	III	IV	V	V	III	III	IV	V	III	III
			2014	III	III	III	III	IV	II	III	III	III	III	III	III
Bai river	Zhaiwan (IV)	Hubei Henan cross-border section	2012	V	V	V	V	V	IV	IV	IV	IV	III	IV	III
			2013	III	III	III	III	IV	V	III	III	III	III	III	IV
			2014	III	IV	IV	III	III	III	III	III	III	III	III	III
Tangbai river	Zhangwan (IV)	Xiangzhou district control section (port)	2012	III	V	III	III	IV	IV	IV	IV	IV	IV	IV	III
			2013	III	IV	IV	IV	IV	IV	III	IV	IV	IV	IV	III
			2014	IV	IV	IV	IV	IV	III	III	III	III	III	III	IV

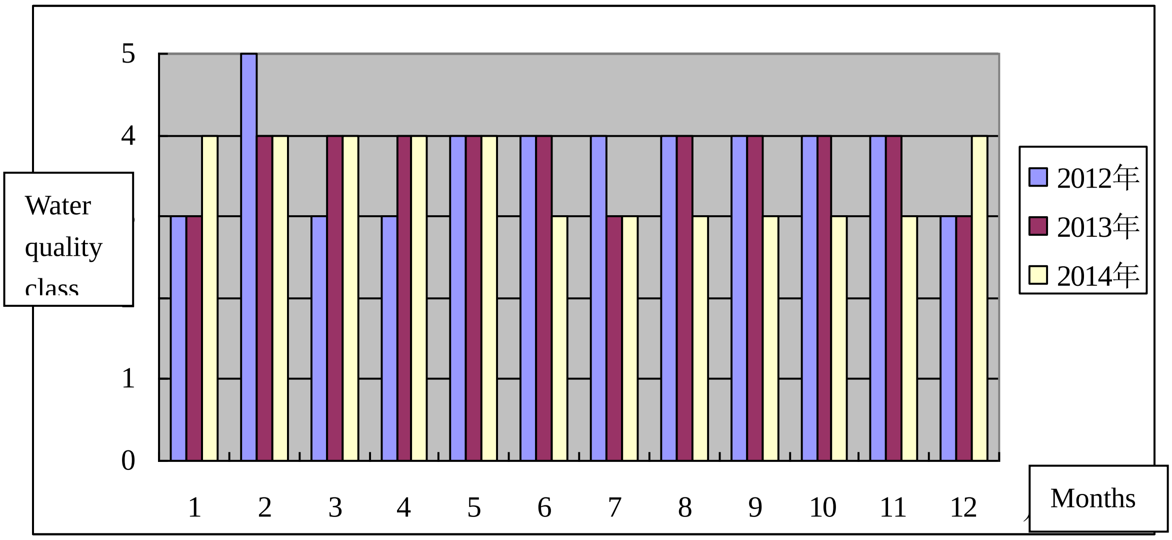


Figure 7.4.5-10 Water quality class diagram of Tangbai river control section from 2012 to 2014

It is thus obvious that, after recent years of water pollution control to Tangbai river basin, the water quality has been improved year by year, which met the requirements of class IV in water function zone, especially in fish breeding season May to August which could maintain class III standard, and create good water quality conditions for fish spawning and migrating etc.

c) Suitability analysis on egg reproduction of Tangbai river first flood

According to the historical investigation, around 2000 Tangbai River occurred the first flood, with dead fish appearing, so special investigation was carried out to solve the problem. Because there is no actually measured flow data at Tangbai river Dongpo flood control and water level station, according to first flood characteristic data of recent 30 years at Guotan and Xindianpu hydrologic stations, which are control sections of Tang river and Bai river as branch of Tangbai river, for occurred time of Tangbai river first flood and peak flow and the highest water level in nearly 10 years, see Table 7.4.5-10.Obviously, the first flood of Tangbai river mostly happened in May to July, the peak flow of Guotan station is greater than that of Xindianpu station.

Table 7.4.5-10 Characteristics table of the first flood of Tangbai River in nearly 10 years

Year	Guotan	Xindianpu

	Occurrence time	Maximum water level	Peak flow	Occurrence time	Maximum water level	Peak flow
2004	July 18th	87.32	3060	July 18th	81.81	2640
2005	June 27th	81.22	258	July 9th	79.02	661
2006	June 23rd	83.21	913	June 24th	77.24	136
2007	May 24th	81.24	300	June 30th	76.97	104
2008	May 5th	80.84	243	May 6th	77.10	115
2009	June 9th	80.14	152	May 30th	77.49	183
2010	July 18th	85.87	1920	May 9th	77.38	182
2011	June 24th	80.60	237	August 4th	76.83	161
2012	July 6th	82.45	787	May 31st	76.67	169
2013	July 2nd	79.94	139	July 3rd	76.93	219
2014	May 6th	78.78	22.5	June 13rd	75.79	27.8

For further analysis on water quality of the first flood of Tangbai river in the same period, supplemental monitoring data of water quality of Tangbai river Zhangwan section (2.5 km to Han river conjunction) was collected from May to September of the year 2009 to 2014 (from 2009 sampling monitoring carried out each month), so as to obtain water quality class of Tangbai river main stream from May to September of the year 2009 to 2014, see Table 7.4.5-11.

Table 7.4.5-9 Evaluation table of water quality class for Tangbai river Zhangwan section from May to September of 2012 to 2014

Year	May	Jun.	Jul.	Aug.	Sep.
2009	V	IV	IV	III	IV
2010	V	V	V	IV	IV
2011	IV	IV	III	III	IV
2012	IV	IV	IV	IV	IV
2013	IV	IV	III	IV	IV
2014	IV	III	III	III	III

Note: In the table, months in gray mark stand for time when the first flood occurred basically consistent with the monitoring time of water quality.

From the table, except in May to July of 2010, during the rest flood monitoring period, Tangbai river water quality can reach class IV standard of "environmental quality standard for surface water" (GB3838-2002), and in some months it can reach class III standard, especially after recent years of water pollution control of Tangbai river basin, the water quality has been improved year by year, maintaining class III standard from May to August, so as to create good condition of water quality for fish spawning breeding and migration.

At the same time, quality monitoring data of Tangbai river water was collected synchronous with surveys to aquatic organisms and early resources monitoring of fish in 2014. Known from Table 7.4.5-12, all indicators meet class IV standard of "environmental quality standard for surface water" (GB3838-2002). Analysts believe that in recent years, the pollution control of Tangbai river basin source also gradually obtained effectiveness, no obvious deterioration of water quality when floods occurring, also no large area of dead fish appearing, so the water quality will not become a restriction factor for ecological regulation of Tangbai river.

Through investigation, when Tangbai river had flood in 2007, the phenomenon of dead fish appeared in pollution river section of downstream in urban area of Nanyang city along Bai river, which was related with enterprises pollutant discharging; and no phenomenon of dead fish occurred in other years during the period of Tangbai river flood.

In summary, in recent years in the situation that pollution control is gradually effective in Tangbai river basin, there will be no phenomenon of dead fish when Tangbai river outbreaks the first flood, the water quality can meet the requirements of fish spawning.

Table 7.4.5-12 Tangbai river water quality monitoring synchronous with surveys to aquatic organisms and early resources monitoring of fish in 2014

Time	May 5th			June 5th			July 3rd			August 5th			September 2nd		
Name of rivers	Tang river	Bai river	Tangbai river	Tang river	Bai river	Tangbai river	Tang river	Bai river	Tangbai river	Tang river	Bai river	Tangbai river	Tang river	Bai river	Tangbai river
Water temperature (°C)	19	19	26	26	26	28	26	26	24	29	29	31	23	22	25
PH	8.3	8.0	8.1	8.2	8.0	8.0	8.1	7.9	8.0	8.0	7.9	8.0	7.9	8.0	8.3
Dissolved oxygen	8.06	8.22	7.72	7.97	6.78	7.79	7.1	6.4	6.2	7.6	6.0	7.3	7.3	7.2	5.5
Permanganate index	3.20	3.34	4.24	1.42	2.16	5.08	1.42	1.88	4.51	2.42	2.56	7.27	1.78	1.70	5.26
BOD_5	2.1	2.8	3.7	3.4	2.1	3.0	2.0	2.4	3.1	4.0	1.0	5.3	3.4	1.8	3.9
Ammonia nitrogen	0.252	0.525	0.823	0.328	0.422	0.643	0.211	0.274	0.697	0.254	0.592	0.364	0.385	0.616	0.353
FN	0.00015	0.00015	0.00015	0.0009	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.0004
Cyanide	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Arsenic	0.00186	0.0004	0.00189	0.00154	0.00121	0.00243	0.00124	0.00127	0.00278	0.00134	0.00139	0.00296	0.00146	0.00144	0.00245
Total mercury	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025
Hexavalent chrome	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Lead	0.000035	0.000035	0.000035	0.000035	0.000035	0.000035	0.00068	0.00084	0.00168	0.00660	0.00092	0.00088	0.00122	0.00105	0.00103
Cadmium	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.00014	0.00012	0.00013	0.000025	0.000025	0.000025
Oils	0.033	0.034	0.028	0.033	0.034	0.034	0.043	0.042	0.038	0.041	0.044	0.042	0.041	0.042	0.040
Electrical conductivity (ms/m)	58.2	26.7	42.2	49.8	42.6	44.1	43.6	39.6	40.1	44.1	40.6	41.2	43.6	44.9	44.9
Total phosphorus	0.073	0.063	0.119	0.067	0.075	0.143	0.186	0.061	0.171	0.041	0.034	0.105	0.064	0.057	0.071
Anionic surfactant	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Fluoride	0.60	0.70	0.56	0.63	0.66	0.55	0.49	0.59	0.56	0.52	0.64	0.51	0.53	0.52	0.60
Chemical oxygen demand	7	8	9	6	7	11	6	6	11	6	6	15	7	6	11
Sulfide	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025
Fecal coliforms (piece/L)	1800	5400	3500	1800	3500	3500	1800	2800	3500	1800	2800	3500	1800	2800	2800
Selenium	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Copper	0.00203	0.00306	0.00396	0.00232	0.00236	0.00212	0.00182	0.00215	0.00339	0.00448	0.00246	0.00265	0.00214	0.00190	0.00433

Zinc	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Total nitrogen	1.06	0.964	2.80	1.55	1.24	4.44	1.40	1.15	4.88	0.283	0.603	1.49	1.60	6.93	5.01

Note: Data is originated from Xiangyang environmental monitoring station

In addition, according to observation results of early resources by Chinese Academy of Water Ecological Engineering Research Institute in 2007 to Han river in Tangbai river (Table 7.4.5-13), we can see when Tangbai river occurred the first to the third flood, eggs can be collected in Han river main stream and no dead fish, which shows that the water quality has been markedly improved, the water quality of flood can meet the requirements of fish breeding.

Table 7.4.5-13 Preliminary analysis on hydrological and hydraulic characteristics of natural reproduction of four domestic fishes in Han river in 2007

Item	Unit	The first peak	The second peak	The third peak
Date of water level rising		June 18th	July 1st	July 8th
Date of maximum water level		June 23rd	July 5th	July 15th
Rising duration	d	6	5	8
Peak time interval	d		7	2
Initial position of the peak	m	33.82	35.42	36.71
Maximum water level of the peak	m	36.86	37.51	39.80
Daily rising rate of water level	m/d	0.51	0.42	0.39
Rising rate of water level	m	3.04	2.09	3.09
Initial flow of the peak	m^3	684	1520	2480
Maximum flow of the peak	m^3	2650	3400	8200
Daily rising rate of flow	m^3/d	327.67	376	715
Flood sources		Tangbai river	Dam regulation	Regulation, interval, Tangbai river
Water temperature	°C	22.8	23.7	26.2
Transparency	cm	12.5	32.5	14. 5
Total egg production	Ten thousand eggs	161866.67	81375.22	172712.19
Four domestic fishes	Ten thousand eggs	1261.94 (black carp126, grass carp 346.78, silver carp 825.4)	No	1983.06 (black carp 217.97, grass carp 571.56, silver carp 907.43, bighead carp

				249.87)
Economic fishes	Ten thousand eggs	5747.65	4256.68	6689.89
Small fishes	Ten thousand eggs	154857.08	77118.54	164039.24
Illustration of flood peak discharge	From June 18 to 23 in 2007, Tangbai river Guotan flow were respectively: 339 m^3/s, 1030 m^3/s, 356 m^3/s, 177 m^3/s, 134 m^3/s, Huangjiagang flow were respectively: 600 m^3/s, 601 m^3/s, 711 m^3/s, 712 m^3/s, 740 m^3/s; from July 8 to 15, Tangbai river Guotan flow were respectively: 518 m^3/s, 824 m^3/s, 354 m^3/s, 211 m^3/s, 144 m^3/s, 125 m^3/s, 582 m^3/s, 1078 m^3/s, Huangjiagang flow were respectively: 1590 m^3/s, 1860 m^3/s, 1850 m^3/s, 1850 m^3/s, 1830 m^3/s, 1870 m^3/s, 1820 m^3/s, 1820 m^3/s.			

d) Feasibility analysis on ecological regulation scheme

In summary, the guarantee rate of flood flow quantity 800m^3/s at Tangbai river Dongpo flood control station calculated in specification related to hydrology is 95%. Through observed flood data to Tangbai river for nearly 30 years, with further analysis we obtain that the guarantee rate in boundary conditions of Huangzhuang >1200m^3/s and Dongpo >600m^3/s is 86.7%; and the guarantee rate in boundary conditions of Huangzhuang >1200m^3/s and Dongpo >300m^3/s 93.3%.And after treatment in recent years, Tangbai river water quality can meet the requirements of class IV standard, so the flood flow and water quality of Tangbai river can meet the ecological scheduling requirements. In recent years, the pollution control of Tangbai river basin source also gradually obtained effectiveness, no obvious deterioration of water quality when floods occurring, also no large area of dead fish appearing, so the water quality will not become restriction factor for ecological regulation of Tangbai river. In addition, according to the water temperature observation data of Tangbai river, in May to September of temperature raising period, the water temperature will be gradually increased, with the minimum temperature of 19°C. After flowing into Han river, due to effect of water in low temperature of Danjiangkou discharge, the water temperature in Yujiahu section (18 km downstream of Tangbai river port) is lower 0.56°C than temperature of natural river, after flowing into main stream of Han river without changing the temperature of main stream, which can satisfy demand of fish spawning for four domestic fishes. Therefore, water quality and water temperature are not restriction factors for ecological regulation of Tangbai river.

The fish spawning season is from May to August, in Tangbai river's high flow years and normal flow years, in the second half of May to August, flood flow quantity is up to 600m³/s, or in low flow years the flood is up 300m³/s, the power flow will be increased in utilizing interval flow of Danjiangkou - Huangzhuang, and Wang Fuzhou, which can make the flow of Huangzhuang hydrologic station be up to 1200m³/s (according to the investigation in 2014, the flood peak discharge in fish spawning of pelagic eggs in Han river is 1,040m³/s, so 1,200m³/s can completely meet the ecological requirements of ecological regulation). Three hubs (Cuijiaying, Yakou and Xinglong) will be successively discharged, with all sluice gates open to make hydrological conditions meet the demand of fish breeding for four domestic fishes and rare fishes such as elopichthys bambus, ochetobius elongatus and luciobrama macrocephalus, etc., at the same time it also can eliminate the barrier of dam, to get the function of spawning grounds such as Yicheng, Guanjiashan, Zhongxiang, Maliang, Zekou etc. maintained, and also minimize the impact on aquatic resources protection zone of downstream, so as to lay a good foundation for the protection of aquatic ecological environment in the middle and lower reaches of Han river.

At the same time, because the ecological regulation is in high flow period, and in situation of runoff forecast accuracy, each regulation can be completed within 1 week, with less impact on shipping and power generation, and the ecological regulation is also feasible in economy.

7.4.5.5 Efficiency analysis on ecological regulation scheme

According to the previous survey, after the completion of Danjiangkou reservoir, the spawning and breeding of four domestic fishes are in high flow years, generally 3 - 4 times of spawning peak process, and 1-2 times in low flow years, which is highly dependent on Tangbai river flood. The current ecological regulation scheme is based on the flood situation of Tangbai river, with gates open 24 hours in advance, until the peak ending to close in 24 hour postponed. Mainly on account of main spawning grounds downstream Tangbai river confluence, there are one to two days from Tangbai river flood to spawning grounds, before the flood arriving spawning grounds, through discharge, the river will restore to original state of the river, and parent fish under dam have certain time to trace upstream to spawning grounds. And spawning grounds of pelagic eggs need special river habitat conditions, which are formed by greater river pattern, the corresponding hydrology conditions after discharge will get recovered. Therefore, original habitat conditions of spawning grounds will have better recovery. On peak discharge, Huangzhuang flow situation in 2014 of 1,040 m^3/s, although no discharge, in Cuijiaying reservoir conditions, Guanjiashan and Zhongxiang spawning grounds under dam finished spawning activity; if in the resumption of the original river state, the corresponding flow above the peak is to meet their spawning breeding activity, and it is relatively easy to achieve Huangzhuang section of more than 1,040 m^3/s peak. As for the drift process, due to the middle and lower reaches of Han river below Xiangfan, including the tributaries of Tangbai river, restore to the natural state of the water, it forms continuous drainage connection with middle and lower reaches of Han river and middle and lower reaches of Yangtze River, no restriction of drifting process. Therefore, it adopts discharge regulation, Yicheng, Guanjiashan, Zhongxiang, Maliang and Zekou can restore to state in 2014, or even close to that of 2004.

7.4.5.6 Research and implementation of ecological regulation in cascade joint

It is recommended as soon as possible to carry out the study on hydraulic and hydrological conditions of fish natural reproduction of pelagic eggs, study and improve the test scheme of regulation, synchronized with carrying out fish over a dam and early resource monitoring, hence to improve scheduling scheme, and establish corresponding operation and management mechanism.

In view the important significance of ecological regulation to maintain aquatic ecological environment of the middle and lower reaches of Han river, construction units should take ecological regulation of implementation test in Xinglong and Cuijiaying as basis, as soon as possible to carry out research on ecological scheduling scheme in cascade joint, and commanded and implemented by authorities responsible for river basin, with preliminary plans: carrying out test scheduling research and complete scheme and approval of ecological regulation in joint from 2016 to 2017, implementing ecological regulation in cascade joint in 2018, and monitoring the effect. Discharge in joint in Cuijiaying and Xinglong hubs will be carried out, with discharge time of 5 to 7 days, until the end of peak.

7.4.6 Fishery administration

To strengthen fishery administration is one of effective means to protect fish resources.

a) To strengthen team construction of fishery

It is recommended by local fishery sectors to establish and improve fishery administration institutions, strengthen the construction of fishery administration team and its capacity, and improve ability of law enforcement and strength of fishery sectors. To strengthen the propaganda of fish resources protection, in strict enforcement, without any fishery production activities in prohibited fishing area, especially those illegal fishing practices in ways of explosives, poisons, electricity and any other means.

b) Strict enforcement of period and area system of prohibited fishing

To make sure prohibited fishing period and area, and fishing during the period in cluster of fish spawning easy for fishing is forbidden, so as to protect fish to successfully complete process of life. To take essential habitat of fish as prohibited fishing area, where any form of fishing activity will be prohibited; to take time easy to capture and important time as prohibited fishing period, when the whole river will be prohibited for fishing, especially for river sections where fish are relatively concentrated.

For Han river prohibited fishing period, it implements spring prohibited fishing period of the Yangtze River, from April 1st to June 30th every year, according to biological characteristics of Han river fish resources reproduction, considering the effect of discharge water in low temperature of Danjiangkou power plant (Huangjiagang water temperature data under Danjiangkou dam for many years show that, the water temperature after the construction of dam is 2.1 - 2°C lower than that before the construction in March to August, 0.8 - 4.7°C higher from September to January, the highest temperature in August reduced about 2°C, and the lowest temperature in January increased 3.5°C. Changes in water temperature of discharge bring certain influence to fish reproduction of Xiangfan section, it should postpone 20 days in case of meeting the requirements of spawning minimum temperature of 18 °C, with fish reproduction period delayed, so it is suggested to adjust prohibited fishing period of Han river for May to July.

According to the prediction of the fish resource investigation and changes, in survey area, at the end of the reservoir, upper reaches of the river water and branch Ying river will be an important habitat river of Yakou shipping hub, it should be a prohibited fishing area to be protected. The survey area is not set prohibited fishing areas, during prohibited fishing period there still has fishing activities. Therefore, it is suggested the local fishery sector, for the protection of fish resources, taking essential fish habitat for prohibited fishing area and strictly enforce system of prohibited fishing period.

c) To strengthen fisheries management

To further strengthen the management of fisheries production, protect the resources of fish, so as to achieve sustainable development of fisheries production. Fishing gears and fishing methods should be limited, small size nets less than 6cm should be resolutely banned, and some fishing methods such as explosives, poisons, electricity etc., whose destruction to fish resources is often devastating, should be strictly prohibited. It is necessary to implement fishing permit system, according to the situation of fish resources to control the number of fishing vessels, and implement quota fishing to control the total amount of fishing and to stipulate fishery catchability standard. In biology, general provisions of fishing standard take fish length, weight and age for first maturity as its capture standards; in economics, it should stipulate suitable capture standards according to the growth of fish and feed utilization of biological resources, so as to ensure that the maximum sustainable utilization in fish resources and quality of product fish. At the same time, we should strengthen the prevention and control of water pollution, prevent the occurrence of water pollution incidents, so as to ensure a good living environment of fish.

7.4.7 To carry out scientific research

Hydropower development has a certain impact on aquatic ecology, therefore, it is recommended that the owners need cooperate with relevant research institutes to carry out relevant research, so as to effectively protect aquatic habitats and fish resources. Recommended related research projects including:

(1) Habitat conservation and habitat restoration research of fish;

(2) Technology study of ecological regulation and formulation and testing of joint scheduling scheme;

(3) Succession of aquatic organisms in the middle and lower reaches of Han River after formation of reservoir area;

(4) Effect evaluation and technology research of fish over fishway;

(5) Evaluation research of artificial reproduction technology and fish tagging and effect.

At present, there has no fishes such as luciobrama macrocephalus, ochetobius elongatus, etc. in the reservoir area has for many years, unable to carry out domestication and breeding research and practice, only as a key concern objective to survey its resources, once found it should focus on key domestication, to carry out corresponding research, so as to successfully lay a solid foundation for artificial domestication and breeding in the future. Leiocassis crassilabris has not been successful in artificial domestication and breeding. Recently domestication and breeding technology research will be carried out, and will be released after the technology is mature.

7.4.8 Fish protection measures during construction period

a) Avoidance measures of ecological impact

In order to reduce the influence of implementation of water projects on aquatic organisms, especially on fish resources, it is recommended before the project development and construction, try to do a good job in preparatory work of construction and planning, and the implementation of water projects should avoid the season of aquatic breeding. To strengthen the propaganda, set aquatic protection warning sign of aquatic organisms, and enhance the construction personnel's environmental awareness. In order to avoid the influence on fish during construction period, it should strictly prohibit fishermen of fishing in illegal means downstream of dam and around reservoir area, especially pay attention to construction personnel of illegal fishing for wild fish in using appointment position, resulting in damage to fish resources.

b) Abatement measures of ecological impact

During construction, construction personnel shall be strictly prohibited to directly throw all kinds of waste into the water, such as domestic waste, in particular to throw toxic and hazardous substances. And it needs carry out timely fishing, temporary rearing or releasing fishes in cofferdam.

c) Measures of ecological management, etc.

Monitoring or investigation of ecological impact should be carried out during construction period and operation period of the project. In the construction period, it is mainly to carry on monitoring to area which is related to construction. Through monitoring to strengthen the ecological management, to carry out environmental education in project affected area, and improve the environmental awareness of construction personnel and management personnel. Through dynamic monitoring and improvement of management, to make ecological environment develop in a healthy or favorable direction.

7.5 Protection measures of terrestrial ecology

7.5.1 Protection of agroecological system

a) Avoidance measures and minimization measures

Construction site is mainly set in the first and second terraces on both sides of Han River, and its occupancy is mainly farmland and woodland. For material field, it should provide temporary windproof and rainproof facilities; for transport vehicles of construction, it should take shielding measures, as far as possible to avoid the adverse impact during construction period to agricultural soil and irrigation water; for temporary highway construction, it should establish implementation plan of construction in rainy season, take temporary measures so as to prevent soil erosion and avoid the pollution of water.

b) Reduction measures

Cultivated land area for temporary occupation should be reduced as far as possible, for example construction of the temporary pavement in hub building, it should take construction scheme of optimization, reduce the occupation of cultivated land, and as far as possible clean well after the completion of construction, so as to reduce the pollution of farmland. Temporary land should be carried out as soon as possible to restore in vegetation after completion of the project, combined with utilization, leveling and rehabilitation.

c) Remedy measures and reconstruction measures

As submergence caused by reservoir area of the project cannot be avoided, it can only plow the field or raise the protection to the flooded farmland, forest and grassland, irrigation and grassland, etc. But for occupation area of construction, on the one hand, it should strictly control the scale; on the other hand, for occupancy of cultivated land of temporary construction site, it should carry on timely reclamation according to the requirements of plan after the completion of construction. Therefore, surface soil deposit field is planned in construction area, and the occupied surface soil of farmland will be preserved for reclamation and vegetation restoration, so as to improve soil fertility.

d) Basic measures of farmland protection

According to "Regulations on the protection of basic farmland in Hubei province" (Second amendment), "If national key construction project location of energy, transportation, water conservancy, military facilities and other does not avoid basic farmland protection areas and need to occupy basic farmland, the construction units must be in accordance with national land management laws, regulations and procedures, to apply for land administrative departments of the people's Government of the city or county. The land administrative departments of the people's governments of the city or county will make and supplement the scheme of cultivated land jointly with competent agricultural administrative department, to clear designated location of basic farmland, size, quality, and the provincial people's Government will submit to the State Council for approval." "The occupied units approved in utilizing basic farmland shall be in accordance with principle of reclaiming the same area with occupied, to reclaim cultivated land with the same quantity and quality of occupied basic farmland; those who do have no conditions for reclamation or do not meet the requirements in quantity and quality confirmed by the administrative department in charge of land of provincial people's government in collaboration with the agricultural administrative departments, should be in accordance with provisions of "Measures for the implementation in 'Land Administration Law of the People's Republic of China' to pay for reclamation fee of cultivated land, which will be used for reclamation of new land." The project will take a certain number of general cultivated lands in Yicheng City and Xiangyang City as basic farmland, and cultivated land reclamation fees will be paid for inadequate part according to the provisions.

7.5.2 Protection measures for plant resource

7.5.2.1 Measures to avoid adverse ecological impact

Appropriate measures shall be taken to avoid adverse ecological impact. This means to protect the environment which has important ecological function. Generally, we avoid irreparable environmental losses by means such as changing project site, changing engineering design, and changing construction plan, etc. According to the characteristics of this project, it is recommended to take the following measures:

a) Carry out strict management on construction work which may cause fire, and prohibit construction personnel to use fire in the forest.

b) Strengthen the control of alien invasive species. At present, the methods of preventing alien invasive species include plant quarantine, artificial control, chemical control, and biological control. According to engineering characteristics, the following measures are suggested: Enhancing the publicity. Construction personnel should be told that it is strictly prohibited to bring in alien species without strict testing and assessment; Alien species are most likely to invade areas with serious deforestation. Therefore, land greening shall be carried out at temporary sites in a timely manner. In soil/water conservation, and greening, give priority to the use of native soil.

The clearing target of the forest land includes various trees in the forest land and remnants of floaters. In cleaning, we should avoid damage to vegetation beyond the cleaning area, so as to protect the terrestrial ecosystem around the reservoir.

7.5.2.2 Mitigation measures of ecological environment

During the construction period, we should avoid the destruction of the vegetation in the project area. For secondary bare area brought by construction, we should timely take rehabilitation measures.

In resettlement plan, we should consider to reduce the destruction of vegetation. In field-lifting, we should make full use of in-situ soil, so as to reduce soil exploitation and vegetation destruction.

7.5.2.3 Rehabilitation measures for vegetation

Protection measures for vegetation are mainly plant restoration, so restoration and reconstruction methods are very important. According to local climate characteristics, we should notice the following technical points:

a) Save the mellow soil in permanent and temporarily occupied sites to provide good soil for plant restoration.

Mellow soil shall be preserved for second ploughing and greening.

b) The area of greening space shall be calculated on the basis of vegetation loss

After the project is completed, greening work shall be carried out in dam area and plant area to reduce the vegetation loss. In greening, we should consider fast-growing trees as well as the variety of tree species, so as to increase anti-insect ability of the ecological corridor.

c) Vegetation restoration measures in quarry area and borrow area

The vegetation coverage and amount of resources is reduced as a result of vegetation destruction in the quarry area and borrow area. Therefore, at the end of construction, ecological rehabilitation measures shall be taken to maintain the consistency of ecological system in quarry area and borrow area.

Project area is a humid zone with subtropics monsoon climate. The vegetation mainly includes grass and shrub such as rhus chinensis, paper mulberry, glochidion puberum, sapium sebiferum and vitexin. Besides, there are artificial vegetation such as arundo donax and black locust scrub, as well as imperata cylindrica, melilotus albus. In plant restoration, local native species shall be used as far as possible to speed up the ecological recovery process.

After the borrow area and quarry area is utilized, land consolidation and earthing-up shall be carried out to create an environment for the growth of vegetation. For waste dump, plant shrub (such as schefflera octophylla and lantanae camarae) + grass seed (such as bahiasgrass and zoysiagrass) for plant restoration; for slopes, plant bahiasgrass and zoysia japonica for water and soil conservation; build a shrub community by transplanting or planting of liquidambar formosana, myrtle, wild peony, and streblus ilicifolius to build a stable natural ecosystem.

After closing the quarry area, plant restoration shall be taken on step surface and ground. Acacia mangium, endospermum chinense and bahiasgrass can be planted in the exploitation area to improve the ecological stability of quarry area.

7.5.3 Protection measures for terrestrial animals

a) Measure for ecological environment

Strengthen publicity by drafting Ecological Environment Protection Handbook, and enhance the awareness of construction personnel by setting signs of environmental protection.

In construction, it is necessary to take effective methods to remove the oil in the wastewater and treat the domestic sewage produced by construction personnel, so as to avoid the pollution of downstream water and survival of terrestrial animals.

Part of farmland having tiger frog will be submerged by the project. Therefore, in field-lifting, we should avoid construction during its reproduction season and hibernation period and save the topsoil.

b) Mitigation measures

Blasting and construction (such as construction time and construction mode) should consider the biological rhythm of the wild animal. Wild birds and animals are looking for food during the morning and nightfall, and the midday is their break time. Therefore, we should avoid blasting during these hours.

c) Rehabilitation and remedial measures

The integrity of biological community is an important factor in maintaining the stability of the ecosystem and food chain. During construction, we should protect the biotic community such as terrestrial vertebrates and plant community. After construction, we shall carry out plant restoration work in the borrow area and quarry area.

d) Management measures

Construction personnel shall strictly abide by Law of PRC on the Protection of Wildlife and they are not allowed to hunt wild animals in the construction area and its surrounding area. The wild animal includes batrachia, zaocys dhumnades and key protected wild animals. Prior to construction, provide the construction personnel with a manual covering related laws and regulations on animal protection.

As human activities will be gradually increasing with the project construction, so we must strengthen management to prevent pollution of domestic waste on the lower reaches of the river.

7.5.4 Ecological restoration measures of construction site

After construction, the terrestrial ecosystem of the construction site shall be should be restored by combining with the soil and water conservation measures. The specific details are shown below.

7.5.4.1 Restoration principle

(1) The principles of protecting the original ecosystem

The project area belongs to plains and hilly areas with strong human activity. Artificial vegetation are widely distributed, while natural vegetation is distributed in the low mountains and hills on the right bank of Han River region. Therefore, the ecological environment of the project area is fragile.

Therefore, in the process of vegetation restoration, we will consider a terrestrial ecosystem consisting of broad-leaved deciduous forest, scrub, and shrub herbosa.

(2) The principle of protecting biological diversity

In vegetation restoration, we should consider not only vegetation coverage, but also species diversity.

(3) The principle of protecting cultivated land resources

The project area owns good agriculture base. There are 416 million hm^2 of cultivated land available in the city, ranking second in the province. Arable land is widely distributed in the project area as the plain and mild slope area is generally cultivated into cultivated land. Although the resources of cultivated land are rich, most of the cultivated land in the project area is classified as "farmland protection area". Therefore, after completing the construction, the original cultivated land shall be restored as early as possible.

7.5.4.2 Partition of ecological restoration

The general idea for ecological restoration of the project area is: Firstly, carry out investigation and analysis of the vegetation status of the project area, so as to find out the types and characteristics of main plant communities; secondly, make an analysis and classification of the site condition of the project area. According to the general layout of the project and its construction, determine the functional requirements after completing the project; Finally, according to above-mentioned information, determine the partition of ecological restoration.

According to above mentioned method, the ecological restoration area is divided into cupressus funebris and deciduous broad-leaved forest area, populus area, shrub herbosa area, river-flat wetland plant area, farming area, landscape area around power station facilities and temporary recovery area.

The partition of ecological restoration is shown in 7.5.4-1.

Table 7.5.4-1 Partition of ecological restoration of the project area

No.	Partition type	Construction land mass
1	Deciduous broad-leaved shrub area	Borrow area
2	Poplar forest area	3# waste dump
3	Shrub grass area	Preventive works in reservoir area
4	River-flat wetland plant area	River flat of inundated area
5	Farming area	1# waste dump, 2# waste dump, stockyard, construction site, camp of the PIU Temporary construction road, external-transport road
6	Landscape area around power plant facilities	Affected area, management area and permanent road area beyond the camp of PIU
7	Temporary restoration area	Part of the temporary construction road

7.5.4.3 Composition of plant community in the restoration area

The composition of plant community was determined mainly by site conditions (altitude, topography, slope direction and position, soil condition, hydrology) and vegetation status.

(1) Deciduous broad-leaved shrub area

The restoration for the borrow area and part of the temporary construction roads are deciduous broad-leaved forest, deciduous broad-leaved shrub and shrub herbosa. Based on regional survey, we find that the area is mainly made of artificial poplar forest and pinus massoniana forest. The scrubs include oriental oak, vitex negundo, rosa cymosa and alchornea davidii.

According to site condition and vegetation status, the borrow area and part of the temporary construction roads can be restored by scrubs such as oriental oak, vitexin, rosa cymosa and alchornea davidii.

(2) Poplar forest area

The poplar forest area is a typical artificial commercial forest, distributing widely around the cultivated land. 3# waste dump lays at the low floodplain and the riverbed partially planted with populus. The ecological restoration for top surface of the waste dump shall be done by populus forest.

(3) Shrub grass area

The main vegetation of the ecological protection area of the reservoir is shrubs, consisting of bermudagrass shrub, white clover shrub, artemisia shrub, motherwort herb shrub, as well as rumex acetosella, rumex dentatus, phytolacca, wild chrysanthemum, savory, wild chrysanthemum, erigeron annuus and artemisia lavandulaefolia. The grasses of the reservoir are in good condition and high coverage. In completing the embankment, use local grasses such as cynodon dactylon for ecological restoration; or, in reinforcement, scoop up 3cm of the in-situ turf, and place them along the embankment with 500m as a section.

(4) River-flat wetland plant area

As it is a inundated area, we should consider the purification function and landscape function of the aquatic plants for restoration. Consider the mix of aquatic plants-floating plants-submerged plants. For aquatic plants, we can use reed, cattail, arrowhead etc.; For floating plants, we can use water lilies, caltrop, and gorgon fruit; for submerged plants, we can use antirrhinum, vallisneria natans and potamogeton.

(5) The landscape area of surrounding facilities

The surrounding landscape area is mainly distributed with ornamental plants. At the project area, the PIU camp and permanent sites are terraces, the vegetation of ornamental plant should consider species with good moisture resistance.

For restoration of external influence area of the PIU camp, we can use arbor species such as camphor, amorpha fruticosa, ligustrum lucidum, metasequoia glyptostroboides etc; evergreen shrubs such as buxus sinica, ligustrum quihoui, pittosporum tobira; others that can be considered include camptotheca acuminata, robinia pseudoacacia, lespedeza formosa, crape myrtle, and azaleas; and herbaceous species such as white clover and wood sorrel.

The restoration of hydro-junction area can use grasses such as white clover and creeping oxalis.

The permanent road is a external-transport channel. The trees on both sides of the road should consider regional plant species with regional characteristics. For arbor species, we can use poplar, metasequoia, taxodium ascendens, and camphor; for shrubs, we can use lobular privet, ligustrum sinense, buxus, boxwood, pittosporum tobira etc.; for grasses, we can use cynodon dactylon, or white clover and creeping wood sorrel.

(6) Temporary restoration area

Temporary recovery area mainly refers to temporary construction road. As the surrounding of temporary recovery area is mainly cultivated land, we can use woody plants such as amorpha fruticosa and herbaceous plants such as hispid arthraxon and cynodon for restoration.

7.5.4.4 Structure of plant community in the restoration area

The structure of plant community is based on the characteristics of tree species, the structure of tree species in natural community, and site conditions.

(1) Proportion of tree species

The percentage of various species in the plant community should be based on the growth principle of each species. It varies due to different species, community type and site conditions. In area with poor site condition, the number of associated species can be appropriately reduced; in early stage of vegetation restoration, the dominant species of each layer shall account for about 50%, while associated species shall account for 25% ~ 50%. In special site conditions, the proportion of species can be adjusted in accordance with actual needs.

(2) Mixed mode of tree species

① Ecological restoration of temporary construction area

Mixed mode of tree species in temporary construction area means the arrangement or configuration of tree species. The commonly adopted mixed mode is inter-line mode, strip-like mode, block-like mode and star-like mode.

For arborous layer tree species, we use interline mode. In this mode, the dominant species and its accompanying species are arranged line by line.

For shrubs, we use strip-like mode. In this mode, the dominant species and its associated species are arranged line by line, and arbors and shrubs are arranged alternatively in each line.

For herbaceous plants, we use blend-seeding in accordance with the above-mentioned ratio.

② Surrounding facilities of power station

The modes of plant cultivation of this area can be determined on the basis of the landscape requirements of power plant, which mainly include isolated-planting mode, opposite-planting mode, row-planting mode, clump -planting mode and group-planting mode and .

(3) Density of tree species

The density of tree species forms the quantity basis of community structure, affecting the growth, production and quality of the tree species. Over-crowded planting will make the space of each sapling too small, thus resulting lack of light and malnutrition. Over-scattered planting will result in stout and unhealthy trunks and poor ecosystem stability and diversity due to the growth of weeds.

The species density shall be determined after taking all factors into consideration such as cultivation objectives, site condition and species characteristics, so as to improve the stability of ecosystems. The community structure is detailed in Table 7.5.4-2.

Table 7.5.4-2 List of community structure

Community type	Percentage of dominant tree species in arborous layer (%)	Percentage of dominant species in shrub layer (%)	Percentage of dominant tree species in herb layer (%)	Plant density
Quercus variabilis shrub	/	60	50	Plant spacing is 1.5m × 2m for shrub, while the planting density is $3g/m^2$ for herbaceous plants.
Vitex negundo shrub	/	50	50	
Rosa cymosa shrub	/	60	50	
Alchornea shrub	/	60	50	

The grass in the shrub restoration area such as bermuda grass and white clover are those with strong growth force and adaptability, so we can use randomized large-scale seeding method to accelerate the restoration work.

The plant density around the power plant should be determined according to its landscape requirement.

Plant spacing of temporary restoration site is 1.5m × 2m for shrub, while the planting density is $3g/m^2$ for herbaceous plants.

7.5.4.5 Modification of site condition

(1) Collection of surface soil

As the construction brings large disturbance to the surface layer, so a large amount cultivated soil is needed in plant restoration and re-cultivation period. The cultivated soil mainly comes from the topsoil of the borrow area. For the aim of re-cultivation, the topsoil of the borrow area shall be stripped off. According to geological survey, the thickness of top soil in borrow area of Lijiawan is 50cm, while the thickness of top soil in areas such as Longgang is 20cm. Arrange a storage yard to store the top soil. The slope of storage yard is about 1:2, and its height is about 2.0m. Its surrounding shall be reinforced by bagged soil. Outside of the reinforced area, arrange temporary drain ditch and sand basin.

(2) Restoration of damaged soil

① Waste dump

It is difficult for plants in the top soil of the waste dump to restore in a very short period of time, as the waste dump is a mixture of stone, gravel, and weathered materials. Therefore, the soil restoration of the waste dump is the key in its ecological restoration in the short term.

We mainly use top soil collected in above mentioned methods for soil restoration. In early stage, we use pioneer plants such as legume for soil restoration, which owns high nitrogen fixing capacity and adaptability. Therefore, the top soil is mixed with the base material for greening, so as to reduce the use of top soil.

② Ecosystem restoration of temporary facilities and road affected areas

Temporary facilities and road affected area bring little damage to the topsoil, such as soil compaction and decline of soil fertility. Therefore, soil improvement and fertilizing measures shall be taken to restore the organic matter such as nitrogen, phosphorus, potassium and other substances necessary for the growth of vegetation.

③ Ecosystem restoration of land re-cultivation area

This area has relatively high demands on soil condition. We can use cultivated topsoil stripped off in pre-construction period for re-cultivation. In the early stage of re-cultivation, we can use organic fertilizer to improve the fertility of the soil. This area can be re-cultivated as dry land, paddy field, planting with paddy rice, wheat, maize, potato and peanuts.

④ Ecological restoration for slope of permanent & temporary roads

As the permanent roads and temporary roads are built up on a relatively flat terrain, the slope is relatively flat. Therefore, we can use grass seed for restoration of slope. For permanent and temporary roads with relatively abrupt slope on the right bank of the dam, it is difficult to reach our restoration purpose by sowing grass seeds. According to its unique habitat conditions, we can vine plants such as ivy, parthenocissus, and akebia stem for vegetation restoration. We can build planter box both on the downhill and uphill of the slope for these vine plants.

7.5.4.6 Planting technology

(1) Land preparation before planting

Land preparation is an important technical measure for ensuring the survival of the plant. We adopt a hole-like land preparation mode. The shape of the hole is square or round. For annual or biennial seedling, the specifications is 40cm(L)×40cm(B)×30cm(H); for triennial or quadrennial seedling, the specifications is 50cm(L)×50cm(B)×40cm(H).Specifications of seedlings or trees for power facilities shall be determined by the size of soil ball.

(2) Protection and treatment before planting

In planting bare-root seedlings, we shall go through processes such as digging, grading, packaging, transportation and planting. Each process must be well arranged to ensure a high survival rate of the seedlings.

(3) Planting and sowing method

We plant the seedlings in a hole by hole mode. After land preparation, put the seedlings into the hole and stretch its roots. Then, backfill the soil layer by layer to tight the seedling root and soil.

For herbaceous plants, its seed must be well processed before sowing. Use cold water or warm water for soaking to accelerate its germination. For legume seeds, the soaking time is 12 ~ 16h; for grass-family seeds, the soaking time is 1 ~ 2d; during the soaking, change the water 2 to 3 times. The sowing time shall be determined in accordance with the factors such as biological characteristics, natural conditions, rainfall, and soil moisture. Annual herbaceous plants are suitable for sowing in spring, while perennial herbaceous plants are suitable for sowing in summer. To ensure survival rate, we suggest a dibble seeding method. The sowing depth is 2 ~ 4cm, dibble spacing is 0.5m, and spacing is 0.3m.

7.5.4.7 Sources of seedlings and grass seeds

The seedlings and seeds can be obtained by market purchasing and seedling-raising.

(1) Market purchases

Some of the seedlings which can be directly purchased in market include amorpha fruticosa, ligustrum lucidum, camphor, quercus variabilis, virginia creeper, ivy and ornamental plant used for the power plant. Seeds of herbaceous plant can be obtained through the market; or, scoop up the greensward for 3cm and place it along the embankment 500m by 500m for protection of new embankment.

(2) Seedling-raising

For a small amount of seed unable to be purchased from the market, we can get it by raising seedlings in temporary nurseries.

The number of seedlings of this kind is relatively few. Therefore, land acquisition is not needed for the construction of the nursery. The seedlings will be planted by local farmers, while we will provide seed and technical services. After that, the seedlings will be purchased by us. By this way, the economic income of local farmers is increased. Of which, the seedlings can be purchased in market.

7.5.4.8 Irrigation

For vegetation restoration of temporary sites, surroundings of power station and waste dump, we can use water supply system in the construction period; for quarry area, it is unrealistic to bring water from the Han River due to its long distance. Therefore, we will adopt a water storage irrigation method by taking the advantage of the regional topographical conditions.

7.5.5 Mitigation measures for Wanyangzhou Wetland Park

(1) Protection of wetland ecosystems. Shallow waters such as the beach and Jiangxinzhou are important habitat for the survival of wading birds (such as egret). Therefore, relevant departments shall strengthen the management of sand mining activities in this area.

(2) Preventive works and the field-lifting shall be carried out by taking into consideration of wetland park planning. The working range and arrangement of temporary site shall be controlled in way to reduce the impact on wetland. The construction plan should solicit opinions of Wetland Park Management Office. Combined with the planning of Wanyangzhou Wetland Park, the surrounding area of waters such as Han River and Wetland

Park shall be planted with local wetland vegetation for restoration.

7.6 Measures for soil and water conservation

7.6.1 Scope and areas for soil erosion control

7.6.1.1 Responsibility scope of prevention and control

The responsibility scope of soil and water conservation mainly includes two areas: project construction area and directly affected area.

The project construction area refers to the area of land requisition, rented land and land use. According to Technical Specification for Water and Soil Conservation of Construction Project, Feasibility Report and field investigation, the construction area is divided into reservoir protection area and dam project area. The dam project area include dam construction area, the PIU camp, borrow area, temporary soil storage area, waste dump, construction road area, and production and living area. The reservoir protection area includes inundated area, engineering area, waste dump, construction road area, and production and living area. These areas are key places for management. Its size will be determined by the floor area of the construction.

Directly-affected area refers to the place that may cause direct damage to the surrounding area due to construction activities in construction area.

In accordance with statistical study, the responsibility scope of soil and water conservation totals 9, 175.42 hm², of which the project construction area is 9, 126.18 hm² and directly affected area is 49.24hm². The responsibility scope of soil and water conservation is shown in Table 7.6.1-1.

Table 7.6.1-1 Responsibility scope of soil and water conservation Unit: hm²

Project areas			Responsibility scopes			Notes
			Subtotal	Project construction area	Directly affected area	
Dam project area	Dam construction area	Hub area	61.20	61.20		Directly affected area is included in managing scope
		Earth-rock dam area	20.17	20.17		Directly affected area is included in managing scope
		Cofferdam	19.90	19.90		Directly affected area is included in

Project areas			Responsibility scopes			Notes
			Subtotal	Project construction area	Directly affected area	
		area				managing scope
		Open diversion channel area	82.08	82.08		Directly affected area is included in managing scope
		Management scope Other lands	29.43	24.34	5.09	Upstream is the reservoir inundated area, 15m away from downstream and 10m away from the management line of the dam head are included
	The PIU camp		7.50	7.50		Directly affected area is included in managing scope
	Borrow area		6.97	6.75	0.22	2m around
	Temporary soil storage area		28 .12	28.00	0.12	② Within 2m range of the soil storage site
Dam project area	Waste dump		104.75	103.09	1.66	Production and living area, and adjacent side earth-rock dam shall not be included in directly affected area, other areas shall be included within 2m of its periphery
	Road engineering area	Approach road area	1.10	0.70	0.40	Upper slope 3m, lower slope 5m
		Road construction area	2.80	2.20	0.60	
	Production and living area		21.55	21.15	0.40	
	Subtotal		385.57	377.08	8.49	
Reservoir protection area	Reservoir inundated area		8494.12	8494.12		Not included in directly affected area
	Preventive works area	Flood diversion area	82.80	82.80		
		Anti-submerge area	43.20	43.20		
	Waste dump		156.51	125.31	31.20	Within 2m range of the outside of non-ditch or Ditch; for abrupt place in the waste dump: upper slope 2m; lower slope 4m
	Road construction area		3.41	3.27	0.14	
	Production and living area		0.45	0.40	0.05	
	Resettlement and special facility		9.36		9.36	

Project areas		Responsibility scopes: Subtotal	Responsibility scopes: Project construction area	Responsibility scopes: Directly affected area	Notes
	rehabilitation area				
	Subtotal	8789.85	8749.10	40.75	
Total		9175.42	9126.18	49.24	

7.6.1.2 Partition of soil erosion control

The design depth for the project is suitable for feasibility study stage. Meanwhile, soil and water loss caused by the project is mostly concentrated in the construction period. Therefore, we arrange the areas for soil erosion control in accordance with the terrain topography, project layout, design and construction characteristics, and responsibility scope.

