SFG2574 REV

WB-Funded Project

Han River Inland Waterway Improvement Project in Hubei

(Yakou Navigation Complex Project)

Cumulative Effects Assessment Report

(Project Supplemental Environmental Impact Assessment Report)

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Acronyms and Abbreviations

CEA/CIA	Cumulative Effects/Impacts Assessment
CEQ	Council for Environmental Quality
EA	Environmental Assessment
EIA	Environmental Impact Assessment
ESIA	Environmental and Social Impact Assessment
IFC	International Finance Group
HRB	Han River Basin
MLHR	Middle and Lower Reaches of Han River
MEP	Ministry of Environmental Protection
NEPA	National Environmental Policy Act (United States)
NGO	Non-governmental Organizations
RCIA	Rapid Cumulative Impact Assessment
RFFAs	Reasonably Foresseable Future Activities
VECs	Valued Environmental Components
RFFA	Reasonably Foreseeable Future Actions
SEPA	State Environmental Protection Agency
WB	World Bank
WBG	World Bank Group
mu	1 hactare = 15 mu

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1 Introduction

This Cumulative Effects[1] Assessment (CEA) is part of the Environmental Assessemnt (EA) for Hubei Han River Inland Waterway Improvement Project, i.e. Yakou Navigation Complext Project (Yakou Complex hereafter). The Yakou Complex forms a critical stage of the Han River cascade system that has been determined in various water resource and inland waterway plans for the Han River. The direct and indirect impacts of the Yakou complex are assessed in an Environemntal and Social Impact Assessment (ESIA) conducted during the project preparation. The CEA addresses the accumulation of meaningful impacts to the Han River study area due to the implementation of the plans and reasonably foreseeable future actions (RFFAs). As is well-known, conducting a CEA requires extensive information collection, iterative scoping and analysis processes, wide expert and stakeholder consultation, and intra-agency coordination, which often take many years to maturalize. Therefore, this CEA intends to lay out a solid study framework, identify key cumulative issues and mitigation strategies, namely Step 1 CEA, building on which a more detailed CEA will be carried out during the implementation of and financed by the Yakou Complex development.

Section 1.1 briefly introduces the Yakou Complex. Section 1.2 describes Han River Basin (HRB) and the cascade development on the river. Section 1.3 discusses the purpose, process and methodology of the study. Section 1.4 outlines the CEA report structure.

1.1 Yakou Complex

Yakou Navigation Complex locates at Yakou Village, 15.7km downstream from Yicheng City, Hubei, 52.67km downstream of the existing Cuijiaying dam and 59.38km upstream of the planned Nianpanshan dam. It is a low-head run-of-water navigation and hydropower complex that integrate multiple functions including navigation, power generation, irrigation and tourism. The controlled drainage area of the dam is 133,087km^2 and the average annual discharge is 1,100m^3/s. Main structure of the Yakou dam include a earth-rock dam, sluice gates, low-head powerhouse, ship lock, fish pass and fish reproduction facilties. The normal water level of the Yakou reservoir is 52.22m, with a storage capacity of 350.2 million m^3, subject to daily regulation; the construction of the dam results in the formation of a 52.67km Grade-III waterway; the designed ship lock allows the passage of 1000t ships; the power station has an installed capacity of 75.0MW with the average annual energy output of 253 million kW·h. The location of Yakou Navigation Complex is shown in Figure 1-1.

After Yakou reservoir is formed, the entire impounded area will be limited within existing embankments on both sides of the Han River. The total impounded area is 99,495.03mu (6600 ha), including 71,911.0mu (4790 ha) water area and 27,584.03mu (1840 ha) land area. The impounded area of the reservoir after Yakou navigation complex is completed is shown in Figure 1-2.

[1] In this study Effects and Impacts are interchangeable. The CEA reports uses Effects because it is a more commonly used term among international environmental assessment practioners.

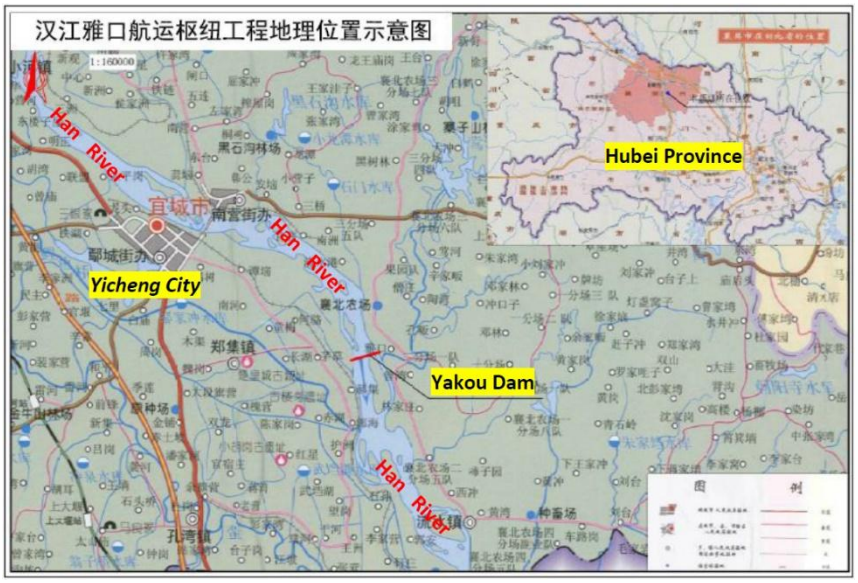


Figure 1-1 Geographical location of Yakou Navigation Complex

The construction of Yakou Complex is in line with the national strategy of sustainable energy development and local electric power development strategy. It will strengthen the economic bond and promote the social and economic development of Xiangyang Municipality, and will improve Han River navigation network, moving forward toward the objective of Han River navigation planning.

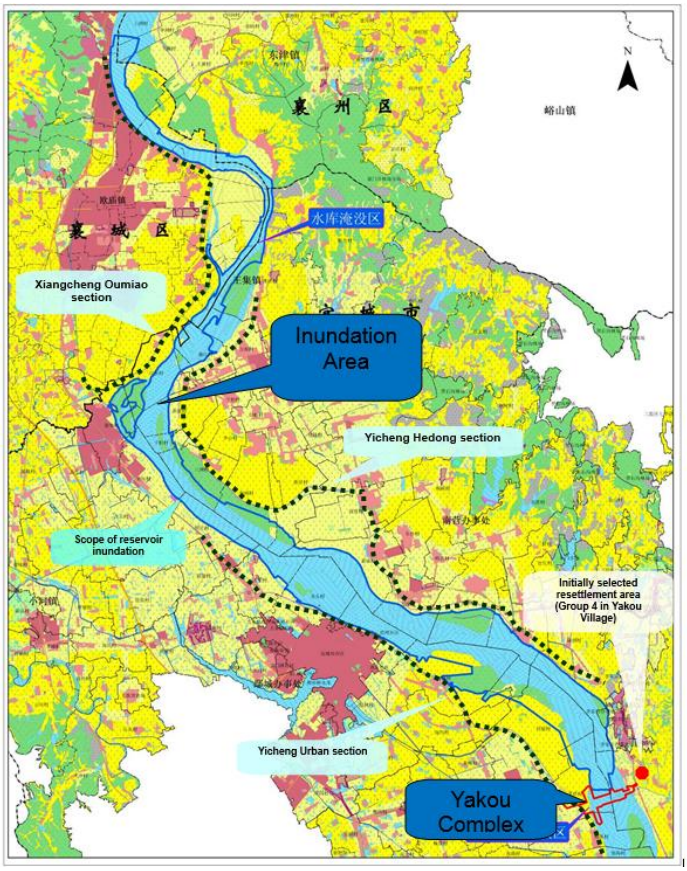


Figure 1-2 Yakou Dam and Reservoir

1.2 Han River Basin and Cascade Development

1.2.1 General

Han River is the largest tributary in the middle reach of the Yangtze River. It originates from south piedmont of Qinling Mountains, passes through Shaanxi Province and Hubei Province, and flows into Yangtze River in Wuhan City. Han River Basin (HRB) encompasses south Shaanxi Province, west Henan Province, north and middle Hubei Province, northeast Sichuan Province and southeast Gansu Province. The total length of mainstem of Han River is 1,567km, with total fall of 1,964m and the total basin area of $15.9\times10^4 km^2$. The average annual runoff is 56.6 billion m^3. Figure 1-3 shows the map of Han River system.

Han River Basin is high in northwest and low in southeast, and the elevation falls to 1000m from 3000m from west to east. The northwestern part of the basin is the famous Qinba Mountains; the valley of Han River is mainly formed from ravines and some basins sporadically. The middle and lower reaches of Han River incline eastwards, from low hilly areas toward wide Jianghan Plain. The plain is flat with dense streams, numerous lakes and ponds, widespread embankments, and the elevation is generally lower than 50m.

Han River is divided into three typical reaches. The **upper reach** refers to the section above Danjiangkou, 918km long, having the controlled drainage area of $9.52\times10^4 km^2$, with alternative distribution of ravines and basins, featured by numerous shoals and fast flow velocity. River bed is formed from pebbles and also other materials in some positions, and river bed has large longitudinal slope, with average gradient above 0.6‰. Main tributaries in upper reach includes Bao River, Xun River, Jia River and Dan River at left bank and Ren River and Du River at right bank. The landform includes medium and low mountainous land, accounting for 79%, also hills, 18%, and valley basin, 3%.

The **middle reach** refers to the section from Danjiangkou to Zhongxiang, 270km long, with controlled drainage area of 4.68×104 km^2. In the middle reach, Han River wanders through low hills with wide and shallow water, 300~400m wide in drought period and 2~3km wide in flood period. There are numerous shoals and there are erosion and deposition on riverbed. The fall of water level of upper reach is 52.6m, with average gradient of 0.19‰. The main tributaries along the middle reach Han River include Xiaoqing River and Tangbai River at left bank and Nan River, Man River and Bei River at right bank. The landform includes plain, accounting for 51.6%, and also hilly area, 25.4%, and low hills, 23%. Yakou Navigation Complex locates in the middle reach of Han River.

The **lower reach** refers to the section from Zhongxiang to Hankou, 382km long, with controlled drainage area of 1.70×104 km^2. In the lower reach, Han River flows through Jianghan Plain, with embankments constructed at both banks. The sand riverbed narrows gradually to only 200m at the river mouth. The lower reach is a meandering waterway, having a fall of 41.8m, with average gradient of 0.06‰. Hanbei River feeds into Han River at left bank and Dongjing River at right bank separates from Han River and flows into Yangtze River. The landform includes mainly plain, accounting for 51%, and also hilly area, 22%, and low hills, 27%.

According to statistics, Han River has 20 tributaries that each has a catchment area above 1,000km2, among which, 8 tributaries has a catchment area above 5,000km2, namely Tangbai River, Dan River, Yun River, Du River, Ren River, Nan River, Xun River and Jia River. There are mainly six tributaries at middle and low reaches, namely Bei River, Nan

River, Xiaoqing River, Tangbai River, Man River and Zhupi River.

Figure 1-3 Map of Han River Basin

1.2.2 Han River Basin Planning

Since 1950s, Changjiang (Yantze River) Water Resources Commission and other relevant institutions have formulated and updated various HRB plans for the purposes of flood control, water supply, water resources and aquatic ecosystem protection, power generation, navigation and water & soil conservation etc. The Changjiang Water Resources Commission proposed *Report on Key Points of Han River Basin Planning* in 1956 and the *Report on Development Plan of Han River Mainstem in Upper Reach* in 1966. Danjiangkou dam, the first and largest navigation and hydropower complex, was completed and put into operation in 1973. Danjiangkou reservoir has multi-year regulation capacity hence controls the hydroligc regime of the middle and lower reaches of Han River. Subsequently, Shiquan and Ankang stages were built in 1974 and 1992 respectively; both located in the upper stream.

The middle and lower Han River (MLHR) mainstem is located in Hubei Province. In 1993, the Changjiang Water Resources Commission issued the *Comprehensive Utilization and Planning Report of Han River Mainstem below Jia River*. In 2004, Hubei Provincial Water Resources and Hydropower Planning, Survey and Design Institute published the *Construction Plan of Pilot Modernized Hydraulic Complexes at Middle and Lower Reaches of Han River in Hubei Province*. In 2009, Changjiang Institute of Survey, Planning, Design and Research published the revised *Comprehensive Utilization and Planning Report of Han River Mainstem below Jia River*.

In 2010, Changjiang Water Resources Commission completed the *Comprehensive Planning Report of the Han River Mainstem* (2010 Revision). This planning document proposed to construct a 15-stage cascade on the Han River mainstem. Figure 1-4 provide an overview of the plan. Details of each stage are presented in the next subsection.

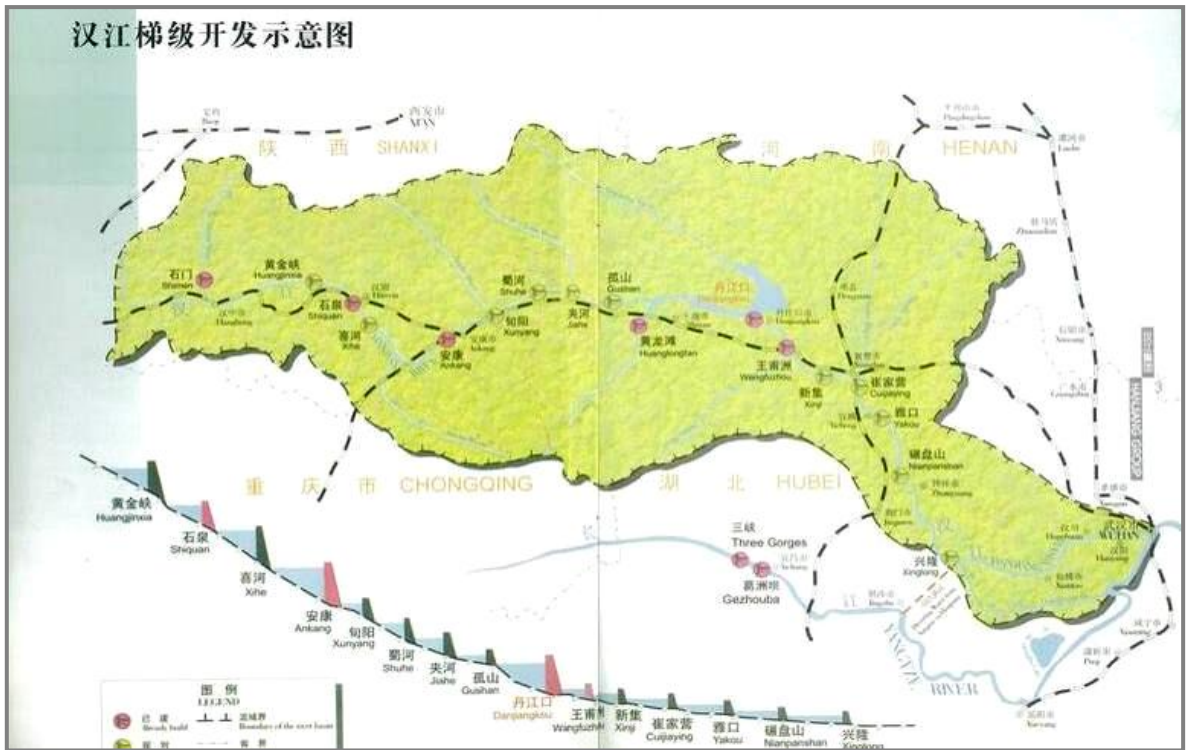


Figure 1-4 Cascade development on Han River mainstem

1.2.3 Han River Mainstem Cascade Development

1. Upper Reach Han River Dam and Reservoir System

On the upper reach of Han River mainstem, eight complexes are planned, of which four have been constructed, namely Shiquan (put into operation in 1974), Ankang (1992), Xihe (2007) and Shuhe (2010); the remaining four are under construction as this CEA is being conducted. Figure 1-5 provides description of each dam/complex; Table 1-1 shows technical paramters; Figure 1-6 shows hydrologic profile of these dams and reservoirs on the upper reach of Han River; Table 1-1 presents engineering paramters.

Stage1 - Huangjinxia Complex Dam Site, Hanzhong City, Shaanxi Province

- Under construction; dam hight 68m; upstream drainage area 17,950km2; normal pool level 450m; storage capacity 114 million m3; annual average flow (at dam site) 242m3/s; installed capacity 135MW; navigable by ship lift;
- Main structure consists of dam, sluice gate, power house, shiplift, and fish pass.

Stage 2 - Shiquan Complex, Shiquan County, Shaanxi Province

- Built in 1974/1975; dam hight 65m; upstream drainage area 23,400km2; normal pool level 410m; storage capacity 292 million m3; annual average flow (at dam site) 330 m3/s; installed capacity 225MW; navigable by 59t slope type ship lift;
- Main structure consists of dam, sluice gate, power house, and shiplift.

Stage 3- Xihe Complex, Shiquan County/Hanyin County, Shaanxi Province

- Bilt in 2007; dam hight 60.8m; upstream drainage area 25,207km2; normal pool level 362m; storage capacity 154 million m3; annual average flow (at dam site) 352 m3/s; installed capacity 180MW; navigable by 50t ship lift;
- Main structure consists of dam, sluice gate, power house, and shiplift.

Stage 4 - Ankang Complex, Ankang City, Shaanxi Province

- Built in 1992; dam hight 128m; upstream drainage area 35,700km2; normal pool level 330m; storage capacity 2.47 billion m3; annual average flow (at dam site) 564 m3/s; installed capacity 852.5MW; navigable by a 100t ship lift;
- Main structure consists of dam, sluice gate, power house, and shiplift.

Stage 5 - Xunyang Complex Dam Site, Shuhe Township, Shaanxi Province

- Under construction; dam hight 58m; upstream drainage area 42,400km2; normal pool level 241m; storage capacity 260 million m3; annual average flow (at dam site) 635 m3/s; installed capacity 320MW; navigable by 300t ship lift;
- Main structure consists of dam, sluice gate, power house, shiplift and fish pass.

Stage 6 - Shuhe Complex, Shuhe Township, Shaanxi Province

- Built in 2010; dam hight 71m; upstream drainage area 49,400km2; normal pool level 217.3m; storage capacity 176 million m3; ; annual average flow (at dam site) 720 m3/s; installed capacity 170MW; navigable by 300t ship lift;
- Main structure consists of dam, sluice gate, power house, shiplift and fish pass.

Stage 7 - Baihe Complex Dam Site, Baihe County of Shaanxi and Xunxi County of Hubei Province

- Under constrution; dam hight 71m; upstream drainage area 51,100km2; normal pool level 217.3m; storage capacity 130 million m3; annual average flow (at dam site) 734 m3/s; installed capacity 180MW; navigable by ship lift;
- Main structure consists of dam, sluice gate, power house, shiplift and fish pass.

Stage 8 - Gushan Complex Dam Site, Yunxi County of Hubei Province

- Under construction; dam hight 71m; upstream drainage area 60,440 km2; normal pool level 177.23m; storage capacity 210 million m3; annual average flow (at dam site) 778 m3/s; installed capacity 180MW; navigable by ship lift;
- Main structure consists of dam, sluice gate, power house, shiplift and fish pass.

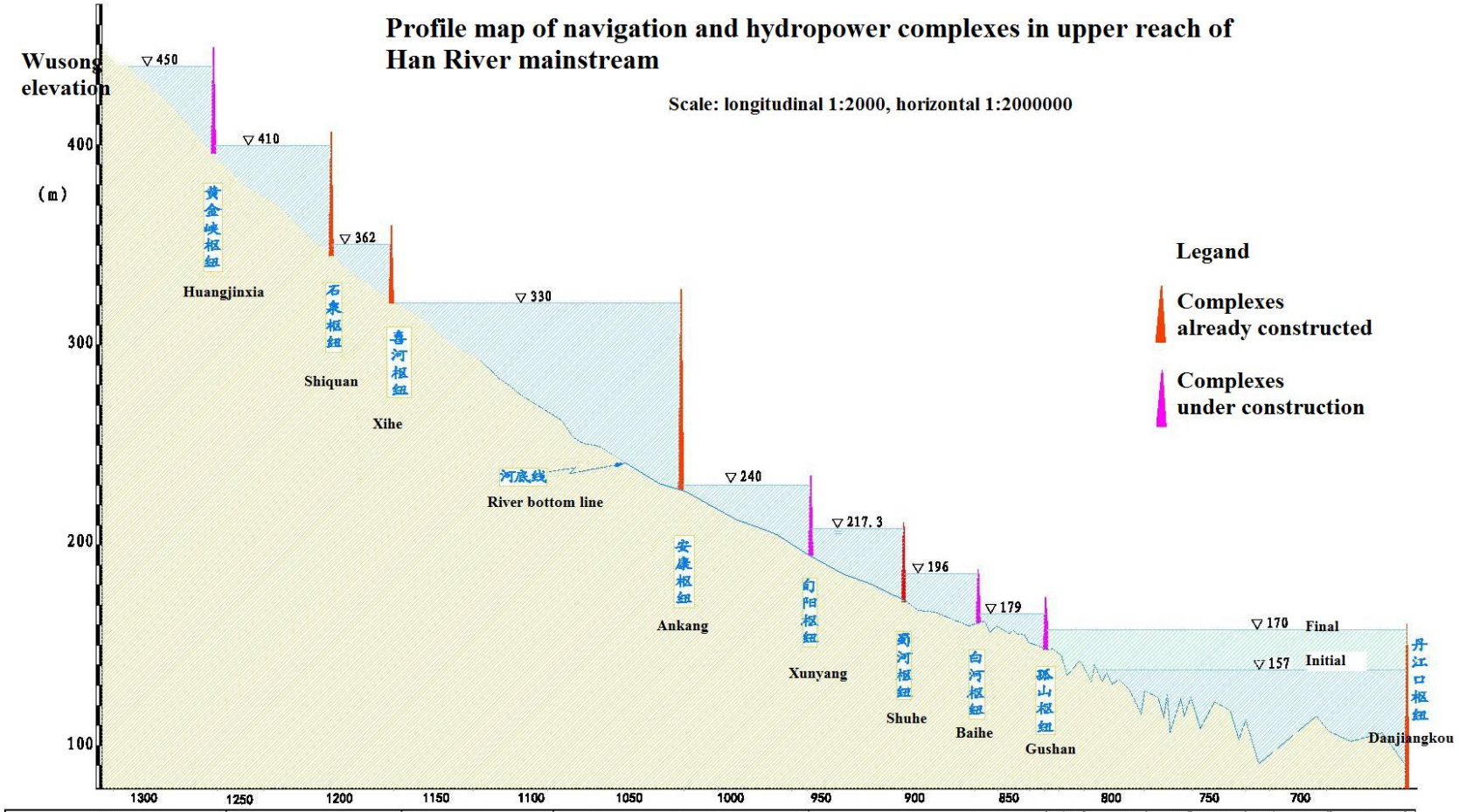
Figure 1- 5 Upper Reach Han River Dams and Reservoirs

Table 1-1: Engineering parameters of the dams and reserovirs in upper reach of Han River mainstem

Item	Unit	Huangjinxia	Shiquan	Xihe	Ankang	Xunyang	Shuhe	Baihe	Gushan
Basin area	10,000 km^2	1.80	2.34	2.52	3.57	4.24	4.94	5.11	6.04
Average discharge	m^3/s	242	330	352	564	635	720	734	778
Normal water level	m	450	410	362	330	241	217.3	195.5(193.73)	179(177.23)
Dead pool level	m	440	400	360	300	239	215	193.5(191.73)	176.77(175)
Drawdown depth	m	10	10	2	30	2	2.3	2	2.33
Backwater length (reservoir length)	km	60	53	41.5	128	55.6 (63.4)	47	39.8	34.9
Reservoir area under normal water level	km^2	12.40	25.10	11.29	77.50	23.6	11.34	9.59	10.3
Reservoir capacity under normal water level	100 million m^3	1.14	2.92	1.54	24.71	2.6	1.76	1.30	2.1
Dead storage	100 million m^3	0.45	1.25	1.34	8.48	2.14	1.5	1.08	1.86
Regulating capacity	100 million m^3	0.69	1.67	0.20	16.23	0.46	0.26	0.22	0.24
Type of regulation		Daily	Seasonal	Daily	Incomplete annual	Daily	Daily	Daily	Daily
Installed capacity	MW	135	225	180	852.5	320	270	180	180
Annual electricity generation capacity	100 million kW·h	3.63	8.0	5.3	26.6	8.59	8.9	5.5	6.12
Utilization time	h	2703	3552	2939	3126	2684	3283	3079	3546
Type		Dam-type	Dam-type	Dam-type	Dam-type	Dam-type	Dam-type	Dam-type	Dam-type
Construction site		Hanzhong, Shaanxi	Shiquan, Shaanxi	Shiquan, Shaanxi	Ankang, Shaanxi	Xunyang, Shaanxi	Xunyang, Shaanxi	Xunyang, Shaanxi and Yunxi, Hubei	Yunxi and Yun (two counties) of Hubei
Progress		Started in February 2016	Completed	Completed	Completed	Restarted in December 2015	Completed	Started in November 2015	Started in April 2016

Completion time			1974	2007	1992		2010		
Developer		Shaanxi provincial Department of Water Resources	Datang Shaanxi Hydropower Co., Ltd.	Shaanxi Han River Investment and Development Co., Ltd.	State Grid Shaanxi Electric Power Company	Shaanxi Han River Investment and Development Co., Ltd.	Shaanxi Han River Investment and Development Co., Ltd.	CGN Han River Hydropower Development Co., Ltd.	Han River Hydro-power Development Co., Ltd.

Note: all water level data use Wusong elevation system and those in in parentheses use Huanghai elevation system.



Places	Yangxian	Gushan	Huangjinxia		Shiquan	Xihe	Hanyangping	Hanwangcheng	Ziyang	Dadaohe	Huoshiyan	Ankang	Lvhe	Xunyang	Shuhe	Yanghe	Baihe	Xifengzui	Gushan	Anchenggou	Duhe	Yunxian	Anyangkou	Yuanhekou	Longkou	Danjiangkou
Distance to estuary km	1313		1258	1235	1196	1163		1130		1090	1068	1022	1003	964	956	908		870	858	842	834	837	813	782	766	730.5	717	688.5	649
Normal water level, m			450	410	410	362		330				330	240	240	217	218	196	196	179	179	170								
Bottom elevation, m	452		406	384.2	355	333		306.8		278.2	260	237.8	227.2	210	206	183		172.8	170	162.4	156	147	140	123	121	112	102	90.4

Figure 1-6 Profile Map of Dams and Reservoirs in Upper Reach of Han River Mainstem

2. Middle and Lower Han River Dam and Reservoir System

The middle and lower reaches of Han River are located at EL 111°～115° and NL 30°～33°, namely, the river section from Danjiangkou to the river mouth of Han River (where Han River flows into Yangtze River). The total length of the river section is 652km, and the catchment area is 6.4×10^4 km^2.

Seven complexes are planned for the middle and lower Han River mainstem, of which four have been constructed, namely Danjiangkou (built in 1973 and upgraded in 2014), Wangfuzhou (2000), Cuijiaying (2010) and Xinglong (2015); the remaining three are have not started construction yet.

Figure 1-6 provides description of each dam; Table 1-2 shows engineering paramters; Figure 1-7 shows hydrologic profile these dams and reservoirs. ***For easy reference, the 7 dams on the middle and lower Han River are numbered from Stage 1 to Stage 7.***

1) Danjiangkou complex is located 800m downstream of the confluence of the mainstem of Han River and Dan River in Danjiangkou City, Hubei Province. The controlled drainage area is 9.52×10^4 km^2, and the average discharge at the dam site is 1,230 m^3 /s.

Stage 1 – Danjiangkou Complex, MLH River Mile 0 km

- Danjiang complex was put into operation in 1973; normal pool level 157m; normal storage capacity 17.45 billion m3; annual average flow (at dam site) 1230 m3/s; installed capacity 900MW; navigable by ship elevator;
- South-to-North Diversion Project intends to move water from Danjiangkou reservoir to north China

to alleviate its severe water scarcity issue. To meet the objective, the dam was heightened to allow normal water level of 170m and reservoir storage capacity increased to 29.05 billion m3. The project was put into operation on December 12, 2014. Annual diversion water amounted to 2-3 billion m3.

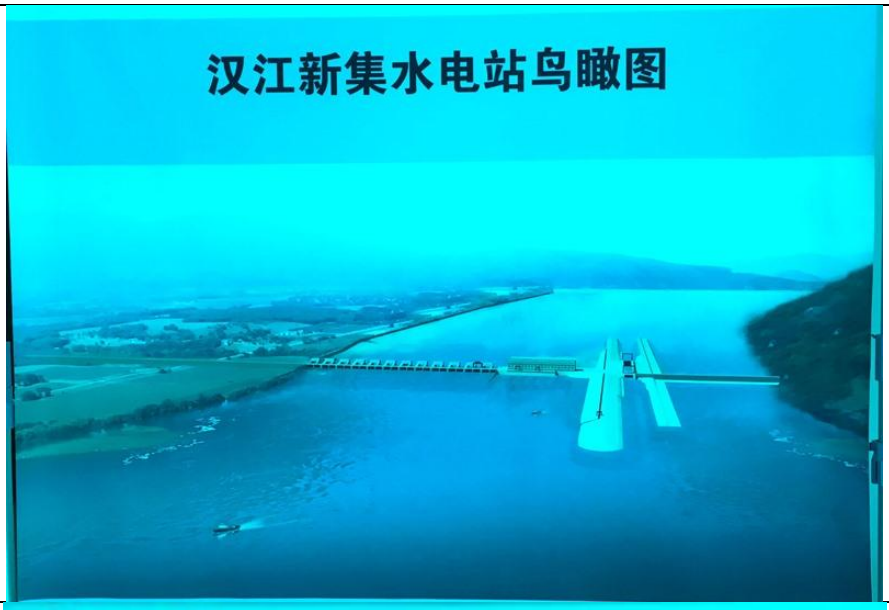
- No fish pass built. No fish pass.

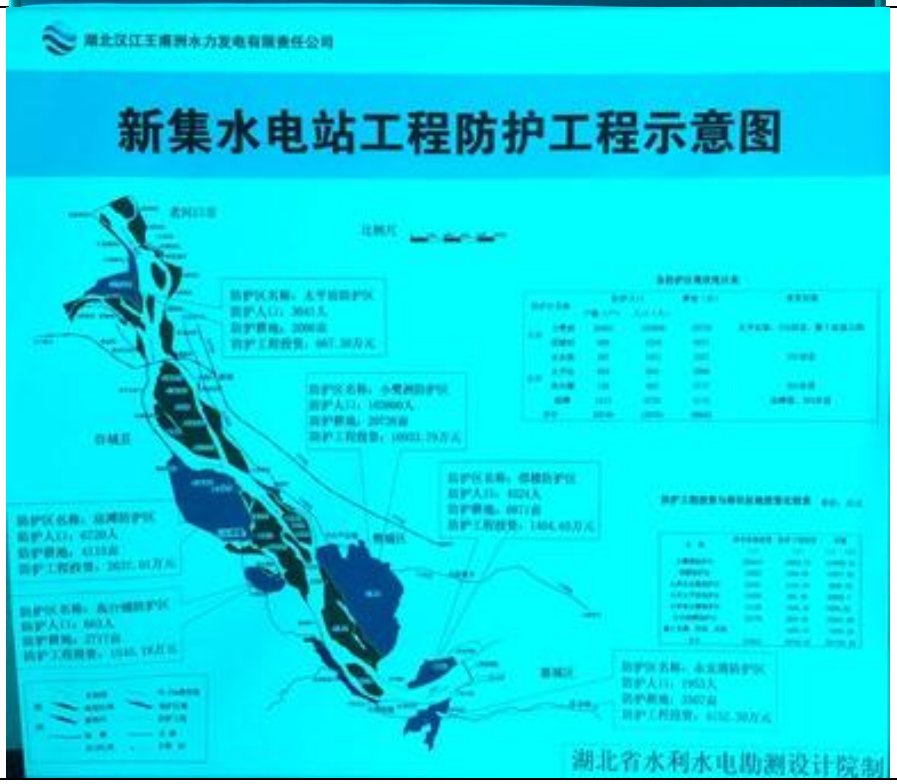
2) Wangfuzhou complex is located at about 3km downstream from Laohekou City in Hubei Province, and 30km downstream of Danjiangkou Complex. Wangfuzhou Hydropower Complex is the first power and navigation complex below Danjiangkou Reservoir. The controlled drainage area is 9.53×10^4 km^2, and the average discharge at the dam site is 1,215 m^3 /s.

Stage 2 - Wangfuzhou Complex, MLH River Mile 30km

- Built in 2000; upstream drainage area 95,300 km2; 30km downstram of Danjiangkou dam; normal pool level 86.23m; storage capacity 150 million m3; annual average flow (at dam site) 1215 m3/s; installed capacity 109 MW; navigable by ship lock;
- Main structure consists of dam, sluice gate, power house, and ship lock;
- No fish pass.

3) Xinji complex is located in the territories of Xiangcheng District and Fancheng District in Xiangyang City, Hubei Province, and the dam site is located at Baimadong, 47.5km downstream of Wangfuzhou Complex, 63.5km upstream of Cuijiaying Complex, and 28km upstream of of Xiangyang City. The controlled drainage area is10.3×10^4 km^2, and the average discharge at the dam site is 1,290 m^3 /s.





Stage 3 – Xinji complex design drawings, MLH River Mile 77.5km

- Under preparation; upstream drainage area 10,300 km2; 47.5 km downstream of Wangfuzhou dam; normal pool level 76.23m; storage capacity 301 million m3; annual average flow (at dam site) 1282 m3/s; installed capacity 120 MW; navigable by ship lock;
- Main structure consists of dam, sluice gate, power house, shiplift and fish pass;

4) Cuijiaying Complex is located in Panggong Sub-district of Xiangyang City, 17km downstream from Xiangyang City, and the controlled drainage area is13.06×10^4 km^2. This complex is the fourth complex among the seven complexes along mainstem of Han River in Hubei Province, which is 142km away from Danjiangkou Complex, 109km away from Wangfuzhou Complex, and 515km away from the river mouth

(where Han River flows into Yangtze River). The average discharge at the dam site is 1,470 m^3 /s.

Stage 4 - Cuijiaying complex, MLH River Mile 142km

- Built in 2010; upstream drainage area 13,060 km2; 142 km downstream of Danjaingkou dam; normal pool level 62.73m; storage capacity 301 million m3; annual average flow (at dam site) 1470 m3/s; installed capacity 96 MW; navigable by ship lock;
- Main structure consists of dam, sluice gate, power house, shiplift and fish pass;

5) Yakou Complex is located in the middle reach of Han River and in the territory of Yicheng City in Hubei Province, which is 81.58km away from Xiangyang City, 56.14km away from Cuijiaying Navigation and Hydropower Complex, 15.74km away from the downtown of Yicheng City. The controlled drainage area is13.31×10^4 km^2, and the average discharge at the dam site is 1,487 m^3 /s.

Stage 5 – Yakou complex, dam site, MLH River Mile 196 km

- Under preparation; upstream drainage area 13,310 km2; 56.14 km downstream of Cuijiaying dam; normal pool level 55.22m; storage capacity 608 million m3; annual average flow (at dam site) 1520m3/s; installed capacity 75 MW; navigable by ship lock;
- Main structure consists of dam, sluice gate, power house, shiplift and fish pass;

6) Nianpanshan complex is located in the territory of Zhongxiang City at middle and lower reaches of Han River, and the dam site is located at Yanshantou in Wenji Town, and 63.95km downstream of Yakou complex. The controlled drainage area is14.03×10^4 km^2, and the average discharge at the dam site is 1,630 m^3 /s.

Stage 6 – Nianpanshan complex, dam site, MLH River Mile 260 km

- Under preparation; upstream drainage area 14,030 km2; normal pool level 50.72m; storage capacity 877 million m3; annual average flow (at dam site) 1569m3/s; installed capacity 200 MW; navigable by ship lock;
- Main structure consists of dam, sluice gate, power house, shiplift and fish pass;

7) Xinglong Complex is the last complex at middle and lower reaches of Han River, and it

is located in Duobao Township in Tianmen City and Gaoshibei Township in Qianjiang City at the lower reach of Han River in Hubei Province, 378.3km away from Danjiangkou Complex and 273.7km away from the river mouth. The controlled drainage area is14.42×10^4 km^2, and the average discharge at the dam site is 1,569 m^3 /s.

Stage 7 – Xinglong complex, MLH River Mile 378.3 km

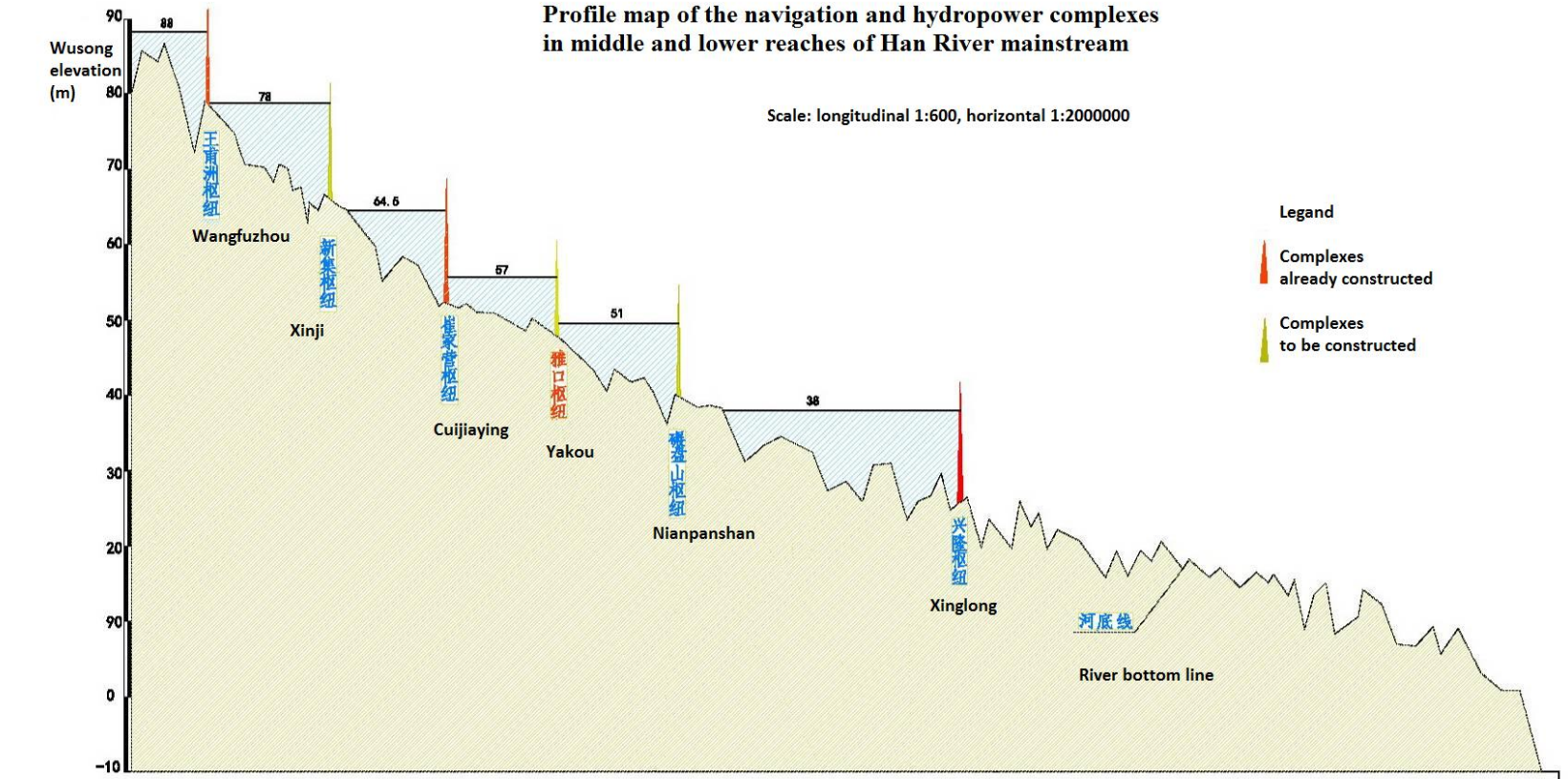
- Built in 2015; upstream drainage area 14,420 km2; normal pool level 36.23m; storage capacity 273 million m3; annual average flow (at dam site) 1569m3/s; installed capacity 37 MW; navigable by ship lock;
- Main structure consists of dam, sluice gate, power house, shiplift and fish pass;

Figure 1-7 Middle and Lower Han River Dams and Reservoirs

Table 1-2: Engineering parameters of the dams and reserovirs in middle and lower reaches of Han River mainstem

Item	Unit	Danjiangkou (initial)	Danjiangkou (late)	Wangfuzhou	Xinji	Cuijiaying	Yakou	Nianpanshan	Xinglong
Basin area	10^4 km^2	9.52	9.52	9.53	10.3	13.06	13.31	14.03	14.42
Average discharge	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	55.22	50.72	36.23
Dead pool level	m	140	150	85.48	75.93	62.23	54.72	50.32	/
Drawdown depth	m	17	20	0.75	0.3	0.5	0.5	0.4	/
Reservoir capacity under normal water level	100 million m^3	174.5	290.5	1.495	3.012	2.45	6.08	8.77	2.73
Dead storage	100 million m^3	76.5	126.9	1.207	2.806	2.05	5.41	7.94	/
Regulating capacity	100 million m^3	98	163.6	0.288	0.206	0.40	0.67	0.83	None
Type of regulation		Annual	Incomplete overyear regulation	Anti-regulating reservoir of Danjiangkou	Daily	Daily	Daily		None
Installed capacity	MW	900	900	109	120	96	80	200	37
Annual electricity generation capacity	100 million kW·h	38.3	33.78	5.81	5.03	4.3	3.72	6.5	2.18
Functions		Flood control, power generation, Irrigation, navigation	Flood control, water supply, power generation, navigation	Power generation, navigation, irrigation, breeding, tourism	Power generation, navigation	Power generation, navigation	Power generation, navigation, irrigation	Power generation, navigation, irrigation	Power generation, navigation, irrigation
Progress		Completed	Completed	Completed	Approved (under preparation)	Completed	Approved (under preparation)	Feasibility study stage	Completed

Completion time		1973	2014	2000		2010			2015
Construction site		Danjiangkou	Danjiangkou	Laohekou	Xiangyang	Xiangyang	Yicheng	Zhongxiang	Qianjiang
Developer		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.	Han River Water Conservancy and Hydropower Group Co., Ltd.	Datang Xiangyang Hydropower Co., Ltd.	Preparation Group of Yakou Navigation Complex Project	Han River Modern Hydropower Co., Ltd.	Hubei Provincial South-to-North Water Diversion Project Management Bureau



Places	Danjiangko	Wangfuzho	Xinji	Zhutiaopu	Xiangfan	Cuijiaying	Yicheng	Yakou	Zhuandouwan	Lihekou	Nianpanshan	Huangzhuang	Huajiawan	Jiukou	Shayang	Xinglong Town	Zekou	Yuekou	Pengshi River	Heyang	Wanfu gate	Chenghuang	Makou	Hanchuan	Xingou	Caidian	Estuary
Distance to estuary, km	649	616	562	549	532	507	468	455	427	402	398	379	342	318	295	269	239	206	184	153	137	103	85	75	51	31	0
Normal water level, m	0	88/78	78/64.5			64.5/57		57/51			51/38					38											
Bottom elevation	81.0	79.0	65.0		57.0	52.5	50.0	48.2	43.5		39.5	37.7	34.0	28.0	26.8	27.0	23.9	19.9	21.0	17.6	17.0	16.8	15.8	12.4	9.0	6.0	-7.4

Figure 1-8 Profile Map of the Dams and Reservoris in Middle and Lower Reaches of Han River Mainstem

1.3 CEA Purpose, Scope and Methodology

1.3.1 CEA Study Purpose

Consideration of cumulative effects is a requirement of domestic EIA regulations and World Bank safeguard policy. Per Chinese EIA law, Planning Environmental Assesemnt Code and relevant technical guidelines, cumulative effects associated with basin water resource and hydropower development should be predicted and assessed. For a system-wide planning for the Han River mainstem cascade development, it is important to consider cumulative effects of possible actions.

Consideration of cumulative effects requires a broader perspective than examining just the direct and indirect impacts of a single proposed project or activity like the Yakou project. It requires that future impacts be assessed in the context of past and present impacts to each important resource (i.e. environmental, ecological or social element). Often it requires consideration of how actions by others (including those projects completely unrelated to the proposed project) have and will affect the same resources.

The CEA analyzes the impacts on the environment that result from implementation of the Han River mainstem cascade development when added to other past, present and reasonably foreseeable future actions regardless of who undertakes such other actions. Domestic

1.3.2 CEA Study Process

In determining the CEA study process and methodology, a review of domestic and international good practices and past experiences in China were carried out during the stuty. Several domestic EIA technical guidelines regarding planning EIA and basin development provide useful guidance. Internationally recognized methodological document, such as the "Considering Cumulative Effects Under the National Environmental Policy Act" (1997, Council on Environemntal Quality (CEQ), referred to as CEQ guidance) and "Cumulative Impact Assessment and Management Guidance for the Private Sector in Emerging Markets" (2013, International Finance Corporation, World Bank Group), were examined as well. The two guidance documents describe similar steps for CEA study. There have been numerous studies following the CEQ guidance conducted sicne the CEQ guidance was published in 1997. Hence, in carrying out the CEA, the CEQ 11-step process was followed.

The 11 steps are grouped into three assessment phases as following.

1) Scoping for cumulative effects
   Step 1: Identify the significant cumulative effects issues associated with the proposed actions and define the assessment goals;
   Step 2: Establish the geographic scope for the analysis;
   Step 3: Establish the time frame for the analysis;
   Step 4: Identify other actions affecting the resources, ecosystems, and human communities of concern;

2) Describing the affected environment
   Step 5: Characterize the resources, ecosystems, and human communities identified in scoping in terms of their response to changes and capacity to withstand stress;
   Step 6: Characterize the stresses affecting these resources, ecosystems, and human communities and their relation to regulatory thresholds;

Step 7: Develop a baseline condition for the resources, ecosystems, and human communities;

3) Determing the environmental consequences of cumulative effects
Step 8: Identify the important cause-and-effect relationships between human activities and resources, ecosystems, and human communities;
Step 9: Determine the magnitude and significance of cumulative effects;
Step 10: Modify or add alternatives to avoid, minimize, or mitigate significant cumulative effects;
Step 11: Monitor the cumulative effects of the selected alternative and adapt management;

World Bank Group International Finance Cooperation (IFC) "Cumulative Impact Assessment and Management: Guidance for the Private Sector in Emerging Markets" (2013) recommends a rapid cumulatve impact assessment (RCIA) process for emerging markets (e.g. developing countries). The RCIA consists of a 6-step process as described in below.

Step 1: Scoping Phase I – VECs, Spatial and Temporal Boundaries

Step 2: Scoping Phase II – Other Activities and Environmental Drivers

Step 3: Establish Information on Baseline Status of VECs
Step 4: Assess Cumulative Impacts on VECs
Step 5: Assess Significance of Predicted Cumulative Impacts

Step 6: Management of Cumulative Impacts – Design and Implementation

Though termed and organized differently, there is no substantive difference between the two referenced study processes. The US CEQ process is more descriptive and explitly suggests alternatives analysis and adamptive management, which is what this study intends to articulate. Hence, the study follows the CEQ 11-step study process while taking into account the IFC method wehre appropriate.

1.3.3 CEA Methodology

The CEQ guidance document provides 11 analysis methods for cumulative effects assessment. These methods have been employed in the CEA and pertinent EA studies.

1. Questions, interviews and panels.
2. Checklists
3. Matrices
4. Network and system diagrams
5. Modeling
6. Trends analysis
7. Overlay mapping and Geographic Information System (GIS)
8. Carrying capacity analysis
9. Ecosystem analysis

10. Econmic impact analysis

11. Social impact analysis

1.4 Structure of the CEA report

The CEA report consists of 10 chapters.

Chapter 1: Introduction, which briefly introduces Yakou Navigation Complex Project, the Han River planning and cascade development, and the CEA purpose, scope and study methods.;

Chapter 2: Prior studies and reports which form the information baisis of the CEA report;

Chapter 3: Definition of CEA scoping, including key cumulatie effects issues, spatial and temporal coverage, and actions;

Chapter 4: Affected environmental which discusses historical condtions and trends of identified VECs and thresholds;

Chapter 5: Public consultation and inter-agency coordination, which is critical for scoping during the study and implementation of mitigation measures ;

Chapter 6: Formualtion of development scenarios for assessment;

Chapter 7: Cumulative effects assessment, which assesses the cumulative impacts on the VECs and the significance of the cumulative impacts.

Chapter 8: Cumulatve effects mitigation plans, makes management strategy based on the prediction of cumulative impacts.

Chapter 9: Conclusion and recommendations.

2 Prior Studies and Reports

Since 1950s', there has been various plans formulated and updated for Han River in the areas of flood control, irrigation, water supply, hyrodpower, navigation, water resource and ecological protection. Till the year of 2000, three dams were built in the upper reach of Han River, namely Danjaingkou (1973), Shiquan (1974) and Ankang (1992); one dam was built on the middle reach (Wangfuzhou, 2000, immediately next to Danjiangkou); and the primary purposes were for flood control, irrigation and power generation. Since EIA requirement prior to late 1970s was absent in China, no EIAs prepared for Danjiangkou and Shiquan though fishery survey and studies were carried out in 1950s in anticipation of the Danjiangkou dam project.

Since after 2000, along with the accelerated cascade development on the Han River mainstem and the advance of environmental assessement legistation, Ministry of Environmental Protection (MEP) has strengthened the review of project level EIA and pushed forward system-wide review of indirect, induced and cumulative impacts of development projects. Notably, in line with the EIA Law (enacted in 2003), the MEP required project proponent to carry out retrospective environmental impact assessment of Han River cascade development when the project proponent proposed for a single complex development.

In addtion, in the EIA process MEP requires the development on specific ecosystem protection or restoration plans, such as fishery resource restoration program or ecological scheduling program. Such assessment studies and MEP requirements encompass elements of strategic and cumulative environmental impacts assessment and management. For example, it is explicitly stated in the two retrospective EIA for upper and middle and lower Han River cascade development that " *The retrospective assessment should examine, at river basin level, the environmental elements that feature with strong interity, wide impact scope, longer timeframe and cumulative characteristics…*"

The CEA was conducted primarily through comprehensive review of available pertinent studies and reports and consultation with various stakeholders including technical experts, government agencies, dam/reservoir operators, potentially affected people and NGOs. This section lists and summarizes key studies and reports that are pertinent to this cumulative effect assessment study. Since there has been evolving assessment on one subject in different stage, the CEA intended to the latest information for assessment. For example, the *Retrospective Environmental Impact Assessment for Cascade Development on the Mid-Low Reaches of Han River Mainstem* was prepared in 2012-2013, which considered cumulative effects of all dams on the middle and lower Han River. Afterwards, the EIAs for Yakou and Ninapanshan complex were prepared with much greater details on impacts assessment and mitigation mareus. Hence the updated information and data were adopted by this CEA.

