黃河水利水電工程

ENGINEERING PROJECTS OF WATER CONSERVANCY AND HYDROPOWER DEVELOPMENT ON YELLOW RIVER

黄河的洪水主要来自中游的三个区域：河口镇至龙门区间，龙门至三门峡区间，三门峡至花园口区间。上游来的洪水组成中游洪水的基流。

黄河流域多年平均降水量476mm。从地区分配来看，降水量从东南向西北递减；从时间分配看，全年降水量的60%～80%集中在夏秋两季，多形成暴雨洪水。尤其在黄河"汛期"的7月、8月、9月、10月这四个月，不仅集中了全年水量的60%，而且集中了全年85%左右的泥沙。

黄河比降陡，落差大，水力资源丰富。可开发的500kw以上的资源约为2800万kw。

干流工程

在黄河干流上兴建大型水利枢纽工程，是从一九五五年制定黄河综合利用规划以后开始的。规划拟在黄河干流龙羊峡以下布置46座水利水电工程，选择了三门峡、刘家峡两座综合性水利枢纽和青铜峡、渡口堂等处灌溉枢纽作为第一期工程。三十多年来，规划逐步得到实施，同时在实践中不断加以修正。在修订的规划中，根据近期技术可能性和两岸工农业发展的需要，已将干流原规划的46座水利水电工程合并为29座，其中龙羊峡、刘家峡、大柳树、碛口、龙门、三门峡、小浪底等七座大型水利水电工程为开发黄河的关键性工程。目前，除刘家峡、青铜峡、三盛公（即渡口堂）、三门峡四座水利枢纽已建成外，还增建了盐锅峡、八盘峡、天桥三座水电站。库容巨大的龙羊峡水库也于1987年10月开始蓄水发电。已建成的八座大型水利枢纽和水电站，总发电装机容量362万kw，年发电量176.7亿kw·h，总库容410亿m^3，有效库容299.4亿m^3。

继龙羊峡之后的李家峡水电站于1987年开工，装机容量200万kw，年发电量59.2亿kw·h。

黄河干流水利水电工程建设有效地推动了沿黄地区的经济发展，获得了巨大的经济效益。除了在防洪、灌溉、供水中发挥显著作用外，还提供了巨大的发电效益。据1987年底统计，仅刘家峡、盐锅峡、青铜峡、八盘峡四座水电站的累计发电量已达1376.9亿kw·h，总产值89.5亿元，上交税利为投资的5倍。同时，大规模的工程实践为在多泥沙河流上水库的规划设计施工和管理运用提供了丰富的经验。尤其是三门峡水库"调水调沙"运用，为在多泥沙河流上兴修大型水库长期保持有效库容开创了成功的先例。

WATER CONSERVANCY AND HYDROPOWER PROJECTS ON THE YELLOW RIVER

THE YELLOW RIVER

The Yellow River originates in the Yao-Gu-Zong-Lie piedmont basin on northern slope of Pa-Yen-Ka-La Mountains in Qinghai province. It transverses nine provinces or autonomous regions, including Qinghai, Gansu, Sichuan, Ningxia, Inner Mongolia, Shaanxi, Shanxi, Henan and Shangdong provinces to empty itself into Bohai sea. The river flows through the Qinghai-Tibet Plateau, Loess plateau and the great North China alluvial plain, descending in three steps from west to east with a total fall of 4448m. The total length of Yellow River is 5464 km and the drainage area 753,000 km^2. With respect to morphology of different reaches, the Yellow River is commenly divided into upper, middle and lower reaches. The reaches from river source to Hekouzhen in Inner Mongolia Autonomous Region are named as the upper reaches, the middle reaches from Hekouzhen to Taohuayu (near Zhengzhou) in Henan province, and the lower reaches downstream of Taohuayu.