This project is located on terraces of the shore in Han River, and the landform in the area is Simple. Based on construction technology, production methods and characteristics of the project, we divide the areas for soil erosion control of the project into the following parts, as shown in Table 7.6.1-2.

The protection zones are detailed in Table 7.6.1-2. For overall layout of monitoring points and soil erosion protection zones, please refer to Figure 27.

Table 7.6.1-2 Areas for soil erosion control

Topography and geomorphology	First-level protection zones	Second-level protection zones	Notes
Plain Hills	Protection zone of dam project area	1. Control area in dam construction area	Hub, earth-rock dam, cofferdam, diversion channel and other lands within management scope
		2. Protection zone in the PIU camp	1, on the left bank
		3. Protection zone in borrow area	1 borrow area
		4. Protection zone in temporary soil storage area	2 soil storage areas
		5. Protection zone of waste dump	3 waste dumps
		6. Protection zone of road works	Approach road 0.500km, construction road 8.550km, and non-overlapping part 2.650km

Topography and geomorphology	First-level protection zones	Second-level protection zones	Notes
		7. Control area for production and living area	A protection zone in the left and right bank
	Protection zone for reservoir preventive works area	1. Protection zone in reservoir inundated area	Inundated area after the completion of the reservoir
		2. Protection zones of preventive works	Flood diversion Ditch 30km, drain ditch 48km
		3. Protection zone of waste dump	Both sides of flood diversion Ditch and drain ditch
		4. Protection zone of construction road	Construction road 4.090km
		5. Control site for production and living area	Production and living area of preventive works
		6. Resettlement and special facility rehabilitation area	

7.6.2 Principles and objectives of soil erosion control

a) Control target

This project goes through Yicheng city, Xiangcheng District and Xiangzhou District, which belong to key soil erosion control regions in Hubei Province. At the same time, the project goes through the Han River. Therefore, the control standard for soil erosion is Grade-I.

According to data from local weather station, the average rainfall of the project area is 840 ~ 878.0mm. The force of soil erosion mainly comes from water. For areas with more than 800 mm of rainfall, the value of control target for soil erosion, vegetation recovery and forest coverage shall be increased by 2% above.

Table 7.6.2 Target value for soil erosion control

Control index	Standard value		Control target	
	Construction period	Trial operation period	Construction period	Trial operation period
Disturbed land remediation rate (%)	*	95	*	95
Total control of soil erosion (%)	*	95	*	97
Controlled ratio of soil erosion modulus	0.7	0.8	0.7	1.0
Slag blocking rate (%)	95	95	95	95
Vegetation restoration rate (%)	*	97	*	99

Forest coverage rate (%)	*	25	*	17

a) Control principle

Principles of engineering measures: The soil erosion control measures shall be planned in a principle which minimizes the disturbance of ground surface and earthwork excavation. Temporary measures as well as permanent measures shall be taken into consideration. Meanwhile, engineering measures as well as vegetation measures shall be taken into consideration.

Principles of vegetation measures: The measures shall be planned with a principle that the measure itself is suitable for the natural environment of the project area; besides, greening and beautification shall also be taken into consideration.

Principles of temporary measures: For temporary soil storage site, we need to arrange temporary protective measures.

7.6.3 Measures for soil and water conservation

7.6.3.1 Protection zone of dam project area

a) Protection zone in dam construction area

The dam construction area is within the scope of the cofferdam. According to requirements of soil and water conservation, we should make reasonable arrangements for excavation and backfilling procedure; the excavation slope shall be controlled in a stable side slope; we should also avoid off-line evacuation; the evacuation shall be carried out in sunny days as far as possible; removing of the cofferdam shall be carried out in dry season, and the residue shall be transported to a designated area.

b) Protection zone in the PIU camp

The camp site of the PIU is planned on the right bank of the earth-rock dam. The camp covers an area of 7.50hm², and its designed elevation is 59.0m.

Engineering measures: Before starting the construction, strip off the topsoil by 30 cm in sites which need to be hardened within ancillary facilities area. Place the soil into the green area for further use. Camp of the PIU, production and living area of the right bank, and 1# waste dump are a whole for earth filling. On water side, we use gabion retaining wall. From the top of the retaining wall, to 0.5m of normal water level, we use gabion for protection of bank and slope. We arranged drainage ditch (30cm x 30cm trapezoidal cross-section, slope 1: 1, masonry thickness 30cm) for water discharge of the principal part. Meanwhile, we arrange desilting basin at the outlet of drain ditch.

Vegetation measures: After the completion of the project, the surface of PIU camp will be a "hardening +green" mode. The area of greening and beautification will be 2.63hm². The plan will put forward corresponding recommendations for vegetation measures. As the PIU camp is close to the right bank of earth-rock dam, the vegetation species and its arrangement shall be consistent with the greening of earth-rock dam. For suggestion of vegetation measures, please refer to that for dam construction areas.

Temporary measures: In construction, temporary protective measures shall be taken to temporary topsoil, excavated earthwork and relevant materials. Use bagged soil for temporary obstruction, and pile the soil into a 0.5m*0.5m (width*height) trapezoid section with a slope ratio of 1:1. For its surface, scatter white clover seed for vegetation protection.

c) Protection zone in borrow area

The borrow area is dry land, covering an area of 6.75hm².

Engineering measures: It includes re-cultivation measures such as the stripping-off of topsoil, returning and re-cultivation. During the process of soil excavation, make a reasonable arrangement of the excavation procedure. The stripped-off topsoil and waste shall be stored in a reasonable manner for future use. The amount of stripped-off topsoil in borrow area is 20, 300 m³, and re-cultivated area is 6.75hm².

Drainage measures: The runoff surrounding the borrow area shall be discharged in a timely manner through the drain ditch. The maximum rainfall during 1h is 62.9mm (once in ten years) . According to the formula of uniform flow for open channel, the drain ditch is designed as a trapezoidal masonry section(bottom width 40cm, depth 30cm, slope ratio 1 : 1, brickwork thickness 30cm).At the outlet of the drainage ditch, we have designed a rectangular desilting basin

(3.0m (length) x 2.0m (width) x 1.0m (depth). Thickness of the stone masonry is 30cm. During the raining season in construction period, we will arrange designated personnel for desilting work. The drain ditch in borrow area is 1,102m, and the number of basin is 2.

Temporary measures: The stripped-off topsoil will be stacked in a vacant place of the soil storage area. Its stacking height will be controlled at 2m and slope will be controlled at 1: 2. To prevent soil erosion, use bagged soil for temporary retaining. The retaining wall will be a section 50 cm * 50 cm (top width * height) and its slope is 1: 1. Scatter trifolium seed (50kg/hm²) onto the surface of the stacked topsoil. At initial stage, use non-woven fabric to prevent soil erosion.

The bagged soil for retaining is 2,160m, non-woven fabric is 10,700m², and trifolium repens clover seed scattered is 1.07hm².

d) Protection zone in temporary soil storage area

The temporary soil storage area is mainly dry land and forest land, covering an area of 28.00hm². During peak period, the average height of #1 soil storage area and #2 soil storage area are 13m and 11m, respectively. After completing the project, the #2 soil storage area located in the downstream of the sluice will be used as a discharge channel, which no longer needs restoration measures.

The #1 soil storage area is located on the right bank, and it now is dry-land. After the end of the project, this area will be re-cultivated. The area for re-cultivation is 7.00hm².

The slope for #1 soil storage area and #2 soil storage area will be controlled at 1: 1 in order to prevent soil erosion, and its surroundings shall be retained by bagged soil.

As there is no runoff surrounding the soil storage area, there is no need to set up additional drainages.

e) Protection zone of waste dump

There are 3 waste dumps, covering an area of 103.09hm². The land types include dry land, forest land and inland tidal flat.

1) Engineering measures

To ensure the stability of the waste residue, its staking procedure should be strictly controlled.

Surface treatment: Strip off the available topsoil in the waste dump by 30 cm and stack the topsoil at the back of the waste dump(no more than 2m), and take protective measures for retaining. In addition, some of the topsoil stripped off in the construction area will be shipped from the temporary soil storage area to waste dump for backfill.

Retaining: #1waste dump and #3 waste dump will be retained by a 2m width) gabion bank protection at its water side to prevent them from soil erosion. The water side of #2 waste dump is adjacent to an open diversion channel. The slope of the diversion channel is retained by a steel-wire gabion. The protection of #2 waste dump is connected with the top of diversion channel, and its width is 5~10m.

The retaining wall is 1.5m high, and has a top width of 1.0m and base width of 2.0m. Its burial depth is 0.5m. The specification for slope protection is 2.0m×1.0m×0.3m.

Drainage measures: The section size of drain ditch for waste dumps is: bottom width 40cm, depth 30 cm, and slope ratio 1: 1. Considering the surface drainage of waste dump during construction period and drainage issues after its re-cultivation, we have designed drain ditch at the top of the waste dump. The ditch is a trapezoidal cross-section (30cm×30cm) and the spacing between two drain ditches is 50m.

A desilting basin will be arranged at the outlet of the drain ditch. Its plane size is 3.0m x 2.0m, depth is 1.0m, and brickwork thickness is 30cm.

Re-cultivation: The waste will be leveled off and compacted by a tractor for 3-4 times. The waste slope is not less than 1: 3. # waste dump and #3 waste dump are mainly cultivated land. After the end of the project, the elevation of this area will be lifted up, to be 2.78 higher than normal water level.

The stripped-off topsoil is 248,200 m^3, and topsoil returned is 357,300m^3. The retaining wall is 4, 206m long and the revetment and bank protection is 57, 304m long. The drain ditch is 7, 134m long, while top drain ditch is 20, 991m. There are 6 desilting basin. The re-cultivated area is 78.49hm^2.

2) Vegetation measures

The design has considered the vegetation measures for #2 waste dump and #1 waste dumps. However, these measures are mainly focusing on estimation of its areas and investment. Therefore, the plan will put forward detailed vegetation measures.

According to overall arrangement of soil and water conservation plan and the site condition, the waste dump and waste residue will set up protection forest. The protection forest can retain the waste residue to enhance stability, and restore vegetation to increase the green space.

Land reclamation project: In order to restore the damaged land to an available state, land improvement measures such as leveling off, reconstruction and restoration shall be taken.

Selection of tree species: The following principles should be followed in the selection of tree species: Developed root system and root turion; vigorous growth; high fertilizer retention ability; strong adaptability and resistance; certain economic value; corresponding species for various landforms.

3) Temporary measures

In construction period, the stripped-off topsoil shall be stacked up in the back of waste dump with a height less than 2m. Retaining measures shall be taken by piling up a trapezoid section which is 0.5m wide, 0.5m high and has a slope ratio of 1:1. Scatter white clover seeds on the surface of the waste dump for temporary protection. In order to increase its survival rate, cover the surface with non-woven fabric.

f) Protection zone of road works

The construction road shall be planned by taking into consideration of permanent roads and existing roads. The permanent road in dam project area is 0.500km, and temporary roads have a length of 2.650km. The total area of occupied land is 2.90hm^2, of which the permanently occupied land is 0.70hm^2, while temporarily occupied land is 2.20hm^2.

After construction is completed, the left-bank approach road will continue to be used while temporary road will be restored. The approach road has concrete pavement, while the remaining roads are of clay-bound macadam.

1) Protection zone in approach road area

Engineering measures: Before construction, the topsoil shall be stripped off by 30 cm for road greening of the road sides. The stripped-off topsoil can temporarily be stacked up on the left-bank production and living area. Its protective measures shall be included in production and living area.

A drain ditch shall be arranged on the inner slope. The ditch is of rectangular section with a bottom width of 30cm and depth of 30cm. A desilting basin shall be arranged at the low-lying part of the drain ditch. According to the design, the stripped-off topsoil is 900m³, the drain ditch is 1,000m, and the number of desilting basin is 2.

Vegetation measures: Triennial cinnamomum camphora will be planted on the slope sides of the permanent road. The spacing is 3m. Bermuda grass seeds will be scattered at the embankment slope (50kg/hm²). The number of cinnamomum camphora needed is 334, while the sowing area for bermuda grass seed is 0.08hm².

2) Protection zone of construction road area

Most of the temporary roads in the dam project area have been included in each zone, and the soil erosion control measures are also included in relevant zones. The temporary roads only consider the approach road to material yard and construction road outside the foundation pit of dam construction area.

Engineering measures: Before construction, the topsoil shall be stripped off by 30cm for vegetation restoration or re-cultivation. The stripped-off topsoil from the approach road of the borrow area can be stored in the borrow area, while the stripped-off topsoil can be transported to temporary soil storage area. The corresponding protective measures are included in the stacking area.

After construction is completed, the surface of the construction road need to be loosen and leveled off, and arable land occupied need to be re-cultivated.

According to the design, the topsoil which needs to be stripped off is 4,700 m³. The surface soil which needs to be loosened and leveled off is 4,400m³. The occupied land which needs to be re-cultivated is 1.15hm^2.

Vegetation measures: At the end of the project, the vegetation restoration measures should be carried out at construction roads of inland tidal flat area and vacant land area. The poplar is planned for vegetation restoration. The plant spacing is 3.0m×3.0m. Under the 3.0m×3.0m poplar tree, bermuda grass seed will be planted (50kg/hm^2) The number of poplar needed is 1, 167, and the bermuda grass will cover an area of 1.05hm^2.

Temporary measures: Temporary drain ditch is planned on both sides of the newly-built construction road. The ditch is of trapezoidal section, and has a bottom width of 30 cm, depth of 30 cm, and slope ratio of 1: 1. A desilting basin will be set up in low-lying section of the drain ditch. Its plane size is 1.5m ×1.0m, depth is 1.0m, and brickwork thickness is 6 cm. White clover seeds shall be scattered on slope sides of the construction road (50kg/hm^2). According to the design, the drain ditch needed is 5,300m, and the white clover seed covers an area of 0.05hm^2.

7.6.3.2 Protection zone for reservoir preventive works area

a) Protection zone of reservoir inundated area

Immersion problem does not exist in reservoir inundated area, and there is no elevated-up protection area.

Construction progress shall be arranged on the basis of construction progress. The soil erosion control measures have been detailed in resettlement report, so this plan will not repeat.

b) Protection zone of preventive works

1) Protection zone of flood diversion canal

The length of flood diversion canal is 30.00km, which are located in Yicheng city. It covers an area of 82.80hm^2, and the land types in the area include paddy field, dry land, forest land and vacant land. The two sides of flood diversion canal are waste dumps used for storing excavated earthwork.

Engineering measures: The topsoil in this area shall be stripped off by 30cm and then stacked up in the waste dumps. Corresponding protective measures are included in waste dump area. After the construction, the topsoil will be returned for re-cultivation or vegetation rehabilitation. According to our calculation, the stripped-off topsoil is 195,700 m^3.

Vegetation measures: Use bermuda grass seed for vegetation restoration of the flood diversion canal area (Class A seed, $50kg/hm^2$). The bermuda grass seed will cover an area of $13.80hm^2$.

Temporary measures: Use waterproof cloth to protect the bare slope from soil erosion. The quantities of waterproof cloth needed are calculated in a way by considering 30% of its total covering area. The waterproof cloth covers an area of 126,000 m^2, and the waterproof cloth needed is $37{,}800m^2$.

2) Anti-immersion zone

Anti-immersion drain ditch totals 48.000km, which are located in Yicheng city. It covers an area of $43.20hm^2$. The land types include paddy field, dry land, forest land and vacant land. The two sides of anti-immersion drain ditch are waste dump used to store earthworks.

Engineering measures: The topsoil in this area shall be stripped off by 30cm and then stacked up in the waste dumps. Corresponding protective measures are included in waste dump area. After the construction, the topsoil will be returned for re-cultivation or vegetation rehabilitation. According to our calculation, the stripped-off topsoil in anti-immersion zone totals 102, $100m^3$.

Temporary measures: Use waterproof cloth to protect the bare slope from soil erosion. The quantities of waterproof cloth needed are calculated in a way by considering 30% of its total covering area. The waterproof cloth covers an area of 76,800 m^2, so the waterproof cloth needed is 23,000 m^2.

c) Protection zone of spoil area

The spoil area is located on both side of the flood diversion canal and drain ditch, which is used to stack earthwork excavated. Its slope is 1: 2. For waste dump of flood diversion canal, the average stacking height is 1.5 m. The width is about 19 ~ 27m. For waste dump of drain ditch, the average stacking height is 1.0m. The waste dump covers an area of 125.31hm², and its land types include paddy land, dry land and vacant land.

1) Engineering measures

Surface treatment and re-cultivation: The reclamation measures for paddy land, dry land and forest land occupied by the waste dump include topsoil stripping-off, returning and re-cultivation. In addition, the topsoil of vacant land is stripped off for vegetation restoration after the construction is completed. The stripped-off topsoil of waste dump is 296,200, and topsoil returned is 594,000m³. The re-cultivated area totals 72.18hm².

Retaining measures: the lower slope of the waste dump of flood diversion canals (where there is relatively uneven terrain) need to be retained by bagged soil. The retaining part is a trapezoid section 50cm×50cm (top width × height) with a slope ratio of 1: 1.For other waste dumps where the terrain is relatively flat, the bagged soil will not be used as retaining measures. According to calculation, the bagged soil for retaining is 12, 000m long.

Drainage measures: Drainage measures should be arranged on the one side of waste dump. The drain ditch is trapezoidal section with a bottom width of 30 cm and depth of 40cm. Its slope ratio is 1:1. At the outlet of the drainage ditch, we have designed a rectangular desilting basin (1.5m (length) x 1.0m (width) x1.0m (depth). Its brickwork thickness is 6cm. During the raining season in construction period, we will arrange designated personnel for desilting work. During the construction period, it is used for collecting surrounding water. After completion of the construction, it can be used for drainage in farmland. The drain ditch in waste dump protection zone is 156,000m, and the number of desilting basins is 312.

Vegetation measures: Vegetation restoration measures shall be taken to areas where its original land type is forest land in the waste dump. After the completion of the construction, the fast-growing poplar will be planted for vegetation restoration of the original forest land area. Besides, bermuda grass seed will be sowed for vegetation restoration. Use triennial poplar for vegetation restoration. The plant spacing is 3m×3m(50kg/hm²)

The vegetation measures for vacant land are the same as that of the forest land.

A total of 59, 033 poplar will be planted in the waste dump protection zone for vegetation restoration, and bermuda grass seeds totals will cover an area of 53.13hm².

Temporary measures: The stripped-off topsoil from waste dump area and preventive works area can be stacked up in non-construction section of the waste dump area, or backfilled on the surface of the waste dump. The slope of stacking area will be controlled at about 1: 2, and the stacking height will be controlled at 2m. In case of rain, high winds or other weather conditions, use waterproof cloth to prevent this area from soil erosion. The quantities of waterproof cloth needed are calculated in a way by considering 30% of its total covering area. The waterproof cloth covers an area of 59,900 m², so the waterproof cloth needed is 18,000m².

d) Protection zone of construction road area

The length construction road is 4.090km. The road width is 6m, and its subgrade has a width of 8m. The clay-bound macadam road covers an area of 3.27hm², and the land types include dry land, forest land and vacant land.

1) Engineering measures

Before construction, the topsoil shall be stripped off by 30cm for vegetation restoration or re-cultivation. Stripped-off topsoil can be shipped to waste dump for storage, and its corresponding protective measures are included in temporary storage area.

After construction is completed, the surface of the construction road need to be loosen and leveled off, and arable land occupied need to be re-cultivated.

According to the design, the topsoil which needs to be stripped off is 0.53 m³. The surface soil which needs to be loosened and leveled off is 6, 540m³. The occupied land which needs to be re-cultivated is 0.25hm².

2) Vegetation measures

Vegetation restoration measures shall be taken to areas where its original land type is forest land in the construction road area. After the completion of the construction, the fast-growing poplar will be planted for vegetation restoration of the original forest land area. Besides, bermuda grass seed will be sowed for vegetation restoration. Use triennial poplar for vegetation restoration. The plant spacing is 3m×3m (50kg/hm²)

The vegetation measures for vacant land are the same as that of the forest land.

The number of poplar needed is 3, 356, and the bermuda grass will cover an area of 3.02 hm².

3) Temporary measures

Temporary drain ditch is planned on both sides of the newly-built construction road. The ditch is of trapezoidal section, and has a bottom width of 30 cm, depth of 30 cm, and slope ratio of 1: 1. A desilting basin will be set up in low-lying section of the drain ditch. Its plane size is 1.5m ×1.0m, depth is 1.0m, and brickwork thickness is 6 cm. White clover seeds shall be scattered on slope sides of the construction road (50kg/hm²).

According to the design, the drain ditch needed is 8,181m, and the white clover seed covers an area of 0.08 hm².

e) Protection zone for production and living area

The production and living area covers an area of 0.40hm². The land types include dry land and vacant land.

1) Engineering measures

According main design, the topsoil from the dry land in this area will be stripped off by 30 cm before leveling-off. This plan intends to strip off the topsoil in part of the vacant land. The stripped off topsoil will be stacked in a corner of the production and living area, and will be used for re-cultivation of cultivated land and vegetation restoration of other land types after the construction is completed.

After completion of the construction site, the hardened layer and construction waste will be transported to the waste dump. The quantities will be calculated by taking into consideration of 60% of covering area. The thickness of hardened layer will be calculated by 20 cm.

According to the design, the stripped-off soil in production and living area is 900 m³. The hardened layer will be removed by 480m. 0.12hm² of land will be re-cultivated.

2) Vegetation measures

After the completion of the construction, the fast-growing poplar will be planted for vegetation restoration of the vacant land in production and living area. Besides, bermuda grass seed will be sowed for vegetation restoration. Use triennial poplar for vegetation restoration. The plant spacing is 3m×3m (50kg/hm²)

The number of poplar needed is 311, and the bermuda grass will cover an area of 0.28hm².

3) Temporary measures

The stripped-off topsoil will be stacked in open space. The stacking height will be controlled at 2 m, and slope of stacking area will be controlled at 1:2. Put waterproof cloth on the surface of the stacked area for water and soil conservation.

Meanwhile, drain ditch will be arranged around the construction area. The ditch is a trapezoidal section with bottom width of 30cm and depth of 30cm. A desilting basin will be set up around the drain ditch. Its plane size is 1.5m ×1.0m, depth is 1.0m, and brickwork thickness is 6 cm.

According to calculation, the number of drain ditch that need to be excavated is 759m. The number of desilting basin that needs to be excavated is 8. Besides, the waterproof cloth that needed is 500m².

f) Resettlement and special facility reconstruction area

1) Resettlement area

The soil erosion control and legal liability for resettlement area have been transferred, so this plan will repeat. This plan only proposes constructive suggestions for soil conservation control and preliminary estimates of investment in soil erosion control.

The corresponding measures that must be taken to reduce the impact on water and soil erosion include:

(1) Unified planning should be carried out as to land area for resettlement. Besides, local resettlement department shall prepare soil and water conservation plan. The resettlement building should be arranged in a reasonable way. The waste soil and waste

residue after "three supplies and one leveling" shall be used for leveling of house-building plot. When used in soil backfilling, it should be compacted to meet stability requirements. Other waste residue shall be stacked up in a certain place for construction of the village and town.

(2) When necessary, vegetation protection measures should be taken on the exposed surface of the excavation site.

(3) A reasonably drainage system should be arranged in the resettlement area, so as to prevent the area from water and soil erosion.

(4) After house demolition is completed, the wood and bricks shall be recycled as far as possible. Other wastes shall be transported to lower areas for soil backfilling. Meanwhile, greening measures shall be taken in the resettlement area. As to greening, plant some evergreen trees, shrubs and flowers for water and soil conservation, vegetation restoration and landscape improvement.

2) Rehabilitation of special facilities

The rehabilitation covers roads, telecommunication facilities and transmission lines. For rehabilitation of telecommunications facilities and transmission lines, the plan does not cover at this stage yet. We just proposed the following requirements for soil and water conservation:

Tractor road, optical cable, and electric cable shall be rehabilitated by relevant units through cash compensation. Pumping station, drainage culvert***

(1) In selecting sites for rehabilitation, try to avoid cultivated land and forest land.

(2) To avoid soil and water loss, avoid earthworks in rainy season, and use excavated earth for soil backfilling.

(3) Build necessary drainage system.

7.7 Atmospheric and acoustic environment protection measures

7.7.1 Protection of ambient air

a) Control target

The ambient air in construction area and resident area shall meet the Grade-II standard in GB3095-1996-Ambient Air Quality Standard. The daily average of TSP shall be controlled within 0.30mg/L.

b) Control measures

The ambient air protection measures shall be combined with factors such as construction organization, construction technology, construction equipment, pollutants reduction, and protection of construction area and sensitive receptors.

1) Consider the following dust control measures for foundation pit excavation

Optimization of construction methods and construction technology; optimization of blasting method; take presplitting blasting, smooth blasting and buffer blasting measures to reduce dust; use straw bag to cover the blasting area to reduce the blasting dust; adopt wet operation; use drilling and blasting equipment having dust collector. In non-rainy days, take watering measures 3-5 times to accelerate the sedimentation of dust.

2) Dust control measures in production of concrete and the processing of gravel

Use closed mixing plant for production; adopt closed transportation for cement and fly ash; strengthen the monitoring of concrete production system and dust collecting equipment. In sand production, pay attention to the maintenance of the sprayer to ensure the humidification of aggregate; equip the breaker with dust collector to reduce dust.

Take dust reducing measures in concrete production system and gravel processing systems. In non-rainy days, take watering measures for 4-7 times; System operators must wear protective equipment such as dust masks for labor safety and health protection.

3) Dust and waste gas control measures in transportation

Transport vehicles should comply with relevant emission standards of the state; at the end of construction road, use a vehicle-washing tank to wash the dust of the vehicle; use canvas cover or closed container when transporting earthworks; in day without rain, use watering car for de-dusting.

4) Air pollution and control measures in sensitive receptors

Prevention measures in living area of construction personnel: Construction personnel should wear dust masks and other protective equipment; watering should be carried out in a frequent way to maintain the humidity of the material. Retaining and watering measures shall be taken in the stacking area of topsoil.

Ambient air protection measures of residential area outside the project: carry out transportation in a closed way; control the traffic flow; control the speed of the vehicle within 40km/h; clean up the road, and take watering measures.

7.7.2 Acoustic environment protection

a) Control target

This noise of the project mainly comes from excavation, drilling, gravel crushing, blasting, and traffic noise. The noise generated by the construction is temporary, and the acoustic energy is not accumulated. Therefore, the control target for acoustic environment quality is to meet regional environmental requirements. The acoustic environment in Category 1, Category 2 and Category 4 cannot meet the requirement stated in GB3096-2008: Environmental Quality Standard for Noise. Therefore, the objective of the noise control is to reduce the impact of construction noise through effective control measures.

b) Noise control measures

1) Operation noise control in excavation and filling

- Equipment selection

To reduce operation noise, the construction unit must select excavation/filling equipment which complies with relevant national environmental protection standards. For instance, noise of transport vehicle shall comply with GB16170-1996: Limits of Noise Emitted by Stationary Road Vehicles and GB1495-79: Permissible Noise Limit Emitted by Power-driven Vehicles; other construction machineries shall comply with GB12523-90: Limits of Noise in Site Boundary. While meeting above standards, choose low-noise equipment and construction technology as far as possible.

- Sound insulation wall

Build a sound insulation wall on the red line for land acquisition close to Yakou

Village and Maocao Village to further reduce noise impact.

Common materials for sound insulation wall: Brick walls, precast concrete slabs, sandwich panels, gypsum unit masonry, fly-ash lightweight block. Add sound - absorbing materials with certain thickness to help reduce the noise. Above-mentioned sound insulation wall made of these materials all have good insulation effect. Common sound insulation wall are divided into 3 types according to its materials: brick walls, precast concrete slabs, and sandwich panels. As to materials performance and cost, see Table 7.7.2.

Table 7.7.2 Materials for sound insulation wall and its cost

No.	Materials	Thickness mm	Sound insulation factor dB(A)	Unit price Yuan/m^2
1	Brick wall (two-sided plastering)	280	30	95
2	Normal concrete precast slab (putty gunite)	160	28	138
3	Composite gypsum slab	150	26	125
4	Aerated concrete wall	150	27	160
5	Cinder block	190	24	130
6	Sandwich panels	120	25	168
7	Gypsum block	120	27	134

Table 7.7.2 shows that sound insulation walls made of all kinds of materials all have a good sound insulation effect. As the left-bank levee has a wall with an average height of 5m and thickness of about 0.3m, we suggest adding sandwich panels on the levee for building a sound insulation wall after taking into consideration of cost, security, and convenience of construction. The installed length of sandwich panels is about 300m, and its average height is 5m.

2) Noise control in excavation and blasting

Reduce the total amount of charge and explosive quantity in a sound; for heading blasting, avoid the residential area; use advanced blasting technology such as millisecond loose blasting to reduce the sound by 3-10dB.

Set up warning line to prevent blasting damage.

Strictly control the blasting time. Avoid late-night blasting to ensure a good living and working environment in construction area and surrounding residential area. The proposed blasting time is 17:00-17:30. Give warning sirens 15 minutes before blasting.

3) Operation noise control in gravel processing and concrete mixing

The following control measures can be taken: Select low-noise equipment and technology; reduce the working time of high-noise equipment; use damping cushion and sound insulation device; strengthen the maintenance of equipment before using; take full use of the topography and natural noise barrier; make reasonable arrangement of construction time and equipment; avoid high-noise construction activities at night.

4) Traffic noise control

The roads having relatively high traffic noise include the road section with aggregate processing system and external road section. To reduce the impact of road noise and running safety of transport vehicles, we suggest following measures: Arrange designated personnel for traffic control in dangerous sections and noise -reduction sections; slow-down the vehicle speed in these sections, and use of horn are prohibited Strengthen road maintenance and vehicle maintenance.

To further reduce the traffic noise of approach road, we propose to take traffic control measures in road sections going across/close to residential areas:

① Arrange horn prohibition and speed restriction board at the entrance road to the village and town(the speed limit is 20km/h).Arrange 2 horn prohibition and speed restriction boards and 5 speed humps in the entrance road through the villages and towns.

② Avoid the going out of vehicles after 22:00.

③Strengthen the maintenance of the road and maintenance of vehicles.

④ Vehicles must comply with the GB16170-1996: Limits of Noise Emitted by Stationary Road Vehicles and GB1495-79: Permissible Noise Limit Emitted by Power-Driven Vehicles.

7.8 Mitigation measures in resettlement

7.8.1 Protection measures for land resources

The Article 31 of the Land Administration Law of PRC stipulates that (August 1998): The State fosters the system of compensations to acquired cultivated land. In the cases of occupying cultivated land for non-agricultural construction, the units occupying the cultivated land should be responsible for reclaiming the same amount of land in the same quality as that occupied according to the principle of “reclaiming the same amount of land occupied". Whereas units which occupy the cultivated land are not available with conditions of reclamation of land or the land reclaimed is not up to requirements, the units concerned should pay land reclamation fees prescribed by provinces, autonomous regions and municipalities for reclaiming land for cultivation the land reclaimed. We should rationally use land resources according to the principle of resettlement planning. We should fully protect the environment and strictly prohibit random reclamation and felling. We should promote courtyard greening and adjust the planting structure to restore the living standards of relocated people in a short time.

The compensation for reservoir inundation, water and soil conservation and environmental protection is the key in ensuring the smooth implementation of resettlement and soil protection. Therefore, local government and relevant departments should strengthen the supervision and management of the use of resettlement funds, so as to ensure the use of funds as ear-marked.

7.8.2 Mitigation measures in resettlement area

7.8.2.1 Domestic sewage treatment

a) Wastewater

Due to poor economic development, the domestic sewage of the resettlement area is mainly from human and animal manure. As farmers use them as farm manure, there is less direct discharge and less impact on the water environment.

b) Plan selection

The domestic sewage in the resettlement area will be treated by the sewage treatment plant or the biogas tank, and the domestic sewage of relocated people buying/building houses in the urban city will be incorporated into regional sewage treatment system.

For domestic sewages from concentrated resettlement area, we use unpowered treatment equipment for centralized processing. The effluent water after treatment can be used in surrounding cultivated lands or garden plots.

For domestic sewage from decentralized rural resettlement areas, we use biogas pool for treatment. Each rural relocated household will arrange a biogas tank ($8m^3$).The organic component from the sewage can be degraded, and the harmful bacteria are killed in the high-temperature environment of the biogas tank. The biogas tank preliminarily digesters the sewage and provide fuels for the relocated people. Besides, the flushing and transudates of the biogas tank can be used as farm manure, saving a part of fertilizer costs.

7.8.2.2 Domestic waste treatment

Bio waste generated in domestic life can be fermented in the biogas tank. Meanwhile, we propose to build a waste transfer station for each of the resettlement area for storing the biochemical waste. Sanitation department will carry out the waste lorry work regularly.

7.8.2.3 Ecological mitigation measures

a) Vegetation protection measures

In construction, greening and farmland protection measures shall be taken in resettlement areas to avoid the impact on forest vegetation.

The biogas tank can be used for sewage treatment and fuel, thus reducing the demand for fuel wood. Therefore, this will further reduce deforestation.

Strengthen the forest protection project and prohibit deforestation. After the completion of resettlement houses, encourage farmers to develop courtyard economy by planting trees around the house.

b) Protection measures for terrestrial animals

Carry out ecological education in the resettlement area. On one hand, forbid the killing of wild animals; on the other hand, control the use of chemical fertilizers and pesticides.

7.8.3 Health protection measures for resettlement area

a) Protection measures for drinking-water source

To protect drinking-water sources, we should take the following measures: Set up clear signs in wells/water tunnels, and delineate the scope of cleaning. Within 30m of the wells, no residential housings, pens, toilet or sump are allowed. Within 5m of the wells, no toilet brushing, washing, or livestock drinking are allowed. For newly-built wells, dry up the well and use chlorine for disinfectants; carry out cleaning 1-2 time every year during its year of service.

The following measures should be taken to protect the underground drinking-water source of relocated people: For concentrated resettlement area, build water-storage tanks; for decentralized resettlement area, build specialized water facilities.

b) Control measures for epidemics

The main measures to be taken include: Take a sampled health monitoring of the project affected people before/after the construction and during the construction period; carry out sanitation & cleaning work; carry out education on health and epidemic prevention through promotional materials, radios and conferences.

Carry out planned and large-scale deratting activities to reduce the rat density to a safe level. Put toxicant bait for deratting of the resettlement area 2 times a year. Distribute the deratting pellets (1kg/40 people). Strengthen the management of manure matters in rainy season to prevent it from overflow. To prevent Encephalitis B, we should carry out anti-mosquito and pest control activities.

To prevent Encephalitis B, we should carry out anti-mosquito and pest control activities. Newly-built house should pay attention to ventilation and light transmission; house, toilet, and pens for livestock shall be separated; remove construction waste and fill up the ditch; spray anti-mosquito drugs to eliminate the breeding ground of mosquitos. Encourage people to hang mosquito nets in summer and autumn days.

Carry out sanitation management in the resettlement area; make planning for drinking water; make regular monitoring of drinking-water sources.

7.8.4 Other measures

a) Special design of environmental protection

We propose to carry out special design for environmental protection and set aside environmental protection funds for its implementation.

B) EIA for special facilities

For larger rehabilitation projects of special facilities, we propose to carry out environmental impact assessment (EIA).

7.9 Other mitigation measures

7.9.1 Geological mitigation measures

The main geological disasters of the assessment area include landslide, dilapidation (including collapse of banks), uneven settlement of soft-rock foundation, sand liquefaction, dam foundation infiltration, slope failure, flooding and inundation. The prevention measures for geological disasters should be based on the actual situation of the project area and the characteristics of the geological disasters. The prevention measures shall uphold the principle of "stressing prevention while combining prevention with abatement". We provide the following prevention measures and suggestions for reference.

a) Control measures for landslide

The measures shall be carried out in accordance with the scale, stability and damage degree brought by the landslide. For landslide in the inundated area, there is no need for governance as long as there is no sedimentation of river silt. For steep landslide in semi-inundated area, use wire mesh for retaining; for gentle landslide in semi-inundated area, use retaining wall and toe wall for retaining. For sediments within the reservoir area, establish revetment at its front, and take drainage measures.

b) Control measures for dilapidation (including collapse of river bank)

Use stonework revetment, retaining wall, enrockment or dry-laid rubble for protection. Meanwhile, for sections having residents or farmland, protective embankment engineering and biological measures can be taken.

For Tianjian quarry area, adopt a step by step mining process to reduce slope height.

c) Control measures for uneven settlement of soft-rock foundation

We propose to take corresponding structural or foundation treatment measures to ensure the foundation stability of the construction area.

d) Control measures for vibration liquefaction of sand

For sand on the surface of the construction area, we propose to take replacement or "strengthening with heavy punning method" for protection.

e) Control measures for dam foundation infiltration

For artificial reservoir banks, we should reinforce the vulnerable section, and backfill the wells and ponds; for artificial reservoir banks at the direct water-retaining section, we should take measures such as grouting, stone revetment, and curtain grouting (to relative confining bed).

For dam foundation, we propose curtain grouting method (to relative confining bed).

f) Control measures for slope failure in foundation pit excavation

We suggest a slope ratio of 1: 2.6 ~ 1: 3.0 and appropriate waterproof and slope supporting measures in excavation.

g) Control measures for inundation and immersion

The inundated area mainly includes farmland, houses and part of the urban area in Yicheng city, so we propose to take engineering and agricultural measures.

7.9.2 Protection plan for cultivated land and farmland

7.9.2.1 Protection measures for cultivated land

In construction, we should avoid the occupation of farmland as far as possible.

For occupied cultivated land (if really necessary), we should take farmland reclamation measures.

We should try to avoid the occupation of cultivated land. In cases which really need to occupy cultivated land, we should take topsoil restoration and vegetation restoration measures.

7.9.2.2 Protection measures for inundation-affected cultivated land

The inundation problem mainly occurs in left-bank Zhangjiazui-Nanzhou section, right-bank Zhangjiazui- Lijiadian section and Ruanjiapo-Yakou dam area. The designed normal water level of Yakou Shipping Hub is 55.22m. The inundated-affected length from right-bank Ruanjiapo - Yakou dam section is 1, 062m. The inundated-affected length from left-bank Nanzhou - Nanying River section is 367m. The inundated-affected length from right-bank Nanzhou - Nanying River section is 135m. According to calculation of seepage, the inundated area on right bank is 18.71km^2; the inundated area on left bank is 9.01km^2.

For seriously inundated area, we propose to add the number of drain ditch to reduce groundwater, thus reducing its adverse effects. For slight inundated area, we propose to adjust the planting structure of the crops to reduce adverse effects.

We propose to arrange drain ditch from Han River dam -Yakou Shipping Hub to discharge the seepage of the dam. The drain ditch has a bottom width of 2m, height of 2m, and slope of 1:1.5. Its length totals 25km. We also propose to arrange drain ditch along the inner part of the dam from Xinzhou Village (Nanji town)- Nanzhou Village(Nanying sub-district) to discharge the seepage. The drain ditch has a bottom width of 2m, height of 2m, and slope of 1:1.5. Its length totals 23km. The seepage will finally arrive at Han River through these drain ditches.

7.9.2.3 Protection measures for basic farmland

a) Overview of project-occupied basic farmland

The basic farmland occupied by the project totals 270.31 hm^2.

In May 2014, the Construction Unit entrusted Beijing Kuashikong Land Planning and Design Institute Co Ltd to compile Implementation Impact Assessment Report on Overall Plan of Land Utilization in Yakou Shipping Hub Project along Han River. This report has carried out impact analysis of the occupied land and formulated land compensation plan.

b) Relationship with county-level and district-level land use planning

The construction of the project is in line with Xiangyang Land Use Planning (1997-2010). The newly added land use quota has been included in the quota for water conservancy project.

According to Section 1, Article 4 of Approval Management for Overall Planning of Land Use in Hubei Province(Hubei Soil Resources [2006] No.25), project land which need to modify its overall planning can adjust the overall land use planning according to its needs. NDRC has agreed to the construction of the project and issued its investment plan in its letter of reply.

At present, the county- city-, district- level government has prepared the locally adjusted land-use planning. The project complies with the overall planning of land use after its adjustment.

c) Measures to reduce the occupation of basic farmland

(1) To reduce the occupation of basic farmland

In construction of preventive works, we should make full use of existing preventive works, so as to reduce the occupation of basic farmland.

(2) Protection of basic farmland in construction

The soil of plough layer in occupied cultivated land and basic farmland shall be stripped off by 30cm and stored in an area for soil backfill.

Take slope protection and biological measures, as well as site protection and drainage measures during the construction period.

(3) The number of temporary land use shall be strictly controlled, and basic farmland shall not be occupied

In construction process, some of the temporary land will inevitably be occupied (including some of the cultivated land). It is suggested that the local land and resources departments should strictly control the quantity and type of temporary land. Construction units should take the initiative in applying for number, location and type of temporary land; signing temporary land use agreement; providing compensation for temporary land; and performing statutory obligations for land reclamation. However, basic farmland is not allowed to be occupied.

(4) Reduce the occupation of basic farmland in preventive works

In the construction of dams and other preventive works, we should reduce the use of basic farmland to avoid the impact on tributaries and gullies brought by rising waters.

(5) Take appropriate measures to reduce the impact on surrounding basic farmland

The project unit shall remove the landslide on both side of the reservoir area, and take retaining measures in slopes and sections with poor stability. After taking the above measures, we can effectively prevent geological hazards, thus reducing the impact on surrounding basic farmland.

(6) Strengthen the later-period management and investment of basic farmland

The productive capacity of cultivated land is an embodiment of natural soil condition and labor input. To ensure the quality of basic farmland, we must strengthen its management and investment. As to strengthening management, we mean to prevent abandonment or excessive cultivation. As to increasing investment, we mean the inputs of labor and capital improvement in farmland irrigation and drainage facilities and the promotion of organic fertilizers.

7.9.3 Domestic waste treatment

7.9.3.1 Treatment of domestic waste in the construction area

a) Amount of domestic waste in construction area

The number of staff in peak construction period is 1,500. Suppose the day output of domestic waste is 1.0kg/person, then the amount of domestic waste is 1.5t/day and 548t/year. Therefore, the amount of domestic waste in construction period is about 2,190t.

b) Collection of domestic waste

Sanitation facilities such as public toilet, garbage cans will be arranged in accordance with CJJ25-2005: Standard for Setting of Town Environmental Sanitation Facilities. The public facilities will be permanent, semi-permanent or temporary facilities in accordance with real needs. Garbage can (boxes) and fruit-rind boxes: For convenience of collection and removal, we propose to arrange garbage can (box) and fruit-rind boxes in densely populated areas.

c) Treatments

According to our analysis, we find that the content of inorganic matter is relatively high in domestic waste (See Table 7.9.3). The inorganic garbage shall be stored in backfill area, and kitchen waste shall be transported for use by local farms and farmers.

Table 7.9.3 Component of domestic waste in construction area

Organic components						Inorganic components			
Kitchen waste	Fresh fruit-rind	Wood and grass	Scraps			Scraps		Coal ash	Brick slag
			Plastic	Fabric	Waste paper	Glass	Metal		
21.1%	6.7%	6.2%	4.6%	0.1%	1.2%	1.35%	0.05%	44%	14.7%

According to Table 7.9.3 and our prediction, the amount of domestic waste during construction period is only 2,190t. If we use landfill method, its storage requirement is only 2,000m^3; if we adopt incineration method, we will produce fly ash; meanwhile, due to its amount and organic components, we do not suggest composting treatment. Therefore, we recommend using landfill method for treatment of domestic waste.

According to our survey, the project area already has a built a landfill site- Nanzhou Domestic Waste Landfill Site. Therefore, we can hand the domestic waste to local sanitation department for treatment.

d) Processing flow

We adopt a centralized treatment process for domestic waste. For inorganic waste, we will store it in the refuse collection station in the construction camp. For kitchen waste, we can hand it to local farms for treatment. For other waste, we will hand it to local sanitation department. The treatment process is shown in Figure 7.7.3.

Figure 7.9.3 Treatment process of domestic waste in construction area

e) Mitigation measures in waste collection

We should seal and compress the domestic waste in its transportation. The garbage leachate should be collected by dedicated container and sent to the Nanzhou Domestic Waste Landfill for treatment.

f) Feasibility analysis of relying on Nanzhou Domestic Waster Landfill for waste disposal

Nanzhou Domestic Waste Landfill has been listed as a central-budget funded project by national and provincial development and reform commission (NDRC [2009] No.477; Provincial development and reform commission [2009] No. 262). The landfill is about 18 km away from Yicheng city, and it is located at Group 10 of Nanzhou, Nanying Office. Covering an area of 150 acres, it has a processing capacity of 172-240 t/day. Its total storage capacity is 120 million m^3 and design life is 16 years.

Its construction starts in June 2009, and is completed and put into trial operation in March 2010. Its operation mode: Transportation; dangerous waste inspection; weighing and dumping; stratified compaction; covering by a 25cm yellow soil. To prevent the white trash from flying out, a anti-fly net is arranged. Besides, a dedicated person is arranged for chemical spray to kill mosquitoes and flies. The garbage leachate shall be treated in a leachate treatment plant by using a MBR+NF+RO process. The water after being treated will reach the standard stated in Table 2 of GB16889-2008. In April 2012, the landfill has passed the acceptance Xiangyang Municipal Bureau of Environmental Protection.

In summary, the Nanzhou Domestic Waste Landfill can meet the processing requirements of domestic waste in the construction area. The receive proof issued by Yicheng Urban Administrative and Law Enforcement Bureau can be seen in Attachment 11.

7.9.3.2 Vessels garbage treatment

During the operation period, the ship lock along the Yangtze River should be equipped with ships to receive the ship garbage; the waste from hub management unit is included in urban waste transport system.

7.9.4 Population health assurance measures

7.9.4.1 Sanitary cleaning

Sanitation measures shall be taken to reduce the density of pathogenic microorganisms and insect-pollinated animals in construction area. Sanitation measures include disinfection and killing of vector organisms.

a) Site disinfection

Scope and object: This includes cleaning and disinfection of toilet, manure pit, pen barn, garbage dumps and newly buried graves (in recent 10 years). After construction is completed, the temporary office, construction camp, temporary toilet, and dump site will be removed.

Method and frequency: We will use carbonic acid for disinfection in accordance with Technical Standard For disinfection. Meanwhile, we will pay attention to the cleaning of wastes. The temporary sites and key pollution-source site shall be cleaned and disinfected.

b) Vector control

This mainly includes the control of rodents, mosquitoes and flies.

Scope: Office and living area and temporary construction camps.

Method and frequency: For control of rodent, we use trap method and bait method; for control of mosquito and fly, we use Miehailing aerosol. The drugs and tools will be distributed to construction staff under the guidance of health and epidemic prevention personnel. In construction period, the disinfection work for living area will be carried out in spring and autumn.