Table 2-1 List and Summary of Major Studies and Reports Pertinent to the Cumulative Effects Assessment

Document Title	Document Time	Project Proponent / EIA Institute	Sumary/Note
Retrospective Environmental Impact Assessment for Cascade Development on the Mid-Low Reaches of Han River Mainstem	2012.08	Datang Xiangyang Hyrdopower Co., Ltd. / Hubei Academy of Environmental Sciences	• The Datang company is the project proponent of Xinji Complex; MEP required the company to conduct a restropective EIA in addtion to the project EIA. • Hubei Academy of Environmental Sciences was commissioned by the company to carry out the study. The retrospective EIA includes a review of the already built hydro/navigation complexes and planned complexes on the mid-low reaches of Han River.
Retrospective EIA for Cascade Development on the Upper Reach of Han River Mainstem	2012.12	Shaanxi Government, Shaanxi Han River Investment Development Co., Ltd., Zhongguanghe Han River Hydropower Development Co., Ltd./ China Hydropower Consulting Group Beijing Engineering Corporation Co., Ltd.	• The three project proponents (responsible for development of Huangjinxia, Xunyang and Baihe complex respectively) were required to conduct a restropective EIA in addtion to the project EIAs. • China Hydropower Consulting was hired by the project proponents to carry oout the study. • The retrospective EIA includes a review of the already built hydro/navigation complexes and planned complexes on the upper reaches of Han River.
Impacts of South to North Diversion Project on Fishery Resources in the Middle and lower Han River and Protection Technologies: Special Study Report	2004	NA	• Comprehensive survey on aquatic life and fishery resources in the midle and lower Han River carried out in 2004; • Assessment of the impacts resulting from the project, and proposed protection measures; • Included a useful analysis on the trends of fish communities by comparing the results of the 3 comprehsenvie fish surveys since 1950s.
Han River Wanfuzhou Hydro-Complex Environmental Impact Assessment: Approval Document by Hubei Provincial Environmental Protection Department; and Wangfuzhou Project Completion Acceptance of Environmental Impact Survey Report: Technical Opinions by SEPA Environmental Engineering Evaluation Center	1988.10 2004.11	NA	• The Hubei Provincial Environmental Protection Bureau approved the Wangfuzhou project EIA in 1988; • The project was completed in 2000. Completion acceptance was approved in 2004 following the project pilot operation, monitoring and assessment.

Han River Cuijiaying Hydro-Navigation Complex Environmental Impact Assessment and approval by SEPA	2005.5	Hubei Province Communication Deparatment/ Second Harbor Engineering Investigation and Design Institute	• The project is financed by the World Bank; • The EIA required fish pass, fish reproduction facility and program; • The EIA included a preliminary assessment of cumulative impacts of the planned 9 dams in Hubei Province.
Han River Xinglong Hydro-Complex Environmental Impact Assessment: Approval Document by MEP	2005.5	South to North Diversion Engineering Construction Administration Bureau /	• The EIA required fish pass, fish reproduction facility and program;
Dam Heightening for Danjaingkou Hydro-Complex Project Environmental Impact Assessment Report: Reply for EIA Evaluation Opinions	2004.10	Ministry of Water Resources	• The approval required in-depth assessment of the project impacts on downstream economic fishes, ecosystem in the master report.
Han River Xinji Hydro-Power Station Environmental Impact Assessment Report: Expert Technical Review Opinions	2011. 12	NA	• The EIA required fish pass, fish reproduction facility and program, protecton of fish habitats, fishery administration and aquatic monitoring to be carried out.
Han River Yakou Hydro-Navigation Complex Environmental Impact Assessment Report and MEP approval	2016.2	Port and Habor Administration Bureau, Hubei Provincial Communication Department / China Hydropower Consulting Group Zhongnan Engineering Corporation Co., Ltd.	• The EIA required fish pass, fish reproduction facility and program, and aquatic monitoring to be carried out. • Ecologial scheduling is required; • Mainstem and tributary fish habitat protection required.
Analysis Report for Coordinated Ecological Scheduling Plan for Han River Cascades Downstream of Danjaingkou and approval by the Hubei Provincial Government	2015.12	Hubei Provincial Communication Department / China Hydropower Consulting Group Zhongnan Engineering Corporation Co., Ltd.	• Involve all Han River mainstem dams/reservoirs downstream of Danjiangkou reservoir (included) • Hubei Provincial Environmental Protection Departmetn, Transportation Department, Water Resources Department and Agriculture Department; involved dam/reservoir owners to implement based on assigned responsiblities
Yicheng Wanyangzhou National Wetland Park Core Area Constructive Detaled Planning	2016.7	Wangyangzhou wetland park management committee/ Hubei Forest Survey and Design Institute	• Detailed planning is compatible with the Yakou dam construction.
Han River Nianpanshan Hydro-Navigation Complex Environmental Impact Assessment	2017.1	Hubei Provincial Nipanshan Hydro-power Complex	• The EIA required fish pass, fish reproduction facility and program, and aquatic monitoring to be carried out.

Report and MEP approval		Engineering Construction Bureau / Zhongnan Safety and Environmental Technology Co., Ltd.	• Ecologial scheduling is required; • Mainstem and tributary fish habitat protection required.

A list of the pertinent reports and studies is presented in below.

(1) *Overall Planning Report of Han River Mainstem* (2010 revision);

(2) *Comprehensive Utilization and Planning Report of Han River Mainstem below Jia River*;

(3) *Construction Plan of Pilot Modernized Hydraulic Complexes at Middle and Lower Reaches of Han River in Hubei Province* ("the *Construction Plan*"), and the comments of review and approval authorities;

(4) Navigation Planning Report of Han River as Part of Yangtze River System;

(5) *High-grade Waterway Construction Program for Han River and Jianghan Canal (2011-2015)* (revision);

(6) *EIA Report of South-to-north Water Diversion Middle Route in Middle and Lower Reaches of Han River*;

(7) *Environmental Impact Statement of Danjiangkou Dam Heightening Project* and the approval documents;

(8) *Environmental Impact Survey Report of Han River Wangfuzhou Hydropower Complex in Hubei for the Purpose of Final Acceptance* and the approval documents;

(9) *Environmental Impact Statement of Han River Cuijiaying Navigation and Hydropower Complex* and the approval document;

(10) *Survey Report for Environmental Protection Acceptance of Han River Cuijiaying Navigation and Hydropower Complex Project*;

(11) *Environmental Impact Statement of Han River Xinji Hydropower Complex in Hubei* and the approval documents;

(12) *Environmental Impact Statement of Han River Yakou Navigation Complex Project* and the approval documents;

(13) *Environmental Impact Statement of Han River Nianpanshan Hydropower Complex Project* (draft for preliminary review);

(14) *Environmental Impact Statement of Han River Xinglong Hydropower Complex as part of South-to-north Water Diversion Middle Route* and the approval documents;

(15) *Research on Water Environment Impacts of South-to-north Water Diversion*

Middle Route in the Middle and Lower Reaches of Han River and the Mitigation Measures;

(16) *Research on Ecological Environment Impacts of South-to-north Water Diversion Middle Route in the Middle and Lower Reaches of Han River and the Eco-compensation Policies;*

(17) *Environmental Impact Statement of High-grade Waterway Construction Program for Han River and Jianghan Canal (2011-2015)* and the reviewing documents;

(18) *Retrospective EIA Report of Hydropower Development in the Middle and Lower Reaches of Han River Mainstem* and the reviewing documents;

3 Scoping for Cumulative Effects Assessment

Cumulative effects assessment starts with **scoping** which includes the following steps: *a) identify the significant cumulative effects issues associated with the proposed actions and define the assessment goals; b) establishing geographic scope and time frame for the analysis; and c) identifying other actions affecting the resources, ecosystems, and human communities of concern.* Put another way, it is to identify the major receptors of impacts – valuable environmental components (VECs) and the sources of impacts – reasonably foreseeable future actions (RFFAs), through various pathway in greater spatial and temporal scales.

Cumulative effect assessment process is inevitably iterative rather than linear. Thorough scoping through refinement and narrowing the focus of the cumulative effects analysis to important issues is necessary. This section discusses how the geographic scope and time frame were defined through applying the scoping principles and the identified actions affecting the VECs.

3.1 Initial Identification of Cumulative Effects Issues

The Han River provides a significant link to the country's transportation network while at the same time supporting valuable ecosystems that should be sustained for future generations. Development activities in and along the Han River should be carried out in an environmentally sustainable manner, both in the vicinity of the dams and along the entire length of the river. To aid in the effort, cumulative environmental effects are considered in assessing cascade development and other reasonably foreseeable future activities (RFFAs).

In accordance with the CEQ Guidance for cumulative effects assessment, the CEA intended to assess the full direct, indirect, and cumulative impacs of future cascade development of the Han River cascade development on the valued environmental components (VECs). Considering the extensive study workload and complex institutional background, the current CEA prepared during the Yakou project preparation set a study goal of providing a preliminary assessment and more importantly a solid and concrete study framework for further studies. At this preliminary study stage, the following VECs were identified, which should be further examined and expanded in future CEA study.

The initial identification of VECs was carried out through review of pertinent planning documents and EIAs, and seeking opinions from government agencies (such as water resource and fishery bureaus), technical experts and NGOs such as Green Han River based in Xiangyang City.

The following VECs and cumulative effects issues were identified and discussed. Besides, other potential VECs such as recreation, socio-economics and cultural relics were considered in the baseline part of the CEA study. Nonetheless, at this preliminary CEA study stage, below discussed VECs are of high priority. Reasons for assigning higher priority to these VECs included: a) relative importance or value of the component (e.g. water quality is essential to aquatic life, recreation and other uses), b) sensitivity of the VEC to ongoing factors affecting the sustainability of the component, and c) sensitivity to changes related to commercial navigation on the Han River.

- ***Flow regime***. Studies suggest that affected by South-to-North Water Diversion Project (under full operation) added to other projects, annual average flow rate

will reduce cumulatively along the length of middle and lower Han River until Xinglong cross-section. Below Xinglong, compensated by Jianghan Canal (that brings water from Yangtze River to Han River) the flow rate will restore.

- ***Water quality***, which has seen improvement and remained stable in recent years, primarily due to the implementation of strengthed standards and pollution control measures on domestic and industrial wastewater. The Han River mainstem water quality has fully attained designated standard (Class II). While, since 1990s, several algae blooms occurred in the mainstem, indicating eutrophication that is caused by nutrient load combined with suitable flow regime amd weather conditions. The tributaries of middle and lower Han River are generally polluted. The upper reach of Han River is of very good water quality given its vast mountainous area, less population and very limited industrial activites.
- ***Fish.*** The fish species in Han Rive have great similarities with those of middle and lowe Yangtze River basin. Since 1973 when Danjiangkou dam was built, the fish movment from Yangtze and mid-lower Han River to upreach Han River has been vitually blocked. Historically, water pollution, over-fishing and dam construction have contributed to the declining of fishery resources, in particular the fish species with floating eggs, represented by the so-called *Four Domesticated Fish* (*black, grass, silver, and bighead carp*). In recent years, due to water quality improvement, enhanced fish protection and fishery administration, there are also positive signs of fishery resources in river.
- ***Riparian/floodplain areas***. Riparian/floodplain areas include riverine wetlands and certain terrestrial areas. This is a less studied topic across reviewed documents, compared to aquatic ecosystem. Nonetheless, the unique ecological values and services have been more and more recognized in recent two decades, and that it was recognized various sources contributed to the effective effects on riparian areas, such as dam and bank stabilization structures, farming and grazing, and urban development activities, etc.

These priority VECs also displayed significant interdependencies or sensitivity to related influences. In this context, conditions of certain VECs become important “drivers” that influence other VECs in in the overall system. Notably, improvements in water quality VEC will drive the other compoennts of the aquatic ecosystem of the Han River toward improved conditons. The conditions of fish should improve, while riparian resources may benefit to a lesser enxtent. Cleaner water and improved aquatic resources in turn will enhance recreation and fishing. Improved recreational conditions often stimulate riverfront development, in urban areas, which add to local economic growth, but concomitantly may contribute to loss of riparian areas.

It is noted that the ecological values of riparian/floodplain resources is more confounding in part because of somewhat limited knowledge of he VEC. Lack of knowledge about the VEC was correlated with the relatively low recognization of its biogeochemical, hydrological and ecological processes that are distinctive from terrestrial ecosystem. Hence in this CEA, special efforts was made to improve the understanding the riparian and floodplain ecology. In future CEA study, this riparian and floodplain ecosystem aspect should be expanded.

3.2 Defining CEA Geographic Boundaries

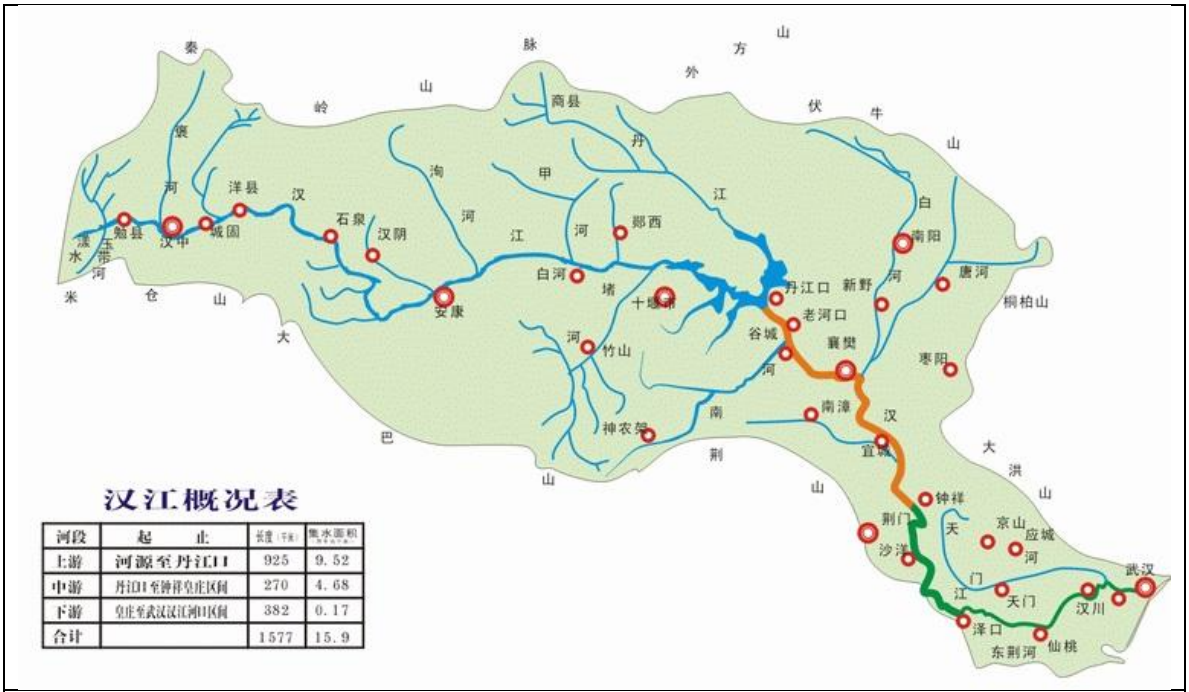
At the intial scoping stage, the CEA study intended to cover the entire 15-stage cascade development on the Han River mainsteam and the whole Han River Basin (HRB). A review of relevant planning, environmental assessment related documents and institutional background (in particular the inter-agency coordination aspecct) were carried out. It was recognized that given the scale and complexity of the whole Han River system and pertinent institutional complexities, and the extensive efforts needed to collect and analyze needed data, it is feasible and pragmatic to limit the study scope in a smaller geogrphacal area.

The CEQ guidance suggests that "*For water resources, an appropriate regional boundary may be a river basin or parts thereof.*" It also provides some possible geographic boundaries for different resources (VECs). For instance, possible geographic areas for the assessment of water quality include "*streams, watershed, river basin, estuary, aquifer, or parts thereof"*. For fishery resources, it may include "*stream, river basin, estuary, or parts thereof; spawning area and migration route"*. From a system standpoint, a sub-system such as a portion of a river or a river basin can be singled out as an independent system for study as long as the study boundary is clearly defined and the material and energy flows into and out of the system are identified.

CEA study scope is highly relevant to its study goals. During the CEA study, several challenges and opportunities associated with the Han River cascade development were agreed among government agencies, development project proponents, and technical experts. Among other cumulative impact issues, water quality deteriatation and impacts on fishery resources stood out. It was also recognized that addressing cumulative effects from multiple projects (such as construction of dams/locks) and other actions or activities (such as urban development, agricultural and industrial activities, and new environmental regulations) will require close intra-agency collaboration that should be coordinated by high-level government (e.g. provincial government or basin level administration) and building a sustained and robust mechanism to share information, collaborate and take concerted actions. This is particularly important considering the fact that the cascade development on the Han River is handled by several development proponents with different sectoral background, including state-owned energy compnaies, water resources and transport agencies (see Table 1-1 and 1-2 for the various developers/operators of dams and reservoirs on the Han River). Therefore, the CEA study should aim to deepen common understanding of the important cumulative effects issues among these stakeholders, and explore how to build and enhance practical and implementable action plans and coordination mechanisms. To meet this shared goal, expanding the CEA to the whole HRB that is 1, 577 km in length, 159,000 km2 in area and covers three provinces (the river flows through Shaanxi and Hubei provinces but the basin area includes southwest Henan Province) seems to be unrealistic.

Another consideration is that the CEA intends to examine cascade development which in the middle and lower Han River have a primary development objective to support inland waterway. It is noted that the freight volume being transported along the middle and lower reaches mainstem accounted for more than 95% of the whole mainstem Han River (2013).

Figure 3.1 and Table 3.1 shows the Han River basin, including mainstem, major tributaries and the illustration of upper reach (blue), middle reach (yellow) and low reach (green). Table 2-1 provides more technical details.



河段	起　止	长度（千米）	集水面积
上游	河源至丹江口	925	9.52
中游	丹江口至钟祥皇庄区间	270	4.68
下游	皇庄至武汉汉江河口区间	382	0.17
合计		1577	15.9

Figure 3-1 Han River Basin

Han River originates from Hanzhong City in Shaanxi Province, and the total length of the mainstem is 1,577km. Above Danjiangkou is the upper reach, about 925km long, and the catchment area is 95,220km^2 . The mainstem flows in east-west direction, and passes through Qin Mountains and Daba Mountain, with high gradient. From Danjiangkou to Huangzhuang in Zhongxiang is the middle reach of Han River, about 270km long, and the catchment area is 45,120km^2. The riverbed is wide and shallow and the water flow is scattered, and the river section is wandering river channel. Below Huangzhuang is the lower reach, about 382km long, the catchment area is 18,660km^2, and the river section is meandering river channel. The total length of the middle and lower reaches is 652km, accounting for 41.3% of the total length of Han River.

Table 3-1 Characteristics of the upper, middle and lower reaches of Han River Basin

Item	Upper reach	Middle reach	Lower reach
Position	Shaanxi, Hubei	Hubei	Hubei
Starting and ending points	Hanzhong to Danjiangkou	Danjiangkou to Zhongxiang	Zhongxiang to river mouth
Length	925km	270km	382km
Controlled drainage area	9.52×10^4 km^2	4.68×10^4 km^2	1.70×10^4 km^2
Average gradient	0.6‰	0.19‰	0.06‰
Main tributaries	Left bank: Bao River, Xun River, Jia River and Danjiang River; Right bank: Ren River, Du River, etc.	Left bank: Xiaoqing River and Tangbai River; Right bank: Nan River, Man River, Bei River, etc.	Hanbei River inflows on the left bank; Dongjing River on the right bank outflows into Yangtze River.
Main landform	Mainly medium and low mountainous land, accounting for 79%, hills, 18%, and valley basin, 3%.	Mainly plain, accounting for 51.6%, mountainous land, 25.4%, and hills, 23%.	Plain accounting for 51%, mountainous land, 22%, and hills, 27%.
Cascade development	Huangjinxia - Shiquan - Xihe - Ankang-	Wangfuzhou - Xinji - Cuijiaying - Yakou -	Xinglong

	Xunyang - Shuhe - Baihe- Gushan - Danjiangkou	Nianpanshan	

From technical perspective, putting CEA emphasis on middle and lower Han River can lead to reasonable results. The middle and lower Han River refers to the river section between Danjiangkou and the Han River confluence with Yangtze River in Wuhan City. The separation point of the upper reach and middle reach, Danjiangkou Dam, forms a huge Danjiangkou Reservoir. The Danjiangkou reservoir was built and put into operation in 1973 and since then it constitutes a control stage on the Han River. By "control" it means the Danjiangkou hydro-complex has the multi-year regulation capacity and its realeses to downstream is not subject to inflows from upstream in general, whereas all the dams planned for the middle and lower Han River are of run-off type that doesn't have regulation capacity or have daily regulation capacity only. Therefore, the hydraulic regimes of the mid-low reaches of Han River (which is fundamental to water quality, aquatic ecosystem and other VECs) is largely subject to the water releases from Danjaingkou hydro-complex and tributaries along the middle and lower Han River, notably the Tangbai River which joins the Han River in Xiangyang City, upstream of the Cuijiaying hydro-navigation complex. Figure 3-2 shows the comparison of Danjiangkou reservoir and the 6 downstram dams/reservoirs.

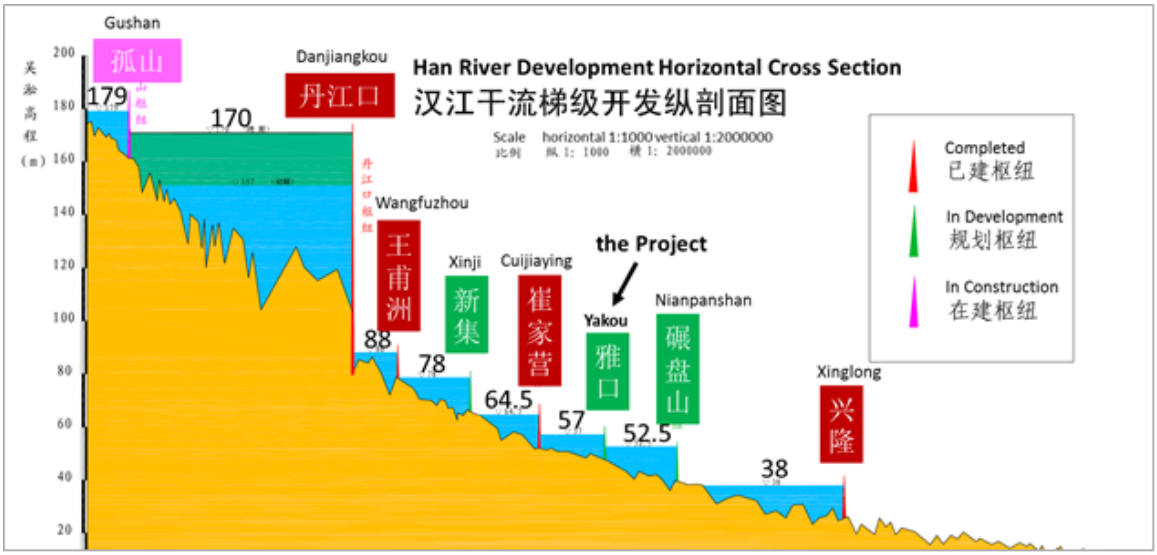


Figure 3-2 Dams and Reservoirs on Middle and Lower Han River

One of the key VECs identified for the Han River CEA study is fishery resources. Assessing cumulative effects of cascade development on the fishery resources should consider migration route, spawning area, wintering and feeding ground. Numerous studies have been conducted and tended to agree that the Danjiangkou Dam has not only played a controlling role over the hydraulic regime downstream, but also affected the fishery resources on the middle and lower Han River. There were few historical data and studies dedicated to the impacts of Danjiangkou Dam over fish migration from its downstream to upstream. In China it was since late 1970s fish pass facilities were taken into account for dam/reservoir design. The Danjiangkou dam, built in 1973, didn't take fish pass into account due to historical reasons. The dam has blocked potential movement of the fish

going up river since then. Other studies indicate that the Danjiangkou Reservoir affects water temperature downstream that has affected downstream fish habitats. For example, immediate river sections downstream of Danjiangkou becomes wintering and feeding grounds as water releases from Danjiangkou in winter time are warmer than the ambient environment, whereas, in Spring and Summer time the water releases from the dam is cooler that leads to postponing of fish spawning season.

The above discussed scoping process that took into account the CEA study goal, institutional and technical considerations led to the conclusion that it is technicaly justifiable and intutionally pragmatic to define the CEA geographic area as the middle and lower Han River mainstem and basin. In fact, the area of influence considered in the CEA varies among environmental elements categories according to characteristcs of each environmental elements. Therefore, while geographic boundaries for the CEA were generally set as the mi-low reaches Han River mainstem, floodplain and tributaries, flexibility was reserved to adjust these boundaries as the environmental elements conditions dictated.

3.3 Defining CEA Time Frame

There are 7 dams planned on the middle and lower Han River. To number them along the length of the river, Stage 1 Danjiangkou, Stage 2 Wangfuzhou, Stage 4 Cuijiaying and Stage 7 Xinglong have been built; Stage 3 Xinji, Stage 5 Yakou and Stage 6 Nianpanshan are at pre-construction stage. Completion of the remaining dams in coming 3-5 years is a highly probable scenario.

The initial phase Danjiangkou complex was completed in 1973; its dam was heightened recently in 2014 to meet to South to North Diversion. The Wangfuzhou, Cuijiaying and Xinglong complexes were put into operation in 2000, 2010 and 2015 respectively. The South-to-North Water Diversion Phase-I was put into operation at the end of 2014 but the actual water diversion in 2015 and 2016 only reached 20-30% of the designed target. Therefore, the base year of this CEA is defined as Year 2014 when South-to-North Water Diversion Project had not be implemented (to be adjusted for some environmental elements according to actual assessment needs), and the forecast year is Year 2020 when all the navigation complexes at middle and lower reaches of Han River are expected be completed.

Further, aside from cascading dam construction, consideration of cumulative effects should include operation, maintenance and implementation of all actions determined to be appropriate throughout the planning horizon. Therefore, operational stage should be taken into account when defninig the time frame for CEA.

This report should be viewed as the outcome of the first step of the CEA study for the intended subject. The project owner of the Yakou project will support a follow-up CEA study building on this repor during implementation of the Yakou project through 2017-2020.

3.4 Identification of Reasonably Foreseeable Future Actions

With CEA scope determined, the following past, ongoing and reasonably foreseeable future actions (RFFAs) and affected valued environmental components (VECs) were

identified through literature review, consultation with experts and stakeholders. These RFFAs will affect (VECs) in a combined manner through various possible pathways.

- Construction and operation of dams and reservoirs on the middle and lower Han River mainstem. There are 6 dams planned below Danjiangkou dam. To number them along the length of the river, Stage 1 Danjiangkou, Stage 2 Wangfuzhou, Stage 4 Cuijiaying and Stage 7 Xinglong have been built; Stage 3 Xinji, Stage 5 Yakou and Stage 6 Nianpanshan are at pre-construction stage. Completion of the 6 dams in coming 5 years is a highly probable scenario.
- Construction and operation of Sout-to-North Water Diversion Project (Diversion Project hereafter in this report), which intended to divert water from Danjiangkou reservoir to northern China to alleviate its severe water scarcity. The associated major activity included heightening the Danjiangkou dam that was completed in 2014. Subsequently increasing of the reservoir capacity and diversion works were put into operation at the end of 2014. Nonetheless, actual water diversion and reservoir storage have been significantly below the designed targets (20%-30% of the designed targets) during 2015-2016. Therefore the impacts of the South-to-North Water Diversion Project on the middle and lower Han River has been smaller than predicted, and the significance of future effects is less definite based on a literature review of the anticipated water demand in Hebei and Henan Provinces (two major receptors of the diverted water in northern China) and policy and insitutional complexities.
- Actions that have contributed and will contribute to the water quality and fishery resources such as the implementation of strengthened river water quality standard and zoning requirements, Han River basin water pollution control regulation, basin-wide domestic and industrial wastewater treatment facilities, and strengthened general fishery administration, establishement of wetland park. A new Hubei Han River Middle and Lower Reaches Basin Water Pollutants Comprehensive Discharge Standards was being formulated in 2016 by the provincial government during development of this CEA.
- Broader actions that have affected and will continue to have potential impacts on the river, including land use changes associated urban development, industrial development, and population expansion. Tourism development and creation of recreational opportunities is also considered; they will have potential negative impacts; but if well planned and managed, they will provide excellent opporutnities for ecosystem restoration.

4 Affected Environment

The second CEA phase following **scoping** is to describe affected environment. Steps include *a) characterizing the VECs identified during scoping phase in terms of their responses to change and capacity to withstand stresses; b) characterizing the stresses affecting these VECs and their relation to regulatory thresholds*, and *c) define a baseline conditions for the VECs.*

Compared to the descriptions of environmental and social baselines or assessment on current situations in traditional EIAs, CEA treats this subject with a broader perspective. Since CEA considers effects resulting from past, present and future actions, it emphasizes to examine the environmental conditions and and to link them to various stresses. In doing so, comprehensive review of available historical studies, reports and monitoring records have to be conducted. Given this is a significant endeavor, it should focus on specific valued environmental components (VECs) that are representative of the health and sustainability of ecosystem.

The study area includes the middle and lower Han River, which extends from the Danjiangkou hydo-complex (included) in Shiyan City to Hankou District, Wuhan City wehre the Han River empties into the Yantze River. The area includes 652 km of Han River meainstem, 8 major tributaries and a total drainage aera of 63,800 square kilometers. The drainage area encompasses portions of Hubei and Henan Provinces; about 43, 800 km2 are in Hubei and 20,000 km2 are in Henan. Within the sub- basin, in total 7 dams were planned, of which Danjiangkou, Wangfuzhou, Cuijiaying and Xinglong were already built; the remaining three (Xinji, Yakou and Nianpanshan) have had FSR and EIA approved domestically. Upon completion of the remaining three dams/locks, the middle and lower Han River mainstem will be turned into a Grade III navigation channel and allow for year-round navigation of 1000 t vessels. The 6 complexes downstream of Danjiangkou are of low head, run-off type that have daily or no regulation capacity. All the complexes can generate electricity.

4.1 Hydrologic Regimes

According to historical records obtained from the hydrologic measuring stations on the middle and lower Han River, including Huangjiagang, Xiangyang, Huangzhuang (Nipanshan), Shayang, Qianjiang, Xiantao stations, the flow processes through the year 1956-2012, which are shown in Figure 4-1 and 4-2.

During 2006-2012, the average annual discharge of **Huangjiagang Station** is 1,180 m^3/s, that of **Xiangyang Station** is 1,280 m^3/s, that of **Huangzhuang Station** is 1,520m^3/s, that of **Shayang Station** is 1,430 m^3/s, and that of **Xiantao Station** is 1,240m^3/s. After the initial construction of Danjiangkou Complex is completed, the peak discharge reduces significantly, the flow at the middle and lower reaches becomes even and gentle, the discharge increases in dry season, and the normal season extends. The river section below Xiangyang is affected by regional precipitation and tributary inflow, and the annual change range of discharge is greater than that in the river section above Xiangyang. Rise and fall of water level is consistent with the discharge. Due to fewer tributaries above Xiangyang, the fluctuation of water level is small.

Implementation of water resource project in the river basin has broung pronounced changes to the spatial and temporal distribution of river runoff: river level elevated, river surface widended, water body area increased. The Han River mainstem runoff reduced to certain extent compared to original natural state.

Figure 4-1 Location of Hydrologic Measuring Stations in Middle and Lower Han Rirver

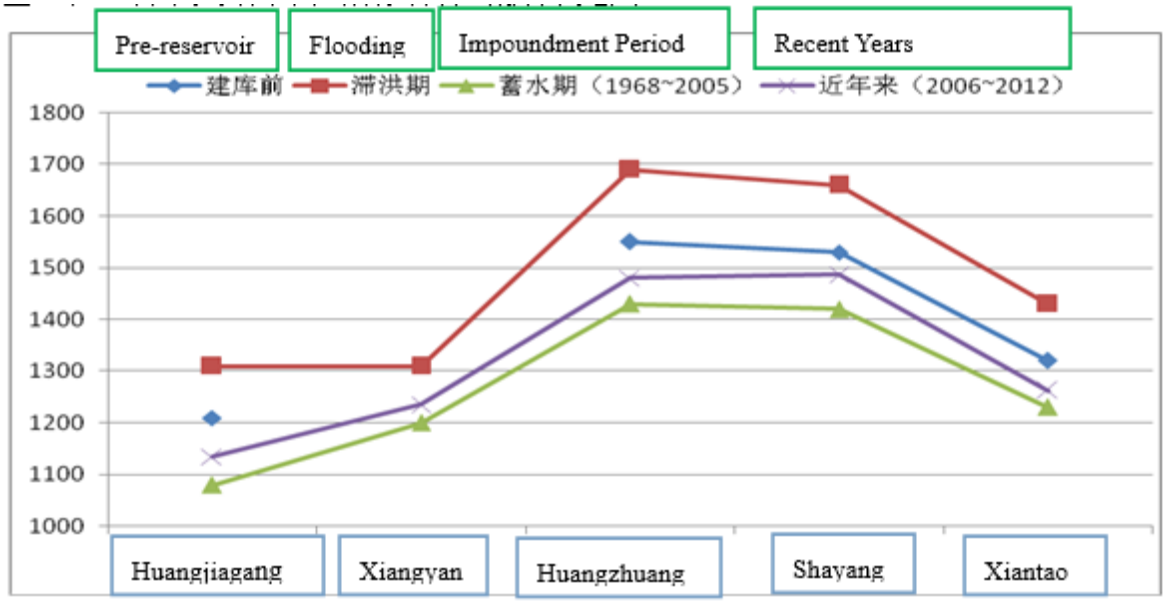


Figure 4-2 Actual Runoff During 1956-2012

4.1.1 Mainstem Runoff

Han River is a rain-source river, and the runoff is mainly from rainfall, therefore the

annual distribution of runoff is quite uneven. The runoff volume in flood season (May ~ October) accounts for 78.9% of the total annual runoff volume, and that from November to April in the second year only accounts for 21.1%, and the inflow in January and February is the least. The interannual change of runoff of Han River is quite large, and the ratio of the maximum runoff to the minimum runoff is higher than 3 times. The runoff producing capacity has regional difference, and the main runoff producing area is above Danjiangkou. According to statistics, as for the in-flowing runoff of Danjiangkou Reservoir, the inflow above Bai River accounts for 73.2%, the inflow of Du River accounts for 17.3%, the inflow of Dan River accounts for 4.3%, and the inflow of other tributaries and sections accounts for 5.2%. As for the inflow of the river channel at the middle and lower reaches, the discharge of the reservoir accounts for 77.4% of the runoff volume of Huangzhuang, the inflow of Nan River accounts for 4.1%, the inflow of Tangbai River accounts for 7.3%, and the inflow of other tributaries and sections accounts for 11.2%.

Along the mainstem at the middle and lower reaches of Han River, four complexes have been constructed, i.e. Danjiangkou Complex, Wangfuzhou Complex, Cuijiaying Complex and Xinglong Complex, and the construction of these complexes causes certain impact on the annual distribution of the runoff at the lower reach. In particular, the construction of Danjiangkou Reservoir causes the runoff of the river channel at the lower reach of Han River to reduce in flood season and increase in dry season. The Danjiangkou Reservoir began impounding water in November 1967, and the project was completed in 1973. Because the reservoir has a storage capacity of 10.2 billion m3, the completion of Danjiangkou Reservoir has a significant regulation of the runoff at the middle and lower reaches of Han River and is beneficial to the annual redistribution of the runoff. For example, according to the data of Huangzhuang Hydrologic Station measured before Danjiangkou Reservoir was built (1956 ~ 1967) and after the reservoir was built (1968 ~ 2004), the measured annual distribution of runoff increased in dry season and reduced in flood season; the runoff volume percentage increased to 31.9% from 22.7% in dry season (November ~ April) and reduced to 68.1% from 77.3% in flood season (May ~ October).

The change trends of monthly average discharge for years measured by the hydrologic stations at the middle and lower reaches of Han River are basically the same, and the discharge is the largest in September and is the smallest in January.

4.1.2 Sedimentation

After Danjiangkou Reservoir was constructed, all the sediment from the mainstem and the tributaries above Danjiangkou Reservoir has been almost intercepted within Danjiangkou Reservoir. At present, multiple reservoirs have been constructed along the mainstem at the middle and lower reaches of Han River, such as Danjiangkou Reservoir, Wangfuzhou Reservoir and Cuijiaying Reservoir, the sediment discharge of the river section below Danjiangkou Reservoir is small, and the sediment content in the water body is also small. The sediment is mainly from each tributary below Danjiangkou Reservoir as well as from riverbed erosion. According to the actual data of Huangjiagang Hydrologic Station, between 1952 and 1967 before Danjiangkou Reservoir began impounding water, the annual average sediment discharge of Huangjiagang was 10,036t/a, and between 1969 and 1990 after the reservoir was constructed and began impounding water, the annual average sediment discharge was only 106×10^4t/a.

After Danjiangkou Reservoir began impounding water, severe erosion occurs in the riverbed at the middle reach of Han River. The sediment in the mainstem at the middle and

lower reaches of Han River is mainly from riverbed erosion of Nan River, Tangbai River and the river section of Qianliu River from Wangfuzhou to Cuijiaying. Compared with the situation before Danjiangkou Reservoir was constructed, the incoming sediment reduces remarkably. According to statistical analysis, the annual sediment discharge of Huangjiagang Hydrologic Station is only 1% of that before the reservoir was constructed, and the annual sediment discharge of Huangzhuang Hydrologic Station is only 20% of that before the reservoir was constructed. In the meanwhile, the composition of the sediment in the river section below Danjiangkou Reservoir is coarsened. According to the statistics of Xiangyang Station, between 1956 and 1959 before the reservoir was constructed, the annual average median particle size of suspended sediment was 0.013～0.04mm, the average particle size 0.033～0.058mm and the maximum particle size 0.4～0.8mm; between 1974 and 1979 after the reservoir was constructed, the median particle size was 0.037～0.12lmm, the average particle size 0.113～0.12lmm and the maximum particle size 0.784～1.1lmm; in 1989, the median particle size was 0.023mm, the average particle size 0.217mm and the maximum particle size 1.45mm.

4.2 Water Quality

4.2.1 Water Qualty Monitoring Network

The water environment monitoring network of Hubei Province sets 19 routine water quality monitoring cross-sections along the Han River mainstem, i.e., Yangwei, Chenjiapo, Caiwan, Shenwan, Xianrendu, Baijiawan, Yujiahu, Guoan, Zhuandou, Huangzhuang, Luohanzha, Zekou, Yuekou, Hannan Village, Shilou, Xiaohe, Xingou, Zongguan and Longwangmiao.

The tributaries of Han River which are brought into monitoring are Bei River, Nan River, Xiaoqing River, Tangbai River, Man River and Zhupi River. The water quality monitoring cross-sections of the tributaries are usually set at the river mouths.

Figure 4-1, Table 4-1 and 4-2 provide details of these monitoring sites.

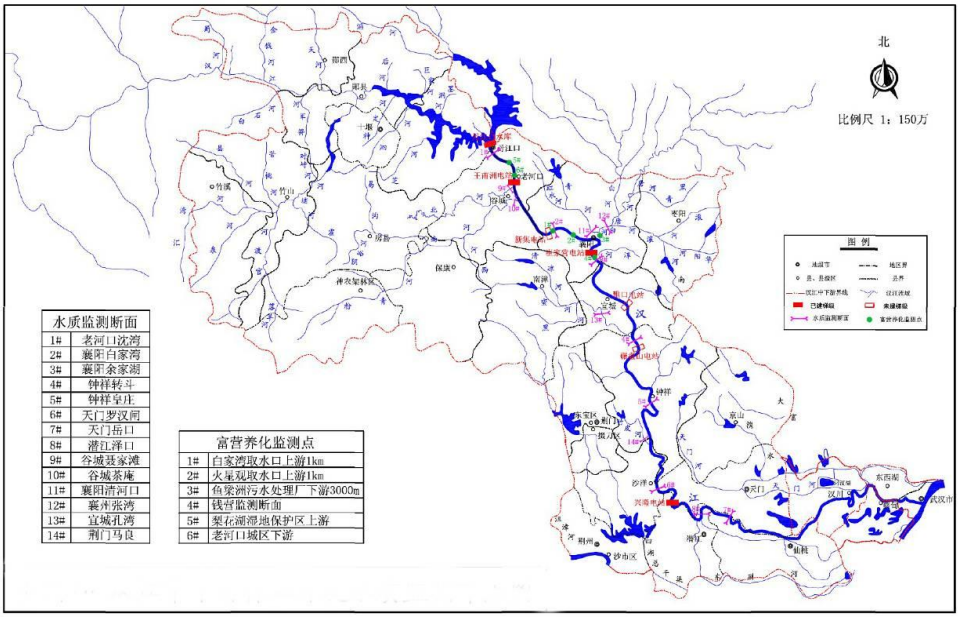


Figure 4-3 Water Quality Monitoring Stations in the Middle and Lower Han River Mainstem and Tributaries

Table 4-1 Names of Water Quality Monitoring Cross-sections and Eutrophication Monitoring Points in Figure 4-3

水质监测断面		Water quality monitoring cross-section			
1#	老河口沈湾	Shenwan in Laohekou			
2#	襄阳白家湾	Baijiawan in Xiangyang			
3#	襄阳余家湖	Yujiahu in Xiangyang			
4#	钟祥转斗	Zhuandou in Zhongxiang			
5#	钟祥皇庄	Huangzhuang in Zhongxiang			
6#	天门罗汉闸	Luohanzha in Tianmen			
7#	天门岳口	Yuekou in Tianmen			
8#	潜江泽口	Zekou in Qianjiang	富营养化监测点		Eutrophication monitoring point
9#	谷城聂家滩	Niejiatan in Gucheng	1#	白家湾取水口上游 1km	1km upstream from Baijiawan water intake
10#	谷城茶庵	Chaan in Gucheng	2#	火星观取水口上游 1km	1km upstream from Huoxingguan water intake
11#	襄阳清河口	Qinghekou in Xiangyang	3#	鱼梁洲污水处理厂下游 3000m	3000m downstream from Yuliangzhou sewage treatment plant
12#	襄州张湾	Zhangwan in Xiangzhou	4#	钱营监测断面	Qianying monitoring cross-section
13#	宜城孔湾	Kongwan in Yicheng	5#	梨花湖湿地保护区上游	Upstream from Lihuahu Wetland Reserve
14#	荆门马良	Maliang in Jingmen	6#	老河口城区下游	Downstream from the urban area of Laohekou

Table 4-2 Water Quality Monitoring Sections in Middle and lower Han River Mainstem And Tributaries

No.	City/county	Name of cross-section	Description	Relation with the location of power station	Applicable standard (GB3838-2002)
Water Quality Sampling Locations On Mainstem					
1	Laohekou City	Shenwan	Boundary of the city (Shiyan - Xiangyang)	Wangfuzhou reservoir area	II
2	Xiangyang City	Baijiawan	Entrance cross-section of Xiangyang City	Cuijiaying reservoir area	III
3		Yujiahu	About 4km from Qianying; exit cross-section of the city	Cuijiaying reservoir area	III
4	Zhongxiang City	Zhuandou	Entrance cross-section of Zhongxiang	Proposed Nianpanshan reservoir area	II
5		Huangzhuang	Under Zhongxiang Bridge of Han River	Below the dam of proposed Nianpanshan reservoir	II
6	Tianmen City	Luohanzha	Entrance cross-section of Tianmen	Xinglong reservoir area	II
7	Tianmen City	Yuekou	500km upstream from Yuekou Bridge of Han River	Below the dam of Xinglong reservoir	II
8	Qianjiang City	Zekou	About 7km away from the outlet of Salt chemical plant	Below the dam of Xinglong reservoir	II
Water Quality Sampling Locations on Tributaries					
1	Gucheng County	Bei River, Niejiatan	Under Niejiatan Bridge, 4km away from Han River	-	III
2	Gucheng	Nan River,	100m before flowing into	-	III

No.	City/county	Name of cross-section	Description	Relation with the location of power station	Applicable standard (GB3838-2002)
Water Quality Sampling Locations On Mainstem					
	County	River mouth	the river		
3	Xiangyang City	Xiaoqing River, Qing River mouth	Under the highway bridge, before flowing into the river	-	IV
4	Xiangzhou District	Tangbai River, Zhangwan	Tangbai River mouth	-	IV
5	Yicheng City	Man River, Kongwan	Under Kongwan Bridge	-	III
6	Jingmen City	Zhupi River, Maliang	Zhupi River mouth	-	IV

4.2.2 Water Quality During 2001-2011

Water quality information was obtained from several sources:

- *Retrospective EIA Report for the Cascade Development on Mid-low Reaches Han River (2012)* documents water quality monitoring data in wet, normal and dry seasons during 2001-2011 based on regular water quality monitoring at 8 cross-sections on the mainstream and 6 locations on tributaries. These water quality sampling locations are shown in Figure 3-1 and Table 3.1
- *Yakou Project EIA Report (2015)* documents water quality monitoring data in wet, normal and dry seasons during 2011-2013 of 6 river cross-sections on the Xiangyang section of Han River mainstream, and 2012-2014 Tanbai River regular cross-section.
- *Nianpanshan Project EIA Report (2016)* documents 2014 whole-year water quality monitoring data of 2 cross-sections on the Zhongxiang section of Han River mainstream.

Overall, 15 years of water quality moniroing data that were sampled throughout the mid-low reaches of Han River were available for assessment.

Single factor assessment method ws adopted to evaluate nine monitoring factors (dissolved oxygen, permanganate index, BOD_5, ammonia nitrogen, total phosphorus, total mercury, total lead, volatile penol, petroleum) measured in three periods (wet, normal and dry seasons) from 2001 to 2011. This method can indicate attainment of Han River designated uses. As Table 3-1 shows, Han River mainstem are assigned as either Class II or Class III while its tributaries are assigned Class III or IV. According to national standards Surface Water Quality Standard (GB3838-2002),

- *Class I refers to (river) source and national nature reserve;*
- *Class II is suitable for centralized drinking water source area (Class I protection subarea), habitats for rare aquatic lifes, spawning area for fish and shrimp, and feeding area of fry fish;*
- *Class III is suitable for centralized drinking water source area (Class II protection subarea), wintering area and migratory route for for fish and shrips, aquaculture area and swimming area;*
- *Class IV is suitable for general industrial water use and non-direct contact recreational water uses.*

- *Class V is suitable for agricultural and general recreational uses.*

1. Han River mainstem

Attainment of designated uses: The water quality classification assessment results about the typical monitoring cross-sections along the mainstem at the middle and lower reaches of Han River from 2001 to 2011 show that: the water quality of the mainstem at the middle and lower reaches of Han River is mainly Class-II and III. Among the water quality results of eight monitoring cross-sections (Shenwan in Laohekou, Baijiawan and Yujiahu in Xiangyang, Zhuandou and Huangzhuang in Zhongxiang, Luohanzha and Yuekou in Tianmen and Zekou in Qianjiang) in wet, dry and normal seasons from 2001 to 2011, there are 248 results of Class-II and Class-III water quality, accounting for 94.3% of the total results (263). The water quality data of some cross-sections in different years exceeds the standard, and there are 49 results exceeding the standard, 19 in wet season, 18 in dry seam and 12 in normal season. The results exceeding the standard in wet season are more than those in dry season, and the latter are more than those in normal season.

Spatial variation: The water quality of the mainstem of Han River has spatial variation. According to the monitoring results about the mainstem at the middle and lower reaches of Han River from 2001 to 2011, the water quality monitored at the cross-sections above the entrance cross-section of Zhongxiang (Zhuandou in Zhongxiang) and below Tianmen cross-section is good, and the water quality of 93.9% of the cross-sections is classified as Class-II or Class-III. The water quality monitored at the cross-sections from the entrance cross-section of Zhongxiang to the entrance cross-section of Tianmen is bad, and 42.4% of the water period at Zhuandou Cross-section, the entrance cross-section of Zhongxiang with severe pollution, cannot meet the specified Class-II standard, and 33.3% of the water period at Huangzhuang Cross-section in Zhongxiang cannot meet the specified Class-II standard. The primary exceeding-standard factor is total phosphorus and the secondary exceeding-standard factors are ammonia nitrogen and BOD_5. 45.5% of the water period at Luohanzha Cross-section in Tianmen exceeds the specified Class-II standard, and the primary exceeding-standard factor is total phosphorus.

Reasons of non-compliance: According to the survey and analysis, the reasons for the water quality of Zhongxiang Section of Han River exceeding standard before 2011 include the following aspects: ①accumulative effect of pollutant concentration. The mainstem at the middle and lower reaches of Han river continuously accepted the sewage from cities and townships and enterprises in Xiangyang, Jingmen and Tianmen along the river, and the self-cleaning capacity of the water body was overloaded and the accumulative effect of pollutants was formed; ② agricultural non-point source pollution impact. Zhongxiang Section of Han River is located in Jianghan Plain, where agricultural activities are frequent. In the meantime, the terrain is flat with low vegetation coverage, the unit load caused by rainfall runoff is large, and surface runoff is easy to be formed due to high population density on both banks in Jianghan Plain, centralized agricultural activities, large application amount of chemical fertilizers and pesticides and flat terrain. Therefore the unit load carried by the runoff is large. The effect of agricultural non-point source may be observed obviously from that the exceeding-standard phenomenon mainly occurs in wet season and the exceeding-standard factors are mainly total phosphorous and ammonia nitrogen;③ abundant phosphate rock resources at the middle and lower reaches. The effect of natural dissolution and mining pollution of phosphate rocks is one important reason for total phosphorous exceeding the standard in Zhongxiang Section and at the lower reach of Han River.

