China

"Guanyinge Multipurpose Dam Project "

Project Summary

Borrower	Ministry of Foreign Trade and Economic Cooperation, People's Republic of China (currently Ministry of Finance)
Executing Agency	Liaoning Provincial Water Resources and Electricity Department (currently Liaoning Provincial Water Resources Department)
Exchange of Notes	(3 times) 26 July, 1988 / 16 May, 1989 / 2 November, 1990
Date of Loan Agreement	(3 times) 3 August, 1988 / 23 May, 1989 / 19 November, 1990
Loan Disbursed Period	7 years from the validity date of Loan Agreement
Loan Amount	¥18,225 million (total of three Loan Agreements)
Loan Disbursed Amount	¥18,062 million (same as above)
Procurement Conditions	General Untied
Loan Conditions	Interest Rate: 2.5% Repayment Period: 30 years (10 years for grace period)

<Reference>

(1) Currency: Yuan

(2) Exchange Rate

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
$/Yuan	0.2687	0.2118	0.1915	0.1840	0.1739	0.1724	0.1184	0.1202	0.1205	0.1208
¥/Yuan	33.81	30.35	25.74	23.04	21.69	21.79	11.81	12.36	13.98	15.70

(Source) IMF "IFS"

(3) Fiscal Year: January 1 ~ December 31

(4) Terminology

RCD construction method..... Roller Compacted Dam concrete construction method (By this method, rollers are used for mechanical compaction rather than using vibrators for compaction).

Grouting..... A curtain-like waterproof membrane constructed underground to prevent water loss through the ground.

Rock pocket..... Parts where the frame and concrete are not mixed.

1. Project Summary and Comparison of Original Plan and Actual

1.1 Project Location

1.2 Project Summary

This project aimed to construct a concrete gravity-type dam with a water catchment volume of 2.168 billion m^3 at Xiaoshi, Guanyinge, 40km up from Benxi on the Taizi River that runs through Liaoning province. The executing agency was Liaoning Provincial Water Resources and Electricity Department (currently Liaoning Provincial Water Resources Department). The project was approved under the Seventh Five Year Plan in April 1985, and construction began in 1986. The primary objective of this dam is flood control, but it has a number of secondary objectives, such as water supply for urban and industrial demand, water supply for irrigation, power generation and raising aquatic produce.

The JBIC loan covered the entire foreign currency potion of the project cost.

1.3 Background

1.3.1 Overview of Liaoning Province

(1) Geography of Liaoning Province

Liaoning is the southernmost of the three provinces of the northeast of China, the others being Heilongjiang and Jilin provinces. The Liaodong peninsula, which juts out into the Gulf of Bo Hai, has good natural ports at Dalian and Yingkou and plays an important role as a gateway to the Northeast. The province has mountain ranges on both its eastern and western edges, with the Liao He plain between. The Liao He river system, which is the largest river of the Northeast, has built up alluvial deposits on the plain, which occupies one third of the province's land area.

The province has a warm, moist monsoon climate, giving it the highest rainfall among the provinces of the Northeast.

Liaoning province has 1.5% of China's land area and 3.4% of its population (see Table 1). Mountains occupy 62% of the province's area, while only 26% (37,600km^2) is under cultivation, and only 20% of that is irrigated. Therefore the province is not self sufficient in food.

The provincial capital is Shenyang. Other major cities include Anshan and Benxi, which are centers of the ferrous metals industry. Both marine and land transport have been developed, and the province has two large ports at Dalian and Yingkou. Racially, 92% of the population are Han Chinese, with other races accounting for only 8%. Liaoning is also the origin of the Manchu people, who founded the Qing Dynasty, and there are now approximately two million Manchu people in the province.

Table 1 Land Area, Population, GDP per Head in Liaoning Province

	Land area ($10,000km^2$)	Population (10,000 persons, 1996)	GDP per head (Yuan, 1995)
Liaoning Province	14.57	4,116	7,730
Total for China	960.00	122,389	5,634
Share of national total	1.5%	3.4%	137.2%

(Source) China Yearbook

(2) Industries of Liaoning Province

Liaoning has abundant subterranean resources, such as coal, iron ore and oil, which it has used to develop into one of China's leading centers of heavy chemical engineering. At the time, in 1988, industry accounted for 85% of the total agricultural and industrial production. The province's share of China's industrial production value (5.4%) is the third largest, behind Jiangsu with 8.9% and Shandong with 6.0%. The main industries, such as ferrous metals, energy, petrochemicals and mechanical engineering, are concentrated on heavy industry, and Liaoning has a 10% share of heavy industry in China (for raw steel alone, the province's share is 22%). In particular, the province is famous for ferrous metals and cement from Benxi, petrochemicals and fabrics from Liaoyang, ferrous metals and chemicals from Anshan, thread from Yingkou and a variety of light industry. However these industries have a high proportion of state-owned enterprises, which suffer from "Northeast Syndrome", with decrepit equipment that hinders modernization.