7.9.4.2 Sanitation and anti-epidemic plan

a) Health quarantine and health inspection

1) Health quarantine

Construction personnel and management personnel entering the construction area shall undergo health quarantine to control the spread of disease.

Quarantine range: Construction personnel and management personnel.

Quarantine items: Malaria, leptospirosis.

Quarantine frequency: Construction personnel and management personnel must be quarantined before entering; in construction period, 10% of the construction personnel shall be quarantined twice.

2) Health check

New infection may occur as medical condition changes. The medical examination can help grasp the health status of the labor force in different construction periods. The medical examination is once a year for construction personnel such as catering staff, staff engaged in environment like dust, high noise, etc. Medical examination is once in 2 year for other personnel. The results of medical examination shall be documented.

b) Immunization

Scope and object: This is mainly for construction personnel.

Vaccination or medication items: For malaria, we use preventive medication method; for leptospirosis, typhoid fever and other infectious diseases, we use vaccination method. The reserve of vaccine drugs for malaria, leptospirosis and salmonella typhimurium is 2 for each person. In addition, the medical units in the construction area shall have adequate reserve of tetanus vaccines.

Date: Generally, the vaccination will be taken in epidemic season.

c) Health publicity and management

The contractor and construction management unit should strengthen the introduction of health publicity through a variety of forms such as blackboard, posters and newspapers, so as to help the staff know about disease prevention and control knowledge in typhoid fever, leptospirosis, epidemic hemorrhagic fever, malaria and other infectious disease.

We will strengthen the protection of drinking water source, disinfection and monitoring work, and provide water supply points at the construction site to ensure the safety of construction staff. We will strengthen health supervision and management in canteen of the construction area, so as to ensure the health of the diet.

The construction units and engineering management departments should specify the responsible person for sanitation and anti-epidemic, whose responsibility is to establish and perfect the disease reporting system. We should carry out regular rodent and mosquito control activities and health inspection activities in every quarter.

7.9.4.3 Public sanitary facilities

A rational arrangement of public health facilities for construction area is the key for mosquito and fly control. According to overall design, we will build temporary public toilets on the left/right bank aggregate processing plant, and comprehensive processing plant, machinery and auto repair plant, and build mobile toilets in left/right bank construction area.

The temporary public toilet shall be no less than 30m away from canteen; the number of squatting position is 50/person; the roof height of the toilet shall be no less than 2m. Besides, water supply and lighting systems shall also be considered. Fecal sewage shall be treated as domestic sewage. The feces of mobile toilet shall be removed in a timely manner. (The cleaning work shall be carried out in every 3 days; in summer, the cleaning work shall be carried out every day or every two days.)

Trash can (boxes) shall be arranged in left/right bank living area and the PIU camps. The domestic waste shall be shipped to waste landfill for treatment.

7.9.5 Compensation for fishermen along Han River

According to our survey, the number of fishermen in Yakou Reservoir is about 237, of which 147 people own Fishermen Certificate. In order to solve fishermen's production and living issues, we recommend following measures: The first measure is living allowance. The fishermen shall be provided with basic living allowance; the second measure is re-employment through fish cultivating, laboring in other areas and doing business; the third measure is training. The training fund will be provided by the Construction Unit. The fund for above-mentioned items is 914,000, which is shown in Table 7.9.5 and will be included in plant operating costs.

Table 7.9.5 Compensation estimation of the Han River fishermen

No.	Items	Number	Unit	Unit price (Yuan)	Cost (ten thousand Yuan)
1	Living allowance	237	Person	2000	47.4
2	Job-seeking subsidies				40
2.1	Fish farm subsidies	1	Item	200000	20
2.2	Other job-seeking subsidies	1	Item	200000	20
3	Training	2	Times	20000	4
4	Total				91.4

8 Environmental risk assessment

8.1 Assessment level

The aim of environmental risk assessment (ERA) is to provide information and basis for engineering design and environmental management, in accordance with *Notice on Risk Assessment of Hidden Danger in Serious Environmental Pollution* (No. 057) issued by SEPA, *On Strengthening Environmental Risk Management in EIA* issued by SEPA ([2005] No.152), and *Guide for Environmental risk Assessment of Construction Project* (HJ/T169-2004).

According to *Guide for Environmental Risk Assessment of Construction Project* (HJ/T169-2004), the project risk is caused by indirect behavior and the work grade in environmental risk assessment is Category II.

8.2 Risk factor identification

The Yakou Shipping Hub is designed for shipping and power generation, and it is not designed for flood control. According to the characteristics of the project, the environmental risks of the project mainly come from shipping business and dam safety. In addition, there are some other environmental risks in the construction period. This includes environmental risk of the powder house, and collapsing risk of the retaining wall.

The accidents in the channel mainly include: Corresponding environmental risks from ship collision, oil leakage, sewage treatment accident, transportation of hazardous goods, and break of flood embankment.

8.3 Risk prediction assessment

8.3.1 Risk analysis of waste water discharge in construction

According to our survey, the pollution mainly comes from waste of foundation pit and concrete mixing system. The main pollutant is SS; meanwhile, there are wastewater containing oil which comes from machinery and equipment washing. The main pollutants are oils. Constrained by the management level of construction team, there may be cases that the waste water is discharged into the river without any treatment. Meanwhile, as there are 1500 construction staff in peak hours, there may exist cases that the domestic waste is directly discharged into the river.

If the waste water is directly discharged into the river or the waste water after treatment is not reused as required, the Han River will be polluted, thus affecting the production and living of downstream residents.

a) Prediction model

The annual discharge of Yichang section in Han River is 1, 100 m³/s, and this means it is a "large river". According to the guidelines, we use a Two-dimensional Steady-State Mixed Attenuation Model (side discharge) for prediction. For details, see Section 6.1.5.

b) Parameter value

1) Hydraulic parameters of the river

Table 8.3.1-1 Hydraulic parameters of downstream river in Yakou Shipping Hub

Parameters	Dry season flow m^3/s	Average depth m	Channel width m	Average flow rate m/s	Average gradient ‰	Lateral diffusion coefficient My m^2/s
Value	387	2.7	430	0.33	0.061	0.512

2) Other model parameters

Table 8.3.1-2 Prediction parameters for sewage discharge

Parameters		C_h(mg/L)	C_p(mg/L)	Q_p(m^3/s)	K(1/d)
SS	Discharge without treatment	13.0	25000	0.033	/
	Discharge after treatment	13.0	150	0.033	/
COD	Discharge without treatment	9.24	300	0.0125	0.13
	Discharge after treatment	9.24	50	0.0125	0.13

c) Calculation results

According to our predictive analysis, the waste water from the concrete mixing system discharging into the downstream river without treatment has caused some pollution within 400m of the downstream section (400m away from the downstream section, the concentration of suspended solids is lower than 20mg / L, which brings little impact the Han River); after the domestic sewage is discharged into the downstream water without treatment, the COD is 9.4 mg/L or less, which is in line with Class II standard of *Environmental Quality Standards for Surface Water* (GB3838-2002). Therefore, the downstream water of the Han River is just slightly affected.

As the downstream section of the does not appear turbid even though untreated waste water from concrete mixing system and foundation pit, we propose to reuse the waste water after treatment, so as to reduce the impact on the water of the river.

The water flow is relatively high, so waste water discharged into the river can be quickly mixed with the water within a short time. Therefore, the impact on pH of the river is slight. In addition, cofferdam demolition will also cause water pollution, and its main pollutants are suspended solids. However, under the influence of natural river flow, the water quality can see fast recovery.

8.3.3 Risk analysis of oil spill

8.3.3.1 Hazards and toxicity of substances

According to predictive analysis, the cargo of the shipping hub mainly include mineral building materials, coals, timbers, oils, food, and others(including cement, fertilizer, steel, ore, and general merchandise). The freight volume in 2015, 2020 and 2030 will be 366 × 104t, 501 × 104t and 758 × 104t, of which oil shipment will account for 2.73%, 3.99%, and 3.96%, respectively,

According to *Identification of Major Hazard* (GBl8218-2000), *Risk Gradation of Occupational Toxicant* (GB50844-85), we find that the hazardous substances during the operation period of the project are oil.

The hazardous characteristics of oil mainly include:

Inflammable and explosive: According to *Fire Prevention Code of Petro Chemical Enterprise Design* (GB50160-2008) and *Code for Design of Oil Depot* (GB50074-2002), oil is a highly flammable liquid with high flash point. Its fire risk is Category C-A.

Flowable: As a liquid, oil has low viscosity and good liquidity. Once oil spills, it will not only bring economic losses and environmental pollution, but will also cause combustion and explosion.

Volatile: Due to its low boiling point, oil can evaporate at room temperature. Therefore, in normal operation and its storage period, the volatilization of these materials is inevitable. The vapor volatilized when the refined oil spills is easy to explode if it is mixed with air. Therefore, we should take measures to reduce evaporation, or take ventilation and other measures to reduce the concentration of oil gas.

Easy to accumulate static electricity: Refined oil has poor conductivity. In its flow, filtering, mixing, spraying, washing, filling, and shaking process, it is easy to accumulate static charge. During its storage and transportation period, the collision and rubbing between this flammable liquid and pipes, containers, as well as filter medium, impurities, and air may result in the accumulation of static electricity. Besides, electrostatic discharge is a key factor in fire and explosion.

Thermal expansivity: After the oil is heated, its volume will expand. If the container is too full that it exceeds the security level, it may result in damage of the vessel or pipe, thus causing oil spills and leaks.

Toxicity: Vapors from oil product can cause irritative symptoms to the eye and upper airways. If its concentration is too high, it can cause breathing difficulties and other symptoms of hypoxia in a few minutes.

Table 8.3.2-1 Physicochemical and toxicological properties of oil

Category	Items	Nature
Physical and chemical properties	Appearance and properties	Brown liquid with slight viscosity
	Melting point / boiling point (℃)	-18/282-338
	Relative density	Compared with water 0.87-0.9; compared with air>1
	Solubility	Insoluble in water; freely soluble in benzene, carbon

		disulfide, and alcohols; soluble in fat
Danger of combustion and explosion	Flash point / ignition temperature (℃)	50/227-257
	Explosive limit (vol%)	1.4-4.5
	Stability	Stable
	Fire classification (building regulations)	Category C-A
	Category of explosion hazard	T3 / ⅡA, flammable liquid with high flash point
	Hazardous characteristics	Risk of explosion when meeting with fire, heat or oxidants; risk of cracking and explosion in high heat or increased pressure within containers
	Fire fighting methods	Extinguishant type: Carbon dioxide, foam, dry powder, sand

8.3.3.2 Retrospective study of oil spill accidents

According to statistical data of accidents in hydropower project, the risk probability of oil spill is relatively high. As there is no proven calculation method in analysis of risk probability due to objective conditions and uncertainties, we statistical data analysis for help.

According to statistics from Hubei Provincial Marine Affairs Bureau, we calculate that the maximum risk probability of oil spill is once in 8-12 years. The statistic of oil spill accidents (including its volume spilled) in Yangtze River in recent years is shown in Table 8.3.3-2.

Table 8.3.3-2 Statistics of oil spill accidents (including its volume spilled) in Yangtze River in recent ten years

No.	Accident time	Location	Causes	Volume of oil spills (t)	Oil type
1	1995.6.19	Gudonghema in Wan County	Operational errors	1028	Aviation kerosene
2	1997.3.28	Nanjing Yangzi 10-2 wharf	Operation errors in oil loading	5	Gasoline
3	1997.6.2	Qixia Anchorage, Port of Nanjing	Operational errors in ship-to-ship transfer	6	Crude oil
4	1997.6.3	Qixia Anchorage, Port of Nanjing	Explosion and sinkage	1000	Crude oil

5	1998.2.6	Near Yupeng Gas Station, Dashengguan Waterway, Nanjing City	Sinkage	35	Crude oil
6	1998.7.30	Baozitan in Wan County	' loss	5	Crude oil
7	1998.9.12	Near 101 buoy light, Wusongkou	Collision with the ship Chongmingdao	272	Heavy oil
8	1999.4.18	Shanghai Refinery Dock	Pipeline burst	0.2	Fuel
9	1999.7.25	Wharf of Wu Mountain , Wanzhou District, Chongqing	Operational errors	20	Diesel fuel
10	2003.2.9	Liuhekou of Yangtze River	Collision	20	Refined oil
11	2003.8.5	Wharf of Shanghai Wujing Power Plant	Collision	85	Fuel oil

Table 8.3.3-2 (Continued)

No.	Accident time	Location	Causes	Volume of oil spills (t)	Oil type
12	2004.4.18	276 buoy light water area in estuary of Yangtze River	Collision	30	Fuel oil
13	2005.4.8	Water area in estuary of Yangtze River	Collision	67	Fuel and toluene
14	2005.9.17	Water area in wharf of Shanghai Zhabei Power Plant	Collision	185	Gasoline
15	2006.12.12	Wharf of Yangshan Oil Depot	Operational errors	11	Fuel

As seen from the table, the accident-prone area is located at downstream and upstream of the Yangtze River. The major oil spill accident happens in Wan County (upper reaches of the Yangtze River), and the amount of oil spill is 1, 028t.

8.3.3.3 Prediction on influence of oil spill accident

a) Accident source

It is predicted by project design that in 2015, 2020 and 2030, the freight volume will be 366 × 104t, 501 × 104t and 758 × 104t, respectively. In 2015, the freight volume is 3.66 million t, of which coal, mineral building materials, timber, and agricultural, animal husbandry and fishery products accounts for 97.27%, while oil accounts for about 2.73%; In 2020, the freight volume is 5.01 million t, of which coal, mineral building materials, timber, and agricultural, animal husbandry and fishery products accounts for 96.01%, while oil accounts for about 3.99%; In 2030, the freight volume is 5.01 million t, of which coal, mineral building materials, timber, and agricultural, animal husbandry and fishery products accounts for 96.04%, while oil accounts for about 3.94%;

The designed ship size is 67.5m × 10.8m × 2.0m (L × W × draft); the designed ship fleet size is 167m × 21.6m × 2.0m (L × W × draft); the designed fleet type is double line and double row. According to distribution and operation mode of the existing transport vessels, we predict that the passing vessels will include cargo, pushing fleets, cargo vessels, and barges. Of which, 500 ~ 1000t single cargo shipping and fleet shipping will be the principal part. Referring to relevant statistics, the largest single oil carrying capacity for a 1, 000t ship (maximum shipping level) is 70 m^3 (about 60 t). Therefore, we predict the source intensity in oil spill accident is 60 tons.

b) Prediction on impact of oil spill accident

(1) Physical and chemical processes in oil spill

① Convection and diffusion theory.

The movement of oil spill on the water is mainly done by convection and diffusion. The convection is mainly constrained by the wind above the oil-film and the flow underneath the oil-film. Diffusion is a phenomenon caused by synthetic action of gravity, inertial force, friction, viscosity and surface tension. The impact on oil-film brought by wind is represented by wind drift. Diffusion (or widening) of the oil-film is also an extremely complex process. Diffusion of oil-film is divided into 3 stages: Inertial stage, viscosity stage and surface tension stage.

② Evaporation

1/2 to 2/3 of the oil spill will evaporate within a few hours or one day. Due to evaporation, the physical and chemical properties of the oil-film will see important changes. As evaporation depends on many factors, and these factors in turn are subject to changes, it is difficult to accurately calculate the evaporation rate.

③ Dissolution

Hydrocarbons dissolved in water have potential biological toxicity on biological system. Due to its low dissolvability, we can ignore the dissolution rate when analyzing the movement of the oil-film.

④ Vertical diffusion or vertical transportation

The residence time of oil-film is usually subject to the vertical transportation of small oil particles and its emulsification in water.

⑤ Formation of emulsion

Heavy crude oil has high viscosity, and will generally form stable emulsion-like oil.

⑥ Deposition

Various forms of oil are likely to be adsorbed by sediment particles, thus sinking to the bottom or be bonded on the shore. In mucky sediments, the permeation of oil is minimal (only the upper few centimeters will be affected).

Based on numerical model of convection and diffusion, we have given the big picture of oil-film distribution. By this big picture, we can predict the scope of oil spills, and the place with maximum hazard occurs.

(2) Calculation mode of oil-spill extension

The extension of oil film plays a leading role in early stage, while diffusion plays a leading role in final stage. Among various formulas, FAY formula is the one receiving extensive attention which only considers the extension of oil-film.

The extension of oil-film increases its membrane area and decreases its thickness. When the film thickness is greater than its critical thickness, the film will maintain its integrity; when the film thickness is equal to or less than its critical thickness, the film will split into fragments and continue to extend.

(3) Calculation method for oil-film drifting

The oil spill will extend into oil-film and drift in the water under the influence of wind and water flow. Besides, the area of equivalent-circle oil-film is constantly increasing. Thus, the polluted area of oil spill is equivalent to the water area of equivalent-circle oil-film which is constantly drifting. The magnitude of drifting can be judged by the center shift of the equivalent-circle.

(4) Analysis of predicted results

Assuming a a 5t oil spill, and using the calculation mode used by Environmental Impact Report of Jiangxi Ganjiang River Navigation Project, and the parameters of drifting and diffusion are taking into account of wind speed and flow rates, our prediction is: From beginning-5'05", inertial stage of continuous membrane; 5'05"-25'15", viscous expansion stage of continuous membrane; 25'15"- 4 h 01' 40", tension expansion stage of continuous membrane ; over 4 h 01' 40", continuous membrane exist no more. The critical thickness of continuous membrane is 0.01mm, and its drift distance of continuous membrane is 20.12km.

Table 8.3.3 Prediction of oil-film expansion

No.	Time (s)	Diameter (m)	Area (m)	Thickness (mm)	Distance (m)
1	100	31.97	744.64	7.50	189
2	300	69.87	3720.51	1.32	854
3	600	89.21	6113.55	0.87	1677
4	900	98.76	7487.75	0.65	2556
5	1500	122.93	9340.33	0.53	3199
6	3000	224.29	39021.45	0.09	8376
7	6000	403.73	127324.19	0.04	10081
8	9000	509.32	202749.04	0.03	15342
9	13000	646.51	360023.22	0.02	16721
10	14500	695.50	377566.18	0.01	20122
11	15500	695.50	377566.18	0.01	23417

Suppose oil spill accident occurs near the Xiaohe Town of Han River, then the oil-film will drift along the Han River and reach the water source protection zone of Yicheng City (4.5km away) after 30min. The film thickness is 0.36mm. After continued pollution for 45min, the oil film will drift away from this area and no longer cause pollution. After 50min, the oil-film will arrive at Wanyangzhou National Wetland Park (8.4km away). The oil-film thickness is 0.09mm. After continued pollution for 50mins, it will drift away from this area and no longer cause pollution; after 4h 10min, the oil-film will arrive at the spawning grounds (21.5km away). The film thickness is 0.01mm. After continued pollution of 50min, the oil-film will drift away from this area and no longer cause pollution; After 4h 20min, the oil-film will arrive at water intake of Xiangnan Prison Water Plant (23.7km away). The film thickness is 0.01mm. After continued pollution 50min, the oil-film will drift away from the water intake and no longer cause pollution; After 4h30min, the oil-film will arrive at water intake of resettlement area of Danjiangkou(26.0 km away). The film thickness is 0.01mm. After continued pollution 50min, the oil-film will drift away from this area and no longer cause pollution.

As the river section is non-reciprocal, the accident will not cause pollution to water intake of Wangji Town Water Plant, and Xiangyang Cuijiaying Provincial Wetland Park at the upstream. Besides, due to the existence of dam, the accident will not cause pollution to water intake of Liushui Town Water Plant and spawning grounds of Guanjiashan and Dengjiatai at the downstream.

As the amount of oil spills or and its spilling time is uncertain, once oil spill accident occurs, we should promptly take emergency measures and notify downstream water intake points.

To protect the water quality of the Yangtze River, we must strengthen our environmental management as far as possible to prevent such accidents from happening. To this aim, we should establish relevant systems, make contingency plan, and improve the staff's qualities.

c) Analysis of impact on water intake in various accident conditions

If the accident site is located at upstream of the water intake of Yicheng Water Supply Company and its distance is greater than 20.12km, the pollution on water intake will be relatively light; If the accident site is located at upstream of the water intake and the distance is less than 20.12km, then the water intake will be seriously polluted; If the accident site is located at downstream of the water intake and is outside of the water source protection area, the pollution on water intake will be light; if oil spill accident site is located at downstream approach channel of the dam, the areas within 20.12km from the dam will be impacted.

If an oil spill accident happens at the channel of the reservoir area, the drinking water intake near the accident site will be polluted.

d) Risk analysis of aquatic ecosystem

(1) Acute intoxication effect

Once the oil spill accident happens, it may pollute the water intake for production and drinking along the channel, thus affecting the creatures, fish, and agricultural irrigation. The contamination hazard of oil is determined by its chemical composition, characteristics and form. Low-boiling aromatic hydrocarbons are toxic to all living things; high-boiling aromatic hydrocarbons have a long-term toxicity, posing threat to aquatic organisms.

(2) Analysis of the impact on fish

① Acute toxicity test on fish

According to results of toxicity tests for several different fish larvae, the 96hLC50 value of carp larvae is 0.5 ~ 3.0mg / L. Therefore, the accidental release of oil can cause acute poisoning of fishes.

② Analysis on oil accumulation in fish

Oil residues can cause changes in fish resources and mutation of fish due to chronic poisoning. Once contacting oil molecules, oil-stink will occur in a short time, thus affecting its food value. Take the #20 fuel as an example, if oil concentration is 0.01mg / L, most fish and shrimp will have an oil smell within 7 days. Within 30 days, most fish will have a peculiar smell.

(3) Impact on phytoplankton

Experiments show that oil will destroy the cells of phytoplankton, damage the chlorophyll, and interfere with gas exchange, thus impeding their photosynthesis. This destructive effect depends on the type and concentration of oil, and the species of phytoplankton. Toxicity tests from home and abroad show that phytoplankton (bait for fish and shrimp)-has low tolerance to various oils. As to acute poisoning of oil, the lethal concentration for phytoplankton is 0.1 ~ 10.0mg / L (typically 1.0 ~ 3.6mg / L). For more sensitive species, even when the oil concentration is less than 0.1mg / L, its cell division and growth rate will be impacted.

(4) Impact on zooplankton

As to acute poisoning caused by oil, the lethal concentration of zooplankton is 0.1 ~ 15mg / L. Relevant impact experiments on copepod larva show that the oil sensitivity of permanent (lifelong) zooplankton is greater than that of the staged (temporary) benthic larvae. Besides, the oil sensitivity of both is greater than that of the adult.

In summary, we must strictly implement risk prevention measures and emergency plans to avoid the oil spill accident.

8.3.4 Water pollution accidents caused by navigation

a) Probability analysis

In fleet sailing, sinking is a small-probability accident. In inland waterways, sinking accident of cargo ships rarely occur. It is impossible to quantify the probability of occurrence, as it is subject to channel condition, weather condition, traffic volume, and captain's skills, and more. Since the shipping line opens, there is only one sinking accident according to statistics. The main cause of the accident is heavy fog and low visibility, and the sharp turn in the channel. By improving conditions of the shipping lines, collision and sinking accident never happen again.

By statistical analysis of historical data and investigations of similar projects, we believe the collision and capsizing accident will not happen in inland Category IV channels in general conditions. From a qualitative point of view, after the completion of Yakou Shipping Hub, the channel depth will be increased, and the rocks in the channel of Han River will be removed by blasting, thus increasing the vessel safety. Due to the improvement of the channel, the chances of shipping accident will be much smaller than before.

b) Risk analysis of vessel pollution

The water pollution risk brought by sunken ship is related to the cargo on the ship. According to our survey, the passing ships in Han River are mainly engaged in transportation of non-metallic minerals, cement, porcelain clay, albite, grain, fertilizer, etc., which accounts for more than 80% of the total transport volume. Even if these cargos are submerged in the water, it will not cause pollution accident. The transportation of pesticides, toxic chemicals, burning oil is relatively few. However, once accident occurs, it will cause a greater impact on downstream water environment.

From an environmental point of view, the water flow of the reservoir will be slower and can be manually adjusted after the completion of the dam. If shipping incident occurs, the cargo on the ship will not be drifted away, which is beneficial for rescue and salvage. When necessary, we can control and reduce the discharged volume of the dam, thus slowing the diffusion of pollutants.

8.3.5 Risk analysis of water quality pollution of drinking water

According to the analysis of risk possibility, when the pollutants are concentratedly discharged at the upstream of Xiaohe County, they may form slack water area at tail area of reservoir when entering into the Han River water body along with Wangjiadagou, which is harmful for the spread of pollutants in the reach, and may affect intake water quality in Yicheng waterworks for a short time. Similarly, Yidaodagou receives urban sewage and industrial wastewater in Yicheng. When accidents happen in all kinds of waste water treatment facilities, and untreated wastewater is directly discharged into the Han River through Guohai Floodgate, it may affect intake water quality in Liushui County at the downstream of Guohai Floodgate, 5km away from the downstream of the other side of the Han River for a short time. It will reduce the water quality guarantee rate, which will bring some risks.

The accident emissions of industrial wastewater in Wangjiadagou and Yidaodagou are predicted with the current untreated industrial emissions, and domestic sewage emissions are predicted with the per capita integrated displacement method. The pollutant emissions prediction results are shown in Table 8.3.5-1.

Table 8.3.5-1 Prediction results of sewage emissions and amount of pollutants into river in Wangjiadagou

Names of sewage outlets	Sewage collection source	Sewage emissions (m3/s)	Amount of COD into river (mg/l)	Amount of NH_3-N into river (mg/l)
Wangjiadagou sewage outlet	Industrial wastewater	0.05	5000	800
	Rural sewage	0.08	218.06	17.08
	Livestock pollution	0.02	180.22	6.56
	Farmland runoff pollution	0.07	186.75	17.82
	Total	0.22	643.14	135.61
Yidaodagou sewage outlet	Urban sewage	0.42	218.06	17.08
	Industrial wastewater	0.07	5000	800
	Rural sewage	0.05	218.06	17.08
	Livestock pollution	0.03	185.71	5.17
	Farmland runoff pollution	0.06	190.66	19.36
	Total	0.63	642.5	131.74

The discharge in Wangjiadagou and Yidaodagou can be seen as side discharge. According to the requirements of "Guidelines for Environmental Impact Assessment of Surface Water Environment" (HJ/T2.3-93), a two-dimensional mixed steady-state model of side discharge should be adopted in the prediction of sewage emissions' impact on water quality.

A Hydrological conditions

The river hydraulic parameters are shown in Table 8.3.5-2.

Table 8.3.5-2 River hydraulic parameters of dam downstream in Yakou Shipping Hub

Parameters	Water flow in dry season m^3/s	Mean depth m	Channel width m	Mean flow rate m	Average gradient ‰
Wangjiadagou	470	8.5	1200	0.02	0.023
Yidaodagou	450	2.7	430	0.33	0.061

B Water quality background conditions

The current reservoir pollutant concentrations c_h, are respectively taken from section water quality at 200m from the downstream of Wangjiadagou and Yakou dam predicted in 6.1.3.3, among which the background concentrations of COD_{Cr} and NH_3-N in Wangjiadagou are respectively 13.89mg/L and 0.085mg/L, while those in Yidaodagou are respectively 13.79mg/L and 0.090mg/L.

C Lateral mixing coefficient M_y

The lateral mixing coefficient M_y is determined by adopting Taylor method applicable to rivers recommended in the guidelines, that is

$$M_y = (0.058H + 0.0065B)\sqrt{gHI}$$

According to the above formula and the calculation results of reach section at normal water level, the lateral mixing coefficients of section of Wangjiadagou and Yidaodagou are respectively 0.874 m^2/s and 0.512m^2/s.

2) Calculation results

The concentrations of CODCr and NH3-N in water body of the affected areas reach the predicted water quality concentration in Yakou dam section. The emissions affected areas are shown in Table 8.3.5-3.

Table 8.3.5-3 Accident emissions affected areas Unit: m

Sections	Months	1	2	3	4	5	6	7	8	9	10	11	12
Wangjiadagou pollution discharge	Length	2900	3500	3650	2250	2150	1700	750	700	700	950	1900	2950
	Width	210	240	246	162	156	180	168	162	162	132	144	210
Yidaodagou pollution discharge	Length	4060	4900	5110	3150	3010	2380	1050	980	980	1330	2660	4130
	Width	175	200	205	135	130	150	140	135	135	110	120	175

The above table shows, the longest distance affected by Wangjiadagou section emissions is about 3650m, and that of Yidaodagou is about 5110m, both of which occur in the driest month (March). Since the distance between Wangjiadagou estuary and water intake in Yicheng waterwoks at the downstream is about 9.0km, which is longer than the distance of accident emissions polluted areas, the accident emissions will not adversely affect intake water quality in Yicheng waterwoks; while the distance between Yidaodagou estuary and water intake in Liushui County waterworks at the downstream is about 5.0km, but the river width is about 400m, which is wider than the maximum width

205m in polluted areas, so the accident emissions will not adversely affect intake water quality in Liushui County waterworks.

8.3.7 Other risk analyses

8.3.7.1 Risk analysis of explosive magazines

a) Risk identification and analysis of source item

The power station has built 170t firer (explosives), and the transport and storage of explosives have certain environmental risks. The explosive magazines are set up at 180m hillside on the left bank of the dam for safety and transport management. The explosive magazines which are about 1.5km away from water area are ground explosive magazines. Its risk type is explosion, and hazard factors are mainly lightning, static electricity, electrical sparks, and anthropic factors, etc. There are no sensitive objectives and facilities around the explosive magazines, which are also far way from the main construction area. Therefore, when explosion occur in the explosive magazines, the main environmental hazards caused include fire, and substances containing toxic chemicals enter water body, which will pollute water quality and destroy the aquatic environment.

b) Risk assessment

The power station is located at the mountain area. If the explosive magazine accident causes fire, it would bring great damage to forest ecology in project area, and might affect the surrounding rare animals and plants. When the accident happens, the chemicals in the explosives will be melted by rain and flow around, and substances containing toxic chemicals will enter water body, which may cause the death of fish and other aquatic organisms.

The explosive magazine is the key for safety and fire management in the construction area. Therefore, its management and accident precautionary measures are strict. According to the construction of other hydropower projects, the probability of explosion is very small. Since the explosive magazine in the project is far from the waters, the water pollution probability caused by the accident is also very small.

8.3.7.2 Risk analysis of slag wall collapse

The river regulation area in the project is higher than normal water level in the reservoir. The block wall adopts gravity and M7.5 masonry retaining structure. Its slip-resisting and overturn-resisting stability is analyzed, and ground supporting capacity is calculated, which meet the stability requirements of backfilling area. When quality problems and irresistible natural factors (such as earthquakes, flash floods, etc.) occur in retaining wall in river regulation area, collapse may happen. Retaining wall collapse will lead to the increase of soil erosion, and deposit in river, affecting flood. Since Yakou Shipping Hub Project is low head hydropower station, and river regulation area is near the powerhouse, whose crest level is higher than that of the powerhouse, the retaining wall collapse will lead to the increase of gravel in the river, directly threatening the safety of generating set of the powerhouse, and affecting the operation of the generating system of the powerhouse.

8.3.7.3 Risk analysis of "water bloom" in reservoir local waters

a) Han River "water bloom" investigation and cause analysis

The untreated industrial wastewater and sewage in the middle and lower reaches of Han River are discharged into the downstream river or the Han River, causing water pollution. After the first occurrence of "water bloom" in the Han River in dry season (late February to early March) in 1992, and "water bloom" occurred many times thereafter, respectively in February 1998, April 1998, February 2000, and February 2003.

From mid-February to early March in 1992, "water bloom" occurred in the main stream of the Han River, about 240km starting from Qianjiang. The water color suddenly changed into brown, with an increase in chromaticity and algae (mainly diatoms, accounting for 95%). This had increased the difficulty of waterworks’ treatment and affected water usage.

"Water bloom" occurred again in February 1998, which even affected Yicheng, with a larger scope and more serious degree. The algae peak was 2.6×10^7 cells/liter, higher than 2.02×10^7 cells/liter in 1992. And the algae were mainly diatoms and green algae. "Water bloom" occurred again in April 1998.

From late February to mid-March in 2000, "water bloom" occurred in nearly 240km reach from Qianjiang to Hankou, with algae amount up to 3.52×10^7 cells/liter, lasting about 20 days.

In February 4, 2003, the water body in middle and lower reaches of Han River was abnormally brown again. The dissolved oxygen got over-saturation, and algal bloomed, with an amount up to 3.5×10^7 cells/liter. The water body went back to normal in the morning of February 9.

Research shows that "water bloom" is the result of many factors. These factors include: slow flow conditions; certain nitrogen and phosphorus nutrients as well as biochemical oxygen demand and trace elements concentration in the water body; suitable temperature and light conditions, etc. Since it’s relatively easy for the ecosystems of water bodies in lakes and reservoirs to satisfy the above conditions (especially water flow condition), so "water bloom" occur far more in water bodies of lakes and reservoirs than the river when other conditions are met.

"Water bloom" in a large area rarely happens in large rivers such as Han River. But through a comprehensive analysis of the corresponding external conditions when diatom "water bloom" occurred in Han River, it’s found that the Han River reach had become a narrow "lake" system during "water bloom" period, and its causes of "water bloom" were basically as same as the conditions when eutrophication and algal blooming occurred in general lake and reservoir system. The monitoring data of hydrology, meteorology and water quality when "water bloom" occurred at downstream reach of Han River are listed in Table 6.1.3-8, and they are compared with those of February 1996 when "water bloom" didn’t occur.

Table 8.3.7-1 Investigation table of hydrology and water quality parameters in the middle and lower reaches of the Han River

Time	Water level m	Flow m^3/s	Flow velocity m/s	Water temperature ℃	pH	COD_{Mn} mg/L	BOD_5 mg/L	NH3-N mg/L	TP mg/L	Algae 10^5cells/l
1992.2	23.9	473	0.23	7.9	8.65	2.48	2.05	0.21	0.093	157
1998.2	23.2	322	0.59	11.3	7.97	3.7	3.99	3.99	0.23	170
2000.2		450		12.82	7.9-8.4	3.39			0.075	352
2003.2				12.5	8.82	6.16			0.189	350
1996.2	23.1	798	0.88	6.8	8.01	2.84	2.13	2.13	0.141	0.15

According to a comprehensive analysis, the causes of "water bloom" in the middle and lower reaches of the Han River include the following: firstly, with the economic development, water pollution in the Han River has become increasingly serious, and nitrogen, phosphorus and other nutrients needed by algae are in serious excess; the second cause is changes in hydrologic regime, and when the Han River is in dry season, the water level of the Yangtze River is high, thus producing backwater phenomenon on Han River, leading to slower flow velocity from the Han River estuary to Xiantao; thirdly, temperature is high when "water bloom" occurs. With sufficient nutrients, increased temperature and slowed flow velocity, algal blooms are easily induced so as to lead to serious "water bloom".

b) Risk analysis of "water bloom" in the Han River

According to the analysis of causes of "water bloom", water quality in the downstream of the Han River is worse than that of the upstream and midstream. And organism and N, P index discharged by industrial and domestic pollution sources in large and medium towns along the shore of main stream is high in the downstream section, especially in dry season; when "water bloom" occurs, the flow, water level and flow velocity in the middle and lower reaches of the Han River are significantly lower compared with previous years; for example, the average flow of Xiantao railway station in February 1992 is $473m^3/s$, only 55% of average flow in the same period of many years ($852m^3/s$). High temperature is an important factor in inducing "water bloom" in the Han

River. When "water blooms" occur, the weather is fine and temperature increases; when the weather is cloudy and the temperature drops, "water blooms" disappear.

Therefore, "water bloom" occurs when the pollution load, meteorological, and hydrological conditions are fulfilled. After the project is completed, it’s subject to flow impact. With small discharged flow, high temperatures, and excessive pollutants emissions, "water bloom" risk may occur in the water body of the dam.

8.3.7.4 Risk analysis of oil spill in powerhouse maintenance

During the powerhouse maintenance, if fault occurs due to improper maintenance, causing oil leakage into the Han River water body, thus pollute dam water quality, certain measures need to be taken.

8.4 Risk prevention measures

8.4.1 Water pollution prevention measures during the construction

The environmental protection measures on wastewater and sewage treatment during the construction should be practically implemented. Wastewater should be reused after being treated according to the requirements, and treated sewage should be used for irrigation or watering and lowering dust in construction area.

The environmental protection publicity and education on construction workers should be strengthened, and their awareness of environmental protection should be enhanced.

The construction site of water treatment facilities should be checked from time to time, and wastewater and sewage should be prohibited from being discharged directly into the Han River.

8.4.2 Accident risk prevention measures for construction ships

The construction of the Project will affect the shipping in section where the project is constructed. Necessary prevention measures need to be taken to prevent shipping accident risk.

Port and waterway safety supervision should be implemented during the construction of the Project, and beacon lights should be provided to prevent the accident risk of ships. Sign board should be set in the water intake to remind the passing ships to protect the water source and enhance safety awareness; ships should be prohibited to anchor, lighter and discharge the pollutants in the waters.

8.4.3 Accident risk prevention measures for oil spill

Since the ship's flow in lock and approach channel during the operation of the project is large, necessary prevention measures need to be taken to prevent shipping accident risk. In view of the ship's flow in waterway in the reservoir area during the operation of the project will significantly increase, the relevant departments should increase emergency equipment in location of the project in order to reduce the accident probability and loss caused by accident pollution.

Accident risk prevention measures for ships during the operation should be in strict accordance with "Emergency Equipment Requirements for Oil Spill at Port Terminal" (JT/T451-2009) promulgated by the Ministry of Transport. It should be equipped with emergency equipment library and discharge interception equipment (including oil booms 1000m, $20m^3$ / h and above skimmers, two sets of oil trawls with a total volume of 4 m^3, 2t and above oil absorbent materials, 1t and above concentrated oil spill dispersants, oil spill dispersant spray devices with spray rates of 0.13t/h and above, and floating storage devices with effective volumes of 20 m^3 and above), as well as one defence ship for laying booms, and oil recovery ships with skimming capacities of $40m^3$/h and above.

Emergency equipment in Xiangyang City are mainly 25 ships belong to Xiangyang Local Maritime Bureau. In view of the ship's flow in waterway in the reservoir area during the operation of the project will significantly increase, the relevant departments are recommended to increase emergency equipment in location of the project in order to reduce the accident probability and loss caused by accident pollution. In addition, it is recommended to improve regional salvage rescue mechanism. With the improvement of shipping conditions and increase of transport ships, salvage relief agencies and appropriate equipment should be set up in order to take effective relief on accidents. Sign board should be set to remind the passing ships to strengthen safety awareness, and enable them to make emergency calls immediately to notify emergency organizations when accidents happen.

8.4.4 Accident risk prevention measures for water pollution of ships sailing

a) The port and shipping department and maritime department should make reasonable arrangements for the ships to stop and leave the lock as well as sail on the waterway during the operation to avoid collision accident.

b) The production safety awareness of ship operators and oil handling personnel should be strengthened to ensure safety in production; and their risk prevention awareness should also be strengthened so that they can make the fastest emergency response when risk accidents happen.

c) In order to effectively protect waterway environment in the Han River, and prevent major accidents caused by leakage of poisonous, flammable and explosive substances, it’s prohibited to carry such dangerous goods in the service area, and management office in the service area should strengthen marine supervision and inspection to ensure the safe transport of such substances.

d) The lock should be equipped with television and camera monitoring device and floating oil audible and visual alarm device to conduct accident oil spill monitoring.

8.4.5 Risk prevention measures for drinking water pollution

(1) Minimum discharge flow: the key development task of Yakou Shipping Hub is shipping. In order to meet minimum water depth requirement of downstream shipping, the power station should work at base load at the off-peak of daily load of electrical system. The discharge flow should be no less than 450m3/s, equivalent to 40.9% of

average flow of many years. The river course in tail area of the reservoir is straight, and is not easy to form stagnant area, reducing pollution accumulation risk.

(2) Considering from the water supply safety, during the operation of Yakou reservoir, pollution control should be strengthened, and "Implementation Plan" should be implemented to ensure that all enterprises' emissions meet the standard, and emergency measures such as closure and sewage guiding should be taken when necessary.

(3) Monitoring of water quality in reservoir should be strengthened to prevent water pollution accidents.

(4) When pollution risk happen in enterprises in Reservoir, joint scheduling should be initiated timely, and discharge flow should be increased within a short time to rapidly dilute the pollutants.

(5) Emergency gate should be added at the bottom of the culvert pipe by taking use of the dam which has been built 1.5km from the estuary of Wangjiadagou. When accidental emission occurs, the water gate should be closed to stop wastewater from flowing into the Han River.

(6) Guohai gate which has been built at downstream outlet of Yidaodagou should be used. When accidental emission occurs, the water gate should be closed.

After the implementation of the above measures, the intake water quality safety is considered from the perspective of water quality and water flow, which can minimize the risk of water intake in Yicheng waterworks and Liushui County waterworks.

8.4.7 Other risk prevention measures

8.4.7.1 Explosive and fuel oil security measures

During transportation process, relevant regulations on transportation of hazardous goods must be strictly followed that explosive transportation cannot have mixed loading of explosive and detonator, and transportation vehicle of oil materials must be equipped with oil tank with excellent impermeability, ensuring that no environmental harm might be caused.

Final determination of the location of explosive magazine must be strictly in accordance with safety protection distance and should be determined and coordinated together with local police department and management department through on-site location selection, ensuring enough safety distance from the construction camp. Loading and delivery must be strictly in accordance with Hazardous Chemical Safety Management Regulations. Fire source control must be strict followed and be equipped with corresponding fire apparatus.

Explosive magazine of the project should meet design and fire specification requirements. Given the character of the influence of explosive magazine, explosive magazine custodian should have intensified training, regulations on explosive storage and use should be strictly followed, safety responsiblity should be exercise, examination of fire equippment, apparatus and personnel safety passgeway should be strengthened, and explosive magazine incident emergencyrescue plan should be drafted. After incident, attention should be paid to incident waste water collection and disposal and a post-incident assessment should be conducted.

8.4.7.2 Retaining wall collapse risk management measure

Soil conservation measures of the riverway treatment area should be promptly implemented that power generation must be immediately stopped when retaining wall collapses so as to minimize soil erosion amount caused and reduce sedimentation of reservoir and riverway as much as possible ensuring normal flood discharge of the riverway.

8.4.7.3 Reservoir partial water area “water bloom” risk prevention measure

“Water bloom” occurs in periods with highly varied sunlight and water temperature conditions. Therefore, the most important approach to prevent and control Han River “water bloom” is to improve Han River hydrological regime and carry out ecological regulation preventing the occurrence of critical hydrological condition that might cause "water bloom". Implement ecological regulation, ensure water quantity and water quality of the middle and lower reaches of Han River, meet ecological and environmental requirements, build ecological regulation compensation mechanism regarding the middle and lower reaches of Han River, and provide economic, political, policy and technical compensations to property entities cooperating with ecological regulation. Meanwhile, hydrological and meteorological forecast works and water quality real-time monitoring work should be reinforced. Ecological regulation may control occurrence of river "water bloom" to a certain extent, but strict management of river water quality is the real solution to "water bloom" problem. Water pollution prevention and treatment is the ultimate measure to prevent and control "water bloom". Therefore, plans such as basin water resources protection plan and water pollution prevention and treatment plan should be formulated and implemented; industrial structure and water usage structure adjusted and ecological economic model built; environmental treatment and pollution control reinforced, pollutant especially nutriment input strictly controlled, waterfront city pollution disposal management enhanced and pollution treatment capabilities improved; accuracy of real-time water quality monitoring system and motility and effectiveness of water pollution emergency plan ensured; reservoir area water quality protection regulations formulated through reinforced management and reservoir water quality ensured; basin eco-environmental building strengthened so as to control diffused pollution and soil erosion.

8.4.7.4 Plant area examination and oil leak incident risk prevention measures

Facilitating oil treatment, turbine oil system of hub power units should be equipped with two $30m^3$ horizontal oil tanks with one being net oil tank and the other being operating oil tank. Oil tank chamber should be equipped with oil-blocking threshold preventing oil spills from oil draining during an incident. Lubricating oil should reenter lubricating oil tank via power units in an airtight circuit during the whole process. Turbine oil system has a relatively low probability of causing oil spills. Power station is not equipped with transformer oil tank because its main transformer is subcontracted for maintenance and maintenance unit should have its own oil tank equipment.

Oil tank chamber of the turbine oil system is an independent space equipped with oil-blocking threshold for the prevention and treatment of oil leak and spill during a fire disaster. Consequently, the probability of risk incidents such as oil spill and oil leak happening to turbine oil system is relatively low. To prevent oil spills of turbine oil system, emergency plans of Yakou shipping hub project such as *Hydro turbine Overspeed and Oil System Fire Disaster Management Plan* and *Generator Fire Disaster Incident Site Management Plan* have relevant risk emergency measures to handle turbine oil system risk incident.

8.5 Risk incident emergency plan

8.5.1 Regional incident risk emergency plan and emergency capacity

Regarding emergent channel environmental pollution incident, regional water incident risk emergency plan should be formulated and standing regional incident risk emergency response center should be built. Prompt and effective management can be carried out so as to maximally reduce life, financial and environmental harm caused by the pollution incident once emergent water incident happens. Regional incident risk emergency plan situation will be introduced from the following two aspects of Xiangyang city emergent environmental incident emergency plan and Xiangyang city water incident emergency plan.

8.5.1.1 Xiangyang city emergent environmental incident emergency plan

The plan is applicable to various emergent environmental incidents (such as water pollution incident, atmospheric pollution incident, solid waste pollution incident, noise pollution incident and radiation pollution incident) and their derivative emergent environmental incidents happened under the administrative jurisdiction of Xiangyang city, with its main contents listed as follows:

a) Prevention and warning

Adhering to the principles of early discovery, early reporting and early management, comprehensive analysis and risk assessment works regarding environmental information, natural disaster information, regular environmental monitoring data and radiation environmental monitoring data of the city area should be carried out. Various relevant departments should be responsible for the receiving, reporting, management and statistical analysis of emergent environmental incident information in accordance with their functional roles. Environmental protection department should be responsible for receiving and managing information on environmental pollution and radiation incident, and warning information monitoring, as well as disposal and warning information monitoring of algae pollution caused by water body eutrophication together with water conservancy (water affairs) and meteorological departments. Transport department should be responsible for pollution incident caused by transport incidents (including ship and port pollution incidents) as well as the receiving, management and warning information monitoring of Han River oil spills information.

After receiving report on possible pollution incident, city emergent environmental incident emergency command office should immediately report to command and issue warning information to emergency member units, so as to prepare for emergency response. Emergent incident warning is divided into four levels according to the severity of the emergent incident, level of emergency and scope of areas possibly affected.

b) Emergency response

Level I, level II, level III and level IV emergency responses should be launched according to relevant regulations when mega, major, relatively major and ordinary emergent environmental incidents occur. When ordinary emergent environmental incident happens, county government of the incident area should immediately launch emergency plan of the corresponding level, implement incident investigation, determination and assessment, organize relevant departments to carry out emergency management works, promptly adopt measure to control further development, and report to city government and relevant departments according to regulations. When relatively major emergent environmental incident or above happens, county government of the incident area should firstly execute emergency response, launch emergency plan of the corresponding level for early management with priority given to pollution source control which prevents the incident from further developments such as secondary pollution and derivative pollution incidents, and meanwhile immediately report to city government so that city government can launch Level III emergency response.

According to site situation and actual need, city emergent environmental incident emergency command should establish multiple on-site working groups, determine leading and participating departments, allocate work and coordinate effort so as to accomplish emergency management work. Working groups include environmental monitoring group, emergency rescue group, transportation guarantee group, medical rescue group, emergency guarantee group, social security group, aftermath management group, and comprehensive information group. On-site management personnel should be equipped with professional protection gear in accordance with various types of environmental incidents, take security measures and strictly implement procedures of emergency personnel going in and out of incident site.

c) Later period management

It comprises aftermath management and summative assessment, among which aftermath management mainly includes on-site management works utilizing emergency management and rescue forces to eradicate hidden pollution problem of the incident according to scientific conclusion of the expert group and relevant professional monitoring opinions. Environmental monitoring and assessment work can be continued according to actual situation.