Trends of improvement: Over the period of 2001-2011, with the increasing of municipal sewage treatment rate along the river banks and the intensifying of industrial pollution regulation (including closing enterprises), the pollutant holding quantity of the mainstem of Han River has decreased to some extent and the water quality has shown a trend of getting better. From 2001 to 2011, the proportion of the monitoring cross-sections along the mainstem at the middle and lower reaches of Han River meeting Class-III standards had been rising gradually. From 2008 to 2011, all of the water quality indicators of the eight monitoring cross-sections (Shenwan in Laohekou, Baijiawan and Yujiahu in Xiangyang, Zhuandou and Huangzhuang in Zhongxiang, Luohanzha and Yuekou in Tianmen and Zekou in Qianjiang) could meet the planning objectives, the water quality qualification rate in wet, dry and normal seasons was 100%, and the water quality has been getting better remarkably.

2. Han River tributaries

Attainment of designated uses: The water quality classification assessment results about the monitoring cross-sections along the tributaries at the middle and lower reaches of Han River from 2001 to 2011 show that: of the water sampled at the monitoring cross-sections at the river mouths of Bei River, Nan River, Xiaoqing River, Tangbai River, Man River and Zhupi River, the main tributaries of Han River, 52.5% were Class-V or worse than Class-V. Among the six tributaries, the water quality of Xiaoqing River, Tangbai River and Zhupi River exceeds the standard severely, and the exceeding-standard rate of Tangbai River is 81.8% and that of Zhupi River 93.9%. The number of years when the water quality exceeds the standard in dry and normal seasons is greater than the number of years when the water quality exceeds the standard in wet season.

Reasons of non-compliance and improverment trends: The major reason for the tributaries exceeding the standard is surrounding industrial and domestic pollution point sources. Specifically,

①Tangbai River is one important source of domestic water and industrial water demanded by the people along the river, and the main pollutants include industrial wastewater and urban domestic sewage. The most severely-polluted river sections include: the section of Bai River downstream from the urban area of Nanyang City, the section of Tuan River downstream from the county site of Neixiang County and the section of Tang River downstream Chengguan Township in Tanghe County. According to *Surface Waster Environmental Function Category of Hubei Province* (EZBF [2000]10), the water environmental function of Tangbai River is general industrial water consumption area and Class-V standard is adopted. The water quality monitoring data of the exit cross-section of Tangbai River Basin shows that: between 2001 and 2011, the water quality is in the state of fluctuation, and the water quality of Tangbai River is Class-III ~ V; the water quality of Bai River is Class-IV ~ worse than Class-V, which is mainly caused by organic pollution, and the exceeding-standard factors include BOD, ammonia nitrogen and total phosphorous. Since 2011, due to strengthening pollution control, urban domestic sewage and industrial wastewater treatment has been carried out, and the water quality has been improved obviously. The data of the exit cross-section shows that the water quality is Class-III.

②The water quality pollution at the lower reach of Xiaoqing River is mainly caused by domestic sewage from Daligou and the area along Dengcheng Avenue. Xiangyang municipal government has implemented landscape belt for Xiaoqing River, carried out environmental remediation surrounding Xiaoqing River and Daligou, and brought domestic sewage along Dengcheng Avenue into Zhangwan sewage interception works, and the water

quality of Xiaoqing River has been improved gradually.

③Zhupi River is the unique river passing through the urban area of Jingmen City, and the water pollution is mainly caused by industrial wastewater and waste residues and domestic sewage and garbage which are discharged into the river. Through overyear treatment, at present, the industrial wastewater of the central urban area has realized up-to-standard discharge, the domestic sewage has basically been discharged into the urban sewage drainage pipe network for treatment, and the water quality of Zhupi River has been improved to some extent. However, because the runoff volume of Zhupi River is small and the water environmental capacity is quite limited, the water quality of Zhupi River still exceeds the standard severely, and it is impossible to improve the water quality in the short term.

④The industry at the lower reach of Man River is developed, and the water pollution is mainly caused by the industrial wastewater discharged by chemical plants, food enterprises and industrial parks. With strengthening pollution control, the water quality has been improved to some extent but still cannot meet the requirements (Class III), and it is required to further optimize the industrial distribution, intensifying the management of the existing pollution enterprises and increase the rate of reaching the standard and the sewage recycling rate.

⑤Through closing some heavy-pollution enterprises such as small paper mills, the water quality of Bei River and Nan River has been improved remarkably, and it is expected to be further improved after the urban sewage treatment plants are constructed and put into operation.

4.2.3 Water quality in recent years

1. Han River mainstem (Xiangyang Section)

The water quality monitoring results of the mainstem of Han River (Xiangyang Section) in wet, normal and dry seasons from 2011 to 2013 show that: the water quality in Xiangyang Section of Han River is good, and the water quality of Fujiazhai Cross-section and Baijiawan Cross-section meets Class-II standard specified in *Environmental Quality Standards for Surface Wate*r (GB3838-2002), and the water quality of Xianrendu Cross-section, Qianying Cross-section, Yujiahu Cross-section and Guoan Cross-section meets Class-III standard specified in *Environmental Quality Standards for Surface Wate*r (GB3838-2002). According to pollution factor analysis, the water quality pollution in Xiangyang Section of Han River is mainly organic pollution, and the water quality at Yujiahu Cross-section is obviously worse than that at Baijiawan Cross-section, showing that the urban sewage discharge causes certain impact on the water quality of the river.

2. Han River tributary Tangbai River

According to the monitoring results of routine monitoring cross-sections at Tangbai River shown in *Environmental Condition Notification of Xiangyang City* in 2012 ~2014, the water quality category of Tangbai River in 2012 ~ 2014 is obtained on the basis of statistics. The result indicates that, through water pollution control in Tangbai River Basin in recent years, the water quality has been improved year by year, the water quality in 2014 could meet Class-IV standard, and especially in fish breeding season from May to August the water quality can basically keep meeting Class-III standard, which provides good water conditions for fish spawning, breeding and migration.

3. Han River mainstem and tributaries in Zhongxiang section

The full-year water quality monitoring data of the mainstem of Han River (Zhongxiang Section) in 2014 indicates that: all the monitoring indicators measured at Zhongxiang Section of Han River can meet Class-II standard specified in *Environmental Quality Standards for Surface Wate*r (GB3838-2002).

In 2014, the EIA insitute of Nianpanshan Project entrusted Zhongxiang Environmental Monitoring Station to monitor the water quality at the three major cross-sections at the dam site of Nianpanshan Hydropower Complex and at the upper reach and the lower reach as well as the major interval tributaries. The monitoring results show that: the water quality at each monitoring cross-section at the mainstem of Han River can meet Class-II standard specified in *Environmental Quality Standards for Surface Wate*r (GB3838-2002).

However, The water quality of the main interval tributaries is polluted severely, and the main exceeding-standard indicators of Man River include COD, ammonia nitrogen, total phosphorous and total nitrogen, among which, the total nitrogen exceeds the standard most severely and the maximum exceeding-standard rate is 7.6 times.

4.2.4 Eutrophication assessment

The Eutrophication of Wangfuzhou and Cuijiaying reservoirs were studied. Xiangyang Environmental Protection Monitoring Station carried out monitoring on the water bodies of Wangfuzhou and Cuijiaying reservoirs on August 6 ~ 8, 2012, and the main monitoring indicators include water temperature, transparency, pH, dissolved oxygen, total phosphorous, total nitrogen, suspended solids, permanganate index, BOD_5, COD, ammonia nitrogen and chlorophyll a.

The monitoring results indicate that: the comprehensive eutrophication status index TLI(∑) of Cuijiaying Reservoir is 53.0~62.5, and the eutrophication degree is mild and moderate eutrophication, because Cuijiaying Reserve has been constructed only for a short time and the bottom pollution source releases pollutants and causes temporary rising of concentration of pollutants like total phosphorous and total nitrogen. The comprehensive eutrophication status index TLI(∑) of Wangfuzhou Reservoir is 44.6~48.0, the eutrophication degree is moderate, and the water quality is good.

4.3 Aquatic Ecosystem

4.3.1 Fish

The fishery resources of the Han River include a wide range of species, feeding levels and reproductive conditions that reflect varying degrees of environmental change. Factors important to sustaining viable fish populations include good water quality, suitable habitats and hydraulic regimes, and sufficient food supplies; reproductive viability as evidenced by genetic connection between populations and number of gravid females and larval individuals.

The historical conditions of fishery resources in Han River come from several sources, including earliest records dated back to 1950s, surveys conducted in 1970-1990s, and 2004; and recent surveys in 2008 and 2014.

4.3.1.1 Historical Conditions (Year 1958-2004)

1. Fish species and population

Pertinent studies often refer to a Hubei Ichthyography (Fishes in Hubei Province)

published in 1987 which lists 93 species found the in middle and lower Han River mainstem, that is, downstream of Danjaingkou Dam. Three comprehensive surveys on fishery resources for the middle and lower Han River were conducted before 2004, as described in below.

- A survey conducted in 1958 for Danjiangkou area (before the Danjaingkou dam was built) reported collection of 43 fish species, of which 30 are fish typical of flowing river-like conditions.
- A survey conducted along the length of the middle and lower Han River during 1976-1978 (shortly after the Danjiangkou dam was put into operation) reported 75 species;
- A survey conducted along the length of the middle and lower Han River in 2004 (when there were only two dams, namely Stage 1 Danjiangkou and Stage 2 Wangfuzhou, were built) reported 81 fish species. Annx 1 provides an inventory of fishes of this survey. Compared to the 1976-1978 survey, *Ochetobius elongates (鱤)* and *Luciobrama microcephalus (鯇)* were not found in the 2004 survey, while several other new species such as the *Acheilognathus macropterus* (Bleeker, 大鳍鱊) were found.

The 2004 survey reported 81 species that belong to 8 orders, 18 families and 59 genuses. The Cypriniformes order (common carp) accounted for 59.3%. The fish species inhibiting on the middle and lower Han River are mostly common species, such as common carp and crucian carp. River segment between Danjiangkou and Xiangfan remained flowing water conditions mostly; substrate featured with pebble and coarse sands due to years of flushing caused by clear water releases from Danjiangkou reservoir. Hence many fishes favoring flowing water inhibited in the segment. Whereas in the river segment downstream of Shayang such fishes were much small in numbers.

In terms of population, in the 1976-1978 suvey, top three were grass carp (22%), *Coreius heterodon* (Bleeker, 铜鱼，16%) and *Parabramis pekinensis* (Basilewsky, 长春鳊, 8%) ; while in the 2004 survey the top three were common carp (48%), crucian carp (10%), and *Parabramis pekinensis* (Basilewsky, 长春鳊, 10%); the *Coreius heterodon* (Bleeker, 铜鱼) declined dramatically; black carp, bighead carp and *Elopichthys Bambusa*(鱘) were rarely found. Typical large predatory fish species such as *Ochetobius elongates (鱤)* and *Luciobrama microcephalus (鯇)* and *Elopichthys Bambusa*(鱘) favor flowing water but had not been found in Han River for decades. It should be noted that the three large predatory fish species of *Elopichthys Bambusa* (鱘), *Ochetobius elongates (鱤)* and *Luciobrama microcephalus (鯇)* were given special attention; a Fishery Species Reserve was established in the middle and lower Han River mainstem though the they have not been found in the river for many years.

In terms of rare and migratory fish species, there were records of *Acipenser dabryanu* (长江鲟) and *Psephuyrus gladius* (白鲟) reported in 1950's, but they were not found in the 1970s and 2004 survey. There was historical record that *Myxocyprinus asiaticus* (胭脂鱼) appeared in Han River, however none was found in the three comprehensive surveys. The three species live in mainstem of the Yangtze River particulary the upstream primarily. Two economic migratory species, *Anguilla japonica* Temminck et Schlegei (鳗鲡) and *Coilia ectenes* Jordan et Seale (长颌鲚) coud be found in the mid-low reaches of Han River. The former appeared downstram of Wangfuzhou dam but the number is extremely small; the latter appeared in lower reach (downstream of Shayang) and maintained a considerable

population.

In summary, in the mid-low reaches of Han River, fishes in favor of flowing waters (represented by the *Four Domesticated Fish*) include many species but account for a small amount, in small sizes and showing a declining trend. Large preddatory fish species such as *Elopichthys Bambusa* (鱘) , *Ochetobius elongates (鱎)* and *Luciobrama microcephalus (鯇)* have basically disappeard. Fishes in favor of still or slow-moving waters (such as comon carp and crucian carp) presents a dominating amount due to the fact that the slow-moving waters and many embayments form lake-like conditions in the mid-low reaches of Han River. There are very few migratory fishes in this river section.

2. Fish habitats.

Fish habitats are relevant to the features of eggs. Spawning grounds for fish species with floating eggs and spawning grounds for fish species with sticky eggs require different environmental conditions. Reviews of the spawning grounds and amount of eggs during 1976-1978 survey, the 2004 survey and recent studies show the changes and tendency of fish habitats.

1) Spawning grounds of fish species with floating eggs.

The 2004 survey covered the mid reach of Han River mainstem and its tributaries Tang River and Bai River[2]. 16 fish species with floating eggs were caught which were categorizied into 3 groups: the *Four Domesticated Fishes*; other economic fishes; and small-size fishes.

- The *Four Domesticated Fish*: In the mid reach Han River mainstem, there were 5 spawning grounds located in Miaotan, Yicheng, Guanjiashan, Zhongxiang and Maliang; 93.3 milion eggs were found.

- Other economic fishes such as *Squaliobarbus curriculus* (Richardson, 赤眼鱒) and *Culter ilishaeformis* (Bleeker, 翹嘴鮊): In the mid reach Han River mainstem, there were 7 spawning grounds located in Miaotan, Xiangfan, Yicheng, Guanjiashan, Zhongxiang, Maliang and Chengjiakou; 364 million eggs were found.

- Small-sized fishes: In the mid reach Han River mainstem, there were 15 spawning grounds; 15.9 bilion eggs were found.

- In the tributary Tangbai River, no spawning grounds for the *Four Domesticated Fishes* were found; four spawning grounds for other economic fishes in Xindian, Zhuji, Bukou and Changzhuang were found; 5 spawning grounds for small-sized fishes were found.

Compare the 2004 survey with the 1976-1978 survey results, in the mainstem Han River the spawning ground for fish species with floating eggs reduced from 6 to 5. Wangfuzhou spawning grounds was gone due to the formation of Wangfuzhou reservoir. More specifically,

- The *Four Domesticated Fishes*: Spawning grounds reduced from 6 to 5; the Xiangfan spawning ground disappeared and other spawning grounds moved locations; fish eggs reduced from 471 to 93.3 million;
- Other economic fishes: Spawning grounds increased from 6 to 7; one more location

[2] Tang River and Bai Rier converge and form the Tangbai River which finally empties into Han River in Xiangyang City.

was found in 2004 and others moved; fish eggs reduced from 903 to 364 million;

- Small-sized fishes: spawning grounds greatly increased from 6 to 15; fish eggs greately increased from 1.1 to 15.9 billion.
- In the tributary Tangbai River, no spawning grounds for the *Four Domesticated Fish* were found in 2004, while in 1978 there were 2. Only one economic fish species, namely *Squaliobarbus curriculus* (Richardson, 赤眼鱒) was found with much smaller population, while there were 12 found in 1976-1978. The *Squaliobarbus curriculus* (Richardson, 赤眼鱒) is known as more pollution tolerant. Small-sized fish species remained largely unchanged in terms of amount of eggs. During 1978-2004, there was only one hydro-complex, namely Wangfuzhou complex was built on the mid-low reaches of Han Rier mainstem. The marked change of fish species, population and habitats had to do with seveal reasons such as over-fishing, wastewater discharge and other development activities.

2) Fish species with sticky eggs

Fish species with sticky eggs include common carp (鲤鱼) and crucian carp (鲫鱼), *Pelteobagrus fulvidraco* (Richardson, 黄颡鱼), catfish（鲇鱼）, *Xenocypris davidi* Bleeker （黄尾鲴）, etc. The fishes can be categorized in to two groups according to substrate type: those eggs attach to water plants, terrestical plant or floating waterweeds and those attach to gravels. Spawning grounds of fish species with sticky eggs are found in slow-moving waters where tributary flow-in causing micro-flow regime such as the rive mouths of Nan River, Bei River, Du River, Xiaoqing River, Tangbai River, Man River and Hanbei River; and embayments or wide wetland areas along the Han River mainstem such as Wangfuzhou, Cihe, Yaoji, Gaoshibei and Chenghuang wetland areas. During the 2004 survey, several relatively centralized spawning gounds were found but the amount of eggs was not quantitively studied due to time constraints.

3. Analysis of cumulative effects on fishery resources

The comprehensive fishery resource survey and study conducted **in 2004** concluded that three major sources of impacts contributed to the changes and tends to fish conditions in the middle and lower Han River:

- ***Overfishing***. In particular, since after late1970s, advancement of fishing technologies (such as very thick fish net and electronic trawler) and highly intensive fishing severely damaged the fishery resource. The total fish harvesting peaked in 1997-1998 then experienced signifincant declining: the size and diversity of catches descreased significantly; large and old individuals rarely catched; grass carp and silver carp were rarely found in populations; bighead, black carp and *Elopichthys Bambusa*(鱘) were difficult to found; *Ochetobius elongates (鲥)* and *Luciobrama microcephalus (鲧)* literally disappeared. Accordingly, the spawning scale of four Chinese carps (namely the *Four Domesticated Fish, including black, grass, silver, and bighead carp*) and major economic fishes dwindled markedly while the spawning scale of small-sized fishes grew markedly. Since after 2002, fishing prohibition in the Yangtze River and middle and lower Han River in spring was carried out, which had seen mixed results.

- ***Severe water pollution.*** Mutli-year water quality monitoring results showed the

major tributaries of middle and lower Han River were severely polluted. Organic pollutant indicators were at the level of Surface Water Class IV~V standards (see prior section fo the interpretation of surface sater classification); some were even worse than Class V. The pollution in Xiaoqing River, Zhupi River, Tangbai Rier and Man River were particularly severe. The tributary and non-point source poullution affected the Han River mainstem water quality obviously; Tangbai River, Man River and Nan River were to top 3 contributor in terms of pollution load; main pollutions were COD, BOD5, NH3-N and total phosphorus. In urban river segments, shoreline pollution plumes were present in various scales. In the lower reach of Han River mainstem (from Xiantao to Zongguan of Wuhan), during dry seasons, due to high water level of Yangtze River, the water quality was prone to eutrophication. During 1992-2003, 5 'algal blooms' occurred on the lower reach of Han River.

Due to the increased nutrients levels in the middle and lower Han River mainstem, and combined with the lowered turbidity, aquatic productivity improved markedly, which may be the primarily reason for the high fish stocking. Nonetheless, increased probability of eutrophication would lead to reduced diversity of aquatic lifes, affect the reproduction and growth of fish species favoring flowing water conditions. Some of the severely polluted tributaries of the middle and lower Han River were not able to support fish life. When Tanbai River had the first flood in a year, large amount of fish fatality was often observed; the spawning grounds of the Four Domesticated Fish in the Tangbai River had disappeared. Among the economic fishes, only the pollution tolerant *Squaliobarbus curriculus* (Richardson, 赤眼鱒) existed in mall populations in the Tangbai River, while its spawning scale in 2004 was only 48% of that in 1978.

- ***Impacts of Danjiangkou and Wangfuzhou dam/reservoir.*** Until 2004, on the middle and lower Han River only two dams, namely Stage 1 Danjiangkou and Stage 2 Wangfuzhou were built. After completion of Danjiangkou dam, hydrologic regime of the middle and lower Han River was altered markedly due to the regulation of Danjiangkou reservoir; the flow rate and water depth variance redued; clear water releases lead to improved transparency; flushing of river channel intensified; mid- and bottom layer water release from the reservoir lead to lowered river water temperature in warm seasons and increased temeperature in winter. The 1977-1978 survey showed that, downstream of Danjiangkou dam, fish spawning season was postponed; spawning ground of fish species with floating eggs moved downstream or disappear; and the period of growth shortened. On positive side, the aquatic life productivity improved; conditions were improved in terms of fish wintering, spawning of fish species with sticky eggs, and fattening of certain fish species. As time went on, fishes gradually adapted to the altered environment and were able complete the spawning, feeding, growth and wintering lifestages downstream of Danjaingkou dam and maintain their popuations.

  Completoin of Wangfuzhou dam in the year 2000 resulted in disappear of the 30km rapid flow river segment between Danjiangkou and Wangfuzhou dam. Wangfuzhou dam has no fish passage. The impoundment of Wangfuzhou reservoir is beneficial for the growth of plankton, aquatic macrophytes and benthic organisms. Improved water productivity is beneficial for fish species with sticky eggs and overall fish stocking. Meanwhile, as a low head and run-of-river type of complex, widened

water surface and slowed flow velogicy effectively mitigated the impact of cool water releases from Danjaingkou reservoir.

The clear water releases from Danjiangkou reservoir led to flusing of river bed along the length of the river, which had extended to downstream of Xianfang. River bed scouring caused lowered river level (1.6~2.0m at Huangjiagang and other hydrologic measurement stations) and increased drop between the river channel and river flats. Durations of the river flats flooding thus reduced, resulting dwindled fish habitats. Extended length is needed for the recovering of water temperature, affecting fish growth and reproduction. The clear water releases also caused incaresed transparency of river water in the middle and lower Han River mainstem. Meanwhile, during the same period there were increased nutrients levels; the rive had more stable flow rate and water level primarily because of the Danjiangkou reserovir's regulation. These conditios combined were beneficial for the growth of aquatic macrophytes and plankton, and the reproduction of fish species with sticky eggs.

During the period, the fish compostion changed as well. Spawning grounds of fish species with floating eggs moved downstream markedly; a previous spawning ground in Wangfuzhou disappeared (due to formulation of the reservoir). The spawning and reproduction of the *Four Domesticated Fish* replied on the water rise processes caused by tributary inflow and river sectional rises. The fish catches in the middle and lower Han River during the 2 decades after Danjiangkou dam was built shown significant increases of fish species favoring still or slowing moving water, among which fish species with sticky eggs like crucian carp and common carp accounted for more than 50%.

4.3.1.2 Recent Fish Studies

During the EIA studies for Yakou and Nianpanshan projects, a special study on aquatic lifes were carried out; fishery surveys were conducted during July-Septeber, 2014. The survey was conducted shortly after fishing closing season started. Till 2014, two more dams were built on the mainstem of middle and lower Han River, namely Stage 4 Cuijiaying and Stage 7 Xinglong.

The fish suvey covered the mainstem segment and tributaries between Yicheng (upstream of Yakou dam) and Zhongxiang (downstream of Nianpanshan dam). The study reported 63 species found in this river segement, of which the Cypriniformes order (common carp) accounted for 73%; no protected at either national or provincial level, Red List included, endangered or migratory species found.

The key findings of the 2014 survey are summarized in below:

- Compared to the 2004 survey, the total catches descreased markedly. It was recognized that due to the short duration of the 2014 survey there was no complete data available for comparision. This finding was made mainly based on the fact that fishery sector workers had reduced markedly over the period of time and the opinions of interviewed fishermen.
- In terms of the weight of the catches, common carp and crucian carp were dominant, which is generally consistent with the 2004 survey.
- In terms of the *Four Doemsticated Fish* (*black, grass, silver, and bighead carp*) and

other economic fishes, no grass, black, bighead carps were caught; only silver carp was caught. The majority of the catches were small-sized individuals. While this pattern is generally consistent with the 2004 survey, it was noted that the populations of the Four Domesticated Fish further reduced.

- In terms of fish species with floating eggs, it was noted that the 25 species were caught in the 1978 survey; 16 species were caught in the 2004 survey and only 8 were caught in the 2004 survey.
- In terms of reasons, the 2014 survey generally repeated the conclusions made in the 2004 survey report that hydraulic projects, overfishing and water pollution were the main sources of impacts on the fish conditions changes. Nonetheless, the 2014 survey was not able to expand the analysis on the new projects such as Cuijiaying and Xinglong's impacts.

The 2014 fish survey included a special study on the spawning areas for fish species with floating eggs and sticky eggs. The below picture shows that in 2014, from Xiangyang to Zhongxiang mainsteam Han River segment, two spawning grounds of fish species with floating eggs existed in Guanjiashan and Dengjiatai. Compared to the historical surveys, in the middle Han River mainstem there were 6 spawning grounds found in the 1976-1978 survey; 5 in the 2004 survey; and only 2 found in the 2014 survey. In the major tributary of Tangbai River, in the 1976-1978 survey 1 spawning gound was found, which was not found in the 2004 survey.

Figure 4-4 Spawning Grounds for Fish of Floating Eggs (2014)

For fish species with sticky eggs, in the same river segment, several spawning grounds existed in the mainstem and tributaries. (Note: this picture is not complete; there are several other spawning grounds existed in mainstem and tributaries downstream of Yakou dam/Ying River, which is not shown on the map.)

Figure 4-5 Spawning Grounds for Fish of Sticky Eggs (2014)

On reasons of the changes of fishery habiat, the 2014 survey concluded that, 1) dam and reservoir formation on the mainstem led to needed flow velocity, water rises and floating distance inadequate for the successful completion of spawning and hatching of fish species with floating eggs. In addition, drought in the those years and the preparation for the South-to-North Diversion Project operation (increased storage in Danjiangkou reservoir and reduced releases in 2014) contributed to the effects; 2) overfishing; 3) wastewater discharge caused river pollution, in particular the severely polluted Tangbai River.

The review of historical trends and conditions of fishery resources on the middle and lower Han River mainsteam and tributaries resulted in the following conclusions and recommendations:

- Historical studies listed 93 fish species in the middle and lower Han River. Species of concern included five species under Hubei provincial level of protection (*Saurogobio gracilicaudatus* Yao et Yang *(细尾蛇鮈)*, *Scaphesthes macrolepis* (Bleeker) *(多鳞铲颌鱼)*, *Leiocassis longirostris* Gunther *(长吻鮠)*, *Luciobrama microcephalus (鲸)* and *Ochetobius elongates (鳍)*), one species included in the Red List (*Liobagrus marginatus* (Gunther) *(白缘鱼央)*), and one sea-river migratory species (*Anguilla japonica* Temminck et Schlegei). None of these fish species were found in the 2014 survey. Only 3 species of provincial level of protection ((*Saurogobio gracilicaudatus* Yao et Yang *(细尾蛇鮈)*, *Scaphesthes macrolepis* (Bleeker) *(多鳞铲颌鱼)*, *Leiocassis longirostris* Gunther *(长吻鮠)*,) were found in the 2004 survey.
- The 1970-1980's fish survey and 2004 survey on the middle and lower Han River reported 75 and 81 fish species respectively. A survey conducted on the Yicheng to Zhongxiang river segment reported 63 species in 2014. General trend over the years were that fish species with floating eggs (represented by the *Four Domesticated Fish*) presented diversity but the population size reduced significantly. Common carp and crucian carp have replaced the Four Domesticated Fish as the dominant species. Small-sized fishes have become

dominant as well. Spawning grounds for fish species with floating eggs reduced from 7 (6 in the mainstem, 1 in a major tributary Tangbai River) to 5 in 2004 and 2 in 2014. Overall the fishery resource in terms of population size and diversity in the middle and lower Han River has dwindled.

- Major sources of impacts included overfishing, water pollution and hydrologic projects. Prior to 2004, there were only two dams built on the middle and lower Han River, namely Stage 1 Danjiangkou and Stage 2 Wangfuzhou. Downstream of the two dams remained long flowing-water river section while the size of fish species with floating eggs (such as the Four Domesticated Fish) that reply on such flow regimes already reduced significantly. Hence overfish and water pollution were considered more significant sources of impacts. Since 2010 two additional dams (Stage 4 Cuijiaying and Stage 7 Xinglong) were built. Compounded by the South-to-North Water Diversion Project (put into operation at the end of 2014), impacts from the cascade development became more significant. Other sources of cumulative effects such as in-stream mining and loss of riparian habitats must exist but have been less well documented in available documents.
- Fish species of which the reproduction are not sensitive to the change of flow regimes or favor lake-like conditions have become more dominant and such trend is expected to continue along with the formation of reservoir systems along the middle and lower Han River.
- Given the trends and status of fishery resources in the middle and lower Han River, various protective measures taken in the past decade or so have been identified, including water quality improvement regulation and development of industrial/domestic wastewater treatment facilities, fish-closing season mandated since around 2002, establishment of fishery resource conservation area, and ecological scheduling, fish passasge and reproduction program and restoration of fish habitats that specifically targt the protection and restoration of fish species with floating eggs. Some positive signs of fishery community restoration appeared in the past two years. Continuous implementation, further studies on opportunities for sustain fish communities and diversity, long-term ecosystem monitoring should be carried out for fish resource sustainability in the middle and lower Han River (see details in subsequent sections of this report).

4.3.2 Other Aquatic Life

All aquatic organisms, from minute microscopic plankton to the largest fish, reflect the water quality of their environment, thus, potentially can serve as biological indicators of water quality conditions and trends. Smaller organisms, especially algae and macroinvertebrates, have most often been studied in this regard, in part, because of their relative ease in field collection and laboratory processing. Characterizations of water quality has been the primary motivation for the biological surveys which have been conducted along the Han River in the past aquatic ecosystem studies.

4.3.2.1 Phytoplankton

Algae is the primary producer that forms a basis of the food chain and are a foundational component of the Han River aquatic ecosystem. Alage in running waters may occur as attached forms on all types of solid objects including macrophytes and as films on mud and silt surfaces. Alage also occur as free floating or planktonic forms. Beause alage

are sensitive to environmental changes, hence analysis of algae is conducted widely for water quality monitoring and pollution assessment.

The September 2004 survey that covered the mainstem mid-low reaches of Han River and Tangbai River showed that among the 7 divisions, 84 genus and 195 species of phytoplankton collected, three algae divisions were predominant: diatoms accounted for 43.08%; green algae 30.26%; and blue algae 16.92%. In terms of biomass, the algae in low reach is higher than the mid reach, indicating higher level of water pollution and the Tangbai River is more polluted than the mainstem.

Monitoring carried out through 1977, 1990's, 2000 and 2004 suggested that algae in the Han River had been increasing, indicating worsening water quality. During 1992 to 2003, five algae blooms occured in the low reach of Han River during dry seasons.

The 2014 survey covering Xiangyang to Zhongxiang mainstem river segment and tributaries (Chun River, Weishui River and Ying River) reported 8 divisions, 65 genuses and 124 species phytoplankton, of which 71 diatoms, 29 green alage and 10 blue algae species were collected. Phytoplankton biodiversity indicator (Shannon-Wiener) of algaes sampled from 9 cross-sections indicated that the zooplankton biodiversity indicator ranged from 0.78~3.59 (the higher, the better water quality). Most cross-sections presented clean (larger than 3) or slightly polluted (between 2 and 3) level water quality.

4.3.2.2 Zooplankton

The September 2004 survey collected 158 species of zooplankton, including protozoa, rotifera and crustacean plankton, in Han River mainstem and Tangbai River. Comparing the result with prior studies carried out in 1977 and 2003, it is found that the zooplankton has dramatically increased in species and numbers; the protozoa increased from 52.5% to 66.8%.

The April and July 2014 survey covering Xiangyang to Zhongxiang mainstem river segment and tributaries (Chun River, Weishui River and Ying River) reported 62 genuses and 110 species. Zooplankton biodiversity indicator (Shannon-Wiener) of the sampled from 9 cross-sections indicated that due to relatively low nutrient level of the mainstem the number and biomass of zooplankton were extremely low and presented a simple pattern, whereas the surveyed tribuatories presented a higher level of zooplankton activity.

4.3.2.3 Zoobenthos

Zoobenthos (benthic macroinvertebreate) consists an important component of freshwater ecocystem and serves as food for fish and other economic aquatic animals. Some zoobenthos such as shrip and crab are important economic aquatic animal themselves. In addition, zoobenthos is widely used as biological indicator for environmental monitoring.

Historical record suggested there were 33 species of zoobenthos in the mid low reaches of Han River; in a 2003 survey, 24 were collected. In the September 2004 survey, 18 were found. Among the zoobenthos collected, of molluscs the *Corbicula fluminea* (河蚬) and *Semisulcospira cancellata*（方格短沟卷）that inhabits in sandy substrate were most common; of oligochaetes the pollution-tolerant *Branchiura sowerbyi (苏氏尾鳃蚓)* that inhibits in sand-muddy substrate with slow-moving waters were most common; and of aquatic insects, the river-type *Rheotanytarsus* sp.(长跗摇蚊) and *Polypedilum* sp. (多足摇蚊) were most common.

The species number and abundancy of zoobenthos are closely linked to habitats situations. In the mid reach (such as Danjiangkou, Laohekou and Huiliuwan locations), hard mud and sands are dominating substrate. Nevertheless, a thin layer of mud that contain relatively abundant organics are suitable for zonbenthos' growth. At locations of Yujiahu and Yakou, river bed changes due to current-driven erosion, the substrate are sands that lack nutrient and zoobenthos are scarce. From Huangzhuang to Hankou, nutrients in the dandy substrate are higher and the abundance of zoobenthos increases. Overall, the density and biomass of zoobenthos in the mid reach is higher than those in the low reach. In addition, a trend analysis showed that through 1977 to 2003 and to 2004, species number and biomass in the low reach of Han River increased, indicating worsening water quality.

The April and July 2014 survey covering Xiangyang to Zhongxiang mainstem river segment and tributaries (Chun River, Weishui River and Ying River) reported 36 species of zoobenthos. Biodiversity indicator (Shannon-Wiener) assessment for zoobenthos indicated low biodiversity levels, of which the tributatries Chun and Ying rivers were higher while the Weishui river was lower.

4.4 Land Use

Land use represents various sources of cumulative effects and consequences. Land development for urbanization and industrialization along the middle and lower Han River basin contributed to the pressure on the ecosystem and resources. Turning riparian area into construction land is a typical phenomenon of land use change. Figure 4-6 shows the land use pattern in the middle and lower Han River basin in 2013.

The terrain in the middle and lower HRB is high in northwest and low in southeast, and there are various landforms including high mountains, hills, plain and wetland. The landform features in different regions are distinctly different. The first region is the river section from Danjiangkou to Xiangfan (currently Xiangyang), which is 162km long, and the first; second and third terraces are developed on both banks, 3~6m, 7~10m and 10~30m higher than the river water respectively. The valley slopes on both banks are asymmetrical. On the right bank is mainly hilly land and on the left bank is the south edge of Nanxiang Basin. The second region is the river section from Xiangfan to Jiukou in Zhongxiang, which is 170km long, and the first, second and third terraces are developed on both banks, 5~10m, 20~30m and 30~70m higher than the river water respectively. On both banks are hilly lands. The third region is the river section from Zhongxiang to Wuhan, which is 320km long and located in Jianghan Plain. The terrain is low and the elevation on both banks is 25~45m. The middle and lower Han River Basin has a total drainage area of 44,900 km2.

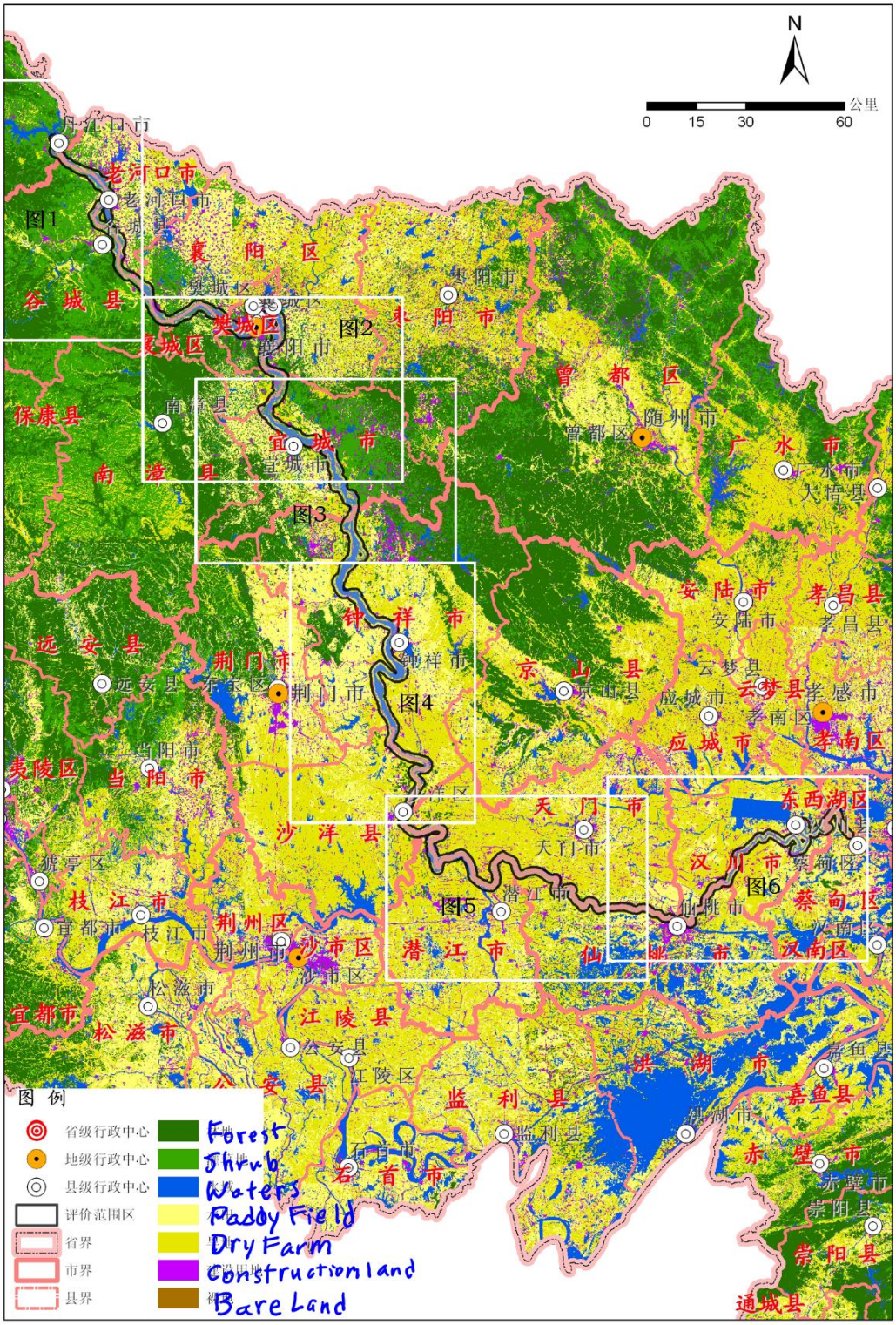


Figure 4-6 Land Use in the Middle and Lower Han River Basin (2013)

Analysis of aerial photos (2013) shows that agricultural land is dominant in the middle and lower Han River basin. The primary arable land and human settlement area are distributed as follows: in the mid reach, namely between Danjiangkou and Zhongxiang, a roughly 15 km wide corridor consists of river valley plain, alluvial plain and peripheral hilly area; downstream of Zhongxian, namely the low reach area, the river runs through Jianghan Plain where there are vast paddy fields, dense river network, lakes and dikes.

According to 1999 statistics, there was 1.14 million hectares of arable land, including 0.44 million ha paddy fiels and 238,000 ha. vegetable fields. The total population was 17.7 million, including an urban population of 5.34 million.

The middle and lower Han River basin covers ten cities and one forestry district[3], including the largest city Wuhan and the second largest, Xiangyang City, in the Hubei Province. Total administrative area of the 11 cities/forestry district has a total administrative area of 67,900km2, accounting to 36.5% of Hubei Province. Land use statistics of several key cities (2013) are described in below.

- Shiyang City：The total land area of Shiyan City is 2,366,616.35 ha, including agricultural land of 2,223,887.79 ha, accounting for 93.97% of the total area; construction land of 93,453.51 ha, 3.95%; and other land of 49,275.05 ha, 2.08%.
- Xiangyang City: The total land area of Xiangyang City is 1,972,768.16ha, with diversified land types, including agricultural land of 1,622,857.13 ha, accounting for 82.26 % of the total area; construction land of 309,424.07ha, 15.68 %; and other land of 40,486.96 ha, 2.05%. The mountainous land in the west is mainly for forest, the hilly land in the east is mainly for grain and cotton production, and the downland and plain in the central region is mainly for grain, cotton and rape production. The construction land is centralized in the urban area, and the proportion of land utilization decreases progressively from cities and towns to the surrounding areas.
- Jingmen City: The total land area of Jingmen City is 1,233,942.99 ha, including agricultural land of 932,962.09 ha, accounting for 75.61% of the total area; construction land of 279,173.46 ha, 22.62%; and unused land of 21,807.44 ha, 1.77%. In Jingmen City, there are abundant land resources with high degree of development and utilization, the area of cultivated land and forest land is large, agricultural foundation is excellent, regional differentiation characteristics of land are obvious, and there are excellent natural landscape advantages.
- Qianjiang City: The total land area of Qianjiang City is 192,950.90 ha, including agricultural land of 154,469.71 ha, accounting for 80.06% of the total area; construction land of 21,058.56 ha, 10.91%; and unused land of 17,422.63 ha, 9.03%.

4.5 Riparian/Floodplain Ecology

Following domestic EIA guidelines, various environmental studies on the Han River cascade development considered terrestrial ecology that covers land corridors along the Han River mainstream, inundated area and ecolgocially sensitive areas nearby. Typical study areas are within 1000m each side of the mainstream.

For the past decade or so, riparian and floodplain ecology have recived more and more attention and its special ecological functions as opposed to typcial terrestrial ecology recognized. The riparian/floodplain ecogloy covers terrestrial habitats, wetlands, soils and geology, island and floodplain hydrology. According to the definition of "riparian" developed by the US National Research Council (2002), it ecompasses the above components and related processes:

"*Riparian areas are transitional between terrestrial and aquatic ecosystems and are*

[3] Shennongjia Forestry District is a juristiction under direct administration of the province.

distinguished by gradients of biophysical conditions, ecological processes, and biota. They are areas through which surface and subsurface hydrology connect waterbodies with their adjacent uplands. They include thoese portions of terrestrial ecosystems that significantly influence exchanges of energy and matter with aquatic ecosystems (i.e., a zone of influence). Riparian areas are adjacent to perennial, intermittent and ephemerial stream, lakes and estuarien-marine shorelines."

"*Further, riparian areas include portions of the channeled system and associated features (gravel bars, islands, wood debris); a vegetated zone of varying successional states influenced by floods, sediment deposition, soil-formation processes and water availability; and a transitional zone to the uplands of the valley wall – all underlain by alluvial aquifers. Although they occypy only a small portion of the total land base in most watersheds, riparian areas are regional hotspots for biodiversity and exhibit high rates of biological productivity in contrast to larger landscapes*."

Each of the identified components and related processes are influenced by both natural processes and man-induced stresses. For example, compounding the influence of natural processes are changed floodplain hydrology and characteristics resulting from development projects or other human induced changes in land use. These influences include dams and other instream developments, activities along the riverbank or within the riparian zone, and upstream activities throughout the watershed. The floodplain hydrology resulting from the combination of natural and human influences, subsequently, affects the full spectrum of riparian features. It also significantly affects the suitability of the riparian zone ofr various human activities such as agriculture, recreation, transportation, housing and commerce.

Figure 4-7 shows riparian area that is located between waterbody (aquatic) and upland areas. Specific to the Han River context, riparian areas are more expansive compared to wetland because ripariain areas may include not only portions of wetlands, but also non-vegetated portions of point bars[4], and encompass certain terrestrial areas that do not nessisarily requie inundation and saturation nearthe surface, as do wetlands.

[4] A **point bar** is a depositional feature made of alluvium that accumulates on the inside bend of streams and rivers below the slip-off slope. Point bars are found in abundance in mature or meandering streams. They are crescent-shaped and located on the inside of a stream bend, being very similar to, though often smaller than, towheads, or river islands.

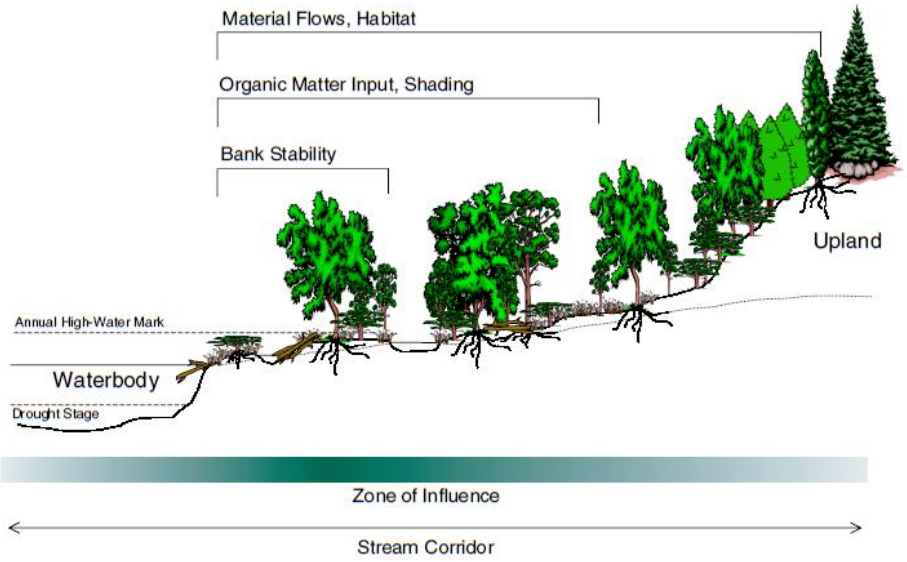


FIGURE ES-1 Schematic of a generic riparian area showing a zone of influence relative to aquatic and upland areas. The intensity of riparian influence is depicted with shading. "Material flows" refers to energy, organic matter, water, sediment, and nutrient flow.

Figure 4-7 Riparian Areas

For purposes of describing the affected environment, the following components, processes, habitats and species are addressed: physiography and geomorphic considerations, floodplain descriptions, soils and sedimentation, hydrological considerations, corridors, riparian habitats, wetlands, riparian edge/shorelines areas, and wildlife.

4.5.1 Physiography and geomorphy

The Han River, 1579 km in length, is the largest tributary of Yangtze River. The Han River originates Jushui in Qingling Mountain, flows through Hanzhong and Ankang in Shaanxi Province, enters Hubei Province at Shuhekou, then flows through Yunxi, Yunxian, Danjiangkou, Laohekou, Gucheng, Xiangfan (i.e., Xiangyang), Yicheng, Zhongxiang, Qianjiang, Xiantao, Hanchuang, Caidian city/county/district and finally joins the Yangtze River in Wuhan City. It has a total basin area of 159,000 km2 that covers south Shaanxi Province, southwest Henan Province, north and middle Hubei Province and a corner in northeastern Sichuan Province.

In terms of physiography, in Hubei Provicne the Han River basin in general is high in northwest and low in southeast. Upstream of Danjiangkou (literally it means Dan River mouth) is the upper reach of the river basin that belongs to Qingba Mountains and the ridges are mostly 1000m above sea level. The river valley is narrow; river current is rapid due to slopy river bed. From Danjiangkou to Zhongxiang, the mid reach has a length of 270km with a drainage area of 46,800 km2 across the E'bei low platreau; the river flows through wider valley and is about 80-450m above sea level. Downstream of Zhongxiang, the mainstem has a length of 382 km with a drainage area of 170,000km2 that belongs to Jianghan Plain with sea level elevation mostly below 50m. Han River's tributaries are relatively short. Along the mid to low reaches of Han River, from upstream to downstream, major tributaries include the Tangbai, Nan, Man and Hanbei rivers.

Along the mid-low reaches, upstream of Xiangyang, the right bank is close to hills while the left bank featured with terrace and wide alluvial flat. Between Xiangyang and

Nianpanshan, the left bank is close to hills while the right bank is mostly alluvial flat. Low reach of the rive is meandering slow-moving waters across the Jianghan Plain. Dikes and embankment are widespread for flood control purpose. The mid to low reaches of Han River basin has been subject to human activities for a long history. Though the historical and current conditions of general physiography and geomorphy are essentially the same, localized changes in the floodplain have occurred along the mainstem and major tributaries as result of land use changes as well as a consequence of river flow pattern changes from dams and locks formuation.

4.5.2 Riparian soils

Riparian soils are highly variable in structure, particle size distribution, and other factor that occur not only horizontally across a riparian area but also vertically within a soil profile. Such variability results from interactions between stremflow patterns and sediment transport in conjunction with variations in local geology, channel morphology, and streamside vegetation. Sediments deposited on floodplains undergo biogeochemical changes that occur over time transform flood-deposited sediment into riparian soils which, because of their high levels of nutrient and organic matter, are higly productive agricultural soils.

4.5.3 Groundwater conditions

Riparian areas receive water from direct precipitation, groundwater discharge, overland and shallow subsurface flow, from adjacent uplands, and from the Han River by various pathways. Riparian area is distinctive from upland by the dynamic surface and subsurface hydraulic connection with waterbodies, and this aspect should be further studied in the future. The general information of groundwater and recharge conditions based on available references is discussed in this sub-section.

1. Xiangyang Section

The groundwater in Xiangyang area mainly exists in sand layer and sand-gravel layer in Quaternary high floodplain and first terrace, and belongs to pore phreatic water with large volume. The buried depth of the groundwater in high floodplain is 3-5m, and the buried depth in first terrace is 2.2-4.5m. The groundwater level is more than 1m higher than the water level of Han River, and the groundwater is mainly recharged by atmospheric precipitation. The groundwater on both banks of Han River is discharged to Han River and the water of Han River will flow backwards in flooding season to recharge the groundwater temporarily. The buried depth of groundwater in Quaternary second terrace and Longgang region is usually large, and the water-bearing capability is low.

2. Yakou Complex Section

Gaojiage - Nanzhou Section on the left bank and Sanjiazhou - Xiaohe Town Section and Hongshantou - Wanqiying Section on the right bank belong to first terrace or high floodplain. The upper layer is mainly silty loam, and the lower is sand or sand-gravel with high water permeability. The groundwater is divided into pore water in Quaternary loose bed and confined water in bedrock, of which the buried depth is small, usually 1.8～3.7m. Quaternary pore phreatic water exists in fine sand layer and sand-gravel layer in riverbed, floodplain and first terrace, mainly recharged by atmospheric precipitation and discharged to Han River. Confined water in bedrock exists in loose sandstone and sand gravel, and the relative water resisting layer is formed from clay rock and marlstone with extremely low water permeability or thin sandstone layer with good consolidation property. Confined

aquifer is distributed steadily in thickness, usually about 20m, and the confined water level is 46.34～51.33m, usually higher or lower than the water surface of Han River.

3. Nianpanshan Complex Section

The groundwater in Zhongxiang region mainly is Quaternary pore water. The buried depth of the groundwater in first terrace is 3-6m, and the groundwater level is 41.7-46.4m. The groundwater is usually discharged to Han River. The ground elevation of the first terrace is 48m, 6m higher than the surface of the river in normal season.

