DAM CONSTRUCTION AND MANAGEMENT IN CHINA

MINISTRY OF WATER RESOURCES, PEOPLE'S REPUBLIC OF CHINA

Dam Construction and Management in China

1. Overview

1.1 Reservoirs

China is one of the countries that has a very long history in building dams and reservoirs. The Anfengtang Reservoir in the Huai River Basin was built during the Warring States period, around 2,600 years ago. The reservoir is still serving multiple purposes including irrigation, thanks to good maintenance over many generations. Since 1949, China has been engaged in large-scale construction of water conservancy and built a large number of reservoirs that are critical to people's livelihood and overall socioeconomic development, and play a major role in flood prevention, water supply, irrigation, power generation and environmental improvement.

Anfengtang Reservoir

Layout of major reservoirs, water projects and dikes in China

China is also one of the countries in the world that has the most reservoirs. According to the *Bulletin of the First National Census for Water*, as of 31 December 2011, there were 98,002 reservoirs in China (excluding Hong Kong SAR, Macao SAR & Taiwan)(See Table 1 for details), of which, 97,246 were completed and 756 still in progress, registering a combined reservoir capacity of 932.312 billion m^3.

Table 1 Number and Combined Capacity of Reservoirs in Various Sizes

Size	Total	Large			Medium	Small		
		Subtotal	Large (1)	Large (2)		Subtotal	Small (1)	Small (2)
No.	98,002	756	127	629	3,938	93,308	17,949	75,359
Combined capacity (in billion m^3)	932.312	749.985	566.507	183.478	111.976	70.351	49.638	20.713

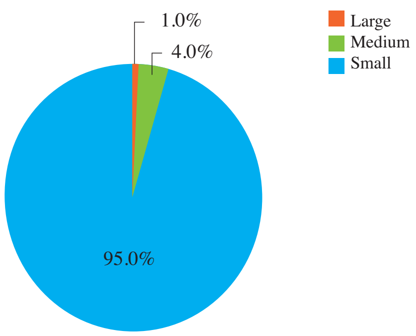

Fig. 1 Water flows of reservoirs in various sizes

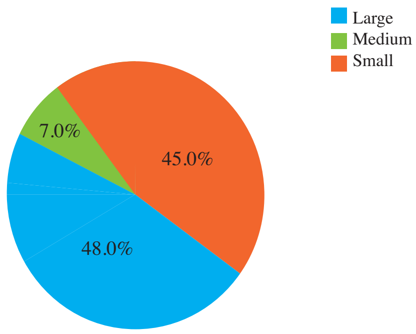

Fig. 2 Ratio of combined capacity of reservoirs in various sizes

In terms of regional distribution, the number of reservoirs in Hunan, Jiangxi, Guangdong, Sichuan, Shangdong, Hubei and Yunnan provinces account for over 60% of the national total, of which, Hunan has 14,121 reservoirs, ranking No.1 in the country, accounting for 14.4% of the national total.

1.2 Construction of Dams

Hydropower is both a renewable energy encouraged by the government, and the best green energy. At present, the installed capacity of large hydropower stations under construction in China accounts for over 50% of the world total. In addition, China is a world leader in terms of dam building technology, engineering quality, and budgetary estimate control capacity.

In July 2015, the construction of the tallest dam in the world—the 314m-high clay core earth rock fill dam of Shuangjiangkou hydropower station on the Dadu River was commenced. Hitherto, China ranks No. 1 in the world in terms of the number of reservoirs, number of high dams (≥ 100m in height), and the number of ultra-high dams under construction (≥ 200m in height). The world's highest arch dam, highest concrete face rock fill dam, and highest compacted concrete dam are all located in China.

China has built 20 large reservoirs (≥10 billion m^3 in capacity) or high dams (≥200m in height) (refer to Table 2 for details). At the same time, over 10 such large reservoirs are planned or under construction (refer to Table 3 for details).

Table 2 Completed High Dams (≥200m) and Large Reservoirs (≥10 billion m^3) in China