As a result, Liaoning's growth rate in real GDP between 1980 and 1992, 8.5%, was below the national average for provinces, which stood at 9.2%. In the ranking of provinces by growth rate, Liaoning comes in 21st place.

To escape from this situation, Dalian was made an "Economic and Technical Development Zone" and Shenyang "Experimental City for Comprehensive Reform of the Economic System". Reforms of all kinds are under way.

The main reform moves are as follows:

1984 Dalian was designated as an open coastal city, and an "Economic and Technical Development Zone" was constructed.

1986 A bankruptcy system was put into effect throughout China.

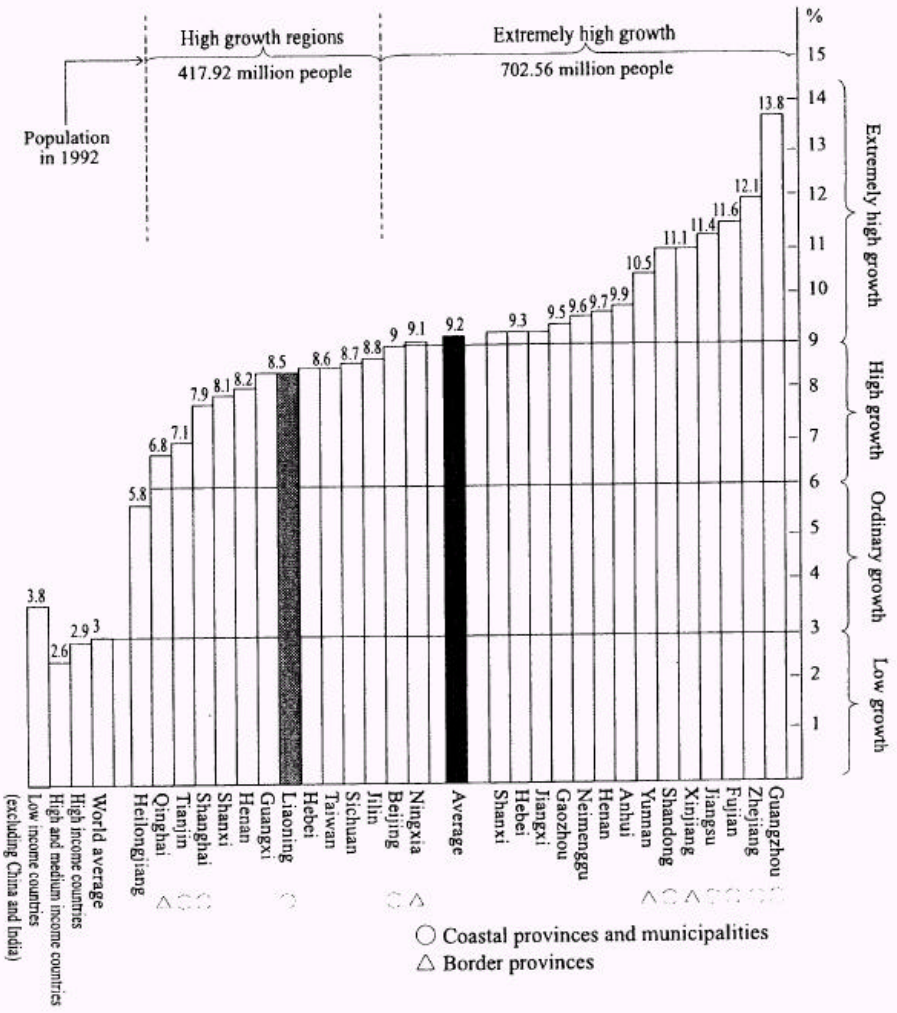
1987 Shenyang was made "Experimental City for Reform of the Science and Technology System".

1988 The Liaoning Peninsula was designated "Open Coastal Zone" (covering two thirds of the provincial population).

1992 The establishment of "Economic and Technical Development Zones" in Yingkou and Shenyang was approved.

The policy is for mechanical and electrical industries to join petrochemicals and ferrous metals as the four mainstays of ongoing development in Liaoning province.

Figure 1 Economic Development of Each Province in China



(Source) Reiitsu Kojima "Modern Chinese Economy", Iwanami Shinsho (1997)
Tatsumi Okabe "China Research Handbook", Iwanami Shoten (1996)

(3) Overview of the Taizi River Valley

Three rivers flow through Liaoning province, cutting across it diagonally from the mountains in the northeast to the Gulf of Bohai in the southwest. The three rivers, in order from the north, are the Liao He, the Hun He and the Taizi River. Of these, the Hun He and Taizi River merge on the plain between Anshan and Yingkou before flowing through Yingkou. The total length of the Taizi River is 413km and its valley covers 10.9% of Liaoning province. The total population of the river's valley is 6.45 million, 16% of the province's total (as of 1995), with a population density of 407 people/km^2. The valley contains four major industrial cities: Benxi, Liaodong,

Anshan and Yingkou at the mouth. The urban population is 3.29 million, more than half the population of the valley.