4. River Section below Xinglong Complex

The groundwater on both sides of the river channel at the lower reach of Han River mainly includes Quaternary pore phreatic water, pore confined water, fissure-pore confined water in clastic rock and fissure water in bedrock. Pore phreatic water mostly exists in sandy soil and loam and is recharged through vertical infiltration of atmospheric precipitation. In flooding season, surface water recharges phreatic water and in dry season the phreatic water is discharged to the surface water. Pore confined water aquifer group is composed of silt, fine sand, sand cobble (gravel) layer and sandy loam, which has strong hydraulic connection with river water and is also recharged by the overflow of upper and lower aquifer groups. Fissure-pore confined water in clastic rock exists in the fissures and pores of the underlying Neogene clastic rocks, and is mainly recharged by Quaternary pore water and surface water at the edge of the basin. Fissure water in bedrock exists in the fissures of fine-grain quartz sandstone in Wutong Formation of upper Devonian system, and the water-bearing capability mainly depends on structural conditions and is low in general.

There is strong hydraulic connection between the groundwater on both banks of the mainstem and the surface water. In general, the groundwater is recharged by precipitation and discharged to Han River. When the water level of Han River rises in flood season, the groundwater may berecharged by surface water.

4.5.4 Riparian ecosystem

Various activities in combination have cumulatively affected riparian areas along the Han River. As riparian areas have become hydrologically disconnected from their adjacent stream channels, many ecological functions have been lost. Such disconnections occur, for example, when local topography and soils are altered by agriculrual activities or by development and its asociated infrastructure. Floodplain and instream sand and gravel mining also potentially modify riaprian hydrology, influencing groundwater levels, overbank flow, bank stability and the character of riparian vegetation. Impoundment of the river for navigation has elevated the water table and thas significnatly affecte riparian and floodplain resources. Deepwater habitats of navigation pools have replaced the varied habitats of islands, gavel bars, riffles, and channel wetlands, while some new habitats have been created in embayments.

This subsection describes riparian ecosystem, including riparian plants, riparian habitats and wildlife, including waterfowls, amphibian, reptiles and mammals.

4.5.4.1 Riparian corridor

The 2013 Han River retrospective EIA study survey in addressing terrestrial ecology covered the innudation area and 1000m of each side of the mainstem Han River (i.e. assessment area). It should be noted that this corridor (study area) is wider than riparian

area. Within this study area, several types of ecosystems were identified, including the following. Remote sensing photo of the 1000-meter wide corridors at both side of the river is shown in Figure 4-6 in Section 4.4 Land Use. According to the field survey, the landform of assessment area includes plain and low mountains and hills, mainly involving forest ecosystem, grassland ecosystem, agricultural ecosystem, wetland ecosystem and city/town/village ecosystem, etc.

- Forest ecosystem, dominated by poplar (*Populus euramevicanacv*) and dryland wilow (*Saliz matsudana*), distributed along the river bank linearly and on some islands. The total forest ecosystem area is 152 km2, accounting to 9.18% of the total. There are only a few varieties of undergrowth herbaceous plants. According to the difference of understory species, the communities may be divided into different associations, such as *Populus euramevicanacv-Perilla frutescens*, *Populus euramevicanacv—Sapium sebiferum—Cynodon dactylon*, and so on.
- Grassland ecosystem are distributed widely on river bank and alluvial flats. The total grassland ecosystem area is 167 km2, accounting to 10.12% of the total. It mainly includes herbal shrubs such as *Xanthium strumarium*, *Cynodon dactylon* and *Setaria viridis*.
- Agro-ecosystem scattered along river banks, including corn, sesame, penuts and white gourds. The total agro ecosystem area is about 652 km2, account to 39.4% of the total.
- Urban and village ecosystem has an area of 141.08 km2, or 8.53% of the total.
- Wetland ecosytem, dominated by bushwood and plants on bottomland.

In general, the ecological regime in the assessment area is relatively consistent, and mainly is wetland ecosystem. There is a little native vegetation in the area, which is mostly replaced with cultivated vegetation, and the habitat situation is ordinary.

4.5.4.2 Riparian habitats and wildlife

1. Habitat types

Riparian edge/shorelines areas are physical, chemical and biological transition zones between terrestrial habitats and open water. Such areas are important for a variety of birds, mammals, amphibians, reptiles and fishes, dependent on this limited habtat type. Rooted aquatic plants or macrophytes represent a conspicuous group of organism primarily found in riparian edge/shoreline areas, as well as in embayments. The aquatic vascular plants inhibit in waters and wetland; its distribution is subject to water depth, transparency, water quality, sustrate type and other organisms. These are food for herbivorous and omnivorous fish and provide bases for eggs of the fish species with sticky eggs.

Of the 1000-meter wide corridor surveyed, the bottomland wetland that constitutes a large portion of riparian areas should be the emphasis of this assessment considering its ecological values and the impoundment of water due to dam/reservoir formation. Major wetland habitat types include riverine open water, riverine emergent, riverine aquatic bed, palustrine open water, palustrine emergent, palustrine scrubb/shrub.

2. Riparian plants

According to the 2004 survey results, 15 species of emergent plants and 13 species of submerged plants were observed along the mid-low reaches of Han River. The overall distribution area was considered small; the community structure is simple and the species composition tended to be unitary. Along the mid reach of Han River, the widespread alluvial flats, low water turbidity and silt-sand-pebble sustrate favor submerged plants; dominant communities consisted of Potamogetonaceae, *Hydrilla verticillata* (L.F.) and Royle and *Ceratophyllum demersum* L. Along the low reach, shoals and flats are less; water tubidity and pollution level are higher than the mid-reach; community structure consisted of a emergent layer and submerged layer. The emergent layer had *Typha orioentalis* Presil as singular-dominant community, with accompanying *P. otamogeton Malaianus* Miq. and *Myriophyllum spicatum* L.; while the submerged layer had dominant communities consisting of *Alternanthera philoxeroides* Mart.Griseb and *Ceratophyllum demersum* L., with accompanying *Myriophyllum spicatum* L. in some locations.

3. Birds

94 species of birds were observed in the vicinity of the Han River corridor, including 32 winter migratory bird species; 17 summer migratory bird species; 41 resident bird species; and 4 stopover bird species. Of the 94 species, there are 44 waterfowls, including 13 swimming bird species (e.g. geese, ducks, swans) and 31 wading bird species (e.g. egrets, herons, sandpiper). The 94 bird species studied included those inhibiting in uplands hence those are not the focus of the ripariain habitat wildlife study.

National level protected waterfowls include the following two wading birds.

- Oriental White Stork (*Ciconia boyciana, 东方白鹳*): A national class I protected large wading bird species; 110-128 cm in length and 3.9-4.5 kg in weight. Breeding in northeastern China starting in March, it winters in lakes in low reach of Yangtze River and southern area. *In the assessment area, the Oriental White Stork were found primarily in the Lihuahu Nature Reserve in Laohekou City*.
- Black Stork (*Ciconia nigra，黑鹳*): A national class I protected large wading bird species; 100 cm in length. It was found in riverine wetland along the Han River.

Oriental White Stork

Oriental White Stork

Figure 4-8 Protected Waterfowls (I)

Four national class II protected waterfowls were recorded in the assessment area, including Rewick's Swan (小天鹅), White-fronted Goose (白额燕), Mandarin Duck (鸳鸯), and *Numenius minutus （小杓鹬）*.

Rewick's Swan

White-fronted Goose

Mandarin Duck

Figure 4-9 Protected Waterfowls (II)

4. Amphibian

In the assessment area, there is mainly 1 order, 4 families and 8 species of amphibians, 1 species of the second category of national key protected animals, i.e., tiger frog (*Hoplobatrachus rugulosus)*, and 4 species of Hubei provincial key protected animals, i.e., *Bufo bufo gargarizans*, *Fejervarya limnocharis*, *Pelophylax nigromaculata* and *Microhyla ornata*. According to the life habits, the amphibians in the assessment area may be divided into three ecological types: still-water type (feeding in still water or slow flow), terrestrial type (feeding and acting on land), and tree-inhabiting type (acting and feeding in trees close to water sources).

5. Reptiles

In the assessment area, there are 2 orders, 6 families and 12 species of reptiles, no national key protected reptile identified, and 2 species of Hubei provincial key protected animals: *Bungarus multicinctus* and *Elaphe taeniura*. According to the life habits, the reptiles in the assessment area may be divided into three ecological types: shrub and rock crack type (frequently acting under shrubs and in rock cracks on the roadsides), forest-inhabiting and waterside type (acting on the slopes near streams in valleys) and water-inhabiting type (living and foraging in water).

6. Mammals

15 mammal species occur in the assesemnt area, including Eurasian River Otter

(national class II protected), bat, porcupine, rabbit, etc.

4.6 Socio-Economics

The administrative regions in Hubei Province directly involved in the cascade development on the mainstem middle and lower Han River include Shiyan City (Danjiangkou City and Laohekou City), Xiangyang City (Gucheng County, Xiangyang District, Xiangzhou District and Yicheng City), Jingmen City (Zhongxiang City) and Qianjiang City. The socioeconomic profile (2013) of the Shiyan City, Xiangyang City, Jingmen City and Qianjiang City is described as below:

- Shiyan City: According to the statistical notification of national economic and social development of Shiyan City in 2015, the registered population at the end of 2015 is 3,459.4 thousand, the permanent resident population is 3,383.0 thousand, and the natural population growth rate is 6.36‰. The gross domestic product (GDP) of the whole city realizes CNY 130.012 billion, among which, the value added of the primary industry is CNY 15.748 billion with growth rate of 4.7%, the valued added of the secondary industry is CNY 63.611 billion with growth rate of 4.3%, and the value added of the tertiary industry is CNY 50.653 billion with growth rate of 13.0%. The structure ratio of the three industries is 12.1:48.9:39.0. Per capita GDP is CNY 38,431, with growth rate of 7.2%. The per capita disposable income of permanent urban resident in the whole year is CNY 24,057, and the per capita disposal income of permanent rural resident in the whole year is CNY 7,779.
- Xiangyang City: According to the statistical notification of national economic and social development of Xiangyang City in 2015, the permanent resident population at the end of 2015 is 5,614 thousand, and the natural population growth rate is 6.79‰. The gross domestic product (GDP) of the whole city realizes CNY 338.21 billion, among which, the value added of the primary industry is CNY 40.21 billion with growth rate of 4.8%, the valued added of the secondary industry is CNY 192.29 billion with growth rate of 9.0%, and the value added of the tertiary industry is CNY 105.71 billion with growth rate of 10.1%. The structure ratio of the three industries is 11.9:56.9:31.2. The per capita disposable income of permanent urban resident in the whole year is CNY 20,282, and the per capita disposal income of permanent rural resident in the whole year is CNY 13,650.
- Jingmen City: According to the statistical notification of national economic and social development of Jingmen City in 2015, the gross domestic product (GDP) of the whole city realizes CNY 138.846 billion, with growth rate of 9.2%. The growth rate of the primary, secondary and tertiary industries is 5.1%, 10.0% and 9.7%, respectively, and the structure ratio is 14.5:52.5:33.0. The permanent resident population at the end of 2015 is 2,896.3 thousand, and the natural population growth rate is 3.8‰. The per capita disposable income of urban resident is CNY 26,731, with growth rate of 8.5%, and the per capita disposal income of rural resident is CNY 14,716, with growth rate of 9.2%.
- Qianjiang City: According to the statistical notification of national economic and social development of Qianjiang City in 2015, the gross domestic product (GDP) of the whole city realizes CNY 54.02 billion, with growth rate of 12.9%. The value added of the primary industry is CNY 6.030 billion with growth rate of 4.8%, the valued added of the secondary industry is CNY 26.020 billion with growth rate of 15.7%, and the value added of the tertiary industry is CNY 12.126 billion with growth rate of 11.8%. The structure ratio of the three industries is 13.7:58.9:27.4.

4.7 Cultural Relics

Hubei Provincial Institute of Cultural Heritage and Archaeology carried out field survey on cultural heritages in the construction area and inundation area of the 3 complexes that had not been built. The survey results indicate that: most of the cultural heritages are underground ancient sites and tombs, and the time span is from the Neolithic Age to the Dynasties of Ming and Qing. The cultural heritages and historic sites in Han Dynasty and Six Dynasties are in the majority, and the ground cultural heritage sites are fewer and usually from the Dynasties of Ming and Qing.

- Five county-level cultural heritage sites were discovered in the footprint of Xinji complex, i.e., Wangjiazui historic site in Fancheng District, Geleizui historic site in Gucheng County, Malinggou historic site and cemetery, Nangang historic site and Chenjiabukou historic site;
- Twelve cultural heritage sites are discovered at Yakou, all of which are ancient graveyards, and except for Wangjiagang graveyard which is county-level, all the other have not been classified.
- Four cultural heritage sites are discovered at Nianpanshan, i.e., Jiangpo cemetery that has not been classified, Jiexiao Kefeng arch, municipal Yujiahe graveyard and Yuexiangguan historic site.

4.8 Senstive Areas and Recreational Areas

There are several nature reserves, scenic areas, wetland parks and a fishery resource conservation zone on the middle and lower Han River.

- Laohekou Lihuahu Nature Reserve and Laohekou Lihuahu Scenic Area. Both build on Wangfuzhou reservoir and were authorized/established after the reservoir had been formualated.
- Gucheng Han River National Wetland Park, located in Gucheng County, immediate downstream of Wangfuzhou dam and extends to tailwaters of Xinji reservoir. Impoundment of the Xinji reservoir will inundate peripheral area of the wetland park.
- Xiangyang Cuijiaying Provincial Wetland Park, located in Xiangyang City. It builds on the Cuijiaying reservoir and was authorizied/established after the Cuijiaying reservoir had been formualated.
- Yicheng Wanyangzhou National Wetland Park, located in Yicheng City. It will be part of the future Yakou reservoir;
- Two fisery resource conseravation zones in the lower reach of Han River. They have been discussed in previous sections on fish hence will not be repeated in this section.

Review of these areas' history and administration indicate their multi-purposes. Some of them such as the Lihuhu nature and Cuijiaying wetland park were established on the Wangfuzhou reservoir and Cuijiaying reservoir after they were formulated, with an apparent purpose of protecting the impounded reservoir. The wetland park, based on domestic regulations, is not considered legally protected area. The Yicheng Wangyangzhou wetland park was established in order to prevent the waters and riparian area from further development that were already intense. It was also proposed for the purpose of provding recreational opportunities. Nonetheless, even creating recreational areas provides good

opportunities for ecosystem protection and restoration.

Figure 4-10 shows the above-mentioned nature reserve, scenic area and wetland parks; all are located in the middle reach of Han River mainstem. Figure 4-11 shows the two fishery resource conservation zones in the lower reach of Han River mainstem.

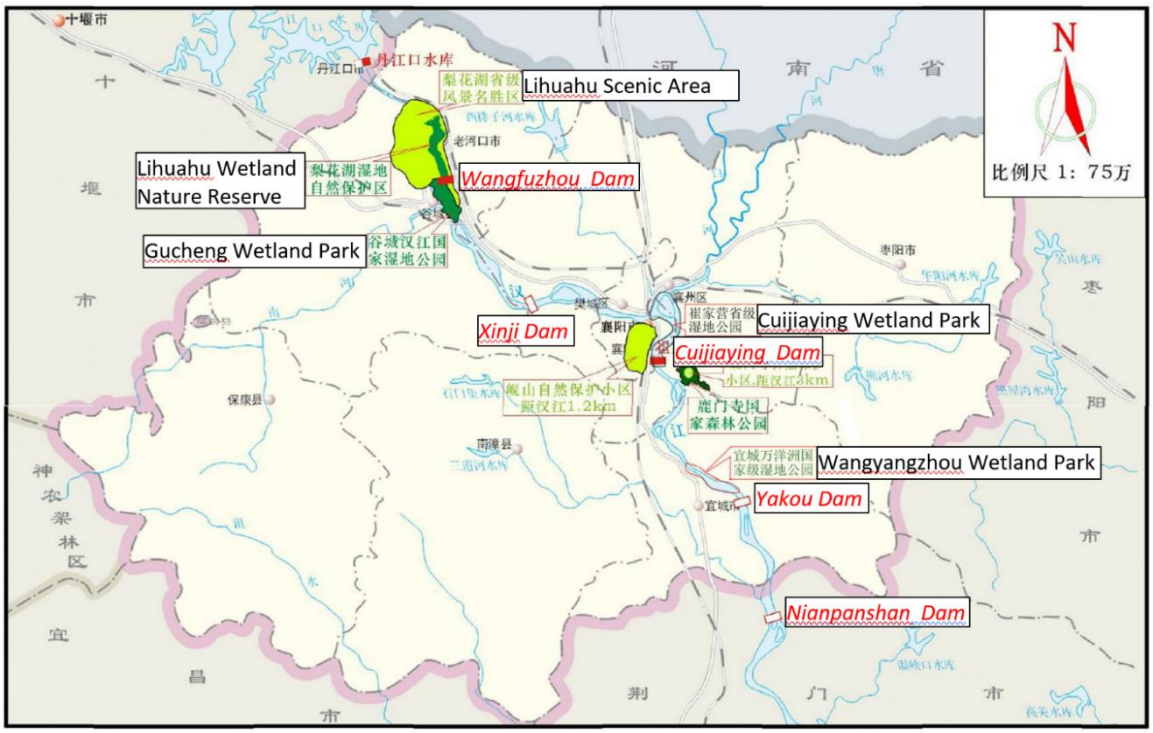


Figure 4-10 Nature Rservr, Wetland Parks Along Middle and Lower Han River

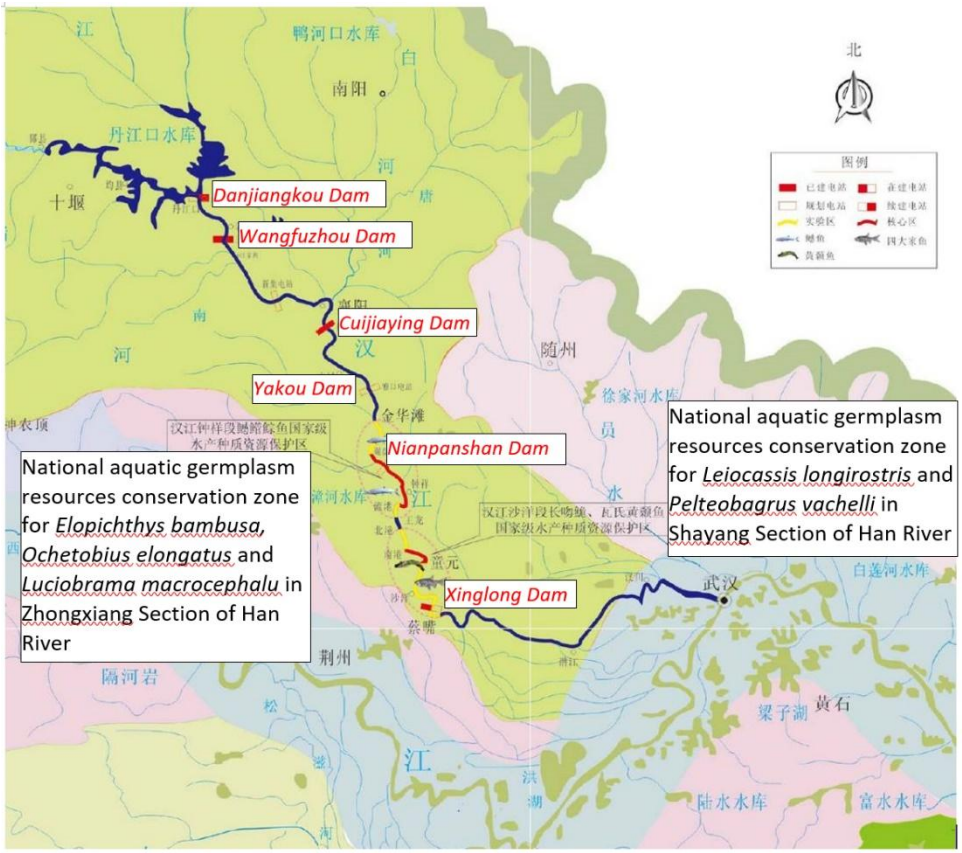


Figure 4-11 Two Fisery Resource Conservation Zones in Lower Han River

Table 4-3 Summary of Ecologically Sensitive Areas

No.	Name of sensitive receptor		General situation of sensitive receptors								
			Level	County/city	Area (ha)	Type	Main protected object	Characteristics of sensitive receptor	Main effect	Location	Administrative governing
1	Nature reserve	Lihuahu Nature Reserve in Laohekou	Municipal	Laohekou City	4200	Wetland ecology	Freshwater lake ecosystem and rare water birds	Abundant wetland plant and animal resources, including, 55 families, 215 genera and 375 species of vascular plants; one species of the first category of national protected wild animals: *Ciconia ciconia*; four species of the second category of national protected wild animals: *Aix galericulata*, *Numenius minutus*, *Anser albifrons* and *Hoplobatrachus rugulosus;* and 60 species of Hubei provincial key protected wild animals.	No effect	Located in the water area of Han River from Danjiangkou Reservoir dam to Wangfuzhou dam, and located upstream from the reservoir tail of Xinji Hydropower Station, namely, the water area of Wangfuzhou Reservoir	Forestry
2	Nature conservation sub-area	Xian Mountain Nature conservation spot	Provincial	Xiangyang City	1000	Ornamental forest	Cultural landscape and historical site	Forests	No effect	The minimum distance from Han River is 1.2km	Forestry
3		Lumen Temple Nature conservation spot	Provincial	Xiangyang District	1000	Ornamental forest	Cultural landscape and historical site	The existing cultural and historical scenic spots include Lumen Memorial Archway, Bajiao Well, Courtyard, Rainstorm Pool, Longtou Pool, etc.	No effect	8.5km downstream from Cuijiaying; the minimum distance from the right bank of Han River is 3km	Forestry
4	Scenic spot	Lihuahu Scenic Spot in Laohekou	National	Laohekou City	33260	Scenic spot	Natural landscape, wetland vegetation, freshwater lake ecosystem and rare water birds	Main scenic spots include National Defense Education Base, Han River Manor, Mengqiaoquan, Han River Sightseeing Resort, Wangfuzhou Ecological Agricultural Tourism Park, Baihua Mountain, etc.	No effect	Located in the water area of Han River from Danjiangkou Reservoir dam to Wangfuzhou dam, and located upstream from the reservoir tail of Xinji Hydropower Station, namely, the water area of Wangfuzhou Reservoir	Tourism
5	Wetland park	Gucheng Han River National Wetland Park	National	Gucheng County	2130	Wetland ecology and scenic spot	Wetland ecosystem	The wetland park is divided into six functional zones, among which, the ecological conservation zone is the key protection area of the park, and the construction principle is to maintain the original natural landscape, restore some degraded areas and build a paradise of wild animals and plants.	The backwater inundation at the reservoir tail of Xinji Hydropower Station involves the wetland conservation zone.	Located at the reservoir tail of Xinji Hydropower Station	Forestry
6		Proposed Wanyangzhou National Wetland Park in Yicheng	National	Yicheng City	2466.03	Wetland ecology and scenic spot	Permanent river wetland and flood plain wetland	The wetland park is divided into five functional zones: wetland conservation zone, taking up 59.13%; restoration and reconstruction zone, 30.08%; popularization and education zone, 7.7%; reasonable utilization zone, 3.08%; and management and service zone, 0.01%	The inundation caused by Yakou Complex involves wetland park	The water area is entirely within the flooded line of Yakou Reservoir	Forestry
7	Forest park	Lumen Temple National Forest Park	National	Xiangzhou District	1171	Scenic spot	Natural landscape and forest vegetation	The area of forest is more than 2,600mu, the forest coverage reaches 92.5%, and there are more than 30 natural landscape spots.	No effect	8.5km downstream from Cuijiaying	Forestry

4.9 Regulatory Thresholds for VECs

Regulatory thresholds for priority VECs are defined based on pertinent regulations and environmetnal standards, sectoral development planning.

4.9.1 Hydrologic Regimes

The threshold is defined by environmtental flow releases. In 2006, MEP issued the *Hydropower and Water Resources Construction Project Water Environment and Aquatic Ecology Protection Technology and Policy Seminar Minutes* (No.11 of 2006) and the *EIA Technical Guide for Ecological Water Use, Low Temperature Water and Fish Pass in Hydropower and Water Resources Construction Project (Trial)* (No.4 of 2006), stipulating that hydropower project must discharge certain volume of ecological flow so as to preserve basic ecological demand of rivers, which shall be incorporated in the overall water resources arrangement of the project. Therefore, for the near term, minimum discharge in low flow season and flood regulation in fish reproductive season of the planned Xinji, Yakou and Nianpanshan hydropower complexes need to be emphatically analyzed so as to meet the demands of downstream ecological water use and other water uses.

According to operation statistics of the already constructed complexes in the middle and lower reaches of Han River, currently the minimum daily discharge of Danjiangkou and Wangfuzhou complexes both surpass 300 m^3/s, and the minimum daily discharge of Cuijiaying complex surpasses 500 m^3/s. Based on Tenant method, it is determined that the minimum daily discharge of Danjiangkou, Wangfuzhou or Cuijiaying is higher than 20% of average annual runoff, indicating "good" condition i.e. satisfying the water volumes needed for stable aquatic ecosystems as well as the required discharges for navigation. To meet the navigable water depth in the middle and lower reaches of Han River, Xinji power station need to discharge 300 m^3/s equivalent to 23% of the current average annual runoff; Yakou and Nianpanshan both need to discharge 450 m^3/s, above 20% of the current average annual runoff. Based on Tenant method, it is determined that when minimum daily discharge of a hydropower complex exceeds 20% of its average annual runoff, it is of "good" condition causing no significant impact on downstream aquatic ecosystem.

Tennant method is developed based on collecting large quantities of research data and the method is proven effective in terms of preserving good local ecological conditions when data/survey support is less but more specific ecological conditions of the assessment area are needed. Therefore, in order to satisfy river channel ecological water use and navigation water use in the downstream, the reasonable minimum discharge is determined as 450 m^3/s for Yakou navigation complex.

Likewise, the minimum ecological flow for each dam water releases requirements are the following,

- Danjiang dam/reservoir: 450 m3/s;
- Wangfuzhou dam/reservoir: 200 m3/s;
- Xinji dam/reservoir: 300 m3/s;
- Cuijiaying: 470 m3/s;
- Yakou: 450 m3/s;
- Nipanshan: 450 m3/s;
- Xinglong: 490 m3/s.

4.9.2 Water Quality

The thresholds are dictated by designated surface water zoning and drinking water source protection zone. According to water environment functional zoning of Han River mainstream and considering *Surface Water Environmental Quality* (GB3838-2002), different river sections are designated different water quality targets. According to *Hubei Province Surface Water Environment Functional Zone Classification* issued by Hubei Government Office (No. 10 of 2000), main applicable functions of river sections in the middle and lower reaches of Han River mainstream are: river sections in Laohekou urban area, Xiangyang urban area and Wuhan urban area are Grade-II drinking water source protection zones, to follow Class-III surface water environment quality standards; remaining river sections are Grade I drinking water source protection zones, to follow Class II surface water environment quality standards. Tributaries are designated lower standards, ranging from Class-III to Class-IV.

Table 4-3 Water Quality Functional Zoning for Middle and Lower Han River Mainstem

<table>
<tr><th>River sections</th><th>City</th><th>Main applicable functions</th><th>Complexes involved</th><th>Applicable surface water quality standard (GB3838-2002)</th></tr>
<tr><td>Danjiangkou city river section</td><td>Danjiangkou city</td><td rowspan="2">Grade I drinking water source protection zone</td><td rowspan="2">Danjiangkou</td><td rowspan="2">II</td></tr>
<tr><td>River section from Fujiazhai to 100m downstream of water plant water intake</td><td rowspan="3">Laohekou city</td></tr>
<tr><td>River section from 100m downstream of water plant water intake to Jiangjiazhou</td><td>Grade II drinking water source protection zone</td><td>Wangfuzhou</td><td>III</td></tr>
<tr><td>River section downstream of Jiangjiazhou</td><td rowspan="2">Grade I drinking water source protection zone</td><td rowspan="2"></td><td rowspan="2">II</td></tr>
<tr><td>River section upstream of Baijiawan</td><td rowspan="2">Xiangyang city</td></tr>
<tr><td>River section from Baijiawan to Yujiahu</td><td>General fish reserve</td><td>Xinji, Cuijiaying</td><td>III</td></tr>
<tr><td>Yicheng city river section</td><td>Yicheng city</td><td rowspan="7">Grade I drinking water source protection zones</td><td>Yakou</td><td rowspan="7">II</td></tr>
<tr><td>Zhongxiang city river section</td><td>Zhongxiang city</td><td>Nianpanshan</td></tr>
<tr><td>Shayang city river section</td><td>Shayang city</td><td></td></tr>
<tr><td>Tianmen city river section</td><td rowspan="2">Tianmen city</td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td>Qianjiang city river section</td><td>Qianjiang city</td><td>Xinglong</td></tr>
<tr><td>Xiantao city river section</td><td>Xiantao city</td><td></td></tr>
<tr><td>Wuhan city river section</td><td>Wuhan city</td><td>Grade II drinking water source protection zone</td><td></td><td>III</td></tr>
</table>

Table 4-4 Water Quality Functional Zoning for Tributaries

Tributary	River section	Main applicable function	Applicable standard category (GB3838-2002)
Nan River	Gucheng county estuary section [Manaoguan to estuary (Cha'an)]	General fish reserve	Ⅲ
Bei River	Gucheng county estuary section	General fish reserve	Ⅲ
Xiaoqing River	Xiangyang city Qing River bridge to Qing River estuary	General industrial water area	Ⅳ
Tangbai River	Xiangzhou district river section	General industrial water area	IV
		General industrial water area	IV
Man River	Yicheng, Zhongxiang river section	General fish reserve	Ⅲ
Zhupi River	Zhongxiang river section	General industrial water area	IV

4.9.3 Fish

It is learned that the available aquatic background information are from the aquatic ecology research report of affected river sections in Yakou navigation complex EIA conducted in preparation stage and from numerous aquatic ecology surveys in the middle and lower reaches of Han River since 1978. National Aquatic Germplasm resources conservation zone of Leiocassis longirostris and Pelteobaggrus vachelli in Shayang section of Han River, and National Aquatic Germplasm resources conservation zone of Elopichthys bambusa, Ochetobibus elongatus and Luciobrama macrocephalus in the Zhongxiang section of Han River, coded 4206 and 4207 respectively, are 2 of the 63 national aquatic germplasm resources conservation zones (second batch) released on December 22, 2008 (Ministry of Agriculture No. 1130 Announcement). See Table 5-7 and Figure 38 for protected sensitive aquatic receptors.

Table 4-5 Fishery Resource Protection Targets

Serial No.	Name of protection target		Sensitive receptors overview						
			Level	County/city located	Area (ha)	Type	Main protected subject	Relation to Construction of navigation and hydropower complexes along Han River	Administrative jurisdiction
1	Germplasm resources conservation zone	National aquatic germplasm resources conservation zone of Elopichthys bambusa , Ochetobibus elongatus and Luciobrama macrocephalus in the Zhongxiang section of Han River	National	Zhongxiang city	4320	Germplasm resources conservation zone	Elopichthys bambusa, Ochetobibus elongatus, Luciobrama macrocephalus; other protected species including Siniperca chuatsi, Pelteobagrus fulvidraco, Leiocassis longirostris	Han River section where Nianpanshan hydropower complex locates	Ministry of Agriculture
2	Germplasm resources conservation zone	National aquatic germplasm resources conservation	National	Shayang county	3750	Germplasm resources conservation zone	Important economic fishes such as Leiocassis longirostris, Pelteobaggrus vachelli and their spawning	Han River section where Xinglong hydropower complex locates	Ministry of Agriculture

Serial No.	Name of protection target		Sensitive receptors overview						
			Level	County/city located	Area (ha)	Type	Main protected subject	Relation to Construction of navigation and hydropower complexes along Han River	Administrative jurisdiction
		zone of Leiocassis longirostris and Pelteobaggrus vachelli in Shayang section of Han River					grounds; other protected species including Mylopharyngodon piceus, Ctenopharyngodon idellus, Hypophthalmichthys molitrix, Aristichthys nobilis, Carassius auratus, Megalobrama amblycephala, Elopichthys bambusa, Ochetobibus elongatus, Luciobrama macrocephalus,Culter mongolicus, Culter alburnus		
3	"Three grounds" of fish	spawning ground		Xiangyang city,Yicheng city,Zhongxiang city,Shayang county,Qianjiang city		"Three grounds" of fish	Mainly reproductive grounds for fish with pelagic eggs such as "four major Chinese carps" (current situation prevails)	Mainly distributed in the Han River section between Cuijiaying and Xinglong complexes as well as Zekou river section downstream of Xinglong	

In the process of constructing navigation and hydropower complexes along Han River mainstream, relevant national/local laws and regulations listed below must be followed:

- *Fisheries Law of the People's Republic of China* (revised in August, 2004);
- *China Aquatic Resources Protection Action Plan* released by the State Council in February 2006;
- *Aquatic Germplasm Resources Management Interim Measures* released by the Ministry of Agriculture and became effective on March 1, 2011;
- *Notice on Intensified Implementation of Hydropower Development Eco-environmental Protection Measures* (No. 65 [2014]) by the Ministry of Environmental Protection and National Energy Administration;
- *Notice on Further Intensifying Aquatic Organism Resources Protection and Strictly Managing Environmental Impact Assessment* (No. 86 [2013]) by the Ministry of Environmental Protection and Ministry of Agriculture.

The objective of aquatic ecological protection is to preserve living environment of aquatic organism in river sections, ensure certain amount of river discharge and habitable environment for fish. Effective measures shall be taken to avoid disappearing of fish species, reduce impact on fish stock as much as possible, and maintain stable fish population

4.9.4 Riparian Areas

There is only general regulatory requirements on the protection of terrestrial ecolgoy

because of the status quo in the area. The middle and lower reaches of Han River region has the landform featuring plain and low mountains and hills, including forest ecosystem mainly of Populus euramevicana and Salix matsudana forests, grassland ecosystem mainly of Xanthium sibiricum, Cynodon dactylon and Setaria viridis, as well as wetland and agricultural ecosystem ecosystems mainly of mud flats in shrubland and scrub-grassland. Generally speaking, the area has little native vegetation and has been largely replaced by cultivated vegetation and habitat condition is fine. The objective of terrestrial ecological protection is to, through reasonable development and protection of land and water resources, as well as reasonable project construction and resettlement plan, reduce landscape and ecological damage, prevent soil erosion, preserve the entirety of basin ecosystem, protect basin vegetation, flora and fauna diversity and ensure that affected rare and peculiar species won't disappear from the basin as result of constructing navigation and hydropower complexes along Han River.

More attention has been given to ecologically sensitive areas, such as the Lihuahu Wetland Nature Reserve. Nonetheless, recognizing that the riparian areas along the Han River has been subject to long history of human activiteis and its ecological fuctions, the CEA study gives special attention to riparian areas.

5 Inter-Agency Coordination and Public Consultation

For this CEA study, the 'public' is defined as other government agencies, local government, potential affected peoples by the cascade development, non-government organizations (NGOs), and technical experts.

Given the complexities and extensive coverage of cumulative effects, public consultation is particularly important for CEA for the following reasons:

- Inputs from specialized government agencies such as water resource department, agricultural and fishery departments are important for defninng VECs.
- Inputs from government agencies are also critical to collect information on reasonable foreseeable future activities as data and planning documents for some of these activities are sector-specific and may not be adequately known by others;
- Inputs from technical experts, the general public and NGOs are critical to define VECs and understand concerns and concequences of development activities;
- Measures developed to address cumulative effects mostly involve extensive inter-agency coordination. Reaching consensus among those stakeholders at early stage and set up an inter-agency coordination mechanism is necessary.

This section first discusses insitutional background of basin management in China and Hubei Province, then existing inter-agency coordination mechanism, and the results of public consultation activities during the CEA process and how they contributed to the CEA scoping and development of mitigation plans.

5.1 Overview of Water-Related Administration in China

At central government level, several ministries are involved into the administration of water-related business, as reflected in Table below.

Table 5-1 Water-related Administration

Agencies	Authority
Ministry of Water Resources	• Water resource policy, stratety and planning; • Coordinate and guarantee water for living and production, and ecological environmental purposes; • Water resource protection and flooding/drought prevention and control; • Water conservation; and • Prevention and control of water and soil erosion.
Ministry of Environmental Protection	• Administration of water environmental pollution prevention and control; • Formulating administrative insitutions for water pollution prevention and control; • Administration and supervision for the protection of drinking water resource protection zone; • Water environment monitoring and information disseminaiton;
Ministry of Housingand Urban and Rural Development	• Guiding the urban water supply, water conservation inspection; • Guiding the construction of urban wastewater treatment facilities and drainage/sewer networks;
Ministry of Land and Natural	• Administration of hydrogeological survey and assessment;

Resources	• Monitoring and administering groundwater over-exploitation and pollution.
Ministry of Transportation	• Supervision of water transportation security; • Emergency responses for traffic accidents on central-government administered waters, pollution accidents caused by vessels and water facilities.
Ministry of Agriculture	• Protection of the ecological water environment of fishery waters; • Fishing vessels inspection; fishing and fish port administration; • Non point source pollution control in rural areas.
State Administration of Forestry	• Administration and protection of wetland
National Development and Reform Commission	• Participate in the planning for water resrouce development and ecological environment • Coordinate agricultural, forestry and water resrouce development planning

Under the Ministry of Water Resources (MoWR), there are seven basin-level water resource commissions across China fulfilling the responsibilities on behalf of the ministry. Thus the Han River is under the administration of Yantze River Basin Water Resource Commission.

The central government ministries' responsibilities are passed on to its line agencies at provincial and below levels. It should be noted that in practice the principle of "Local Administration" is adhered to in the country's administrative system, that is to say, local government takes ultimate responsibility for water resources. In the case of Han River, the mid-low reaches is governed by the Hubei provincial government, while the water resource commission plays an assisting role.

There are many government agencies involved in water affairs. It is widely considered that there are disconnections among the management of water resources, hydropower, waterway navigation, fisheries, water supply, irrigation and drainage, and flooding control. The management fragmentation of water quantity and water quality, waters in urban and rural areas, surface and groundwater exists. There are also functions overlapping among different agencies. For example, the water resource bureau is in charge of water resource protection while the environmental protection bureau is in charge of water pollution control. Coordianation between the two agencies is absoluately necessary but not always goes well.

International good practices are that an integrated river basin management should be applied; public involvement encouraged; and a comprehensive legal and regulatory system established. The experiences can be borrowed by China. An integrated basin management system should be established and backed by legal insitutions; inter-agency and inter-territory coordination should be in place. These are necessary to achive good coordination among water resources, water environment and water ecology.

In recent years, the Government of China has been pushing forward institutional reformation in the area. At local government level, combining water-related functions into one government agency (i.e. water affairs bureau) has been piloted in some regions and is being scaled up. In December 2016, the central government issued *Opinions on Comprehensive Appliation of River Chief System*, which stipulates that the head of a local government assumes the River Chief role. She/he will be responsible and held acountable for the administration of water resources under the jurisdiction of the government. The Governor of Hubei Province hence is the River Chief of the Han River section under the jurisdiction of Hubei Province. This policy is considered an institutional innovation for addressing the very complicated water issue in China. In February 2016, the central government issued document to push forward river basin level environmental supervision,

administration and enforcement institution.

In summary, effective governing water issues always requires close coordination of several government agencies. During this study, consultation of pertinent agencies and other stakehoders including the public and non-government organizations (NGOs) were emphasized.

5.2 Han River Basin Existing Inter-Agency Coordination Mechanism

The 7 dams on the mid-low reaches of Han River are managed by several project owners that are affiliated to water resources agencies, transportation agency and state-owned power enterprise, as listed in Table X below.

Table 5-2 Project Owners of 7 Dams

Hydro-complex	Project Owner	Location
Danjiangkou	Danjiangkou Hydrocomplex Administative Bureau under Hanjiang Water Resource and Hydropower Group Co., Ltd.	Shiyan City
Wangfuzhou	Danjiangkou Hydrocomplex Administative Bureau under Hanjiang Water Resource and Hydropower Group Co., Ltd.	Laohekou City
Xinji	Datang Xiangyang Hydropower Co., Ltd. under China Datang Cooporation	Xiangcheng District, Xiangyang City
Cuijaying	Cuijiaying Hydro-Navigation Complex Management Unit under the Port and Navigatoin Administrative Bureau of Hubei Provincial Transportation Department	Xiangyang City
Yakou	Yakou Hydro-Navigation Complex Management Unit under the Port and Navigatoin Administrative Bureau of Hubei Provincial Transportation Department	Yicheng City, Xiangyang City
Nianpanshan	Han River Hydropower Development Co., Ltd. under Hubei Provincial Water Resources Department	Zhongxiang City
Xinglong	Hubei Provincial South-North Diversion Administrative Bureau	Tianmen City and Qianjiang City

Per domestic regulations, all the projects owners have environmental management office and dedicated staff to be responsible for day-to-day environmental protection of repective hydro-complex.

Beyond these hydro-complexes, as already discussed above, various agencies are involved in the administration of the Han River. These agencies have built the networks of river hydrologic and water environmental monitoring stations according to their responsibilities on water resources or water environment. The project owners the hydro-complexes carried out monitoring and investigation on hydro-copmlex operation, engineering safety as well as water regime, water environment and ecological environment of the river section to be developed. However, the relevant data are not shared among those stakeholders, thus making it difficult to systematically review and analyze.

Efforts have been made to strengthen coordination among those stakeholders of Han River. Several recent examples are discussed in below.

In January 2013, the Ministry of Water Resources approved the *Pilot Program for Accelerating the Implementation of the Most Stringent Water Resource Management System in Han River Basin* prepared by the Changjiang Water Resources Committee (CWRC) jointly with each provincial and municipal water resource authority in the Han River basin. Under the central government's Most Stringent Water Resource Management Initiative, it is the only pilot program that targets basin level water resource management. This pilot program aims to follow the principle of basin-wide water resource allocation, water conservation and protection, to build various systems on basin water resource management

and protection, water supply and drinking water source protection, coordinated Han River water resource allocation and scheduling, coordinated territorial and basin collaboration.

Another initiative is the *Joint Meeting System for the Unified Operation Management of Danjiangkou, Wangfuzhou, Cuijiaying and Xinglong Complexes along Han River and the Navigation Facilities along Jianghan Canal (Tentative)* formulated jointly by Hubei Provincial Port, Waterway and Maritime Safety Administration, the four hydro-complexes aon Han River and the Jianghan Canal. This joint meeting proposed to actively build a joint navigation scheduling mechanism for Han River and Jianghan Canal as well as a emergency warning mechanism for flood control and plan to establish Han River Navigation Command Center which will make full efforts to serve complex facilities and well accomplish maritime control and standard ship type promotion.

Duing the EA preparation for Yakou project, considering the cumulative impacts resulting from cascae development and operation on middle and lower Han River, the Ministry of Environmental Protection required to develop a coordinated ecological scheduling plan during its review of the Yakou EIA. The Yakou project owner Hubei Provincial Transportation Deparmtent thus commissioned an Analysis Report for *Coordinated Ecological Scheduling Plan for Han River Cascades Downstream of Danjaingkou*. The Hubei Provincial Government approved the plan in November 2015. The approval document stipulates that close coordination among pertinent parties must be in place to implement the plan on a annual basis. These stakeholders include Hubei Provincial Environmental Protection Departmetn, Transportation Department, Water Resources Department and Agriculture Department and involved dam/reservoir owners. Subsequently, during review of the Nianpanshan project EIA in 2016, the MEP emphasized that the plan must be implemented.

5.3 Public Consultation

5.3.1 Public Opinions and Feedback

During preparation of this CEA, two public meetings were held in June 2016 to invite inputs from pertinent governmental agencies, organizations and individuals on issues that should be factored into the study. Figure 5-1 shows the locations of the public meetings. Such public meetings also exemplified a stakeholder dialogue mechanism that should be continued and further developed during the next stage detailed CEA and more importantly, a form of inter-agency coordination.

One public meeting was held in **Xiangyang** City with participants from 18 governmental agencies of Danjiangkou City[5], Laohekou City, Xiangcheng District and Yicheng District[6]; the other meeting was held in **Zhongxiang** with participants from 15 governmental agencies of Zhongxiang City[7] and Qianjiang City. The meeting process and details are documented in the public consultation section of this report. Table X lists key issues that were raised on the public meetings. Table X also includes comments from individuals and NGO that were consulted during the EIA development for Yakou hydro-complex.

Questions discussed on the meetings included the following,

[5] Danjiangkou City is a county-level city under the Shiyan City, a prefecture level city.
[6] Laohekou City, Xiangcheng District and Yicheng City are all under the jurisdiction of Xiangyang City.
[7] Zhongxiang City is a county-level city under Jingmen City, a prefecture level city.

Topic one: *what are the existing or potential impacts on hydrological and water resources utilization due to construction of navigation complexes along the middle and lower reaches of Han River mainstream? What kinds of environmental protection measures are suggested to be taken to mitigate the existing and potential environmental problems?*

Topic two: *what are the existing or potential impacts on aquatic ecology and terrestrial ecology due to construction of navigation complexes along the middle and lower reaches of Han River mainstream? What kinds of environmental protection measures are suggested to be taken in regard to the existing and possible eco-environmental problems?*

Topic three: *what are the existing or potential impacts on water environment due to construction of navigation complexes along the middle and lower reaches of Han River mainstream? What kinds of environmental protection measures are suggested to be taken in regard to the existing and possible water environmental problems?*

Topic four: *what are the already caused or possible socio-environmental impacts (such as Han River shipping, urban flood prevention, water supply, resettlement, urban drainage and flood drainage, population health and cultural relics and historic sites) of the construction of navigation complexes along the middle and lower reaches of Han River mainstream? What kinds of environmental protection measures are suggested to be taken in regard to the existing and possible socio-environmental problems?*

Topic five: *what kinds of environmental risks are there in implementing the construction of navigation complexes along the middle and lower reaches of Han River mainstream? Are there any opinions and suggestions to environmental management work in implementing the construction of the complexes?*

Topic six: *what kinds of economic and environmental benefits are there in constructing navigation complexes along the middle and lower reaches of Han River mainstream? What is the attitude towards constructing the complexes?*

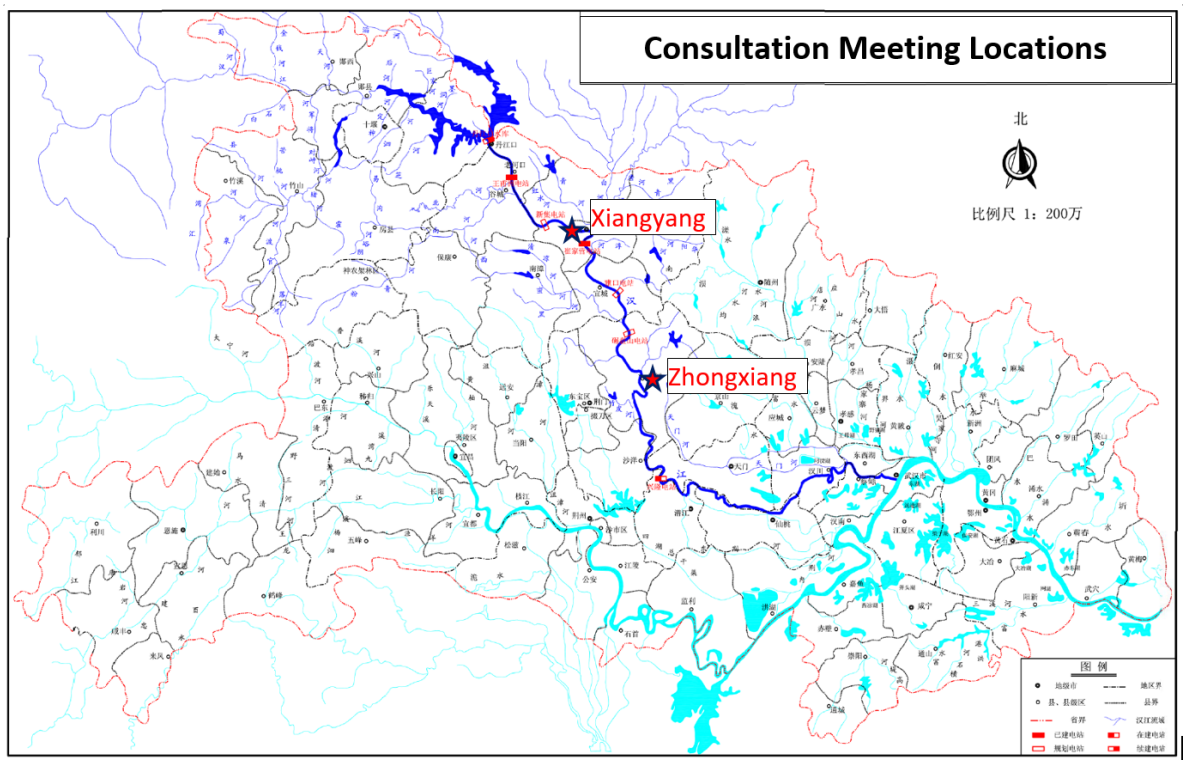


Figure 5-1 Locations of Public Consultation for CEA

Table 5-3 and -4 summrize key comments and feedback collected on the meetings.