The Yellow River, which flows from its source eastwards through swamps and grasslands and cross the Zhaling and Eling lakes, the biggest fresh highland lakes in China, up to Maduo county, is called the reaches of river source. There are lush pastures and vast expanses of open landscape along both banks. From Maduo to Longyangxia, the river transverses through wide valley of alluviam, ancient lakes and gorges, surrounded by high mountains betweem Pa-Yen-Ka-La Mountain and Jishi Mountain, winding in a large S-shaped route. Farther downtream, in a distance of 916 km from Longyangxia to Qingtongxia, the Yellow River roars swiftly through 19 long gouges and 17 wide valleys alternatively. In the gouge reaches, many good dam sites are available for exploitation of hydropower resources and the reaches is considered as a rich mining area in hydropower development due to the large gradient and low sediment load.

Downstream from Qingtongxia, the Yellow River flows much quieter through the wide alluvial plain and deserts

of Ningxia and Inner Mongolia area. As early as in the Qin Danasty, ancient irrigation canals were built in this area which was one of the oldest irrigation districts taking water from the Yellow River, praised as a "lush southern-type field under the Great Wall".

The Middle Yellow River near Hekouzhen in the Inner Mongolia, turning southwards in front of Luliang Mountains, roars in gorges seperating Shaanxi and Shanxi provinces. At greater part of this reach, the river width is 400—600 m with numerous shoals and hanging cliffs on both banks. The reach is also rich in exploitable hydropower resources. Getting out of the gorge at Yumenkou, the Yellow River enters a wike alluvial plain where its largest tributary——Wei River is confluenced, then turns sharply to the east in front of Qingling Mountains at Tongguan and flows through Sanmenxia and its last series of gorges to Taohuayu. The outlet of the gorge section is in Memgjin county, Henan province, where the dam site of the proposed Xiaolangdi project is located. The Middle Yellow River flows through the largest loess plateau in the world. Great amount of streams and gullies deep cutting the loess, bringing huge amount of sediment to the Yellow River, making it the muddiest river in the world.

Below Taohuayu, the Yellow River, wandering on the North China Plain confined by the levee system along both banks totally 1370 km in length, becomes a well known suspended river due to the unceasing aggradation. This has rendered the arduouness of flood prevention on lower reaches of the Yellow River, quite unique all over the world.

WATER AND SEDIMENT

Generally speaking, the Yellow River is deficient in water and abundant in sediment load. Annual runoff amounts to 58 billion m^3 estimated for period of 1919—1979, a series of 61 years, which accounts only 2% of that for all rivers of China. With an annual sediment load of 1.6 billion tons and mean sediment concentration of 35 kg/m^3, the Yellow River is the heaviest sediment laden river in the world. 60% of the runoff comes from the upper reaches, while 90% of the sediment comes from the middle reaches.

Floods that threaten the safety of lower reaches originate mainly from three regions in the middle reaches: Hekouzhen to Longmen, Longmen to Sanmenxia and Sanmenxia to Huayuankou. Floods from the upper reaches

comprise the base flow of flood from the middle reaches.

The annual precipitation, averaged for whole basin, is 476 mm and decreases from southeast to northwest. 60—80% or more of the precipitation falls in summer and autumn, frenquently causing storm floods. In the flood season, from July to October, not only 60% of the runoff takes place, but also 85% of the sediment load is being transported.

The Yellow River is rich in hydropower resources due to its steep slope and great fall. The hydropower available for exploitation with project capacity of each exceeding 0.5 MW is to be 28000 MW.