Agriculture in the valley is strongly restricted by natural and geographical factors, and

mountainous terrain is dominant in the upper reaches of the river. The topsoil is thin and the soil contains many stones. Good farmland is almost entirely confined to the area upstream of Shenyang, and 70% of the area's farmers are concentrated at the west end of the Changda Railway (which runs from Changchun to Dalian). The share of the province's total provided by the Taizi River amounts to 25.3% of the surface water and 51.6% of groundwater.

Thus development of the water resources of the Taizi River is extremely important for the economic development of Liaoning province.

Table 2 Basic Data on the Taizi River Valley

		Units	(1) Liaoning province	(2) Taizi River	(2)/(1) %
Area	Total area	km^2	145,900	15,845	10.9
	Forested area	km^2	52,242	6,886	13.2
	Cultivated area	km^2	44,085	3,882	8.8
	Effective irrigated area	km^2	12,038	1,180	9.8
Population	Total	10,000 people	4,034	645	16.0
	Urban	10,000 people	3,419	329	9.6
	Rural	10,000 people	615	316	51.4
Total water intake volume	Total	100 million m^3	436	139	32.0
	Surface water	100 million m^3	325	82	25.3
	Groundwater	100 million m^3	111	57	51.6

(Source) (1) "China National Resources Book, Liaoning Edition", China Environment and Science Publishing Company, 1995.
"China Water Conservance Yearbook 1996", China Water and Electricity Concervance Publishing Company, 1997 (1995 data)
"Liaoning Yearbook 1997", People's Government Liaoning Province 1997 (1995 data)
(2) Dept. of Water Conservancy Liaoning Province materials.

1.3.2 Objectives of Constructing Multi-purpose Dam in Liaoning Province

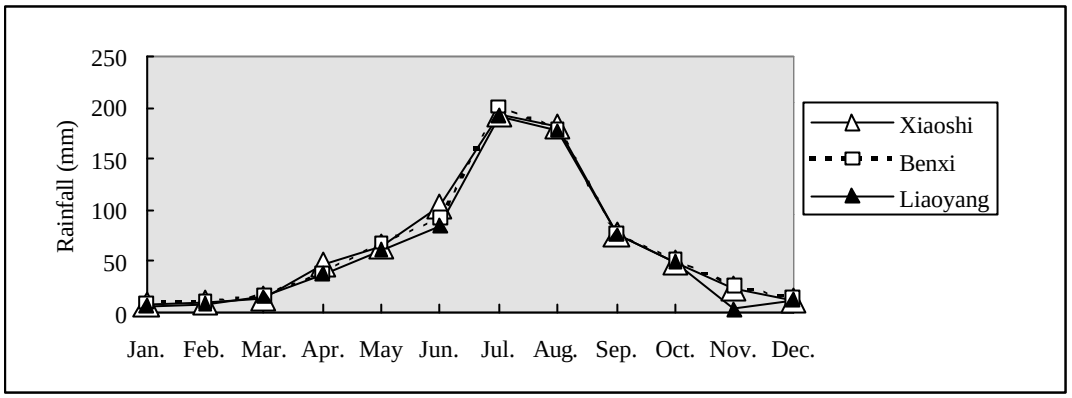
(1) The Necessity of the Multi-purpose Dam

As mentioned above, the Taizi River valley affected by this project has a concentration of important industrial cities, such as Benxi, Shenyang, Anshan and Yingkou, and agriculture has developed on the flat land around the lower reaches of the river. Therefore the valley plays a key role as the center of industry and agriculture in Liaoning province. The average annual rainfall of the Taizi River valley is not very high, at around 800mm (maximum 1,100mm. minimum 500mm), but most of it is concentrated between June and August, when the area is prone to flood damage. In order to meet increasing demand for urban, industrial and agricultural water supplies, it is necessary to spread the supply of water evenly through the year. Thus the main reason for this project's importance lies in its objectives for water use and control.

Many tributaries flow into the Taizi River, and dams such as the Tanghe Dam, the Sandao He Dam and the Shenwo Dam have already been built on the main tributaries. This project built the

Guanyinge Multi-purpose Dam at Xiaoshi in Benxi district, at the furthest upstream point of the main stream.