Table 5-3 Opinions from Attendants of Xiangyang Public Consultation Meeting

Stakeholders	Attitude	Main opinions
Xiangyang Municipal CPPCC	Favor	Construction of navigation complexes along the middle and lower reaches of Han River is of great importance to socio-economic development in regions along the river. Construction of navigation complexes along Han River shall be actively supported. All sectors of society is urged to further enhance Han River ecological protection work, in particular given the potential adverse impact in terms of agriculture, forestry, fishery and land after the initial operation of south-to-north water diversion in 2015. The follow-up complex construction process also need to pay attention, in particular to changing trends of water quality and fishery.
Yicheng Municipal Environmental Protection Bureau	Favor	Environmental impact of constructing navigation complexes along the middle and lower reaches of Han River is extensive, including impact on ground water. It is suggested that navigation environmental protection work shall be strengthened such as pollution prevention and control of thousand-ton ship. Through transportation, tourism and pollution situations, adverse impact shall be accurately controlled and macro protection plan be proposed so as to better protect water quality. Han River Water Environment Protection Regulations released shall be consulted and executed.
Xiangyang Municipal Forestry Bureau	Favor	Minimum discharge of Danjiangkou is merely 384 m^3/s, adversely impacting ecological water use downstream, in particular wetland water uses on the two banks. Complex construction raises and stabilizes water level benefiting wetland development and protection and effectively promoting wetland landscape building and forestry production. However, mud flat inundation and reduced forest land resources need to be compensated through requisition-compensation balance. After reservoir formation, water bloom phenomenon occurs easily due to raised water level, reduced flow velocity and decreased water environment capacity, affecting biodiversity. It is suggested that impact on wetland biological resources shall be monitored on a long-term basis.
Xiangyang Municipal Development and Reform Commission	Favor	Water transport development is lagging behind in the middle and lower reaches of Han River failing Grade III waterway standards. After been included in the Twelfth Five Year Plan, Provincial Port and Waterway Administration has been actively promoting the construction of Yakou navigation complex. Generally it does more good than harm as it promotes local socio-economic development. however, after reservoir formation, purification capability will be reduced and its adverse impact need to be mitigated through adopting the following measures: 1. Build ecological protection coordination management system, coordinating relations between the upper and lower reaches, between various complexes and between different regions, for instance building reservoir conservation forest in the upper reach through unified implementation; 2. Improve Han River ecological compensation mechanism, implement sewage treatment and sewage interception treatment project; 3. Increase ecological protection investment by bringing in social capital on the basis on government investment, for instance in terms of domestic sewage treatment and domestic garbage treatment; 4. Build eco-environmental monitoring support system by science and technology; 5. Promote active public consultation of eco-environmental protection, for instance by strengthening publicity and organizing volunteering activities.
Xiangyang Municipal Bureau of Aquatic	Favor	Construction of navigation complexes along Han River has created a series of environmental problems, changed biodiversity, obviously reduced fish species and the number of major economic fish, as well as impacted spawning and breeding of fish with pelagic eggs including the

Stakeholders	Attitude	Main opinions
Products		four major Chinese carps. Rare fish such as *Anguilla japonica* and *Myxocyprinus asiaticus* are difficult to find. Adverse impact cannot be overlooked as fishermen' livelihood is affected by reduced number of fishery and aquatic products. It is suggested that compensation measures shall be taken to restore fish spawning ground and build artificial fingerling breeding ground. Fisherman compensation measures shall be carried out in accordance with *Fishery Law of the People's Republic of China.*
Xiangyang Municipal Culture Bureau	Favor	Currently, Yakou PIU and cultural relic departments has fully communicated and coordinated that a good working linkage relations has been established. Cultural relic exploration within the construction land requisition area has been completed and protection measures such as relic excavation will then be implemented as planned. Given that relevant departments are reporting the "Tea Road", which include Han River waterway, cultural relic exploration shall be further conducted during the process of project implementation, for instance wharf construction.
Xiangyang Water Resources Bureau and Xiangyang Waterway Administration	Favor	Reduced discharge from Danjiangkou has brought down water level in the middle and lower reaches of Han River, adversely affecting embankment projects and small-sized water resources facilities along the bank. Examples being water intake between Xiao River and Yicheng is difficult during dry flow season, clear water discharge downstream of the dam site and potential threat to reservoir bank stability by washing. Observation and monitoring shall be enhanced in order to further understand geographic conditions on either bank of Han River, so as to promptly adopt relevant treatment measures.
Xiangyang Municipal People's Congress	Favor	Long construction period of complex is beneficial to effective utilization of water resources, generally bringing more good than harm. Discharge downstream of Danjiangkou has been reduced. In terms of pollution drainage, by fully considering protection along Han River, a highly operable coordinated protection mechanism can be built, including promote waste water treatment of polluting enterprises and breeding farm ensuring up-to-standard release; strengthen management of catering, leisure and sand excavation by building scientific compensation mechanism; handle the relationship between development and protection, reduce industrial project, increase and green projects. Special attention need to be paid to protecting the upper reach for failure in the upper reach affects the lower reach.
Laohekou Municipal Environmental Protection Bureau	Favor	Build long-term monitoring mechanism, basin monitoring platform, tracking monitoring and release monitoring results.
Danjiangkou Municipal Environmental Protection Bureau	Favor	Construction of navigation complexes along Han River affects self-purification effect. Some suggestions on seasonal water bloom phenomenon and aquatic ecological protection: 1. Build an effective and coordinated management mechanism facilitating the implementation of relevant protection measures such as ecological regulation; 2. Strengthen breeding and releasing; 3. Formulate ecological compensation standards and actively carry out ecological compensation measures.
Villager representative	Favor	It is hoped that Yakou navigation complex will start construction as soon as possible, various resettlement compensation measures will be carried out and ecological agriculture will be actively developed. As regard to adverse impacts such as heavy sand wind in areas surrounding the construction area caused by construction, it is suggested that dust settling through watering surrounding areas during construction period can be strengthened so as to better protection surrounding environment.

Stakeholders	Attitude	Main opinions
Enterprise representative	Favor	Han River Group adheres to the concept of developing through environmental protection. Besides pursuing economic benefits, it also greatly increases investment in environmental protection by obeying ecological protection work arrangement of the entire basin, in areas such as joint ecological operation and water bloom prevention and control in the middle and lower reaches of Han River, earnestly carrying out corporate social responsibility.

Table 5-4 Opinions from Attendants of Zhongxiang Public Consultation Meeting

Stakeholders	Attitude	Main opinions
Zhongxiang Municipal People's Government	Favor	After the construction of navigation complexes along Han River, in particular after south-to-north water diversion, water bloom phenomenon happened within Zhongxiang area. Research on water bloom shall be strengthened so that reasonable and effective solution to water bloom problem can be identified. Reduced discharge from Danjiangkou has adversely affected irrigation and water intake facilities along the middle and lower reaches of Han River. Complex construction is beneficial to mitigating reduced water volume.
Zhongxiang Municipal Environmental Protection Bureau	Favor	Yakou project has already been approved by Environmental Protection Bureau. Environmental assessment of Nianpanshan project is in the process and will be approved by Environmental Protection Bureau prior construction. Therefore, it is suggested that environmental protection measures shall be implemented strictly according to environmental assessment and approval requirements during the process of project construction, so as to reduce adverse impact on surrounding environment. Functional departments shall strengthen monitoring and management so as to avoid pollution incident.
Zhongxiang Municipal Agriculture Bureau	Favor	Generally speaking, construction of navigation complexes along the middle and lower reaches of Han River has little impact on agriculture. Project construction shall be supported as it positively affects pumping irrigation. It is suggested that effective subsurface drainage measures shall be taken regarding arable land affected by ground water submersion in the reservoir area, so as to prevent soil gleying.
Zhongxiang Municipal Bureau of Aquatic Products	Favor	Construction of navigation complexes along the middle and lower reaches of Han River is beneficial to Zhongxiang as in Zhongxiang section is the national germplasm resources conservation zones of *Elopichthys bambusa*, *Ochetobibus elongatus* and *Luciobrama macrocephalus*. Massive annual investment of complex construction is tremendously helpful to breeding and releasing implementation and fish resources restoration. However, complex construction has also blocked spawning migratory passageway of the four major Chinese carps. Spawning conditions need to be restored by increasing discharge in flood spawning season and implementing joint ecological regulation.
Zhongxiang Municipal Administration of Culture, Sports, Press, Publication, Radio, Film and Television	Favor	In the process of constructing navigation complexes along Han River, cultural relic exploration and protection works shall be actively conducted.
Zhongxiang Municipal Forestry Bureau	Favor	In the process of constructing navigation complexes along the middle and lower reaches of Han River, some forestry resources will be inundated by reservoir, adversely affecting the protection of wild animals and plants, in particular wetland resources and migrant bird protection. Therefore, protection of wild animals and plants and wetland resources shall be

Stakeholders	Attitude	Main opinions
		strengthened.
Zhongxiang Municipal Land and Resources Bureau	Favor	Rising water level has inevitably caused inundation. Arable land in the reservoir area has carried out relevant planning following natural drainage and adopted requisition-compensation balance measures by compensating every basic farmland taken.
Zhongxiang Municipal Water Bureau	Favor	First, environmental problems already occurred need to be reported. After Xinglong water storage, during February and March, water bloom phenomenon happened downstream of Xinglong complex. Results of water quality monitoring of the same period reveal TN and TP exceeding standards and water environment capacity reduced. Second, rising ground water level has led to inundation of surrounding farmland and reduced crop yield, as well as failed tap water pumping in urban area during draught. Given the existing adverse impact, it is suggested that ecological compensation measures shall be actively formulated through research and then gradually implemented.
Zhongxiang Municipal Maritime Bureau	Favor	After constructing navigation complexes along Han River, clear water discharge may undercut riverway downstream and bank slope through washing. Observation shall be strengthened. To ensure navigation safety, navigation control center shall be built and Han River joint maritime scheduling be implemented. To protect water quality of Han River, it is suggested that navigation ship must be equipped with sewage treatment facilities and garbage collection device ensuring that garbage must be treated ashore when passing ship sluice.
Qianjiang Municipal People's Congress	Favor	Support construction of navigation and hydropower complexes along the middle and lower reaches of Han River and strengthen communication and coordination between various departments and different regions.
Qianjiang Municipal Environmental Protection Bureau	Favor	In regard to existing water bloom and ground water submersion problems, measures such as discharging ecological flow from various complexes and creating subsurface drainage channel need to be taken.
Villager representative	Favor	It is hoped that construction will start as soon as possible. It is suggested that Nianpanshan Command and Yakou Command shall formulate unified resettlement compensation regulations, in particular on defining arable land and flood land, so as to avoid socially destabilizing factors.

5.3.1 Information Disclosure

Since project preparation, project information/documents including resettlement plan and environmental impact assessment have been disclosed to the general public of the project affected area. Below shows internet disclosure.

Figure 5-2 CEA Report Disclosure on Internet

6 Formulation of Alternative Development Scenarios

Section 6 to 8 of this report follows the last stage, namely determining the environmental consequences of cumulative effects of the CEQ cumulative effects assessment process. This stage comprises of the following steps.

Step 8: Identify the important cause-and-effect relationships between human activities and resources, ecosystems, and human communities;
Step 9: Determine the magnitude and significance of cumulative effects;
Step 10: Modify or add alternatives to avoid, minimize, or mitigate significant cumulative effects;
Step 11: Monitor the cumulative effects of the selected alternative and adapt management;

Conducting CEA requires refinement of various assessment steps and elements, which is conducted in an iterative manner. This section builds on Section 3 which presents a preliminary description of reasonably foreseeable future actions (RFFAs) and cumulative effect issues. Given the uncertain nature of cumulative effects into the future, formulation of alternative development scenarios for assessment is needed. This section presents details of the RFFAs introduced in Section 3 of this report, based on which several alternative development scenarios are developed.

6.1 Past activities

1. Danjiangkou hydropower complex and South-to-north Water Diversion Project

As the largest hydropower project on Han River mainstream, Danjiangkou hydropower complex has been a major factor affecting ecological environment of the middle and lower reaches of Han River for decades. The initial works of Danjiangkou complex was started in September 1958 and completed in 1973, with a crest elevation of 162m, a normal water level of 157m (corresponding to reservoir capacity of 17.45 billion m3), a reservoir storage capacity of 9.8 billion m3, a reservoir area of 745km2, a backwater length of 177km in Han River and 80km in Dan River respectively, a total installed capacity of 900 thousand kW and an annual power generation capacity of 3.83 billion kW·h.

The South-to-North Water Diversion Project conveys water from Danjiangkou reservoir to north China via northern Tangbai River Plain and west border of North China Plain by means of gravity diversion, with an average annual diversion volume of 9.5 billion m3/year. The associated major activity included heightening the Danjiangkou dam that was completed in 2014. Subsequently increasing of the reservoir capacity and diversion works were put into operation at the end of 2014. Nonetheless, actual water diversion and reservoir storage have been significantly below the designed targets (20%-30% of the designed targets) during 2015-2016. Therefore the impacts of the South-to-North Water Diversion Project on the middle and lower Han River has been smaller than predicted.

2. Cascade development on the middle and lower Han River mainsteam

There are 6 dams planned below Danjiangkou dam. To number them along the length of the river, Stage 1 Danjiangkou, Stage 2 Wangfuzhou, Stage 4 Cuijiaying and Stage 7 Xinglong have been built. The remaing stages, namely Stage 3 Xinji, Stage 5 Yakou and Stage 6 Nianpanshan are at pre-construction stage. Completion of the 6 dams in coming 5

years is a highly probable scenario.

3. Jianghan Canal

The JiangHan Canal connects the Jing River section of Yangtze River to Han River at the downstram of Xinglong dam. The main channel has a total length of 67.23 km, a channel bottom width of 60 m, a designed water depth of 5.62~5.85 m, a design inner gradient of 1:2~1:3.5; a designed channel discharge of 350 m3/s and a maximum flow rate of 500 m3/s. The canal is a multi-purpose project. It is a controlled Grade III waterway with 1000t ship lock. It also replenishes waters from Yangtze River to Han River lower reach.

The project was completed and put into operation in September 2014. Through Jianghan Canal, it is estimated that annually 3.1 billion m3 of water is transferred from Yangtze River to Han River downstream section below Xinglong, which compensates the water volume and positively benefits the lower reach of Han River in terms of ecological environment, agricultural irrigation and navigation. The main channel of Jianghan Canal enters Han River below the Xinglong dam, the last complex constructed along Han River, causing no impact on hydrological regime in the Han River section above Xinglong dam.

4. Han River waterway improvement

Han River has undergone a series of waterway improvement projects since 1990, including the following

- waterway regulation project of Xiangfan to Hankou section started in 1990 and completed in 1996 with the focus of the 153 km waterway between Xiangfan to Huangzhuang section and three acute curves in Makou, Xinggou and Caidian. After regulation, river regime was under control with increased shoal water depth, waterway width and curvature radius, basically reaching Grade IV waterway standards.
- The waterway regulation project of the 117 km section from Danjiangkou to Xiangfan, implemented in July 2003, featured a Grade IV waterway, and its main structure was completed by the end of 2005.

5. Other activities

Historical records and field visits suggest that other activities occurring in-stream or in the vicinity of Han River have affected the Han River ecosystem over the years. Notably, in-stream sand mining and other water works. In recent years the government agency have taken actions to eliminate illegal sand mining, build survailance mechanism, which have contributed to the restoration of aquatic productivity and fishery resources.

In addition, as analyzed in the Affected Enviroment section, overfishing and water pollution were key sources of impacts that have seriously affected the fishery resources in the Han River.

On positive side, in the past dacede or so, actions have been taken to address water pollution and fishery resources declining such as the implementation of strengthened river water quality standard and zoning requirements, Han River basin water pollution control regulation, basin-wide domestic and industrial wastewater treatment facilities, and strengthened general fishery administration, establishement of wetland parks. The impacts of such actions are difficult to quantify but the benefits are recognized.

6.2 Present Activities and Reasonably Foreseeable Future Actions

In CEA studies, present activities refer to ongoing activities and those actions that are

planned or very likely to happen in near future. Therefore, there is no distinctive difference between present activities and RFFAs.

1. South-to-North Water Diversion Project

As discussed earlier, the designed diversion capacity of the project is 9.5 billion m3/year. Actual water diversion and reservoir storage have been significantly below the designed targets (20%-30% of the designed targets) during 2015-2016. Therefore the impacts of the South-to-North Water Diversion Project on the middle and lower Han River has been smaller than predicted, and the significance of future effects is less definite based on a literature review of the anticipated water demand in Hebei and Henan Provinces (two major receptors of the diverted water in northern China) and policy and insitutional complexities. Notwithstanding the uncertainties, meeting the designed diversion capacity should be considered as part of a ‘maximum development scenario’.

2. Complete the 3 remaining stages of Han River mainstem cascade development in coming 3-5 years.

There are 6 dams planned below Danjiangkou dam. To number them along the length of the river, Stage 1 Danjiangkou, Stage 2 Wangfuzhou, Stage 4 Cuijiaying and Stage 7 Xinglong have been built. The remaing stages, namely Stage 3 Xinji, Stage 5 Yakou and Stage 6 Nianpanshan are at pre-construction stage. Completion of the 6 dams in coming 5 years is a highly probable scenario.

Navigation and hydropower complexes constructed along the middle and lower reaches of Han River have a total reservoir capacity of 315.04 m3, a guaranteed output of 337.4 MW, a total installed capacity of 1542 MW and an annual power generation capacity of 61.32×108 kW • h. All complexes are daily storage reservoirs with almost no regulation capability and are of excellent power generation and navigation effectiveness without spatially and temporally changing runoff distribution of Han River mainstream, which is particularly important to regional economic development in the middle and lower reaches of Han River.

Planned navigation and hydropower complexes along middle and lower reaches of Han River, with the exception of Danjiangkou hydropower complex being power station at dam toe, are all low-head run-of-river type, featuring relatively low normal storage water level, as they only blocks water in low flow season. In flood season, natural flood flowing conditions of river channels are maintained as much as possible because the reservoirs almost have no flood regulation capability. Therefore, these complexes at downstream of Danjiangkou affect hydrological regime mainly in terms of water level rise and flow rate reduction, which is to a certain extent compensatory to water level reduction in the middle reach of Han River resulting from implementation of south-to-north water diversion. Decrease of discharge and water level in the lower reach of Han River caused by south-to-north water diversion is mainly compensated by Yangtze-Han Water Diversion. Reservoirs constructed at downstream of Danjiangkou are all mixed-type reservoirs causing stratification phenomenon, therefore power station construction has little impact on the distribution of water temperature variations. As the first power station on the middle and lower reach and the only power station with overyear storage capability, Danjiangkou hydropower complex will lead the way in terms of diversion and storage, bring benefits to power stations downstream in power generation and flood prevention, thus fully play its leading role as a flagship power station. Construction of other low-dam runoff power

stations in the middle and lower reaches may reduce inundated area around the middle and lower reaches of Han River mainstream and lessen impact on resettlement and terrestrial ecology.

Previous analysis has explained that Wangfuzhou, Cuijiaying and Xinglong complexes have affected the aquatic and riparian ecology in the middle and lower Han River to a certain extent. Impacts resulting from the development of remainng Xinji, Yakou and Nianpanshan stages is one of the study golas of this CEA study.

3. Han River embankment reinforcement

Han River embankment reinforcement project is located in the transitional zone of Jianghan Plain, partially of which are low elevation area. In the project area, 1.121 million Mu arable land and 2.434 million people are protected by existing embankments on both banks. The embankment reinforcement project will include Laohekou urban embankment, Hongshanzui embankment, Taipingdian embankment, Xiangyang urban left embankment, and Yicheng Hedong embankment on the left bank, as well as Xiangyang urban right embankment, Oumiao embankment, Gucheng Wangmatao embankment and Yicheng urban embankment on the right bank, covering a total length of 142.747km.

The Han River embankment reinforcement project of Hubei province is a fairly important flood prevention and control project. Implementation of the project is essential to prevent flood and protect life and property in Han River basin and local areas, preserve normal production and living, protect eco-environment and promote sustained socio-economic development in the region. Implementation of the project will not cause major changes in terms of hydrological regime and will have only limited impact on river habitat and ecology. Relevant ecological restoration and compensation measures can be carried out through intensifying environmental management work during construction period so as to effectively reduce and mitigate adverse impacts on the environment.

4. Other activities into the future

- Socio-economic development planning

After long-term arrangement and development, economic and social development in Han River basin had gradually formed its own features: resources development and utilization is taking shape as basin enjoys abundant resources; agriculture boasts high industrialization level as it is one of the main agricultural zones of Hubei province; the industrial development is of significance in Hubei province; urbanization is speeding up with dynamic county-level and regional economic vitality; living standards of urban and rural residents are substantially improved with rapid development in social and public causes.

As for economic development trends of Han River basin within Hubei province from 2005 to 2020, the primary industry is to greatly promote ecologic agriculture and feature agriculture, continue to adjust planting structure and improve product quality. The proportion of industrial added value against regional total output has decreased and is estimated to be below 10% by 2020. Secondary industry accelerates development of high and new technological sectors while maintaining development of advantageous sectors such as automobile, metallurgy, chemical engineering and building materials. Tertiary industry is expected to see substantial development and the sectors such as transportation, telecommunication, education, tourism and financial service will enjoy the fastest development as their development potentials become increasingly potent, forming intensive belts of tertiary industry in Wuhan, Xiangfan, Shiyan, Qianjiang, Xiantao and Tianmen.

Proportion of tertiary industry against regional total output is catching up with that of the secondary industry and may even surpass that of the secondary industry. Navigation development planning is related to whether the main development objectives of the entire basin can be achieved, involving resources utilization, and it need to meet both the anticipated and obligatory indicators.

- Ecological environmental protection planning

Hubei province and Shaanxi province have both formulated ecological function zoning and ecological environmental planning according to ecological protection requirements, defined important ecosystem service areas, proposed major ecologically sensitive functional zone and important ecological service zone according to the sensitivity to ecological environment as well as type and significance of ecosystem service functions, analyzed common problems concerning functional zones and explored solutions to ecological environmental protection and management.

As the water source of south-to-north water diversion middle route project, upstream basin of Han River is of particularly significant strategic position in national ecological environmental protection and the areas involved in the planned waterway construction have formulated South-to-north Water Diversion Project Ecological Environmental Protection Planning, Hubei Province Danjiangkou Reservoir Area and Upstream Area Water Pollution Prevention and Treatment and Soil Conservation Planning, Hubei Province Middle and Lower Reaches of Han River Basin Water Pollution Prevention and Treatment Planning, and West Hubei Ecological and Cultural Tourism Circle Ecological Feature Planning.

Planning includes intensifying ecological protection, giving priority to constructing key ecological functional zones, controlling pollutant discharge, stepping up basin water pollution prevention and treatment, intensifying monitoring on resources development activities, stepping up prevention and treatment of water, air, urban noise pollution and disposal and comprehensive utilization of solid waste and hazardous waste, improving the level of environmental monitoring, building emergency response system for emergent environmental incidents and implementing total quantity control of pollutant discharge.

A new Hubei Han River Middle and Lower Reaches Basin Water Pollutants Comprehensive Discharge Standards was being formulated in 2016 by the provincial government during development of this CEA.

6.3 Formulation of Development Scenarios

The most likely condition of cascade development is that the the planned 7 dams/reservoirs on the mid-low reaches of Han River will be put into operation around 2020, namely the remaining three complexes Xinji, Yakou and Ninapanshan will be built around 2020. However, throughout the planning horizon it is highly certain in terms of other activities. For example, since the South-to-North Water Diversion Project was put into operation in Dec 2014, annual transfer volume was 20% of the planned objective, hence much less impacts on the hydraulic regime of middle and lower Han River.

To address the inherent difficulties associated with predicting the high uncertain future, several scenarios were postulated, which considers status quo of water diversion of the South-to-North Water Diversion; fully realized water diversion objective of the South-to-North Water Diversion, cascade development alternatives, as presented in Table.

Table 6-1 Formualtion of Development Scenarios

Scenario setting	Scenarios	Scenario description
Status Quo Scenario	• South-to-north water diversion baseline transfer volume remains unchanged; • Wangfuzhou, Cuijiaying and Xinglong operate normally after completion	• After the operation of South-to-north water diversion project in December 2014, actual annual transfer volume is around 2 billion m3 and was only 20% of the designed transfer volume • Wangfuzhou, Cuijiaying and Xinglong complexes already completed and operate normally
Medium Development Scenario	• South-to-north water diversion transfer volume reaching designed objective; • Wangfuzhou, Cuijiaying and Xinglong operate normally after completion	• Differs from baseline scenario only in terms of south-to-north water diversion phase-I project reaching designed scale of 9.5 billion m3
High Development Scenario	• South-to-north water diversion transfer volume reaching designed objective; • Wangfuzhou, Cuijiaying and Xinglong operate normally after completion • Xinji,Yakou and Nianpanshan all completed	• Relevant development planning all implemented and south-to-north water diversion phase-I project reaching designed scale of 9.5 billion m3 • Complexes along the middle and lower reaches of Han River all completed

According to analysis of activities described above, main activities causing adverse impact on water environment and ecological environment in the middle and lower reaches of Han River are South-to-North Water Diversion Project as well as the construction and operation of navigation and hydropower complexes along the middle and lower reaches of Han River mainstem.

According to the progress of implementing South-to-North Water Diversion and the construction of hydropower and navigation complexes along the middle and lower reaches of Han River, Danjiangkou dam heightening and the South-to-North Water Diversion project were completed and started operation in the end of 2014; Wangfuzhou, Cuijiaying and Xinglong complexes were completed and started operation in 2000, 2010 and 2015 respectively. It is predicted that by 2020 all planned complexes will be completed.

7 Cumulative Effects Assessment

7.1 Overview

Based on the development of scenarios discussed in the prior section, this section is devoted to further analysis of cumulative effects. At this stage of preliminary cumulative effects assessment, the analysis focuses on VECs of high priority: flow regime, water quality, fish and riparian areas.

Given the fundamental functions, hydrological regimes were given particular attention in carrying out the CEA study. This section discusses the cumulative effects of the three scenarios on hydrological regimes, followed by discussions on water quality, fish and riparian areas.

7.2 Cumulative Effects on Hydrological Regimes

Hydrological regimes refer to temporal and spatial variations of flow rate, river depth and width, flow patterns, and sediment transportation induced by flow regimes. Hydrological regimes of mid-low reaches of Han River are affected not only by the releases of dams and inflows from tributaries, but also localized conditions. Hydrological regimes are fundamental to the valued environmental components (VECs). For instance, minimum water releases from upstream dams are mandated for each dam along the mid-low reaches of Han River in order to meet ecological, navigation and water supply demands downstream. Another example is that fish species with floating eggs require certain level of flow velocity and floating distance in order to complete its breeding lifecycle. Localized flow patterns are also closely related to to riparian ecological conditions.

7.2.1 Impacts on flow rate

Impacts on the flow rate is assessed based on data collected from hydrological measurement stations in the middle and lower reaches of Han River. Figure X shows the 5 major hydrological measurement stations, namely

- Huangjiagang Station: downstream of Danjiangkou complex;
- Xiangyang Station: upstream of Cuijiaying complex and Tangbai River. The Tangbai River is a major tributary of Han River in its middle reach;
- Huangzhuang Station and Shayang Station: downstream of proposed Lianpanshan complex and upstream of Xinglong complex;
- Xiantao Station: located in the lower reach of Han River; downstream of Xinglong complex and Jianghan Canal.

Figure 7-1 Location of Hydrologic Measuring Station in Middle and Lower Han River

1) Status quo scenario

According to analysis of 15 years' flow rate data (2001- 2015) measured at the five hydrological stations, there were no considerable changes in terms of annual and interannual variation before and after the 3 complexes (Wangfuzhou, Cuijiaying and Xinglong) that were put into operation during the period. Likewise, the trends of annual and interannual average variations were basically the same during the same seasons, indicating little impact on mainstream discharge due to the operation of the three complexes. In 2015, affected by the initial operation of South-to-North Water Diversion, flow rate during different water seasons of the abovementioned five hydrological stations decreased by 27.3-77.4 m3/s, a 3.32-9.85% decrease rate, compared with the average value from 2001 to 2014.

In recent years, minimum daily releases from Danjiangkou and Wangfuzhou complexes have exceeded 300 m3/s, and minimum daily discharges of Cuijiaying complex has exceeded 500 m3/s. Based on Tenant method, minimum daily releases from Danjiangkou, Wangfuzhou and Cuijiaying should exceed 20% of their annual average runoff volume, hence under the status quo scenario, the water volume still satisfies what is needed to ensure stable aquatic ecosystems and normal navigation.

2) Middle development scenario

Compared to status quo scenario, the middle scenario considers that the South-to-North Diversion Project will fully meet its planned objective, the existing complexes will remain operational, and the three proposed complexes, Xinji, Yakou and Nianpanshan will not be built.

Under this scenario, the South-to-North Water Diversion will reach the designed scale of 9.5 billion m3/year, releases from Danjiangkou reservoir will be further reduced as

annual average flow decreases by 96.8-273.8 m3/s, a 5.90-18.91% decrease. Huangjiagang cross-section will have the largest decrease margin, followed by Xiangyang and then Xiantao cross-section. River segment downstream of Shayang cross-section will have less flow reduction due to the water compsentation contributed by Jianghan Canal. Generally, the flow reduction over the length of middle and low Han River is cumulatively decreasing.

Regulation and storage capability of Danjiangkou reservoir has been improved since Danjiangkou dam heightened in 2010 . Releases from Danjiangkou reservoir adheres to compensatory release principle, which favors river regime situations in dry years and the flow rate increases substantially in terms of dry-flow guarantee rate at each cross-sections over the length of downstream Han River. Since the South-to-Noth Diversion project put into operation, the duration of mainstream dry-flow has increased and normal flow decreased, the flow of the Han River mainstream tends to be homogenized.

3) High development scenario

This development scenario adds the full development of Xinji, Yakou and Nianpanshan hydro-navigation complexes to the medium development scenario. Compared to the medium development scenario, there will be little change to the flow rate at the Huangjiagang cross-section, while there will be marginal decrease at the remaining downstream cross-sections. It should be noted that all the dams/reservoirs downstream of Danjiangkou are of run-off type that has only daily regulation capacity, that is to say, they can hardly affect the monthly or yearly flow rates. These dams won't change flow allocation at the dam sites.

According to government regulations on the operation of cascade reservoirs along the middle and lower Han River, minimum water releases are mandated for each dam. Specifically, the minimum water releases requirements are the following

- Danjiang dam/reservoir: 450 m3/s;
- Wangfuzhou dam/reservoir: 200 m3/s;
- Xinji dam/reservoir: 300 m3/s;
- Cuijiaying: 470 m3/s;
- Yakou: 450 m3/s;
- Nipanshan: 450 m3/s;
- Xinglong: 490 m3/s.

The requirement of minimum water releases are set in order to meet the ecological flow, navigation and water supply needs of the middle and low reaches of Han River.

7.2.2 Impacts on River Width and Depth

1) Status quo scenario

Annual average river width of main control cross sections along the middle and lower reaches of Han River reaches maximum at Huangjiagang section, decreases gradually to Xiangyang section, increases gradually in Xiangyang-Shayang section, and then continues to narrow down till reaching minimum at Xiantao section. Annual average water surface width varies between 329.2～555.7 m. Annual average water depth of main control cross sections along the middle and lower reaches of Han River increases gradually from Huangjiagang to Xiangyang, decreases gradually from Xiangyang to Huangzhuang, and then increases again from Huangzhuang to Shayang till reaching maximum at Xiantao section. Annual average water depth varies between 2.15～5.07 m.

Construction of cascading dams along the middle and lower reaches of Han River mainstream will previously uninterrupted natural river channel to connected navigable river channel segement and pools. Water depth and surface width of Wangfuzhou reservoir is 6.14 and 4.54 times that of the natural circumstances; water depth and water surface width of Cuijiaying reservoir is 6.12 and 3.5 times that of the natural circumstances.

In 2015, affected by the initial operation of South-to-North Water Diversion project and the built Xinglong complex, water surface width at various main control cross sections along the middle and lower reaches of Han River all slightly decreased with the exception of increase in Shayang river section mainly due to the Xinglong complex raises water level of the river section.

2) Medium development scenario

Under this scenario, the variation trend of annual average water surface width at main control cross sections along the middle and lower reaches of Han River remains unchanged. It reaches maximum at Huangjiagang section, decreases gradually in Xiangyang section, then increases from Xiangyang to Shayang, and narrows down till reaching maximum at Xiantao section.

Water surface width of various main control cross sections along the middle and lower reaches of Han River all further decreased, with the exception of Shayang section. Compared with the status quo scenario, annual average water surface width has decreased by 5.6-77.4m, a decrease rate of 1.65-11.90%. Water depth of various river sections follows the same variation trends. Water surface width, all decreases, with the exception of water depth in Shayang river section as it is controlled by Xinglong complex.

3) High development scenario

The implementation of all planned complexes has little impact on main control cross sections in terms of water surface width and water depth. However, the construction of Xinji, Yakou and Nianpanshan complexes raises water levels in respective reservoir areas, leading consequently to increased water surface width and water depth. In conclusion, water surface width and water depth of various control cross sections vary mainly under the influence of South-to-North Water Diversion and receive little impact from construction of the complexes. However, water depth and water surface width of various reservoir areas are greatly affected by the formation of reservoir area. 7.2.3 Impacts on flow velocity

1) Status quo scenario

After the completion and operation of hydropower and navigation complexes along the middle and lower reaches of Han River, formation of reservoirs will lead to reduced flow velocity. Flow velocity of Wangfuzhou reservoir area is merely 0.04 times that of natural flow velocity, flow velocity of Cuijiaying reservoir merely 0.05 times and flow velocity of Cuijiaying reservoir merely 0.04 times. In 2015, affected by the initial operation of South-to-North Water Diversion project and the operation Xinglong complex, annual average flow velocity of main control cross sections along the middle and lower reaches of Han River mainstream slightly decreased.

2) Medium development scenario

Under the medium scenario, annual average flow velocity of main control cross sections along the middle and lower reaches of Han River will further decrease by around 0.02-0.37 m/s. Shayang section will have the biggest decrease margin followed by Xiangyang section and then Xiantao section. Flow velocity reduction in the river sections

upstream of Xinglong (Huangjiagang, Xiangyang, Huangzhuang and Shayang) is mainly influenced by water level and discharge variations. In the river section downstream of Xinglong (Xiantao section), flow velocity reduction is less as it is affected both by inflow from upstream and backwater of Yangtze River.

3) High development scenario

After the completion and operation of hydropower and navigation complexes, annual average flow velocity of main control cross sections along the middle and lower reaches of Han River will exhibit a decreasing trend. However, compared with the interim scenario, decreasing margin is smaller. Control cross sections in Huangjiagang and Xiantao will have no flow velocity variations as they are relatively far away from the complexes. Given that flow velocity in reservoir areas is greatly affected by the formation of reservoir area, after the formation of Xinji, Yakou and Nianpanshan reservoirs, the average flow velocity at dam site were 0.09, 0.13 and 0.08 times that prior to reservoir construction.

7.2.4 Impact on water level variation

1) Status quo scenario

Wangfuzhou, Cuijiaying and Xinglong reservoirs are all daily storage reservoirs with almost no storage regulating capacity. Therefore, after those reservioirs became operational, water level variations are in line with inflow variations from upstream. In 2015, affected by the initial operation South-to-Noth Diversion project, with the exception of Shayang section water level of which is raised due to the influence of the construction of Xinglong complex project, annual average water level of all other river sections decreased, with the biggest decrease being around 0.12m, generally descending slowly from upstream to downstream.

2) Medium development scenario

Under the medium scenario, affected by the decreased water releases from Danjiangkou, annual average water level in the middle and lower reaches of Han River mainstream will, with the exception of Shayang section, decrease further in Huangzhuang and Huangjiagang by 0.39 m and 0.23 m respectively. Generally over the length of the river the descending extent gets smaller gradually.

3) High development scenario

Compared with the middle development scenario, water levels of Huangjiagang station, Xiangyang station and Shayang station will remain unchanged while water levels of Huangzhuang station and Xiantao station will decrease. This is mainly because the cascade development results in water intake conditions at some river segment. Increased water intaking in return causes the water level to decrease slightly.

7.2.5 Impact on sedimentation

1) Status quo scenario

Since the operation of Danjiangkou reservoir in 1974, water flow and sediment transport conditions of river sections downstream of Danjiangkou reservoir have undergone certain changes. After regulated by Danjiangkou reservoir, by comparing the runoff at dam site and natural runoff, it is found that runoff volume has increased by 31.3% in the low flow season of December to February and has decreased by 33.4% in the flood season from May to October, and annual runoff volume decreased by 28.8%. Meanwhile, due to the blocking effect of the dam and reduced total runoff volume, sediment outflow from the

reservoir has substantially decreased. Annual sediment discharge measured at Huangjiagang station has been reduced from 92.45 million t/a (1956-1967) to 0.11 million t/a (1991-2012), only accounting for 0.119% of that prior to reservoir construction.

In 2015, affected by the initial operation of South-to-Noth Diversion project, inflowing water volume and sediment of the middle and lower reaches of Han River was further changed, and the accretion and erosion of river channel in the middle and lower reaches of Han River changes. The project has led to reduced water releases to the downstream middle and lower reaches of Han River. Sediment deposit has also been reduced in Wangfuzhou and Cuijiaying reservoir areas due to clear water discharge and flushing. A more even distribution of water and sediment across the year is seen. Analysis of river channel sedimentation and erosion in the middle and lower reaches of Han River is summarized as follows:

- From immediate downstream of Danjiangkou to the tail of the backwater of Xinglong dam/reservoir: The river flow variation has been accelerated in the river segment. Operation of the Diversion project takes away the water of normal flow mainly, meaning more rapid decrease from peak flow to dry flow, which comprisess the flushing function of the normal flow and slow down erosion-sedimentation balance and navigation channel stabilization.
- Sedimentation in the Xinglong reservoir: The Xinglong dam forms a 53.33 km2 reservoir with widened river surface and much reduced flow velocity which leads to certain degree of sediment deposit in the reservoir area of Xinglong. As the operation time of Xinglong complex increases, reservoir sediment will reach a balanced state.
- From immediate downstream of Xinglong dam to river estuary: The Jianghan Canal joins the Han River about 1 km downstream of Xinglong dam. It transfers water from Yangtze River to Han River and helps increase the overyear guarantee rate of normal flow at Xiantao station cross-section substantially. Thus the sediment deposit in the river section from downstream of Xinglong dam to estuary has been improved, yet it has not been restored to the previous level before the Water Diversion project was operational.

2) Medium development scenario

Under the medium development scenario, affected by further decrease of total releases from Danjiangkou reservoir, annual sediment discharge further decreases during most periods, in particular in flood season, with the exception of few dry flow months.

Riverbed in the middle and lower reaches of Han River will experience changes in terms of sedimentation and erosion. While there are both sedimentation and erosion, erosion prevails. Sedimentation and erosion changes are smaller in the river section between the dam site of Danjiangkou reservoir and Xiangfan for its riverbed is coarsened and with good erosion resistance, due to long-term erosion after the operation of Danjiangkou reservoir in 1974. Erosion in the river section between Huangzhuang and Xiantao is relatively large. Erosion intensity gradually weakens in riverbed downstream of Xiantao. Assuming that average river width of Danjiangkou dam-Xiangfan section, Xiangfan-Huangzhuang section, Huangzhuang-Xiantao section and Xiantao-estuary section are 1000m, 800m, 500m and 300m respectively, it is calculated that in the normal flow year of 2020, erosion depth of the abovementioned river sections are 0.017, 0.103, 0.26 and 0.103 m respectively.

It shall be pointed out that riverbed in the section between Huangzhuang and Xiantao has relatively large erosion and some shoal, island and fiver flats of the river section will undergo corresponding adjustments and changes due to riverbed erosion. River regime change within reservoir area of Xinglong hydropower complex is relatively small. Curving river channels such as Changtuoyuan, Sigang, Zekou and Zhanggang downstream of Xinglong may undergo partial adjustment of mainstream scouring point due to swayed mainstream line caused by riverbed erosion. River section with relatively poor bank control may occur severe erosion of river bank or flats.

3) High development scenario

The completion of all planned complexes below Danjiangkou will form corresponding reservoirs along the middle and lower Han River, causing further reduction sediments concentration in the lower reach and river mouth. Sediment brought by inflow from upstream will to a certain extent form deposit within those reservoirs as flow velocity reduces.

Water and sediment inflow to Xinji reservoir is unevenly distributed within the year, with sediment inflow concentrated in flood season. Between June and September, it receives 91.7% of its annual sediment inflows and 63.6% of its annual water inflows. Compared with sediment distribution, water distribution is more uneven. Affected by Danjiangkou, annual average sediment discharge of Xinji dam site is only 4.3% of that prior to reservoir construction because sediment inflows from upstream of Danjiangkou basically remain in Danjiangkou reservoir. In addition, large quantity of sediment is blocked by reservoir, for instance Wangfuzhou reservoir, constructed on the Han River mainstream between Danjiangkou and Xinji, as well as Nan River reservoir constructed on tributary Nan River. Sediment deposit is not obvious after Xinji reservoir construction because Xinji reservoir receives relatively small sediment inflows and it is affected by south-to-north water diversion in terms of water and sediment conditions.

Operation of Danjiangkou, Wangfuzhou and Cuijiaying reservoirs in the upstream of Yakou navigation complex have to a certain extent reduced sediment inflows to downstream river section. After the completion and water storage of Yakou navigation complex, water level of the reservoir area will be raised, water surface gradient narrowed, flow velocity reduced and a certain amount of sediment deposit formed within the reservoir area. Calculation results of reservoir areas with different sedimentation life reveal that after 20 years of reservoir operation, suspended load of sediment deposit will be 24.93 million m3; after 80 to 100 years of reservoir operation, suspended load desilting rates will be 86.56% to 88.28% respectively since sediment deposit will basically reach a balance state.

Recorded maximum annual sediment discharge at Nianpanshan was 263 million t (year 1964, prior to the operation of Danjiangkou reservoir) and minimum annual sediment discharge was 0.712 million t (year 1999). The maximum discharge being as much as 369 times that of the minimum. According to sediment delivery ratio after 50 years of reservoir operation, sediment delivery ratio has been generally and continuously increasing, as the annual average sediment delivery ratio of the first ten years was 66.2% and the annual average sediment delivery ratio from year 41 to 50 was 69.1%, and has increased along with the increase of operation time. Reservoir sediment deposit has gradually become more balanced.

7.2.6 Summary

Under the status quo scenario, comparing with situation prior to 2014 when the South-to-Noth Deiversion project was operation, affected by the initial operation of the Diversion project as well as the operation of Xinglong complex, with the exception of rising in Shayang section (located in Xinglong reservoir area), water surface width and water depth in all other river sections all decreased by a very small margin, indicating little impact of constructing the complexes along Han River on flow velocity and water level. There are fewer sediments arriving to the reservoir areas of Wangfuzhou, Cuijiaying and Xinglong complexes. Sediment deposit phenomenon weakens in the river section from downstream of Xinglong dam to river mouth due to water supplemented by Jianghan Canal.

Under the medium development scenario, discharge in the middle and lower reaches of Han River mainstream is mainly controlled by realeases from the Danjiangkou reservoir. Annual average discharge, flow velocity and water level of main control cross sections (excluding Shayang river section of Xinglong reservoir area) along the middle and lower reaches of Han River further decrease. This scenario further changes hydrological and sedimentation conditions in the middle and lower reaches of Han River including further deceased sediment discharge, more balanced water and sediment distribution within the year and dynamic sedimentation and erosion changes in river channels.

Under the high development scenario, after completion of all planned complexes, the middle and lower reaches of Han River will form a cascade of seven navigation and hydropower complexes along the river, including Danjiangkou, Wangfuzhou, Xinji, Cuijiaying, Yakou, Nianpanshan and Xinglong. Considering the influence of South-to-North Water Diversion, impact on hydrological regime is mainly shown in the changes and variations of water form, water level, flow velocity and discharge, generally with a slow descending from upstream to downstream as mainstream discharge becomes homogenized (dry flow discharge increases and normal discharge decreases over time). Given that all reservoirs of complexes along the middle and lower reaches of Han River receive relatively small sediment inflows and considering the impact of South-to-North Water Diversion on flow and sediment, sediment deposit is not obvious after forming various reservoirs. The reservoir deposition increases and will be more balanced with the increase of reservoir operation time.

In conclusion, after the implementation of South-to-North Water Diversion project, discharge further reduces. According to the latest Danjiangkou reservoir operation and scheduling requirements, after reaching the designed annual transfer volume of 9.5 billion m3, Danjiangkou reservoir still needs to maintain a minimum discharge of 450 m3/s in order to meet the ecological, navigation, domestic and production demands in the middle and lower reaches of Han River. The completion of hydropower and navigation complexes from Danjiangkou to Xinglong section and the formation of reservoirs will result in certain compensatory effect in the aspects of ecology, navigation and water supply after the implementation of South-to-North Water Diversion. These complexes are all runoff-type with daily regulation capacity, without causing substantial impact on water discharge or water temperature. Their main impact on hydrological regime of Han River is the obviously reduced flow velocity and increased water depth with respective reservoir. In addition, decreased sediment volume discharged from Danjiangkou and the construction of various reservoirs will lead to dynamic impact on sedimentation-erosion balance of Han River. Changes of hydrological regime and sedimentation-erosion balance of river channel will impact aquatic ecology, riparian ecology and water quality.

Variation of hydrological regime is an important factor causing changes in water environment and aquatic ecology. According to analysis results of cumulative impact on hydrological regime as stated above, it is believed that hydrological regime variation brought out by the high development scenario is the most significant. Therefore, further cumulative impact analysis on VECs will place emphaisis on the impacts under the high development scenario.

7.3 Cumulative Effects on Water Quality

This subsection describes cumulative effects on water environment that consists of water environment carrying capacity, key parameters of water quality and water temperature.

7.3.1 Carrying capacity analysis

Carrying capacity in the ecological context is defined as the threshold of stress below which populations and ecosystem fuctions can be sustained. When cumulative effects exceed the carrying capacity of a resource, ecosystem, and human community, the concequences are significant. Often, in the case of water quality related programs, statutory limites (or standards) are regulatory threshholds of the carrying capacity of water in the region of interest.

According to results of relevant studies on the carrying capacity analysis of water environmental in the middle and lower Han River:

- Under the status quo scenario, in the middle and lower reaches of Han River, water environment carrying capacity of COD is 488002 t/a, water environment carrying capacity of ammonia-nitrogen is 33220 t/a and water environment carrying capacity of TP is 1006 t/a;
- under the medium development scenario, in the middle and lower reaches of Han River, water environment carrying capacity of COD is 327194 t/a, water environment carrying capacity of ammonia-nitrogen is 22729 t/a and water environment carrying capacity of TP is 669 t/a;
- under the high development scenario, in the middle and lower reaches of Han River, water environment carrying capacity of ammonia-nitrogen is 18168 t/a ， water environment carrying capacity of COD is 257614 t/a and water environment carrying capacity of TP is 531 t/a.

It can be noted from the numbers that under the status quo scenario, spatial and temporal distribution of water environment capacity changes due to reduced discharge from Danjiangkou reservoir. Under the medium development scenario, in the middle and lower reaches of Han River mainstream, loss of COD water environment carrying capacity is 160808 t/a；loss of ammonia nitrogen water environment carrying capacity is 10472 t/a and loss of TP water environment carrying capacity is 337 t/a; under the high development scenario, in the middle and lower reaches of Han River mainstream, loss of COD water environment carrying capacity is 64218 t/a, loss of ammonia-nitrogen water environment carrying capacity is 4561 t/a and loss of TP water environment carrying capacity is 132 t/a.

From the analysis above, it is learned that loss of water environment carrying capacity in the middle and lower reaches of Han River is mainly caused by reduced discharge resulting from the implementation of South-to-North Water Diversion Project. Other factors such as reduced flow velocity resulting from constructing navigation complexes

along Han River further reduce the self-purifying capability of water, leading to further decrease of water environment carrying capacity, which shows pronounced cumulative effects. Loss of water environment carrying capacity in the middle and lower reaches of Han River is largely concentrated in the river section from downstream of Danjiangkou dam to Gaoshibei, whereas the river section downstream of Gaoshibei has little environment carrying capacity loss thanks to the Jianghan Canal which brings water from the Yantze River to Han River, resulting much less loss of carrying capacity downstream of Xinglong complex.

7.3.2 Impact on key paramters of water quality

7.3.2.1 Impact on COD, NH3-N and TP

Numerous studies have been conducted on the water quality of the middle and lower Han River. This subsection summarizes findings and results of these pertinent studies, primarily the Assessment and Countermeasure Study on the Impacts of South-to-North Diversion Middle Route Project on the Water Environment of Middle and Lower Han River. The study takes into account the completion of all cascade development and full operation of the South-to-North Diversion Project.

Water quality monitoring at regular monitoring cross-sections in the middle and lower reaches of Han River reveals that organic pollutants are the dominant pollutant. Therefore, water quality indicators in this study include permanganate index (CODMn), ammonia nitrogen (NH3-N) and total phosphorus (TP).

Prediction adopts one-dimensional water quality model, one-dimensional Saint-Venant equation for sideway influx and one-dimensional convection diffusion equation for point and non-point pollution inflow to simulate hydrodynamic features and water quality variations of the river channel. Based on actual monitoring data in the initial periods from various hydrological stations and water level stations, as well as water quality monitoring data from water quality cross sections, initial discharge Q, water level Z and water quality indicator are determined as initial calculating conditions by means of interpolation on cross sections in mainstream and tributaries. Boundary conditions include boundary discharge Q of mainstream in the upper reach, water level Z in the lower reach, water quality indicator, mainstream reservoir operation rules, and mainstream sluice station operation rules of Han River. The study divides the 652 km river section into 157 cross sections and determines time step being 0.25 hour. Analysis of the mathematical modeling results is as follows:

(1) Under status quo scenario, in Baijiawan-Longwangmiao river section, COD_{Mn} concentration is 1.77-2.59 mg/L, with all monitoring cross sections meeting Class II standards of Surface Water Environment Quality Standards (GB3838-2002); ammonia-nitrogen concentration is 0.12-0.83 mg/L, with Baijiawan cross section meeting Class II standards and all other cross sections meeting Class III standards; TP concentration is 0.03~0.12 mg/L, with Baijiawan, Yujiahu, Zhuandou, Huangzhuang, Luohanzha and Zekou cross sections meeting Class II standards and all other cross sections meeting Class III standards.

(2) Under middle development scenario, in Baijiawan-Longwangmiao river section, COD_{Mn} concentration is 2.62~3.81 mg/L, with all monitoring cross sections meeting Class II standards of Surface Water Environment Quality Standards (GB3838-2002); ammonia-nitrogen concentration is 0.19~1.21 mg/L, with Baijiawan cross section meeting Class II standards, Yujiahu, Zhuandou and Huangzhuang cross sections meeting

Class IV standards, and Luohanzha, Zekou, Yuekou, Hannancun, Shidou, Xiaohe, Xinggou, Zongguan and Longwangmiao cross sections meeting Class III standards; TP concentration is 0.04~0.17 mg/L, with Baijiawan cross section meeting Class II standards and all other cross sections meeting Class III standards.

(3) Under high development scenario, in Baijiawan-Longwangmiao river section the COD_{Mn} concentration is 2.8~4.11 mg/L, with Baijiawan, Luohanzha, Zekou,Yuekou, Hannancun, Shidou, Xiaohe, Xinggou, Zongguan and Longwangmiao cross sections meeting Class II standards of Surface Water Environment Quality Standards (GB3838-2002), Yujiahu, Zhuandou and Huangzhuang cross sections meeting Class III standards; in Baijiawan-Longwangmiao river section, ammonia-nitrogen concentration is 0.2~1.4 mg/L, with Baijiawan cross section meeting Class II standards, Yujiahu, Zhuandou, Huangzhuang, Luohanzha, Zekou, Yuekou, Hannancun, Shidou, Xiaohe, Xinggou, Zongguan and Longwangmiao cross sections meeting Class IV standards; in Baijiawan-Longwangmiao river section, TP concentration is 0.04~0.19 mg/L and is progressively increasing from upstream to downstream, with Baijiawan cross section meeting Class II standards, Yujiahu, Zhuandou, Huangzhuang, Luohanzha, Zekou, Yuekou, Hannancun, Shidou, Xiaohe, Xinggou, Zongguan and Longwangmiao cross sections meeting Class III standards.