DAM PROJECTS ON MAIN STEM OF THE YELLOW RIVER

Construction of huge water conservancy and hydropower projects commenced after the Comprehensive Yellow River Basin Plan was adopted in 1955. 46 dam projects downstream Longyangxia were defined by the plan for harnessing the Yellow River. Two key projects of multi-purpose exploitation, Sanmenxia and Liujiaxia water conservancy and hydrpower projects, and Qingtongxia, Sanshengong and other projects mainly for irrigation were chosen in the plan as first stage projects. Being implemented step by step, this plan has subjected to modification and adjustment in practice for past 30 odd years. In recent revision of the plan, 29 water conservancy and hydropower projects is planned to be built on the main course instead of 46 originally planned, among which seven large projects are listed as the key projects of exploitating the Yellow River, that is, Longyangxia, Liujuaxia, Dalirshu, Zhikou, Longmen, Sanmenxia and Xiaolangdi Projects. The Liujiaxia, Qingtongxia, Sanshengong and Sanmenxia projects and other hydropower stations at Yanguoxia, Bapanxia and Tianqiao were already built and the huge Longyangxia project has been put into operation and commenced already impoundment in October 1987. All together, there are 8 water conservancy or hydropower projects already completed on the main Yellow River. The total installed capacity is 3620 MW and ammual output of electricity amounts to 17.67 billion kwhr. The total storage capacity is 41.0 billion m^3, among which 29.9 billion m^3 is effective capacity.

Next to Longyangxia project, another huge hydropower project at Leejiaxia is now under construction. Its installed calacity will be 2000 MW and output of electrici-

ty 5. 92 billion kwhr per year.

Completion of the projects mentioned above has effectively promoted development of economy in regions along the Yellow River and given enormous economic benefits. According to the statistics made in 1987, in addition to the significant benefits in flood prevention and irrigation, the cumulative power output of the four upstream hydropower stations at Liujiaxia, Yanguoxia, Qingtongxia and Bapanxia amounted to 137. 7 billion kwhr, equivalent to 8. 95 billion yuan, and only the profits and taxes returned to the Government equal to 5 times of their investment. More than this, practice in the construction of these projects has provided valuable experiences in planning, design, construction and management of dams and reservoirs on rivers with high sediment load. Especially the operation mode of regulation of water and sediment in the Sanmenxia Reservoir has created a successful precedent for building large reservoirs on heavily sediment laden rivers.

龙羊峡水利枢纽

龙羊峡水利枢纽位于青海省，是黄河干流唯一具有多年调节能力的水利枢纽。电站装机容量128万kw，水库调节径流，可使现有的刘家峡等4座水电站增加保证出力30万kw，并在防洪、防凌、工农业供水上发挥巨大作用。

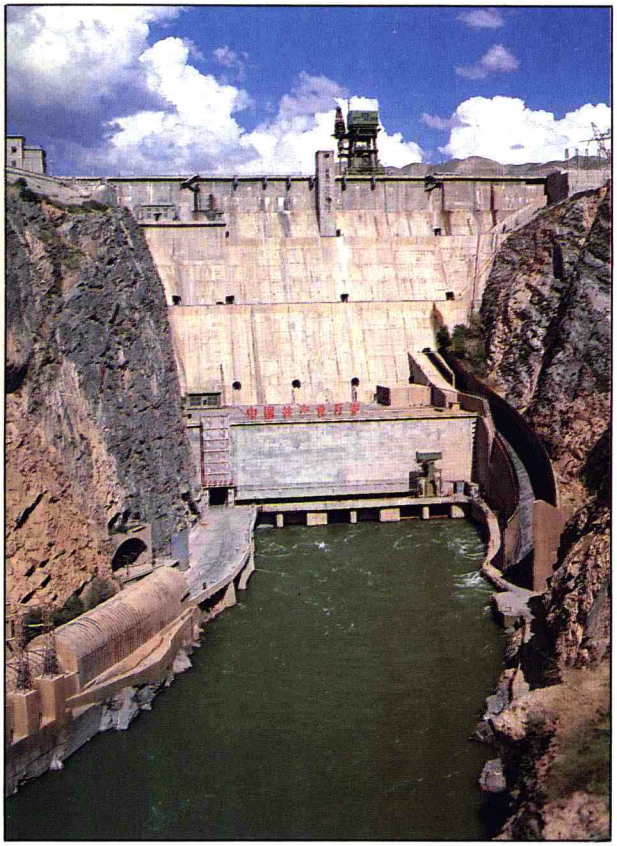
General view of Longyangxia project

The Longyangxia project, situated in Qinghai province, a reservoir capable to carry out perennial regulation of flow, is very beneficial to utilization of water resources and plays an important role in hydropower development, flood and ice run control and water supply. It's installed capacity is 1280 MW, and the guaranteed power output of the existing downstream hydropower plants may be increased by 300MW.