Figure 2 Average Rainfall Volume in the Taizi River Valley



(Source) Liaoning Provincial Water Resources Department materials

In the whole of Liaoning province there are 21 large multi-purpose dams with capacities of 100 million m^3 or more. Most of them are multi-purpose dams for the purposes of flood control, irrigation, power generation and water produce raising. The Seventh Five-Year Plan for Liaoning province (1986~1990) planned the construction of the Guanmen Shan Dam, the Biliu He Dam and the Songshu Dam, as well as this one. The Eighth Five-Year Plan (1991~1995) included the construction of the Baishi Dam (now under construction with JBIC funding) and the Jinling Multi-purpose Dam.

1.4 Objectives

The Guanyinge Multi-purpose Dam (referred to below as "the Guanyinge Dam"), which was constructed under this project, is a concrete gravity-type dam with a water capacity of 2.168 billion m^3. It is located at Guanyinge in Xiaoshi about 40km upstream of Benxi. As mentioned above, flood control is the main purpose of this dam, but it has a number of secondary objectives, such as water supply for urban and industrial demand, water supply for irrigation, power generation and raising aquatic produce.

(1) Flood control

The Taizi River valley has suffered floods exceeding 10,000m^3/s on seven occasions since 1870. Of these, the largest was in 1960, when the flow reached 18,100m^3/s. That was described as a flood magnitude that would recur once in 150 years. After that there were further floods in 1975 and 1985. Thus floods were happening at intervals of 10~15 years, and the damage caused made the construction of a dam for flood control an urgent necessity.

Table 3 Flood Damage Caused by the Taizi River

1960	Inundation of 7.9km^2 of Benxi to a depth of 0.5~3.0m, two rail and one road bridge washed out, 39 factories inundated, 1,512.7km^2 of farmland inundated, damage to transport, electrical power and communications.	Value of damage	1.764 billion Yuan
1975	Uncleared land flooded.	Value of damage	Negligible
1985	491km^2 inundated in Shenyang and Anshan. 18,600 houses destroyed.	Value of damage	1.765 billion Yuan

(Source) Liaoning Provincial Water Resources Department materials

(2) Urban and Industrial Water Supplies

Demand for urban and industrial water supplies in the region was pressing, and before the dam was completed, water supplies were restricted for four months of the year. The shortage of water was impeding industrial production. According to the initial plan, the average amount of water supplied annually from the Guanyinge Dam was to reach 947 million m^3. Cooperation with the Shenwo Dam and Tanghe Dam downstream would raise the total supply volume to 1.173 billion m^3. Within the water supplied from the dam, 790 million m^3 (70%) was to be used for urban water supplies, which would greatly relieve the strained water supply situation in the four cities of the river's middle and lower reaches, namely Benxi, Liaoyang, Anshan and Yingkou.

(3) Irrigation Water Supply

Annual rice consumption in Liaoning province is four million tons, of which the province has to depend on imports from other provinces for one million tons. In order to raise the province's self sufficiency rate, the cities of Yingkou and Panjin plan to develop 17,600ha of new rice paddies. The plan will require a new source of 383 million tons of water for farming annually, of which 280 million tons is to be provided from this project. A review after the completion of the project found that 16,500ha of new paddies had been created, producing rice harvests of approximately 600,000 tons.

(4) Power Generation

China has the largest water resources of any country in the world, and its developable stored hydroelectric power has been put at 379 million kW (in 1994). Of that, only about 10% has been developed. Therefore the construction of hydroelectric power stations is being promoted nationwide, and the total of all planned projects is put at 156GW (around 40% of all stored hydroelectric resources).

In Liaoning province, nearly 90% of electricity is generated in thermal power stations. The province is working to develop its hydroelectric resources with a view to effective use of its energy resources. At the Guanyinge Dam, the water released for water supply and irrigation water supply is used to generate a peak output of 19,500kW (three generators x 6,500kW), reaching approximately 170MWh per year.

(5) Raising Aquatic Produce

After the dam was built, a water surface area of approximately 60km^2 (77.8km^2 at the time of maximum water level), at normal water level, was created. The raising of freshwater fish was planned, with anticipated production of seven million tons per year. The Dahoufang Dam on the upper reaches of the Hun He has already been used for raising fish, and it was decided that the fish-raising team from the Dahoufang Dam should pass on the benefit of its experience to Guanyinge Dam.

1.5 History

Table 4 shows the history of the project.