In addition, according to TP prediction and results of comparing Wangfuzhou and Cuijiaying eutrophication monitoring, it is determined that reservoir area will undergo light eutrophication after the completion of Xinji, Yakou and Nianpanshan complexes.

In conclusion, the planned 9.5 billion m3/year water diversion and development of all planned complexes will obviously affect water quality of Han River, as CODmn , ammonia-nitrogen and TP concentrations in the river section downstream of Yujiahu cross section all increase by varying degrees, among which ammonia-nitrogen concentration of various cross sections rise by around 26.3% on average, leaving Yujiahu cross section as the only one meeting Class II standards of Surface Water Environment Quality Standards (GB3838-2002) while all other monitoring cross sections exceed standards by varying degrees. It is partially attributable to the relatively high background concentration of indicators such as TP and ammonia-nitrogen in water bodies of the middle and lower reaches of Han River as they can meet Class III and IV standards of Surface Water Environment Quality Standards (GB3838-2002) respectively. The water quality of midle and lower Han River will not undergo severe deterioration of water quality.

7.3.2.2 Impact on drinking water source areas

There are 17 sub-county level drinking water sources areas downstream of Danjiangkou dam in the middle and lower Han River. Locations of these drinking water source areas from upstream to downstream are as follows (see Figure 7-2).

- water source areas of Laohekou water plant is in Wangfuzhou reservoir area;
- water sources areas of Gucheng county water plant and Taipingdian water plant of Xiangyang are in the planned Xinji reservoir area;
- water sources areas of Baijiawan water plant of Xiangyang and Huoxingguan water plant are in the reservoir area of Cuijiaying navigation and hydropower complex;
- water sources areas of Yicheng water plant is in the planned Yakou complex reservoir area;
- Zhongxiang Huangzhuang water source and Shayang water source are in the

reservoir area of Xinglong complex;

- all remaining water sources areas are downstream of Xinglong complex.

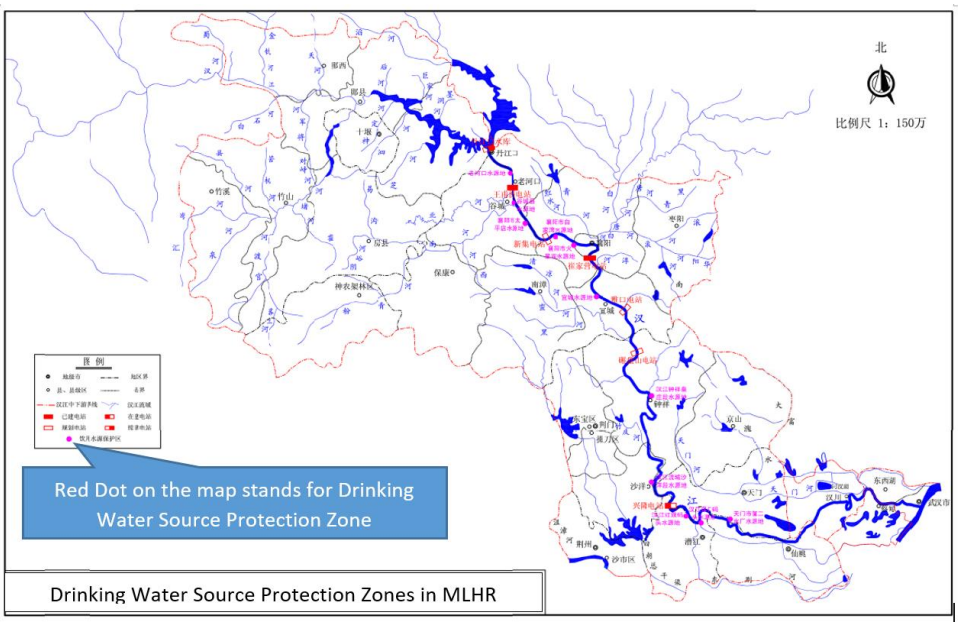


Figure 7-2 Drinking Water Source Protection Zones in Middle and Lower Han River

According to results of water quality impact prediction, water quality in the river section upstream of Baijiawan cross section can meet Class III standards of Surface Water Environment Quality Standards (GB3838-2002), whereas water quality in the river section downstream of Yujiahu cross section cannot meet Class III standards of Surface Water Environment Quality Standards (GB3838-2002). Therefore, in calculating non-point and tributary load conditions of 2020, considering 9.5 billion m3 of water diversion and completion of all planned complexes, water quality of various drinking water sources (Laohekou, Gucheng and Xiangyang Taipingdian) upstream of Xinji complex dam site can meet relevant drinking water source requirements; Huoxingguan water source of Xiangyang can also meet relevant drinking water source requirements as it is close to Baijiawan cross section and has no pollution in between; indicators such as CODmn, ammonia-nitrogen and TP in water bodies of various drinking water sources located in the river section downstream of Xiangyang cannot meet the requirements of designated standard for drinking water source.

The calculation results listed above is predicted based on the current pollution load (2013), for currently Han River basin has a relatively low urban sewage treatment rate and a relatively low sewage treatment plant collection rate, as there is essentially no treatment of agricultural non-point pollution, rural domestic pollution and livestock and poultry breeding pollution, indicating huge potential in further reducing pollutant discharge load. It is estimated that by reaching the designed sewage treatment capability through improving sewage collecting facilities of sewage treatment plants; upgrading existing sewage treatment plants, in places such as Laohekou, Gucheng, Xiangyang, Yicheng, Zhongxiang and Hanchuan, following Grade I (A) standards on top of greatly promoting treatment of livestock and poultry breeding pollution and “contiguous rural environmental treatment”, COD and ammonia-nitrogen discharges in Han River basin will be greatly reduced to be within environmental capacity that water quality of various drinking water sources in the river section downstream of Xiangyang can meet water quality requirements of being drinking water source. Therefore, while constructing navigation complexes along Han

River, basin water pollution treatment need to be reinforced so as to ensure that of water source reaching drinking water quality standards.

7.3.3 Impact on water temperature

Among the reservoirs along the middle and lower Han River, the Danjiangkou reservoir is stratified and has multi-year regulation capacity controlling water temperature, which enables it to play a controlling role in water temperature. All other reservoirs downstream of Danjiang are of daily or no regulation capacity, with little influence over water temperature.

Danjiangkou reservoir has a stably stratified water temperature structure. According to results of water temperature monitoring, from November to March the reservoir water temperatures exhibit vertically even distribution with no horizontal difference. From April to October, during temperature rising period and early temperature falling periods, water temperature exhibit stratification showing a 16 ℃ temperature gap between upper and lower water layers, with annual average water temperature of the reservoir surface water being 18.4℃ and annual average water temperature of the lower layer being 11.6℃.

Water temperature of Danjiangkou discharge is warm in winter and cool in summer. Water temperature in the middle and lower reaches of Han River mainstream is mainly affected by the temperature of water discharged from Danjiangkou. According water temperature monitoring data from Huangjiagang hydrological station over the years, annual average water temperature of Huangjiagang hydrological station has reduced by 0.7℃ after reservoir construction compared with that of prior reservoir construction. During February to August water temperature decreases by 3-5℃ on average, with an average of 4.4℃ decrease from April to June; water temperature increases during other months by 2.8℃ on average, with the maximum being 4.9℃. Annual water temperature variation is down from 22.7℃ to 18.9℃.

Reduced flow velocity of water flow formed after formation of various reservoirs along the Han River is of certain positive effect to restoring low-temperature water discharged from Danjiangkou. According to relevant research findings, after the implementation of South-to-North Water Diversion Project, areas affected by low-temperature discharge are mainly Wangfuzhou and Xinji reservoir areas, yet without big drop in temperature. For instance, during April to October, after Danjiangkou dam heightening, water temperature of reservoir orifice discharge is lower than that of prior the dam heightening, with a temperature drop of 0.04℃(October) to 2.30℃(July). Water temperature along the river gradually rises. In July, the time of the biggest temperature drop, water temperatures differ by 0.56℃ between 120 km from the dam (i.e. near Cuijiaying dam tail) and baseline water temperature of the river channel; river water temperature is basically restored to baseline water temperature around 200 km from the dam (i.e. near Yakou dam site).

7.3.4 Summary

(1) Water environment capacity

Affected by implementing South-to-North Water Diversion, reduced discharge in the middle and lower reaches of Han River has caused significant loss in terms of water environment capacity, which further reduces due to cascade development along the middle and lower Han River. According to initial estimate, after implementing South-to-North Water Diversion the cascade development, in the middle and lower reaches of Han River

mainstream, COD water environment capacity loss is 64218 t/a, ammonia nitrogen water environment capacity loss is 4561 t/a and TP water environment capacity loss is 132 t/a. Loss of water environment capacity in the middle and lower reaches of Han River is largely concentrated in the river section between downstream of the dam of Danjiangkou reservoir and Gaoshibei section, whereas the river section downstream of Gaoshibei has little loss thanks to water supplement from Jianghan Canal that compensates flow from Yantze River to Han River.

(2) Water quality

After the completion of all planned complexes (in addition to the South-to-North Water Diversion), in Baijiawan-Longwangmiao river section in the middle and lower reaches of Han River, CODmn concentration is 2.8~4.11 mg/L, ammonia-nitrogen concentration is 0.2~1.4 mg/Land TP concentration is 0.04~0.19 mg/L. Compared with planned water quality objectives, except for water quality of Baijiawan cross section not exceeding standards, cross sections including Yujiahu, Zhuandou, Huangzhuang, Luohanzha, Zekou, Yuekou, Hannancun, Shilou, Xiaohe, Xingou, Zongguan and Longwangmiao all exceed standards by varying degrees. Water quality of various drinking water sources in the river section upstream of the dam site of Cuijiaying complex can meet water quality requirements of being drinking water sources, whereas water quality of various drinking water sources in the river section downstream are not meeting water quality requirements of being drinking water sources, with ammonia-nitrogen being the main indicator exceeding standards. Loss of environmental capacity due to the Water Diversion and cascade development are largely compensated by measures such as enhancing collection and treatment capability of sewage treatment plant and enhanced rural pollution treatment, ensuring water quality of water sources meet standards.

(3) Water temperature

After the complete implementation of constructing all navigation complexes along Han River (on top of south-to-north water diversion), various cross sections in the middle and lower reaches of Han River will have decreased annual average water temperature following as ascending order of temperature variations from upstream to downstream. The planned Xinji hydropower station, Yakou navigation complex and Nianpanshan hydropower complex are of mixed-type structure and are power station with only daily storage ability, basically without low-temperature discharge.

7.4 Cumulative Effects on Fish

7.4.1 Impact on fish composition

The operation of South-to-North Diversion Project will lead to reduced flow rate and velocity in the middle and lower Han River. Prediction shows water quality downstream of Xianfan will decrease, featured by the increase of ammonia-nitrogen and total phosphate, which favors the growth of plankton biomass and changes the composition of aquatic organisms. Moreover, the water temperature of releases from Danjiangkou reservoir will also have impacts to fish.

Completion of the cascade in the middle and lower Han River will compensate the impacts imposed by the Diversion Project in terms of maintaining water level and cross-section. In a cumulative sense, implemention of all the planned cascade and the Diversion project will lead to reduced flow velocity, increased distribution and biomass of aquatic vascular plants, and favorable conditions for the reproduction of resident fish

species. Specifically,

- The number of resident fishes such as *Cyprinus carpio*, *Carassius auratus* and *Pelteobagrus fulvidraco* will increase;
- The distribution areas of fish species favoring flowing water such as Lepturichthys fimbriata, Leptobotia taeniaps, Rhinogobio typus, Opsariicjthys bidens, Glyptothorax sinensis and Gobiobotia brevirostris will narrow down to the river section upstream of Xiangyang, due to eco-environmental changes;
- Downstream of Cuijiaying reservoir houses several spawning areas for fish species with floating eggs. Completion of the cascade and formulation of reservoirs will negatively affect those spawning areas and lead to population shrinking of fish species with floating eggs, such as Mylopharyngodon piceus, Ctenopharyngodon idellus, Hypophthalmichthys molitrix, Aristichthys nobilis, Squaliobarbus curriculus, Parabramis pekinensis and Elopichthys bambusa. The populations of some fish favoring slow flowing water and still water such as Cyprinus carpio, Carassius auratus, Silurus asotus and Siniperca chuatsi, as well as some small-sized fish will increase, whereas the number of fish favoring flowing water will decrease or disappear;
- Fish composition in the lower reach of Han River will change for not getting fingerling supplement from fish with pelagic eggs in the middle reach, and will be mainly lake-type resident fishes showing less fish biodiversity and decreased diversity index.
- On positive side, due to a smaller flow velocity and less frequent water exchange, there will be a larger fish forage base such as plankton and zoobenthos, and an increased population and biomass as a result of improved foraging and growing conditions of fish.
- The number of some fish in the lower reach of Han River, in particular fish with pelagic eggs such as the “four major Chinese carps” will be reduced as they rely on fingerling supplements from several spawning grounds in the middle reach which will be affected by hydropower complexes and blocked by dams. Such fish can then only be supplemented by fish from the smaller Zekou spawning ground and fish from Yangtze River.

7.4.2 Impact on fish migration

Migration includes reproductive migration and feeding migration. In the middle and lower reaches of Han River, there are no fish that needs to undergo reproductive migration to the upper reach. As to fish that needs to undergo reproductive migration to the Yangtze River and ocean, such as *Coreius heterodon* (Bleeker) and *Anguillidae*, their migration processes can be aided by fish passes constructed in Cuijiaying, Yakou, Nianpanshan and Xinglong cascades. After the completion of each cascade/reservoir, feeding grounds for the existing fish will be formed in new river sections and reservoirs, therefore project construction has no substantial impact on fish feeding migration.

7.4.3 Impact on fish reproduction

7.4.3.1 Impact on reproduction of fish with floating eggs

Han River is the largest tributary of Yangtze River. Fish resources in the Han River basin are of great similarities to that in the middle and lower reaches of Yangtze River, as they frequently exchanges. Generally speaking, fattened fish in the middle and lower

reaches of Yangtze River and lakes swims upstream to Han River for feeding and reproduction, and juvenile fish growing in Han River swims downstream to the middle and lower reaches of Yangtze River and other lakes for feeding and fattening.

According to relevant research results, there were altogether five spawning grounds for the four major Chinese carps (i.e. *Four Domesticated Fish, referring to black, grass, silver, and bighead carp, representative of fish species with floating eggs*) in Miaotan, Yicheng, Guanjiashan, Zhongxiang and Maliang in the middle and lower reaches of the Han River mainstream. Those spawning grounds have undertaken rapid shrinking or even disappearing due to multiple reasons such as the the cascade development of Wangfuzhou, Cuijiaying and Xinglong complexes along the middle and lower reaches of Han River, as well as overfishing and water quality problems.

The completion of Danjiangkou dam (1973) blocks fish migration between the upper reach of and the middle and lower reaches of Han River and Yangtze River. Though fish passages are included in the Cuijiaying dam and Xinglong dams, the conspensatory effects on fish migration will take time to realize. Currently, between the tailwater of Xinglong reservoir and Cuijiaying dam there is about 210 km of flowing river section. There is also flowing water river section between the tailwater of Cuijiaying reservoir and Wanfuzhou dam. Impacts on the fish spawning grounds are noted in below.

- After the completion of Xinji complex, reservoir backwater will inundate about 30 km of flowing river section. Cihe/Miaotan spawning ground of fish with pelagic eggs, located in the river section, will disappear due to changes of hydrological regime as the river hydrological regime of the section between upstream of the reservoir tail to flowing section of Wangfuzhou dam can no longer satisfy spawning requirements for fish with pelagic eggs. There will be about 4.3 km river segment between Xinji dam Cuijiaying reservoir tailwater remain as flowing water. New spawning ground is likely to form for fish species that need less flowing water stimulation.
- The formulation of Cuijaying reservoir (2010) has led to the inundation of the spawning ground in the Xiangyang city river section. It has no impacts on the spawning ground downstram of the Cuijiaying dam.
- It is expected that after completion of Yakou dam and formulation of the Yakou reservoir, Yicheng spawning ground will be inundated. As for fish upstream of the Yakou dam, fish with pelagic eggs can only spawn under open discharge condition as Yakou and Cuijiaying are linked causing the narrowing of flowing habitat as well as the inundation of Yicheng spawning ground. However, given the blocking effect of the dam, fertilized eggs and juvenile fish swiming downstream cannot swim back upstream after fattening resulting in substantial loss of resources.
- According to the 2014 survey, at immediate downstream of Yakou dam (Nianpanshan reservoir area) and Nianpanshan dam there are spawning grounds of fish with pelagic eggs, including the four major Chinese carps, namely the Guanjiashan spawning ground downstream of Yakou dam and Zhongxiang spawning ground downstream of Nianpanshan dam. Given that both Yakou and Nianpanshan complexes are of no regulation capability, generally they have no obvious impact on spawning grounds downstream. Yet the reservoirs impose flattening effects on flood peaking process. Flood peak process may not be obvious in the case of small-discharge flood peak. It is likely difficult to meet the flood peak demands of spawning grounds downstream of the dam after flood peak being flattened by the Yakou and Nianpanshan reservoirs.

- After the completion of Yakou and Nianpanshan complexes, between Yakou and Xinglong dam, only Guanjiashan and Zhongxiang spawning grounds for the *Four Domesticated Fish* and other fish species with floating eggs will remain. Although spawning environmental conditions for fish with pelagic eggs exist, due to the limited length of flowing water section above the tailwater of Xinglong reservoir, during medium and small-sized floodings, fertilized eggs cannot flow across the dam as fertilized eggs will sink down to reservoir area, resulting in low hatching rate. Only with certain discharge volume or open discharge, flowing hatching process can be realized. Considering the blocking effect of the dam, it will be difficult for fertilized eggs and juvenile fish to swim upstream of Xinglong dam after fattening. In addition, given that multiple blockages exist upstream of Xinglong dam due to existence of multiple cascades along Han River, except for the cases of large flood or open discharge when hydrological regimes situation may be restored, hydrological regime of the area cannot meet relevant spawning and reproductive demands.
- Backwater of Xinlong reservoir has a length of 76.4 km that will inundate the Maliang spawning ground, causing it to disappear. Xinglong complex will not impact the spawning grounds in its downstream.

7.4.3.2 Impact on reproduction of fish with sticky eggs

Spawning grounds of fish with grass-adhering eggs usually need attachments such as aquatic plants as fertilized eggs need to hatch on aquatic plants. Once a reservoir forms, shallow areas such as side slope, reservoir gulf, tributary estuary and inundated dam area are of plentiful aquatic plants thus beneficial to spawning and reproduction of fish with sticky eggs. Given that the spawning and reproductive periods of fish with sticky eggs are between March and May, reservoir operation need to be regulated to avoid abrupt rise and drop of water level upstream and downstream of the dam so as to prevent spawn dying from drying due to water level decrease.

As to spawning grounds of fish with gravel-adhering eggs, the status quo is that the spawning grounds are limited along the river. They will be inundated after reservoir formation. New spawning grounds will be difficult to form as along the bank of the reservoir area are mostly grit and sediment. It is possible that similar spawning grounds could exist in Chun River and some sections of Wei River, yet the two tributaries are of poor water quality environments and intense human activities, making it difficult to perform relevant ecological functions.

7.4.4 Impact of Water Temperature on Fish

Various fish species with floating eggs perform reproduction when water temperature is between 16-32℃ in Han River mainstream. Major economic fishes usually start spawning when water temperature is around 18℃. Species such as *Hemiculter bleekeri* Warpachowsky and *Xenocypris argentea* Gunther starts spawning when water temperature is at least 16℃ whereas *Aristichthys nobilis* starts spawning when water temperature reaches 20℃.

Releases from Danjiangkou reservoir has led to cooler dam discharge water in spring and summer times than water in natural river channel. According to results of the 2004 survey on fish with floating eggs in the middle reach of Han River as well as tributaries of Tang River and Bai River, low-temperature discharges from Danjiangkou reservoir did not cause the disappearance of fish spawning in Miaotan spawning ground, closest to Danjiangkou, and other spawning grounds downstream, for water temperature along the

river section rose progressively along the lengh of the river as temperature rose in April and May exceeding water temperature. However, fish production periods postponed for around 20-30 days (extending to mid- and late August)compared that of prior dam construction, under the combined influence of water temperature and runoff regulation,

Storage increase of the Danjiangkou Reservoir associated with the South-to-North Diversion will lead to further increase of water level making the temperature of water discharged further lower. However, according to water temperature prediction, area affected will be limited to river section upstream of Yakou, with only very small variations in terms of water temperature. Given that currently there is no large-scale fish spawning grounds in the river section upstream of Yakou, reproductive periods of fish in the middle and lower reaches of Han River fish are unlikely to be further postponed, and the fish reproductive periods will postpone for nearly one month.

7.4.5 Impact on fishery resource conservation zone

In the middle and lower reaches of Han River there are currently two national-level fisery resource conservation zones, namely

- National Aquatic Germplasm Resources Conservation Zone of *Elopichthys bambusa*(鱘), *Ochetobibus elongatus(鳇)* and *Luciobrama macrocephalus(鯇),* located in the Zhongxiang section of Han River, and
- National Aquatic Germplasm resources conservation zone of *Leiocassis longirostris (长吻鮠)* and *Pelteobaggrus vachelli (瓦氏黄颡鱼), located in* Shayang section of Han River.

(1) Cumulative impacts on the National Aquatic Fihsery Resources Conservation Zone of *Elopichthys bambusa*(鱘), *Ochetobibus elongatus(鳇)* and *Luciobrama macrocephalus(鯇)*

The conservation zone is located between Jihuatan and Wanglong, with with a total length of 108km and a total area of 4320 ha. The main protected subjects include *Elopichthys bambusa*, *Ochetobibus elongatus* and *Luciobrama microcephalus*. Other species under protection include *Siniperca chuatsi*, *Pelteobagrus fulvidraco* and *Leiocassis longirostris,* etc. The conservation zone was authorized by Ministry of Agriculture in 2008.

The three protected fish speices spawn sticky eggs hence its breeding is sensitive to flow velocity and floating distance. Nonetheless the resource of the three fish species experienced substantial decrease over the past 4 decades in Han River, similarly to other fish species with sticky eggs. In a 1970s' survey, *Elopichthys bambusa*(鱘) and *Luciobrama macrocephalus(鯇)* were caught in the middle to lower Han River. The 2003-2004 fishery resource survey didn't find the two fishery species. The 2014 survey didn't find the two fish speices either. Findings of *Ochetobibus elongatus(鳇)* are rarely seen in available survey reports.

The Nianpanshan dam is located in the Experimental Zone of the conservation zone. Core Zone of th econservation zone is located downstram of Nianpanshan dam. Impacts scoping determined that the impacts on the conservation zone should consider Nipanshan and Xinglong dams/reservoirs primarily.

As already assessed in the Yakou project EIA, the construction and operation of Yakou dam/reservoir won't have impacts on the conservation zone given the facts that Yakou dam is way upstream of the conservation zone and the weak regulation capacity of

the Yakou reservoir over its downstream flow regime. The South-to-North Diversion project has negative impacts on the conservation zone as it reduces the the flow rate of the the middle to lower Han River mainstream. Whereas, formulation of the Nianpanshan and Xinglong reservoirs increases the water depth and maintains a more stable water surface, which are benefitial to the conservation zone. Meanwhile, population increase of small-sized fishes is also conducive to inhabiting and fattening of predatory *Elopichthys bambusa*, *Ochetobibus elongatus* and *Luciobrama microcephalus.*

Construction of Nianpanshan dam will have temporary impacts on the conservation zone. The dam will also have blocking effect over the migration of three fishes. Main spawning area (Nianpanshan to Tanggang) of the three fish species is downstream of Nianpanshan dam site with a length of about 40 km featuring natural river channel. After flowing downstream for 10 km and entering Xinglong reservoir area, spawn may sink down resulting in lower hatching rate due to slower water flow velocity, affecting the resource abundance and protection.

In conclusion, the South-to-Norht Diversion, cascade development, and the established of the conservation zone have synergestic and cumulative impacts on the conservation zone of *Elopichthys bambusa*(鱯), *Ochetobibus elongatus(鰉)* and *Luciobrama macrocephalus(鯨).* The status quo of the resource abundance of the three fish species in the Han River, similar to other fish species with floating eggs, are extreme according to several rounds of fishery resources surveys that were carried out in the past 15 years, and has not seen recovery even after the conservation zone was officially established in 2008. Reintroducing the fish species through fish breeding and releases, fish passes, protection and restoration of fish spawning grounds, enhancing monitoring and regulation, and carrying out studies for resource recovery are included in the authorization of Nianpanshan and Xinglong projects. In 2016, Ministry of Agriculture authorized the assessment of impacts of Nianpanshan project on the conservation zone and protection plan.

(2) Cumulative impact on National Aquatic Germplasm Resources Conservation Zone of *Leiocassis longirostris (长吻鮠)* and *Pelteobaggrus vachelli (瓦氏黄颡鱼)*

The conservation zone is locatd between Beigang of Maliang and Caizui river section of Lishi (75 km), including main protected subjects such as important economic fishes of *Leiocassis longirostris (长吻鮠)* and *Pelteobaggrus vachelli (瓦氏黄颡鱼)* and their spawning grounds, as well as other protected species such as the *Four Domesticated Fish (black, grass, silver, and bighead carp),* Crusian Carp, *Carassius auratus, Megalobrama amblycephala, Elopichthys bambusa, Ochetobibus elongatus, Luciobrama macrocephalus, Culter mongolicus and Culter alburnus.*

The Core Zone and Experimental Zone of the conservation zone are located in Xinglong reservoir. For *Leiocassis longirostris (长吻鮠)* and *Pelteobaggrus vachelli (瓦氏黄颡鱼),* they have a higher rate of fertilization and survival under certain level of stimulation from flowing water. Nonetheless, the two fish speices spawn sticky eggs that do not need long-distance floating to complete their breeding life stage. Therefore, under reasonable scheduling, reproduction can be maintained. In addition, as water level rises and water surface broadens due to river impoundment, better fattening and wintering conditions are provided to the two fish species. Hence, the Xinglong dam/reservoir has limited impact on them.

Existing spawning ground of fish with pelagic eggs within Xinglong reservoir area

include Maliang spawning ground, situated at the reservoir tailwater area. After the formulation of reservoir, the river channel widens and broadens, and flow velocity decreases, making it no longer suitable for reproduction of fish with floating eggs in particular the "*Four Domesticated Fish (black, grass, silver, and bighead carp) and Elopichthys bambusa, Ochetobibus elongatus and Luciobrama macrocephalus*. Maliang spawning ground has substantially disappeared after the formulation of Xinglong reservoir. In addition, the Nianpanshan project will bring down the scale of Zhongxiang spawning ground, affecting supplement of fish with floating eggs to the downstram conservation zone.

In conclusion, cascade development of Nianpanshan and Xinglong will have limited impacts on the conservation of *Leiocassis longirostris (长吻鮠)* and *Pelteobaggrus vachelli (瓦氏黄颡鱼)* but will have more pronounced impacts on the fish species with floating eggs and their spawning grounds. Nonetheless, fishery resource survey conducted through 1970s to the last 15 years show that fish species with floating eggs have sharply declined due to overfishing (particularly in the 1990s), water pollution, and cascade development. For future sustainability of fishery resources, emphasis should be put on reintroducing the fish species through fish breeding and releases, building and operation of fish passes, protection and restoration of fish spawning grounds, enhancing monitoring and regulation, and carrying out studies for resource recovery.

7.4.6 Summary

The Danjiangkou dam/reservoir was put into operation in 1973. Various rounds of fishery resources survey since then showed declining of fishery resources in the middle and lower Han River and its tributaries. Numerous studies suggested that main reasons included overfishing, water pollution and water resources development projects (including the South-to-Noth Deversion project and cascade dam/reservoir development) and other development activities such as in-stream mining. Over the past decade, the province has made much efforts in controlling industrial and domestic wastewater collection and treatment, strengthening fishery resource reguatlion, which has lead to improvement of Han River quality and signs of fishery resource recovery. Nonetheless, fish population and composition studies have changed, the resource abundance of fish species with floating eggs, notably the Four Domesticated *Fish (black, grass, silver, and carp)* declined sharply, the predatory *Elopichthys Bambusa*(鱘), *Ochetobius elongates (鳇)* and *Luciobrama microcephalus (鲹)* were not found for many years. Whereas, small-sized and fish species favor lake-like conditions such as common carp and crucian carp become more dominant.

Cumulative effect assessment suggests that the South-to-North Diversion project heightened the Danjiangkou dam and expanded the reservoir storage. Reduced releases with lower temperature will have impacts on the fish in the middle and lower reaches of Han River. The cascade development along the middle and lower reaches of Han River will compensate the effects to a certain extent. The spacious, deep and slow-moving waters in various reservoirs are more advantageous for fish wintering and feeding, particularly for population and biomass increase of fish species favoring still waters.

Completion of the cascade development along the middle and lower reaches of Han River will have negative impacts on the reproduction and migration of fish with floating eggs. If no measures are taken, spawning grounds of the Four Domesticated Fish as well as rare fish species such as *Elopichthys bambusa, Ochetobibus elongatus and Luciobrama macrocephalus* will narrow down or suffer lower hatching rates. Zhongxiang spawning

ground will downsize due to Nianpanshan project; Maliang spawning ground will disappear due to Xinglong project. Zekou spawning ground located in the downstream will be less affected. As there are currently no spawning ground or conservation zone where Xinji complex is located, its construction will have limited impacts.

The Nianpanshan and Xinglong projects involve two fisery resource conservation zones that were authorized by Ministry of Agriculture. Construciton impacts of Nianpanshan project will be temporary. Operation of the two projects will have limited impacts on the protected fish species.

To mitigate the cumulative effects, strictly adhering to the regulations on releases from Danjiangkou and each dam/reservoir to guarantee downstram ecological flow, water supply and water supply needs is mandated. For future sustainability of fishery resources, emphasis should be put on reintroducing the fish species through fish breeding and releases, building and operation of fish passes, protection and restoration of fish spawning grounds, enhancing monitoring and regulation, and carrying out studies for fishey resource recovery.

7.5 Cumulative Effects on Riparian Areas

Following domestic EIA guidelines, various environmental studies on the Han River cascade development considered terrestrial ecology that covers land corridors along the Han River mainstream, inundated area and ecolgocially sensitive areas nearby. Typical study areas are within 1000m each side of the mainstream.

For the past decade or so, riparian and floodplain ecology have recived more attention and its special ecological functions as opposed to typcial terrestrial ecology recognized. The riparian/floodplain ecogloy covers terrestrial habitats, wetlands, soils and geology, island and floodplain hydrology.

"*Riparian areas are transitional between terrestrial and aquatic ecosystems and are distinguished by gradients of biophysical conditions, ecological processes, and biota. They are areas through which surface and subsurface hydrology connect waterbodies with their adjacent uplands. They include thoese portions of terrestrial ecosystems that significantly influence exchanges of energy and matter with aquatic ecosystems (i.e., a zone of influence). Riparian areas are adjacent to perennial, intermittent and ephemerial stream, lakes and estuarien-marine shorelines*."

"*Further, riparian areas include portions of the channeled system and associated features (gravel bars, islands, wood debris); a vegetated zone of varying successional states influenced by floods, sediment deposition, soil-formation processes and water availability; and a transitional zone to the uplands of the valley wall – all underlain by alluvial aquifers. Although they occypy only a small portion of the total land base in most watersheds, riparian areas are regional hotspots for biodiversity and exhibit high rates of biological productivity in contrast to larger landscapes*."

In this CEA study, the findings and results of previous terrestrial ecology and impacts were reviewed and consolidated to deepen the understanding of riparian and floodplain ecosystem and its distinctive ecological functions and processes. It is also noted that this subject has been less well studied and should be further assessed in the next step cumulative effect studies.

7.5.1 Impact on Vegetation

The Xinji project will totally occupy and flood an area of 4060.74 ha, including

183.33 ha woodland, 14.55ha shrubby grassland, and 225.87 ha farmland. Affected woodland are mainly *pinus massoniana*, *cypress*, *quercus variabilis and Robinia pseudoacacia*, etc. In the affected shrub grassland there are mainly *vitex negundo shrub, rosa cymosa - pyracantha fortuneana* Shrub, *Quercus variabilis* shrub, etc.; in the affected farmland, there are mainly: potatoes, peanut, corn, sesame etc.

The Yakou project will occupy and flood an area of 3544 ha, including 680ha woodland, shrub and grassland; and 2864 ha farmland which are primarly river floodplain. The woodland is mainly populus trees along river banks. The main crops include: corn, sesame, peanut, white gourd, cotton etc. As the project feasibility proceeds, the total land occupation and flooding were markedly reduced through land elevation and other design optimization measures.

The Nianpanshan project will occupy and flood a total area of 4278 ha including woodland and shrub land 480ha, and 3798 ha farmlands (mainly river flats. The woodland mainly populus and *pterocarya stenoptera* trees along river banks. The main crops include: corn, sesame, peanut, white gourd, cotton etc.

Overall, the middle and lower Han River basin has been extensively affected by human being for a long history. Along Han River, river flats, populus trees, shrub and herbaceous plants mainly include common perilla, cynodon, green bristlegrass, reed are dominant. No national protected plants are recorded. These affected flora species are common and widely distributed in the project area. The cascade development won't lead to extinction or significant reduction of the species abundance.

After the completion of the cascade development in middle and lower reaches of Han River, in the short term, the total biomass in the area will be reduced. According to the distribution pattern of regional vegetation, the inundated area mainly includes farmland, woodland, shrub grassland, etc. The affected vegetation are common and widely distributed species, for example, *populus, saliz matsudana and Pterocarya hupehensis Skan* in woodland; cynodon, green bristlegrass, phragmites communis, leonurus, cogongrass and common perilla in shrub grassland; and corn, sesame, peanut, melon, cotton, and others in farmland. The loss of vegetation has minimal effect on the total biomass of the whole Han River basin. At the same time, with impoundment of the reservoir, by carrying out water and soil conservation and ecological restoration, in long term the overall production and biomass of the vegetation will increase, and a substantial increase of plant species and quantity, especially riparian and aquatic plants is anticipated.

7.5.2 Impact on Wetland and Wildlife

River impoundment will bring changes to wildlife habitats and move wildlifes to peripheral of reservoirs. Meanwhile, formation of spacious reservoir and wetland will also attract a large number of birds including swimming birds and wading birds.

After the reservoir impoundment, animals in flooded areas will move to the surrounding of the reservoir, which causes the increase of density of amphibians, reptiles and rodents, making their living space smaller. For birds and animals such as *lepus europaeus* (rabbit), yellow weasel, etc., due to their strong migration ability and diversified sources of food, the reservoir impoundment has limited impact on their survival.

Reservoir impoundment will form wetland and islands that will provide new habitats for waterfowls, and attract more water birds to come to the reservoir for inhabitation and reproduction, so the population size and individual number will be increased by a large

margin, such as egrets, kingfishers, herons, great white egrets, intermediate egrets, pond herons, mallard etc.. At the same time it will also provide abundant still water or slow flow water for some amphibians such as bufo gargarizans, pelophylax nigromaculata, pelophylax hubeiensis, which is beneficial to the population development.

7.5.3 Impact on sensitive areas and recreational areas

There are several ecologically sensitive areas and recreational areas on the middle and lower Han River, including wetland park and nature reserve.

- Laohekou Lihuahu Nature Reserve and Laohekou Lihuahu Scenic Area. Both build on Wangfuzhou reservoir and were authorized/established after the reservoir had been formualated.
- Gucheng Han River National Wetland Park, located in Gucheng County, immediate downstream of Wangfuzhou dam and extends to tailwaters of Xinji reservoir. Impoundment of the Xinji reservoir will inundate peripheral area of the wetland park.
- Xiangyang Cuijiaying Provincial Wetland Park, located in Xiangyang City. It builds on the Cuijiaying reservoir and was authorizied/established after the Cuijiaying reservoir had been formualated.
- Yicheng Wanyangzhou National Wetland Park, located in Yicheng City. It will be part of the future Yakou reservoir;
- Two fisery resource conseravation zones in the lower reach of Han River. They have been discussed in previous sections on fish hence will not be repeated in this section.

In addition, there are two nature sub-reserves (Yanshan and Lumensi) and Lumensi Natural Forest Park in the vicinity of Han River. Nevertheless, all are located on upper land and far from the river hence no impacts of the cascade development are anticipated. It should be noted that a wetland park and nature reserve is under the administration of forest department; a scenic zone is under tourism department.

This section put emphasis of cumulative effects assessment on the wetland parks. A general observation of the history and management of these wetland parks is that some were authorized and established after a reservoir is formulated in order to protect the reservoir and its associated ecosystem. In other cases, either the impacts of cascade development on the wetland park have to be carefully assessed (and mitigation measures developed), or the planning of a wetland park should take into account future river impoundment.

7.5.3.1 Cumulative Effects on Wetland Parks

Wetland refers to marshland, peatland and water area that is natural, artificial, permanent or temporary as well as water that is still, flowing, fresh, brackish or saline, including water area not exceeding 6 m in terms of water depth at low tide.

The middle and lower Han River meanders through low hilly and plain landform. The river bed is wide with permanent waters in the middle and widespread river flats between embankments. Only during flooding seasons, mudflats within embankment on both sides of riverway will be fully inundated.

After completing the cascade development along the middle and lower reaches of Han River, it is anticipated that there will be limited changes to the area of wetland. During dry

seasons, water level of Han River will be stabilized. Formation of reservoir area will expand wetland areas on flood land of reservoir bank, creating favorable conditions for hygrophyte growth on reservoir bank. Previous xerophytic vegetation will gradually be replaced by hygrophyte such as Gramineae and Cyperaceae, forming new vegetation community. Previous wetland will migrate to the previous floating plant area due to rising water level, ultimately leading to increased total biomass and wetland area on both banks of the reservoir area. Biodiversity will not be obviously changed. After implementing of the cascade development plan, total wetland area will increase; many shoals at both side of the river bank will remain. The number of birds will increase.

Among the three planned cascade development projects, the Xinji project involves Gucheng Han River National Wetland Park and the Yakou project involves Yicheng National Wetland Park. Nipanshan project doesn't involve any designated wetland park. Detailed impact assessment is discussed in below.

1. Impact of Xinji project on Gucheng Han River National Wetland Park

Figure 7-3 shows the planning map for Gucheng Han River National Wetland Park. The wetland park is located immediately downstream of Wangfuzhou dam. The zoning map shows an ecological conservation area at its bottom, and various recreational areas, including a farming experience zone (green), culture demonstration zone (yellow), science education zone (purple) and wetland and bottomland recreational zone (blue).

1) Coordination with wetland park planning

Xinji hydropower station has been a recommended project in several plans back in the early 90s and in recent Han River development plan of Changjiang Water Resources Commission. As early as May 2008, the Provincial People's Government issued order to reserve the area of future project development. Gucheng Municipal Government proposed to establishe the Gucheng Han River Wetland Park in July 2009, which was approved State Forestry Administration in December 2009. Subsequent Gucheng Han River National Wetland Park General Planning (State Forestry Bureau Survey Scheme Designing Institute, August 2009) takes into account the development of Xinji hydropower station and its impact on water level increase. Therefore, the basin-level water resource and hydropower planning, the Xinji project and the master planning of Gucheng Han River National Wetland Park are totally compatible.

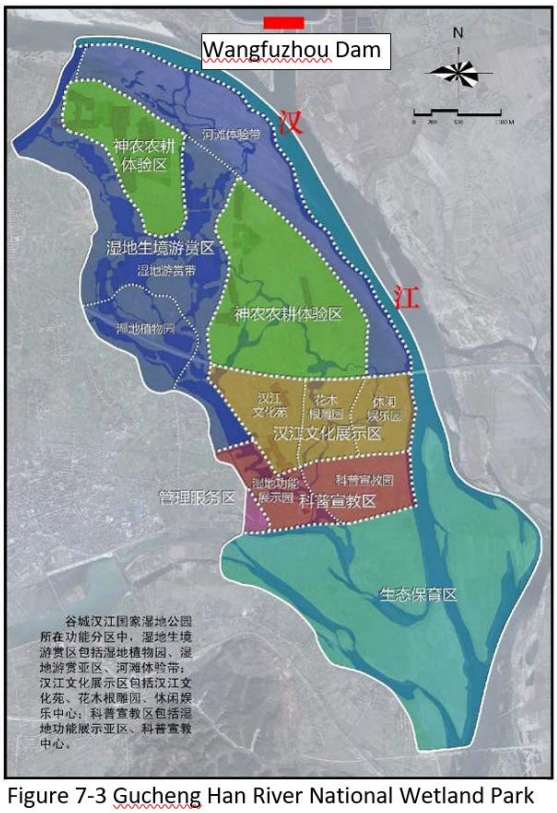


Figure 7-3 Gucheng Han River National Wetland Park

2) Impact on wetland park

Gucheng Han River Wetland Park is located in the reservoir tailwaer area of Xinji reservoir. According to backwater calculation, under normal operating condition (non-flood condition), backwater reaches the confluence of Nan River, with a water level increase around 1 meter, which affects the the ecological conservation zone

of the wetland park. Main affected areas are the sand beach on the east side of Geleizui No. 4 Group and the southern parts of two shoals on its east side, covering a total affected area of 36.84 ha, taking up 4.95% and 1.72% of conservation area and wetland park total area respectively. The affected area will experience long-term rather than periodic inundation. Other functional area and conservation area are basically not affected, maintaining their landforms and functions. Therefore, generally speaking Xinji reservoir backwater has minimal impacts on the wetland landform and function and is in line with the principle of "preserving previous wetland landscape" of the ecological conservation area. In addition, combined with reservoir construction, additional water surface resources will be formed, creating new tourism resources for the wetland park on top of current resources of the wetland.

2. Impact of Yakou project on Yicheng Wanyangzhou National Wetland Park

Figure 7-4 shows the zoning map of Yicheng Wangyangzhou National Wetland Park. The wetland park planning is devoped in line with the impoundment of Yakou reservoir. It has significant sections of riparian areas restoration and restricting development acitivities, in addition to a science eduction zone and a reasonable utilization and management zone. The Yicheng Municipal Government approved the detailed planning on October 26, 2016, and requsted the municipal forestry bureau to implement the plan as soon as possible.

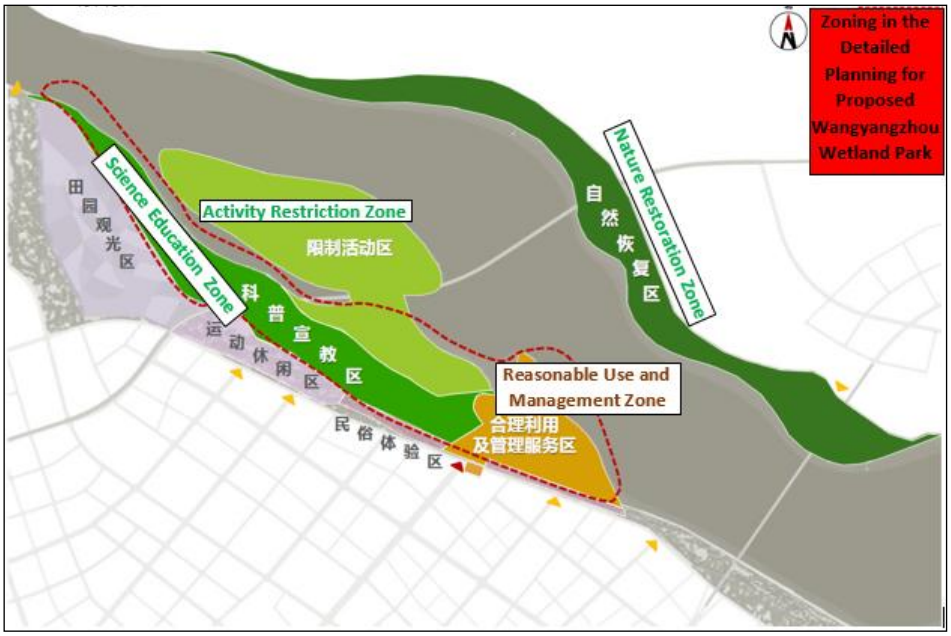


Figure 7-4 Zoning of Wangyangzhou Wetland Park Detailed Planning (2016)

1) Coordination with wetland park planning

On December 31, 2013, State Forestry Administration approved the establishment of "Yicheng Wanyangzhou National Wetland Park in Yicheng (Pilot)" under Reply (Forestry Wetland Development [2013] No. 243) and agreed to "*carry out the pilot work*". The reasons of establishing the wetland park was that unregulated sand mining, grazing, land reclaimation for farming and aquaculture in the river stream and river flats became more and more severe; natural river flow in the segemetn disturbed; water quality deteriorated; and wetland system integrity damaged. In addtion, the Yicheng city intended to provide Yicheng citizens a ideal place of ecotourism, recreation and vacation in the center of the

city. Nonetheless, since approval of the master plan in 2013, no significant physical progress has been made in implementing the plan as it is unfunded, except that the city government upgraded river embankment and green belts at the core urban area along the river.

As discussed in the Yakou project EIA, the wetland park does not meet the criteria of protected area or critical natural habitats as defined by domestic law and regulation or in terms of its particular biodiversity values. Therefore, the responsible authorities Yicheng Municipal Government Forestry Bureau and Hubei Provincial Forestry Department agreed on the development of Yakou dam/reservoir in March and May 2015 respectively. In addition, according to the Yakou project EIA approved by Ministry of Environmetnal Protection, the impacts of Yakou project on the wetland park is considered acceptable.

Since the Yakou project has been approved and implementation will start soon, implementation of the Yicheng wetland planning must start timely. A Constructive Detailed Planning for the Core Zone of Yicheng Wanyangzhou National Wetland Park was prepared in July 2016; subsequently it was approved by Yicheng Municipal Government in October, 2016. This Constructive Detailed Planning fully takes into account future river impoundment caused by the Yakou project, hence the Yakou project development and the wetland park development are coordinated.

2) Impact on wetland functions

Impacts of the Yakou project on the planned Wanyangzhou wetland park has been detailed in the Yakou project EIA and is summarized here.

The Yakou dam is 15 km downstream of the center and 4.5 km downstram of the wetland park's lower boundary, hence no construction impacts are anticipated. The forthcoming Yakou reservoir however will cause elevated river level along the Han River river section where the planned wetland park is located. The river impoundment will invevitably result in inundation and loss of wetland habitats such as shoals and river flats, causing shrinking of wetland plants in terms of biomass and community distribution, and wild lifes. There are alternative habitats along the Han River and in the nearby ponds, lakes or farmland for the potentially affected birds, reptiles and other animals.

On positive side, it is noted that the major ecological threats in the wetland park area is the dropdown of water level; river flats and shoals have been occupied by production activities; human disturbance is very intensive. Human acitivies have caused the shrinking of bird habitats. The Yakou project impoundment will inundate vegation, meanwhile it will turn the occupied riparian area such as farmland to river and return habitats to waterfowls.

The implementation of the wetland park plan will improve the management of the wetland area through clearly defined functional zoninig, restrictions on detrimental development activities, and putting in place day-to-day oversight. The detailed planning of the wetland park includes a set of conservation measures including restoration of aquatic and riparian ecosystem, directives on shoreline use, planning for flora and other programs for associated facilities. Overall, the ecological and public benefits of the wetland park implementation will apparently outweigh the negative impacts. The wetland park planning should be funded and implemented in a timely manner.

7.5.3.2 Impact of cascade development on Lihuahu Wetland Nature Reserve

As described earlier, the Lihuahu Nature Reserve builds on Wangfuzhou reservoir and was authorized/established after the reservoir had been formualated. Only the

South-to-North Diversion Project may have impact on the nature reserve.

In the river section from downstream of Danjiangkou dam to the backwater end of Xinglong complex, the multi-year average water level of Huangjiagang river section will decrease by 0.29-0.45 m; the multi-year average water level of Xiangfan river section will decrease by 0.31-0.51 m, indicating reduced riverway width and riparian wetland area. As result, hygrophilous vegetation on river flat will be replaced by terrestrial vegetation (mainly grassland and shrub land).

While, for Lihuahu Nature Reserve, due to the Wangfuzhou dam and embankment around, water level change won't be significant, hence the wetland area, indicating a relatively small impact of the South-to-North Water Diversion Project on the Lihuahu Nature Reserve.

7.5.4 Summary

The South-to-Northe Diversion Project will lead to reduced water flow, river surface and riparian wetland area, cascade development and formulation of cascaded reservoirs will compensate such impacts to certain extent.

Flora affected by the cascade development along the middle and lower reaches of Han River are mainly common species in the region. Small-quantity loss will not cause extinction of such plants. Cascade construction and reservoir impoundment will narrow the habitats for wildlifes, leading to poorer survival conditions due to increased population density, yet it won't lead to extinction of such wildlifes either.

Reservoir impoundment and strengthened regulation the reservoirs will be beneficial for the introduction and inhabiting of wterfowls and reptiles that facor still waters; their communities and individual numbers will increase dramatically.