8.5.1.2 Xiangyang city water incident emergency plan

Currently, Xiangyang Municipal Government and relevant functional departments have established a relatively thorough regional incident risk prevention management system, with standing incident risk emergency response center. Once risk incident happens, incident emergency measures can be taken promptly. Main contents of *Xiangyang City Water Incident Emergency Plan* approved by Xiangyang Municipal People's Government include:

a) Emergency command system and main responsibilities

Xiangyang city water incident emergency command is the commanding organ of water incident emergency response works of the whole city, guiding the whole city in water incident emergency management work. Main responsibilities of Xiangyang city emergency command include:

① implements decision and instruction of city emergency committee;

② organizes and commands mega, major and relatively major water incident emergency responses, decides on-site command, and offers suggestion of closing emergency status to city emergency committee;

③ determines through research major decision and work opinion of water incident emergency work of the whole city;

④ guides water incident emergency rescue work of the whole city.

b) Standing organization

City emergency command has an affiliated office and has established Xiangyang Municipal Water Search and Rescue Center under the local maritime bureau to function as the working organ of city emergency command responsible for daily works of city emergency command and operation and management works of water search and rescue works. Director of Municipal Water Search and Rescue Center is the deputy head of city transport bureau, and deputy directors of Municipal Water Search and Rescue Center are directors of local maritime bureau and city port navigation department.

c) On-site command

After mega, major and relatively major water incidents, city emergency command should establish on-site command in the incident stricken area according to need. General command is taken by main leaders of the county (city, district) people's government, or appointed by provincial or municipal emergency commands; on-site command members are comprised by leaders of relevant county (city, district) departments and units as well as leaders of local township government of the incident stricken area according to emergent incident situation. On-site command should establish various professional groups according to need.

d) Emergency response procedure

Various members of city emergency command should establish a thorough monitoring organ, comprehensively analyze warning information of possible mega, major and relatively major water incidents, and promptly report and delivery relevant information to Municipal Emergency Joint Action Center and Municipal Water Search and Rescue Center.

Relevant units, ship and personnel involved in water activities should pay attention to receiving warning signal, and take corresponding prevention measures according to various warning levels so as to prevent life, financial and environmental harm caused by water incident.

City emergency command and its various member units should promptly conduct preparation works according to warning information and their functions. Maritime professional emergency teams on various levels should be on standby preparing for emergency rescue.

After water incident, distressed persons or on-site witnesses should immediately report to local maritime management department or public security and fire departments, and ship in distress should also report to superior unit. After receiving reporting, public security, fire and ship departments should promptly report to local water incident emergency command organ or maritime management organ. After receiving reporting, water incident emergency command organ or maritime management organ should, regarding fire, explosion and leakage pollution incidents of ship carrying hazardous goods affecting normal navigation of other ships or unit and residential safety, promptly ask instructions after verification from executive deputy general commander and notify maritime station (team) and ship management point about implementing traffic control on ships going upstream and downstream in the river sections upstream and downstream of the incident area. Emergency plan should be launched and traffic regulation of the entire navigable area should be implemented if necessary.

8.5.1.3 Regional incident risk emergency capacity

a) Regional incident risk emergency capacity

According to *Hubei Provincial "11th Five Year" Period Water Emergency System Building Plan* (August 2006), on March 27 of 2006, Hubei provincial government drafted and approved *Hubei Provincial Emergent Public Incident General Emergency Plan*, and *Hubei Provincial Water Search and Rescue Emergency Plan*. Following unified arrangement of provincial government, city- and prefecture-level governments also completed the formulation of relevant water search and rescue emergency plans in June 2006. Yangtze River Water Search and Rescue Coordination Center has formulated Yangtze River Water Search and Rescue Emergency Plan and 18 sub-plans of search and rescue, established search and rescue expert tank promoting rescue expert system, and has established the "1540" response mechanism of "stand-by boat reaching incident site within 15 minutes from port area and 40 minutes from other areas after receiving warning" and conducted regular emergency rescue drills for accelerating response.

Hubei provincial water emergency command center has basically been built with "water emergency search and rescue office" established under both provincial transportation department and Yangtze River maritime bureau. Regarding Hubei section of mainstream Yangtze River including 1053 kilometers of mainstream main channel and 231 kilometers of tributary riverway water area, "Yangtze River Water Search and Rescue Coordination Center", 4 search and rescue centers, 15 search and rescue sub-centers and 59 frontline emergency rescue stations are established, with one station in 21.8km on average, basically completing key water area search and rescue network.

In comprehensive analysis, Hubei water emergency system is relatively complete and capable of “stand-by boat reaching incident site within 15 minutes from port area and 40 minutes from other areas after receiving warning” in terms of emergency response time.

b) Cuijiaying incident risk emergency capacity

According to potential project risk analysis, construction unit formulated two feature emergency plans of *Hubei Provincial Han River Cuijiaying Navigation and Hydropower Junction Ship Oil Pollution Incident Emergency Plan* and *Hubei Provincial Han River Cuijiaying Navigation and Hydropower Junction Hazardous Goods Passing Sluice Safety Measure and Incident Emergency Plan*, and has taken relevant risk prevention measures.

Relevant oil spill emergency equipment is allocated in accordance with *Hubei Provincial Han River Cuijiaying Navigation and Hydropower Junction Ship Oil Pollution Incident Emergency Plan*. See Table 8.5.1 for detailed allocation situation.

Table 8.5.1 Cuijiaying navigation and hydropower junction emergency equipment allocation situation

Item	Placement location	Number (type)
Flashlight	Management office emergency supplies warehouse	5 units
Pollution boom	Management office emergency supplies warehouse	10 bags
Sorbent mat	Management office emergency supplies warehouse	10 bags
Sorbent sponge	Management office emergency supplies warehouse	20 bags
Rescue rod	Management office emergency supplies warehouse	5 units
Saw dust	Management office emergency supplies warehouse	30 KG
Life jacket	Management office emergency supplies warehouse	40 suits
Buoy	Management office emergency supplies warehouse	10 pieces

8.5.2 Hub environmental risk incident emergency plan

Construction of the project will necessarily bring potential danger. Incident probability will inevitably drop if high-level prevention measures are taken. However, incident occurrence is still possible. Once incident happens, the abovementioned project emergency prevention measures should be taken so as to control and reduce harm caused by the incident. In addition, emergency plan need to be formulated and relevant measures need to be taken.

Emergent incident of the project involves Xiangyang city of Hubei province, and incident emergency of the project should be included into and emergency plan of the project should be formulated based on Xiangyang city emergent public incident emergency plan system according to relevant requirements and statements.

(1) Emergency planning area

Emergency planning area of the project includes: A. oil tank area; B. blasting material reservoir area; C. environmental protection target area, mainly including residential area and water area in the surroundings.

Emergency incident includes: fire disaster, explosion, oil depot oil spills and etc.

(2) Emergency organizational structure and personnel

① Emergency leading organ

Emergency general leading organ is Xiangyang city emergent environmental incident emergency leaders group serving as a coordinating command organ of unified leadership of emergency management work regarding emergent public incident. Group leader is the mayor of Xiangyang city and deputy group leaders are deputy mayor of the municipal government, deputy secretary general of the municipal government and director of municipal environmental protection bureau; group members include director of municipal public security bureau, director of municipal health bureau, director of municipal transportation bureau, director of municipal management bureau, and leaders in charge of various county (city, district) governments and management committees of economic development zones.

Command center is established under Xiangyang Municipal Environmental Protection Bureau. Leaders group has an affiliated office (office is established under Municipal Environmental Protection Bureau). Office has its affiliated environmental monitoring group, on-site monitoring group, comprehensive coordination group, examination and supervision group, and publicity and education group being responsible to specific work tasks. Municipal environmental monitoring sub-team is responsible for daily work and organizational implementation.

Xiangyang city emergent environmental incident emergency response command center automatically forms once incident happens. Command center should launch corresponding emergency plan according to emergency situation, and provide emergency response and rescue to environmental pollution and damage incident under its administrative jurisdiction. On-site emergency leadership should be under the general command of group leader or deputy group leader according to levels of incident response.

② On-site command

On-site command is appointed by emergency command center. Generally speaking, fire group leader acts as the on-site commander responsible for guiding the whole process of emergency response action; security section chief is responsible for guiding oil spills emergency action.

③ Emergency rescue worker

Emergency rescue workers include: A. danger source control team mainly responsible for on-site rescue work under emergency circumstances and promptly controlling danger source comprised of construction unit and fire and security divisions of contractor units with local professional protection team also included if necessary; B. casualty rescue team responsible for on-site search and rescue and emergency treatment of the injured and transportation of the injured to medical points for treatment run by unit responsible for the incident and medical organ of the construction area; C. medical rescue group responsible for emergency rescue of the injured and transportation of the severely injured to hospital for further treatment run by medical organ of the construction area and coordinated by local hospitals; D. fire group responsible for on-site fire extinguishment, equipment container cooling, water injection explosion containment, rescue of the injured and cleanup work of pollution area after incident comprised of construction unit, contractor fire personnel and local public security fire team; E. safety evacuation group responsible for protective guidance of personnel on site and in the surroundings, personnel evacuation and on-site and surrounding material transfer comprised of members of safety supervision and security departments of construction unit and contractor as well as local governmental personnel; F. security alert group responsible for placing security alert, prohibiting entry of irrelevant personnel and vehicle into dangerous area and carrying security parole in personnel evacuation area comprised of members of security divisions of construction unit and contractor as well as local police department; H. material supply group responsible for organizing market supply of rescue supplies, equipment and device, and logistical supplies, delivery of rescue supplies and personnel run by construction unit and local county or district government; I. environmental monitoring group responsible for conducting environmental emergency monitoring on atmosphere, water quality, soil and such, determining the scope of the affected area and concentrations of hazardous matters, making correct environmental impact assessment of the incident, providing command personnel with the basis for decision making and incident pollution eradication, and disposing of hazardous substance of the incident site run by environmental protection management office of construction unit and contractor unit as well as local environmental protection bureau; J. expert consulting group responsible for providing incident emergency rescue plan and safety measures, guiding site rescue work, participating in incident survey analysis and formulating prevention measures comprised of technical experts of safety supervision departments of construction unit and contractor unit as well as relevant local departments and organized by leading organ; K. comprehensive coordination group responsible for comprehensive coordination, information communication and issuance of incident new reporting and emergency announcement run by construction unit and local reporting departments; L. aftermath management group responsible for site management and aftermath casualty work run by construction unit and relevant local governmental departments. See Figure 8.5.2 for emergency procedures.

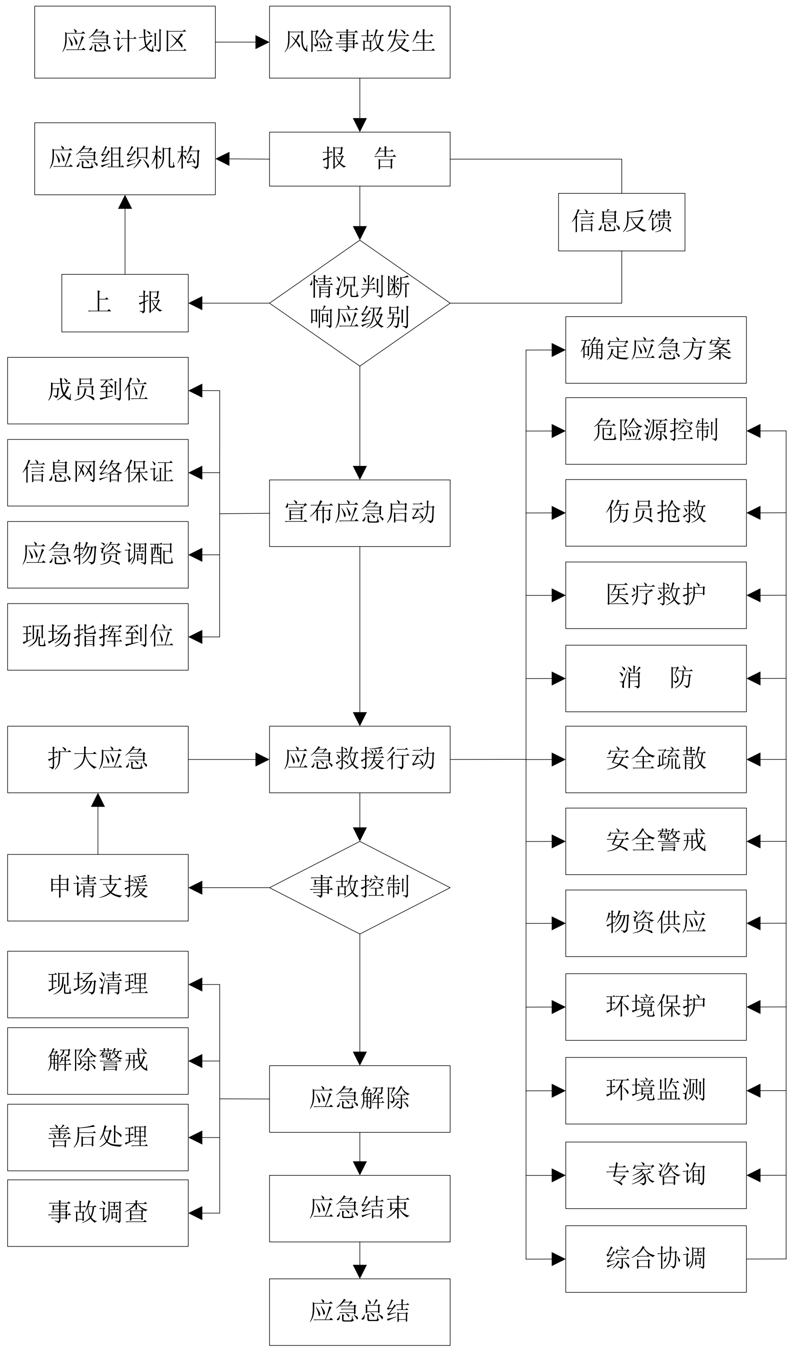


Figure 8.5.2 Incident emergency procedure map

原文	译文
应急计划区	Emergency planning area
风险事故发生	Risk incident occurrence
应急组织机构	Emergency organizing organ

报告	Reporting
上报	Reporting to superior unit
情况判断响应级别	Response level according to situation
信息反馈	Information feedback
成员到位	Members in place
信息网络保证	Information network guarantee
应急物资调配	Emergency supplies allocation
现场指挥到位	On-site command in place
宣布应急启动	Emergency launch announcement
扩大应急	Emergency activity expansion
应急救援行动	Emergency rescue activity
申请支援	Rescue application
事故控制	Incident control
现场清理	Site cleanup
解除警戒	Warning lifted
善后处理	Aftermath management
事故调查	Incident investigation
应急解除	Emergency lifted
应急结束	Emergency closure
应急总结	Emergency summarization
确定应急方案	Emergency plan determination
危险源控制	Hazardous source control
伤员抢救	Rescue the injured
医疗救护	Medical rescue and treatment
消防	Fire control
安全疏散	Safe evacuation

安全警戒	Safety caution
物资供应	Material supply
环境 保护	Environmental protection
环境监测	Environmental monitoring
专家咨询	Expert consulting
综合协调	Comprehensive coordination

④ Planned multi-level response

Incidents are divided into the following four levels: mega (Level I), major (Level II), relatively major (Level III) and ordinary (Level IV). For different incident levels, multi-level response is implemented.

When an incident occurs corresponding emergency plan should be launched and implemented. Level I and level II responses: incident emergency command center should offer on-site command under unified leadership and arrange detailed organization and implementation emergency rescue plans for major and mega incidents; organize all emergency forces to promptly carry out emergency rescue work in accordance with emergency rescue plan; adopt emergency management measures to controversies occurred during emergency work according to incident situation; adjust, revise, supplement and improve emergency plan according problems occurred and situation changes during the process of plan implementation so as to ensure that personnel are performing their various duties and rescue work is carrying out flexibly; scientifically organize personnel and supplies evacuation work with technical support in accordance with site situation; keep close contact with on-site emergency command and emergency leading organ so as to regularly report and announce incident site situation, cooperate with superior departments for carrying out incident investigation and management works, properly maintain social order and handle casualty aftermath and relief works, issue announcement in appropriate timing disclosing incident reason, responsibility and management decisions to the general public, and accept social supervision. Level III and level IV responses: relevant departments should carry out emergency management works in accordance with their relevant functions, prevent incident from expanding and spreading, ensure smooth information channel and report promptly to leading organ.

Given that environmental pollution incidents are unforeseeable, featuring long affecting time and easy derivative development, on-site command can upgrade or downgrade response level at any time in accordance with actual site situation.

⑤ Emergency rescue guarantee

A. Oil depot fire disaster and explosion emergency equipment

It mainly includes professional fire water storage equipment, fire hydrant, fire extinguisher, fire dike, fire engine, fire water collection system and oil spill control emergency equipment and apparatus.

B. Blasting material warehouse fire disaster and explosion emergency equipment

It mainly includes fire water storage equipment, fire hydrant and fire engine.

⑥ Police reporting and communication contact information

Emergency police reporting method generally include police reporting, reporting, telephone reporting. Reporting water emergency information should include time, location, and distress situation, as well as name, type and contact information of ship or persons in distress.

A. Police reporting method: allocate special-purpose police reporting telephone in enclosed management area of the construction area, and allocate fire disaster siren in construction area; local fire reporting telephone line 119.

B. Emergency communication: communication between emergency leading organ and on-site command through interphone and telephone; communication between on-site command and emergency rescue worker through interphone; interphone using channel one (fire channel) during emergency process; interpersonal communication between emergency leading organ and on-site command if wireless communication fails.

C. Information reporting procedure: when environmental risk incident happens, it should be report be emergency leading organ, other relevant departments and superior departments after promptly reporting to environmental protection management office and safety supervision division of the construction unit according to reporting procedures through means such as telephone, fax, envoy and written document.

⑦ Emergency monitoring, rescue and control measures

Leader of environmental monitoring group should arrive at incident site with environmental monitoring personnel and emergency investigation materials, immediately carry out investigation work of preliminary analysis, sampling, sample delivery, promptly provide prevention and treatment opinions on monitoring data, type and character of pollutant and control method, issue emergency monitoring briefing, provide scientific basis regarding post-incident safety protection distance, emergency personnel site entry requirements, and scope and route of public evacuation, ensuring safe protection of the general public and rescue personnel.

⑧ Emergency prevention measure

Danger source control group and fire group should investigate and collect evidence on from the incident site, conduct survey analysis on type, happening time, pollution source, major pollutants and impact scope and level of the incident, form initial opinion and provide feedback to on-site command and emergency leading organ.

Security alert group should place warning signs in the incident area and prohibit irrelevant personnel from entering. Through coordination among various groups and professional personnel taking charge, it helps promptly control danger source, cut off its route of transmission, control fire- and explosion-proof areas, promptly manage pollution source preventing pollution from spreading, and provide various supplies and equipment needed by material supply team.

⑨ Personnel evacuation organization plan

Safety evacuation group is responsible for rescuing entrapped personnel from the disaster stricken area; safety evacuation group should implement emergency evacuation regarding irrelevant personnel in the caution area with the coordination of the construction unit.

On-site command should comprehensively consider opinions of the expert group and relevant departments and promptly provide suggestions to leaders group on massive personnel emergency evacuation, with clear evacuating scope, time and direction if the incident may harm personnel safety in a relatively large surrounding.

On-site command should promptly issue incident information and promptly issue personnel emergency evacuation announcement after gaining approval from the leaders group; local government and various relevant departments should conduct personnel evacuation promptly, orderly, comprehensively and safely in accordance with instructions from the leaders group, and properly handle temporary living guarantee of the evacuated personnel.

⑩ Incident emergency rescue shutdown procedure and restoring measures

Proposed by on-site command and approved by the leaders group, on-site command announces lifting emergency status and issue relevant information after the entire processes of emergency response and rescue work are completed, i.e. incident site is under control and incident condition is eradicated; leakage or emission of pollution source is reduced to rated value; harm caused by the incident is completely eradicated with no possibility of reoccurrence; various professional emergency response actions no longer need to be continued on the incident site; necessary protective measures are taken to prevent the public from further harm and the medium and long-term effects of the incident is getting reasonable and reduced as much as possible.

Construction unit should cooperate with relevant departments to properly carry out site cleanup and eradicate harming factor.

Aftermath management group should provide relevant technical support such as disposal opinions on actual and possible harm to human body, animals and plants, soil, water body and air caused by the incident, carry out tracking monitoring of the incident site and surrounding environment until they both are in line with national environmental protection standards, and properly carry out incident investigation management.

⑪Emergency training plan

To ensure the effectiveness and feasibility of the emergency plan, training and maintenance beforehand of personnel, equipment and apparatus involved must be carried out, so that every member participating in emergency actions is on top of his role.

Regular emergency personnel training should be organized annually so that personnel trained can use, repair and take care of various emergency equipment and apparatus and perform emergency response capability under the instruction of command personnel.

Conduct regular emergency drill to various actual combat capabilities by checking emergency organ, team, equipment, apparatus and communication under simulated incident status. Through drill, discover weak links as well as revise and improve emergency plan.

⑫Public education and information

Promote public education in residential areas surrounding possible incident sites and issue relevant information.

8.5.3 Ship pollution risk incident emergency plan

8.5.3.1 Incident emergency plan system positioning and emergency response procedure

According to classification principle of national emergent public incident emergency plan system determined by *National Emergent Public Incident Overall Emergency Plan* (2006.1.8) of the State Council, the project should be included in emergent public incident local emergency plan and emergent public incident departmental emergency plan. Management procedure of emergent public incident emergency mainly includes the following four aspects:

(1) Information reporting

After mega or major emergent public incident, it should be immediately reported to superior emergency command organ and notified to relevant areas and departments. During the process of emergency response, further information should be promptly reported.

According to *Prevention and Treatment of Ship Polluting Marine Environment Management Regulation*, ship pollution incidents are divided into the following grades:

Mega ship pollution incident refers to ship pollution incidents with over 1000 tons of oil spill or causing direct economic loss of over 200 million Yuan;

Major ship pollution incident refers to ship pollution incidents with 500 to 1000 tons of oil spill or causing direct economic loss of between 100 and 200 million Yuan;

Relatively major ship pollution incident refers to ship pollution incidents with less than 500 tons of oil spill or causing direct economic loss of less than 100 million Yuan;

Ordinary ship pollution incident refers to ship pollution incidents with less than 100 tons of oil spill or causing direct economic loss of less than 50 million Yuan;

Once ship pollution incident happens, corresponding emergency plan should be launched with measures taken to control and eliminate pollution and it should be reported to local maritime management organ.

(2) Early stage management

After emergent public incident happens, while reporting information on mega or major emergent public incident, relevant emergency plan should be launched in accordance with function and regulation, so as to promptly and effectively manage and control situation.

(3) Emergency response

In terms of mega emergent public incident which early management failed to effectively control its situation, relevant plan should be promptly launched and management work should be carried out under the unified leadership of superior emergency command organ or led by relevant regions and departments. On-site emergency command organ is responsible for site emergency management work. In terms of emergent public incident which requires coordinated management of various departments, management authority of that particular type of emergent public incident should take the lead and other departments should coordinate.

(4) Emergency closure

On-site emergency command organ should be withdrawn after emergency management work of mega emergent public incident ends or relevant hazardous factors are eliminated.

8.5.3.2 Emergency plan for oil spill risk

a) Emergency response command organization

In the project, in view of potential waterway environmental pollution accidents, an emergency plan for regional water accident risks is worked out, and a standing accident risk emergency response center is established. Once a sudden water accident occurs, timely, prompt, accurate and effective treatment will be carried out to minimize life and property losses and environmental hazards caused by pollution accident.

Emergency command system (headquarter) is a command organization to deal with the matters related to emergency response to sudden water accidents and provide guidance. A water rescue center of project management department will be built in local marine board, which will serve as the standing organization of emergency headquarter and be responsible for the daily work of the emergency headquarter as well as the management of water rescue.

Each member of the emergency headquarter will build a monitoring organization to carry out comprehensive analysis for warning information that may cause extra-serious, major and large water emergency and report relevant information to emergency linkage center and water rescue center in time. Related units, ships and personnel engaged in water activities shall pay attention to such warning information and take corresponding prevention measures as per the grade of warning information, in order to prevent water emergency from harming life, property and environment. The emergency headquarter and its members shall make preparation promptly according to the warning information and their respective responsibilities. Professional marine emergency teams at all levels shall be put on standby and be ready for emergency rescue.

After water emergency occurs, people in distress or any witness nearby shall immediately report to local marine administration department, police office or fire department, and the ship in distress shall report to such organizations at the same time. After receiving the report, the police office, the fire department and the shipowner shall report to the local water emergency headquarter or marine administration department in time. Upon receipt of the report, the water emergency headquarter or the marine administration department shall check and verify any combustion, explosion, leakage and pollution accident of the ship carrying hazardous articles that may endanger normal shipping of other ships, organization and resident safety, and shall immediately ask the deputy commander in chief for instructions and inform the marine office (team) and ship management points upstream and downstream from the accident waterway section for implementing traffic control. If necessary, the contingency plant shall be initiated for implementing traffic control within the whole navigation area.

b) Emergency communication

In order to guarantee the timely, accurate and reliable transmission of reports, warning information and notification about sudden ship oil spill accidents and all kinds of information related to emergency response, a smooth, effective, rapid and sensitive warning system and a command communication network shall be established among all port districts, including connection with the oil spill emergency response command system of the marine system.

An independent emergency center shall be established in the headquarter of Han River waterway project construction and shall be equipped with first-aid equipment and apparatuses. A special emergency phone number shall be set and be answered by a specially-assigned person for 24 hours, who will inform the emergency center promptly in case of any emergency. The emergency center will initiate emergency program and contact emergency leading group according to the emergency plan, and the leading group will inform water use organizations and districts, organize and mobilize personnel, vehicles and equipment, and carry out joint emergency actions, in order to minimize the impacts of ship pollution accident on the environment.

c) Emergency prevention team and exercise

Fully utilize the original emergency prevention strength of the marine board system, attract firefighters to participate in and build an emergency prevention team, and encourage qualified companies to joint in the professional oil spill emergency response team. Carry out regular training and exercise, enhance the understanding of emergency prevention operation regulations, master the operation of emergency prevention equipment, and strengthen the ability of handling sudden oil spill accidents.

The emergency team will be composed of PIU internal personnel and external collaboration and support team which will be deployed by Changjiang Waterway Bureau and Xiangyang Marine Bureau as per the impact degree of the accident. The emergency response team includes commander and control personnel, emergency service department, project contractors and other possible affected parties like water plant. Besides warning and communication systems, an accident treatment leading and command system shall be established.

d) Emergency monitoring

An emergency monitoring system for ship’s oil spill accidents shall be built and improved, in order to find ship’s oil spill or other water accidents in time, rapidly determine the position, property and scale of the accidents, and provide reference for selecting emergency response measures and programs.

If a ship pollution accident occurs, the ship shall report to the local marine board truthfully, and take corresponding measures according to the program and requirements of pollution accident emergency plan. After sending an initial report, the ship shall send supplementary report according to the progress of the accident. After receiving the report about ship pollution accident, the local marine board shall predict the trend of oil spill drifting as well as the possible impacts on water intakes of the water plants downstream and take response measures according to the program of pollution accident emergency plan after confirmation.

Response contents include: reporting to superior competent departments, cargo owners, insurance company, marine department and environmental protection department (including time, place, ship name, position, hydrologic regime, measures that have been taken, required rescue, etc.); taking emergency measures and using working ships for laying oil containment booms and oil absorbent felts and operating oil suction machines. If some oil still drifts to the bank of the waterway after containment control and collection, organize wharf personnel, external collaboration organization and nearby people for removing oil contamination on the banks. Simultaneously, oil spill monitoring shall be carried out to control the diffusion area.

After oil spill accident occurs, promptly inform nearby and downstream water plants, especially Yicheng Water Plant, and carry out follow-up monitoring on the water quality of the water intake. In case of any exceeding-standard pollution, stop water intaking immediately. At the same time, inform local bureau of aquatic products, so that it can get to the oil spill site immediately to carry out follow-up monitoring and survey for the fishes in Han River and carry out rescue operation if finding any protected fish.

After the accident is dealt with completely, the organization causing the trouble or the ship owner shall make a written report about accident cause, oil spill volume, pollution removal and treatment process, pollution range and impact degree, and submit it to local marine board and environmental protection bureau, which will organize survey and determine the compensation costs for the losses caused by the oil spill accident. And the organization causing trouble or the shipowner shall give economic compensation as per the final verdict of the court.

f) Personnel training

Emergency response management staff, facility operators and emergency decontamination personnel shall take part in relevant professional training, so that the emergency response personnel will take appointment with certificates, get familiar with emergency response theories and have practical experience in oil spill control and decontamination.

g) Regular check

Regular planned check shall be carried out once every year, and the members of emergency command organization and their contact information shall be updated in time.

9 Environmental Monitoring and Management Planning

9.1 Environmental monitoring plan

9.1.1 Monitoring purposes

The purpose of environmental monitoring is to verify the results of environmental impact prediction and assessment and to provide scientific basis for environmental pollution control and environmental management.

9.1.2 Principles in planning monitoring sites

A) Consistency with engineering features

The scope, object and key points of the monitoring work should consider the characteristics of construction and operation, and fully reflect the changes in the surrounding environment as well as the environmental impact brought by these changes.

B) Pertinence principle

Rationally select primary factors, monitoring sites and monitoring items according to the prediction of engineering features, environmental status and environmental impact.

C) Economic and operational principles

In accordance with relevant technical specifications, the monitoring items, frequency, time interval and method shall be conducted on the premise of accomplishing the main task. Therefore, former monitoring results by relevant institutions can be used to reduce cost.

9.1.3 Environmental monitoring during construction period

9.1.3.1 Water environment monitoring

a) Monitoring of construction waste water

1) Layout of monitoring sites

Monitoring sites shall be set up in main discharge ports of domestic sewage and industrial wastewater in accordance with relevant requirements in technical specification for environmental monitoring. The monitoring object of industrial wastewater is wastewater from aggregate, concrete mixing plant and the pit. The monitoring object of domestic sewage will be the concentrated area of camp buildings.

2) Technical requirements for monitoring

Water sampling and analysis shall be conducted in accordance with the provisions of HJ/T91-2002 Technical Specifications for Monitoring of Surface Water and Sewage and HJ/92-2002 and Technical Specifications for Monitoring of Total Water Pollutant Emissions. The monitoring items, monitoring cycle, and monitoring period and monitoring frequency are shown in Table 9.1.3-1.

Table 9.1.3-1 Monitoring plan for construction waste water

Items	Monitoring sites	Monitoring parameters	Monitoring frequency and time	Notes
Foundation pit wastewater	\ of foundation pit	SS, pH, Cd and Pb, As, Hg, flow	Once a month during the discharge period	To monitor the quality of reclaimed water and effect of wastewater treatment
Aggregates \ wastewater	Outlet of aggregate processing sites	SS, pH, Cd and Pb, As, Hg, flow	During normal production period, the monitoring frequency is once a month (1 year for peak-hour year and 1 year for normal year)	
Concrete Mixing-use wastewater	Outlet of mixing system	SS, pH, flow	During the operation period of mixing system, the monitoring frequency is once a month (one year for peak-hour year and one year for normal year).	
Domestic sewage	Outlet of domestic sewage	CODcr, BOD5, TN, TP, fecal coliforms, animal and vegetable oils, sewage flow	The monitoring frequency is once a month (1 year for peak-hour year and 1 year for normal year).	

b) Monitoring of river water quality during construction period

1) Layout of monitoring sites

To reflect the water quality and understand its environmental impact of the construction area, we planned two sites for water quality monitoring at both upstream and downstream of Han River. Specific monitoring sites are shown in Table 9.1.3-2.

2) Technical requirements for monitoring

Water sampling and analysis shall be conducted according to the methods stated in GB3838-2002-Environmental Quality Standard for Surface Water. The monitoring items, monitoring cycle, and monitoring period and monitoring frequency are shown in Table 9.1.3-2.

To prevent water pollution caused by re-suspension of sediments, we propose to strengthen the monitoring of water quality at the downstream of Han River during the early period of dam construction. The monitoring items recommended include heavy metals such as total Pb, Cd, Hg, and CR-VI.

Table 9.1.3-2 River water quality monitoring plan

Monitoring sites	Monitoring parameters	Monitoring frequency and time	Notes
Upstream of dam (500m from the dam)	pH, SS, PPC, NH, COD, BOD5, DO, total Pb, total Cd, total As, total Hg, CR-VI, oils, fecal coliforms	The monitoring frequency is once(3 days) a month(1 year for peak-hour year and 1 year for normal year).	Timely analysis and treatment of monitoring data.
About 1km at downstream of the dam			

9.1.3.2 Atmospheric environment monitoring

a) Layout of monitoring sites

To monitor the impact of exhaust gas and acoustic noise on environmental sensitive spots, we arrange 3 monitoring sites (left bank of the dam -Yakou Village; right bank of the dam- Haoji Village; residential area of material yard) in accordance with Technical Specifications for Environmental Monitoring.

b) Contents of monitoring

SO2, NO2, TSP (primary target), and wind direction, wind speed.

c) Monitoring period and frequency

The frequency is 1 time for each quarter during the construction period. Each time will last 5 consecutive days.

d) Monitoring methods

The monitoring methods shall be implemented in accordance with the provisions issued by Ministry of Environmental Protection.

9.1.3.3 Acoustic environment monitoring

a) Layout of monitoring sites

Noise monitoring sites shall be decided in accordance with the construction progress, noise source distribution and distance of sensitive receivers. 5 noise monitoring points shall be arranged, namely, the left and right bank of the dam, entrance road of the plant, construction camps and residential area.

b) Contents of monitoring

A-weighted sound level and LAeq.

c) Monitoring period and frequency

1 time per month during the construction period (including daytime and nighttime monitoring). Each monitoring will last 2 consecutive days ((including daytime and nighttime monitoring)

d) Monitoring methods

The monitoring methods shall be implemented in accordance with noise monitoring methods stipulated by Ministry of Environmental Protection.

9.1.3.4 Monitoring of terrestrial ecology

a) Monitoring sites

3 monitoring sites (namely, Yakou reservoir area, landfill area area, and material area) shall be arranged in accordance with construction characteristics and conclusions of impact analysis. Each monitoring site shall arrange 3-5 fixed monitoring lines. Each monitoring line shall arrange 3-5 fixed sample plots for trees, shrubs, herbs, amphibians and small mammals. Monitoring of vegetation restoration in the occupied areas is included in soil and water conservation monitoring, as shown in Table 9.1.3.

b) Contents of monitoring

To investigate the vertical and horizontal distribution of plants, plant species, and growth of trees before and after the project; to investigate the distribution, quantity and frequency of occurrence of mammals, birds, amphibians and reptiles. The results of the survey shall be revised by visiting of the market and local residents.

c) Monitoring period and monitoring time

Monitoring period: Construction survey shall be conducted for 2 times.

Monitoring time: April - May.

d) Monitoring methods and results

The monitoring shall be conducted in accordance with the relevant provisions of the state. Comprehensive evaluation and analysis shall be conducted to monitoring results, and monitoring reports shall be prepared to be submitted to the Construction Unit and administrative departments.

9.1.3.5 Monitoring of population health

Health monitoring of construction staff shall be conducted by the local health and epidemic prevention department according to the relevant requirements of the health department (in accordance with a proportion of 10%). The statistical study of pollution diseases and natural focal disease shall be conducted quarterly. Epidemic report system shall be established for timely reporting of infectious diseases. Appropriate measures shall be taken to control the disease.

9.1.4 Environmental monitoring during operation period

Environmental monitoring during operation period includes: Monitoring of drinking water quality, main water pollution source, and fish and aquatic organism.

9.1.4.1 Water environment monitoring

a) Monitoring of waste water

During operation period, outlet of treatment facilities for domestic sewage shall be monitored. This shall be supervised and managed by local environmental protection bureau.

Table 9.1.4-1 Monitoring plan for construction waste water

Items	Monitoring sites	Monitoring parameters	Monitoring frequency and time	Notes
Domestic sewage	Sewage outlet of management area	TP, TN, DO, CODcr, BOD5, total bacteria, animal and vegetable oils, flow	3 times a year	Monitor the condition of sewage treatment and reuse effect

b) Surface water monitoring

(1) Routine monitoring

The monitoring plan is shown in Table 9.1.4-2.

Table 9.1.4 Water environment monitoring during operation period

Monitoring section	Monitoring factor	Monitoring frequency	Notes
Under Cuijiaying dam	pH, SS, DO, CODMn, CODCr, BOD5, NH, TP, TN, Cu, Zn, fluoride, As, Hg, Cd, CR-VI, Pb, cyanide, volatile phenol, petroleum, LAS, sulfide, and fecal coliforms	Monitoring for 6 consecutive years (during high flow season and dry season)	Timely analysis and treatment of monitoring data.
Section of Yicheng Bridge			
Upstream of the dam (500m from the dam)			
About 1km at downstream of the dam			

(2) Monitoring of eutrophication

The monitoring indexes of eutrophication in the Bay of Yakou Reservoir include: TN, TP, Chlorophyll A & opacity, and CODMn. Monitoring frequency is once a year, and the monitoring time is set at June-August.

c) Monitoring of ecological flow under the dam

1) Monitoring purposes

To ensure the operation of ecological discharged flow, a real-time monitoring of the discharged flow will be carried out at different stages. The aim is to provide basic research data of the impact of ecological flow on the downstream water environment, aquatic ecology and the river landscape.

2) Layout of monitoring sections

According to ecological flow-discharge measures during the construction period and operation period, as well as the layout of hydrologic and water level station with automatic hydrological measuring and reporting systems, we plan to arrange an automatic ecological flow monitoring system 1500m away from downstream of the dam.

3) Monitoring plans and technical requirements

After comprehensive comparison, we plan to use cable-tunnel flowmetre and H-ADCP flow-meter for flow monitoring. The real-time data will be send to the automatic water monitoring and reporting system.

4) Monitoring time

To meet the monitoring requirements for ecological flow, the monitoring system will be installed before the water-storage period.

d) On-line monitoring of water hydrological regime

According to requirements of Reply on Ecological Scheduling Scheme for Danjiangkou, Main Stream of Han River (pilot) [2015] No. 235, the flood control stations along Taibai River shall install hydrological collection and transmission system, and monitor the flood peak discharge during May-September.

9.1.4.2 Monitoring of aquatic ecosystem

The inundation area of Yakou Reservoir (a channel-type reservoir) is small. Ecological monitoring in the operation period will focus on the monitoring of aquatic ecosystem. The monitoring items include planktons, benthos, attaching organisms, periphytons, aquatic vascular plants, fish populations, and fish spawning sites. The aim is timely monitor the ecological environment after the operation of the power station, and provide basis for conservation of biodiversity and ecological management. Monitoring area include the mainstream and its tributaries from Cuijiaying Dam to mouth of Han River, with focus on Yakou Reservoir, key tributaries and downstream section of the dam.

a) Contents of monitoring

1) Monitoring of aquatic ecological factors

Hydrology, hydrodynamic characteristics, and water's physical and chemical properties (mainly the component of N and P and the distribution of concentration field); and species, distribution density, biomass and water temperature of phytoplankton, zooplankton, benthos, and aquatic vascular plants.

2) Population dynamics of fishes and change of community structure

The monitoring items include fish species composition, population structure, spatial distribution of resources and its accumulation effect. The focus will be the trends of fish population dynamics and community structures.

3) Monitoring of larval resources of fishes

The monitoring items include species composition and proportion, spatial and temporal distribution, larval resources, hydrological factors (temperature, flow rate, water level), distribution and size variation of spawning sites, breeding time, and population size of breeding population.

b) Monitoring sections

According to the controlling principle and representative principle, we arrange 8 monitoring sections (namely, sampling sites) along the mainstream and major tributaries. Namely, upper part of Cuijiaying Dam, lower part of Cuijiaying Dam, Wei River, Yicheng bridge, Chun River, Ying River, Yakou Dam, and Huji.

Figure 9.1.4 Monitoring sections of aquatic ecosystem

For fish resources, we will not arrange fixed monitoring sections. The focus of monitoring will be key tributaries from Cuijiaying Shipping Hub to Nianpanshan Dam. We will arrange 1 monitoring section in Zhongxiang and 1 monitoring section in Hanchuan. If necessary, mobile monitoring will be conducted.

c) Monitoring period

The monitoring shall be conducted for 7 years within 20 years after reservoir interception. Namely, during the 3rd, 5th, 7th, 10th, 15th, 20th year (costs of aquatic biological monitoring during operating period shall be included in the cost of power plants).

Water chemical factors, marine plankton, benthic animals, aquatic vascular plants shall be monitored in April and October. Fish population shall be monitored in March-June and October - November. Each monitoring shall last 20 days. Monitoring of fish spawning site shall be carried out in March-July. The number of monitoring in a year shall not be less than 60 days. The frequency, time and items of monitoring shall be adjusted accordingly with the operation status of other cascade hydropower stations. 20 years later, a long-term plan for further monitoring shall be formulated in accordance with the status of fishery resources.

9.1.4.3 Monitoring of fish-pass effect and enhancement and releasing

a) Monitoring of fish-pass effect

As the number, vanity and specifications of fish in the fish-way shall be monitored, we need to collect the fishes in the fish-way. We can use a fish collection pool built near the fish-way to collect fish. The arrangement of fish collection pool is shown in Figure 9.1.4.

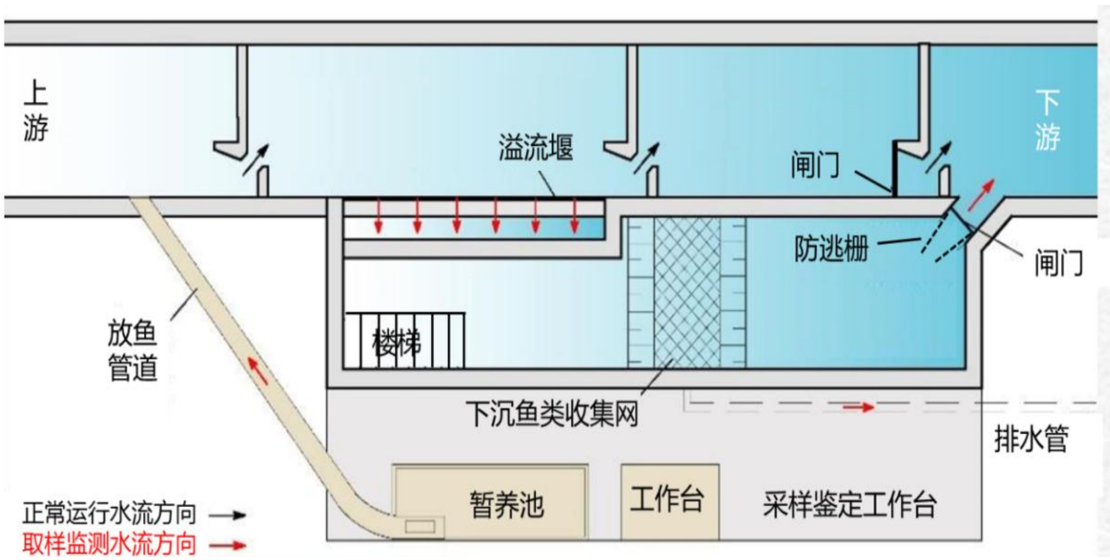


Figure 9.1.4. Schematic diagram of the fish collection pool

The monitoring items to be monitored in the fish collection pool include:(1) Fish species; (2) number of the fish; (3) size of the fish; (4)growth status of fish;(5) fish in various entrances; (6) fish in different operation conditions; (7) clusters and distribution of fishes in downstream of the dam.

After formal operation of the fish-way, in addition to the above-mentioned monitoring, fish resources both in upstream and downstream of the dam shall be monitored to see its changes and get an objective evaluation on the protection effect of the fish-way.

The monitoring of fish-pass effect shall be carried out in March-september. During March-May, the monitoring item will focus on up-going fish. During August-September, the monitoring item will focus on down-going fish.

b) Monitoring of enhancement and releasing

Combined with the monitoring results of fish resources, the plan of enhancement and releasing shall be improved. According to the requirements of environmental impact report, the construction unit should regularly report to local environmental protection department on the monitoring results.

The report on operation and monitoring of the enhancement and releasing station shall send to local EPB before March of each year.

1) Monitoring and evaluation contents

Physical and chemical indexes of water body: Water temperature, pH, salinity, turbidity, hardness, alkalinity, SiO2, DO, TP, TN, etc.

Food organisms: Varieties and quantities of phytoplankton (content of chlorophyll a), periphytic algae, zooplankton and benthic animals.

Fish resources： Its species composition and proportion, temporal and spatial distribution, population structure and resource status. Main monitoring items will include the four Chinese carps, namely, silver carp, bighead carp, grass carp and black carp. The population variation of squaliobarbus curriculus, bream, leiocassis longirostris, pelteobagrus fulvidraco and round kiss will also be monitored.

Ecological habits of fish: This includes distribution, scale, propagation time and frequency of spawning site, as well as the situation of wintering ground and feeding ground. The focus will be the changes of "3-grounds" and the size of the fish spawning.

2) Time and frequency of monitoring and evaluation

The monitoring shall be carried out every other year since the start of the project and its completion (i.e. construction period) . That is, during the 1st, 3rd, 5th, 8th, 12th, 16th, 20th year. The monitoring will last 10 years. physical and chemical indexes of water body, phytoplankton (content of chlorophyll a), algae, zooplankton and zoobenthos shall be monitored in March, July, and November; the monitoring of fish resources shall be carried out in May-July and October -November. The monitoring for fish spawning sites shall be carried out in May-August, with a focus on June-July.

3) Monitoring method

The monitoring shall be carried out in accordance with Standard for Investigation of Reservoir Fishery Resources (SL 167-96), Manual for Investigation of Fishery Resources in Inland Waters, and Research Methods of Freshwater Plankton.

4) Contents of monitoring report

The operating condition of enhancement and releasing stations; ②The situation of regular releasing; ③The status and changes of fish resources in water area; ④The effect on proliferation of fish; ⑤The result of preliminary research for mitigation of impact on fish resources; ⑥ The next-phase work plan.

9.1.4.4 Monitoring of terrestrial ecosystem

a) Monitoring section

The section to be monitored includes areas surrounding the reservoir and main construction area.

b) ' and frequency

The monitoring shall be carried out 1 and 3 years after the reservoir impoundment. Each monitoring lasts one year. The monitoring period is April-June and August-October each year.

c) Monitoring method

The monitoring shall be carried out in accordance with the provisions of the relevant norms on biological investigation.

9.1.4.5 Monitoring of population health

According to the requirement of resettlement plan, a survey on population health in the reservoir area and the resettlement area will be carried out and a sampling survey in typical areas will also be carried out.

The layout of environmental monitoring sites is shown in attached Figure 24.

9.1.5 Monitoring of soil and water conservation

9.1.5.1 Monitoring scope and focus

The monitoring scope will be the project construction area, including main project area, approach road area, temporary construction area, temporary road area, soil borrow area, quarry area, sand quarry area, spoil area, relocation and special-facility rehabilitation area, and inundated area.

According to the forecast on water loss and soil erosion, the monitoring focus will be spoil area, material yard, resettlement and special-facility rehabilitation area, major excavation area(such as landfill area, approach road, and embankment slope), and construction area(sections) without prompt preventive measures.