李界范　摄

by Li Jiefan

刘家峡水利枢纽位于甘肃省。电站装机容量 116 万 kw，水库的调节作用，使现有宁蒙引黄灌区的供水保证率由建库前的 50%左右提高到 75%以上；保证在百年一遇洪水时兰州市安全泄量不超过 6500m³/s；在宁蒙河段融冰期间，控制下泄流量，缓解凌汛威胁，水库水面可以常年通航；每年约有 5 万多公斤鲜鱼供应市场。



Liujiaxia water conservancy project is located in Gansu province. The installed capacity is 1160 MW. Due to the reservoir, the guatantee of water supply for irrigation in the existing Ningxia—Inner Mongolia irrigation districts has rised from 50% to above 75%; flood discharge with a frequency of once in hundred years will not exceed the safety value of 6500m³/s at Lanzhou; outlet discharge can be controlled during the ice melting period in Ningxia- Inner Mongolia reaches to alleviate the possible damages caused by ice flood; navigation becomes possible in the reservoir area all year around and more than 50 tons of fish for sale on the market .

刘家峡水利枢纽大坝
A high dam at Liujiaxia

高峡出平湖——刘家峡水库　Reservoir Liujiaxia

盐锅峡水电站工程

在刘家峡下游，相距 32km，是一座以发电为主，兼有灌溉效益的水电工程。

Yanguoxia hydropower project, situated at 32 km downstream Liujiaxia dam, is functional mainly to generate electricity and also beneficial to irrigation.

八盘峡水电站

位于甘肃省兰州市，上距盐锅峡水电站 17km。

Bapanxia hydropower project located at 17 km downstream the Yangouxia hydropower project.

韩三当　摄

by Han Sandang

Qingtongxia water conservancy project situated in Ningxia Autonomous Region, at 80 km upstream the city of Yinchuan. Completion of Qingtonxia project has marked the end of diversion of water from the Yellow River without dam and enabled to extend irrigated area by 2.5 times than that in 1949. The irrigated area with stable productivity is one of the 12 production bases of grain in China.