The South-to-North Water Diversion Project and cascade development will have limited impacts on the existing wetland parks and ecologically sensitive areas on the river. The planned Yicheng City Wanyangzhou Wetland Park should be implemented in a timely manner in order to meet its objectives of restoring local aquatic and wetland ecosystem, and provide recreational

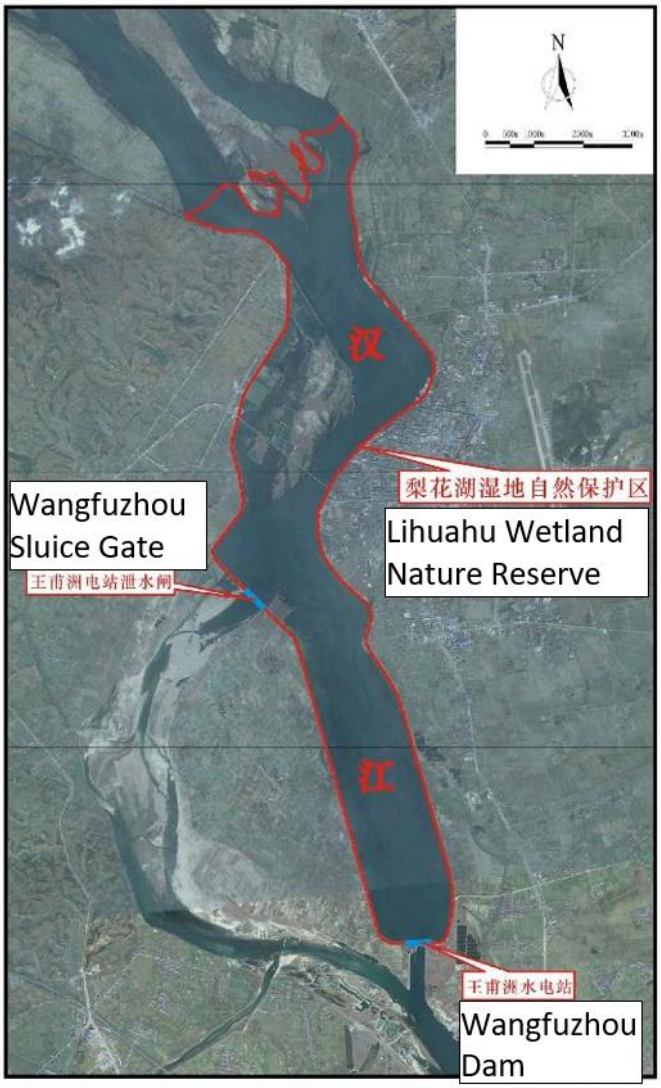


Figure 7-5 Lihuahu Wetland Nature Reserve on Wangfuzhou Reservoir

opportunities to local communities.

Given the complexity of riparian area dynamics and the fact that it is less studied compared to other resources such as aquatic ecology, further study on riparian resources along the middle and lower reaches of Han River should be carried out next step.

8 Cumulative Effects Mitigation Plans

8.1 Overview

In developing mitigation plans for cumulative effects, the following have been considered:

- Environmental protection measures included in the EIA of each dam project on the Han River. Except that the Danjiangkou dam was built during late 1950 to early 1970 when there was no regulatory requirement on EIA in China, other projects have had EIAs prepared and approved by MEP. These EIAs included environmental protectgion measures and monitrong plans;
- Since the enactment of EIA law in 2003, the depth and width of EIA and pertinent environmental protection plans have been evolving over the years. In addtion to mitigation plans for project and site-specific impacts, other mitigation measures have been developed to address long-term operational impacts such as fish pass, fish reproduction program and habitat restoration, and cumulative impacts such as ecological scheduling;

These mitigation measures can be interpreted as the the following,

- The ecological scheduling, by allowing river flows to mimic natural hydrologic regime including seasonal flooding, will be beneficial for improvement of water quality, reproduction of fish species in particular the species with floating eggs, and sustaining of riparian/wetland vegetation;
- Habitat protection and restoration that may span a wide array of different types of habitats, fauna and flora. The Yakou EIA approval requires the following major measures: a) ensure minimum dam releases (ecological flow); (b)mainstem fish habitats protection through prohibiting fishing in a specific period of time in a year and instream mining and structural development; b) tributary habitat restoration including building fish habitats and environmental rehabilitation of Tangbai River (largest tributary of the middle Han River); c) insitutional measures such as prohibiting fishing in a designated mainstream and tributary river sections. Similar measures are required in the approved EIA for Nipanshan project. In addition, implementation of the Wanyangzhou wetland park and strengthening management of existing fish resource reserves in lower stream of Han River will also be beneficial for aquatic, riparian and wetland habitats protection and restoration.
- Fish pass and fish reproduction program. Except the two upper-most dams (Danjiangkou and Wangfuzhou), fish passes are included in all the remaining projects, which will allow connectivity of navigation pools along a large portion of middle and lower Han River from Wangfuzhou to the Yangtze River, and provide migrating route for fishes. Meanwhile, fish reproduction programs have been included in the operation of these projects. The fish reproduction program primarily aims to reintroduce native species and restore the population of fishery resources that have been declining over the past 3-4 decades, such as the *Four Domesticated Fish (black, grass, silver, and bighead carp).*

In assessing these cumulative effects on the major VECs and the mitigation plans, This CEA noted the following,

- These existing measures encompass key elements of international acknowledged practices that address cumulative impacts associated with this type of projects. It is recognized that a comprehensive approach is needed to address long term ecosystem sustainability of the Han River. Using a systemic perspective to examine environmental conditions and cumulative impacts can help identify measures that might be overlooked at the project specific level (e.g. floodplain/riparian ecosystem);
- Inter-agency coordination becomes more and more important (and challenging) in ensuring implementation and effectiveness of the mitigation plans. For example, to implement the ecological scheduling program would require all the dams along the middle and lower Han River mainstream to open their gates and release waters in a coordinated way. This program was made possible because Hubei Provincial Govenrment made a strong commitment to leading the implementing the program. Another example is that the habitat restoration efforts in the tributaries, which will need collaboration of local governments.
- Continuous monitoring of ecosystem conditions is needed given the present data limitations and high uncertain futures. Further studies and exploration of ecosystem restoration opportunities are also necessary. For example, besides identified mainstream and tributary habitats, other types of habitats such as riparian wetland, shoals, island, and embayments merit further examination. Effectiveness of fish pass warrants continuous monitoring and enhancement measures may be needed.

Considering the scientific, insitutional and timing uncertainties associated with the cumulative impacts and various mitigation measures, the CEA suggests an adaptive management approach that encompasses continuous monitoring and evaluating ecolgoial conditions and trends, building and enhancing inter-agency coorination mechanism that features concerted efforts of pertinent agencies and led by strong leadership, and continuing study, update and implementation of ecosystem protection and restoration plan. To this end, a follow-up cumulative effect assessment building this report will be supported by the Yakou project during its implementation.

Table 8-1 shows an overview of the inter-agency coordination requirements for implementation of cumulative effects mitigation plans. Table 8-2 shows overview of benefits of the mitigation plans addressing cumulative effects on VECs. This table shall be expanded in the next step CEA.

Table 8-1 Inter-agency Coordination for Implementation of Cumulative Effects Mitigation Plans

Mitigation Measures/Plans for Cumulative Effects	Approval	Implementation Location / Scope	Implementation Agency and Inter-agency Coordination	Implementation Timing/Frequency	To be continued
Ecological Scheduling (including seasonal flooding)	• MEP approval of Yakou EIA (Feb, 2016) • Hubei Provincial Government Approval of <*Hubei Province Han River Mainstream Danjiangkou Downstream Cascade Ecological Scheduling Plan* > (Nov, 2015)	All Han River mainstream dams/reservoirs downstream of Danjiangkou reservoir (included)	Hubei Provincial Environmental Protection Departmetn, Transportation Department, Water Resources Department and Agriculture Department; involved dam/reservoir owners	• Preparation, experimental studies and tests during 2016-2017. • Annual implemenation	
Habitat protection – mainstream tail waters	• MEP approval of Yakou EIA (Feb, 2016)	• Fishing ban during March-August at 5km tailwater section downstream of Cuijiaying dam and 7km tailwater section downstream of Yakou dam • 450m3/s ecological flow releases from Yakou dam	• Fishing ban to be coordinated with the local agriculture and fishing bureau • Ecological flow releases by Yakou project operator	Annual implementation and permanent	
Habitat restoration - Tributary Ying River	MEP approval of Yakou EIA (Feb, 2016)	Ying River, from Erku to confluence of Han River mainstream	To be coordinated with local government	During implementation of Yakou project	
Habitat protection Planning study	MEP approval of Yakou EIA (Feb, 2016)	Area of influence of Yakou project	Yakou project owner	During implementation of Yakou project	
Habitat restoration – implementation of Wanyanghzou wetland park	• MEP approval of Yakou EIA (Feb, 2016) • Proposal approved by State Forestry Administration, May 2013	Han River mainstream section in central Yicheng city	Local forestry bureau and Wanyangzhou wetland management committee	During implementation of Yakou project	

	• Detailed planning approved by Yicheng government, Oct 2016				
Habitat protection – mainstream Han River	MEP approval of Nianpanshan EIA (Jan, 2017)	• Ecological flow releases from Nianpanshan dam • Fishing ban at 11km mainstream section downstream of Yakou dam to Man River confluence; • Whole Nianpanshan reservoir and core area of Aquatic Germplasm Resources Conservation Zone of *Elopichthys bambusa*(鱘), *Ochetobibus elongatus(鱤)* and *Luciobrama macrocephalus(鯇)* downstream of Nianpanshan dam.	• Fishing ban to be coordinated with the local agriculture and fishing bureau • Expansion of the protection scope of the fishery resources conseravation zone to be coordinated with its management authority	During implementation of the Nianpanshan project	
Habitat restoration - Tributary Man River	MEP approval of Nianpanshan EIA (Jan, 2017)	• Man River	• To be coordinated with the ongoing planing for water pollution control for the main tributaries of Nianpanshan reservoir	To be determined	
Fish pass, fish reproduction and releases program	MEP approval of EIAs for Xinji, Cuijiaying, Yakou, Nianpanshan and Xinglong projects	Xinji, Cuijiaying, Yakou, Nianpanshan and Xinglong dam	Dam project owners to finance, build and operate.	• Fish pass and reproduction facilities to be built during dam construction, • Continuous	

				operation of the facilities and reproduction program	

Table 8-2 Overview of Benefits of Mitigation Plans Addressing Cumulative Effects on VECs

Mitigation Measures/Plans for Cumulative Effects	Benefits on Major Valuable Environmental Environmental Components(VECs)				
	Water Quality	Fish	Riparian Resources	(To be continued in next step study)	(To be continued in next step study)
Ecological scheduling, including seasonal flooding	+ Would benefit river assimilation capacity and deduction of water pollutants	+ Would benefit reproduction of fish species with floating eggs, such as the *Four Domesticated Fish (black, grass, silver, and bighead carp)* and *Elopichthys bambusa*(鱘), *Ochetobibus elongatus(鱤)* and *Luciobrama macrocephalus(鯪)*	+ Would benefit native vegetation dependent on seasonal patterns to sustain them		
Habitat protection – protect mainstream tailwaters downstream of Cuijiaying and Yakou dam		+ Would benefit spawning and breeding of flow water type fish species. Enhance habitat diversity and offer protection from over-fishing.			
Habitat restoration - Tributary Ying River	+ Would benefit water quality improvement along the Ying River	+ Would create fish habitats such as spawning shoals and riparian vegetation for various fish species and offer protection from	+ Would create/enhance riparian habitats and provide educational opportunities related to value of riparian resources		

		overfishing			
Habitat restoration – implementation of Wanyanghzou wetland park	+ Would benefit river water quality improvement by restricting wastewater discharge and restroring overall aquatic and riparian ecosystem	+ Would benefit fish habitats and diversity by overall improvement of aquatic and riparian ecosystem	+ Would restore currently disturbed riparian ecosystem through wetland restoration and management strengthening		+ Would provide great recreational opportunities by creating a public park for local communities
Habitat protection – mainstream Han River Nianpanshan reservoir and downstream of Nianpanshan dam	+ Would benefit water quality improvement through strengthened regulation of reservoir and fishery resource conservation zone	+ Would benefit protection of various fish species in particular the *Elopichthys bambusa*(鱘), *Ochetobibus elongatus(鮠)* and *Luciobrama macrocephalus(鯁)*	+ Enhance riparian areas and provision of related educational opportunities		
Habitat restoration - Tributary Man River	+ Would benefit water quality improvement along the Ying River	+ Would create fish habitats such as spawning shoals and riparian vegetation for various fish species and offer protection from overfishing	+ Would create/enhance riparian habitats and provide educational opportunities related to value of riparian resources		
Fish pass, fish reproduction and releases program		+ Would allow connectivity of navigation pools along a large portion of middle and lower Han River and provide migrating route for fishes; Would restore and reintroduce population of fishery resources that have been declining over			

		the past 3-4 decades, such as the *Four Domesticated Fish* (black, grass, silver, and bighead carp) and *Elopichthys bambusa*(鱘), *Ochetobibus elongatus(鱎)* and *Luciobrama macrocephalus(鯪)*			

8.2 Coordinated Ecological Scheduling Program

Considering the cumulative impacts resulting from cascae development and operation on middle and lower Han River, the Ministry of Environmental Protection required to develop a coordinated ecological scheduling plan during its review of the Yakou EIA. The Yakou project owner Hubei Provincial Transportation Department thus commissioned an Analysis Report for Coordinated Ecological Scheduling Plan for Han River Cascades Downstream of Danjaingkou. The Hubei Provincial Government approved the plan in November 2015, which paved the way for MEP to approve the Yakou EIA. Subsequently, during review of the Nianpanshan project EIA in 2016, the MEP emphasized that the plan must be implemented.

Ecological scheduling by coordinated dam releases that allows previously controlled river flows to mimic natural hydrologic regimes (including seasonal flooding) along a river will have various benefits to water quality, fish and riparian wetlands, as discussed in prior section. Ecological scheduling is an internationally proven practice in migitating cumulative impacts imposed by river cascade development. For example, in the US, pursuant to the Endangered Species Act, the US Fish and Wildlife Service has required dam operators to adjust river flows to more closely mimic pre-settlement hydrologic river patterns. Such practices have been applied in Missouri River dam and reservoir system, upper Mississippi River, etc.

This section summarizes the fingins and recommendations of the Analysis Report for Coordinated Ecological Scheduling Plan for Han River Cascades Downstream of Danjaingkou and the procinial government approval.

After implementing the cascade development on the middle and lower Han River, hydrological conditions required by the breeding of the four major Chinese carps (i.e. the *Four Domesticated Fish*) such as rising water and flow velocity will be difficult to be met given the rising water level and reduced flow velocity under normal operation of each dam/reservoirs. However, given that Cuijiaying, Yakou, Nianpanshan and Xinglong are all low-head dams, the reservoir section can be turned to the natural river capable of maintaining and restoring spawning ground functions if all discharge sluices are open and when inflow from upstream can meet hydrological conditions required for fish breeding.

Based on this hydrological and ecological analysis, during June to August every year, ecological scheduling will be implemented throughout the middle and lower reaches of Han River according to upstream inflow and tributary inflow situations. Through ensuring certain ecological discharge from Danjiangkoudam and coupled with the flooding process of the Tangbai River (largest tributary of middle Han River), it is proposed to implement full open discharge of the cascades at least twice a year, so as to ensure the success of spawning in existing spawning grounds and completion of fertilized egg floating-hatching process, and unblocked fish migratory passageway.

During implementing ecological scheduling operation, when inflow increases from 800 m3/s to 1200 m3/s, obvious water level rise occurs. Flow velocity at various cross sections exceeds 0.5 m/s, meeting spawning requirements of the four major Chinese carps in terms of basic hydrological conditions.

Based on multi-year analysis of flood peak process during the spawning periods of the four major Chinese carps, the breeding of the four major Chinese carps in the middle and lower reaches of Han River relies on flood of Tangbai River, while the releases from

Danjiangkou facilitate the scale of spawning. Larval resources of the four major Chinese carps were always found when there was the flood from Tanbai River and when flow rate reaching 1200 m3/s at Huangzhuang hydrological station (located at about 75km below Yakou dam), suggesting the hydrological scheduling requirement is met.

Therefore, ecological scheduling operation shall be based on flood occurrence in Tangbai River. Taking into account other inflows in this section and flood process of Tangbai River, during May to August ecological scheduling operation shall be jointly implemented at least twice a year. Specifically,

- Ecological scheduling shall be promptly launched when Dongpo Flood Prevention Station of Tangbai River forecasts 24 hours beforehand flood of or exceeding 600 m3/s during mid-and late May to August in high flow year and normal flow year, or flood of or exceeding 300 m3/s in dry flow year. Namely, ecological scheduling operation shall be launched right away when Tangbai River forecasts flood discharge reaching 600 m3/s during mid-and late May to July every year.
- Shall there be no flood of 600 m3/s scale during mid-and late May to July, the year is determined as dry flow year. Ecological scheduling operation shall be launched when Tangbai River forecasts flood discharge reaching 300m3/s after entering August. Meanwhile, Danjiangkou needs to release 400 m3/s of ecological discharge to ensure that flow rate at Huangzhuang hydrological station reaches 1200 m3/s. Meanwhile, Wangfuzhou will discharge fully the inflow. The four dams of Cuijiaying, Yakou, Nianpanshan and Xinglong will open sluices for pre-discharge 24 hours beforehand, in order to bring down reservoir water level.
- When real-time discharge of Dongpo Flood Prevention Station of Tangbai River reaches the triggering flow rate for ecological scheduling, open discharge will be jointly implemented by Cuijiaying, Yakou, Nianpanshan and Xinglong dams so as to facilitate fish swimming upstream to spawning grounds. Open discharge will last about 5 to 7 days till the end of flood peak so as to facilitate fertilized eggs floating downstream.
- In extremely dry flow year, under the conditions that there is no flood of or exceeding 600 m3/s at Dongpo Flood Prevention Station of Tangbai River during mid- and late May to August, and there is also no flood of or exceeding 300 m3/s in August, a joint ecological scheduling operation following the above mentioned methods shall be launched when a flood of any scale occurs in Tangbai River or Han River mainstream in early and mid-September during autumn flood season.

The Cuijiaying, Yakou, Nianpanshan and Xinglong dams will successively perform open discharge and the releases by opening all sluices can lead to hydrological conditions meeting breeding requirements of the four major Chinese carps and rare fish such as *Elopichthys bambusa*, *Ochetobibus elongatus* and *Luciobrama macrocephalus*. Meanwhile, it can also remove dam blockage effects, helping maintaining and restoring spawning grounds of the four major Chinese carps in Yicheng, Guanjiashan, Zhongxiang, Maliang and Zekou. In addition, considering that the ecological scheduling operation is to be conducted during flood season, it is also economically feasible as it has little impact on shipping and power generation, because each operation can be completed within one week under accurate inflow forecasting. Implementation of ecological scheduling, combined with fish pass and artificial breeding and releasing, can substantially reduce cumulative adverse impact on aquatic eco-environment in the middle and lower reaches of Han River resulting from cascade development.

Ecological scheduling by allowing seasonal flooding will have other benefits on water quality and riparian wetland as well. Seasonal floods help remove sediments, nutrient and some contaminants, accelerate assimilation of water pollutants, and prevent eutrophiccation. It helps connect the river with lakes and wetlands and help sustain riparian vegetation dependent on seasonal patterns.

8.3 Habitat Protection and Restoration Plan

Protection measures for the mainstream and tributary habitats have been included in project specific EIAs for each dam/reservoir development.

8.3.1 Xinji project

- Mainstream habitat protection

Xinji is located between Wangfuzhou and Cuijiaying porjects. According to development features of the 3 stages, natural river sections on the mainstream have been reserved in the tailwater section upstream of Xinji reservoir and downstream of Xinji dam. Therefore, the two tailwater sections are designated as protected mainstream habitats:

- ✓ the 18 km river section between Xinji reservoir tailwater and and dam site of Wangfuzhou, and
- ✓ the 4.3 km river section between Xinji dam site and reservoir tail of Cuijiaying reservoir.

The two tailwater sections are designated as fishing-ban area with boundaries signaled and no fishing or development activities such as in-stream sand mining is allowed.

- Tributary habitat protection

According to survey, major tributaries upstream and downstram of Xinji dam incude Bei River and Nan River. After the completion of Xinji project, the natural river section (tailwater section) remained and the tributaries will be an important aquatic ecological habitat. Comparing fish species between mainstream and tributaries shows that, while the number of tributary fish species is less than that of the mainstream, they share certain similarities. After project completion, tributary habitats will provide fish habitats for native fish species. Further habitat restoration opportunities for the tributaries should be explored.

8.3.2 Yakou project

- Mainstream habitat protection

Results of fish survey reveal that fish previously favoring flowing water are mostly found in the reservoir tail water section. Therefore, it is believed that after the completion of reservoir tailwater section can provide suitable habitat for fish favoring flowing water. Given that Cuijiaying dam is located upstream of Yakou navigation complex, under Cuijiaying open discharge during flood season, Yakou reservoir tail will have a certain range of flowing river section. Similarly, during open discharge of Yakou dam in flood season, river section downstream of Yakou dam can basically maintain flowing river section, providing spawning and breeding conditions to fish with floating eggs.

Therefore, the flowing river sections between Cuijiaying dam and Yakou reservoir tailwater, and between downstream of Yakou dam and Nianpanshan reservoir tailwater (where flow velocity exceeding 0.2 m/s) are designated as mainstream habitat protection zone. According to initial estimate, the flowing river sections exceeding the flow velocity

of 0.2 m/s is 5 km and 7 km respectively downstream of Cuijiaying and Yakou dam. The following measures are proposed

- ✓ Fishing ban during March-August at 5km tailwater section downstream of Cuijiaying dam and 7km tailwater section downstream of Yakou dam;
- ✓ No water development or construction such as in-steram sand mining is allowed;
- ✓ Ensure 450m3/s ecological flow releases from Yakou dam and install online flow rate monitoring equpment;
- ✓ Increase releases during fish spawning seasons appropriately to ensure spawning, breeding and inhibiting for fish.

- Tributary habitat protection

Tributaries constitute an intergral part of river ecosystem and a major part of river biodiversity. Research results demonstrate that completion of many fishes' lifecycle, including feeding, breeding and wintering, often occurs while moving between mainstream and tributaries. Considering the impacts of cascade development on the Han River mainstream, the flowing water conditions in tributaries becomes more critical to flowing-water type fish species, especially those fish species whose breeding need stimulation of flowing water.

There are no major tributaries between Cuijiaying dam and Yakou dam except two seasonal rain channels (Chun River and Wei River), both being gated by regulation facilities. Man River and Ying River join the Han River at about 10km downstream of Yakou dam. The Man River has a length of 184km with drainage area. The Man River's water quality is poor with scarce fish resources, making it not suitable for fish habitat protection currently. While, the Ying River, 63km in length, has a drainage area of 404km2 and flow rate of 5.35m3/s. Though two reservoirs were built in its upstream, its downstram has alternated curving and straight sections, shoal and ponds, rapid and slow currents. Substrate type include pebble, cobble, sands and sludge, providing spawning and breeding conditions for fish speicies with sticky eggs. Hence the Ying River is ideal for habitat protection and restoration. The proposed protection section extends for Erku to river confluence with Han River mainstream, approximately 18km long (see picture below).

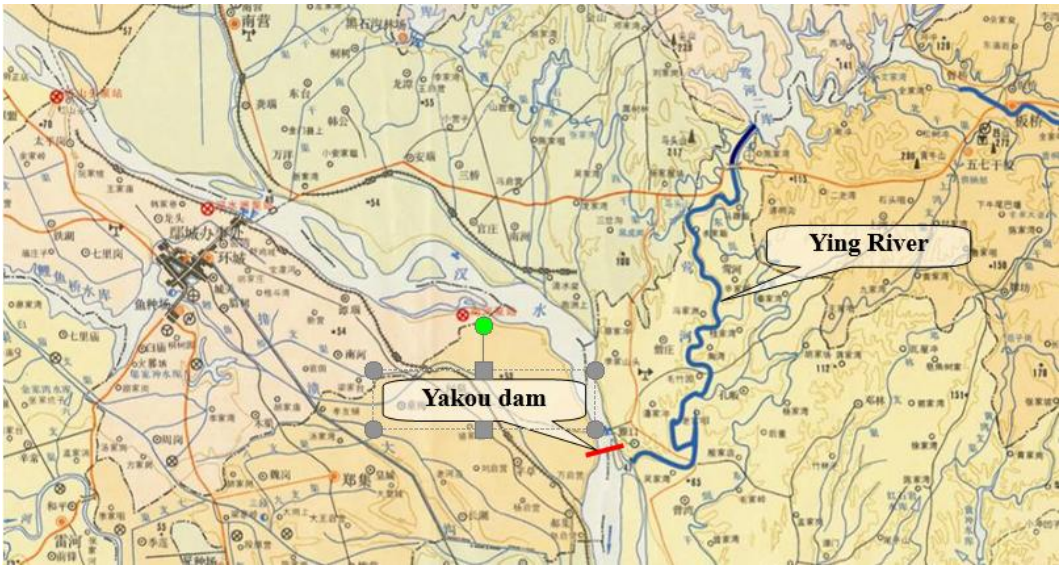


Figure 8-1 Location of Ying River (Tributary Habitat Restoration)

Targeted fish species for protection in the tributary habitats are native species and

commercially important species, including *culter alburnus, rhinogobio typus, squaliobarbus curriculus, xenocypris argentea gunther, hypophthalmichthys molitrix, aristichthys nobilis, mylopharyngodon piceus, ctenopharyngodon idellus, distoechodon tumirostris, parabramis pekinensis, squalidus argentatus, and saurogobio gracilicaudatus*.

The main habitat protection measures are as follows:

- ✓ 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 3~5m2.
- ✓ Fishing in the protected tributary segments shall be banned; these segments shall be marked with "no fishing" signs.
- ✓ Long-term monitoring of fish species, aquatic life, and water quality shall be implemented.
- ✓ 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.
- ✓ 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" signals.

8.3.3 Nianpanshan project

- Mainstream habitat protection

Similar to above, downstream sections of Yakou dam and Nianpanshan dam will form flowing water river sections that can provide favorable conditions for the breeding of fish species with floating eggs. Upstream Nianpanshan dam, the Han River section between the Man River's confluence and Nianpanshan dam site, 47km in length, is the experimental zone of Aquatic Germplasm Resources Conservation Area of *Elopichthys bambusa*(鱘), *Ochetobibus elongatus(鱤)* and *Luciobrama macrocephalus(鯇).* While the 86.6 km long section from Nianpanshan dam extending downstream to Guanmiaozha is designated as the core zone of the Conservation Area. Namely, the river section between Man River confluence and Guanmiaozha are under strict regulation of the Conservation Zone. It is proposed to extend the protection scope by covering the 11 km long section between Yakou dam to Man River confluence, as a way to protect the mainsteam habitat.

- Tributary habitat protection

Within the assessment area there are two major tributaries, namely Li River and Man River joining the Nianpanshan reservoir. According to research data and site survey, Li River, located in Yangwanxi of Lingkuang County in Zhongxiang city, has a small basin area and poor water quality, mainly inhabiting small-sized fish. Man River is 188 km in length and has a basin area of 3244 km2 and an annual average discharge of 46 m3/s. During EIA study for Yakou project, Man River was considered not suitable for tributary habitat restoration given its poor water quality scarce fish resources. Nonetheless, during the preparation of Nianpanshan EIA, Man River was chosen to carry out tributary habitat

restoration to meet regulatory requirement on habitat protection.

Currently, the planing for water pollution control for the main tributaries of Nianpanshan reservoir is ongoing, which covers the Man River. Therefore, it is proposed that habitat protection measures will be impelemented after the planned water pollution control measures take effective and the Man River quality has been improved effectively.

In addition, at the confluence of the tributary with mainstream Han River, the flow water and micro-flowing water are favorable for fish spawning and breeding, hence the certain protective measure should be carried out to protect the confluence habitats.

8.4 Fish Pass

Except the two upper-most dams (Danjiangkou and Wangfuzhou), fish passes are included in all the remaining projects, which will allow connectivity of navigation pools along a large portion of middle and lower Han River from Wangfuzhou to the Yangtze River, and provide around 600 km long migrating route for fishes on the mainstream Han River. At present, the fish pass of Cuijiaying and Xinglong projects are already put into operation.

8.4.1 Xinji fish pass

Information regarding the the type and dsign of Xinji fish pass is inadequate. The Expet Opinion on Technical Review of Xinji Project EIA (December 2011) indicates that water level is 74.43m and 64.12m before and after the Xinji dam; design speed of fish pass adopts 1.0m/s; bottom slope is 1/60; the fish cell size is 2.0*3.5m; and water depth is 1.5-2.0m.

According to the current situations of migratory and semi-migratory fish surveyed and combined with features of Xinji hydropower station, fish-passing subjects are selected to be: semi-migratory fish species such as the Four Domesticated Fish (*Ctenopharyngodon idellus*, *Mylopharyngodon piceus*, *Hypophthalmichthys molitrix*, *Aristichthys nobilis)*, *Coreius heterodon* and *Elopichthys bambusa*.

As planned, Xinji project will be built around 2020. In the next step follow-up CEA, further information on the technical and operational aspects of Xinji fish pass should be examined.

8.4.2 Yakou fish pass

The Yakou project FSR and EIA include details of fish pass design. Total length of Yakou fish pass is 951.08m, among which ecological passage (nature-imitated pass, ses picture) is 560.58m and engineering fishway section is 390.5m. The ecological passage has a trapezoid cross section, with a 2.0m bottom width, a 1:2.5 side slope, a water depth of 2.0m, and surface water width of 12.0m under normal operating water depth, and a passageway longitudinal gradient of 1%. There are 45 sections (section length 10m, divided by 200mm grouted rubble diaphragm) and 2 resting sections (total length 60m). Side slope uses reinforced grouted rubble and bottom paved by pebble or gravel stone.

Figure 8-2 Nature Imitation Fish Pass

The fish pass design adopts 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. The fish pass general layout is shown in below figure.

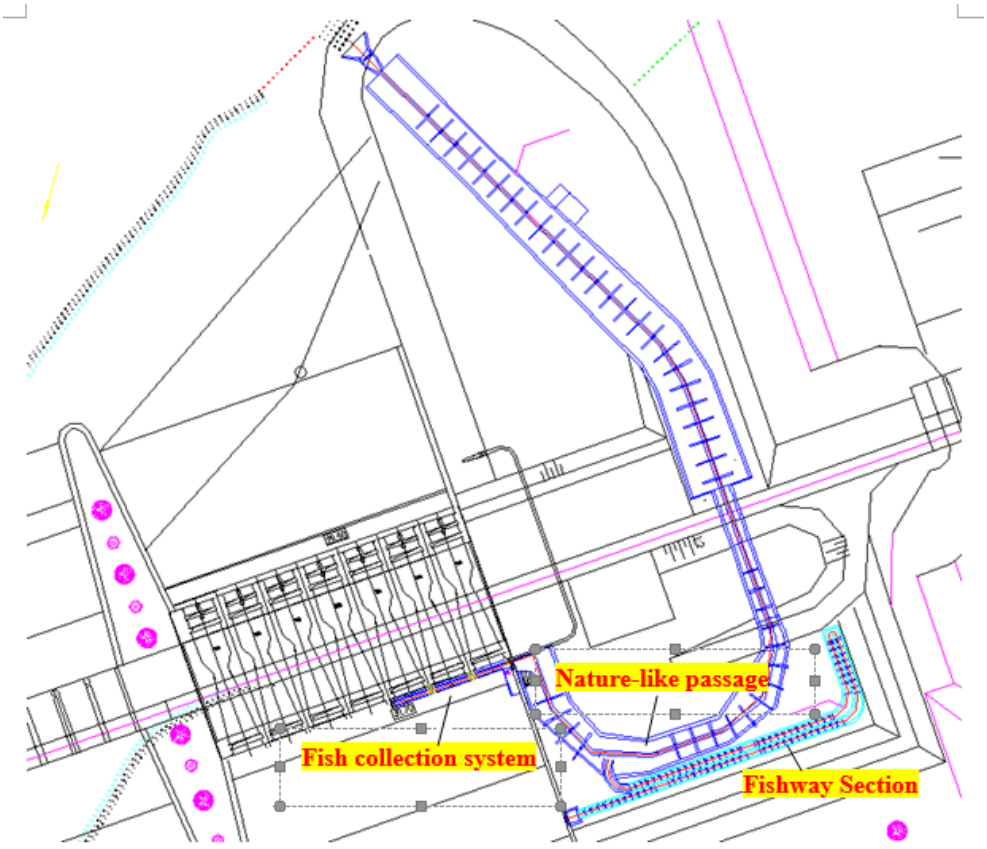


Figure 8-2 Yakou Fish Pass Layout

8.4.3 Nianpanshan fish pass

The Nianpanshan project FSR and EIA include details of fish pass design. A one-sided vertical gap type of fish pass was recommended. Two inlets at the elevation of 38.3m and 40.6m were designed to accommodate varied river levels. The outlet is set at 48.82m. The total length of the fish pass is 1,123m. operational water depth is 1.5-4.0m. General layout is shown in below picture.

Figure 8-3 Nianpanshan Fish Pass

8.5 Fish Breeding Facilities and Release Program

In compliance with domestic regulation, Xinji, Cuijiaying, Nianpanshan and Xinglong projects include fish breeding facilities and is mandated to carry out fish breeding and releases program. Cuijiaying and Xinglong projects' fish program is under operation after the two projects were operational. Danjiangkou and Wangfuzhou were built when there was no such regulations. Fish breeding facilities has been planned for Danjiangkou complex. Figure 8-shows the locations of these fish breeding facilities on the middle and lower Han River.

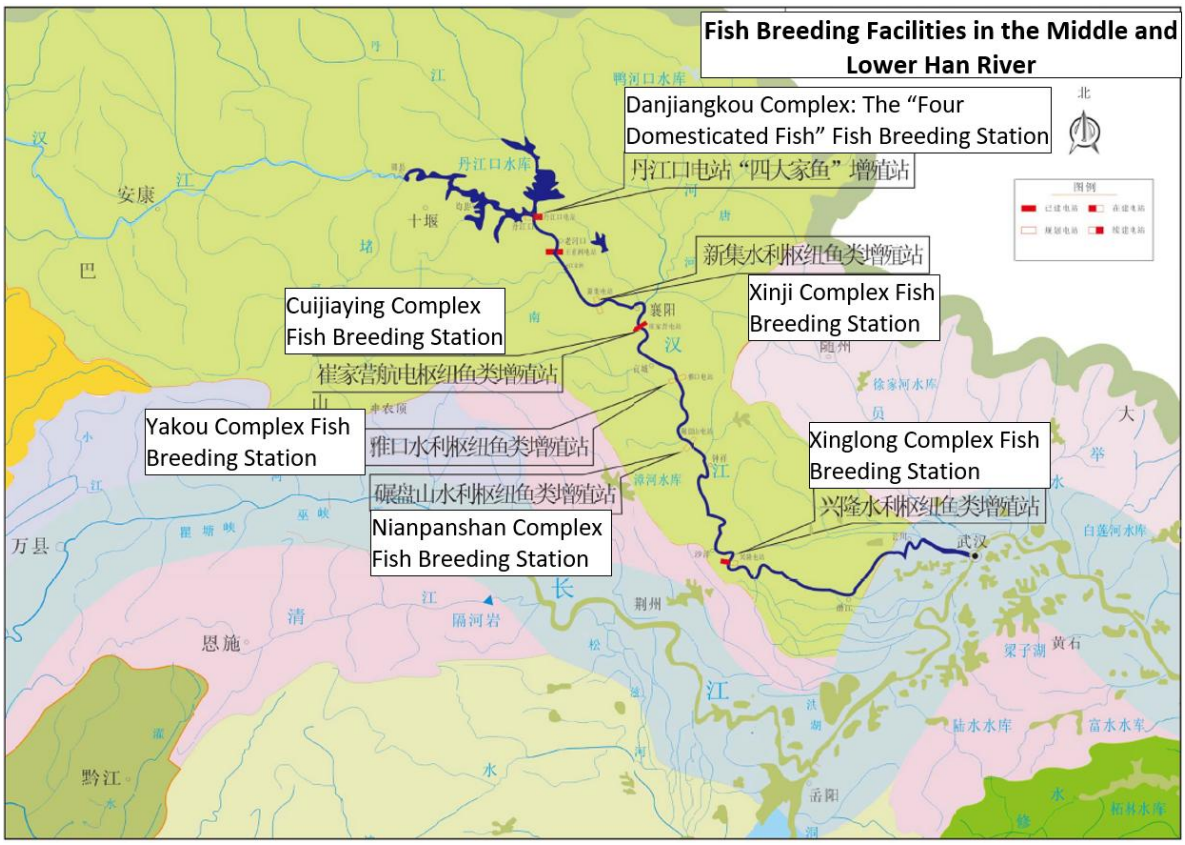


Figure 8-4 Fish Breeding Faciliteis on the Middle and Lower Han River

8.5.1 Xinji Fish Program

A fish breeding and release station is included in the design of the Xinji project. It is required that apart from releasing task, the fish breeding and releasing station is also responsible for relevant research on fish breeding and releasing technology. Subjects of artificial breeding and releasing mainly include key protected aquatic wildlife of Hubei province and commercial important fish species such as *Onychostoma macrolepis*, *Saurogobio gracilicaudatus*, *Parabramis pekinensis*, *Megalobrama skolkovii*, *Siniperca chuatsi*, *Xenocypris microlepis*, *Culter mongolicus*, *Pelteobagrus fulvidraco* and *Squaliobarbus curriculus.*

8.5.2 Yakou Fish Program

By deisgn, the Yakou fish reproduction facility has an area of 86.7mu. General layout is shown in below picture.

Figure 8-5 Yakou Fish Breeding Facility

The Yakou fish program targeted species include *leiocassis longirostris, megalobrama skolkovii, parabramis pekinensis, squaliobarbus curriculus, distoechodon tumirostris, leiocassis crassilabris,* the Four Domesticated Fish and three large fish species *Elopichthys bambusa*(鱘), *Ochetobibus elongatus(鱤)* and *Luciobrama macrocephalus(鯇).* Nonetheless, *the Ochetobibus elongatus(鱤)* and *Luciobrama macrocephalus(鯇)* have disappeared in the river for many years and it is impossible to carry out domestication or reproduction research or practice; they can only be key observatory subjects needing survey on resources situation. The Four Domesticated Fish (*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; Hubei province can provide enough quality fries on its own. The *Elopichthys bambusa*(鱘), being a ferocious large fish of relatively great impact to fish populations, is not suitable for releasing at the moment. In the future, it may be suitable for breeding and releasing based on further resources monitoring situations. The *Leiocassis crassilabris* is currently not yet successful in artificial domestication and reproduction, and may be suitable for breeding and releasing when with matured technology resulting from the recently started research on domestication and reproduction technologies. Therefore, immediate key releasing species include *The Four Domesticated Fish, leiocassis longirostris, megalobrama skolkovii, parabramis pekinensis, squaliobarbus curriculus and distoechodon tumirostris*. Breeding and releasing subject added in the long term include *leiocassis crassilabris*.

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 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.

Preliminary releasing number is 4 million fish/year, among which 3.5 million are to be

subcontracted for cultivation and 500 thousand fish are to be reproduced and cultivated by the breeding and releasing station.

3 releasing locations were proposed, namely Tangbai River confluence, Wei River confluence, and Ying River confluence with Han River. 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.

8.5.3 Nianpanshan Fish Program

According to the Nianpanshan FSR and EIA, its fish program is identical with Yakou project's fish program in general, except that the releasing locations are placed upstream and downstream of Nianpanshan dam.

8.6 Riparian Areas Protection and Restoration

Section 7.5 discussed the cumulative effects on Han River's riparian and terrestrial ecosystem. In conducting this CEA, it is recognized that terrestrial ecology study is a regular domestic requirement for such type of water project and the study covers riparian areas from spatial perspective. The terrestrical ecology studies of previous EIAs and retrospective EIAs also covered subject matters of river flat wetland, wetland park, and upland fauna and flora. Nonetheless, review of these EIAs and retrospective EIAs suggests that among other ecosystems such as aquatic system, the riparian areas have been less well studied. This is not a surprise as internationally the unique ecological function and value of riparian area received attention only in the past 2-3 decades only.

Therefore, on riparian area this CEA intends to discuss general ideas of and strategies for the protection and restoration of riparian ecosystem pertinent to the middle and lower Han River, and leaving detailed work to be carried out in the next step follow-up CEA. In addition, the Wangyangzhou Wetland Park will be used as a case to present existing measures and opportunities for the development of future riparian ecysstem protection and restoration plan.

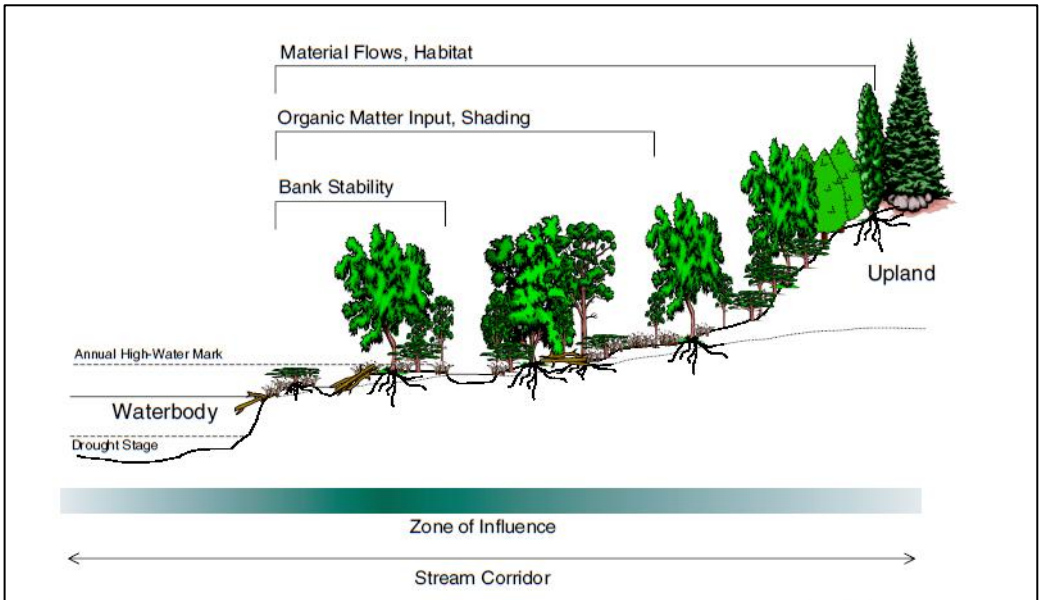


FIGURE ES-1 Schematic of a generic riparian area showing a zone of influence relative to aquatic and upland areas. The intensity of riparian influence is depicted with shading. "Material flows" refers to energy, organic matter, water, sediment, and nutrient flow.

Figure 8-6 Riparian Areas

The picture shows riparian area that is located between waterbody (aquatic) and upland areas. Specific to the Han River context, riparian areas are more expansive compared to wetland because ripariain areas may include not only portions of wetlands, but also non-vegetated portions of point bars[8], and encompass certain terrestrial areas that do not nessisarily requie inundation and saturation nearthe surface, as do wetlands.

The CEA recognized that cumulative effects on riparian areas come from several major sources,

- Changes in the hydrology of river and riparian areas, including construction of dams, river bank stabilization structures, channelization and withdrawals of surface and ground water;
- Agriculatural activities such as row crop and livestock grazing on riparian areas;
- Urban development activities particulary when occurring on or in the vicinity of ripariain areas;
- Recreational activities as riparian areas are popular sites for those activities;
- Other industry such as mining and transportation activities when occurring in-stream, on riparian areas or in the vicinity.

8.6.1 Analysis of Existing Measures Addressing Riparian Areas

Generally speaking, riparian areas restoration measures may range from relatively straightforward measures such as planting vegetation, removing small-control structures, or reducing or removing a stressor such as grazing or farming on riparian areas, to more holistic watershed approaches.

- Reestablising the hydrologic regime.
  Where natural hydrologic regimes and cooresponding sediment transport regimes have been significantly altered by dams, levees, locks, low-water diversion channels, or off-stream storage ponds, the most important restoration need is to reestablisih or restore these disbursement regimes to the extent possible. Specifically, changes in flow regime such as dam re-regulation to return the hydrologic regime to a more natural state, focusing on reestablishing the magnitude, frequency, and duration of peak flows needed to reconnect and periodically reconfigure channel and floodplain habitats. This approach has the greatest potential for restoring riparian functioning.

  In the case of Han River, ecological scheduling will be carried out through coordinated dam opeations to create articial flooding process along the middle to lower Han River. The current design of ecolgocial scheduling targets fish reproduction primiarly. Nonetheless, it provides a institutionalized mechanism for riparian areas restoration. By scientifically modifying the dam operation plan, it can re-create a more natural flow regime and associated sediment dynamics that are of fundamental importance for recovering riparian vegetion and plant communities and the functions they provide.

- Vegetation restoration
  Because of the fundamental importance of vegetation to the ecological functioning

[8] A **point bar** is a depositional feature made of alluvium that accumulates on the inside bend of streams and rivers below the slip-off slope. Point bars are found in abundance in mature or meandering streams. They are crescent-shaped and located on the inside of a stream bend, being very similar to, though often smaller than, towheads, or river islands.

of riparian areas, where such vegetation has been dgreaded or removed, its recovery is a necessary part of any restoration effort. Removing and put limit on land- and water-use practices (e.g. construction, grazing and farming on riparian areas) that caused degradation and planting native plants will be effective.

Another type of comprehensive vegetation approach is to build constructed buffer zones, which can be considered an effective conservation practice. Under proper conditions, buffer zones are highly effective in removing pollutants from overland and shallow subsurface flow; they provide various types of habitats, flood control, groundwater discharge and other environmental services.

- Other activities
  Educational programs are needed to help understand the ecological importance and intrinsic human values associated with the riparian areas. Such educations programs on riparian areas needs to reach traditional educational and research institutions, plicy makers, natural resources personnel, government officials, developers and the public at large.

  Recreational use of riparian areas provides an excellent opportunity to foster stewardship of riparian areas. However, recreational development in riparian areas lacks sounds ecological assessment and planning. Careful design using a landscape perspective, limitations on certain uses that are incompatible with preservation or rehabilitation of riparian areas, and involvement of the local community and other stakholders are needed. The goal of managing recreational activities in riparian areas is to perpetuate natural functions (e.g., wildlife habitat) whle still allowing human use and enjoyment of these areas.

8.6.2 Wanyangzhou Wetland Park

The proposed Wanyangzhou wetland park in Yicheng city is intended for providing recreational opportunities for local communities. It also provides excellent opportunities for preserving and restoring ripariain areas along the Han River.

According to the resource baslines suevey, local government proposed to build the wetland park because "*unregulated sand mining, grazing, land reclaimation for farming and aquaculture in the river stream and river flats became more and more severe; natural river flow in the segemetn disturbed; water quality deteriorated; and wetland system integrity damaged*." Below figure shows the current resource status of the Han River section. A vast riparian area adjacent to Yicheng urban center has been subject to severe human disturbance and lost its original ecological functions and habitats significantly. Due to the lowering of Han River level over the years, more and more river flats and shoals were utilized by local residents, which has reduced the habtats for wetland birds.

A Yicheng *Wangyangzhou National Wetland Park Core Area Constructive Detailed Planning*. According to the detailed planning, the zoning of the core zone of the wetland park is shown in **Figure 8-7**. The general layout of the wetland park is shown in Figure 8-8. It has significant sections of riparian areas restoration and restricting development acitivities, in addition to a science eduction zone and a reasonable utilization and management zone. The Yicheng Municipal Government approved the detailed planning on October 26, 2016, and requsted the municipal forestry bureau to implement the plan as soon as possible.

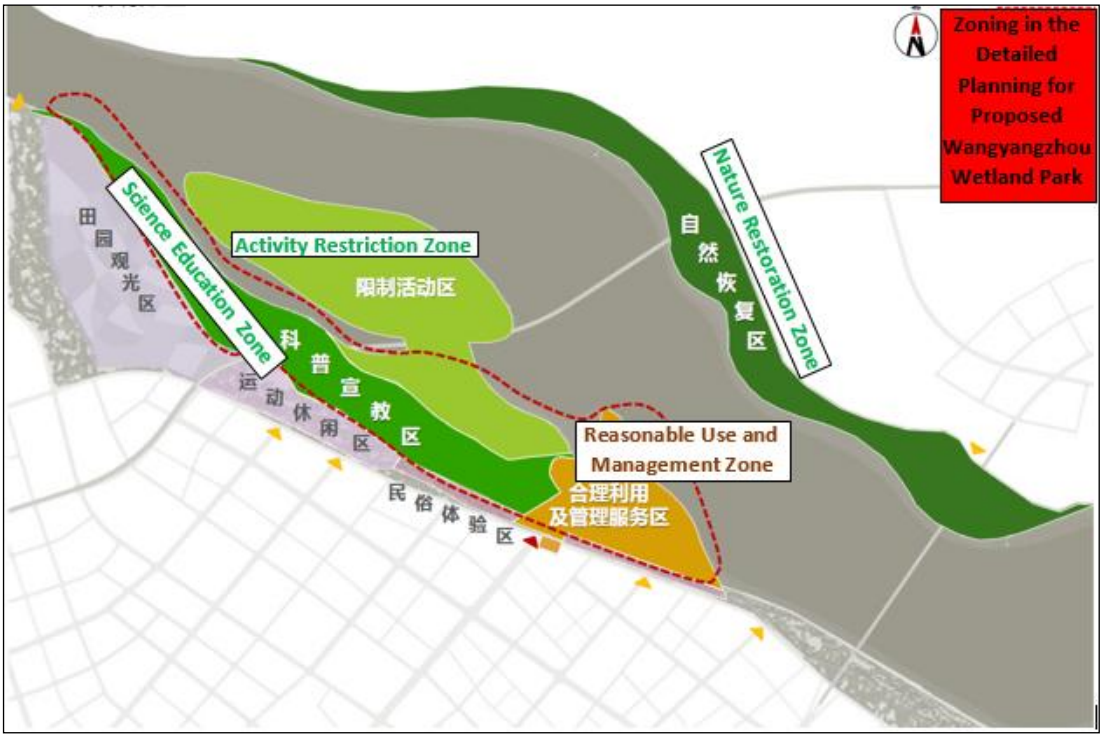


Figure 8-7 Zoning for the Wangyangzhou Wetland Park

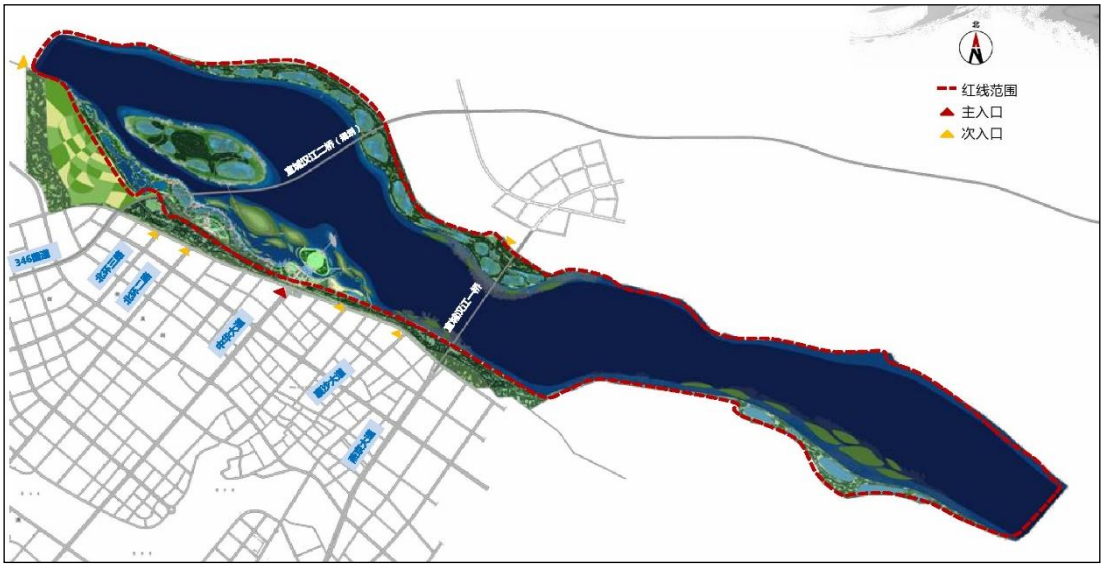


Figure 8-8 Layout of Wangyangzhou Wetland Park

The "wetland" in the context of the Wanyangzhou survey and planning documents includes both waterbodies and adjacent riparian areas. It is worth noting that the restoration zone are primarily riparian areas. The wetland park planing indicates that to ensure the implementation of the wetland park planning, limitations on human activities and facilitation of natural restoration will need to be carried out.