Table 4 History of the Project

1984	June	Feasibility study (F/S) completed on the Chinese side by Institute of Observation and Design, Water Resources and Electricity Department, Liaoning Province.
1985	April	National Planning Committee approved the above F/S. Dam designated as a project under the Seventh Five-Year Plan.
1986	September	Contract signed for the implementation of F/S by JICA.
1987	April	Start of F/S by JICA.
	May	Preliminary design comp leted by the Institute of Observation and Design, Water Resources and Electricity Department, Liaoning Province.
	August	The Ministry of Economics and Trade included this project among 31 presented to the Japanese government as 3R candidate projects.
	December	The Ministry of Economics and Trade formally asked for ten projects including this one to be implemented using the residue of 2R.
1988	March	Completion of F/S interim report.
	28 Mar ~ 10 April	Visit to China by JBIC Appraisal Mission.
	26 July	Exchange of Notes for FY 1988 loan (the Second ODA Loan)
	3 August	Loan Agreement for the FY 1988 loan (the Second ODA Loan) (for this project (I)).
	25 August ~ 30 August	Japanese government's intention to assist 42 projects with ¥810 billion explained during Prime Minister Takeshita's visit to China.
	September	Completion of F/S by JICA
1989	16 May	Exchange of Notes for FY 1989 loan (the Second ODA Loan)
	23 May	Loan Agreement for FY 1989 loan (the Second ODA Loan) (for this project (II))
	4 June	“Tiananmen Incident” occurred.
	14 July ~ 16 July	At the Arche Summit, a moratorium on contacts with Chinese government ministers and high-level officials was adopted.
1990	19 January	China made a formal request for FY 1990 projects (17 projects).
	19 January	China visited by the Director of the Ministry of Foreign Affairs Economic Cooperation Dept., who explained to the Chinese side that "preliminary preparations" were under way for the FY 1990 projects.
	5 April ~ 24 June	JBIC conducted a preliminary study on FY 1990 projects (16 projects, excluding the Beijing Shisanling Water Pumping and Generation Project).
	July 4	Findings of the preliminary study reported to the government.
	9 July ~ 11 July	At the Houston Summit, Prime Minister Kaifu announced that Japan would begin gradually implementing the Third ODA Loan, beginning with projects which aim to improve the public welfare and contribute to openness, are highly urgent and are ready to proceed.
	31 July ~ 1 August	Government mission.
	9 August ~ 21 August	JBIC Appraisal Mission
	30 August	Appraisal report presented to the government.
	19 September	Prior Notification
	2 November	Exchange of Notes for the First portion of FY 1990 loan (the Third ODA Loan)
	19 November	Loan agreement for the First portion of FY 1990 loan (the Third ODA Loan) (for the project (III))

2. Analysis and Evaluation

2.1 Evaluation on Project Implementation

2.1.1 Project Scope

(1) Project Scope Summary

The scope of this project was as shown in Table 5. It extended through three years, being two years for phase 1 and one year for phase 2. There were no major changes in project scope and it was implemented largely as planned. The specifications for the Guanyinge Dam are described in detail in section four.

Table 5 Project Scope of the Project

Overall plan	Phase 1 (residue of the Second ODA Loan)		Phase 2 (Third ODA Loan)
	Under the 1988 ODA loan	Under the 1989 ODA loan	Under the 1999 ODA loan
Dam construction	- Construction machinery	- Dam wall construction - Procurement of equipment and materials for the above construction works.	- Curtain grouting works - Metal works - Procurement of equipment and materials for the above construction works.
Generation equipment			- Generation equipment
Flood prediction and warning system			- Flood prediction and warning system
Employment of consultants	Employment of consultants		

(2) The Dam Site and Basic Design

The site of the Guanyinge Dam is a symmetrical U-shaped valley, as shown in Figure 3. The slope of the left bank (the right in the photograph) is a steep incline of 50~60 °, while the whole of the right bank is a gently sloping hillside. The river is 540m wide at the widest, and is so shallow that is can be walked across, other than in rainy season. The geology around the dam site is mainly limestone, which is highly permeable. Therefore the dam construction on the site was initially expected to be difficult, but it later became clear that it would be possible to use grouting (a curtain-like waterproof membrane under ground, see Figure 4) to prevent leakage, and therefore the site was chosen. Fortunately, the area to be covered by water did not contain any major faults or limestone caves, which would have caused major leakage. As the rock layers around the enclosed water are insoluble, there was no risk of leakage.