9.1.5.2 Monitoring content and method

a) Monitoring of changes of soil and water conservation in the project area

This mainly includes natural factors such as rainfall, topography, land-form, soil, vegetation coverage and the impact of construction on these factors; land disturbance caused by construction and its area, amount of spoils, excavation and earth-filling volume, and floor area; varieties and areas of water and soil conservation facilities damaged by project construction. The monitoring of rainfall mainly includes the maximum precipitation in 24h, the maximum precipitation in 1h, and more.

We will use high-precision GPS technology and relevant design files to carry out site investigation and topographic survey.

b) Dynamic monitoring of soil and water loss in the project area

The monitoring mainly includes the construction disturbance of surface area, the number of water and soil conservation facilities damaged, and area, distribution, strength, amount of water and soil erosion, as well as the hazard on downstream area and surrounding area.

We mainly use slope measurement method, runoff plot method and desilting basin method for monitoring of water and soil erosion.

c) Monitoring on the effect of soil and water conservation measures

This mainly include the monitoring of the quantity and quality of soil and water conservation measures; trees and grass survival rate, retention rate, growth and coverage rate; condition, operation and stability of protection engineering; and conservation effects. Six monitoring objectives: land reclamation rate, governance of water and soil erosion and its control ratio, restoration ratio of forest and grass vegetation; and vegetation coverage.

The monitoring work will be carried out by field surveys and accounting. Soil and water conservation effect will be calculated in accordance with the provisions of GB / T15774-1995-Calculation Method for Soil and Water Conservation Effect; the slag prevention effect will be calculated by measuring the actual amount of slags.

d) Monitoring of the background value of soil erosion

The background values of soil erosion shall be monitored in construction preparation period.

e) Monitoring of major f soil erosion events

The monitoring will focus on the major events such as secondary landslip, avalanches, landslides, collapse and other potential hazards that may arise in high slopes, high embankment sections, material area and spoil area.

The monitoring shall be carried out by site inspection. The monitoring area will be arranged in concentration area of production and living, weak prevention area, and construction areas without prompt prevention measures.

9.1.5.3 Monitoring period and frequency

a) Monitoring period

The monitoring shall start from construction preparation period and ends in design target year. That is, from May of the first construction year to October of the year of completion. The monitoring period will last 54 years.

b) Monitoring frequency

The monitoring frequency shall be determined by the specific construction arrangements. 40% of the rainfall in the project area is concentrated in April to July. Therefore, April-July will be key monitoring period.

Monitoring frequency for soil and water erosion will be 8-10 times / year. During flood season, the monitoring shall be carried out once a month, of which the temporary sites, construction roads, the construction preparation period shall be monitored once every month.

During the recovery period, the monitoring of water and soil conservation effect shall be 2 times/ year. The monitoring of all kinds of protection works shall be carried out before and after rainy season.

In September of each year, a survey of afforestation survival rate shall be carried out. Areas not meeting the criteria shall be replanted. Retention rate shall be monitored in May and December for two consecutive years. Forest growth shall be monitored once in every autumn. The monitoring objects include tree height, trunk diameter, ground diameter, canopy closure and density.

9.1.5.4 Arrangement of monitoring sites

Monitoring sites: The monitoring sites shall be arranged in typical water and soil conservation areas such as the revetment, drainage work of the dam, kiloton-level wharf, landfill area, spoil area, material area, construction road, temporary sites, and slope of the approach road.

The arrangement of monitoring sites is shown in Table 9.1.5.

Table 9.1.5 Monitoring sites for soil and water conservation

Fixed-point ground monitoring			Monitoring	Notes
Monitoring method	Monitoring sites	Location		
Simple slope measuring method (3 sites)	Project area (1 site)	Slope of the subsidiary dam	√	To measure the quantity of soil and water erosion
	Material area(1 site)	Slope of the material yard for surface soil.	√	
	Field-lifting area (1 site)	Slope of landfill area in Gaobao Village	√	
Desilting method (4 sites)	Spoil area (1 site)	Spoil area of the right bank	√	We can use desilting basin designed for the project to monitor the variation of soil and water loss in the construction area.
	Quarry area(1 site)	Quarry area of Matou Mountain	√	
	Temporary sites(1 site)	Temporary sites of the left bank	√	
	Wharf area(1 site)	Wharf of the right bank	√	
Simple runoff method (4 sites)	Approach road and site road area (1)	Excavation slope of right-bank approach road	√	This includes two areas for comparison.
	Temporary road area (1)	Excavated slope of temporary roads on the left bank	√	

The data is used to calculate the rate of land reclamation rate, control ration of water and soil erosion and newly-added soil and water erosion.

Besides fixed-point monitoring, the monitoring area shall be expanded to landslide and land collapse area.

9.2 Environmental supervision during construction period

9.2.1 Purpose of supervision

Environmental supervision is carried out to meet the environmental requirements of the project, which is: to give full play the potential benefits of the project within the environmental protection investment; to supervise the implementation of environmental protection terms in tender documents; to ensure the health of the population in the project area; to alleviate or eliminate the adverse effects identified in EIA report; and to achieve the harmony and unification of environmental, social and economic benefits.

9.2.2 Supervision mode

a) Construction characteristics and implementing agency

Due to the project impact on the ecological environment, we must attach great importance to environmental protection and supervision during its construction and operation period. Environmental supervision can be divided into two parts: environmental supervision of construction area; and environment supervision of resettlement area. Environmental supervision of construction area is mainly about the oversight of environmental protection work by the Contractor and PIU; while environmental supervision for relocated people are mainly about the oversight of environmental protection work related to resettlement. Meanwhile, the two parts are under the delegation and supervision of competent authorities of the project.

b) Regulatory approach for environmental supervision

1) Environmental supervision of construction area

The Supervision Engineer is required to oversight the environmental protection work carried out by the Contractor, which mainly include five aspects: waste water, waste gas, solid waste, noise and ecology. If any environmental issues are found, the Supervision Engineer shall notify the environment conservator of the Contractor for prompt treatment. Meanwhile, the Supervision Engineer shall schedule a follow-up inspection for those environmental issues.

2) Environmental supervision of resettlement area

The supervision include two methods: bottom-up supervision and top-down supervision. Bottom-up supervision means a environmental report is filled by the local environmental officials, and submitted to the environmental supervision engineer; top-down supervision means the environmental supervision engineer directly carries out site inspection at the resettlement area and report it to Resettlement Office of the PIU, and the Resettlement Office will finally notify the resettlement offices of all levels.

9.2.3 Content of supervision

The supervision shall be carried out in accordance with national and local government policies on environmental protection. Main responsibilities of Supervision Engineer are:

(1) To prepare environmental supervision plan;

(2) To carry out supervision for the Contractor, so as to prevent environmental pollution and damage of vegetation and wildlife.

(3) To carry out overall supervision and inspection of the mitigation measures taken by all construction units and promptly addresses environmental incidents;

(4) To carry out comprehensive inspection of the treatment of slag area and construction sites, including slope stabilization, land recovery and afforestation.

(5) To supervise the implementation of environmental monitoring and audit the environmental report; to put forth corresponding requirements for construction and management based on the monitoring results of water, air, noise, etc.

(6) To keep supervision record and prepare supervision report; to participate in final acceptance.

9.2.4 Environmental supervision agency

Environmental supervision agency shall be determined through public bidding by the PIU. It is independent of both PIU and the Contractor. Meanwhile, it has with some connection both of them. On the one hand, environmental supervision agency owns contractual relation with the PIU, and is commissioned by the PIU to supervise the work of environmental protection; Environmental supervision agency and the Contractor owns working relationship, and its job is to monitor the progress of the environmental protection work by the Contractor. In environmental protection, the environment supervision agency connects the PIU and the Contractor. The environmental protection work specified by the PIU shall be implemented by the Contractor, which shall be supervised by environmental supervision agency. Meanwhile, the implementation of environmental protection shall be reported by the environmental supervision to the PIU. Thus, with the help of environmental supervision agency, the environmental protection of is able to proceed smoothly.

9.3 Environmental management plan (EMP)

9.3.1 Objectives

To ensure the smooth implementation of mitigation measures, so as to relief and control the adverse environmental impact brought by project construction.

9.3.2 Tasks

9.3.2.1 Environmental management during construction period

a) Environmental management tasks of the PIU

The PIU is in charge of environmental management from the start of construction to final acceptance. The work mainly includes:

1) To develop implement plan and management measures for environmental protection;

2) To prepare tender documents and environmental provisions of project contract and tender documents;

3) To prepare annual environmental protection plan;

4) To review and schedule the annual environmental protection funds;

5) To supervise the implementation of mitigation measures by the Contractor;

6) To supervise the implementation of environmental protection during the resettlement process;

7) To build working relationship with environmental protection department and other relevant departments ;

8) To deal with environmental accidents and pollution disputes, and timely report it to relevant authorities;

9) To prepare an annual report on the work of environmental protection and submit monthly, quarterly, annual reports;

10) To organize propaganda, education and training of environmental protection.

b) Environmental management tasks of the Contractor

The Contractor is responsible for the environmental protection work during its construction, including the following:

1) To prepare annual environmental work plan;

2) To inspect the construction progress of environmental protection facilities, and to deal with relevant issues in the implementation process;

3) To audit the use of annual environmental funds;

4) To report the implementation of environmental provisions in the contract.

9.3.2.2 Environmental management during operation period

The work mainly is:

(1) To implement national and local environmental protection laws, regulations and policies;

(2) To implement mitigation measures during the operation period;

(3) To perform environmental monitoring and carry out statistical analysis of the monitoring results;

(4) To monitor the impact of surrounding environment changes on the project and report it to relevant departments to solve the problem;

In addition, the local environmental protection department should strengthen the supervision and management of environmental protection, especially the supervision of basic ecological flow.

9.3.3 Environmental management agencies

9.3.3.1 Environment management of watershed

a) Arrangement of environmental protection agencies for watershed

The Retrospective Assessment states that we should establish a cascade-level environmental protection agencies along the watershed. And carry out ecological survey and long-term monitoring (both aquatic and terrestrial), so as to gradually build an ecological monitoring system and environmental data base along the watershed." Currently, government, traffic, electric power departments at all levels all owns environmental protection agencies. In accordance with relevant national environmental protection policies and regulations, they all have the right to supervise the environmental protection work along the hydro-power development projects.

We will establish a Environmental Monitoring and Management Center in Han River Basin, which will be responsible for collection, collation and reporting of annual environmental work plan, its main contents and capital plan. The environmental management of the hydropower project shall be carried out by environmental protection agencies established by Hubei Provincial Department of Transportation and Department of Water Resources. For instance, the environmental monitoring and management coordination and leading group has two subordinate units: namely, a Watershed Environmental Center and Information Management Center for Environmental Monitoring of Cascade Development along the Han River. Each PIU will have a Environmental Management Committee, under which there is a Environmental Protection Department. The Construction Company shall implement the mitigation measures and the DI shall provide technical support. Thus, a trinity built by "the PIU, the environmental supervision agency, and construction company" will be formed.

b) Arrangement of environmental protection agencies for watershed

The environmental management system will be built by the Port and Channel Bureau of Department of Transportation, and Water Resources Department, under which there are Han River Management Bureau, Project Construction Management Bureau (Ministry of Environmental Protection) and field design, supervision, construction and monitoring unit. The organization is shown in Figure 9.3.3.

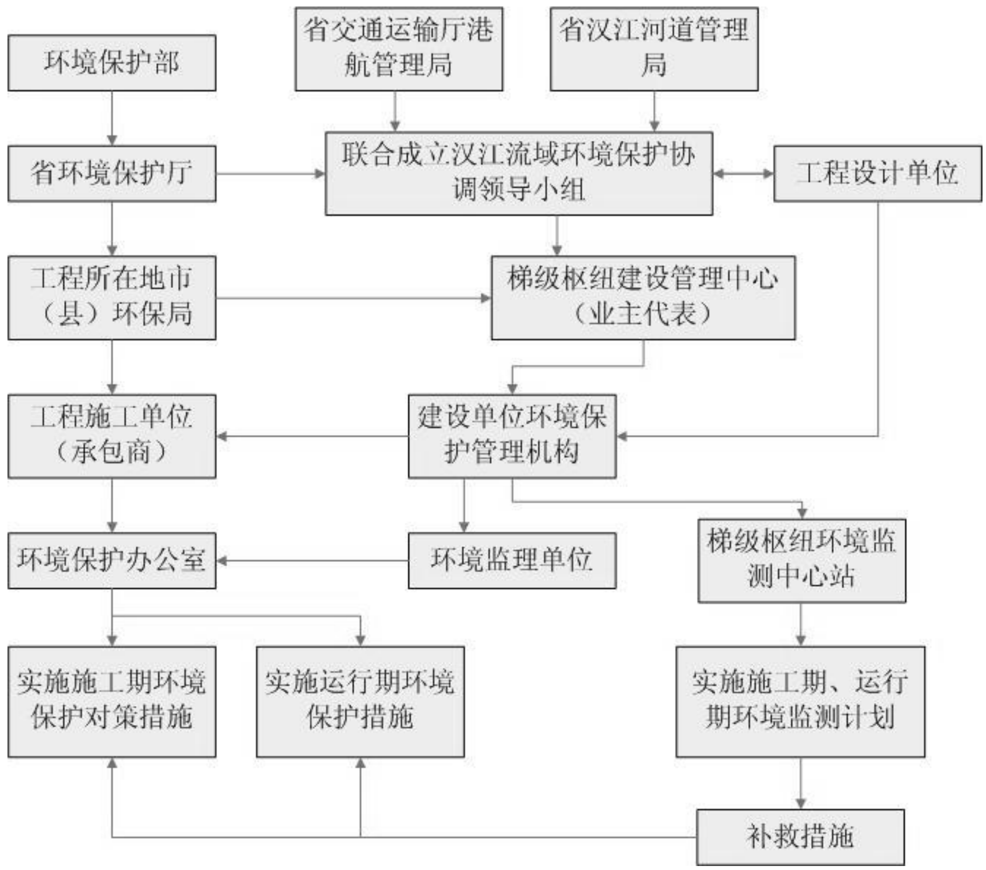


Figure 9.3.3 Arrangement of environmental management organizations of the project along Han River

c) Arrangement of environmental information management system along the watershed

For scientific management of research results and environmental information, a relevant information database should be established.

1) System platform

In selection of the system platform, we mainly consider the following requirements: Good user interface, convenient and flexible query tools; open user interface; and compatibility and openness of data format .

Currently, there are commercial GIS systems such as ArcGIS and MapGIS to choose from. Temporarily, we can select ArcGIS10 as a basic platform and use its expansion module Spatial Analyst as a spatial analyst tool. Then, we can use Avenue, Visual C++ and Visual Basic for software development.

2) System design

(1) Design of system framework

The GIS spatial database and the methodological model base will be the priority in system design and development. Spatial database management system is able to manage attribute data, graphic data, and image data. For methodological model base, we shall provide simulation models of water environment and the ecological environment and data analysis tools.

(2) Database system

A detailed spatial database shall be established, and information to be collected will include: Basic geographic information, ground elevation, land use change, etc.

(3) Methodological model base

This model base is used for deep processing relevant information. It includes modules covering hydrology, water quality, water temperature, land ecology, aquatic ecology, social economy, immigration, and more.

9.3.3.2 Environment management of the project

The project will arrange environmental management agencies in order to complete environmental management tasks in construction period and operation period.

The environmental management agencies shall include the following aspects such as the number of staff, technical requirements, environmental protection equipment:

a) Considering the environmental characteristics of the project, we recommend that a Environmental Management Agency be set up for unified and coordinated management of environmental issues.

b) The Environmental Management Agency shall:

1) be responsible for carrying out the relevant policies and regulations of the state and Hubei Province, and manage the environmental protection work of the project.

2) be responsible for environmental protection in the design phase, including environmental consultation, regional environmental investigation, public participation and relevant environmental issues to resettlement.

3) be responsible for environmental monitoring and management in construction period, including land acquisition and resettlement , bank protection, sewage governance and dust and noise control in sensitive areas.

4) be responsible for the implementation of the fish compensation and proliferation plan; be responsible for the monitoring of regional aquatic organisms; be responsible for assisting local environmental protection department to investigate and deal with the environmental problems in the reservoir area, etc.

9.4 Phased implementation of mitigation measures and acceptance of "three simultaneities"

The implementation of major mitigation measures and the "three simultaneities" is shown in Table 9.4-1. The acceptance plan on water environment protection is shown in Table 9.4-2.

Table 9.4-1 Phased implementation of mitigation measures and "three simultaneities"

No.	Project name and main mitigation measures	Implementation					Planned completion time	Notes
		Construction period				Operation period		
		1	2	3	4			
I	Construction area of the Hub							"Three simultaneities" means to carry out design, construction, and operation of mitigation measures and the main project simultaneously; the acceptance department is Hubei Provincial Environmental Protectio
1	Water and soil conservation						2015-2018	
1.1	Engineering measures: Land treatment, slope protection, flood control in soil borrow area, quarry area, slag yard, construction area and other places							
1.2	Plant protection: slope protection and greening							
1.3	Temporary works: Temporary storage yard, later-stage greening, soil cover, and rain proof measures							
2	Water environment protection							
2.1	Wastewater treatment of aggregate processing and concrete mixing equipment: Sedimentation tank, neutralizing tank, oil separation tank, pipe construction						2015-2018	
2.2	Treatment of domestic sewage in construction: Buried sewage treatment equipment						2015-2018	
2.3	Mitigation measures during operation period of power station: Domestic sewage treatment station in management area, warehousing pollutant control, installation of oil water separation ship						2018	
3	Biological protection measures							
3.1	Protection and rehabilitation measures for fish						2015-2018	
3.1.1	Fish-way construction, operation control facilities and operation managers						2018	
3.1.2	Enhancement and releasing station: Station construction, artificial releasing, stocking and						2018	

No.	Project name and main mitigation measures	Implementation					Planned completion time	Notes
		Construction period				Operation period		
		1	2	3	4			
	enhancement							n Bureau
3.1.3	Other protection and rehabilitation measures for fish: Fishing ban, salvage, monitoring and rehabilitation measures						2015-2018	
3.1.4	Research and experiment of ecological scheduling							
3.1.5	Fish research project							
3.1.6	Construction of hydrological collection and transmission system of Dongpo							
3.2	Plant protection and old trees transplanting						2015-2018	
3.3	Other measures: Greening, slope protection, etc.						2015-2018	
4	Atmospheric environmental protection: Water sprinkling, ventilation, closed construction (for dust control) in soil borrow area, quarry area, slag area, and road & construction area.						2015-2018	

Table 9.4-1 (Continued)

No.	Project name and main mitigation measures	Implementation					Planned completion time	Notes
		Construction period				Operation period		
		1	2	3	4			
5	Acoustic environmental protection: Use topographic barrier for noise control; for crusher which is 100dB above, use porous sound absorbing materials.						2015-2018	Notes
6	Domestic waste treatment: Build garbage station for soil material area, quarry area, slag area, and construction area on the left and right bank						2015-2018	
7	Population health: Sanitary cleaning, site disinfection, health quarantine and health inspection						2015-2018	
8	Environmental monitoring						2015-2018	
II	Resettlement area							
1	Water and soil conservation							
1.1	Engineering measures: Excavation, land-filling, retaining, water interception and drainage system						2015-2018	
1.2	Plant measures: slope protection and greening							
1.3	Temporary works: Temporary storage yard, later-stage greening, soil cover, and rain proof measures							
2	Water environment protection: Septic tank, pipe network of into-county sewage treatment plant, protection of drinking water sources, water wells						2015-2018	
3	Biological protection measures						2015-2018	
4	Population health: Sanitary cleaning, site disinfection, health quarantine and health inspection						2015-2018	
5	Domestic waste treatment: Garbage station in resettlement area						2015-2018	

Table 9.4-2 "Three simultaneities" of water environment protection

Phases	Tasks		Shedule	Responsible party	Responsibility of the PIU
Construction preparation stage		To establish environmental management agencies and management system, and to carry out environmental supervision	Before construction	Port and Channel Bureau of Hubei Provincial Department of Transportation	Responsible for the arrangement and payment of the relevant tasks

Construction period	Water pollution control	To monitor the quality of waste water in sand & stone treatment facilities, concrete treatment facilities, processing factories and sewage treatment facilities.	The 1st year in construction period; the 1st to 4th year in operation period	The Contractor	Responsible for work arrangement and payment of costs; responsible for supervision of implementation of three simultaneities of the Contractor
	Water environment monitoring	To carry out water environmental monitoring, with focus on heavy metal factors	1st years to 4th year of construction period	Port and Channel Bureau of Hubei Provincial Department of Transportation	Work coordination and management
Operation period	Water quality monitoring	To timely monitor the changes in water quality	Initial storage period and operation period	Port and Channel Bureau of Hubei Provincial Department of Transportation	Work coordination and arrangement
	Hydrological monitoring	To carry out flood forecasting and flood monitoring of Tangbai River Basin and provide timely and effective data for ecological operating test	Construction period-operation period	Port and Channel Bureau of Hubei Provincial Department of Transportation	

10 Budgeting of Environmental Protection Work

10.1 Compiling principles

Components of environmental protection work should be determined and environmental protection funds shall be allocated based on the principle of "pollution abatement by producer and environmental protection by developer".

Cost estimate should be made in the principle of "function rehabilitation", that is, the environmental protection funds should be used to at least protect or rehabilitate the functions of the eco-environment.

Cost estimate for engineering measures should be made in reference to the same standards and regulations and the same methods used for Yakou Shipping Hub Project and cost estimate for biological measures should be made in reference to local relevant standards and regulations.

10.2 References

Notice on Forwarding the Notice of State Development Planning Commission on the Issues Concerning Strengthening the Administration of "Price Variance Budget Reserve" in Budgetary Estimate of Large and Medium-sized Capital Construction Projects (E.J.J. [1999] No. 601);

Notice of State Development Planning Commission on Issuing the Interim Provisions on Early-stage Consulting Charges of Construction Projects (J.J.G [1999] No. 1283);

Notice of State Development Planning Commission and Ministry of Construction on Issuing the Charging Rates for Project Survey & Design (2002 revision) (J.J.G. [2002] No. 10);

Provisions on Budget (Estimate) Compilation for Inland River Waterway Construction Projects and the Quotas (J.J.F. [1998] No.112 of Ministry of Communications);

Provisions on Compilation of Budgetary Estimate for Water Conservancy Project Design and the Quotas (S.Z. [2002] No.116 of Ministry of Water Resources), *Supplementary Quotas for Budget and Estimate of Water Conservancy Projects* (S.Z. [2005] No.389 of Ministry of Water Resources), *Quotas for Budgetary Estimate of Water Conservancy & Hydropower Equipment Installation Projects* (S.J.G. [1999] No. 523);

Feasibility Study Report of the project and Hubei Provincial Traffic Engineering Cost

Information (2nd issue of 2014);

Notice on issuing the Provisions on Compilation of Budgetary Estimate for Water and Soil Conservation Projects and the Quotas (S.G.Z. [2003] No. 67 of Ministry of Water Resources), *Provisions on Compilation of Budgetary Estimate for Water and Soil Conservation Projects* (January 2003, Ministry of Water Resources), *Quotas for Budgetary Estimate of Water and Soil Conservation Projects* (January 2003, Ministry of Water Resources);

Local standards and quotas of Hubei province and price inquiries at local area should also be consulted.

10.3 Division of environmental protection work and composition of costs

Environmental protection costs for Yakou Shipping Hub Project consist of four parts, i.e. construction cost, independent fee, basic budget reserve and price variance budget reserve. The construction cost is divided into two parts, one part for structures of the hub and the other part for project affected area.

The environmental protection project includes eight components, namely soil and water conservation, water environment protection, biological conservation, atmospheric environment protection, acoustic environment protection, domestic refuse disposal, human health protection and environmental monitoring.

Cost for engineering measures should be calculated by multiplying the quantities with the unit price, which consists of direct construction cost, indirect cost, profits and taxes.

Cost for plants consists of the cost of materials including seedlings, grass and seeds and the planting fee and maintenance fee. Cost estimate of plants should be made by multiplying the unit cost of seedlings, grass and seeds with their quantity. The estimate of planting fee shall be made in accordance with the Quotas for Budgetary Estimate of Soil and Water Conservation Works in Construction Project. Maintenance fee is composed of all kinds of costs for irrigation, application of fertilizer, weeding, pruning and etc., including sowing of grass and tree seeds (5.00% of planting fee) and planting of turf and trees (10.00% of planting fee). Maintenance fee is calculated on annual basis.

Cost for temporary works should be 2.00% of the total amount of cost for engineering measures and cost for plants.

10.4 Base price and base year

a) Unit price of labor

For the works deemed as traffic project, J.J.F [1998] No. 112 document of Ministry of Communications should be applicable, and according to this document, the unit price of labor is 20.44 Yuan/person/day. For the works deemed as hydropower project, S.Z. [2002] No.116 document of Ministry of Water Resources should be applicable, and according to this document, the unit price of labor is 3.04, 5.62, 6.61 and 7.1 Yuan/man-hour respectively for primary workers, intermediate workers, senior workers and foremen.

b) Unit price of main materials

Unit price of main building materials should be the local market price in August 2009, and unit price of sandy gravels, wind, water and electricity should be calculated on the basis of construction organization design.

Unit price of building materials for soil and water conservation works in construction area should be the same with that of Yakou Shipping Hub Project, rebar: 4490 Yuan/t, cement 32.6: 334.0 Yuan/t, cement 42.6: 376 Yuan/t, block stones: 75 Yuan/m^3, medium-coarse sand: 54.51 Yuan/m^3, pebbles: 46 Yuan/m^3.

Unit price of plants shall be based on the local market price.

Price of wind, water and electricity shall be the same with that of corresponding parts of Yakou Shipping Hub Project. Composite price of electricity is 0.85 Yuan/kW-h, price of wind is 0.17 Yuan/m^3, and price of water is 0.43 Yuan/m^3.

c) The base year should be the same with that of Yakou Shipping Hub Project, that is, the second quarter of 2013.

10.5 Charging rates

b) Charging rates for materials

Other direct cost, indirect cost, profits and taxes for engineering measures should be estimated according to the S.Z. [2002] No.116 document - *Cost Composition and Calculation Standards for Design Budget Estimate of Water Conservancy and Hydropower Project*, and other direct cost, indirect cost, profits and taxes for plants should be estimated according to the *Provisions on*

Compilation of Budgetary Estimate of Soil and Water Conservation Project (June 2003, Ministry of Water Resources).

b) Independent fee

Project management fee: 2.6% of construction cost.

Project supervision fee: 250,000 Yuan per person per year.

Research, survey and design fee: calculated according to the *Charging Rates for Project Survey & Design* (J.J.G. [2002] No. 10 of State Development Planning Commission and Ministry of Construction);

Other taxes and charges: 0.07% of construction cost of environmental protection project.

Soil and water conservancy facilities restoration compensation should be paid on one-off basis, and should be calculated in accordance with the E.Z.F. [2000] No. 28 document – *Notice of Hubei Provincial People's Government on Collecting Soil and Water Conservancy Facilities Restoration Compensation and Soil and Water Conservancy Fee*. The compensation for soil and water conservation facilities should be 1.50 Yuan/m^2.

c) Budget reserve and loan interest during construction

1) Basic budget reserve

The basic budget reserve should be 10.0% of the total amount of cost for engineering measures, cost for plants, cost of temporary works and independent fee.

2) Price variance budget reserve

According to J.T.Z. [1999] No.1340 document of State Development Planning Commission, the price variance budget reserve should be zero.

3) Interest during construction is included in cost estimate of Yakou Shipping Hub Project, and not included in this report.

10.6 Cost estimate

10.6.1 Total cost for environmental protection

10.6.1.1 Total cost for environmental protection

Total cost for environmental protection is 273.0125 million Yuan, accounting for 8.41% of total cost of Yakou Shipping Hub Project (3.245711 billion Yuan), of which the special fund for environmental protection is 151.0828 million Yuan and the special fund for soil and water conservation is 121.9297 million Yuan.

10.6.1.2 Special fund for environmental protection

The special fund for environmental protection is 151.0828 million Yuan, including 89.4253 million Yuan for environmental protection of the hub, 14.6853 million Yuan for independent fee, and 10.4111 million Yuan for basic budget reserve. The estimate of special fund for environmental protection is shown in Table 10.6.1-1 and the estimate of special fund for soil and water conservation is shown in Table 10.6.1-2.

Table 10.6.1-1 Estimate of special fund for environmental protection

No.	Items	Amount (10,000 Yuan)	Proportion (%)	Remarks
Part I	Environmental protection of the hub	11830.73	78.31	
一 I	Water environment protection	2621.1	17.35	
1	Flushing wastewater from aggregate system	1035.1	6.85	
2	Wastewater from concrete system	35.6	0.24	

Table 10.6.1-1 (Continued)

No.	Items	Amount (10,000 Yuan)	Proportion (%)	Remarks
3	Oily wastewater from construction site	51.06	0.34	
4	Domestic sewage from right-bank construction camps	364.63	2.41	
5	Treatment of domestic sewage from PIU’s camps	94.05	0.62	
6	Fecal sewage from construction area	73.86	0.49	
7	Treatment of oily water from construction site	136.8	0.91	
8	Treatment of ship wastewater	830	5.49	
8.1	Receiving ship for ship wastewater	150	0.99	
8.2	Collection and treatment facilities of wastewater from wharfs and ships	460	3.04	

No.	Items	Amount (10,000 Yuan)	Proportion (%)	Remarks
9	Upgrade of water works in the reservoir area	220	1.46	Amortization of investment
II	Atmospheric environment protection	251.01	1.66	
1	Dust reduction and control of aggregate processing system	42.75	0.28	
2	Reduction and control of exhaust from fuel firing	0	0.00	Included in cost estimate of Yakou Shipping Hub Project
3	Traffic dust reduction and control	150.48	1.00	
4	Dust control of construction site	57.78	0.38	
III	Acoustic environment protection	149.79	0.99	
1	Noise control of aggregate system	0.00	0.00	Included in cost estimate of Yakou Shipping Hub Project
2	Traffic noise control	149.79	0.99	
IV	Domestic refuse disposal	202.03	1.34	
1	Disposal of domestic refuse at camps	192.03	1.27	
2	Disposal of domestic refuse on ships	10	0.07	
V	Ecological environment protection	4642.90	47.17	
1	Terrestrial ecology protection	99.95	4.63	
1.1	Ecological restoration	685.70	4.54	
1.2	In-situ conservation and publicity	14.25	0.09	
2	Aquatic ecology protection	6426.52	42.54	
2.1	Construction of fish stock enhancement station	1824.00	12.07	
2.2	Operation of stock enhancement station (first four years)	1103.31	7.30	Reach normal operation scale in the 4th year
	Operation of stock enhancement station (the 5th year to the 25th year)	282.77	1.87	Started to be included in operation cost of power station in the 5th year
2.3	Scientific research	622.55	4.12	
	Research on habitat protection and restoration	150	0.99	
	Research on ecological operation mode	150	0.99	
	Succession of aquatic organism in middle and lower reaches of	200	1.32	

No.	Items	Amount (10,000 Yuan)	Proportion (%)	Remarks
	Han River after the reservoir is completed			

Table 10.6.1-1 (Continued)

No.	Items	Amount (10,000 Yuan)	Proportion (%)	Remarks
	Research on artificial stock enhancement technology	122.55	0.81	
2.4	Habitat protection	871.25	5.77	
2.5	Fishways	1807.76	11.97	Listed in cost of the hub, not included in environmental protection cost
2.6	Compensation for fishermen	197.65	1.31	Only for the first three years, to be included in operation cost from the 4th year
VI	Human health protection	197.65	1.31	
1	Sanitation & cleaning	97.90	0.65	
2	Personal health	28.50	0.19	
3	Management and supervision of food and environmental hygiene	28.50	0.19	
4	Hygiene & epidemic prevention organization at construction area	42.75	0.28	
VII	Cultural relics and historical sites protection	/		Not included in environmental protection cost
VIII	Environmental monitoring & survey	1112.68	7.36	
1	Environmental quality monitoring (water, air and noise)	241.68	1.60	Including water quality monitoring at reservoir area
2	Aquatic ecology monitoring	320.6	2.12	
3	Terrestrial ecology survey	68.4	0.45	
4	Fish passage facility effect monitoring	75	0.50	250,000 Yuan/year only for the first 3 years, to be included in operation cost of power station from the 4th year
5	Enhancement and releasing effect monitoring	165	1.09	550,000 Yuan/year only for the first 3

No.	Items	Amount (10,000 Yuan)	Proportion (%)	Remarks
				years, to be included in operation cost of power station from the 4th year
6	Online monitoring of ecological flow	50	0.33	
	Equipment installment & commissioning	20	0.13	
	Operation cost	30	0.20	100,000 Yuan/year only for the first 3 years, to be included in operation cost of power station from the 4th year
7	Construction and operation of Dongpo flood prevention station	70	0.46	
	Equipment installment & commissioning	40	0.26	
	Operation cost	30	0.20	100,000 Yuan/year only for the first 3 years, to be included in operation cost of power station from the 4th year
8	Human health monitoring	122	0.81	
IX	Prevention and control of environmental risks/accidents	170	1.13	
1	Oil containment boom, oil suction machine, oil absorbent felt, oil absorbent boom	145	0.96	
2	Rescue devices for fishes (nets, drugs, vehicles)	20	0.13	
3	Emergency gate at Wangjiadagou estuary	5	0.03	
Part II	Independent fee	1904.07	12.60	
一 I	Project management cost	699.71	4.63	
1	Project administration cost	319.43	2.11	As per 2.70% of Part I

Table 10.6.1-1 (Continued)

No.	Items	Amount (10,000 Yuan)	Proportion (%)	Remarks
2	Project supervision cost	120.00	0.79	

No.	Items	Amount (10,000 Yuan)	Proportion (%)	Remarks
3	Consulting fee	130.14	0.86	As per 1.10% of Part I
4	Technical and economic evaluation and review fee	53.24	0.35	As per 0.45% of Part I
5	Project insurance premiums	76.90	0.51	As per 0.65% of Part I
II	Cost of production preparation	230.70	1.53	As per 1.95% of Part I
III	Research, survey and design cost	946.46	6.26	
1	Research and test cost	118.31	0.78	As per 1% of Part I
2	Survey and design cost	828.15	5.48	As per 7% of Part I
IV	Other taxes and charges	27.21	0.18	As per 0.23% of Part I
Part III	Basic budget reserve	1373.48	9.09	As per 10% of total amount of Parts I & II
	Total static investment	15108.28	100.00	

10.6.1.3 Special fund for soil and water conservation

The special fund for soil and water conservation is 121.9297 million Yuan, including 83.3664 million Yuan for engineering measures, 15.0913 million Yuan for plants, 3.0863 million Yuan for cost of temporary works, 7.7722 million Yuan for independent fee (including 2.2980 million Yuan for soil and water conservation monitoring cost and 1.52 million Yuan for project supervision cost), 6.5590 million Yuan for budget reserve, and 6.0546 million Yuan for compensation for soil and water conservation. Details are shown in Table 10.6.1-2.

Table 10.6.1-2 General estimate of special fund for soil and water conservation

Unit: 10,000 Yuan

No.	Items	Cost of construction & installation works	Cost of forestry and grass works		Cost of equipment	Independent fee	Total
			Planting cost	Cost of trees, grass and seeds			
	Part I Engineering measures	8336.64					8336.64
(I)	The hub project						
I	Construction of dam	2415.11					2415.11
II	PIU’s camps	84.07					84.07
III	Borrow area	154.30					154.30

IV	Temporary storage area	115.51					115.51
V	Spoil area	2794.25					2794.25
VI	Road works	47.24					47.24
VII	Construction site and camps	641.03					641.03
(II)	Reservoir area protection						

Table 10.6.1-2 (continued)

No.	Items	Cost of construction & installation works	Cost of forestry and grass works		Cost of equipment	Independent fee	Total
			Planting cost	Cost of trees, grass and seeds			
I	Protection works	217.66					217.66
II	Spoil area	1842.31					1842.31
III	Access roads	20.43					20.43
IV	Construction site and camps	4.72					4.72
	Part II Plants		716.59	792.64			1509.13
(I)	The hub project						
I	Construction of dam		368.80	553.20			922.00
II	PIU’s camps		52.60	78.90			131.50
III	Spoil area		73.75	35.10			108.84
IV	Road works		3.71	2.95			6.66
V	Construction site and camps		10.71	6.76			17.47
(II)	Reservoir area protection						
I	Protection works		31.63	3.87			35.51
II	Spoil area		165.13	105.22			270.35
III	Access roads		9.39	5.98			15.37
IV	Construction site and camps		0.87	0.55			1.42
	Part III Temporary works	264.52	40.66	3.45			308.63
I	Temporary protection works	166.06	40.66	3.45			210.17
II	Other temporary works	98.46					98.46
	Part IV Independent fee					777.22	777.22
I	Project management fee					101.54	101.54
II	Research, survey and design cost					208.87	208.87
III	Soil and water conservation supervision cost					152.00	152.00

IV	Soil and water conservation monitoring cost					229.80	229.80
V	Cost of preparing technical evaluation report for final acceptance of soil and water conservation works					85.00	85.00
	Total of Part I, II, III & IV	8601.15	757.25	795.99		777.22	10931.61
	Budget reserve						655.90
	Static investment						11587.51
	Compensation for soil and water conservation						605.46
	Total cost of soil and water conservation						12192.97

11 Economic Benefit-Loss Analysis of Environmental Impacts

Economic benefit and loss of the environmental impacts of the project are analyzed on the basis of EIA and economic verification of mitigation measures. The analysis considers ecological benefits, social environment and the sustained, stable and harmonious development of regional social economy. According to the principle of equivalence and replacement, environmental benefit is calculated with "shadow project approach", and environmental loss is calculated with "replacement cost approach", that is, taking the cost for reducing/eliminating adverse environmental impacts or the cost for restoration/compensation as environmental loss.

11.1 Analysis of environmental benefit

The environment benefits of Yakou Shipping Hub Project consist of three parts, i.e. economic benefits, social benefits and ecological benefits. Economic benefits mainly include shipping cost reduction, electricity generation of power station and irrigation & water supply; social benefits are shown in the improvement of local social economic development due to the construction of ship lock and 1000t waterway; ecological benefits include replacement of fuel firing by the hub and environmental protection cost for the replacement.

11.1.1 Economic benefits

The quantifiable economic benefits include benefit from shipping cost reduction due to waterway upgrade and larger ship size, benefit from reduction of waterway maintenance cost, benefit from cargo volume transferred from other transportation means, benefits of the reservoir, benefit from replacement of thermal power station by hydropower station, as well as truism benefits.

a) Benefit from shipping cost reduction due to waterway upgrade and larger ship size

After Yakou Shipping Hub Project is completed, the waterway of the reservoir section will be upgraded to accommodate 1000t ships (100-300t before), the long-distance water transportation cost will decrease and economic benefits will increase. It is expected that the density of goods flow in this section (from Cuijiaying hydro-junction to Yakou hub) will reach 11 million tons and the freight turnover will reach 1100×50=550 million t·km by 2030. Given that 90% of 100-300t ships will be replaced by 1000t ships, cost reduction will be 0.035 Yuan/t·km and annual benefit from shipping cost reduction will amount to 20.1 million Yuan.

b) Benefit from reduction of waterway maintenance cost

After Yakou Shipping Hub Project is completed, a 50km waterway will be formed upstream from the dam and the waterway maintenance cost will decrease by 2.9 million Yuan every year.

c) Benefit from cargo volume transferred from other transportation means

After Yakou Shipping Hub Project is completed, the waterway in this section will receive great quantity of cargo from other transportation means, 80% from road transportation and 20% from railway transportation. The new addition of cargo volume in this waterway will take up 75% of its total cargo volume. Given that cost reduction is 0.45 Yuan/t·km comparing with road transportation and 0.03 Yuan/t·km comparing with railway transportation, the average price difference will be 0.366 Yuan/t·km. Given that the average shipping distance is 58km, the benefit thus generated (cargo transportation cost reduction) will be: 11 million tons×58km×75%×0.366Yuan/t·km＝175.13 million Yuan. Wharf is a place where goods are transferred from road and railway transportation to water transportation, so wharf construction is an essential part of cargo transfer and won't be explained separately.

d) Benefit of the reservoir

Benefit of the reservoir mainly includes urban water supply and agricultural irrigation. Since the water level of the reservoir will rise after Yakou Shipping Hub Project is completed, water intake cost will decrease by 365,000 Yuan every year and irrigation cost at low flow season will decrease by 3.72 million Yuan every year. So, benefit of the reservoir amounts to 4.085 million Yuan each year.

e) Benefit from replacement of thermal power station by hydropower station

Electric power resources are scarce and distributed unevenly in Hubei province. Yicheng city is a place in lack of electric power. Yakou hub is just located at this place, so construction of power station is imperative. The power station will have an installed capacity of 90,000kW and an annual electricity generation capacity of 358.2 million kW·h. After deducting the electricity generation (24.5 million kW·h) of Cuijiaying hydro-junction which will be affected by this project, the net electricity generation will be 333.7 million kW·h each year. Reduction of thermal power station construction cost and thermal power generation cost when without this project should be deemed as economic benefit of the project.

Given that the equivalent capacity is 105% of installed capacity of hydropower station and the coefficient of utilization of installed capacity of thermal power station is 95%, the capacity of thermal power station is 89,775kW. After deducting the capacity loss (83,910kW) of Cuijiaying Hydro-junction and given that the unit investment is 5000 Yuan/kW, the alternative investment amounts to 419.545 million Yuan.

The alternative investment should be deemed as benefits of the project and be amortized in the three years' construction period (40% in 2011 and 30% in 2012 and 2013). For the thermal power station, given that standard coal consumption is 420g/kW·h, standard coal price is 550Yuan/t and unit operation cost excluding coal consumption is 0.035Yuan/kW·h, we can get that the fuel consumption cost is 77.08 million Yuan each year (333.70×0.42×0.55, in which 333.70 million kW·h is net annual electricity generation of hydropower station after deducting capacity loss of Cuijiaying hydro-junction), and the operation cost excluding coal consumption is 11.68 million Yuan. Therefore, annual operation cost of a 75MW thermal power station totals up to 88.76 million Yuan, which should be deemed as annual operation benefits of the project.

f) Tourism benefit

After the project is completed, the reservoir will provide a broad and clam water area (length: 52.67km), which will greatly improve the environmental conditions of existing scenic spots and also create many new scenic spots for water sports, leisure and sightseeing. This will strongly stimulate the tourism of Yicheng City. After the project is completed, the number of tourists is expected to reach 20,000 in the first year. According to tourism data of Hubei province, the net income from one tourist is 200 Yuan, so the tourism benefit will amount to 4 million Yuan in the first year, which is expected to have an annual growth of 12% in the first 10 years and have an annual growth of 8% later.

On this basis, we can get that the economic internal rate of return is 10.47%, larger than the preset social discount rate 8%, and the accumulated economic net present value will be 461.66 million

Yuan, larger than zero. This demonstrates that the project will bring good economic benefits.

11.1.2 Social benefits

This project is a large-scale infrastructure project. Its main purpose is to provide services to the public rather than earning profits.. After the project is implemented, the section of Han River waterway upstream from Yicheng will be upgraded and larger ships will be allowed to go through this section. This lays a good foundation for further upgrade of the waterway and the construction of Xianggui Canal (from Xiang River to Gui River).

No fee will be levied on the ships going through ship lock. Revenue of the hub mainly comes from electricity generation. Extra expenses for water logging drainage along river bank, urban drainage & sewage and water quality monitoring, water treatment at water intake and reservoir levee maintenance should be paid by the benefited areas.This project will greatly improve the shipping capacity of Han River and even the overall transportation capacity of Hubei province, and especially promote the cargo transportation from and to Hunan province. It will facilitate the development of shipping industry in Hubei province and bring new hope and good returns to the shipping enterprise in distress and their staff.

This project will accelerate urban construction of Yicheng City, improve its investment environment and greatly promote the economic development of this city and even the area upstream.

Both the dam area and the reservoir area have spectacular and beautiful sceneries and they can be developed for tourism, entertainment and leisure to bring more jobs to local residents. Local residents also can develop aquaculture to increase family income. In addition, the project will improve waterway protection, reduce flood prevention pressure and financial pressure of downstream areas on both banks, provide water for downstream farmland irrigation and promote virtuous circle of downstream agricultural ecology. The rise of water level of the reservoir will decrease the cost of urban water supply and farmland irrigation.

This project will greatly improve the shipping capacity of Han River and even the overall transportation capacity of Hubei province, and promote the cargo transportation from and to Hunan province and especially foreign trade transportation. It will in turn facilitate the development of shipping industry in Hubei province and bring new hope and good returns to the shipping enterprises in distress and their staff.

11.1.3 Ecological benefits

According to the power load, characteristics and planning of Hubei electric power system in 2015, Yakou Shipping Hub can effectively replace the thermal power station of equivalent capacity. After the project is completed, the hydropower station will supply 358.2 million kW·h to Hubei electric power system annually, equivalent to 229,600t coal consumption of a thermal power station annually. Given that coal price is 300Yuan/t, the cost of coal consumption is 68.88 million Yuan, which means cost saving due to construction of hydropower station. Given that the consumption of standard coal is 330g/kW·h and carbon (C) content of standard coal is 60% and considering atomic weight conversion of carbon (C) and oxygen (O), CO_2 emission of thermal power station is136,800t, that is to say, the construction of hydropower station will decrease CO_2 emission by136,800t. Given that sulfur dioxide emission is 6.5g/kW·h and sulfur content of standard coal is 1.97%, SO_2 emission of thermal power station is 4,300t, that is to say, the construction of hydropower station will decrease SO_2 emission by 4,300t. The construction of hydropower station also avoids pollution from waste water, gas, residue and heat produced by thermal power station. In other words, the implementation of the project will reduce non-renewable energy consumption and prevent pollution thus incurred. Therefore, the project has great environmental benefits and consists with the requirements of sustainable development.

The soil and water conservation measures proposed in the project will raise soil infiltration rate, mitigate surface erosion by rainwater, improve soil and water conservation, reduce the loss of organic matters in soil such as nitrogen and phosphorus, restore surface vegetation, and effectively curb deterioration of site conditions. It's expected that soil and water loss will decrease by 93,000t after these measures are carried out.

This project will improve surface runoffs by decreasing floods and increasing common waters; improve physiochemical property of soil and increase content of organic matters and oxygen in soil;

increase regional vegetation coverage and improve regional microclimate and ecological environment.

Construction of fishways and stock enhancement and releasing measures will mitigate project impact on fish resources and this will promote the research on artificial breeding technology of some key protected fishes and commercial fishes. Large investment in soil and water conservation and biological protection, about 50% of total environmental protection investment, will generate good biological and environmental benefits. Above all, the project has obvious environmental benefit and the monetized annual environmental benefit amounts to 295 million Yuan.

11.2 Analysis of environmental loss

Environmental loss of the project refers to the loss resulting from environmental impacts of reservoir inundation and project construction. In order to restore local social and biological environment, resettlement and mitigation measures have been planned and the cost of the measures has been listed out. According to the replacement cost approach, environmental loss should be based on the cost of these measures.

11.2.1 Loss incurred from reservoir inundation and permanent land acquisition

We investigated the physical indicators affected by reservoir inundation and land acquisition and the existing production or living conditions of the resettled residents, and according to relevant state policies, regulations and technical specification and in the principle of not reducing their production or living standard, we made plans for resettlement of residents and demolition or reconstruction of special facilities and made an cost estimate. According to our estimate, at the normal water level of 55.22m, total cost for the inundated area amounts to 419.2859 million Yuan, of which compensation for resettled residents is 67.8668 million Yuan, cost of restoration/reconstruction of special facilities is 65.8621 million Yuan, cost of protection works is 165.1864 million Yuan, reservoir bottom cleaning cost is 143,300 Yuan, and other cost is 32.049 million Yuan.