韩三当　摄

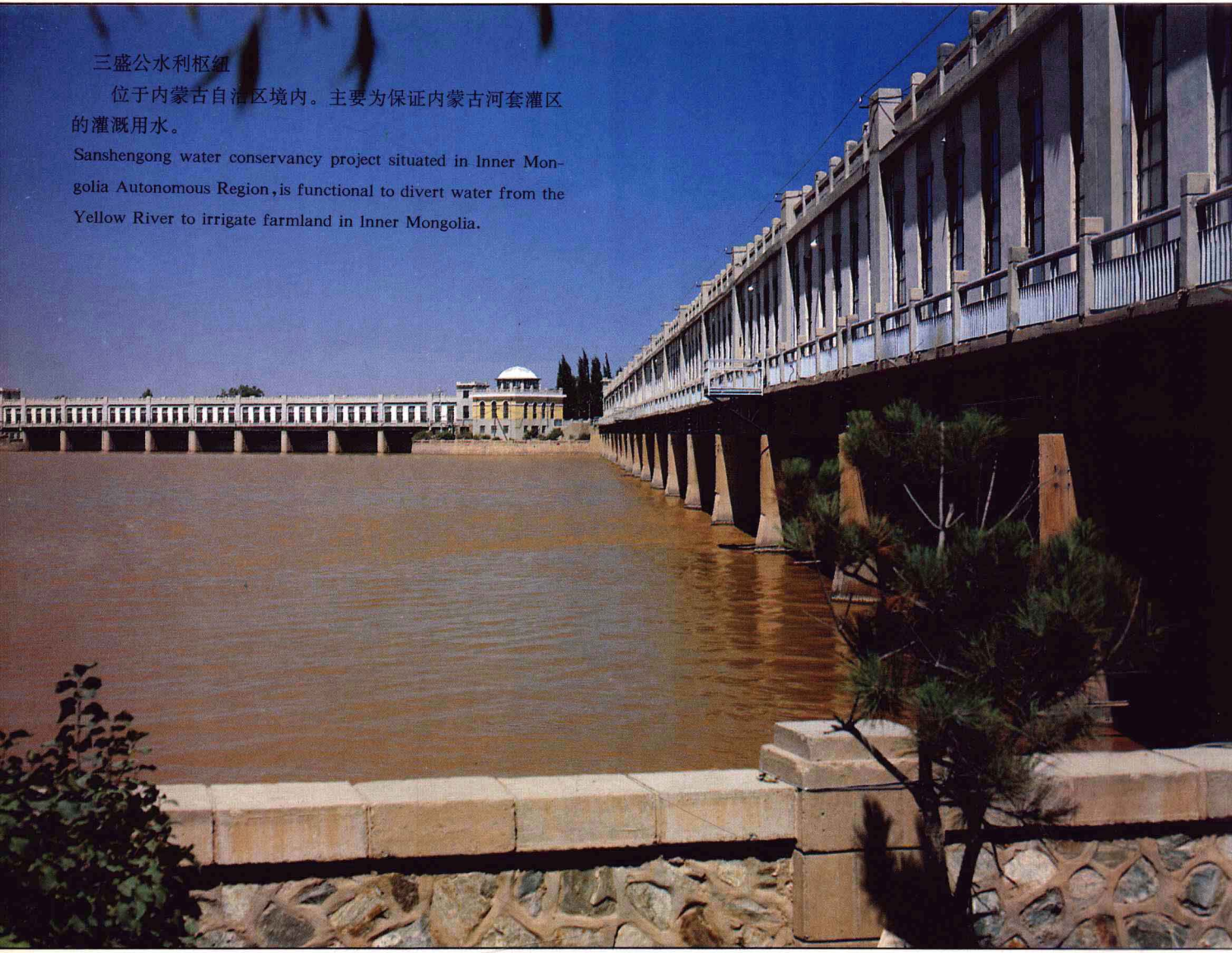
by Han Sandang

李卓　摄

by Li zhuo

青铜峡水利枢纽

位于宁夏回族自治区，下距银川市约 80km。它的建成，结束了古老的宁夏引黄灌区无坝引水的历史，使灌溉面积较 1949 年增长了 2.5 倍，成为全国 12 个商品粮基地之一。



三盛公水利枢纽

位于内蒙古自治区境内。主要为保证内蒙古河套灌区的灌溉用水。

Sanshengong water conservancy project situated in Inner Mongolia Autonomous Region, is functional to divert water from the Yellow River to irrigate farmland in Inner Mongolia.

天桥水电站

位于山西保德、陕西府谷县城上游 8km 处，为低水头河床式径流电站

Tianqiao hydropower project , located at 8 km upstream Baode in Shaanxi province and Fugu in Shanxi province, is a lowhead runoff hydropower plant.

三门峡水利枢纽

三门峡水利枢纽是黄河干流上修建的第一座大型水利工程。1960年建成蓄水，以后曾进行了两次改建，增建2条排沙隧洞，改建4条发电引水钢管用于泄流排沙，打开8个施工导流底孔，加大了泄流排沙能力，坝前水位315m的泄量由3000m³/s增至10000m³/s。1974年以后，水库采用“蓄清排浑”的运用方式，即非汛期抬高水位蓄水；汛期降低水位排沙。通过合理调水调沙，使水库长期保持有效库容，承担着重要的防洪任务，并发挥防凌、发电、灌溉、供水的综合效益。

Sanmenxia water conservancy project is the first high dam project built on the Yellow River. After impoundment in 1960, serious aggradation in the reservoir was observed, so the outlet structures were reconstructed: two tunnels added, four penstocks reformed into outlets and 8 pluged bottom outlets used for diversion during construction period reopen and used as bottom outlets, and as the result, the discharging capacity of the dam has increased from 3,000m³/s to 10,000m³/s at elevation 315 m.