Serial No.	Project Name	River	Dam Type	Dam Height (m)	Capacity (100 million m^3)	Installed capacity (10,000kW)	Completion time (Year)
1	Three Gorges	Yangtze River	Concrete gravity dam	181	393	2250	2009
2	Danjiangkou	Han River	Concrete wide seam gravity dam	117	339.1	90	Dam height increase completed in 2013
3	Longyangxia	Yellow River	Concrete gravity arch dam	178	276.3	128	1990
4	Nuozhadu	Lancang River	Earth core rock fill dam	261.5	237.03	585	2014
5	Xinan River	Xinan River	Concrete gravity dam	105	216.26	66.25	1959
6	Longtan	Hongshui River	Roller compacted concrete gravity dam	192 (216.5)	162.1 (630)	490 (long term)	2008
7	Sanmenxia	Yellow River	Concrete gravity dam	106	162	41	1961
8	Xiaowan	Lancang River	Double curvature arch dam	294.5	150.43	420	2010
9	Shuifeng	Yalu River	Concrete gravity dam	106.4	146.66	90	1943
10	Xinfeng River	Xinfeng River	Concrete gravity dam	105	138.96	29.25	1976
11	Xiluodu	Jinsha River	Double curvature arch dam	285.5	126.7	1386	2014
12	Xiaolangdi	Yellow River	Clay inclined wall dam	160	126.5	180	2001
13	Fengman	2nd Songhua River	Concrete gravity dam	91.7	108	100.4	1953
14	Tianshengqiao Grade I	Nanpan River	Concrete face rock fill dam	178	102.57	120	2000
15	Jinping Grade I	Yalong River	Double curvature arch dam	305	77.6	360	2014
16	Lawaxi	Yellow River	Double curvature arch dam	250	10.79	420	2010
17	Ertan	Yalong River	Double curvature arch dam	240	58	330	1996
18	Shuibuya	Qing River	Concrete face rock fill dam	233	45.8	184	2008
19	Goupitan	Wu River	Double curvature arch dam	230.5	64.55	300	2010
20	Guangzhao	Beipan River	Roller compacted concrete gravity dam	200.5	32.45	104	2009

Table 3 High Dams (≥200m in height) and Large Reservoirs (≥10 billion m^3 in capacity) Planned or Under Construction in China

Serial No.	Name	River	Type	Height (m)	Capacity (100 million m^3)	Installed capacity (10,000kW)	Note
1	Beihetan	Jinsha River	Double curvature arch dam	289	206.02	1400	Planned
2	Shuangjiangkou	Dadu River	Earth core rock fill dam	314	29.42	200	Under construction
3	Lianghekou	Yalong River	Earth core rock fill dam	295	108	300	Planned
4	Wudongde	Jinsha River	Double curvature arch dam	265	74.05	960	Planned
5	Cihaxia	Yellow River	Concrete face rock fill dam	254	46.47	260	Planned
6	Shangzhai	Zhuosijia River	Earth core rock fill dam	253	10.95	45	Planned
7	Dashixia	Kumalake River	Concrete face rock fill dam	251	10.95	60	Planned
8	Changheba	Dadu River	Earth core rock fill dam	240	10.75	390	Under construction
9	Houziyan	Dadu River	Concrete face rock fill dam	223	7.04	170	Under construction
10	Jiangping River	Loushui River	Concrete face rock fill dam	219	13.66	45	Under construction
11	Dagangshan	Dadu River	Double curvature arch dam	210	7.42	260	Under construction
12	Huangdeng	Lancang River	Roller compacted concrete gravity dam	202	16.13	190	Planned

1.3 Reservoir Management

1.3.1 The Reservoir Management System

China exercises a tiered management system over reservoirs with central & local governments taking respective responsibilities. The competent water administration under the State Council, together with other competent departments of the State Council, exercise supervision over the safety of dams across the country. Competent water administrations of local governments above the county level, together with relevant departments at the same level, exercise supervision over the safety of reservoirs within their respective administrative regions. Flood control headquarters at various government levels are responsible for flood control regulation and safety supervision during the flood seasons in accordance with their respective mandates. Water, energy, construction, communications and agriculture authorities are responsible for dam management within their respective jurisdictions. Most of the reservoirs are managed by water authorities, followed by the power sector, whereas a large number of small reservoirs are owned by rural collective economic organizations, with the local township government administering their safety. Following the development of the socialist market economy, all kinds of economic organizations have got involved in the development and management of reservoirs, and thereby become the new-type owners of reservoirs.

1.3.2 Reinforcement of Risky Reservoirs

Following the catastrophic floods in the Yangtze River, Songhua River, and Liao River basins in 1998, China initiated a large-scale program on reinforcement of risky reservoirs. By the end of 2010, reinforcement was carried out on 9,500 risky reservoirs with total approved investment of RMB 117.68 billion, of which, RMB 106.68 billion has already been invested. A reinforcement program covering 5,400 Type (1) small risky reservoirs was initiated in July 2010, with total planned investment of RMB 24.4 billion, and fully completed prior to the flood season of 2012. In April 2011, another reinforcement program covering 41,000 key Type (2) small reservoirs was initiated, with planned investment totaling RMB 38.14 billion and reinforcement to the rest 25,000 Type (2) small reservoirs still in progress and planned to be completed by the end of 2015. In addition, central public finance has made funds available for reinforcement of 4,073

Dahuofang Reservoir in Liaoning Province

small reservoirs newly identified as risky, which shall also be completed by the end of 2015.