11.2.2 Environmental loss

Proper mitigation measures, especially soil and water conservation, should be proposed on the basis of project construction characteristics and adverse impact analysis, and the environmental protection facilities should be designed, be constructed and operate simultaneously with the design, construction and operation of Yakou Shipping Hub Project. According to our estimate, total cost of mitigation measures amounts to 273.0125 million Yuan.

To sum up, the environmental loss of the project totals up to 591 million Yuan.

11.3 Analysis conclusion

The aforesaid analysis shows that the monetized annual environmental benefit amounts to about 295 million Yuan and the total environmental loss amounts to about 591 million Yuan, but the former is on annual basis while the latter is on lump-sum basis, so environmental benefit is far larger than environmental loss. In addition, the project will promote optimization of power network, development of aquaculture and tourism and adjustment of industrial structure and greatly stimulate local social and economic development.

The implementation of mitigation measures will minimize the economic loss incurred from the adverse environmental impacts of the project. In conclusion, this project is feasible from the perspective of the economic benefit and loss of environmental impacts of the project.

12 Public Participation and Consultation

12.1 Objectives

The construction of Han River Yakou Shipping Hub Project plays a role in the revitalization of local social economy, but it would also bring some negative effects to the local ecological environment. Therefore it’s also very important to encourage the stakeholders to participate in the construction activities to make sure that the environmental impacts do not affect the living and working of the PAPs and gain consensus for environmental protection in order to promote project construction.

12.2 Participating groups and methods

12.2.1 Participating groups

The participating groups include the following:

a) PAPs

They are mainly the residents from Oumiao County of Xiangcheng District of Xiangyang, Dongjin County of Xiangyang District, and six towns (subdistricts) include Liushui, Nanying, Wangji, Zhengji, Yancheng, and Xiaohe of Yicheng, which are involved in the reservoir inundation and construction area of the project. In the selection of public representatives, extensiveness and randomness are concerned, and factors such as region, gender and age structure, culture structure and occupation composition are taken into account.

b) Political groups and enterprises

They mainly refer to the local governmental departments and democratic parties in the areas related to project construction, such as Yicheng municipal government, Xiangyang municipal government, Liangxian’s NPC, CPPCC, Environmental Protection Bureau, Water Conservancy Bureau, Land and Resources Bureau, Agricultural Bureau, Forestry Bureau and Immigration Bureau, Yicheng’s Youth League Committee, Women's Federation and Running-water Companies, and the township governments involved in the reservoir inundation, etc.

12.2.2 Participating methods

In order to exchange ideas about the potential environmental impact of project construction with people from all walks of lives, as well as ensure good communication with the public, the following three methods have been taken in the public participation:

a) Participation of political groups and enterprises

The participation of the political groups is mainly by knowing the views of the local governments, NPC and CPPCC as well as the related departments and enterprises involved in project construction by holding discussion meetings, interviews, consultations and other ways, and learning about the attitudes of the local governments towards project construction through political groups.

b) Participation of experts and scholars

The participation of the experts and scholars is mainly by listening to the experts and scholars' opinions and suggestions about environmental factors identification, evaluation and mitigation measures of project construction through expert review, discussion, consultation and direct participation in the EIA, and taking full use of the experts and scholars' knowledge and experience to provide advice and guidance to EIA.

c) Participation of PAPs

The participation of the PAPs is mainly by way of filling the public participation questionnaires, the main participants of which include the residents in the construction area, around the reservoir area and who need to relocate; besides, site discussion meetings are held in the construction area to introduce the project, the possible beneficial and adverse effects of project construction, the measures taken against the adverse effects to the public, and then the opinions and suggestions of the public are carefully consulted and recorded.

12.3 Public participation process

Considering the requirements of "*Interim Procedures on Public Participation in Environmental Impact Assessment*" and project realities, public participation during the EIA is carried out mainly in the form of project information disclosure, public questionnaire surveys and public discussion meetings. The main process of public participation in environmental impact assessment is as follows:

From Aug. ~ Sept. 2012, the Yicheng government hold an EIA discussion meeting with relevant political groups and institutions, introducing the contents and procedures of EIA and listening to the requirements on environment protection, etc. Questionnaire surveys and face-to-face interview were carried out in the project-affected areas to collect public opinions and suggestions, meanwhile, information on EIA was posted on the Yicheng Municipal Government Network and Yicheng as well as Liushui and Zhengji where the dam locates. The first-round public participation was completed in success.

From Aug. ~ Sept. 2014, after the completion of EIA preliminary report, the second-round disclosure of the project EIA was conducted on the Yicheng Municipal Government Network (with an abridged version of the EIA report); concerning that local people don't have a good access to the internet, a visit to the towns and villages around the reservoir areas was conducted and public announcement was posted to guide people on how they can get the abridged version of EIA report; meanwhile, discussion meetings, questionnaire surveys and visits were carried out in 8 villages and towns around the construction areas and reservoir areas involved in project construction to listen to the public opinions and suggestions towards the environmental impact of project construction to further collect the opinions of the public. The second-round public participation was completed in success.

12.4 Results and analysis

12.4.1 Discussion meetings

The discussion meetings is an important way for knowing the public opinions for the EIA of the project. According to relevant provisions of the *Notice on Strengthening Risk Prevention on Strict Environmental Impact Assessment Management* (UNCED [2012] No. 98) and the *Interim Procedures on Public Participation in Environmental Impact Assessment*, the PIU holds several public participation discussion meetings respectively in Yicheng and Xiangyang in Aug. 2014. They have asked for the opinions and suggestions of the local authorities at all levels, 9 towns involved and village representatives on the project construction and EIA.

12.4.1.1 Yicheng Public Participation Discussion Meeting

a) Process of the meeting

The Yicheng Public Participation Discussion Meeting on Yakou Shipping Hub Project Environmental Impact Assessment was held in the conference room on the sixth floor of the Yicheng Municipal People’s Government at 3:00 pm on Aug. 7th, 2014. It was attended by the county government, the CPPCC, NDRC, Forestry Bureau, Environmental Protection Bureau, Land and Resources Bureau, Water Conservancy Bureau, Tourism Bureau, Department of Communications, Construction Bureau, Department of Cultural Affairs, as well as village representatives of 6 towns including Liushui, Nanying, Wangji, Zhengji, Yancheng, and Xiaohe.

The meeting was chaired by the office secretary-general of the Yicheng municipal government. The PIU introduced the basic information about Yakou Shipping Hub Project. The EIA unit, the Zhongnan Engineering Corporation Limited, PowerChina introduced the EIA progress of the project, and introduced the main content and mitigation measures of the EIA as well as public participation and public opinions and suggestions, the potential environmental risks of the project. The attendees proposed corresponding opinions and suggestions on environmental issues involved in project construction and environmental protection of the project.

Yicheng Yakou EIA public discussion meeting

b) Main issues proposed on the meeting

The attendees expressed their views and put forward corresponding opinions and suggestions on environmental issues involved in project construction and environmental protection in the project, which could be summarized into following aspects:

1) The attendees acknowledged the work done by the EIA unit and PIU. They thought that the content of EIA was comprehensive, while the environmental impact prediction and evaluation was facts-based, and the mitigation measures were effective. Nevertheless, they hope that the implementation of such mitigation measures be carried out in strict compliance with the plan.

2) The attendees are supportive towards the project construction since they agree that the project will benefit the local economy and people's livelihood. They suggested PIU to solicit more opinions on infrastructure construction such as the transformation project and immersion treatment in the reservoir area.

3) The attendees thought that the project construction had truncated the spawning migration channels of the "four major Chinese carps", so that compensation measures should be taken.

4) During the project operation, the river velocity slows down, and the self-purification capability of water decreases, so that the reservoir may inundate livestock farms and a large number of arable land, which may cause the increase of ammonia nitrogen and CODcr content of reservoir water, and the degradation of the water quality; at the same time, many floaters in reservoir area will be accumulated, so that the strengthening of water quality monitoring in the reservoir area and floaters clean-up are needed.

5) The attendees are concerned about the impact of project construction on the water environment, air, transportation, etc., and worry that the damage on vegetation due to excavation may harm the ecological environment. They suggested the PIU to strengthen management and coordination, and include any issues of noise problem or traffic interference be included in the report, and take countermeasures in a timely manner.

6) The attendees showed general concerns on land acquisition and resettlement, and proposed the need for full attention to the resettlement. They thought that the primarily proposed inundation standards are too low to protect the legitimate rights and interests of the DPs in the reservoir, and dike safety issues and water logging phenomenon in the reservoir area will be very prominent in the future,

leading to serious impact on farmlands. Moreover, the effective production of the DPs will significantly reduce; while the functioning of old conservancy facilities such as farmland water conservancy and transportation in the reservoir will be severely affected.

c) Problem solving

1) During the project design, we should attach great importance to public requirements, and design in strict accordance with the relevant policies and technical specifications, and focus on communication with the stakeholders. The PIU is recommended to implement mitigation measures in accordance with the requirements of the Environmental Impact Report approved and "three simultaneous" principles of mitigation measures, and strengthen the monitoring of the environmental management and the implementation of measures during the construction.

2) Local departments should supervise the project construction and operation to ensure that the mitigation measures are funded and implemented.

3) The reservoir bottom should be cleaned and disinfected before the impoundment. Compared with the similar projects, ammonia nitrogen and CODcr indicators will not increase significantly because of inundated land after impoundment. In order to prevent floaters deposition, a floating trashrack with underwater trash holding depth of 1.2m is put in the upstream of the inclined trashrack at the entrance of the hydropower station to intercept the floaters, which are salvaged and cleaned up timely.

4) The corresponding countermeasures have been put forward in the report to deal with the impact on ecological environment, wastes and noise pollution generated in the construction, which can minimize the impact on the residents living in the surrounding area. Requirements and suggestions such as optimizing construction technologies and construction scheduling are proposed for blasting work to reduce noise, and suggestions such as traffic control, addition of traffic signs and making full use of special outbound traffic roads are proposed for improving construction traffic.

5) The PIU has been actively coordinating with local planning departments, water supplies department and other related departments for renovation of reservoir embankments, sluice gates, flood diversion channels and pumping stations.

12.4.1.2 Xiangyang Public Participation Discussion Meeting

a) Process of the meeting

The Xiangyang Public Participation Discussion Meeting on the EIA was held in the conference room on the fourth floor of the Xiangyang Municipal People's Government at 9:00 am on August 9th, 2014. It was attended by the county government, CPPCC, NPC, Environmental Protection Bureau, Immigration Office, Forestry Bureau, Construction Bureau, Agricultural Bureau, Bureau of Culture and Sports, as well as the People's Government of Xiangcheng, Xiangyang and Yicheng.

The meeting was chaired by the director of the Xiangyang Department of Transportation. The PIU, the Port and Shipping Administration in Communications Department of Hubei Province introduced project. The EIA unit, the Zhongnan Engineering Corporation Limited, PowerChina introduced the EIA progress of the project, and introduced the main content and mitigation measures of the EIA as well as public participation and public opinions and suggestions, the potential environmental risks of the project. The attendees proposed corresponding opinions and suggestions on environmental issues involved in project construction and environmental protection of the project.

Xiangyang Yakou EIA public discussion meeting

b) Main issues proposed on the meeting

The attendees expressed their views and put forward corresponding opinions and suggestions on environmental issues involved in project construction and environmental protection in the project, which could be summarized into following aspects:

1) The attendees acknowledged the work done by the EIA unit and PIU. They thought that the

content of EIA was comprehensive, while the environmental impact prediction and evaluation was facts-based, and the mitigation measures were effective. Nevertheless, they hope that the implementation of such mitigation measures be carried out in strict compliance with the plan.

2) The attendees thought that the adverse effects of the project could not be ignored. The rare fish resources and fishery water production will be affected; the spawning grounds of fish, the migration of fish, shrimp and crab as well as the production and life of fishermen will be affected. They recommended to restore the spawning grounds of fish and build artificial fish breeding farms; the compensation measures for fishermen should be implemented in accordance with the "Fisheries Law of People's Republic of China " and Article 27 of the province.

3) The attendees expressed their support for the construction, however, after the construction of the reservoir, the river velocity slowed down; the self-purification capability of water decreased; and the water quality in the reservoir was not so good, which might lead to algal bloom.

4) After the impoundment of Cuijiaying and Wangfuzhou Reservoir in the upstream of Han River Yakou, the issue of temporary farmland inundation becomes prominent, and the inundated area is much larger than expected, while compensation standards on the regard lack legal basis. It is suggested that the temporary inundation compensation should be considered and reflected in the project construction.

c) Problem solving

1) During the project design, we should attach great importance to local requirements, and design in strict accordance with the relevant policies and technical specifications, and focus on communication with the stakeholders. The PIU is recommended to implement mitigation measures in accordance with the requirements of the EIA and strengthen the monitoring of the environmental management and the implementation of measures during project construction.

2) Regarding the changes of water quality in the reservoir during project operation, water quality in the reservoir is predicted. It is considered that the rise of water level, and slow down of flow rate may reduce concentration of pollutants in the reservoir, and stop the deterioration of water quality in water intake, so that the drinking water is safe.

3) Regarding the changes of Han River fish stocks and impact on four Chinese carp spawning grounds, according to the findings of the Ecologic Institute of Water Engineering of Chinese Academy of Sciences, the impact of project construction on the Han River rare fish stocks is very limited, and the migration of migratory economic fish and four Chinese carps is impeded but not completely blocked. The further of the spawning ground from the dam, the smaller the impact is. In order to protect the fish stocks, fishways as well as breeding and releasing stations are considered to be built in the project construction. As for the compensation measures for fishermen, considering the construction will not lead to the significant decrease in Han River fish stocks, but only will make it more difficult for fishing, the fishing tools of the fishermen will be transformed. Moreover, each fishman will be compensated by 800 Yuan plus professional training on fishing.

The results showed that all the hearing representatives expressed their support for the project construction, and the PIU made solemn commitments on the meetings that it would fully listen to the opinions of the public and enhance communication in project design, and implement the mitigation measures in accordance with the requirements of the EIA to minimize the adverse environmental impacts.

12.4.2 Group survey

12.4.2.1 Group survey

45 "Project Public Participation Questionnaires (social groups)" were distributed (See Attachment 12) to stakeholders including government departments, EPB offices, Water Conservancy Bureau, Agricultural Bureau, Forestry Bureau, Land and Resources Bureau, Construction Bureau, and Bureau of Animal Husbandry and Aquatic Products, and groups such as the Communist Youth Leagues at two levels, the NPC and CPPCC, and Yicheng Tianhe Water Supply Corporation, as well as PAPs from eight township people's government in Oumiao, Dongjin, Liushui, Nanying, Wangji, Zhengji, Yancheng and Xiaohe, and waterworks in the reservoir area; see Table 12.4.2 for survey results.

Table 12.4.2 Group Survey Results

Questions	Main opinions and Suggestions

1. Are there any contradictions and conflicts between the Construction of Yakou Shipping Hub Project and local industry policies, plans or programs?	Two groups think that there are contradictions, but they can coordinate with each other and develop jointly; 43 groups think that the project construction is in line with the requirements of local planning strategy
2. What beneficial effects will the implementation of the Yakou Shipping Hub Project bring on the local social and economic development?	Promote economic growth; promote local industrial restructuring; promote the construction of infrastructures like transport, power and communications; promote the development of tourism, trade, and services; improve living standards of the residents
3. How is the current environment quality surrounding the project site?	Water, acoustic, atmospheric, geological, ecological as well as social and economic environment are generally considered to be good, which shows that various groups are satisfied with the living environment; organizations in Shuisong area express their dissatisfaction towards the atmospheric environment in the residential area
4. What effects will the implementation of the Han River Yakou Shipping Hub Project bring on the local natural environment?	It has little impact on the natural landscape value and terrestrial ecological environment; it may have adverse environmental impacts on the water quality in Han River and aquatic ecosystems; soil erosion and three wastes and one noise need to be governed.
5. How is the relationship between the implementation of the Yakou Shipping Hub Project and sustainable development of the environment, economy and society?	It is generally believed that the project development can promote the coordinated and sustainable development of environment, economy and society, and only Songbai Town Government believes it may hinder regional economic development
6. Do you support the implementation of the Han River Yakou Shipping Hub Project?	45 groups support the project construction, and no one has opposite opinions. They think that there are no other environmental problems in the project construction which may restrict the engineering development, so the project construction is feasible.
7. What suggestions and opinions does your unit or organization have on the resettlement of the Han River Yakou Shipping Hub Project?	Make a resettlement plan based on the national compensation standards and immigration policies, and resettle the imDPs properly, especially arrange well the production land; improve the living quality of imDPs, implement the compensation fees; implement the land area and location.
8. The suggestions and opinions on the environmental protection of the Han River Yakou Shipping Hub Project of your unit or organization	The mitigation measures should be implemented to minimize the adverse environmental impacts; soil and water conservation should be implemented during the construction process to reduce soil erosion; total control should be implemented in the reservoir area, and the new polluting enterprises should be strictly controlled, and supervision and management of the environment around the reservoir should be strengthened; ecological and residential water in the downstream should be adjusted in the dry season; fish stock enhancement and releasing station should be built to supplement the fishery resources.

9. The suggestions and opinions on the Han River Yakou Shipping Hub Project of your unit or organization	Implement the compensation fees and resettlement; protect the ecological environment, and implement water environmental protection and ensure drinking water safety.

Most of the respondents are highly concerned and put forward valuable opinions and suggestions. The major group opinions are summarized as follows:

a) Yicheng Environmental Protection Bureau hopes to that the project implementation complies with national environmental protection policies in the implementation with focus on water pollution control and environmental protection.

b) The opinions of Immigration Office are as follows: the resettlement location should have a good environment, and be equipped with water, electricity and sanitation facilities. The compensation should be paid according to the State's compensation requirements. The compensation shall make sure that farmers' income and living standards be improved to relieve the worries of the PAPs. The later life of the elderly and the employment of young people should be considered and guaranteed.

c) The opinions of the Yicheng Water Conservancy Bureau are as follows: It concerns about the vegetation damage and soil erosion caused by project construction, and puts forward that the compensation for water and soil conservation facilities must be sufficient and paid in full.

d) The Yicheng waterworks expressed their support for the project construction, and thought that the elevation of water level in the reservoir in the low flow season is favorable for water intaking, but the existing pumping equipment and machine pumping stations should be transformed, and protective treatment needed to be done. Because the main water intake located at the upstream of the main outfall Wangjiadagou, they called for more efforts for water pollution and suggested upgrading waterworks as they worried that the intake water quality might be affected by the impoundment of the reservoir.

e) Yicheng Municipal People's Government expressed its support, but it thought that construction must be implemented as planned. For example, project construction and environmental protection should be started as soon as possible; mitigation measures should be taken towards ecological destruction, air pollution and water pollution; greening and ecological restoration, water pollution control and noise control should be conducted; and problems such as farmers' livelihood problems arising from housing demolition and land acquisition should be solved effectively.

f) Xiangyang Land and Resources Bureau put forward suggestions towards resettlement and geological problems. For example, the most stringent farmland protection and land conservation principle should be adhered to, the monitoring of geological disasters should be strengthened, and the effective mitigation measures should be conducted.

12.4.2.2 Group survey analysis

According to the survey results, 100% of respondents held a positive, caring and supportive attitude towards the project construction. They believe that the project construction could make good use of local resource advantages into economic benefits, so as to promote the local economy and create job opportunities.

However, the adverse project impacts are also concerned, such as ecological damage, drinking water safety, arable land occupation, and resident displacement and resettlement. They hoped that the PIU can take effective countermeasures to reduce these negative impacts in an environmentally sustainable manner; the PIU must adhere to the discharge standards, and take into account environmental and social benefits while gaining good economic benefits. For example, as for construction, vegetation restoration should be conducted for the damaged ecological environment; as for resettlement, the PIU should communicate and contact with the local governments and imDPs to create conditions for the smooth implementation of resettlement work.

12.4.3 Individual survey

a) Respondents

530 questionnaires were distributed and 517 valid questionnaires were returned, so the response rate was 97.5%. Please refer to Attached Table 2 and Table 12.4.3-1 for the detailed data of the household survey.

Table 12.4.3-1 Basic information of respondents

Category	Statistics
Items	Occupation

	Civil servant	Cadre	Farmer	Self-employed entrepreneur	Migrant worker	Enterprise employee
Number of people	91	60	282	26	21	37
Percentage	17.6	11.6	54.5	5	4.1	7.2
Items	Education background					
	Illiterate	Primary school	Middle school	High school	Junior college	Regular college
Number of people	2	41	189	121	57	107
Percentage	0.4	7.9	36.6	23.4	11	20.7
Items	Age					
	＜20	21-30	31-40	41-50	51-60	>61
Number of people	8	49	128	221	82	29
Percentage	1.5	9.5	24.8	42.7	15.9	5.6
Items	Category				Gender	
	Construction area	Reservoir area	Immigrant	Others	Male	Female
Number of people	211	165	34	107	431	86
Percentage	40.8	31.9	6.6	20.7	83.4	16.6

b) Findings

Please refer to Table 12.4.3-2 for the collected public opinions. Please refer to Annex 13 for Public Participation Questionnaire.

Table 12.4.3-2 Public Consultation Survey Results

Serial number	Questions	Survey results statistics of each item (Number of people/ (Percentage %))					
1	Have you heard about Han River Yakou Shipping Hub Project? Do you know a lot about it?	No, this is the first time I've heard of it.	13 (2.5%)	I've heard of it, but I don't know a lot about it.	335 (64.8%)	Yes	169 (32.7%)
2	Do you think the project construction is conducive to the local economic development?	Yes	483 (93.4%)	No	15 (2.9%)	No impact	19 (3.7%)
3	Do you think the project construction can improve your quality of life?	Yes	425 (82.2%)	No	75 (14.5%)	It may worsen my quality of life.	17 (3.3%)

4	How do you think the impact of project construction on the Reservoir environment?	It's beneficial for the Reservoir environment.	384 (74.3%)	It has little impact.	118 (22.8%)	It's harmful for the Reservoir environment.	15 (2.9%)
	If you think it's harmful, what does it mainly impact?	Water quality	5	Aquatic organisms	4	Social economy	6
5	What are the major environmental problems where you live?	Air pollution	83 (16.1%)	Noise	39 (7.5%)	Soil erosion	275 (53.2%)
		Outbreak of infectious diseases	0 (0)	Natural disasters	62 (12.0%)	Others	58 (11.2%)
6	What do you think of the impact of the project construction on the production and living water in the downstream of Han River?	It has negative impact.	119 (23.0%)	It has no impact.	371 (71.8%)	It has positive impact.	27 (5.2%)
7	How do you think about the impact of project construction on the environment in the construction area and the surrounding area?	It has great impact.	57 (11.0%)	It has little impact.	342 (66.2%)	It has no impact.	118 (22.8%)
	If you think it has impact, what does the impact mainly refer to?	Water quality pollution	294 (40.8%)	Regional atmospheric dust pollution	57 (7.9%)	Noise nuisance	41 (5.7%)
		Destruction of vegetation intensifies soil erosion	187 (26.0%)	Construction (life) garbage diaspora	58 (7.9%)	Increase of transport vehicles leads to unsafe hidden dangers	83 (5.7%)
8	What do you think are the main environmental impacts during the operation after the Han River Yakou Shipping Hub	Submerge cultivated garden	153 (21.5%)	Destroy the topography and lead to natural disasters such as landslides	33 (4.6%)	Cause soil erosion	137 (19.3%)

	Project is completed?	Destruct forest vegetation	42 (5.9%)	Affect fish's survival	199 (28.0%)	Affect water quality	146 (20.6%)
9	What do you concern most in the project?	Economic Benefits	188 (36.4%)	Environmental Pollution	141 (27.3%)		
		Job opportunities	43 (8.3%)	Compensation for DPs	145 (28.0%)		
10	What do you think about the overall effect of the project construction?	There are many advantages.	317 (61.3%)	The advantages balance the disadvantages.	142 (27.5%)		
		There are more disadvantages than advantages.	37 (7.2%)	There are no advantages.	21 (4.1%)		
11	Do you support the Construction of Yakou Shipping Hub Project?	Support	457 (88.4%)	Neutral	57 (11.0%)	Oppose	3 (0.6%)

*Note: Questions 7 and 8 are multiple choices, so that the total number is selected as the denominator when calculating percentages.

According to the findings, it shows that:

(1) 97.5% of respondents have heard about the Project, and 32.7% of them know a lot about the project, which shows that the local government has played a positive role in the publicity in pre-construction phase and enhanced the local residents' concern on the project, and the public's opinions are based on adequate understanding of the project.

(2) Due to strong publicity of the local government, the local residents have a deep understanding of the advantages and disadvantages generated in the hydropower project. 93.4% of the respondents agree that the project construction is conducive to the regional economic development, and people who hold different views are mainly public representatives affected by the reservoir inundation; representatives from Xiangyang Health Bureau who believe that the project construction may threaten the safety of drinking water; public representatives from Bureau of Animal Husbandry and Aquatic Products who think that the project construction may harm the fish resources.

(3) 82.2% think that the project construction can improve the quality of life of the residents, and 14.5% of the respondents think that the project construction does not bring direct economic benefits to themselves, i.e. it will not significantly improve their quality of life; respondents who think that the

quality of life may deteriorate are mainly individuals directly affected by the inundation, and only a few respondents think that the drinking water quality may deteriorate.

(4) As for the question "What are the major environmental problems where you live", 53.2% chose soil erosion, followed by air pollution, water quality, natural disasters (mainly floods) and noise. The findings show obvious regional differences: respondents who chose soil erosion are mainly farmers in the construction and reservoir area; respondents who chose water quality are mainly from Xiaohe County, while those who chose noise are mainly residents near the Provincial Highway 218 and China National Highway 207 surrounding the construction area.

23.3% think that the project construction has no impact on the surrounding environment, and those who think it has little impact and great impact account for 66.2% and 11.0% respectively. The main impact is the water quality pollution and destruction of vegetation intensifies soil erosion, followed by dust, noise and life garbage pollution.

(5) 74.3% believe that the project construction is beneficial for the reservoir environment, and only 2.9% of the public believe that it’s harmful, as the water quality in the reservoir is likely to worsen, which may restrict the economic development of the individuals or society. 77.0% think that the project construction has no or positive impact on the production and living water in the downstream of Han River, and 23.0% of the public think that it has a negative impact, which shows that the public is a little worried about the water quality in the downstream of the project. As for the question "What do you think are the main environmental impacts during project operation after the Project is completed", the views of respondents are different, such as affecting the water quality and fish’s survival, as well as destructing forest vegetation and causing soil erosion, etc., which indicates that the public have a relatively clear understanding of the environment, and hope that the environmental protection is concerned when conducting project construction.

(6) The respondents concern most about the economic benefits, which account for 36.4%, followed by the compensation for DPs, accounting for 28.0%, and environmental protection takes up 27.3%, while job opportunities account for only 8.3%, indicating that the public in the region have a great environmental awareness. 61.3% think that the project construction has many advantages; 27.5% think that the advantages balance the disadvantages, while 11.3%. think that there are more disadvantages than advantages.

(7) Among the public involved in the survey, 88.4% of the public support the construction of Yakou Shipping Hub Project; 11.0% remain neutral; three people oppose the implementation of the project (there are 10 opponents in the original investigation, and now there are 3 opponents after communication, explanation and instruction), because they are worried that the project construction will intensify the water pollution in the reservoir, and harm the intaking water quality.

Most respondents request that the PIU shall meet pollution emission standards and focus on environmental protection, and local environmental protection department shall strengthen supervision on project operation, to avoid polluting the surrounding environment; resettlement shall comply with the relevant national policies and compensation standards shall make sure that the living standards of the DPs are at least equivalent to or better than pre-project conditions.

12.4.4 Publicity

12.4.4.1 Network publicity

a) Network publicity

According to the provision in CED 2006 [No. 28] "Interim Procedures on Public Consultation in Environmental Impact Assessment" by the State Environmental Protection Administration, our company and PIU published the "First Publicity of Environmental Impact Assessment of Han River Yakou Shipping Hub Project" on the website of Yicheng Municipal People’s Government on August 7, 2012 (see Figure 12.4.4-1); in August 2014, our company and PIU published the "Second Publicity of Environmental Impact Assessment of Han River Yakou Shipping Hub Project" on Chudu Yicheng Network and the portal of PIU (see Figure 12.4.4-2), along with the simplified version of the report to continue to seek the public's opinion.

b) Publicity feedback

Both of the two network publicities last for more than 10 days, receiving two people’s feedback on the project through telephone, mail and other forms. The main view is that the adverse effect of the project on the ecology and environment is mainly in the reservoir area, such as the impact on the ecological environment due to reservoir inundation, temporary inundation and resettlement; and the impact on Reservoir water quality; as well as the impact on the ecological environment due to sediment deposition and downstream water atrophy; and geological disasters such as landslides and bank collapse in the reservoir area. It is recommended to carry out quantitative study on the positive and negative impact of the project construction on the environment, and establish corresponding mechanisms for evaluation and compensation; carry out analogy investigation on the environmental impact of the constructed project, and sum up experience in time.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湖北汉江雅口航运枢纽工程环境影响评价第一次公示

来源： 发布时间：2012-08-07

根据《中华人民共和国环境影响评价法》、《环境影响评价公众参与暂行办法》和《环境影响评价技术导则—公众参与》等相关法律法规与导则要求，汉江雅口航运枢纽工程环境影响评价工作过程中将开展公众参与工作。

一、建设项目概况

1、建设项目名称

汉江雅口航运枢纽工程。

2、建设项目概要

雅口航运枢纽是汉江中下游规划建设的第五级水利梯级枢纽，工程坝址位于汉江中游河段湖北省宜城市境内，上距襄阳市81.58km，距崔家营航电水利枢纽52.67 km，距宜城市区15.7km，坝址控制流域面积13.31万km2，坝址处多年平均流量1487m3/s。水库正常蓄水位55.72m，总库容6.99亿m3，水库具有日调节性能，工程属Ⅱ等大（2）型工程，枢纽主要建筑物由泄水建筑物、电站厂房、通航建筑物

Figure 12.4.4-1 First Publicity of Yakou EIA of Yicheng Municipal People’s Government


落实市委全会精神 突破性发展工业经济
中共宜城市委、市政府主办
站内搜索
投稿信箱
2014年8月19日 星期二
宜城 21℃～32℃ 无持续风向
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市委五届六次全会 重点工作 任务分解方案
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汉江雅口航运枢纽工程环境影响评价第二次公示

发布时间：2014-08-19　来源：楚都宜城网　【字体显示：大 中 小】

根据《环境影响评价公众参与暂行办法》(环发[2006]28号)的相关要求，对云南省汉江雅口航运枢纽进行第二次公示—即雅口航运枢纽环境影响报告书简本信息公示。

一、建设项目概况

1、工程概况

雅口航运枢纽是汉江干流湖北省内梯级开发中的第6级，工程坝址位于汉江中游河段湖北省宜城市境内，上距襄阳市81.58km，距崔家营航电水利枢纽52.67 km，距宜城市区15.7km。

雅口航运枢纽坝址控制流域面积13.31万km2，坝址处多年平均流量1100m3/s。水库正常蓄水位55.22m，相应库容3.502亿m3，具有日调节能力，渠化Ⅲ级航道52.67km，船闸设计通航船舶吨级1000t，电站装机75.6MW，多年平均发电量3.24亿kW·h，为Ⅱ等大(2)型工程。枢纽主要建筑物由船闸、泄水闸、电站厂房、鱼道、土石坝等组成。工程开发任务以航运为主，兼顾发电、灌溉、旅游等综合利用效益。项目总占地9126.18hm²，其中永久占地8751.87hm²（包括水库淹没区面积8494.12hm²），临时占地374.31hm²。按占地类型划分，其中耕地3059.65hm²，园地7.85hm²，林地1827.95hm²，草地16.99hm²。项目静态总投资31.54亿元。

2、环评主要结论

雅口航运枢纽工程建设对促进汉江航运开发、带动沿岸地区社会经济发展，提供就业机会，改善人民生活水平，改善库区生态环境都具有积极作用。项目的主要不利影响：库区水文条件变化改

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- 孔湾镇开展乡村环境卫生综合整治
- 王集镇实施"三线"促廉政

Figure 12.4.4-2 Second Publicity of Yakou EIA on the Chudu Yicheng Network

湖北省交通运输厅港航管理局
湖北省地方海事局
湖北省船舶检验局

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关于湖北省港口企业安全生产标准化考评二级达标企业（第四批）名单的公示 (2014-07-02)
湖北省江汉运河航道管理处2014年专项公开招聘工作人员公告 (2014-06-20)
关于乙级港口危险货物安全评价机构备案的公示 (2014-06-20)
关于湖北省港口危险货物安全管理专家库（第一期）拟聘任专家名单的公示 (2013-12-03)
省地方海事局关于公布2013年度第1期内河船员适任计算机终端考试成绩的通知 (2013-07-05)
关于做好港口危险货物安全评价机构备案工作的通知（5月31日前备案） (2013-05-21)
关于面向社会征集专家建立湖北省港口危险货物安全管理专家库的通知 (2013-05-21)
湖北省地方海事局关于兴隆水利枢纽二期截流施工航行通告 (2013-03-28)
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湖北省水路交通条例 (2013-03-28)
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省地方海事局关于公布2012年度第1期内河船员适任计算机终端考试成绩的通知 (2013-03-28)
省地方海事局关于公布2012年第1期船员适任计算机终端考试（补考）及消限考试成绩的通知 (2013-03-28)
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汉江雅口航运枢纽工程环境影响评价第二次公示

发布时间：2014-08-18 【字体：大 中 小】 浏览次数：23

根据《环境影响评价公众参与暂行办法》（环发〔2006〕28号）的相关要求，对湖北省汉江雅口航运枢纽进行第二次公示—即雅口航运枢纽环境影响报告书简本信息公示。

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2、环评主要结论

Figure 12.4.4-3 Second Publicity of Yakou EIA on the Portal of the Port and Waterway Administration of Hubei Provincial Department of Transportation

Figure 12.4.4-4 Second Publicity of Yakou EIA on the website of the Xiangyang Environmental Protection Bureau

12.4.4.2 Field publicity

a) The first publicity

Considering that the local residents seldom surf the Internet, and it’s difficult for them to obtain information on the environmental impact assessment of the project from the network, therefore, in August 2012, at the beginning of the EIA, we and the PIU posted the first announcement in residents-concentrated regions involved in the project to notice the basic information of the project and preliminary environmental impact analysis as well as the receiving method of opinions on the environmental impact while conducting the first publicity on the network.

The contents of the first field publicity include the general situation of the proposed project, impact of the project construction on the environment, mitigation measures to prevent and mitigate environmental impact, findings of environmental impact assessment, method and time for the public to consult the abridged edition and supplemental information, scope and major issues of soliciting opinions from the public, specific form and time of soliciting opinions from the public, and the contact information of The PIU and evaluation unit.

b) The second publicity

In August 2014, after the completion of intermediate achievement of the environmental impact report, the second announcement was posted in residents-concentrated regions involved in the project. The main contents of the announcement include the general situation of the project, potential impact of the project construction on the environment, mitigation measures to prevent and mitigate the adverse environmental impact, the main conclusions of the environmental impact assessment, method and duration for the public to consult the abridged version of the environmental impact report. It’s pointed out that the abridged version of the environmental impact report is put on the designated websites, and the public can visit the websites to view at: http: //www.yichengnews.com/ and http://www.hbghj.gov.cn/hbwz/goverment/index.jhtml.

Field publicity in Oumiao County

Field publicity in Xiaohe County

Field publicity in Zhengji County

Field publicity in Wangji County

Field publicity in Nanying Street

Field publicity in Liushui County

Field publicity in Yakou Village

Field publicity in Maocao Village

Figure 12.4.4-5 Photos of field publicity in counties in the Reservoir

It clarifies the scope and major issues of soliciting opinions from the public and the main methods for the public to provide suggestions. The public can contact with The PIU or environmental impact assessment agency by e-mail, fax, letter, etc., and send back public consultation questionnaires and replies or submit written opinions. The duration for the public to provide suggestions is within 15 days after the publicity of the public consultation in environmental impact assessment.

c) Public feedback

As for the field publicity, only part of the public express their hope for the earlier construction of the Yakou Shipping Hub Project and participation in the project construction, and no people feeds back or consults the information by phone or mail.

12.4.4.3 Newspaper publicity

While publicizing on the internet, The PIU, the Port and Waterway Administration of Hubei Provincial Department of Transportation publicized the main contents of Yakou Shipping Hub Project Environmental Impact Assessment and the brief report in Xiangyang’s most influential print media - "Xiangyang Daily" (January 20, 2015 edition).

Public notice on environmental impact in Xiangyang Daily (online edition)

古隆中演义酒业襄阳市区2015年双节订货会活动启幕

为感谢新老客户的厚爱，1月18日，"元春贺岁欢乐派 礼送抽奖喜羊洋——湖北古隆中演义酒业襄阳市区2015年双节促销订货会"襄城西片区活动在襄城壹家臻品酒店成功举行。此次订货会有200余名经销商和特约商到场，场面气氛十分火爆，就此拉开了襄阳市区双节订货会的序幕。

订货会现场气氛热烈，有的经销商在咨询活动，有的在选购产品，有的在积极打款，有的在领取抽奖券……"订货会上的优惠幅度较大，还能抽大奖，让我们的的确确得到了真实惠。"经销商李先生紧紧攥着手中的一沓抽奖券高兴得合不拢嘴。另一位经销商王先生一次性订购了20余万元的产品："这次订货会举办的正是时候，双节期间亲朋好友相聚，古隆中演义酒市场需求很大，我们正好要备货满足市场需求。"

在订货之后，古隆中演义酒业不仅根据经销商订单额度设置一等奖、二等奖、三等奖，还有定满即送活动，同时，现场进行随即抽奖，经销商们个个满载而归。经销商潘女士仅随即抽奖就被抽中了3次："真是太开心了，企业说到做到，非常诚信。这也是我坚持多年和古隆中演义酒合作的最大原因。"

古隆中演义酒业襄阳市区公司总经理谢勇表示，襄阳市区市场订货会将陆续举办襄城西、襄城东、樊城西、樊城中、樊城东共五场，活动现场提供的产品非常丰富，促销手段多种多样，价格比平时订货也有不少优惠，将为各位经销商冲刺双节市场，打下坚实基础。

据了解，2015年刚开年，湖北古隆中演义酒业有限公司喜报频传：金星、李玉琴等7人蝉联湖北省"评酒委员"；董事长郭力荣获"湖北省十大优秀青年企业家"称号；"襄江"品牌荣获首批"湖北老字号"称号。

新的一年，湖北古隆中演义酒业有限公司将继续在产品的品质、企业的品牌、企业社会形象和企业文化等方面多做工作，为经销商和消费者提供优质产品、优质服务，为合作商家提供具有价值提升空间的品牌和平台。

（张海江 魏晓晓）

经销商踊跃下订单。

汉江雅口航运枢纽工程环境影响评价第二次公示

根据《环境影响评价公众参与暂行办法》的相关要求，对湖北省汉江雅口航运枢纽进行第二次公示——即雅口航运枢纽环境影响报告书简本信息公示。

一、建设项目概况

雅口航运枢纽是汉江干流湖北省内梯级开发中的第6级，坝址位于宜城市境内，上距襄阳市81.58km。工程渠化III级航道52.67km，船闸设计通航吨级1000t，电站装机74.2MW，项目静态总投资31.54亿元。

本工程建设对促进汉江航运开发，带动沿岸地区社会经济发展，提供就业机会，改善人民生活水平，改善库区生态环境都具有积极作用。其不利影响包括库区水文条件变化改变鱼类栖息环境，枢纽建设阻隔鱼类洄游；施工产生水土流失、"三废"及噪声影响等。工程建设将对不利影响采取相应的环境保护措施予以缓解或消除，如采取鱼类增殖放流、栖息地保护、修建鱼道、梯级联合生态调度等鱼类综合保护措施减缓鱼类的影响；采用水土保持措施对水土流失进行控制等，从环境保护角度，工程的建设是可行的。

二、征求公众意见的范围和具体形式

征求意见范围：征求公众对本项目环境保护方面的意见，非环境保护方面的内容不在本次征求范围内。

征求意见的具体形式：在"湖北省港航管理局网站"发布报告书简本供公众阅览，征求相关意见。主要征求公众对项目区域环境质量的看法；对目前区域范围内存在的主要环境问题的认识；该项目建设过程中可能存在的环境问题；对本项目环境保护工作的建议；对本项目建设的态度。

三、公众意见反馈方式和起止时间

公众可在公示期限内，以电子邮件、信函方式向环评单位反馈意见，并请注明"雅口航运枢纽公众意见"。

环评单位：中国电建集团中南勘测设计研究院有限公司

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联系人：冯红武 电话：027-83465254

邮箱：474124651@qq.com

公众在发表意见时，请尽量注明日期、您的真实姓名和联系方式，以便根据需要向您反馈。

起止时间：本公告发布之日起10日内(信函以邮戳日期为准)。

Public notice on environmental impact in Xiangyang Daily (newspaper edition)

Figure 12.4.4-6 Publicity of Yakou EIA and the abridged edition in Xiangyang Daily

From January 20, 2015 to the printing and publishing of the report, The PIU and EIA unit haven't received the public's feedback on the publicized contents.

12.4.5 Other forms

12.4.5.1 Government regulation

a) In order to ensure that the standard implemented in the environmental impact assessment meet the functional requirements of the environment in the project area, not causing environmental pollution accident, the CSADI requested the Environmental Protection Bureau of Hubei Province to confirm the environmental quality standards and pollutant discharge standards required to be executed in the environmental impact assessment.

b) City, county and town government departments at all levels in the project area provided census data on forest, agriculture and water conservancy, as well as social economic, land use and epidemic statistics and medical health information for environmental impact assessment.

12.4.5.2 Expert advice

In order to ensure the rationality of the project construction, domestic authoritative experts were repeatedly invited to participate in the interim report review of the project's feasibility, relevant special reports consultation and special consultation review.

During the edition and perfection of the report, in-depth analysis had been made on the issues that experts concern, and reflected in the report.

12.4.5.3 Special Collaboration

The completeness of approval process is another important aspect to analyze the legality of the project, See table 12.4.5 for the current progress of the approval of relevant topics of the project.

Table 12.4.5 List of research situation of Han River Yakou Shipping Hub Project

Serial number	Report name	Preparation unit	Progress
1	Geological Hazard Assessment Report of Construction Land of Han River Yakou Shipping Hub Project	Hubei Provincial Communications Planning and Design Institute	Approved
2	Overlaid Minerals Evaluation Report of Construction Land of Han River Yakou Shipping Hub Project	Hubei Geological Survey	Approved
3	Seismic Safety Evaluation Report of Han River Yakou Shipping Hub Project	Wuhan Institute of Earthquake Engineering	Approved
4	Soil and Water Conservation Assessment Report of Han River Yakou Shipping Hub	Hubei Provincial Water Resources and Hydropower	Compiled

	Project	Planning Survey and Design Institute	
5	Demonstration Report of Water Resources of Han River Yakou Shipping Hub Project	Changjiang Water Resources Commission	Compiled
6	Flood Demonstration and River Stability Assessment Report of Han River Yakou Shipping Hub Project	Changjiang Water Resources Commission	Compiled
7	Cultural Relics Survey Assessment Report of Han River Yakou Shipping Hub Project	Hubei Provincial Institute of Cultural Relics and Archaeology	Approved
8	Waterway and Navigation Safety Demonstration Report of Han River Yakou Shipping Hub Project	Hubei Provincial Communications Planning and Design Institute	Compiled
9	Labor Safety and Industrial Hygiene Pre-assessment Report of Han River Yakou Shipping Hub Project	Beijing Institute of Occupational Disease for Chemical Industry	Compiled
10	Power Access System Report of Han River Yakou Shipping Hub Project	Hubei Electric Engineering Corporation	Compiled
11	Project Safety Pre-assessment Report of Han River Yakou Shipping Hub Project	Beijing Zhongan Quality Assessment Center, Central Technology	Compiled
12	Overall Hydraulic Model Test of Hub of Han River Yakou Shipping Hub Project	Tianjin Research Institute for Water Transport Engineering, M.O.T.	Accepted
13	Social Stability Risk Assessment Report of Han River Yakou Shipping Hub Project	Hubei Provincial Communications Planning and Design Institute	Compiled

For more scientific, objective and fair reflection of environmental problems generated in the Construction of Yakou Shipping Hub Project, and guarantee of the authenticity and authority of the evaluation results, cooperation and consultation have been conducted with the School of Life Science of Wuhan Imagination Technology Development Co, Ltd. and Institute of Hydroecology, MWR & CAS on the professional topics in the environmental impact assessment, and the research results have been introduced into the environmental impact report.

12.4.5.4 Social risk assessment

In September 2014, The PIU commissioned the Hubei Provincial Communications Planning and Design Institute to carry out the investigation and preparation of the "Social Stability Risk Assessment Report of Han River Yakou Shipping Hub Project". In the process of the investigation on social stability risk, the investigation unit designed two questionnaires "Questionnaire Investigation of the Public on Social Stability Risk" and "Interview Investigation of Units on Social Stability Risk" in accordance with the social survey method of the Han River Yakou Shipping Hub Project, which were respectively for the questionnaire investigation of the public and interview investigation of local primary-level organizations.

a) Questionnaire Investigation of the Public on Social Stability Risk

The questionnaire investigation had the function of dividing regions and population. Different regions and population were divided to know the opinions and suggestions on the Construction of Han River Yakou Shipping Hub Project of people from different social classes and regions. Main issues covered in the questionnaire included: land acquisition and demolition, environmental pollution, travel disruption, public security, etc. In addition to the special issues, comments column was also designed to solicit public opinions on the project construction and enrich the coverage of social risk analysis to avoid missing issues. 313 copies of "Questionnaire Investigation of the Public on Social Stability Risk" were distributed, and all of them were taken back. 92.97% of the respondents supported the construction, and only 0.64% of them opposed the construction, and the respondents who kept neutral or opposed were mainly villagers and residents in the project area, because they thought that part of the land would be submerged, leading to the land acquisition and demolition, which would bring adverse effect on production and living. However, through effective communication, they supported the project under the premise of getting proper land acquisition and compensation for house demolition and better arrangements. They required the project construction to minimize the impact on their production and lives.

b) Interview Investigation of Units on Social Stability Risk

The questionnaire was mainly designed to get knowledge of the opinions and suggestions on the Construction of Han River Yakou Shipping Hub Project of the town government along the project line, village committees and the relevant functional departments, as well as put forward mitigation measures on the potential issues in the project construction, such as land acquisition and demolition, environmental pollution, travel disruption, social security, etc. Comments column was also designed to solicit public opinions and avoid missing issues. 18 copies of "Interview Investigation of Units on Social Stability Risk" were distributed, and all of them were taken back. All the units being investigated expressed their support for the project construction.

As for the potential problems in the project, such as land acquisition and demolition and environmental protection, primary-level organizations said that they would collaborate with The PIU to deal with the problems related to the vital interests of the public in a just, fair and open way in accordance with the relevant policies and regulations. Most government departments also made mitigation measures to deal with the possible conflicts and disputes, and actively prepared to study the relevant emergency plan.

12.5 Opinions and suggestions of public consultation

12.5.1 Public opinions and suggestions

The vast majority of the public believed that the project construction was beneficial for the local socio-economic development, so they supported project construction, but they thought that environmental protection needed to be attached importance in the project construction to reduce the negative impact on the environment. Many groups and individuals put forward some helpful opinions and suggestions, mainly include:

(1) Closure and rehabilitation of sewage outlet in the reservoir area, and collection of sewage to sewage plant through the city pipe network.

(2) Regular salvage of floaters in the reservoir area to ensure the safety of water intake there.

(3) Reduction of reservoir impoundment and power generation, scientific control of water discharged downstream to ensure the ecological water demand of the downstream and maintain river health during the dry season.

(4) Regular monitoring of water quality (it's better to establish the ten-day reports system of water quality), and establishment of water pollution warning system.