Figure 3 The Planned Site for Construction of Guanyinge Multi-purpose Dam

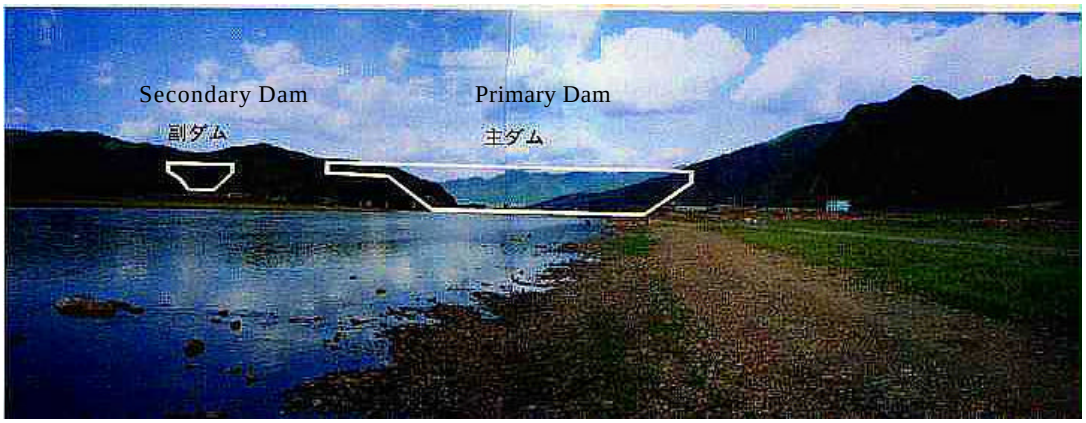
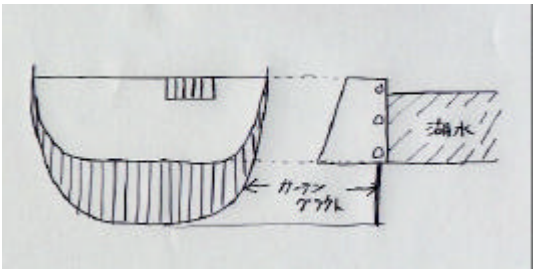


Figure 4 Conceptual Diagram of Curtain Grout



Note A curtain grout is created by boring deep holes down into the rock from near the upstream face of the dam and injecting cement into the holes. The result is a vertical curtain-like water membrane that extends down from the upstream edge of the dam, running along it from bank to bank. The membrane prevents stored water from leaking out by permeating through the rock.

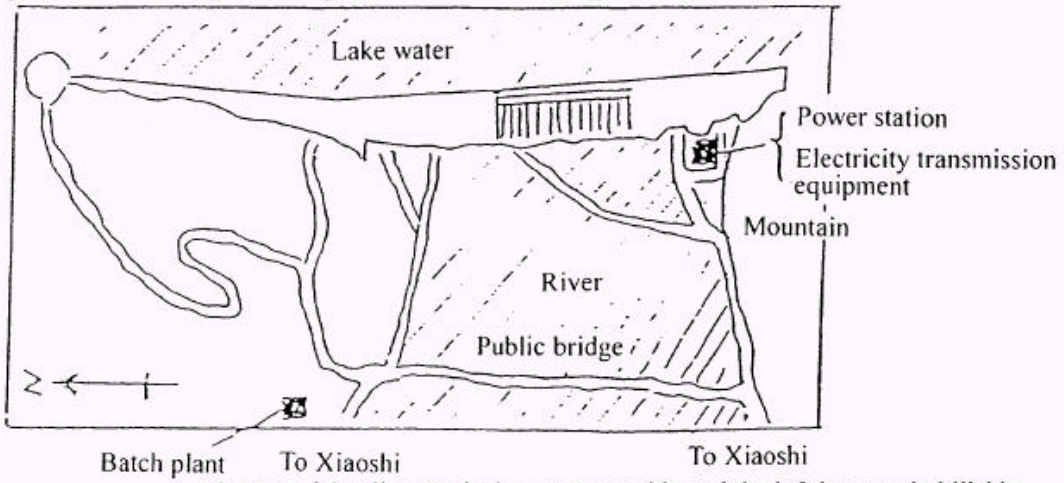
Figures 5 and 6 show the horizontal and vertical cross sections of the dam, respectively. The area around the dam site is mainly flat and the dam wall is long (1,040m) and wide (10m at the top). This configuration made it suitable for construction by mechanized methods, and the RCD method, which will be described later, was chosen for the first time in China.

The secondary dam shown in Figure 3 was not constructed, after it was judged that curtain grout treatment would suffice in place of a real dam. As a result, the curtain grout was extended from 171,000m to 197,800m.

For the construction of the Guanyinge Dam, a concrete batcher plant was built downstream of the dam, and a road was built to allow the dump trucks carrying the mixed concrete from the plant to reach the top of the dam (Figure 5, on the left of the diagram). The road on the left bank (right side) of the dam stops at the bottom of the dam. The dam wall is narrow on the left bank (right) side and wider on the other side because the wall is inclined. The road along the top of the dam is 10m wide. The left bank (right) side is a steep incline, while the other side is a gently-sloping hill. The power station and the electricity transmission equipment are installed at

the bottom of the steep incline. The tailraces are built in part of the dam in the center of the river. Of the 1,040m total length of the dam, there is a 10° angle between the 672m section extending from the left bank (right) side and the 368m section extending from the right bank. The angle is to accommodate faults and other conditions.