9 Conclusion and Recommendations

(1) The cascade development along the middle and lower Han River will greatly benefit regional economic development, navigation, renewable energy supply and irrigation.

(2) After the completion of the planned cascade development, a combination of seven successive dam/reservoir system comprised of Danjiangkou, Wangfuzhou, Xinji, Cuijiaying, Yakou, Nianpanshan and Xinglong will be formed in the middle and lower reaches of Han River. Compouded by the South-to-North water diversion, the cascade development will further alter hydrological regime of the middle and lower reaches of Han River mainstem. Annual average flow velocity and water level of will reduce; water way erosion and sedimentation dynamics in the middle and lower Han River will change.

(3) After the completion of the planned cascade development, total quantity reduction of water resources will lead to loss of water environmental carrying capacity. Water quality will not significantly deterioriate. Reservoir area of various complexes will show slight eutrophication trend. Average water temperature in the river section upstream of Xinji will be lowered.

(4) Main cumulative effects resulting from the cascade development will be on aquatic ecosystem, in particular the fish species with floating eggs as its success of spawning life stage will be compromised by dam blockage and lowered velocity. Existing fish pass and artificial breeding still have limitations. The dam along Han River are all low-head with discharge sluice taking up around 70% of the dam length, boasting excellent discharge capability. Hydrological conditions such as water level and flow velocity of relevant river sections can be rapidly restored to mimic natural riverway level if all discharge facilities are opened. Implementation of ecological scheduling, compbined with fish pass and breeding measures and habitat restoration measures, the impacts on fish can be reduced to acceptable level.

(5) Plants affected by the three planned dams (Xinji, Yakou and Nianpanshan) are common species and cosmopolitan species. They are also extensively distributed in the surroundings of the assessment area. Small quantity loss will not cause the extinction of these plants. In addition, micro-climate in the surroundings of the reservoir area will be improved after reservoir water storage, which is beneficial to vegetation coverage rate and productivity improvement. Construction of planned complexes and reservoir water storage will have little impact on the survival of terrestrial animals, however, their survival space will be narrowed and survival conditions will be worsened due to increased population quantity. After water storage, the reservoir area will attract large numbers of water birds and amphibians favoring still water to inhabit and breed in the reservoir area, leading to increase of population quantity and individual quantity.

(7) Considering that assessment of this stage is mainly conducted on the basis of examining second-hand information obtained, therefore this research proposes that further survey and data collection shall be carried out, so as to better assess and quantify cumulative impact of construction of navigation complexes along Han River basin, in particular the level of impact on water quality and local species from planned construction of navigation complexes along Han River. A stage 2 CEA will be carried out. Long-term monitoring and survey shall be conducted on water quality of different river sections of Han River, and aquatic and riparian habitats within the reservoir area and river section in

the lower reach.

APPENDIX 1: FISH INVENTORY (2014 COMPREHENSIVE SURVEY)

Appendix 1 Inventory of Fish Species in the Middle and Lower Han River (2004 Comprehensive Survey)

种　　类	学　　名	丹江-襄樊	襄樊-沙洋	沙洋-汉口
Species	Latin Name	Danjiang-Xiangfan	Xiangfan-Shayang	Shayang-Hankou
鲤形目	**CYPRINIFORMES**			
鳅科	**Cobitidae**			
沙鳅亚科	**Botiinae**			
中华沙鳅	*Botia superciliaris* Gunther	+	+	+
花斑副沙鳅	*Parabotia fasciata* Dabry de Thiersant	+	+	+
紫薄鳅	*Leptobotia taeniops* (Sauvage)	+	+	+
花鳅亚科	***Cobitinae***			
泥鳅	*Misgurnus anguillicaudatus* (Cantor)	+	+	+
平鳍鳅科	***Homalopteridae***			
平鳍鳅亚科	***Homalopterinae***			
犁头鳅	*LepturichthysFimbriata*(Gunther)	+	+	
鲤科	**Cyprinidae**			
鱊亚科	**Danioninae**			
宽鳍鱲	*Zacco platypus* (Temminck et Schlegel)	+	+	+
马口鱼	*Opsariichthys bidens* Gunther	+	+	+
中华细鲫	*Aphyocypris chinensis* Gunther	+	+	+
雅罗鱼亚科	**Leuciscinae**			
青鱼	*Mylopharyngodon piceus* （Richardson）	+	+	+
草鱼	*Ctenopharyngodon idellus* (Cuvier et Valenciennes)	+	+	+
赤眼鳟	*Squaliobarbus curriculus* (Richardson)	+	+	+
鳡	*Elopichthys bambusa* (Richardson)	+	+	+
鲴亚科	**Xenocyprinae**			
细鳞斜颌鲴	*Xenocypris microlepis* Bleeker	+	+	+
黄尾鲴	*Xenocypris davidi* Bleeker	+	+	+
银鲴	*Xenocypris argentea* Gunther	+	+	+
圆吻鲴	*Distoechodon tumirostris* Peters	+	+	
似鳊	*Pseudobrama simoni* (Bleeker)	+	+	+
鲢亚科	**Hypophthalmichthyinae**			
鳙	*Aristichthys nobilis* (Richardson)	+	+	+
鲢	*Hypophthalmichthysmolitrix*(CuvieretValenciennes)	+	+	+
鲌鲅亚科	**Acheilognathinae**			
中华鲌鲅	*Rhodeus sinensis* Gunther	+	+	+
大鳍鱊	*Acheilognathus macropterus* (Bleeker)	+	+	+
鲂亚科	**Cultrinae**			

䱗　条	*Hemiculter leucisclus* (Basilewsky)	+	+	+
油　䱗	*Hemiculter bleekeri* Warpachowsky	+	+	+
似鲿	*Toxabramis swinhonis* Gunther	+	+	+
鲂	*Megalobrama skolkovii* Dybowsky	+	+	+
团头鲂	*Megalobrama amblycephala* Yih	+	+	+
长春鳊	*Parabramis pekinensis* (Basilewsky)	+	+	+
红鳍原原鲌	*Cultrichthys erythropterus*　(Basilewsky)	+	+	+
蒙古鲌	*mongolicus* (Basilewsky)	+	+	+
翘嘴鲌	*Culter ilishaeformis* (Bleeker)	+	+	+
戴氏鲌	*Culter dabryi* (Bleeker)		+	+
拟尖头鲌	*Culter oxycephaloidaes* (Kreuenberg et Pappenhein)	+	+	+
华鳊	*Sinibrama wui typus* (Rendahl)	+	+	
银飘鱼	*Pseudolaubuca sinensis* Bleeker	+	+	+
寡鳞飘鱼	*Pseudolaubuca engraulis* (Nichols)	+	+	+
鮈亚科	**Gobioninae**			
唇 鱼骨	*Hemibarbus labeo* (Pallas)	+	+	
花 鱼骨	*Hemibarbus maculatus* Bleeker	+	+	+
华鳈	*Sarcocheilichthys sinensis sinensis* Bleeker	+	+	+
黑鳍鳈	*Sarcocheilichthys nigripinis* (Gunther)	+	+	+
吻鮈	*Rhinogobio tybus* Bleeker	+	+	+
圆筒吻鮈	*Rhinogobio cylindricus* Gunther	+		+
长鳍吻鮈	*Rhinogobio ventralis* Sauvager et Dabry			+
棒花鱼	*Abbottina rivularis* (Basilewsky)	+	+	+
似鮈	*Pseudogobio vaillanti*（Sauvage）	+	+	
银鮈	*Squalidus argentatus* (Sauvage et Dabry)	+	+	+
蛇鮈	*Saurogobio dabryi* Blrrker	+	+	+
细尾蛇鮈	*Saurogobio gracilicaudatus* Yao et Yang	+	+	+
铜鱼	*Coreius heterodon* (Bleeker)	+		+
圆口铜鱼	*Coreius guichenoti* (Sauvage et Dabry)			+
麦穗鱼	*Pseudorasbora parva* (Temminck et Schlegel)	+	+	+
鳅鮀亚科	**Gobiobotinae**			
宜昌鳅鮀	*Gobiobotia filifer* (Garman)	+	+	+
鲃亚科	**Barbinae**			
多鳞铲颌鱼	*Scaphesthes macrolepis* (Bleeker)	+		
鲤亚科	**Cyprininae**			
鲤	*Cyprinus (Cyprinus) carpio* Linnaeus	+	+	+
鲫	*Cyprinus carassius* Linnaeus	+	+	+
鲇形目	**SILURIFORMES**			
鲇科	**Siluridae**			
鲇	*Silurus asotus* Linnaeus	+	+	+

鲿科	**Bagridae**			
黄颡鱼	*Pelteobagrus fulvidraco* (Richardson)	+	+	+
瓦氏黄颡鱼	*Pelteobagrus vachelli* (Richardson)	+	+	+
光泽黄颡鱼	*Pelteobagrus nitidus* （Sauvage et Dabry）	+	+	+
长吻鮠	*Leiocassis longirostris* Gunther		+	+
粗唇鮠	*Leiocassis crassilabris* Gunther	+	+	+
切尾拟鲿	*Pseudobagrus truncatus* (Regan)	+	+	+
圆尾拟鲿	*Pseudobagrus tenuis* (Gunther)	+	+	+
大鳍鳠	*Mystus macropterus* (Bleeker)	+	+	+
钝头鮠科	**Amblycipitidae**			
白缘 鱼央	*Liobagrus marginatus* (Gunther)	+	+	+
鮡科	**Sisoridae**			
中华纹胸鮡	*Gluptothorax sinense* (Regan)	+	+	+
颌针鱼目	**BELONIFORMES**			
鱵鱼科	**Hemirhamphidae**			
鱵	*Hemirhamphus kurumeus* Jordan et Starks		+	+
合鳃鱼目	**SYNBRANCHIFORMES**			
合鳃鱼科	**Synbranchidae**			
黄鳝	*Monopterus albus* (Zuiew)	+	+	+
鲈形目	**PERCIFORMES**			
鮨科	**Serranidae**			
鳜	*Siniperca chuatsi* (Basilewsky)	+	+	+
大眼鳜	*Siniperca knera* Garman	+	+	+
斑鳜	*Siniperca scherzera* Steindachner	+	+	+
长体鳜	*Coreosiniperca roulei* (Wu)			+
塘鳢科	**Eleotridae**			
沙塘鳢	*Odontobutis obscura* (Temminck et Schlegel)	+	+	+
黄 鱼幼	*Hypeseleotris swinhonis* (Gunther)		+	+
鰕虎鱼科	**Gobiidae**			
子陵栉鰕虎	*Ctenogobius giurinus* (Rutter)	+	+	+
斗鱼科	**Belontiidae**			
圆尾斗鱼	*Macropodus chinensis* (Bloch)		+	+
刺鳅科	**Mastacembelidae**			
刺鳅	*Mastacembelus aculeatus* (Basilewsky)		+	+
鳢科	**Channidae**			
乌鳢	*Ophiocephlus argus* （Cantor）	+	+	+
刺鳅科	**Mastacembelidae**			
刺鳅	*Mastacembelus aculeatus* (Basilewsky)		+	+
鲑形目	**SALMONIFORMES**			
银鱼科	**Slangidae**			

大银鱼	*Protosalax hyalocranius* (Abbott)		+	+
太湖新银鱼	*Neosalanx tangkehkeii taihuensis* Chen	+	+	+
鲱形目	**CLUPERFORMES**			
鳀科	**Engraulidae**			
长颌鲚	*Coilia ectenes* Jordan et Seale			+
短颌鲚	*Coiliabrachygnathus* Kreyenberget Pappenheim		+	+
鳗鲡目	**ANGUILLIFORMES**			
鳗鲡科	**Anguillidae**			
鳗鲡	*Anguilla japonica* Temminck et Schlegei	+	+	+

APPENDIX 2: PUBLIC CONSULTATION

1 Public Consultation and Information Disclosure

Public consultation is an integral part of environmental impact assessment work and a two-way communication between assessment unit and the general public. Through public consultation, accuracy of environmental impact prediction assessment on water resources and hydropower construction can be verified, implementation situation of environmental protection measures can be learned, and opinions and suggestions of relevant organizations and individuals of the affected area on construction of navigation and hydropower complexes along the middle and lower reaches of Han River mainstream can be learned, providing support to further development in the planned river section, comprehensive environmental and development decision making concerning the middle and lower reaches of Han River mainstream, as well as coordination between economic growth, social progress and environmental protection.

1.1 Overview

1.1.1 Survey Principle

Public consultation follows the principles of openness, equality, extensiveness and convenience aiming to be scientific, objective, fair and comprehensive.

1.1.2 Range of survey

Following requirements in Interim Procedures for Public Consultation for Environmental Impact Assessment (Environmental protection authority 2006 [No. 28]) and World Bank OP 4.01 Environmental Assessment, two-way communication with the general public shall be conducted through multiple channels and stages. This cumulative environmental impact assessment mainly surveys surrounding areas that might be affected by the construction of navigation complexes along the middle and lower reaches of Han River mainstream. Subjects of the survey are mainly Municipal People's Government and relevant functional departments in Danjiangkou, Laohekou, Xiangyang, Yicheng, Zhongxiang and Qianjiang, as well as residents and displaced persons of land requisition in project areas of already constructed and planned complexes.

1.1.3 Contents of survey

Public consultation mainly includes: knowledge level of the general public on the construction of navigation complexes along Han River basin; implementation situation of environmental protection measures for the already constructed projects; what kinds of adverse impact the general public believe the construction of navigation complexes along Han River basin will have on local area; what kinds of environmental problem the general public believe the construction of navigation complexes along Han River basin will cause and what kinds of amendment measures and suggestions shall then be taken; opinions and suggestions of the general public on protection measures taken by complexes; attitude of the general public on constructing new navigation complexes along Han River from the perspective of environmental protection; other specific opinions and suggestions.

1.1.4 Survey methods

Public consultation of this assessment communicates with the general public by adopting the two methods: interviews and discussion meetings.

(1) Have interviews with residents living along the middle and lower reaches of Han

River

A team consisting of members from the PIU and the EIA unit shall have interviews with the general public living along the construction area of navigation and hydropower complexes, presenting the local people with: complex planning and current development situation; environmental problems caused by already constructed projects and environmental protection measures taken; environmentally affected area, level of impact, major adverse and beneficial effects of projects to be constructed during construction and operation periods. Environmental protection opinions and suggestions of the general public on construction of navigation complexes along the middle and lower reaches of Han River are gathered

(2) Convene discussion meetings

On June 21 and 22, 2016, CEA discussion meetings on the construction of navigation complexes along the middle and lower reaches of Han River were respectively held by the Municipal People's Government of Xiangyang and Zhongxiang.

1.2 Interviews

1.2.1 Interview process

On the basis of reading and studying previous data, during May 16 to 18 of 2016, led by the PIU, environmental assessment staff interviewed the PIUs of the complexes along the middle and lower reaches of Han River mainstream and the residents living along the line, in order to learn impact of the projects, such as Danjiangkou hydropower complex, Wangfuzhou hydropower station, Cuijiaying navigation complex and the recently completed Xinglong hydropower complex, on Han River mainstream on daily production and lives of local residents over the years, and learn about local people's concerns over the potential environmental and social impacts of further constructing Yakou Navigation Complex Project on Han River mainstream.

	
Visit and inspect Danjiangkou hydropower complex	Visit and inspect Wangfuzhou hydropower station

Visit and inspect Cuijiaying navigation complex

Visit and inspect Nianpanshan dam site

Visit and inspect Xinglong hydropower complex

Visit and inspect Yangtze-Han Water Diversion project

Figure 1 CEA Interviews

1.2.2 Statistical results

Results of interviews reveal that the general public has a certain amount of knowledge of the construction of navigation and hydropower complexes along Han River basin. Most displaced persons hold that the living and production conditions of their current residence place are better than or similar to that of their original residence place, and only very few people think it's difficult to make the comparison or the projects have advantages and disadvantages; most residents suffering inundation or land occupation are satisfied or basically satisfied with compensation method, and few, mostly displaced persons of Xinglong hydropower complex, are dissatisfied; the public surveyed generally holds that, in terms of major beneficial effects brought by power station already constructed, the construction of navigation complexes along the middle and lower reaches of Han River has promoted local economic development, created massive power generation and improved flood prevention ability. However, some adverse effects and environmental problems have also been created, such as inundation of large amount of fertile farmland, soil erosion during construction and environmental pollution caused by "three wastes and one noise". When asked that whether the three projects of Xinji, Yakou and Nianpanshan shall start construction as soon as possible, the general public favors "timely development" and "development as soon as possible", with no dissenting opinions.

In addition, as to constructing new complexes, some people propose that investment on environmental protection need to be increased to enhance environmental protection and

water quality pollution prevention and control.

Contents of interview with some residents:

Table 1 Results of interviews with residents for the purpose of CEA

Serial No.	Interviewee	Employee/ village	Occupation/ age	Interview content
1	Mr. Zhu	Danjiangkou hydropower complex	Cadre/42	Danjiangkou hydropower complex dam heightening project is an important water source of south-to-north water diversion middle route phase-I and an important supplementary water source to regions along the middle and lower reaches of Han River. Implementation of south-to-north water diversion middle route phase-I might affect to a certain extent hydrological regime, water quality and aquatic eco-environment in the middle and lower reaches and tracking survey and assessment are needed. Construction of navigation complex is greatly helpful to local economy and beneficial to increase local income.
2	Mr. Ye	Wangfuzhou hydropower complex	Cadre/47	Water quality of the river section of the reservoir area, in particular water quality of the dam site section has been obviously improved compared to that of prior reservoir construction, improving water quality of production and domestic water along the river in the reservoir area, which is also beneficial to fishery development in the reservoir area. Fish with pelagic eggs will disappear from the reservoir area for losing spawning conditions and source of fingerling supplement. Fish community of the reservoir area will be mainly lake fish favoring still water and slow flowing water.
3	Qu Wangu, Shen Zhibin and others	Villager near Wangfuzhou hydropower complex	Fisherman	In recent years, Han River has seen increasingly reduced number of fish and less water volume, mainly attributable to many people resorting to electric fishing along the river basin and fewer migratory fish due to some water resources facilities in the Han River basin. In addition non-point pollution caused by the use of pesticide and fertilizer in farmlands on the two banks has also greatly affected fish growth. Mainly concerned about inundation of many fertile land along the river after the completion of Yakou navigation complex.
4	Mr. Qiao	Cuijiaying navigation and hydropower complex	Cadre/41	Water quality of reservoir area has been obviously improved compared to that of prior reservoir construction, besides pollution source treatment measures taken by environmental protection departments, the purification effect of reservoir has also contributed. Fishway constructed has mitigated the impact of dam blockage on migratory and semi-migratory fish. Breeding and releasing has contributed to Han River fishery resources supplement.
5	Zhao Zhengtao and Liwanqing	Qianying village, Cuijiaying dam site	Displaced person	There were altogether 223 people of 57 households from Qianying village resettled for project construction. Income level of displaced persons has substantially increased due to structural changes. According to site interview, resettled in nearby area, displaced persons are satisfied with the current living and production

Serial No.	Interviewee	Employee/ village	Occupation/ age	Interview content
				conditions as they have adapted to life and work after resettlement, enjoying friendly and harmonious relations with neighbors.
6	Mr. Liu	Zhongxiang waterway station	Cadre/41	Given that the dam site of Nianpanshan hydropower complex is located within the core area of national aquatic germplasm resources conservation zone of *Elopichthys bambusa*, *Ochetobibus elongatus* and *Luciobrama macrocephalus* in Zhongxiang section of Han River, during project development measures such as project and ecological compensations will be taken to reduce impact on fish. It is hopeful that after the implementation of Yakou and Nianpanshan projects, fish resources in Han River can be restored to the current level through joint ecological operation and other compensation measures.
7	Mr. Wang	Xinglong hydropower complex	Cadre/47	Completion and operation of water resources facilities along Han River, in particular the completion and operation of Xinglong hydropower complex, have obviously mitigated local flood disasters in recent years and reduced loss caused by flood disasters. Construction of water resources facilities generally brings more good than harm to local people.
5	Ms. Zhang	Resident near Xinglong hydropower complex	Farmer/55	Hydropower station construction along Han River has little impact on fish. Number of fish is decreased as there is excessive human activities on Han River and the excessive number of sand dredger have confined fish survival space. Fish survival is also heavily affected by the use of pesticide and fertilizer.

1.3 Discussion meetings

1.3.1 Participants and time

In terms of construction of navigation complexes along the middle and lower reaches of Han River, the already constructed Danjiangkou hydropower complex, Wangfuzhou hydropower complex and Cuijiaying navigation and hydropower complex, as well as the planned Xinji hydropower station and Yakou hydropower complex are all located in Xiangyang city; the planned Nianpanshan hydropower complex is located in Zhongxiang city; the already constructed Xinglong hydropower complex is located in Qianjiang city.

Therefore, participants of CEI discussion meeting are selected from Municipal People's Government and relevant functional departments of Xiangyang, Zhongxiang and Qianjiang. Representatives of local government and relevant functional departments attending the discussion meeting are representatively asked about their opinions and suggestions to construction of navigation complexes along the middle and lower reaches of Han River.

For the convenience of the participants, various departments and representatives chose Xiangyang and Zhongxiang city for CEI discussion meetings on the construction of navigation and hydropower complexes along the middle and lower reaches of Han River. Meetings were respectively held in afternoon on June 21 and 22, lasting for half a day.

a) Participants of Xiangyang municipal discussion meetings

Participants of Xiangyang Municipal Discussion meeting involve representatives from

relevant departments within the administrative regions of Xiangyang city covering Danjiangkou city, Laohekou city, Xiangcheng district, Yicheng city. From 18 departments came 25 representatives involving representatives from Danjiangkou, Wangfuzhou and Cuijiaying complex administration, preparation office of Xinji and Yakou project, Xiangyang Municipal People's Government and functional department representative mainly including Xiangyang Municipal People's Government, Municipal People's Congress, Municipal CPPCC, Municipal Environmental Protection Bureau, Municipal Development and Reform Commission, Municipal Transportation Bureau (Maritime Bureau), Municipal Immigration Bureau, Municipal Land and Resources Bureau, Municipal Forestry Bureau, Municipal Water Resources Bureau, Municipal Bureau of Aquatic Products, Municipal Agriculture Bureau and Municipal Culture Bureau, as well as Municipal People's Government and functional departments of Danjiangkou, Laohekou, Yicheng mainly including Municipal People's Government, Municipal People's Congress, Municipal Environmental Protection Bureau and Municipal Water Resources Bureau.

b) Participants of Zhongxiang municipal discussion meetings

Participants of Zhongxiang Municipal Discussion meeting involve representatives from relevant departments within the administrative regions covering Zhongxiang city (county-level city) under Jingmen city and Qianjiang city (provincial municipality). From 15 departments came 20 representatives involving representatives from Xinglong complex administration, Nianpanshan Preparation Office, Xiangyang Municipal People's Government and relevant functional departments mainly including Zhongxiang Municipal People's Government, Municipal People's Congress, Municipal CPPCC, Municipal Environmental Protection Bureau, Municipal Development and Reform Commission, Municipal Transportation Bureau (maritime Bureau), Municipal Immigration Bureau, Municipal Land and Resources Bureau, Municipal Forestry Bureau, Municipal Water Resources Bureau, Municipal Bureau of Aquatic Products, Municipal Agriculture Bureau, Municipal Culture Bureau, as well as representatives from Qianjiang Municipal People's Government and relevant functional departments mainly including Municipal People's Government, Municipal People's Congress, Municipal Environmental Protection Bureau and Municipal Water Resources Bureau.

Xiangyang municipal discussion meeting (1)

Xiangyang municipal discussion meeting (2)

	
Zhongxiang municipal discussion meeting (1)	Zhongxiang municipal discussion meeting (2)

Figure 2 Photos of public consultation and discussion meetings

1.3.2 Topics under discussion

Topic one: what are the existing or potential impacts on hydrological and water resources utilization due to construction of navigation complexes along the middle and lower reaches of Han River mainstream? What kinds of environmental protection measures are suggested to be taken to mitigate the existing and potential environmental problems?

Topic two: what are the existing or potential impacts on aquatic ecology and terrestrial ecology due to construction of navigation complexes along the middle and lower reaches of Han River mainstream? What kinds of environmental protection measures are suggested to be taken in regard to the existing and possible eco-environmental problems?

Topic three: what are the existing or potential impacts on water environment due to construction of navigation complexes along the middle and lower reaches of Han River mainstream? What kinds of environmental protection measures are suggested to be taken in regard to the existing and possible water environmental problems?

Topic four: what are the already caused or possible socio-environmental impacts (such as Han River shipping, urban flood prevention, water supply, resettlement, urban drainage and flood drainage, population health and cultural relics and historic sites) of the construction of navigation complexes along the middle and lower reaches of Han River mainstream? What kinds of environmental protection measures are suggested to be taken in regard to the existing and possible socio-environmental problems?

Topic five: what kinds of environmental risks are there in implementing the construction of navigation complexes along the middle and lower reaches of Han River mainstream? Are there any opinions and suggestions to environmental management work in implementing the construction of the complexes?

Topic six: what kinds of economic and environmental benefits are there in constructing navigation complexes along the middle and lower reaches of Han River mainstream? What is the attitude towards constructing the complexes?

1.3.3 Process and conclusion of discussion meetings

During discussion meeting, Port and Waterway Administration of Hubei Provincial Department of Transportation (Yakou PIU) introduced to participants the planning of navigation and hydropower complexes along the middle and lower reaches of Han River

mainstream and the background of this CEA. Our company (assessment unit) introduced major achievements and conclusion of CEA and explained main topics.

During discussion meeting, attending representatives conducted heated discussion on existing and potential environmental problems resulting from construction of navigation complexes along the middle and lower reaches of Han River mainstream, as well as on environmental compensation and protection measures taken. Pragmatic opinions and suggestions were given to this cumulative impact assessment. Details are shown in Table 2~3.

Table 2 Opinions from attendants of Xiangyang discussion meeting

Representative	Organization the representative works in	Attitude	Main opinions
1	Xiangyang Municipal CPPCC	Favor	Construction of navigation complexes along the middle and lower reaches of Han River is of great importance to socio-economic development in regions along the river. Construction of navigation complexes along Han River shall be actively supported. All sectors of society is urged to further enhance Han River ecological protection work, in particular given the potential adverse impact in terms of agriculture, forestry, fishery and land after the initial operation of south-to-north water diversion in 2015. The follow-up complex construction process also need to pay attention, in particular to changing trends of water quality and fishery.
2	Yicheng Municipal Environmental Protection Bureau	Favor	Environmental impact of constructing navigation complexes along the middle and lower reaches of Han River is extensive, including impact on ground water. It is suggested that navigation environmental protection work shall be strengthened such as pollution prevention and control of thousand-ton ship. Through transportation, tourism and pollution situations, adverse impact shall be accurately controlled and macro protection plan be proposed so as to better protect water quality. Han River Water Environment Protection Regulations released shall be consulted and executed.
3	Xiangyang Municipal Forestry Bureau	Favor	Minimum discharge of Danjiangkou is merely 384 m^3/s, adversely impacting ecological water use downstream, in particular wetland water uses on the two banks. Complex construction raises and stabilizes water level benefiting wetland development and protection and effectively promoting wetland landscape building and forestry production. However, mud flat inundation and reduced forest land resources need to be compensated through requisition-compensation balance. After reservoir formation, water bloom phenomenon occurs easily due to raised water level, reduced flow velocity and decreased water environment capacity, affecting biodiversity. It is suggested that impact on wetland biological resources shall be monitored on a long-term basis.
4	Xiangyang Municipal Development and Reform Commission	Favor	Water transport development is lagging behind in the middle and lower reaches of Han River failing Grade III waterway standards. After been included in the Twelfth Five Year Plan, Provincial Port and Waterway Administration has been actively promoting the construction of Yakou navigation complex. Generally it does more good than harm as it promotes local socio-economic development. however, after reservoir formation, purification capability will be reduced and its adverse impact need to be mitigated through adopting the following measures: 1. Build ecological protection coordination management system, coordinating relations between the upper and lower reaches, between various complexes and between different regions, for instance building reservoir conservation forest in the upper reach through unified implementation; 2. Improve Han River ecological compensation mechanism, implement sewage treatment and sewage interception treatment project; 3. Increase ecological protection investment by bringing in social capital on the basis on government investment, for instance in terms of domestic sewage treatment and domestic garbage treatment; 4. Build eco-environmental monitoring support system by science and technology; 5. Promote active public consultation of eco-environmental protection, for instance by strengthening publicity and organizing volunteering activities.
5	Xiangyang Municipal	Favor	Construction of navigation complexes along Han River has created a series of environmental problems, changed biodiversity, obviously reduced fish species and

Representative	Organization the representative works in	Attitude	Main opinions
	Bureau of Aquatic Products		the number of major economic fish, as well as impacted spawning and breeding of fish with pelagic eggs including the four major Chinese carps. Rare fish such as *Anguilla japonica* and *Myxocyprinus asiaticus* are difficult to find. Adverse impact cannot be overlooked as fishermen' livelihood is affected by reduced number of fishery and aquatic products. It is suggested that compensation measures shall be taken to restore fish spawning ground and build artificial fingerling breeding ground. Fisherman compensation measures shall be carried out in accordance with *Fishery Law of the People's Republic of China*.
6	Xiangyang Municipal Culture Bureau	Favor	Currently, Yakou PIU and cultural relic departments has fully communicated and coordinated that a good working linkage relations has been established. Cultural relic exploration within the construction land requisition area has been completed and protection measures such as relic excavation will then be implemented as planned. Given that relevant departments are reporting the "Tea Road", which include Han River waterway, cultural relic exploration shall be further conducted during the process of project implementation, for instance wharf construction.
7	Xiangyang Water Resources Bureau and Xiangyang Waterway Administration	Favor	Reduced discharge from Danjiangkou has brought down water level in the middle and lower reaches of Han River, adversely affecting embankment projects and small-sized water resources facilities along the bank. Examples being water intake between Xiao River and Yicheng is difficult during dry flow season, clear water discharge downstream of the dam site and potential threat to reservoir bank stability by washing. Observation and monitoring shall be enhanced in order to further understand geographic conditions on either bank of Han River, so as to promptly adopt relevant treatment measures.
8	Xiangyang Municipal People's Congress	Favor	Long construction period of complex is beneficial to effective utilization of water resources, generally bringing more good than harm. Discharge downstream of Danjiangkou has been reduced. In terms of pollution drainage, by fully considering protection along Han River, a highly operable coordinated protection mechanism can be built, including promote waste water treatment of polluting enterprises and breeding farm ensuring up-to-standard release; strengthen management of catering, leisure and sand excavation by building scientific compensation mechanism; handle the relationship between development and protection, reduce industrial project, increase and green projects. Special attention need to be paid to protecting the upper reach for failure in the upper reach affects the lower reach.
9	Laohekou Municipal Environmental Protection Bureau	Favor	Build long-term monitoring mechanism, basin monitoring platform, tracking monitoring and release monitoring results.
10	DanjiangkouMunicipal Environmental Protection Bureau	Favor	Construction of navigation complexes along Han River affects self-purification effect. Some suggestions on seasonal water bloom phenomenon and aquatic ecological protection: 1. Build an effective and coordinated management mechanism facilitating the implementation of relevant protection measures such as ecological regulation; 2. Strengthen breeding and releasing; 3. Formulate ecological compensation standards and actively carry out ecological compensation measures.
11	Villager representative	Favor	It is hoped that Yakou navigation complex will start construction as soon as possible, various resettlement compensation measures will be carried out and ecological agriculture will be actively developed. As regard to adverse impacts such as heavy sand wind in areas surrounding the construction area caused by construction, it is suggested that dust settling through watering surrounding areas during construction period can be strengthened so as to better protection surrounding environment.
11	Enterprise representative	Favor	Han River Group adheres to the concept of developing through environmental protection. Besides pursuing economic benefits, it also greatly increases investment in environmental protection by obeying ecological protection work arrangement of the entire basin, in areas such as joint ecological operation and water bloom prevention and control in the middle and lower reaches of Han River, earnestly

Represe ntative	Organization the representative works in	Attitude	Main opinions
			carrying out corporate social responsibility.

Table 3 Opinions from attendants of Zhongxiang discussion meeting

Repre sentat ive	Organization the representative works in	Attitude	Main opinions
1	Zhongxiang Municipal People's Government	Favor	After the construction of navigation complexes along Han River, in particular after south-to-north water diversion, water bloom phenomenon happened within Zhongxiang area. Research on water bloom shall be strengthened so that reasonable and effective solution to water bloom problem can be identified. Reduced discharge from Danjiangkou has adversely affected irrigation and water intake facilities along the middle and lower reaches of Han River. Complex construction is beneficial to mitigating reduced water volume.
2	Zhongxiang Municipal Environmental Protection Bureau	Favor	Yakou project has already been approved by Environmental Protection Bureau. Environmental assessment of Nianpanshan project is in the process and will be approved by Environmental Protection Bureau prior construction. Therefore, it is suggested that environmental protection measures shall be implemented strictly according to environmental assessment and approval requirements during the process of project construction, so as to reduce adverse impact on surrounding environment. Functional departments shall strengthen monitoring and management so as to avoid pollution incident.
3	Zhongxiang Municipal Agriculture Bureau	Favor	Generally speaking, construction of navigation complexes along the middle and lower reaches of Han River has little impact on agriculture. Project construction shall be supported as it positively affects pumping irrigation. It is suggested that effective subsurface drainage measures shall be taken regarding arable land affected by ground water submersion in the reservoir area, so as to prevent soil gleying.
4	Zhongxiang Municipal Bureau of Aquatic Products	Favor	Construction of navigation complexes along the middle and lower reaches of Han River is beneficial to Zhongxiang as in Zhongxiang section is the national germplasm resources conservation zones of *Elopichthys bambusa*, *Ochetobibus elongatus* and *Luciobrama macrocephalus*. Massive annual investment of complex construction is tremendously helpful to breeding and releasing implementation and fish resources restoration. However, complex construction has also blocked spawning migratory passageway of the four major Chinese carps. Spawning conditions need to be restored by increasing discharge in flood spawning season and implementing joint ecological regulation.
5	Zhongxiang Municipal Administration of Culture, Sports, Press, Publication, Radio, Film and Television	Favor	In the process of constructing navigation complexes along Han River, cultural relic exploration and protection works shall be actively conducted.
6	Zhongxiang Municipal Forestry Bureau	Favor	In the process of constructing navigation complexes along the middle and lower reaches of Han River, some forestry resources will be inundated by reservoir, adversely affecting the protection of wild animals and plants, in particular wetland resources and migrant bird protection. Therefore, protection of wild animals and plants and wetland resources shall be strengthened.
7	Zhongxiang Municipal Land and Resources	Favor	Rising water level has inevitably caused inundation. Arable land in the reservoir area has carried out relevant planning following natural drainage and adopted requisition-compensation balance measures by compensating every basic farmland

Representative	Organization the representative works in	Attitude	Main opinions
	Bureau		taken.
8	Zhongxiang Municipal Water Bureau	Favor	First, environmental problems already occurred need to be reported. After Xinglong water storage, during February and March, water bloom phenomenon happened downstream of Xinglong complex. Results of water quality monitoring of the same period reveal TN and TP exceeding standards and water environment capacity reduced. Second, rising ground water level has led to inundation of surrounding farmland and reduced crop yield, as well as failed tap water pumping in urban area during draught. Given the existing adverse impact, it is suggested that ecological compensation measures shall be actively formulated through research and then gradually implemented.
9	Zhongxiang Municipal Maritime Bureau	Favor	After constructing navigation complexes along Han River, clear water discharge may undercut riverway downstream and bank slope through washing. Observation shall be strengthened. To ensure navigation safety, navigation control center shall be built and Han River joint maritime scheduling be implemented. To protect water quality of Han River, it is suggested that navigation ship must be equipped with sewage treatment facilities and garbage collection device ensuring that garbage must be treated ashore when passing ship sluice.
10	Qianjiang Municipal People's Congress	Favor	Support construction of navigation and hydropower complexes along the middle and lower reaches of Han River and strengthen communication and coordination between various departments and different regions.
11	Qianjiang Municipal Environmental Protection Bureau	Favor	In regard to existing water bloom and ground water submersion problems, measures such as discharging ecological flow from various complexes and creating subsurface drainage channel need to be taken.
11	Villager representative	Favor	It is hoped that construction will start as soon as possible. It is suggested that Nianpanshan Command and Yakou Command shall formulate unified resettlement compensation regulations, in particular on defining arable land and flood land, so as to avoid socially destabilizing factors.

Apart from opinions expressed by the main representatives listed above, other participating representatives also expressed their thoughts, holding that rising water level of the reservoir area is beneficial to water intake and has improved agricultural irrigation conditions, with little impact on terrestrial ecological system and other aspects. Currently, displaced persons of already constructed projects have all been properly resettled enjoying improved production and living conditions compared with that of prior project construction. However, complex construction has adversely impacted aquatic ecology, water environment and urban drainage and flood drainage.

Among which, impact on aquatic ecology is mainly: low-temperature discharge from Danjiangkou reservoir and blocking effect of Wangfuzhou and Cuijiaying hydropower complexes affecting aquatic eco-environment such as fish composition in Xiangyang section of Han River, "three grounds" of fish and diversity of fish resources. It is suggested that corresponding fish-passing passageway and breeding and releasing station shall be built together with navigation and hydropower complex as a way to increase breeding and releasing scale and strengthen fishery management so as to increase survival rate of breeding and releasing. Meanwhile, fishery loss needs to have necessary economic compensation.

Impact on water environment is mainly: rising water head after complex construction

has caused reduced water flow. The river section has basically become a semi-closed water body, leading to increased cumulative effect of pollutants within the water and deteriorating water quality. Meanwhile, dam blockage has also increased the risk of pollution incident. After constructing navigation complexes along Han River, sewage treatment shall be raised that outflow standards of urban sewage treatment plant shall reach Grade I(A) level and existing sewage treatment plants shall undergo upgrading and reconstruction.

Impact on urban drainage and flood drainage is mainly: after complex construction, rising water level of the reservoir area has to a certain extent affected urban drainage and flood drainage. Some drainage pipeline network and pumping stations need to be reconstructed. It is suggested that existing drainage, flood drainage and embankment facilities shall be reconstructed so as to meet the requirements after implementing construction of navigation complexes along Han River. The PIU shall fully compensate relevant reconstruction projects.

During discussion meeting, participating representatives conducted heated discussion on main topics such as impact of constructing navigation complexes along Han River basin on hydrology, water resources utilization, ecology, water environment, economic environment, environmental risk, environmental protection measures and environmental management. Participating representatives hold that construction of navigation complexes along the middle and lower reaches of Han River mainstream has tremendously promoted basin and regional economic development, improved flood prevention ability, improved power supply and shipping conditions, and improved water supply and irrigation capability. Meanwhile, it is of certain compensation effect to the middle and lower reaches of Han River affected by south-to-north water diversion project. It is of obvious economic and social benefits. Construction of navigation complexes along the middle and lower reaches of Han River shall be actively implemented and promoted.

1.4 Information disclosure

Since project preparation, project information/documents including resettlement plan and environmental impact assessment have been disclosed to the general public of the project affected area.

Figure 3 CEA report disclosure on website

1.5 Handling of public opinions

This cumulative impact assessment has consulted the public through various ways including internet public announcement, discussion meetings and interviews. Results of questionnaire survey reveal that regarding the question of whether or not the three unconstructed complexes of Xinji,Yakou and Nianpanshan shall be developed as soon as possible, most people are in favor of development as soon as possible or duly and no one is against the development. Some people suggest that unconstructed complexes shall invest more in environmental protection. In addition, according to interviews, some displaced persons of Baoju Village of Duobao County in Tianmen city were unsatisfied with land compensation method in the construction of Xinglong hydropower complex project. It is mainly because the production resettlement is in progress, affecting agricultural production.

Public opinions and suggestions received during discussion meeting and questionnaire survey have been included in this cumulative impact assessment report. Relevant issues have been analyzed and assessed. Environmental protection compensation measures of complexes already completed and under construction have been implemented and mentioned in relevant chapters, mainly including:

(1) Regarding deteriorating water quality after implementation of constructing navigation complexes along Han River, the report has included public opinions and has suggested that sewage treatment shall be raised that outflow standards of urban sewage treatment plant shall reach Grade I (A) level and existing sewage treatment plants shall undergo upgrading and reconstruction.

(2) Regarding impact on aquatic eco-environment such as fish composition, "three grounds" of fish and diversity of fish resources, the report suggests that corresponding fish-passing passageway and breeding and releasing station shall be built together with navigation and hydropower complex. Joint open-discharge operation shall be conducted in the middle and lower reaches of Han River at least two every year during June to August so as to ensure spawning in existing spawning grounds, unblocked passageway for floating hatching of fertilized eggs and fish migration and complete breeding process.

(3) Regarding rising water level of the reservoir area after the completion of complexes and impact on urban drainage and flood drainage, the report has proposed that the PIU shall fully compensate facility reconstruction projects of existing drainage, flood drainage and embankment.

(4) Regarding the dissatisfaction of some displaced persons in terms of compensation methods of project occupied land involving Xinglong hydropower complex, it is suggested that communication with displaced persons during the process of implementing production resettlement shall be strengthened so as to be understood and supported by displaced persons. Meanwhile, implementation schedule of production resettlement shall be accelerated and production resettlement regulations carried out as soon as possible, so as to reduce the loss caused by project construction on displaced persons.

In conclusion, this CEA has consulted the public through various ways including internet public announcement, discussion meetings and interview. Through diverse forms of activities, the public consultation has gained lots of public ideas, opinions and suggestions, providing strong support to comprehensively and objectively analyze possible environmental problems, formulating effective environmental protection and compensation measures to mitigate existing environmental problems in complexes already constructed, as well as improve environmental management.

APPENDIX 3: TERMS OF REFERENCE FOR CUMULATIVE EFFECT ASSESSMENT (STAGE-II)

ToR for Stage-II Cumulative Effects Assessment (CEA)

1 Background and Objective

A preliminary CEA was carried out during the Yakou project preparation. The main outcomes, findings and recommendations include the following,

- Identified key Valued Environmental Components (VECs) and their interdependencies; examined historical conditions and trends of the VECs and major past, present and future actions that have cumulatively affected those VECs;
- Recognized existing measures and mechanism in addressing cumulative effects resulting from cascade development and other development activities on the middle and lower Han River, such as the coordinated ecological scheduling plan backed by inter-agency coordination that is led by Hubei Provincial Government;
- Examined the riparian area and ecosystem restoration concepts and expand the assessment focus from primarily aquatic ecosystem to riparian ecosystem and the dynamic connections between the two;
- Explored the concept of adaptive management and articulated the need of long-term ecosystem monitoring as a way to respond to development uncertainties.

The preliminary CEA presents a solid study framework that integrates above mentioned key steps, methodology, ecosystem components, and institutional aspects relevant to addressing cumulative effects. The proposed Stage-II CEA will broaden and deepen the study by taking the following into consideration:

- Deepen understanding of identified major VECs, namely hydrologic regime, water quality, fish and riparian areas. In particular, the riparian ecosystem, including various habitat types and wildlife, had been less well studied compared to other VECs in traditional studies;
- Examine other VECs such as health and safety, recreation and culture resources considering the abundant history and culture resources in the middle and lower Han River;
- Identify and monitor other major actions and programs that may affect the VECs;
- Accumulate data and develop scientific tools to enhance assessment accuracy and management performance. For example, due to data and time limitations, quantitative assessment of the magnitude and significance of cumulative effects on a couple of VECs were not possible; another example may be to define sustainability levels (thresholds) of a VEC, such as a fish;
- Enhance existing inter-agency coordination mechanism which is critical in addressing cumulative impacts.
- Ecosystem monitoring and adaptive management

A multi-disciplinary team will be hired as the consultant to carry out the CEA during the Yakou project implementation.

2. Scope of Work

2.1 Task 1: Further data collection and desk review

Further collect and update the data and information that are relevant to the CEA study, which may include to but not limited to the following aspects,

- Hydrologic regime of the middle and lower Han River mainstem and tributaries;
- Land uses;
- Groundwater;
- Riparian areas habitats such as riparian wetland, shoals, island, embayment and wildlife such as waterfowls;
- Socio-economics, cultural resources, recreation, health and safety; and
- Relevant new development, environmental and ecology planning, regulations and standards.

2.2 Task 2: Field visits and public consultation

According to previous study results, a field visit will be conducted covering the whole middle and lower Han River Basin targeting at key VECs. The purpose of the field visit is to update and verify the environmental baselines established during the Stage 1 CEA study.

Two stakeholder meetings (on the middle reach and lower reach respectively) will be held to present the findings of the Stage 1 study to the key stakeholders, particularly those consulted during Stage 1 study for their further comments. During the Stage 2 study, such consultation will be continuously carried out throughout the process to better understand and incorporate the stakeholders feedback into the study.

2.3 Task 3: Environmental survey and monitoring

For a detailed cumulative effect study, environmental survey and monitoring is required to obtain necessary information. To this end, a number of specialized institutes shall be entrusted to carry out hydrologic survey, environmental and ecosystem monitoring. The survey and monitoring results shall be used for modelling studies to quantify the cumulative effects.

Hydrology: Hydrologic regime information measured in the mainstream and tributary hydrologic measurement stations. Special attention should be paid to the data regarding ecological scheduling implementation.

Water quality: historical and current water quality monitoring results measured by the Hubei surface water quality monitoring network covering Han River mainstem and tributaries. The water quality monitoring results shall include the high flow season, normal flow season and low flow season.

Water temperature: the measured information on water temperature in front of dam of Danjiangkou dam shall be collected, and shall undergo statistical data and collation to analyze the change trends of water temperature structure in front of dam, average monthly distribution, and reservoir water temperature. Through comparative analysis of the average monthly temperature changes in middle and lower Han River and assess impact scope of discharged water temperature.

Aquatic ecosystem: The Yakou project owner will entrust a professional institute to

carry out current status survey for the aquatic organisms, fish resources and habitats within the scope of survey..

Terrestrial/Riparian ecosystem: The study should examine the fauna and flora occurring on middle and lower Han River riparian areas, including

- Historical conditions and changes of riparian areas habitats (e.g. riparian wetland, shoals, island, embayment) based on satellite images and available literature;
- Riparian wildlife such as waterfowls, reptile, amphibian and mammal species;

2.4 Task 4: Modeling Study

Based on collected information, the hydrodynamic, water quality model for the cascade development on the middle and lower Han River shall be established. Basic information required includes: river morphology, hydrological data of river, rainfall data, reservoir operating rules, water quality, point source pollution, and non-point source pollution. The hydraulic model will focus on dam's operation during flood season and dry season, with particular attention on the operation of ecological scheduling plan. The hydraulic model will also study hydrologic connections between river and groundwater in riparian areas. The water quality model will focus on COD, BOD, ammonia nitrogen and TN.

Establish ecosystem models to evaluate environmental impacts resulting from cascade development on the life-stages of fishes typical of various fish groups and habitats in the middle and lower Han River.

2.5 Task 5: Assessment of cumulative effects

Based on the results of modeling studies, the cumulative effects of cascade development and other actions will be more accurately assessed with focus on the identified key VECs such as hydrologic modification, water quality, fish, riparian areas and other new VECs identified during the study.

2.6 Task 6: Development of monitoring and mitigation plans

Based on the results of cumulative effect assessment, and review of existing mitigation measures, the study will propose a series of monitoring and mitigation plans that should cover the following aspects,

- Mitigation measures for assessed major VECs;
- Performance assessment and recommendations to existing mitigation plans such as ecological scheduling, habitat protection and restoration, fish pass and breeding program;
- Recommendations on building and enhancing inter-agency coordination mechanism;
- Long-term adaptive monitoring and management mechanism for the mitigation plans.

The key cumulative effects and mitigation plans will be finalized based on consultation with key stakeholders, namely relevant authorities and the general public.

2.6 Task 7: Dissemination and training

The staff of relevant local authorities such as Water Resources Bureau, agriculture and

fishery bureau, dam operators, local Environmental Protection Bureau, etc. shall receive necessary training on environmental management. The training plan shall be designed according to the results of the above analysis and assessment to improve the local environmental management capacity.

2.7 Task 8: Reporting

A comprehensive report shall be prepared to reflect all of the main results of the study.

3 Consultant Team Composition

This is a multi-disciplinary study. Key team members of the consultant's team should include, a) environmental scientists and engineers with good knowledge in hydrology, hydraulic modelling, urban and regional planning and environmental compliance; b) biodiversity specialists with good knowledge on aquatic, riparian/wetland ecosystems and wildlife; c) institutional specialist with experiences in water governance issues in China. Skills on cartography and/or GIS analysis is also needed.

4 Schedule and Budget

This study begins within 30 days after the effective date (October 2016) of the project. It shall be completed no later than December 2019, and shall be at least 6 months before the impoundment of the reservoir. This study is expected to last about 24 months (2 years), with the estimated budget of CNY 3.8 million.

S/N	Main task	Time (month)	Budge (CNY 10,000)
Task 1	Further collection of information and preliminary review of information	1	25
Task 2	Site visits and targeted public survey	1	50
Task 3	Environmental survey and monitoring	6	90
Task 4	Establishment of hydrodynamic force and water quality model	3	45
Task 5	Cumulative effect assessment	8	85
Task 6	Development of mitigation measures	2	40
Task 7	Training	1	25
Task 8	Reporting	2	20
Total		24	380