(5) Standardized regulation on the banks of the reservoir area to protect the safety of the levee.

(6) Protection of wetland in the Reservoir, and minimizing the exploitation of marshland.

(7) With the completion of the reservoir dam, the hydrologic condition in Han River changes a lot, which leads to the changes of the living environment of fish and other organisms. The four fish spawning grounds originally in the reservoir area move down or disappear. According to the "Fisheries Law of the People's Republic of China", compensation should be given by The PIU to build the new fish breeding base in Han River.

(8) After the completion of Yakou reservoir, the reservoir water exchange becomes weaker, and the water quality in the middle reservoir becomes worse due to the pollutants discharged from the main tributaries such as Xiaohe industrial parks in the upstream, which may affect the safety of water intake in the reservoir.

By summarizing public opinions and suggestions, we can find that public concerns focus on three aspects: reservoir inundation compensation, water environmental impact and aquatic ecological impact.

(1) Reservoir inundation compensation

The public in the dam sites who opposed the construction mainly because they were worried about the land acquisition, demolition and relocation were not put in place, and the compensation was little, which would damage the interests of individuals. After considering public opinions, The PIU, the Port and Waterway Administration of Hubei Provincial Department of Transportation said the compensation would be made according to the relevant provisions of resettlement, not harming the interests of the local residents.

Resettlement as well as reconstruction or compensation for special facilities need to be conducted for construction area and reservoir inundation. In terms of resettlement, the DPs hope that the government will determine the compensation standards of land, housing and other physical indicators, and formulate the resettlement policy according to the actual situation, and it will publicly announce the DPs, solicit their opinions, and ensure their production and living funds are put in place; it is hoped that the government will solicit public opinions and carry out the corresponding training in accordance with the DPs' knowledge level and technical capacity when formulating the follow-up support policy; in terms of reconstruction or compensation for special facilities, DPs' opinions should be taken into consideration when determining compensation standards, and the status and development of DPs should also be taken into account in the construction scale, location, and technological innovation of other enterprises, what's more, reconstruction for special facilities should be conducted in accordance with the DPs' opinions and meet their living and development needs. The reclamation and requisition-compensation balance of the land occupied temporarily should be implemented after the completion of the construction.

(2) Water environmental impact

The project construction will inevitably affect the surrounding environment. During the investigation, almost all of the public say they can overcome the impact, and they recommend taking effective measures to jointly protect the local environment.

As for the problem that the public are worried about the intake water quality will be polluted, water environmental impact prediction is conducted, which finds that the Reservoir water quality will not deteriorate if the pollution intensity remains the same. And with the implementation of Han River water pollution remediation project in Hubei, the pollution intensity in the reservoir area will decrease a lot. The prediction indicates that by the implementation of Han River water pollution remediation project, the intake water quality can be maintained at least at the current level in the operation of Yakou Shipping Hub.

(3) Ecological environmental impact

After the completion of Yakou Shipping Hub, migratory fish stocks in rivers and lakes continue to decrease, and the production of four major Chinese carps continues to decline. The project construction will reduce the exchange between fish in rivers and lakes, which will lead to changes in the fish population structure. Fishes which love to live in flowing water will decrease, and fishes which like to live in still water will increase gradually, so the amount of overall fish stocks will not reduce. The Yakou Shipping Hub discharges smoothly during the flood period, so that some fishes can be traced back to the dam. Therefore, the hub may impede but not block the migration of the fish stocks.

12.5.2 Adoption of public opinions

As for public opinions and suggestions, the PIU promised that they will respect the public's opinions to protect the environment and maintain social harmony and stability. A statistical analysis will be conducted to know the public's cognition of the construction of Yakou Shipping Hub, as well as their opinions and concerns. The PIU will reflect the public opinions and suggestions to the design institute, make decisions to whether to accept or reject the suggestions, and disclose the results and reasons to the local public; as for public concerns, it should put itself in the public's position and take effective measures to relieve public concerns in accordance with national policies and related specifications, and the public interest should be taken into account throughout the whole process of the design, construction and operation of Yakou Shipping Hub.

According to the opinions of the investigated groups and public, major concerns of the project include: changes in reservoir water quality and the corresponding impact on water supply and drainage; inundation of woodland and farmland; and impact on fish stocks, etc.

The above public opinions are adopted in the EIA and the solutions are implemented in the project design and mitigation measures, notably the following:

a) The opinions and suggestions related to resettlement are reflected to the construction contractor and the resettlement planning department, and public opinions should be given full consideration in the preparation of resettlement plan. The EIA report proposed that issues of resettlement and the corresponding infrastructure planning must be implemented in strict accordance with relevant regulations of the state and Hubei Province. The PIU also promised to audit resettlement funds according to the resettlement plan and the state, and allocate the funds to resettlement offices promptly to properly solve resettlement problems and minimize the impact on the normal production and life of DPs, as well as give a satisfactory answer to the DPs.

b) Concerns about the ecological environment quality and environmental protection of the project will be reflected in the environmental impact report as much as possible to define the project's impact nature, scope and extent, and propose mitigation measures to reduce the adverse environmental impacts. In addition, environmental monitoring, environmental supervision, as well as environmental management and planning are also formulated to reduce the adverse environmental impacts. As for the environmental impacts that are hard to be determined in this stage, it's advised to further study them in the next stage.

According to the survey results of public opinions and environmental status, "eco-environmental impacts, water environmental impact, soil erosion and soil and water conservation" are emphasized in the evaluation process, and corresponding mitigation measures, environmental management and monitoring plan are proposed to deal with the adverse impacts. Therefore, the environmental issues of public concern are answered in the report, and given full consideration in the project design. As long as they are monitored and implemented in the project construction, it will minimize the adverse effects of construction on the environment.

(1) Changes in reservoir water quality and the corresponding impact on water supply and drainage

This suggestion has been taken into full account in the report. The overall change in water quality and water quality of each water intake after building the reservoir are analyzed and calculated, and changes in water quality after building the reservoir are analyzed by prediction; targeted measures are also proposed in the mitigation measures of environmental protection, such as avoiding pollution of the water quality in the reservoir area by the governance of all types of sewage and waste in the construction and operation period; Yakou Reservoir Xiang Deng Fertilizer Plant has newly built sewage treatment facilities, and the sewage will not be discharged into the ditch until it reaches the standard, so it has little impact on downstream water intakes. It’s proposed in the report that sewage outlets cannot be set up near the water intake, and the total amount of the existing pollution sources should be controlled.

(2) Noise and other impacts

As for noise, dust and other environmental pollution generated in the construction, the corresponding mitigation measures have been put forward in the report to minimize the impact on the surrounding residents; and noise impact doesn’t exist in the operation period.

(3) Inundation of woodland and farmland

While the construction brings benefits such as power generation, shipping and promoting tourism, the reservoir will inevitably inundate the woodland and farmland, causing some damage. The actual situation has been taken into full account in the project design, and measures such as Reservoir bank protection project and land protection project have been adopted, which greatly reduce the inundated area, and minimize the impact.

(4) Impact on flood bank

Issues such as soaked flood bank and flood control safety in low-lying areas due to the raise of water level after impoundment have been fully considered in the project design. The heightening and consolidating of flood bank in low-lying areas have been considered in the project implementation plan, and anti-seepage treatment has been implemented in some places to ensure that the flood control safety in the two banks of the Han River will not be affected after impoundment.

(5) Recovery of fish stocks

As for the impact on fish stocks that some groups concern, our company has also commissioned a professional unit, the Institute of Hydroecology, MWR&CAS to carry out a special survey in preparation of the EIA, and conduct analysis and impact assessment combined with the long-term data. After comprehensive judgment, we officially send a letter to The PIU to restore the fishway design, and the design unit has modified the junction layout, and increased fish pass; as for the mitigation measures, measures such as fish breeding and releasing as well as tracking and monitoring are proposed to minimize the adverse impact on fish stocks.

12.6 Conclusions of public consultation

12.6.1 Legality of public consultation

Public consultation is conducted in strict accordance with the relevant provisions in "Interim Procedures on Public Consultation in Environmental Impact Assessment" (CED [2006] No. 28) in the environmental impact assessment of Yakou Shipping Hub, and the relevant information of project environmental impact assessment is publicized promptly, and public opinions are solicited.

At the beginning of the environmental impact assessment in the feasibility study stage of Yakou Shipping Hub, The PIU, the Port and Waterway Administration of Hubei Provincial Department of Transportation conducted the first project information publicity on the Yicheng Municipal Government Network from August 18 to August 28, 2012; meanwhile, EIA information was posted in Yicheng as well as Liushui and Zhengji where the dam locates; from August 16 to August 26, 2014, The PIU conducted the second project and EIA information publicity on Chudu Yicheng Network and the portal of PIU, at the same time, The PIU publicized the main contents of environmental assessment and the brief report in eight villages and towns involved in the project by posting.

Meanwhile, The PIU and evaluation unit investigate the public's opinions on the project construction by two methods in August 2014, including the public consultation in the discussion meetings and distributing the public consultation questionnaires.

Therefore, the process and content of public consultation in the project EIA was legal.

12.6.2 Effectiveness of public consultation

Given that the local economic development level in the Yakou Shipping Hub was not high, and the educational levels of the respondents differed greatly, two information publicity forms were adopted in the project, namely: posting announcement in the information bulletin board of the primary-level organizations, and publicizing project and EIA information on Yicheng Municipal Government Network (Chudu Yicheng Network for the second time). Yicheng Municipal Government Network and Chudu Yicheng Network were local mainstream media platforms, which played a good role in promoting the public consultation in the project EIA. During the public consultation process, public consultation questionnaire (individuals) and public consultation questionnaire (groups) were distributed, and the abridged edition of EIA Report was publicized to solicit public opinions. Various forms of public consultation were also adopted, such as public consultation in the discussion meetings and soliciting public opinions in written form. In summary, the forms of public consultation in the project EIA was effective.

12.6.3 Representativeness of public consultation

After publicity of the second project and EIA information, The PIU and evaluation unit solicited public opinions on the project construction by distributing public consultation questionnaires. Public opinions were collected among relevant government departments, community organizations and the public in three counties and nine towns involved in the Yakou Shipping Hub Project. 487 public consultation questionnaires (individuals) were taken back, and the questionnaires could be divided into two types, questionnaire of construction affected area and Reservoir affected area according to different types of impacts to solicit public opinions in affected areas involved in the project. 45 public consultation questionnaires (groups) were taken back, covering almost all administrative departments in Xiangyang and Yicheng.

Therefore, as Yakou Shipping Hub EIA involved in government departments, community organizations and the public in two levels of governments in Xiangyang and Yicheng and 9 towns, so the respondents were very representative.

12.6.4 Authenticity of public consultation

The public consultation surveys in the project EIA were completed with the coordination of the local government and the participation of the PIU and evaluation unit, especially staffs of the evaluation unit conducted various analysis and communication on the scene for many times. The respondents had fully understood the information of the questionnaire before filling in the public consultation questionnaire, so the survey results met the requirements of authenticity. The publicity of environmental information and distribution of public opinion questionnaire were conducted in strict accordance with the relevant requirements. The publicity contents accurately reflected project-related information; the working process was transparent and efficient; and the survey results were real and reliable.

To sum up, public consultation in Yakou Shipping Hub was in strict accordance with the relevant requirements of the "Interim Procedures on Public Consultation in Environmental Impact Assessment" and "Notice on Strengthening Risk Prevention on Strict Environmental Impact Assessment Management" (CED [2012] No. 98).

13 Feasibility study report

13.1 Compliance with the planning

The project is a hydro-project encouraged by the "Guiding Catalogue of Industrial Structure Adjustment (2011)" issued by National Development and Reform Commission (revised in 2013), therefore it is in line with national industrial policies, as well as the shipping planning of Yangtze River and requirement of Hubei inland navigation development.

The implementation of the project can promote the rational use of water resources of the Han River, promote restructuring of the energy consumption, guarantee the supply of urban water resources along the Han River and it is consistent with socio-economic development goals of the Province. The project construction also complies with the national eco-functioning requirements as well as the requirements on environmental protection of Hubei Province during the twelfth "five-year period".

Moreover, the project adjusted the dam site to comply with the requirements in the *Review Comments on the Retrospective Report on the Environmental Impacts of Hydropower Development in the Middle and Lower Reaches of Han River* , therefore it is in line with the *Integrated Planning Report on Han River*.

13.2 Project feasibility

13.2.1 Construction feasibility

According to the FSR, the river conditions, transport, water, power and materials supply for the project are all satisfactory for project construction; the construction technologies for low-head hydro-junction are quite mature so that there are no technological limits; moreover, the project-involved river section is highly navigable with little sediments and few slopes to guarantee smooth navigation of construction ships; the project also satisfies the legal requirements on flood control, environmental protection, and water conservancy after certain measures are taken. In a word, there exist no technological, environmental or legal limits on the project.

As an infrastructure project, the project has low profitability but it is financially viable and solvent, needless to mention its great economic and social benefits. Therefore, this project is economically feasible. Moreover, once completed, the 52.67 km waterway will significantly improve the navigation capacity, which will also improve the comprehensiveness of the local transportation network. It also creates job opportunities for residents of Xiangyang City and Yicheng City. For instance, it may attract migrant workers to participate in project construction. Moreover, project construction and operation will also promote tourism development and bring new sources of income for local residents. This will promote educational and cultural development of local region, and improve the livelihood of local residents. Therefore, this project is both technologically and socially feasible.

13.2.2 Dam site selection

Dam site is located 15.7km downstream of Yakou City, Xiangbei Farm. The dam site ensures that upstream and downstream water connects well with each other; it also considers the requirements on urban landscaping and water environmental improvement to gain greater social benefits.

Laojiang Ditch and Yidaoo Ditch, two urban sewage ditches are both located in the downstream of the dam, therefore the rise of reservoir water level will not affect urban drainage; although reservoir water velocity slows down and self-purification capacity decreases, the water quality has little change due to fewer pollutants, which has no impact on water quality of water intakes of Yicheng water plants; sluice gates are scattered while the largest backwater dam height is 0.28m, which facilitates flood discharge and reduces water pollution risks during high flow periods; Due to rise in water levels, Wanyangzhou national wetland park enjoys a larger water area and wetlands, which is conducive to the protection of wetland resources, and it has a positive impact on ecological protection.

Construction disturbance area is small and it also occupies a small area of vegetation; it only produces a relatively small amount of soil erosion; the Guanjiashan and Dengjiatan spawning grounds of fish with pelagic eggs are also located in the downstream of the dam, which is respectively 13.5 km and 61.8 km away from Yakou Dam site. The implementation of ecological operation through the spawning period can substantially maintain the ecological functions of the spawning grounds; the dam is located downstream of the city, while the reservoir area is in the county, which improves the scenic view of the county and promote the local development. Moreover, it is line with the *General Urban Planning of Yicheng City*, therefore it is environmentally feasible.

13.2.3 Resources utilization and environmental carrying capacities

a) Resources

1) Land resources

This project is expected to cover an area of 6,996.62 hm^2 in total, of which the hub management area occupies 13.69hm^2 and the reservoir inundated area occupies 6852.61hm^2. But in the project, some land belongs to non-construction land, with total area of 143.18hm2, distributed at Zhengji, Liushui, Kongwan, Liuhou, Nanying, Wangji and Xiaohe. This is inconsistent with the general land use planning of Yicheng City and adjustment should be made. Land reclamation from residential area is necessary to ensure zero increase of total quantity of construction land. Overall, after adjustment, the total quantity of construction land of Yicheng City won't be influenced by the project.

Land use structure should be adjusted based on land characteristics and current land use status in accordance with Yicheng municipal social and economic development strategy. This will promote the reasonable and intensive use of land, prevent redundant construction and industrial structure convergence, coordinate urban and rural economic development, and promote industrial agglomeration.

2) Water resources

The water resources within the river section of the project is mainly used for power generation and shipping. The project adopts the Class II water quality standards, and all the waste water is reutilized after treatment, therefore causing little impact on the water quality; the water utilization during project operation only uses the potential energy of water resources, which has no impact on the water volume and quality, therefore it will not change the water conditions in the project-involved river section and downstream.

Since the dam ensure good connection between upstream and downstream waters, it will not result in dehydrated section; moreover navigation conditions are significantly improved; the water use for power generation and shipping needs do not waste or pollute water, and it will not change the total amount of water resources of Han River.

3) Energy resources

As an energy conservation project, the major energy consumption of the project is during the construction period. Total energy consumption is 44.685 million kWh, and the consumption of diesel is 7176.9t. The equipment used for this project is also highly efficient and in line with the energy conservancy requirements and the national industrial policies.

The installed capacity of Yakou Shipping Hub is 74.2MW, and the annual electricity generation capacity is 253 million kWh. Calculated as per standard coal consumption of 320g/kWh, the power station project will reduce the coal consumption by 80,960 tons of standard coal every year, equaling to reducing CO_2 emission by 212.1 tons every year); meanwhile, the project may reduce SO_2 emission by 690 tons at least every year. After Yakou Shipping Hub is completed, 52.67km-long waterway will be canalized, and the waterway grade will be raised to 1000t grade from 500t grade, the waterway navigation capacity and the operating benefits of the ships will be increased, the shipping will develop towards large size, standardization and serialization, and the oil consumption will be dramatically reduced, which may reduce the consumption of non-renewable resources such as petroleum and coal.

From the above analysis, it can be seen that the land, water and energy resources are sufficient to support the project construction.

b) Environmental carrying capacity

1) Water

According to the water quality measurement by Shenzhen CTI in Aug. 2013, only the content of dissolved oxygen and total nitrogen exceed Class II standards. Wastewater and sewage are treated and reutilized for dusting and greening, thereby will not affect the water quality of the Han River.

2) Air

Environmental monitoring results show that the hub area has a sound air quality of Class II standard specified in *Ambient Air Quality Standard* (GB3095-1996). The impact of the project on ambient air is mainly in the construction period, mainly caused by blasting, construction machinery operation and transport vehicles, etc., the main air pollutant is TSP. Since the construction area is located in the plain, which has good ventilation, construction will not lead to the deterioration of air quality.

3) Solid waste disposal

Solid waste includes living waste, spoil and construction waste. The project sets up a garbage collection system in the living area, so that wastes are stacked together and transported outside for centralized disposal. The spoil from excavated earthwork is stored in the spoil site and its disposal complies with the requirements on water and soil conservation, therefore the project will not result in environmental impact.

Based on the above analysis, water pollutants discharge is rather limited. As long as waste water treatment is conducted as required, it will not adversely affect the water quality of the Han River.

13.2.4 Engineering feasibility

a) Design of normal water level

Based on the comparative study of three designs of 54.72m, 55.22m, 55.72m, the normal water level is determined as 55.22m, and this is determined by comprehensively considering all the important factors and requirements of the project: shipping requirement, water connection, reservoir inundation, energy indexes, investment and budgeting, etc.

After completion of the project, all the three designs had no effect on the navigation of Han River Bridge and Cuijiaying flood control; however, from the perspective of urban flood control, since the current alert water level for the city is 55.47m, therefore it is better that water level is within the alert level (55.47 m); from the perspective of shipping needs and hydro-energy, a higher water level is better but it will also results in significant reservoir inundation and more reservoir protection works; from the shipping perspective, 55.22m and above is relatively better; from perspective of energy efficiency and project investment, 55.72m is most advantageous.

According to the table, there is little difference among normal water level schemes in terms of hydrological regime, water temperature, water quality, inundation and relocation and fine. The lower the normal water level, the less the ecological environmental impact, and the less the impact of relocation resettlement on social economy. Each scheme doesn’t involve natural reserves, scenic spots or other sensitive areas, and the dam doesn’t involve drinking water source protection zone. There is no obvious difference in environmental impact, which is not the factor restricting the selection of normal water level. Therefore, based on the comprehensive analysis of reservoir inundation reduction and economical efficiency, the normal water level of Yakou Shipping Hub Reservoir is recommended to be 55.22m.

b) Shipping scale

According to the *National Planning on Inland Waterways and Ports* (FGJY [2007] No. 1370, Development Planning on Inland Shipping (2002- 2020) (EZBH [2005] No. 21), and the *Reply to Construction Plan of High-grade Waterways for Han River and Jianghan Canal* (FGJC [2012] No. 3043), *Comprehensive Planning on Yangtze River Basin* (2012 ~ 2030) (GH [2012] No. 220) and *Comprehensive Planning on Han River*, the shipping waterways of Han River are classified as: Yangxian ~ Ankang Class V, Ankang ~ Danjiangkou Class IV, Danjiangkou ~ Hankou Class III.

The waterway regulation projects already completed or being implemented in the section of Han River from Xinglong to the river mouth all adopt grade-III(2) design standard that allows the passage of 1000t ships (fleet). The Cuijiaying navigation-power junction already constructed and the Xinglong water conservancy hub being constructed both choose the grade-III(2) ship locks, which allow the passage of the fleet of 1000t ships in the formation of one push boat and four barges in two rows and two lines. The ship locks at Xinji and Nianpanshan hubs are expected to be built as per also grade-III(2) standard. It is forecast that after Yakou Shipping Hub is built, the cross-dam freight volume will reach 7.837 million tons in 2020 and 12.421 million tons in 2040. Based on the above situation and according to the waterway construction plan for the middle and lower reaches of Han River, Yakou Shipping Hub is built as per grade-III(2) standard. It is expected that the annual one-way cross-dam freight volume will reach 6.8 million tons in the short term and 11.01 million tons in the long term. Given that the effective dimension of lock chamber is 180×23.0×3.5m, the ship lock can meet the needs in the short term and in the long term. Technical parameters, e.g. dimensions of waterway and ship lock, will be defined as required by the Navigation Standard of Inland Waterway (GB50139-2004).

To sum up, the grade-III(2) design standard of waterway and ship lock conforms to the overall planning, the navigation planning and the high-grade waterway construction plan of the Han River, the technical parameters, e.g. dimensions of waterway and ship lock, meet the requirements of relevant standards, and therefore the overall design of the project is rational.

c) Rationality analysis of hydroelectric generation

According to the Comprehensive Development Planning on Han River, the recommended installed capacity of this project is 80MW.In the feasibility study stage, three options for the installed capacity, i.e. 64.2 MW, 74.2 MW and 84.2 MW, were provided, and after comparison, 74.2MW was recommended.

We know that the full-load flow rate of Cuijiaying Hydropower Station at upstream is 2232m3/s. For Yakou Shipping Hub, the full-load flow rates will be 1931m3/s or

2670m3/s when the installed capacity is 64.2 MW or 84.2 MW, the former is smaller and the latter is greatly larger than that of Cuijiaying hydro-junction; When the installed capacity is 74.2MW, the full-load flow rate will be 2291m3/s, which is most harmonious with that of Cuijiaying hydro-junction.

With the increase of the installed capacity, annual power generation capacity will increase, althrough the increase is small, so larger installed capacity is favored; From the perspective of capacity benefit and energy benefit, the installed capacity may be properly increased; With larger installed capacity, the investment per kW will be smaller and the extra investment for the increment of the installed capacity is reletively small, so larger installed capacity is favored; with the increase of the installed capacity, annual cost will increase, so in this regard, smaller installed capacity is favored.

Considering that the benefits and economic indicators of 74.2 MW most approach the optimal design and its flow rate best match with that of Cuijiaying hydro-junction at upstream, the recommended installed capacity in feasibility study stage is 74.2MW, which is close to 80MW recommended in the Comprehensive Development Planning on Han River.

13.3 Feasibility analysis of environmental protection targets

13.3.1 Environmental impacts resulting from constructing key hydro-junctions along Han River

Before the Feasibility analysis of the environmental protection targets established for this project, a preliminary analysis on the long-term cumulative environmental impacts of constructing key hydro-junctions along Han River should be carried out. This chapter cites the conclusions of the environmental impact prediction and evaluation after all the hydro-junctions are constructed in the *Retrospective Report on the Environmental Impacts of Hydropower Development in the Middle and Lower Reaches of Han River*.

a) Impact on water regime

After all the seven hydro-junctions in the middle and lower reaches of Han River are constructed, namely Danjiangkou, Wangfuzhou, Xinji, Cuijiaying, Yakou, Nianpanshan and Xinglong from upstream to downstream, and in combination with the South-to-north Water Diversion Project, water regime will be greatly influenced, mainly form of water, water level, flow velocity and flow rate. Due to the South-to-north Water Diversion Project, the width of water surface in the middle and lower reaches of Han River will decrease except Shayang section where the width of water surface will increase (because water level in this section will be raised due to the construction of Xinglong hydro-junction). The construction of the hydro-junctions along Han River has very small influence on major control cross-sections. The flow rate of the mainstream in the middle and lower reaches of Han River mainly depends on the discharge volume from Danjiangkou reservoir, and in general, the flow rate decreases from upstream to downstream. The flow duration of the mainstream tends to be homogenized (longer at dry season and shorter at median water period).

b) Impact on water environment

Due to the influence of the South-to-north Water Diversion Project, the flow rate decreases in the middle and lower reaches of Han River and this results in great loss of water environmental capacity. The construction of the hydro-junctions along Han River will aggravate the loss. According to our preliminary calculation, after the implementation of the South-to-north Water Diversion Project and the construction of the hydro-junctions along Han River, the loss of water environmental capacity of the mainstream for COD, ammonia nitrogen and TP in the middle and lower reaches of Han River will be 64,218t/a, 4,561t/a and 132t/a respectively. The loss of water environmental capacity mainly focuses on the section from Danjiangkou dam to Gaoshibei. Gaoshibei is the mouth where water is transferred from Yangtze River into Han River, so the loss of water environmental capacity is small in the section downstream from Gaoshibei.

After all hydro-junctions along Han River are constructed (in combination with the South-to-north Water Diversion Project), it predicts that except Baijiawan cross-section, water quality at all other cross-sections in the middle and lower reaches of Han River can't reach the preset water quality standards. At the river section upstream from Cuijiaying hydro-junction, the water quality reaches the standard for drinking water source, but at the river section downstream from Cuijiaying hydro-junction, the water quality can't reach the standard for drinking water source, because at most of these drinking water sources, the ammonia nitrogen content in water exceeds the specified limits. After carrying out some measures, e.g. improving sewage collection and treatment capacity of sewage disposal plants and enhancing pollution abatement in rural areas, the loss of water environmental capacity resulting from the construction of hydro-junctions along Han River and the water diversion project may be made up to ensure the water quality at drinking water sources.

c) Impact on aquatic ecology

After Danjiangkou dam is heightened and the water transfer project from Danjiangkou reservoir is completed, the decrease of discharge volume and the discharged low-temperature water will have great influence on the fishes in the middle and lower reaches of Han River. The construction of hydro-junctions will reduce such influence to a large extent. With the area increase of the reservoirs, water flow gets slow and water gets deeper. This is good for wintering and feeding of fishes. Such water environment is very suitable for the fishes inhabiting in standing water. The population size and biomass of these fishes will increase and the species structure will be greatly changed.

After all hydro-junctions are completed, the reservoirs and dams will adversely influence the breeding and migration of the fishes laying pelagic eggs. If no measures are carried out, the size of spawning grounds for four Chinese carps and some rare fishes such as elopichthys bambusa, ochetobius elongatus (Kner) and Luciobrama macrocephalus will reduce and the hatching rate will decrease. Specifically, the size of Yicheng spawning ground will be reduced due to Yakou hydro-junction, the size of Zhongxiang spawning ground will be reduced due to Nianpanshan hydro-junction, Maliang spawning ground will be submerged by Xinglong reservoir, but the Zekou spawning ground will suffer small impact.

With the area increase of the reservoirs, water flow gets slow and water gets deeper. This is good for wintering and feeding of fishes. Such water environment is very suitable for the fishes inhabiting in standing water. The population size of these fishes will increase.

Overall, the construction of all hydro-junctions in the middle and lower reaches of Han River will have effects on the aquatic ecological environment in the middle reaches, so proper engineering and management measures should be taken to mitigate the effects and protect the diversity of species.

d) Impact on terrestrial ecology

The construction of all hydro-junctions in the middle and lower reaches of Han River will cause small losses of vegetation, mainly cosmopolitan species and common species, but won't lead to extinction of species. The construction of hydropower stations and the impoundment of reservoirs will compress the living space of animals and their living conditions will therefore get worse, but this won't threaten their survival. The impounded reservoir will attract a large number of waterfowls and amphibians inhabiting at standing water, so the population size and individual number will increase significantly.

13.3.2 Feasibility analysis of environmental protection objectiveness

The EIA indicators are divided into three types, i.e. environmental indicators, resource indicators and environmental management indicators. Some indicators can't be quantified, so the Feasibility analysis is conducted only for those quantifiable indicators.

a) Ecological environment

1) Occupancy rate of the habitat of important species: in this project, no alternative solution can be provided to avoid important ecological reserve. This is the big difference between waterway development projects and land-based projects. This project involves no natural reserves, scenic spots or germ plasm resources protection areas, but the occupation

of wetland and important habitats is inevitable. The proposed occupancy rate of the habitat (15%) refers to the maximum occupancy rate of water area during project construction.

2) Protection rate of rare and endangered species: Project planning should reach the required protection rate. Reducing project impacts on the protected areas and trying to reach 100% protection rate of rare and endangered species is the comprehensive goal of environmental protection work and great efforts should be made during project construction to achieve this goal.

3) Protection rate of important commercial fishes: Construction of hydro-junctions changes water regime and therefore affects the spawning ground, wintering ground and feeding ground of fishes, so proper measures, such as enhancement and releasing, fish passage facilities and ecological compensation, should be carried out to mitigate the influence.

b) Eater environment

1) Water quality and water environment carrying capacity: Proper measures, such as building urban sewage disposal plants, improving urban sewage treatment rate, strictly controlling industrial pollution sources and abating agricultural non-point source pollution, should be carried out to decrease pollutant discharge, improve water environment quality and restore the water environment carrying capacity.

2) Sewage treatment rate and sewage recycling rate: 100%. This goal can be achieved. Sewage and wastewater produced during project construction will be treated and reused for project construction or for plants irrigation and dust removal at the construction site; the ship sewage will be collected and won't pollute water; other necessary measures may also be carried out by port authority.

3) Safety of drinking water source: Insurance rate of water supply safety should reach 100%. After the sewage treatment measures and the prevention measures for drinking water sources are carried out, the water quality of drinking water source will be ensured.

c) Acoustic environment

During project construction, walls may be built and trees may be planted to reduce noise and the workers may wear earplugs to prevent the damage caused by noise.

The manufacturing and navigating technology of ships may be improved to reduce the noise of sailing ships.

d) Ambient air

Proper measures, such as wetting construction, road maintenance and watering, should be carried out to effectively reduce dust pollution and improve the ambient air quality. The ambient air quality at both sides of waterway mainly depends on local economic and social development level. The increased exhaust emission of ships resulting from waterway promotion has very small impact on regional ambient air quality and won't change the regional air environmental function.

d) Solid wastes

A pond is built at construction site for storage of household wastes, and the wastes will be transported out by Yicheng Municipal Environmental Sanitation Bureau and be buried at Nanzhou refuse landfill. The solid wastes generated by ships will be collected and transported to the solid wastes disposal station. Solid wastes disposal rate should reach 100% and the hazard-free disposal rate should reach 100%.Other proposed measures for wastes collection and disposal should be carried out at port.

f) Environmental management level

1) Implementation rate of environmental impact assessment: to reach 100% through the environmental protection management work at early stages.

2) Implementation rate of ecological environmental protection design: 100% implementation rate can be achieved by carrying out management measures at the design stage;

3) Inspection and acceptance of environmental protection after the project is completed: the 100% conformance of environmental protection with relevant requirements can be achieved by enhancing the environmental protection control during project construction.

4) Operation period management, emergency response systems: a establish

comprehensive environmental management system, a sound emergency planning system shall be formulated. Thus, a 100%-management requirement of environmental protection can be achieved. Ship, waterways, ports and local authorities shall develop the transport system of liquid chemicals and a comprehensive risks emergency plan of ships, ports and waterway systems, controlling risk rate and reducing the environmental impact of accident risks.

13.4 Environmental restraints

Generally speaking, shipping projects are far away from land regions such as forest parks and geological parks, therefore posing no adverse impacts on forest parks and geological parks. However, it involves aquatic organisms in the water and the capacity of water environment. Thus, the engineering construction of the navigation junction of Yakou mainly has several restrictive factors mainly such as a barrier effect on the "Four major Chinese carps" living in the Han River mainly to the Han River and inadequate carrying capacity of local water environment.

a) Carrying capacity of water environment in Han River

According to the pollutant carrying capacity analysis, lakes and reservoirs have weaker diluting and transporting capacity of COD and ammonia nitrogen than rivers, due to slower water flow rate of formulated reservoir and deepened depth of water, which results in small reoxygenation rate and thus leads to weaker pollutant carrying capacity after the reservoir is formulated. However, according to resources support and utilization analysis, there are both environment capacity for COD in actuality year and the planning years within the evaluation scope. Basing on the calculation results of water environment capacity, the water environment capacities of COD and ammonia nitrogen in the reservoir area are 2996t/a and 368.8T/a respectively, which is both above the annual emission volumes of ammonia nitrogen and COD. It can be found that there are still some water environment capacities of Han River after the completion of Yakou project. However, the total volume of nitrogen is out of limits, which is easy to cause eutrophication and high attentions need to be paid to this problem.

b) Aquatic ecosystem of Han River

From the features of the river habitat distribution, most bottomland within has bottom materials such as mud and gravel while gravels and pebbles are rare. Accordingly, aquatic, hygrocolous and terricolous vegetations are relatively rich in the bottomland. Spawning grounds with fishes laying adhesive eggs are especially rich after hygrocolous and terricolous vegetations are flooded during the water-rising stage. The damage of hygrocolous and terricolous vegetations is relatively low after the completion of Yakou hydro-junction. Spawning grounds with fishes laying adhesive eggs can be maintained, which poses little impacts on the breeding of fishes laying adhesive eggs.

However, the water regime will change as the construction of hydro-junction goes on. Hydrological and hydraulic conditions required by the breeding of fishes with pelagic eggs. In recently year, Han River basin has been through continuous droughts and Danjiangkou reservoir has long been operating on low water level. Water inflow in September 2014 was relatively abundant, but reservoir blocked flood peak discharge with basically no discharge due to the official water passing of South-to-North Water Transfer. Flood peak process of the middle and lower reaches of Han River was mainly dependent upon flood from Tangbai River, and the already limited flood peak discharge was attenuated by Cuijiaying reservoir area leaving only about 1600m^3/s. There was basically no flood peak process after attenuation by Xinglong reservoir area. After official operation of South-to-North Water Transfer, the current hydrological regime change could be the new norm. In addition, the water flow in the reservoir area rate slows down after the formation of Cuijiaying reservoir and it becomes hard for pelagic eggs to flow down alongside the dam because of the slow flow rate of drifting. It also led to resource reductions at monitoring points in the early stages.

On one hand, the construction of the Xinglong hydro-junction located in the middle and lower reaches of Han River blocked the passing of fishes living in the lower reach of

Han River and the main streams of Yangtze River, which is below the Zekou area, to migrate to the middle and lower reaches of Han River. The Cuijiaying hydro-junction, on the other hand, blocked the passing of fishes living in waters below the dam to mitigate to the spawning grounds located in the Miaotan above the dam and the tributary of Tangbai River. Even though fish ways have been constructed in order to ease the barrier effect, blocking effects still exist. The blocking effect will be intensified further after the completion of Yakou junction and the breeding conditions of fish with pelagic eggs will deteriorate further.

During the flood, the hub can not regulate runoff process, but have fading effect to small flood process; it has limited impact to fish reproduction of pelagic eggs in the downstream, but has effects of inundation to spawning grounds of fish with pelagic eggs. According to hydrological forecasting results, only in the situation of hub discharge spawning grounds in reservoir area can play a role; at the same time, when breeding in discharge, parent fish can enter spawning grounds in reservoir area through sluice to participate in breeding, which is very beneficial to protect and restore spawning grounds in reservoir area; but even part of mature parent fish can enter the middle and lower reaches of Han river for spawning, with the construction of Danjiangkou reservoir and hydraulic and hydroelectric complex at middle and lower reaches of Han river, it causes water habitats at middle and lower reaches of Han river in dramatically shrinking, drifting reproduction process of fish eggs is not enough and unable to complete life course. Thus, according to inflow conditions of water discharge in Danjiangkou and interval water inflows, especially the conditions of floods in Tangbai River and South River, 2 times joint ecological regulations in the cascade below the Danjiangkou of Han River will be conducted in fish breeding seasons which are from May to August annually. When the flood discharges during high flow years and normal flow years reach the level of $600m^3/s$ and the flood discharges in low flow years reach the level of $300m^3/s$, water flows between Danjiangkou and Huangzhuang will be utilized, the flows for power generation in Wangfuzhou and Xinji will be increased and three junctions including Cuijiaying, Yakou and Xinglong will join into the open discharge for 5-7 days until the flood peak ends.

Only under the circumstance that joint ecological operation of the hydro-junctions below the Danjiangkou of Han River are strictly implemented and open discharges are made in junctions of Cuijiaying, Yakou and Xinglong during breeding periods of fishes, can the natural river state be restored and thus hydrological and hydraulic conditions required for fish with pelagic eggs to breed be met, mitigating adverse effects of the construction of junctions accordingly.

To sum up, the overall layout and scale of the construction contents are reasonable from the perspective of environmental protection under the circumstance that those two aspects of environmental constraints of this engineering construction list above are properly resolved.

13.5 Overall environmental feasibility

In November, 2013, *Review Comments on the Retrospective Report on the Environmental Impacts of Hydropower Development in the Middle and Lower Reaches of Han River (Letter from EPB* [2013] No. 1273) issued by the General Office of the Ministry of Environmental Protection conclude that the hydro-junction construction of Yakou and Nianpanshan will cause obvious adverse impact on fish breeding, migration and important habitats. And in-depth study and demonstration shall be carried out for the property, range and extent of the impacts and the effectiveness of countermeasures for mitigating adverse impacts. It is suggested to further demonstrate the environmental feasibility of the hydro-junction development of Yakou and Nianpanshan on the premise of settling the major adverse impacts caused by the hydro-junction development.

The project has both positive and negative impacts on the ecological and social environment on the reservoir area and the surrounding area.

(1) Positive impacts

The project is located in the middle reach of Han River, and it benefits shipping, power generation, irrigation, tourism, etc. Moreover, it also provides clean energy utilization, therefore it can promote energy conservation and emission reduction.

Once built, the project can relieve the power supply pressure of Xiangyang and Yicheng, therefore promote the local economic development; it will also raise the water level of the involved river section, therefore guarantee sufficient irrigation of surrounding farmlands, thus promoting agricultural development; the water surface of 12,700 ha will promote tourism development and improve the livelihood of the affected residents.

The project is an important part of the overall Han River hydro-development, and is crucial for realizing the shipping objectives of Han River by 2020. The project construction will promote the local socio-economic development, and also promote the economic development of the riverside economic belts.

(2) Negative impacts

The negative impacts mainly include: adverse environmental impacts, environmental capacity of resettlement, damage of aquatic ecology from changes in water regime, and inundation of plants and soil near the reservoir. Impacts like loss of land resources, resettlement of DPs and ecological damages caused by project construction is difficult to reverse, but they can be relieved by proper mitigation and compensation measures.

Reservoir inundation will shrink the habitats of reptiles and small mammals, forcing some animals to migrate upwards. The construction of the reservoir causes decrease in population of fishes with pelagic eggs. The project also acts as a barrier to the fishes. However, by fish releasing during the breeding season, it can effectively protect and restore the fish spawning grounds; meanwhile, to ease the adverse impact of fish barrier of the dam during non-flood season, fish passes are built while habitat protection plan as well as building fish breeding and releasing station are proposed. These measures can effectively mitigate the impact on the fish resources, and it can protect the survival and habitat conditions to ensure the habitation of fish stocks.

Other adverse impacts mainly happen during the construction periods, such as construction works and noises, soil erosion due to construction spoil, etc. However, these impacts will cease once the construction is completed, and most can be reduced by adopting proper countermeasures.

In general, the project is in compliance with the national laws and plans and has a rational design. After taking appropriate mitigation measures, the adverse environmental impacts of the project can be effectively reduced. Therefore, the project is environmentally feasible.

14 Conclusions and Suggestions

14.1 Basin profile and project background

a) Basin overview

Han River is the largest tributary in the middle and lower reaches of Yangtze River, originates from the south piedmont of Qinling Mountains in Shaanxi Province, passes through Shaanxi Province and Hubei Province, and falls into Yangtze River in Wuhan City. The basin consists of three major reaches: above Danjiangkou is the upper reach, from Danjiangkou to Zhongxiang is the middle reach, and from Zhongxiang to Hankou is the lower reach. The project is located in the middle reach.

The total length is 1,567 km, the fall of water level 1,964 m, and the basin area 159 thousand km^2. Among it, the length of the middle reach is about 270 km, the fall of water level 52.6 m, and the basin area 46,800 km^2. At the dam site, the average annual discharge is 1,490m^3/s. After the dam of Danjiangkou Hydropower hub is heightened and 9.5 billion m^3/a of water transfer is completed in the first phase project of the middle line of South-to-North Water Transfer Project, the average annual discharge at the dam site is 1,100m^3/s.

b) Development plans and EIA

1) Development plans

In 2005, according to the *Pilot Planning Outline for Modernization Construction of Water Conservancy at Middle and Lower Reaches of Han River Basin in Hubei Province* (hereinafter referred to as Planning Outline), the development tasks of Han River at middle and lower reaches include flood control, water supply, water resources and water eco-environment protection, power generation, shipping, water and soil conservation etc. According to the Planning Outline, by 2020, a six-level hydro-junction of Wangfuzhou – Xinji – Cuijiaying – Yakou – Nianpanshan – Xinglong will be built below Danjiangkou Reservoir at the main stream of Han River at middle and lower reaches. In 2009, *Comprehensive Development Planning on Han River* clarifies that the 15-level hydro-development plan is Huangjinxia, Shiquan, Xihe, Ankang, Xunyang, Shuhe, Baihe, Gushan, Danjiangkou, Wangfuzhou, Xinji, Cuijiaying, Yakou, Nianpanshan, Xinglong. In December 2010, the *Comprehensive Development Planning on Han River passed the review of* General Institute of Hydropower and Water Resource Planning and Design, and the revised version was issued in May, 2011.

Currently, the four hydro-junctions: Danjiangkou, Wangfuzhou, Cuijiaying and Xinglong have been built, while the Danjiangkou dam heightening project has also been completed. Xinji and Nianpanshan hydro-junctions are in the preparation phase and carrying out feasibility study.

2) EIA reports

Hubei Academy of Environmental Sciences completed *Retrospective Report on the Environmental Impacts of Hydropower Development in the Middle and Lower Reaches of Han River* in August 2012, and the Ministry of Environmental Protection issued its review comments in HBH [2013]No. 1273 Document. It is suggested to further demonstrate the environmental feasibility of the hydro-junction development of Yakou and Nianpanshan on the premise of settling the major adverse impacts caused by the hydro-junction development; Strengthen the alternative habitat protection for aquatic organisms; Increase the connectivity of river channels; plan fish breeding and releasing and fully play the role in compensating fish resources in the basin; Build basin ecological scheduling mechanism and guarantee ecological flow discharge; carry out terrestrial ecological protection measures, and study and build hydro-junction ecological environmental protection organization.

c) Project overview

The dam is located in Yakou Village, Liushui Township, 15.7km downstream from Yicheng City, about 52.67km away from the Cuijiaying hydro-junction (already built) and 59km away from Nianpanshan hydro-junction (still in plan), and about 80km away from the downtown of Xiangyang City. The development tasks of Yakou Shipping Hub are focused on shipping, and integrated utilization benefits like power generation, irrigation and tourism are also considered. The normal water level is 55.22 m, dead storage level 54.72m, total reservoir capacity 407.3 million m^3 (350.2 million m3 at normal water level, regulated reservoir capacity 41.5 million m^3). Backwater length at normal water level is 52.67 km. The hub has the function of daily regulation. installed capacity of the power station is 74.2MW, guaranteed output is 25.4/19.0MW (Before/after Nianpanshan Junction is built) and the average annual electricity output is 322/253 million kWh (Before/after Nianpanshan Junction is built), annual operating hours are 4343/3407h (Before/after Nianpanshan Junction is built)

The main structures include ship lock, sluices, power house, fishway and earth & rockfill dam. From right to left along the dam axis, the overall layout of the dam includes earth & rockfill dam on the right bank, ship lock, connection section, 36-holed sluice, connection section, low-head powerhouse, connection section, 12-holed sluice, earth & rockfill dam on the left bank. The length of the dam layout along the axis is 2,282m.

Single-line grade-I ship lock is adopted. The ship lock is composed of upstream and downstream approach channels, upper and lower lock heads and lock chamber, and the total length is about 1150.5m, with minimum discharge flow is 450m3/s; the sluices are located at the two sides of the powerhouse, with a reinforced concrete open-type flat-bottom structure. The sluice on the right side has 36 holes while that on the left side has 12 holes. The net width of single hole is 14m; in the low-head powerhouse, 7 bulb tubular generator sets are installed with unit quotative discharge 327.30 m3/s; The dam and the connection section is made of rock-earth plastic concrete cut-off wall, The crest elevation is 59.0m, the crest width is 10 m, and the maximum dam height is 14.0m. Fish pass adopts the combination of staggered stimulated natural channel and fishway. The major entrance is located in the left of the tailrace, and connects with the fish collection system on tailrace platform of the powerhouse. The total length of fishway is 814m, the length of stimulated natural channel section is 490m, the slope is 1/100 and trapezoidal cross-section is adopted; the length of fishway section is 326m, and rectangular cross-section is adopted.

The project involves excavation earthwork of 14,137.5 thousand m^3 (natural square), backfilling of 6,853.8 thousand m^3 (natural square), and spoil of 7,518.7 thousand m^3 (natural square). According to the project planning, there will be three waste dumps, two temporary storage sites and one borrow area. The current status of Yakou borrow area is cultivated land, the area is 6.75hm^2, and the reserve is 560 thousand m3. The sand materials and stone materials required for the project will be outsourced, among which, sand and gravel materials will be from Tangbai River sand stock ground, concrete aggregates from Matou Mountain quarry, and rubble materials from Jinniu Mountain and Dong Mountain quarries.

The project construction impact will involve 3 cities (districts), i.e., Xiangcheng District and Xiangyang District in Xiangyang City and Yicheng City, 8 townships (subdistricts) and 36 villages. The area of permanent land acquisition is 8751.87 hectares, including 8494.12 hm^2 of land acquisition for reservoir inundation, 131.75 hm^2 for hub project zone, 126.00 hm^2 for reservoir protection works and other purposes. By the planned level year 2018, the relocation population will be 1,805, and the production arrangement population will be 19,864. As for relocation, the combination modes of centralized arrangement, scattered arrangement within village and going and seeking refuge with friends and relatives will be adopted; as for production arrangement, large-scale agriculture arrangement will be adopted, mainly including cultivated land adjustment within village and planting vegetable in greenhouses.

The total project construction period is 58 months, with workers of 1500 during peak season of construction. Total investment is 3,245.711 million Yuan; funding for environmental protection is 273.0125 million Yuan, accounting for 8.41% of total investment.