As at present, over 50, 000 reservoirs of various sizes have been reinforced with the help of central government subsidies and local investments.

2. Main Achievements & Challenges

2.1 Main Achievements

At present, the combined capacity of all the reservoirs built in China accounts for 1/5 of total annual river runoff in China. 310 million people, 132 large and medium-sized cities and 32 million hectares of farmland are located within the flood control range of these reservoirs. The reservoirs, supplying 240 billion m^3 of water each year, or 37% of the national total, serve as a reliable water source for 16 million hectares of arable land and over 100 large and medium-sized cities. In addition, these reservoirs combine to an installed capacity of over 200 million kW hydropower, accounting for 22% of the national total, and generate 17% of the total annual power output of the whole country.

Reservoirs play an important role in flood control and disaster mitigation. In particular, they help to fend off catastrophic floods by flood detention and peak shaving, thus playing an irreplaceable role in preventing floods and mitigating disasters. Reservoir regulation also plays a key role in replenishing freshwater to suppress salt water intrusion in the Pearl River, in safeguarding water supply security in Macao SAR and the Pearl River Delta and in tackling the outbreak of pollution in the Songhua River. Thanks to large-scale reservoir and dam construction, China has gradually improved its capacity for supplying water resources and ensuring water security, guaranteeing water supply for industry, agriculture, urban life and environmental protection. The growth of hydropower output supplies a big chunk of clean energy for the

Three Gorges Dam is discharging water

fast growing Chinese economy, and helps to effectively improve the energy mix and reduce environmental pollution in China.

2.2 Key Projects

2.2.1 The Three Gorges Comprehensive Water Conservancy Project on the Yangtze River

With 39.3 billion m^3 reservoir capacity, the Three Gorges Project is the largest comprehensive water project in the world, serving multiple purposes including flood control, power generation, navigation and ecological water supplement. The project consists of the dam, the hydropower station and navigation structures. The construction of the Project started in 1994. Damming of the Yangtze River was done in 1997. In 2003 the sluice gate began water storage; the first sets of generators started power generation; and the permanent ship-lock initiated operations. In May 2007, the top of Three Gorges Dam was grouted. In October 2010, water storage level reached 175m for the first time. The Three Gorges Dam is a concrete gravity dam, with a maximum height of 181m, and total grouting of 26.43 million m^3. The hydropower station has a total installed capacity of 22,500MW, and generates over 100 billion kWh of electricity each year. Massive in size, the Three Gorges Dam is also an exemplary project featuring excellent engineering quality, high safety and reliability, short construction cycle, cost-effective investment, and full realization of multiple benefits.

2.2.2 The Xiaolangdi Comprehensive Water Conservancy Project on the Yellow River

The Xiaolangdi Comprehensive Water Conservancy Project registers a total reservoir capacity of 12.65 billion m^3. It not only helps control floods on the Yellow River, but also regulates water and sediment along the river by intercepting sediments with the use of its sedimentation storage capacity, and thereby mitigates sedimentation-induced elevation of the river beds on the lower reaches. It is a loam slopping core rock fill dam, with a maximum height of 160m. The Xiaolangdi project started construction in 1994, completed the main body by 2001, went through final

Xiaolangdi Project

inspection for project acceptance in April 2009, and resettled 200,000 affected population.

2.2.3 Ertan Hydropower Project

With 3,300MW installed capacity, Ertan Hydropower Station is the largest hydropower station completed and commissioned in China in the 20th century. The construction of the double curvature arch dam started in 1991 and was completed in 1999. With a maximum height of 240m, it is the highest arch dam in Asia, and the 3rd highest in the world. It is also the first hydropower project in China that comprehensively practiced international competitive tendering, executed

Ertan Hydropower Station in Sichuan Province

the project owner responsibility system and followed the FIDIC conditions of contract. In 2006, the project won the top honor for environmental protection by construction projects in China – The National Award for Environment-Friendly Engineering Projects.

2.2.4 Jinping Grade I Hydropower Project

Jinping Grade I Hydropower Station is a reservoir for annual water regulation. It has a total reservoir capacity of 7.76 billion m^3, and a regulation capacity

Jinping Grade I Hydropower Project

of 4.91 billion m^3. A concrete double curvature arch dam with a maximum height of 305m, it is the highest double curvature arch dam in the world. The hydropower station registers an installed capacity of 3.3 million kW, guaranteed power output of 1.109 million kW, and average annual power generation volume of 16.287 billion kWh. The project started construction in 2005, and was completed and put into operation in 2014.

2.3 Challenges

2.3.1 Social and economic development still produces considerable demands for dam construction.

China is a vast country with a huge population. Its precipitation is distributed unevenly in time and space; its rivers lack self-regulating capacity; floods and droughts take place with high frequency;

water shortage is both resource-based and caused by inadequate water structures. A certain number of reservoirs still need be constructed in order to effectively regulate floods and water resources, ensure flood control safety, water supply safety, grain security, energy security and ecological security.