The reservoir has been operated according to the scheme of storing the clear and disposing the muddy since 1974, that is to store and regulate the relatively clear water in nonflood season and to operate at low stage in flood season to flush out the sediment. Due to proper regulation of flow and sediment, certain amount of effective storage capacity has been preserved for longterm use for flood and ice run control, irrigation , water supply and electricity generation.

黄河干流各河段主要特征值表

河段	起迄地点	流域面积 (km^2)	河长 (km)	落差 (m)	比降 (‰)	汇入支流 (条)
上游	河源至河口镇	385966	3472	3464	10.0	43
	1. 河源至玛多	20930	270	233	8.6	3
	2. 玛多至龙羊峡	110490	1417	1765	12.5	22
	3. 龙羊峡至下河沿	122722	794	1220	15.4	7
	4. 下河沿至河口镇	131824	990	246	2.5	11
中游	河口镇至桃花峪	343751	1206	890	7.4	30
	1. 河口镇至龙门	111591	725	607	8.4	21
	2. 龙门至三门峡	190842	240	97	4.0	5
	3. 三门峡至桃花峪	41318	241	186	7.7	4
下游	桃花峪至黄河口	22726	786	94	1.2	3
	1. 桃花峪至高村	4429	206	37	1.8	1
	2. 高村至艾山	14990	194	23	1.2	2
	3. 艾山至利津	2733	282	27	0.9	0
	4. 利津至黄河口	574	104	7	0.7	0
全河	河源至黄河口	752443	5464	4448	8.1	76

注：①汇入支流系指流域面积大于 $1000km^2$ 的一级支流。

②桃花峪系指秦厂(三)断面。

Main Characteristics of the Yellow River

Reaches	Location of reaches	Catchment (km^2)	Length (km)	Fall (m)	Slope (‰)	Number of tributaries
Upper	Source——Hekouzhen	385966	3472	3464	10.0	43
	1. Source——Maduo	20930	270	233	8.6	3
	2. Maduo——Longyangxia	110490	1417	1765	12.5	22
	3. Longyanxia——Huanheyuan	122722	794	1220	15.4	7
	4. Huanheyuan——Hekouzhen	131824	990	246	2.5	11
Middle	Hekouzhen——Taohuayu	343751	1206	890	7.4	30
	1. Hekouzhen——Longmen	111591	725	607	8.4	21
	2. Longmen——Sanmenxia	190842	240	97	4.0	5
	3. Sanmenxia——Taohuayu	41318	241	186	7.7	4
Lower	Taohuayu——The mouth	22726	786	94	1.2	1.3
	1. Taohuayu——Gaocun	4429	206	37	1.8	1
	2. Gaocun——Aishan	14990	194	23	1.2	2
	3. Aishan——Lijin	2733	282	27	0.9	0
	4. Lijin——The mouth	574	104	7	0.7	0
Total	Source——Mouth	752443	5464	4448	8.1	76

Notes: 1. The tributary here defined as one with catchment exceeding 1000 km^2

2. Based on the publication of RPDI, YRCC, China.

黄河干流主要测站径流特征值表

站名	实测多年平均年径流量（10^8m^3）	天然径流量（10^8m^3）				
		多年平均年径流量	多年汛期（7～10月）平均值	最大年径流量	最小年径流量	最大与最小年径流量之比
贵　德	222	203	122	326	102	3.2
兰　州	315	323	191	515	166	3.1
河口镇	247	313	191	542	160	3.4
龙　门	319	385	229	653	197	3.3
三门峡	418	498	294	770	240	3.2
花园口	470	559	332	939	274	3.4
利　津		580				

注：特征值统计系列为1919～1975年。