14.2 Environmental baseline

14.2.1 Water environment

According to *Functional Categories of Surface Water Environment in Hubei*

Province (2000), the river section in which the project is located belong to water function zoning "Xiangyang ~ Yicheng ~ Zhongxiang reserve zones of Han River", and the water environment function shall conform to the Class-II standard in *Environmental Quality Standard for Surface Water* (GB3838-2002). There is no corresponding water environment functional zoning for other tributaries in the reservoir area, and the Class-III standard in *Environmental Quality Standard for Surface Water* (GB3838-2002) shall be adopted. According to the monitoring results about the surface water in the river section under assessment collected in August, 2013 and in December, 2014, among the four monitoring sections in the main stream of Han River below Cuijiaying ~ Yakou dam for which the Class-II standard in *Environmental Quality Standard for Surface Water* (GB3838-2002) was adopted, except for dissolved oxygen (Class-IV) and total nitrogen (Class-IV or V) in August 2013 and total nitrogen (Class-IV or V) in December 2014, the other twenty monitoring factors are conforming to the requirements of Class-II standard, and there is no substantial difference in water temperature in monitoring sections. In general, the current water quality of the river section is good. Exceeding-standard dissolvable oxygen is mainly caused contact oxygen dissolution between water and air and oxygen dissolution of algae growth in water at higher air temperature in August. Total nitrogen exceeds standard mainly because some domestic sewage from villages along the river is discharged into the river only after simple treatment. In order to further understand the current status of the surface water environment quality in the project river section, our company entrusted the monitoring unit to carry out supplementary monitoring on the surface water in the project river section in June and October, 2015, and the results showed that all the other indicators are conforming to Class-II standard in *Environmental Quality Standard for Surface Water* (GB3838-2002) except for total nitrogen, which is consistent with the monitoring results of the routine monitoring sections in Han River basin in Xiangyang City.

According to the results of the monitoring on the groundwater on both banks of the proposed project construction area carried out in August 2013, except for ammonia nitrogen, manganese and total coliforms exceeding standard, the other sixteen monitoring indicators are conforming to Class-III standard in Environmental Quality Standard for Groundwater (GB/T14848-1993), which shows that the quality of groundwater in the reservoir area is good. Ammonia nitrogen and total coligorms exceed standard mainly due to the direct discharge of rural domestic sewage which permeating into the groundwater through soil pores, and exceeding-standard manganese is related to higher regional soil manganese background value.

There are five water intakes within the project-impacted area, while four are distributed in the reservoir river section: Wangjizhen water plant water intake, water intake of Yicheng Han River Power Supply Company, water intake of Xiangnan Jail Water Plant and water intake of Danjiangkou resettlement community water plant, respectively located 33km, 20km, 3.2km and 1.5km away from the upstream of the dam site. The daily water supply capacity of Yicheng Han River Water Supply Company is 25 thousand tons, and the water area near its water intake has been zoned as a drinking water source protection zone. There is the water intake of Liushui Township Water Plant 8.0km downstream from the proposed project dam site. There are four agricultural irrigation pumping stations in the reservoir area.

14.2.2 Ecological baseline

a) Terrestrial ecology

According to the results of field survey carried out in September 2013 and April 2014 and with reference to related literatures, the vegetation in this project assessment area includes six types, i.e., broadleaved deciduous forest, bamboo forest, bushwood, shrub-grassland, economic forest and cropland vegetation, and natural vegenation involves 18 formations. In the assessment area, there are 123 families, 370 genera and 582 species of vascular plants (including cultivar), and there are abundant angiosperms, mainly including shrubs and herbs. Plant species mainly include Melia azedarach, Pterocarya stenoptera, Italian poplar, Saliz matsudana, tung tree, Excoecaria sebifera, tea plant, oil-tea camellia, mulberry, etc. According to the survey, there is one big old tree, pistacia chinensis bunge, in the assessment area, 550m away from the reservoir inundation line. Neither reservoir inundation nor land occupation will involve national and provincial key protected wild plant.

In the assessment area, there are 4 classes, 20 orders, 44 families and 81 species of terrestrial vertebrates, including 1 order, 3 families and 5 species of amphibians, 2 orders, 5 families and 10 species of reptiles, 12 orders, 31 families and 56 species of birds and 5 orders, 5 families and 10 species of mammals. There is no first-level key protected wild animal, and there are three species of second-level national protected wild animals, i.e., Buteo, black kite and kestrel. In the assessment, 26 species of Hubei provincial key protected wild animals are founded, including 5 species of amphibians, 2 species of reptiles, 18 species of birds and 1 species of mammals. Among them, amphibians include Bufo bufo gargarigans, Pelophylax nigromaculata, Fejervarya limnocharis, Microhyla ornate and Pelophylax hubeiensis; reptiles include Elaphe taeniura and Zaocys dhumnade; birds include Gymnocalycium asterium, Egretta garzetta, Anas platyrhynchos, Phasianus colchicus, Sterna hirundo, Streptopelia chinensis, Cuculus canorus, Hoopoe, barn swallow, Hirundo daurica, Lanius cristatus, Lanius schach, Oriolus chinensis, Dicrurus macrocercus, Crested myna, cyanopica cyana, Pica pica and Turdus merula; and mammals include Meles meles Linnaeus.

b) Aquatic ecology

According to the results of the survey carried out in April and July 2014 and with reference to historical survey data on the aquatic ecology of the survey river section, in the river section under assessment, there are 8 phylums, 65 genuses and 124 species of phytoplankton, 62 genuses and 110 species of zooplankton, 4 phylums, 30 genuses and 36 species of benthoic animals, 3 phylums, 25 genuses and 39 species of periphytic algae and 12 families, 26 genuses and 36 species of aquatic vascular plants. According to *Hubei Ichthyography* (1987), there are 93 species of fishes in the river section of Han River below Danjiangkou, and 63 species of fishes in the survey river section from Yicheng to

Zhongxiang and its tributaires, which belong to 5 orders, 13 families and 51genuses. Among the 93 recorded species, there are three species of Hubei provincial protected aquatic wild animals, i.e., Saurogobio gracilicaudatus, Scaphesthes macrolepis (Varicorhinus macrolepis) and Leiocassis longirostris, but none of them was found in the survey. In the river section, there is no national protected aquatic wild animal or fish recorded in *China Red Data Book of Endangered Animals*, and there is also no specific species in Yangtze River. Migratory fish includes Anguilla japonica, which was not found in the survey. The main body of fishes in the survey water area is river and plain group of cyprinide fish, the second is southern plain group and paleogene-period group, and there are a few species of China and India mountainous area group and some river-sea migratory species. Advantageous species mainly include current-loving species, such as Culter oxycephalus Bleeker, Saurogobio dabryi, Parabotia bimaculata, Rythroculter ilishaeformis, Rhinogobio typus, Squaliobarbus curriculus, Zacco platypus, Opsariichthys bidens, etc.

According to the results of the survey on the spawning of fish spawning pelagic eggs in the middle reach of Han River carried out by Institute of Hydrology in 2004, there are five spawning grounds of four major Chinese carps in the middle reach of the main stream in Miaotan, Yicheng, Guanjiashan, Zhongxiang and Maliang. This survey only involves two spawning grounds in Guanjiashan and Dengjiatai, both of which are below Yakou dam and 13.5km and 61.8km respectively away from Yakou dam site. There is no spawning ground found in Ying River and Man River. The fishes laying pelagic eggs mainly include four major Chinese carps and other economic fishes, such as Squalidus argentatus, Saurogobio dabryi, Xenocypris argentea, Erythroculter ilishaeformis and Parabramis pekinensis. The spawning grounds of fishes laying adhesive eggs are mainly distributed in river branches with slow flow and lush aquatic plants and in shallow water areas, and such fishes mainly include Mystus macropterus, Glyptothorax sinensis, Zacco platypus, Opsariichthys bidens, Hemibarbus maculates, Scaphesthes macrolepis, etc.

c) Soil erosion

According to the Announcement No. 2 of *Announcement on Dividing National-level Soil Erosion Key Protection and Treatment Zone* of the Ministry of Water Resources from April 29, 2006, Yicheng City, Xiangcheng District and Xiangzhou District, involved in this project, are not national-level protection and treatment zone. According to Announcement of Provincial People's Government on Dividing *Soil Erosion Key Protection and Treatment Zone*, under Hubei Government Document [2000] No. 47 of Hubei Provincial People's Government from August 2000, Xiangcheng district and Xiangzhou district are part of Hubei provincial soil erosion key treatment area, and the area where this project is located has an allowed soil erosion value of 500t/km^2•a. The soil erosion type in the project area mainly is water erosion. Surface runoff caused by atmospheric precipitation causes denudation, carrying and deposition of soil parent materials, and when soil participles are scoured by water, organic matters and mineral elements in soil are also lost. Soil erosion mainly includes sheet erosion and surface erosion

The objectives of ecological protection mainly include: 3 species of national second-level key protection animals, 26 species of Hubei provincial key protected wild animals, 2 large-scale spawning grounds of fishes laying pelagic eggs in Guanjiashan and Dengjiatai, and 5 species of Hubei provincial protected aquatic wild animals. Besides, the ecological protection also involves Xiangyang Cuijiaying Provincial Wetland Park and Yicheng Wanyangzhou National Wetland Park, and the latter takes Han River (Yicheng Section) as the man body, the lower boundary is about 4.5km away from the dam site, and the wetland is permanent riverine wetland and flood plain wetland.

14.2.3 Environmental quality

a) Air quality

According to the results of the monitoring on ambient air in the construction area of Han River Yakou Shipping Hub carried out in August 2013, the air quality in the area is good, and all of fine particles (PM_{10}), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) meet the second-level standard in *Ambient Air Quality Standard* (GB3095-1996) and is conforming to the requirements of Class-2 function zoning.

b) Acoustic conditions

According to the results of the monitoring on seven points in the assessment area carried out in August 2013, the acoustic environment quality in this area is good, and the noise at day and night doesn't exceed the standard. The acoustic environment of one monitoring point in the resident spot on both sides of the approach highway meets Class-4a standard in *Environmental Quality Standard for Noise* (GB3096-2008), and all of the other six points meet Class-1 standard in *Environmental Quality Standard for Noise* (GB3096-2008).

14.2.4 Social environment

Under the jurisdiction of Xiangyang city, and located in the northwest of Hubei province, and the middle reach of Han River, Yicheng city is 76km long from east to west and 53km wide from south to north, covering an territorial area of 2115km^2. Currently, it administers eight townships, two sub-district offices, one industrial park and one provincial-level economic development zone. In 2012, with an entire population of 569.7 thousand, Yicheng city had an annual GDP of 20.19 billion Yuan, with a comparable increase of 13.6%, among which value added in the primary industry was 4.333 billion Yuan, with a comparable increase of 2.0%; value added in the secondary industry was 10.991 billion Yuan, with a comparable increase of 18.0%; value added in the tertiary industry was 4.869 billion Yuan, with a comparable increase of 14.3%. Its per capita disposal income of urban resident was 15366 Yuan, up by 2107 Yuan from last year, and rural per capita net income was 9639 Yuan, up by 1258 Yuan from last year.

In July 2012, Hubei Provincial Institute of cultural relics and Archaeology conducted field survey on the project, and the survey altogether determined 12 underground sites of cultural relics, including Guanzhuang Han dynasty cemetery, Haogou Ring cemetery complex, Wangjiagang cemetery, Tongmei cemetery complex, Six Dynasties cemetery of Tongmei village group 3, Heluo village Six dynasties cemetery, Six dynasties cemetery of Maocao group 3, Tai Mountain temple cemetery, Ming dynasty cemetery of Tannao group, Han dynasty cemetery of Tannao group 3, Nan River village Miaotai cemetery, Yakou village cemetery. Among them, only Wangjiagang Cemetery is a county-level cultural relics protection.

According to the field survey on mineral resources below the project carried out by Hubei Geological Survey, there are two organizations having mining rights along the line of Han River Yakou Shipping Hub Project and in surrounding area, i.e., Yicheng Bawangshan Junguang Quarry and Yicheng Litong Quarry; and two orefileds, i.e., Yicheng Guanzhuang Refractory Clay Mining District and Yicheng Xishan Bauxite and Refractory Clay Mining District. The mineral resources below the project are limestone to be used for building stones of Yicheng Bawangshan Junguang Quarry, and the calculated quantity of resources below the project is 586 thousand m^3. There is no proven mineral resource below the project.

14.3 Environmental impacts

14.3.1 Water environment

a) Water regime

This project adopts a three-phase diversion plan to avoid the cutoff of river. During the first phrase, the right-side riverbed will be used for discharge and shipping. During the second phase, the left-bank canal shall be used for discharge and shipping. During the third phase, a 40-hole sluice gate shall be used for discharge and shipping. The time between the interception period of the third phase and the period when shipping condition is met is called break period, which last 45 days.

The project is designed for a water diversion of 9.5 billion m^3/year for the Danjiangkou Dam Heightening and South-to-North Water Diversion Project (phase 1). After water diversion, the average flow is 1100 m^3/s. To meet a minimum navigable depth of 2.0m, the base flow diverted by Yakou Shipping Hub during its water storage and operation period shall not be 450m^3/s (accounting for 40.91% of the average water flow of the dam area). During the initial storage period, the sluice shall discharge the water at a speed no less than 450 m^3/s. When reaching the dead water level, the condition for power generation is met. The average water level of its downstream is 45.53m.

After the project is completed, the water area will be increased from 35.5 km2 to 111.75 km2. The average velocity will be increased from 0.8m/s to 0.11m/s. The flow pattern will turn from rapid flow to slow flow.

To meet the requirements of navigation in downstream area, the baseload flow of Yakou Shipping Hub shall be 450m3/s. The ensure rate shall be 98%. Affected by the upstream inflow, the daily flow of the downstream channel will see certain impact. The water level amplitude below Yakou dam is basically the same as the pre-project conditions: the maximum hourly amplitude in low flow years is 0.88m and the daily amplitude is 1.74m; the maximum hourly amplitude in high flow years is 0.84m and the daily amplitude is 2.01m. These can all meet the shipping demand of these reaches.

b) Water quality

1) Construction phase

The water pollution mainly comes from sand and gravel processing system, concrete processing system, oily wastewater and domestic sewage from construction workers. The waste water shall be treated to achieve the standard stated in *Miscellaneous Water Quality for Wastewater Reuse* in *Urban City* (GB / T18920-2002). After treatment, the water will be used for irrigation or dust control. After analysis, the report gives the conclusion that even when the accident of waste water pollution occurs in the quarry area or construction area, it will bring adverse impact on the water quality of the upper reaches in Han River.

2) Preliminary stage of water storage and project operation

At preliminary stage of water storage, decayed matters (such as weeds, trees, branches and leaves) and soil in the inundated area will all be decomposed and release organic matters. Decomposition of organic matters will increase concentration of BOD_5, COD, nitrogen and phosphorus and reduce the concentration of dissolved oxygen in the water. If clearing of the reservoir was not done according to the specifications, there may be many extracts at the bottom of reservoir, thus affecting water quality at preliminary stage of water storage.

The backwater length of Yakou reservoir is 52.67km. , After impoundment, the river width will be 0.8km ~ 4km. As two major industrial pollution sources comes from Xiaohe Town and Nanying Sub-District Street office were imported, without considering the attenuation, we can use a complete mixing model for predictions of the overall water quality in the reservoir area. After impoundment, the concentration of CODCr, NH, TN, and TP will be 13.54mg/L ~ 13.89 mg/L, 0.082mg/L~0.090mg/L, 1.81mg / L ~ 2.13mg / L , and 0.06mg / L ~ 0.10 mg/L. The concentration of CODCr at downstream section 200m from Wangjiadagou, middle section of Yakou Reservoir (200m away from downstream of Yicheng Han River Bridge), dam section of Yakou Reservoir will be 13.89mg/L, 13.54 mg / L and 13.79mg / L. The concentration of NH will be 0.085mg/L, 0.082 mg/L and 0.090mg / L. After the reservoir is constructed, the overall water quality in the reservoir area will basically remain the same. The concentration of TN still exceeds the given standard (by a maximum of 3.26 times). The remaining indicators can meet the Category II standards stated in Environmental Quality Standard for Surface Water (GB3838-2002).

According to our prediction, the concentration of CODCr, NH, TN, and TP will be 10.11mg / L, 0.064 mg / L, 1.56mg / L, and 0.08mg / L at the water intake of Yicheng Water Plant during its dry season. The concentration of CODCr, NH, TN, and TP will be 10.81mg/L、0.085mg/L、1.75mg/L、0.06 mg/L at the water intake of Xiangnan Prison Water Plant. The concentration of CODCr, NH, TN, and TP will be 10.11 mg/L、0.085mg/L、1.71mg/L、0.05mg/L at the water intake of Danjiangkou Resettlement Plot Water Plant. Besides TN and TP, other indicators can meet the Category II standard as mentioned above.

According to T*echnical Regulations for Quality Evaluation of Surface Water* (SL 395-2007), we predict that the reservoir will see mild and moderate eutrophication at its common and dry season. However, in addition to TP and TN, other factors will also affect the eutrophication such as the location, shape and operation condition of the reservoir, as well as light and temperature conditions. Considering the number of water exchange in Yakou Reservoir after height of the Danjiangkou Reservoir is lifted up is more than 99, and the water control is just carried out on a daily basis, we believe the chance of eutrophication in the reservoir area is slight. However, as the concentration of TN is relatively high(the concentration of TN at the downstream of Cuijiaying Dam is 1.57mg/L, we should strengthen the control of pollutant in the upstream area and around the reservoir area, so as to prevent eutrophication from happening.

14.3.2 Ecological impacts

a) Terrestrial ecology

1) Impact analysis of ecological system

Yakou Shipping Hub is a center for shipping, power generation, irrigation and tourism. The ecological environment within the evaluation area can be divided into 4 parts: forest ecosystem, wetland ecosystem, agro-ecosystem and town/village ecosystem. These ecosystems can maintain biodiversity and help support habitats. The inundation and land occupation of the project will impact these eco-systems by increasing water areas and reducing the biomass of vegetation. As ecosystems own resistance stability, they will reach a new ecological balance over time. Overall, after the operation of the project, the ecosystem of the evaluation area will not change significantly. The ecological system within the evaluation area will still be dominated by wetland ecosystem and agricultural ecosystem.

2) Impact on terrestrial vegetation

The project construction area covers a total area of 377.08 hm^2, accounting for 0.25% of the total evaluation area. The permanent land covers an area of 131.75 hm^2, dry-land 53.73 hm^2, woodland 21.4hm^2, and other agricultural land 25.47 hm^2; The temporarily occupied land covers an area of 374.31hm^2, accounting for 4.1% of the total area. The land occupied includes farmland, woodland, water areas and water facility land, of which forest land and farmland predominate. The temporarily occupied forest land is few. The plant species are mainly artificial forest, secondary shrub and bushes. Therefore, the impact on the vegetation of the area is slight.

The newly-added inundated area totals 78.68 km², where arable land totals 3095.00 km², woodland totals 6.04 km², and grass land totals 0.93 km². During reservoir impoundment stage, the vegetation will be inundated. Beach land will be inundated by 1,493.73hm², of which overflow land growing crops totals 1,427.87 hm², overflow land growing forest trees totals 65.87 hm². According to the field survey, the inundated area is mainly covered by arable crops, followed by poplar-occupied woodland, as well as grass land with vegetation such as paper mulberry, hemarthria compressa and horseweed. The plants affected by the inundated are local species widely distributed around the reservoir area. Therefore, there is no possibility that the inundation will cause the disappearance or obliteration of plant population. Reservoir inundation had no significant effect on reproduction and preservation of the species, and it will not cause the disappearance of these species. However, this will bring some influence on agricultural ecology. As there is no endemic species in the inundated area, this will have just slight impact on the plant category during the project operation period.

3) Impacts on rare and endangered animals

We found no national key protected wild animals(level I) in the evaluation area, and found 3 species of national key protected wild animals(level III): Namely, common buzzard, black kite, and kestrel. The project will not inundate or occupy its main habitat. The only impact is construction noise and human activity. However, the impact is limited to its activity and foraging area. Generally speaking, the impact on the wild animals is insignificant.

4) Impact on water and soil erosion

The disturbed land area totals 607.72 hm², of which the dam project area totals 352.74hm², and the reservoir protection area totals 254.08hm². The total waste amounts to 7,518,700 m³, of which temporary waste totals 1,096,800 m³, and permanent waste totals 6, 421,900 m^3. The soil and water loss prediction of the project area include three periods: construction preparation period, construction period and natural recovery period. According to our prediction, soil and water loss in the construction period is 10, 9724t, of which newly added amount of soil and water loss is 96, 015t. The soil and water loss on waste dump and temporary soil storage area are significant. Hence, these areas are the focus area in soil erosion control.

b) Aquatic ecology

Activities in reservoir impoundment, the dam area and power plants have caused the changes of natural conditions such as hydrology, sediment, and water temperature in the reservoir area and mainstream and its tributaries of the dam. These changes have directly or indirectly affected the composition of fish species and the amount of fish resources.

1) Impact of the dam and power station

The construction of the dam has blocked the passage of migratory fish, affecting their feeding or spawning activities. For instance, due to the barrier of Danjiangkou Dam, Wangfuzhou Dam, Cuijiaying Dam, and Xinglong Dam, it is more difficult for us to see the migratory fish-eel. Therefore, the construction of Yakou Dam will probably make the eel unable to be seen in this river section.

Construction of the dam will not only block the passage of migratory fish, but also the passage of semi-migratory fish and non-migratory fish. The individual and genetic exchange of semi-migratory fish such as grass carp, black carp, silver carp, bighead carp, and yellowcheck-carp will also be blocked. The construction of dam will separate the fish into two populations: those at the downstream of the dam, and those at the upstream of the dam. As there are still some breeding places and inhabits for these fishes both at the upstream and downstream section of the dam and its tributaries, the impact on the fish is relatively slight.

2) Impact of water regime changes on fish resources

After the construction of the power station, the change of water regime will change the composition of fish species from "fluvial facies" to "lake facies".Fishes such as common carp, crucian carp, catfish, squaliobarbus curriculus, culter alburnus, siniperca chuatsi, yellowcheek carp, rhodeus spinalis, mud fish,pseudorasbora parva, rhodeus sinensis günther , and abbottina rivularis, which are adjusted to slow or still water environment, will become the dominant species, due to the increasing of their spawning grounds and food organisms. The fishes such as four chinese carps, opsariichthys bidens, coreius heterodon, rhinogobio typus, saurogobio dabryi, mahi mahi, loaches, squalidus argentatus, pseudolaubuca sinensis, Yichang gobiobotia pappenheimi, zacco platypus, etc., will gradually shift to the tail of the reservoir and the downstream area of Cuijiaying Dam, due to changes in feeding and reproduction conditions. Therefore, their number will decrease.

3) Impact on the composition of fish

After the construction of the power station, fishes such as lepturichthys fimbriata, pearlite rim and glyptothorax honghensis will retreat to the tributaries of the reservoir and the upstream section of the reservoir, and see their number decreased in the reservoir area, due to their high dependence on lotic environment. As they are adapted to slow/still water, the number of fishes such as silver xenocypris, megalobrama skolkovii, catfishes, and cultrins may increase. Fishes such as alburnus and mandarin fish, due to relatively rich diets, may also maintain a certain population in the reservoir area. Due to increase in water area, suitable reproductive condition, fishes such as carp, crucian carp, pseudorasbora parva, abbottina rivularis will become the dominant species of the reservoir area. Fishes such as four chinese carps bream, parabramis pekinensis, kiss shrew, lepturichthys fimbriata, saurogobio dabryi, etc., will gradually withdraw from the reservoir area.

The construction of the power plant will decrease the number of fishes. However, the impact on fish composition is insignificant.

4) Impact on protected fishes

There are no national-level protected fishes in the investigated river section. The provincial-level protected fishes in the river section include luciobrama macrocephalus, ochetobius elongatus, onychostoma macrolepis,saurogobio gyaoilicaudatus, leiocassis longirostris. However, due to its limited resources, we fail to catch any of them in our investigation period. The spawning conditions for luciobrama macrocephalus and ochetobius elongatus with pelagic eggs will further deteriorate. However, the increasing of water area water productivity may be beneficial for its growth in the area. The onychostoma macrolepis (fond of flowing water) with demersal eggs will see its habitat shrinking and population size declining. However, the tail section of the reservoir and its tributaries may provide a habitat for them; leiocassis longirostris (fond of slow-flowing water) with demersal eggs will see its habitat shrinking; saurogobio gyaoilicaudatus is a kind of fish with pelagic eggs who are fond of flowing water. After the formation of reservoir, its habitat will shrink and population size will decline. Due to genetic differentiation or gradual loss of genetic diversity, it will become endangered species in reservoir area.

5) Impacts on spawning grounds of fishes with pelagic eggs

Seen from the accumulated impacts of the hydro-junction development at middle and lower reaches of Han River on fish resources, with the construction of Danjiangkou Reservoir, fish cannot swim upstream to Danjiangkou dam, and the fish spawning at the upper reach of Han River cannot swim to the middle and lower reaches of Han River and even Yangtze River. The original aquatic ecological functions are mainly undertaken by the middle and lower reaches of Han River, and the corresponding habitats shrink and functions ware weakened. Especially, the temperature of water discharged from Daniangou Reservoir is low and the fish breeding at middle and lower reaches of Han River is delayed for about one month. However, there are still many spawning grounds at middle and lower reaches of Han River, which are important places for fish spawning and breeding at middle and lower reaches of Yangtze River. With the construction of

Wangfuzhou, Cuijiaying and Xinglong hydro-junctions, some spawning grounds are inundated, fish migration channels are obstructed, spawning grounds shrink, breeding groups reduce, and spawning ground size significantly decreases. Especially, in dry year, due to low peak discharge and attenuation of multi-level junctions, the flood peak process is not obvious. At present, the spawning function of the remaining spawning grounds in Yicheng, Guanjiashan and Zhongxiang are weakened obviously. With the construction of Yakou Shipping Hub, the adverse impact on the fish with pelagic eggs at middle and lower reaches of Han River will further increase without ecological regulation. The spawning ground in Yicheng may recover some functions only when the flood peak discharge exceeds $8000m^3/s$ and the junctions discharge water openly for flood control; correspondingly, due to the attenuation of peak flood process caused by Yakou reservoir, adverse impacts may be caused to the spawning grounds in Guanshanjia and Zhongxiang below the dam when peak discharge is low.

Therefore, even if Yakou Shipping Hub is not built at middle and lower reaches of Han River, due to the obstruction of built junctions, the early resources will continuously drift with water below Xinglong dam, mature parents at the lower reach of Han River and at middle and lower reaches of Yangtze River will swim upstream above Xinglong dam and be obstructed, the number of fish groups spawning drifting roes will continuously reduce, and the spawning and breeding functions of the current spawning grounds will also be weakened continuously.

However, according to the study on the hydraulic and hydrological conditions required for the breeding of fish with pelagic eggs at middle and lower reaches of Han River carried out between 2004 and 2007, the breeding of fish with pelagic eggs at middle and lower reaches of Han River mainly depends on the flood of Tangbai River and interval flood, especially Tangbai River flood, and the flood discharge of Danjiangkou reservoir only has the function of facilitation. Therefore, adopting the ecological regulation of open discharging for Cuijiaying, Yakou and Xinglong Hydro-junctions in due time according to the water regime of Tangbai River can recover the natural flow stats of main spawning river sections at middle and lower reaches of Han River and mitigate the adverse impacts of the change of water regime on the breeding of fish with pelagic eggs; moreover, opening sluice in proper time may smooth the connection between the project river section and the lower reach of Han River and the middle and lower reaches of Yangtze River and mitigate the obstruction impact on the breeding groups swimming upstream to spawning groundings. Such measures are of great significance in protecting and the spawning grounds of fish with pelagic eggs at middle and lower reaches of Han River and continuing to play the ecological functions of the spawning grounds of fish with pelagic eggs in Yicheng in reservoir area and in Guanjiashan and Zhongxiang below the dam, which can not only effectively mitigate the adverse impacts of Yakou Hub on fish resources spawning drifting roes, but also mitigate the adverse impacts cased by the built junctions at middle and lower reaches of Han River to a great extent.

14.3.3 Environmental impacts of project construction

During project construction, it will also exert negative impacts on air and acoustic environment, solid waste pollution, and soil erosion, etc.

a) Air pollution

Air pollution is mainly caused by construction dusts and waste gas emission from machinery. The dusts come from soil excavation, soil waste, transportation, temporary storage site and earth filling. Waste gas emission has a small impact on the environment. During the operation of ship locks, it mainly generates SO_2 and NO_2 containing waste gases, but since it only takes a short time for ships to pass the ship locks, the pollutants remain within the waterway and have little impact on the surrounding sensitive receptors.

b) Noise

Noises during construction mainly come from machine operation, vehicle transportation and blasting. The noises from machine operation and vehicle transportation exceed the limits for daylight and nights of Maocao Village group five and group six and

Yakou Village group 4. The blasting has only a short term of impacts on surrounding sensitive receptors due to short duration.

c) Solid waste

A large number of construction workers will produce a large amount of living waste during construction which is unsightly and may also pollute soil and water, so that it needs to be disposed properly. There are about 1,500 workers onsite during peak period, generating garbage 1.50 tons / day, and 2,190 tons in total.

Total earthwork excavation is 14,137,500 m^3 (natural soil), engineering backfill of 6.8538 m^3 (natural soil), the total amount of spoil 7,518,700 m^3 (natural soil). The project sets up 3 waste dumps, 2 temporary storage sites, and 1 soil storage site. It is predicted that a total of disturbance of surface area during construction is 632.06hm^2 (excluding the reservoir inundated area), the damaged water and soil conservation facilities is 403.64hm^2. If soil and water conservation measures are not taken, the amount of soil erosion during project construction is 109,724t, including additional soil erosion 96,015t. The extent of soil erosion in the construction area will reach moderate - severe.

The harm of soil erosion mainly includes: a large area of stripped topsoil leads to soil deterioration and less productivity; vegetation damage leads to less grass and forest coverage, and reduce in the number of species; landslides and other disasters during rain season, which affected the normal construction and operation of the powerhouse; it also threatens the safety of the construction workers; project wastes flow into waterways through rain and floods, which may pollute the Han River.

d) Human health

The large population inflow of construction workers increases the risks of water-borne diseases, posing a certain threat to the health of the local residents and the construction workers. Therefore, the PIU must make sure that the drinking water is clean and food safety management is conducted. Human resources management is also important to prevent the disease transmission.

The coming of construction workers also increases the risk of transmission of malaria during construction, therefore, it is important to increase health promotion to increase the awareness and knowledge of local residents and construction workers of the disease.

14.3.4 Resettlement impact

The project involves resettlement work of 8 towns (and townships) and 36 villages of Xiangcheng District, Xiangyang District and Yicheng City. In 2018, people affected by farmland acquisition has a population of 19,864, and the affected people will be allocated with farmland from other places, plus other compensation methods. There are 1,805 displaced persons, and they may be relocated to another place within their previous village or relocated in a community outside the village. The project affects 2.2 km machinery access roads, one port, two docks, two passenger docks, 2.6km optical cables, 3 km power cables and nine sluices. The affected roads, bridges, power transmission facilities, communication facilities, and water facilities will be transformed or rebuilt. The project site does not affect sensitive receptors such as natural reserves or scenic areas. The resettlement work mainly affects water, air, acoustic environment, and ecology, etc.

Since the resettlement work is carried out by the lump-sum contractor selected by the local government, the PIU only needs to take certain environmental protection measures: using grit chamber to reutilize construction wastewater instead of direct discharge; using water spray to prevent dust; make full use of construction wastes and store those that cannot be reused to the specified dumps; collect domestic garbage and carry out landfill disposal in Yicheng landfill sites for domestic garbage. During project operation, the domestic wastewater will undergo pre-treatment in septic tank first and then be disposed by integrated domestic sewage treatment facility. The disposal of domestic garbage is the same with that during project construction

14.3.5 Environmental risks

Environmental risks of this project mainly stem from the fuel leakage caused by collision, stranding and tipping of ships when navigating and berthing in the project construction and operation period. The risks at present are mainly the oil spillage caused by stranding and collision of ships.

Oil spillage in the project-located river section can basically confined to the reservoir area and will not exert adverse impact on water quality of the reaches under the dam under the premise of timely taking emergency measures. If the oil spillage accidents happen near the upper reaches of the sensitive points such as water intakes, the quality of water near the water intakes will be influenced. If oil spillage in downstream river sections of Yakou Shipping Hub, the oil film will quickly spread and thus cause pollution to the water of the waterway.

Since there is great uncertainty over quantity of the spilled oil and occurrence time of the oil spillage, emergency plan should be initiated once the accident happen and notice should be issued to the managers of the water intakes in the lower reaches to control the drift speed of oil film towards the downstream water and mitigate the pollution impact of oil spillage on water intakes in the lower reaches to the largest extent. The preventive and emergency measures are: location of the oil depot and explosive magazine during the construction period should be selected strictly in accordance with requirements on security protection distance and keep sufficiently safe distance from the residential areas and living areas. Transportation and use of explosive and oil should strictly comply with the relevant regulations and operation procedures. Daily management on ships and docks should be strengthened and the ships should enter the sluice orderly to avoid collision. Various management regulations and operation specifications should be strictly implemented and management and education of the operators should be strengthened to avoid illegal operation. Warning signs should be set up in the reservoir areas and in waters near the water intakes and the water source protection areas along the waterway. The oil spillage prevention facilities should be equipped and permanent regional emergency center should be established.

14.3.6 Public participation

Considering the requirements of "*Interim Procedures on Public Participation in Environmental Impact Assessment*", public participation during the EIA is carried out mainly in the form of project information disclosure, public questionnaire surveys and public discussion meetings. The discussion meetings are convened in Yicheng City and Xiangyang City; three network disclosure is conducted on the Chudu Yicheng Network, Official website of PIU, official website of Xiangyang EPB; announcements are posted in the eight affected towns and counties.

The issuance of questionnaire is after the completion of the report draft. 45 group questionnaires and 530 individual questionnaires are released, and respectively 45 and 517 are returned. All the group respondents are supportive or neutral towards the project construction. As for individual respondents, 88.4% are supportive, 11.0% neutral and 3 people are against immediate project commencement (among the ten respondents who are against the project, 7 changed their mind after listening to PIU's explanation). The three opponents worry that the project will worsen water pollution, especially water pollution of the water intakes.

Most respondents request that the PIU shall meet pollution emission standards and focus on environmental protection, and local environmental protection department shall strengthen supervision on project operation, to avoid polluting the surrounding environment; resettlement shall comply with the relevant national policies and compensation standards shall make sure that the living standards of the DPs are at least equivalent to or better than pre-project conditions.

14.4 Environmental protection measures and investment

14.4.1 Water pollution prevention and control measures

a) The Hub Project construction area

Industrial wastewater shall be reused after it is treated. The wastewater produced by the aggregate processing system in the project construction area will be treated by precipitating fines with flocculates. Fines in water from foundation pits will be precipitated by using flocculates and then supernatant will be pumped and drained out of the pits. Oily wastewater from repair systems can be treated through oil separators.

Domestic wastewater can be treated through a complete set of domestic sewage treatment equipment; the treated wastewater can be used to water the construction area, reducing dust.

During operation, wastewater from living quarters and office areas will be treated through the domestic sewage treatment equipment on the PIU premises that is used during construction. The treated wastewater can be used to water the construction area, reducing dust.

Oily wastewater from power plants will be treated through oil separators; the treated wastewater can be used to water the plant area, reducing dust.

b) Reservoir water pollution control

Before impoundment, the reservoir zone shall be thoroughly cleaned up. The quality of water in the reservoir area shall be protected. Ships shall be equipped with domestic sewage treatment equipment or container that can treat or hold the amount of domestic sewage produced. Domestic sewage from ships shall be collected by vessels approved by maritime authorities. Oily wastewater produced on board of a ship shall be collected by the collection equipment installed on the ship and shall be treated by oily wastewater treatment facilities newly built on land, so as to prevent oily wastewater from polluting the water and ecosystem of the area near the reservoir.

The Han River pollution prevention and control plan requires that a number of water pollution prevention and control projects should be launched in the assessed water area. These projects include industrial wastewater treatment project, domestic sewage treatment project, and ecological management project. After the hub is built and the pollution prevention and control plan is delivered, the quality of Han River water may meet the current functional zoning requirement.

c) Eutrophication prevention and control measures

The quality and quantity of water in the reservoir area shall be monitored and assessed. The main river courses upstream from the reservoir shall be strictly monitored; cross sections shall be regularly monitored. Soil and water conservation efforts shall be intensified in order to reduce soil loss. A combination of engineering measures, ecological measures, and land reclamation shall be taken, coupled with small river pollution control, so as to form a new pattern of soil and water conservation. Vegetation in the areas upstream from and near the reservoir area shall be increased, which will largely reduce nutrient substances flowing into the reservoir area. Soil fertility shall be improved. Eco-friendly agriculture project shall be launched in the upper reaches; new agricultural technologies shall be promoted. Agricultural structure shall be adjusted; the use of nitrogen, phosphorus, and other chemical fertilizers shall be restricted. Nitrogen and phosphorus in wastewater shall be removed by using phosphorus-free synthetic detergent.

14.4.2 Ecosystem protection measures

a) Terrestrial ecosystem protection measures

Coupled with soil and water conservation measures, measures shall be taken to restore the terrestrial ecosystem of the construction sites. In the process of vegetation restoration, the ecosystem of the hills in the construction area shall be protected. Deciduous broad-leaved forests, scrubs, and shrub herbosa shall be increased. *Liquidambar formosana, Rhodomyrtus tomentosa, Melastoma candidum,* and *Streblus ilicifolius* shall be planted or transplanted in the Yakou borrow pit site, so that an independent shrub herbosa can form and the borrow pit can be restored as an area where shrubs and herbaceous plants grow. Hunting (e.g. *Batrachia*, *Zaocys dhumnades*, etc) is forbidden in the construction area and its surrounding areas. In case of accidentally injured animals, these animals shall be treated without delay. Authorities shall promote the protection of wildlife, forbid hunting, and particularly prevent people from hunting the state-level endangered animals. To prevent soil erosion in the project construction area, walls keeping out waste and drains shall be built; vegetation shall be increased.

b) Fish protection measures

1) Fishway

A fishway will be built between the ship lock of the project and the plant on the left side of the separation levee of the ship lock. The fishway will generally be used by black carp, grass carp, silver carp, bighead carp, *Elopichthys bambusa, Luciobrama macrocephalus, Ochetobius elongates, Leiocassis longirostris, Megalobrama skolkovii, Parabramis pekinensis, Distoechodon tumirostris, Squaliobarbus curriculus*, and *Leiocassis crassilabris*. These species are commercially important species that migrate. The fishway will also be used by other fish species. The fishway is built with stones and it mimics natural fishways. Water flows at a rate of 1.1m/s through the fishway's entrance/vertical joints. The fishway is arranged along the left bank of the power plants. Its inlet is located downstream from tail water. A specialized passageway for replenishing water is built; water flows through this passageway at a rate of 1.47m^3/s. Water will be diverted upstream; after it goes through a stilling pool for energy dissipation, it will flow to the fishway, replenishing water in the area. The fishway is 951.08m long in total, of which 560.58m (including 20m of the confluence pool) is the segment mimicking natural fishways. The fishway's gradient is 1/100. The fishway adopts trapezoidal cross-section with bottom area of the cross section being 2.0m wide. The ratio of side slope to the slope is 1:2.5. The water level of the fishway is 2m; at this water level, the water area of the fishway is 12.0m wide. There are a total of 45 separated segments and 2 rest segments. The engineered fishway is 390.5m long; the gap is maintained at 0.06m; its gradient is 1/60; it adopts trapezoidal cross-section; the pool is 3m wide and 3.6m long; seven pools for rest are arranged, of these pools, four are at the river bends.

2) Fish stock enhancement

A fish stock enhancement station shall be built near the PIU premises. The station covers an area of 86.7mu. The fish species that will be released in the near future include black carp, grass carp, silver carp, bighead carp, *Leiocassis longirostris*, *Megalobrama skolkovii*, *Parabramis pekinensis*, *Distoechodon tumirostris*, and *Squaliobarbus curriculus*; the fish species that will be released in the remote future is *Leiocassis crassilabris*. Four million fish will be released per year. Of 4millionn fish, 3.5million black carp, grass carp, silver carp, and bighead carp are bred on commission; 500,000 *Leiocassis longirostris*, *Megalobrama skolkovii*, *Parabramis pekinensis*, *Distoechodon tumirostris*, and *Squaliobarbus curriculus* are released per year. Black carp inhabiting the wild can be collected and domesticated, so relevant technology, coupled with artificial propagation technology, fish fry mass production technology, and fish releasing techniques shall be developed.

3) Habitat protection

It is recommended that the river segments (5km long and 7km long) downstream from Cuijiaying Dam and Yakou Dam where water flows at a rate of at least 0.2m/s should be marked as no-fishing areas. Fishing is forbidden throughout the fish breeding season (from March to August); no-fishing signs shall be put up in the relevant areas to prevent fishing and other activities that may disrupt aquatic habitat. The 18km-long segment from tributary Yinghe Class II power station to the Han River estuary is marked as a no-fishing area for protecting the habitat of fish. Pebbles and gravels are arranged in the area, and aquatic plants are transplanted to the area to create a favorable habitat for fish. Artificial spawning grounds are built for fish. Long-term monitoring of the water quality, fish species, and aquatic life in the aforesaid area will be implemented.

4) Biological regulation

Biological regulation shall be implemented at least two times from May to August every year for hydro-power development projects downstream from Danjiangkou Reservoir in the Han River main stream. From May to August, if Tangbaihe Dongpo flood prevention station forecasts 24 hours in advance that water may flow at a rate of at least 600m^3/s, biological regulation shall be launched. If there is no flood from May to July and if in August, Tangbaihe Dongpo flood prevention station forecasts that water may flow at a rate of at least 300m^3/s, biological regulation shall be launched. If there is no flood and biological regulation is not launched in August, a joint biological regulation shall be launched in early-or mid-September when a flood occurs in the Tangbaihe River and the Han River main stream. When Tangbaihe Dongpo flood prevention station forecasts 24 hours in advance that there may be a flood soon, Wangfuzhou Reservoir shall release flood downstream; Cuijiaying, Yakou, and Xinglong reservoirs shall release flood to lower their water levels. If the rate of flow measured by the Tangbaihe Dongpo flood prevention station reaches the rate of flow at which biological regulation shall be launched, Cuijiaying, Yakou, and Xinglong reservoirs shall release flood together, creating a favorable upstream spawning ground for fish. Flood's release generally lasts five to seven days till the flood peak ends so that the eggs and fry of fish can easily drift downstream from the dams.

c) Soil erosion

The area of land and vegetation disrupted by construction totals 607.72hm^2. The areas where soil is eroded due to construction include terrace, paddy fields, garden plots, woodland, grassland, and water area, which totals 403.64hm^2. Waste generated by construction amounts to 7.5187 million m^3. It is estimated that project construction may cause 109,724 tons of soil loss, of which 96,015 tons are the increased amount of soil loss. There is a large amount of soil loss occurring in waste dumps and temporary spoil grounds, so soil and water conservation measures shall be taken to prevent and control soil loss in these areas particularly.

Measures such as building drains, sand basins, and the walls that keep out waste, as well as planting trees on the surface of waste will be taken to prevent and control soil erosion caused by project construction. Temporarily occupied land for the project shall be rehabilitated; the rehabilitated area totals 183.48 hm^2. After these measures are implemented, 99.9% of the land disrupted by construction will be rehabilitated; 99.7% of the amount of soil loss will be controlled (the ratio of controlled soil loss to total soil loss is 1.02), 97.0% of waste will be retained by walls, 99.5% of vegetation will be restored, and 19.0% of land will be covered by woods and grass. Implementation of these measures will not only control soil erosion in the project area, but it will also restore and improve the project area's original ecosystem and natural environment.

14.4.3 Protection of other environments

a) Atmospheric environment protection

Exhaust gas emitted from the ships that use oil engine and automotive engine shall be treated through a waste gas purifier. Roads and stock grounds shall be watered so as to reduce or prevent dust. After a blast, the quarry area shall be watered to reduce dust; the piles of ore shall also be watered. Sheds shall be built for covering all vehicles. Roads shall be cleaned and watered on a daily basis. Machines shall be examined before they are used. The use of defunct vehicles is banned.

b) Noise control

The following noise control measures shall be taken during construction: the timeframe of transportation shall be strictly controlled; vehicle speed shall be controlled; loud horn shall be banned; roads and vehicles shall be maintained; soundproof walls shall be built along the red line marked for the requisitioned land near the residential areas of Maocao Village and Yakou Village.

During operation, noise made by ships passing through the dam generally will not disturb local residents, but the number of ships passing through the dam shall be regulated, and continuous whistling from ships shall be prevented. A large number of ships traveling and whistling at night shall be banned in the waterway segments along which a large number of residents live. The speed of ships traveling at night shall be controlled.

c) Solid waste treatment

Yicheng, where the project is located, has a domestic waste landfill site, i.e. Nanzhou Domestic Waste Landfill Site. Domestic waste in the Yakou Shipping Hub Project construction area shall be sorted and then transported by Yicheng's sanitation department to the landfill site for disposal. Construction waste shall be collected together and used for backfill; it shall not be randomly piled or discarded. Waste produced when a workboat is being maintained and the domestic waste from a workboat shall be sorted and then collected. Discarded machine parts shall be recycled. Oily cotton yarns and dirty oil shall be transported to qualified hazardous waste treatment organizations for treatment.

14.4.4 Environmental protection investment

An amount of 273.0125 million Yuan is invested in the environmental protection for the Yakou Shipping Hub project. This investment accounts for 8.41% of the total investment (3.245711 billion Yuan) in the project. Of 3.245711 billion Yuan, 151.0828 million Yuan is the amount of investment for the special project of environment protection, accounting for 55.33% of environmental protection investment; 121.9297million Yuan is the amount of investment for the special project of soil and water conservation, accounting for 44.66% of environmental protection investment.

14.5 Conclusion

The Yakou Shipping Hub Project complies with the Han River main stream waterway plan. Construction of the Hub can largely boost the economy of Xiangyang and even Hubei province; it has social benefits too. On the other hand, project construction and operation will negatively affect the area’s environment. However, such negative impact can be mitigated or eliminated by taking the environmental protection measures proposed in this Environmental Impact Assessment. For example, a combination of engineering measures and vegetation measures can be taken to control and reduce soil loss caused due to vegetating being disrupted by construction; environmental management and pollution control measures will be taken to prevent and control waste and noise produced during construction; biological regulation, fishway building, and fish stock enhancement measures can be taken to mitigate the negative impact brought by the change of hydrological condition to the habitat and species of aquatic life, especially Asian carps. Water may be unclean during project operation, but it can be improved after the *Han River (Xiangyang Segment) Water Pollution Prevention and Control Plan* issued by the Xiangyang Minicipal Government is implemented. From the perspective of environmental protection, the Hub Project construction is feasible.

14.6 Suggestions & requirements

a) A basin environmental management center shall be established as early as possible; the monitoring of basin environment shall be intensified.

To coordinate basin ecosystem and environmental protection efforts, it is recommended that a basin environmental management center should be established as early as possible. The center will be responsible for organizing and implementing basin environmental management, such as monitoring basin environment, protecting fish species, and protecting water environment.

b) “Three simultaneities” principle for environmental protection shall be strictly implemented; pollution control shall be tightened

The design of the main works shall focus on the prevention of negative impact of construction to natural environment. The “three simultaneities” principle shall be strictly followed throughout project construction. As required by the *Han River (Xiangyang Segment) Water Pollution Prevention and Control Plan*, the funds for environmental protection shall be made available; the monitoring and management of water pollution sources in basin shall be intensified; water pollutants that are discharged into the reservoir area and its tributaries shall be controlled and discharged in accordance with the relevant standard; sewage treatment plants shall be built in towns along the Han River as quickly as possible in order to reduce the pollution of the Han River.

c) Study on aquatic ecosystem protection shall be conducted as early as possible

After the project is put into operation, study on aquatic ecosystem protection shall be conducted based on the change in the number of fish species in the Han River. Biological regulation plays an important role in maintaining the aquatic ecosystem of the Han River mid-and lower-reaches, so relevant parties shall conduct a study on plans for biological regulation jointly implemented at reservoirs, based on biological regulation implemented at Xinglong Reservoir and Cuijiaying Reservoir. Such plans shall be implemented by river basin management agencies. The effects of fishways and fish stock enhancement and releasing shall be monitored and assessed.

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