Figure 5 Site Layout Diagram of the Guanyinge Multi-purpose Dam



The top of the diagram is the upstream side and the left is a gentle hillside

The Dam is 82m high from its foundations (267m above sea level) and the tailraces are 71.2m high (256.2m). The thickness of the dam wall is 10m at the top and up to 61.2m at the bottom. The dam is made of 65 blocks, each 16m long (16m x 65 = 1,040m), with the exterior of each block being made in ordinary concrete and the interior made using the RCD method for concrete. This is known in China as the "gold-wrapped silver" method (a dual structure system in which gold wraps around silver).

Figure 6 Cross Section of the Guanyinge Multi-purpose Dam

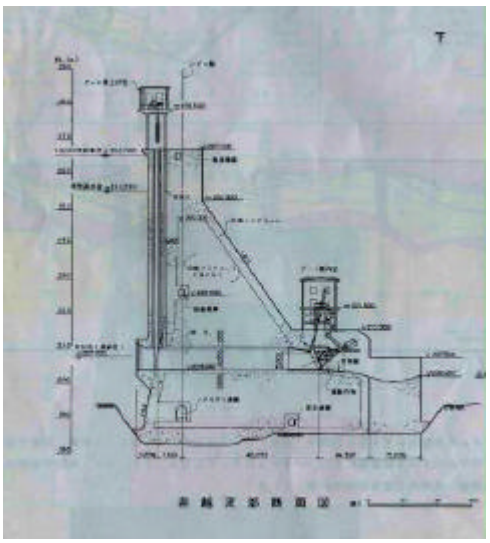
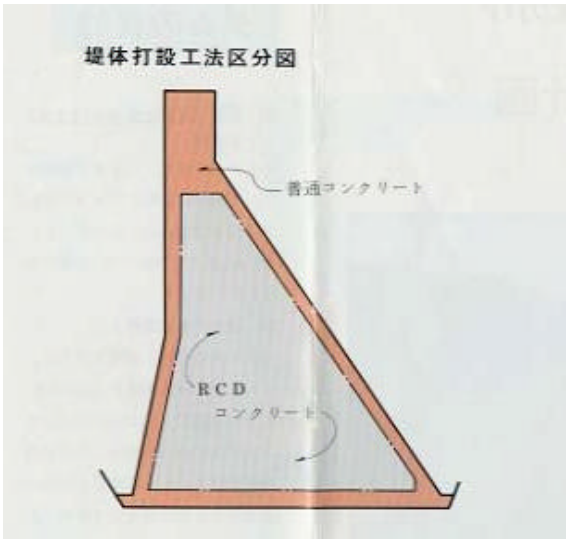


Figure 7 The "Gold-wrapped Silver" Method



(4) Other Dam Specifications

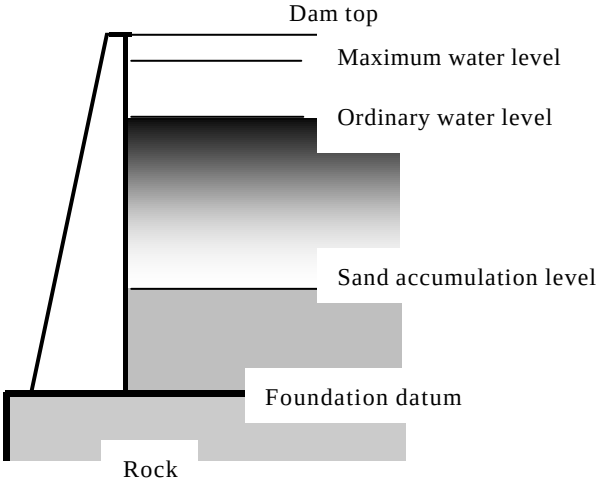
Table 6 details the other main specifications of the dam. The ordinary water level is 70.2m above the base foundations, and its maximum water level (with a probability of once in 10,000 years) is 80.7m. As the river upstream of the dam is mainly rocky there is little sand in the water, and sand accumulation is not expected to be large. Furthermore, the volume of the reservoir is very large. Therefore the planned sand accumulation interval is put at 50 years, with no particular countermeasures beyond allowing enough space for sand accumulation.

Table 6 Main Specifications of Guanyinge Multi-purpose Dam

			Unit	Above sea level	Difference
Main dam	Height of dam top		m	267.0	82.0
	Maximum water level	prob. of once in 10,000 years	m	265.7	80.7
	Design flood water level	prob. of once in 1,000 years	m	263.9	78.9
		Prob. of once in 500 years	m	263.5	78.5
	Normal high water level		m	255.2	70.2
	Sand accumulation level		m	207.7	22.7
	Elevation of dam foundation		m	185.0	0.0
	Length of dam top		m	1,040.0	
	Width of dam top		m	10.0	
	Dam wall volume		m^3	1,970,000.0	
Reservoir volume	Total water storage volume		m^3	2,168,000	
	Volume of water in use		m^3	1,385,000	
	Flood regulation volume		m^3	748,000	
Total annual outflow volume			m^3	1,110,000	
Power station	Type			Above ground, direct downflow from dam.	
	Rated output		kw	19,500	
	Turbine type			Vertical shaft Francis turbine	

Note There were no differences between planned and actual specifications.