2.3.2 Greater importance should be attached to dam safety.

Urbanization results in the concentration and growth of population along the lower reaches of reservoirs, whereas ever more infrastructure construction exposes the dams to more risks. Occasional dam collapse incidents warn us that it is imperative to enhance safety performance of dams on the one hand, and improve emergency responses on the other. Remarkable achievements have been made following years of reinforcements to the risky reservoirs. Such reinforcement exercise, however, remains a long-term task as facilities are aging, legacy problems linger on, and more water supply is needed for development.

2.3.3 Scientific approaches are required to tackle emerging issues associated with the construction and management of dams.

We need to study and address changes in the ways

The Bakun Dam in Malaysia is constructed by a Chinese company

Permanent five-stage ship lock of the Three Gorges Project

water is supplied in the downstream of reservoirs as a result of socioeconomic development, properly handle the requirements for environmental and ecological protection in the course of developing and operating reservoirs, tackle issues associated with better protection of natural and cultural heritages, improve the conditions for relocation and resettlement, and manage problems associated with earthquakes, extreme weather events and other natural disasters.

3. Guiding Philosophies and Main Measures

We will continue to uphold the basic state policy on conserving resources and protecting the environment, and stick to the concept of people-orientation and harmony between Man and Nature. Specifically, efforts will be made to effectively combine development and construction of reservoirs/dams with integrated utilization of water resources, and combine ecological improvement with regional economic development. Great attention will be paid to ecological issues associated with the development of reservoirs, and effective protection of the legitimate rights of the affected population in need of resettlement. We will strike a balance between economic, social and ecological benefits of reservoirs and dams, construct a group of backbone water conservancy projects with the pooling of resources, and develop and utilize hydro resources in a scientific and orderly manner so that 60% of total hydro resources will be developed by 2030.

Equal attention will be paid to construction and management of dams, while consistent emphasis will be placed on dam safety management. Legislation on dam safety will be enhanced to further improve the legal framework and standards system for dam safety management. A comprehensive reservoir and dam safety responsibility system with clear division of duties for responsible persons in various categories will be put in place, the core of which will be the local administrative head responsibility system. A management mechanism that facilitates sound operation of reservoirs will be established and project management effectively improved so as to make sure reservoirs could better safeguard interests of the general public, and provide basic public services to the society. No efforts will be spared in reinforcement of risky reservoirs so that the overall safety of reservoirs and dams in China will be secured. More investments will be made to push forward advancement of science and technology, in a view to optimizing reservoir management and regulation with the use of state-of-the-art technologies and solutions. Further efforts will be exerted to properly manage the dilemma between flood control and benefit enhancement, and promote harmony between Man and Nature, in the hope that benefits of reservoirs/dams to human beings will be maximized and negative impacts of reservoirs/dams minimized. Continuous enhancement of risk awareness will include step-by-step construction of a dam safety emergency management mechanism to reinforce capacity building for better emergency response, more effective prevention and control of disasters relating to dam collapses, and successful safeguard of public security and public interest in the lower reaches of the dams.

4. International Cooperation and Exchanges

Since the 1990s, there have been more frequent bilateral exchanges in the field of water resources. The Ministry of Water Resources (MWR) has established regular bilateral exchange relations with Japan, South Korea, UK, the Netherlands, Canada, USA, Brazil and Switzerland, and engaged in non-regular bilateral exchanges with many countries in the world. MWR completed "Sino-Canada Dam Safety Cooperation" programs and the "Sino-Australia Dam Risk Management Cooperation Program", and initiated the Sino-Japan Reservoir Operation & Management Capacity Building Program and the Sino-Switzerland Dam Safety Reinforcement Program. The ministry also organizes annual academic exchanges for the dam commissions of China, Japan, and South Korea. With regard to project construction, the Xiaolangdi Reservoir Project successfully brought in foreign capital, adopted international competitive tendering, and applied the globally accepted FIDIC contract terms as the exclusive norm for project construction and technical specification, which helps accumulate valuable experiences for the construction and management of water conservancy and hydropower projects in China.

Over the last few years, MWR has successfully hosted the International Conference on Large Dams in 2000, the International Symposium on Dam Safety & Potential Danger Detection in 2005, the International Symposium on Reservoir and Dam Safety Management in 2008, the 1st International Workshop on Rock-fill Dams in 2009, and the International Workshop on Dam Technology and Sustainability in 2011. These events boosted international exchanges and cooperation, and helped Chinese talents in water science and technology to go global. During the 77th Annual Conference of the International Commission on Large Dams (ICOLD) in 2011, a Chinese expert was elected the 22nd President of the Commission.

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