Figure 8 Reservoir Capacity Allocation Diagram



(5) Flood Prediction and Warning System

A flood prediction and warning system was installed as dam-related equipment. It measures rainfall around the dam and also over a wider downstream area, covering Liaodong, Liaozhong and Yingkou and other locations.

The original plan was for this system to use terrestrial waves (VHF) for data communications, but the executing agency reconsidered the method in an effort to overcome topographical limitations and reduce maintenance costs. It finally settled on a system using satellite communications.

The satellite used was "Dongfanghong No.2" for a period of around one year from 1996 to 1997, but that satellite reached the end of its service life and the launch of its successor, "Dongfanghong No.3" failed. To cope with this unexpected turn of events, the Chinese side has installed a VHF data communications system at its own expense. The resumption of satellite-based communications using the "Asia No.2 Satellite" has been considered, but the satellite usage charges are expensive and the terrestrial satellite communications facilities would have to be adjusted at some expense. Furthermore, there is no problem with the existing terrestrial system, and accordingly the policy is to keep on using VHF.

(6) Consulting Services

Table 7 shows the scope of consulting services used in this project. After the project began, the executing agency decided it would manage the construction works for the curtain grouting, metal works and flood prediction and warning system for itself. Therefore these items were removed from the scope of consultant work, reducing its volume by around one tenth. According to the executing agency, the change did not cause any technical problems, but major changes to contract content can cause problems in some cases, and the JBIC must strengthen its monitoring of changes of this kind in future.

Table 7 Scope of Consulting Services

	Initial		After revision	
	T/D	S/V	T/D	S/V
Dam structure	○	○	○	○
Curtain grout	○	○	○	×
Metal works	○	○	○	×
Generation equipment	○	×	○	×
Flood prediction and warning system	○	○	○	×

Note 1 Services marked "O" were carried out and those marked "X" were outside the scope of consulting work.

Note 2 T/D refers to preparation of bidding documents and assistance with tendering. S/V refers to management of construction works.
T/D for the flood prediction and warning system included the detailed design.

(7) Selection of the RCD (Roller Compacted Dam concrete) construction method

One notable technical feature of this project is that it was the first use of the RCD construction method in a Chinese dam. The RCD construction method is a new dam construction method developed by the Japanese Ministry of Construction. By mechanizing the concrete laying, this

method aims to save construction time and money. In this project it enabled a saving of approximately ¥2 billion.

The procedure for this method is as follows: (according to "Photographic Explanation of Dam Construction by the RCD Method" and " Liaoning Provincial Water Resources Department and Guanyinge Water Management Office Documents" from the National Land Development Technology Research Center).

(i) Stiff-consistency concrete containing aggregate is transported by dump trucks etc. (the concrete used in this method is ultra stiff-consistency concrete with a low cement ratio).
(ii) The concrete is spread out evenly to a thickness of 50~75cm using bulldozers. This is the basic form of a layer.
(iii) Lateral joints are formed using vibrating joint forming machine (this does not form vertical joints).
(iv) The concrete is compacted using vibrating rollers. The kind of vibrators used with other concrete types are not used.
(v) A thin layer of mortar is spread between each layer and the one above to improve their bonding.

Step 1 Dump concrete from dump trucks

Step 2 Spread it evenly with bulldozers

Step 3 Prepare lateral joints using a joint forming machine

Step 4 Compact with rollers

Step 5 Inspection of compaction

Step 6 Mortaring

The Department of Water Conservancy reports that particular attention was paid to the following points in the construction of this project:

(i) When dump trucks drive onto a previous layer to dump new concrete, they can damage or dirty the surface where the tires touch. To avoid this, the trucks passed through a pool of water to clean their tires and drove onto metal plates or rubber sheets to prevent damage.

(ii) This method carries a high risk of separation of materials. Specialist staff were assigned to prevent that from happening, and when the concrete was deposited by the dump trucks it was deposited and dispersed in portions rather than being dumped all at once.

(iii) The forms can be uneven and easily deformable, so strong, regular formwork was used and care was taken to apply even pressure.

(iv) The construction area is extensive and cracks and uneveness can easily occur in some water conditions. Care was taken to prevent such problems by spraying water and spreading straw matting.

This project was the first use of this construction method in China, but the contractor employed Japanese engineers with experience of the method and endeavored to acquire the skills including transfer of technology. As a result, the construction was completed without problems. There have been no reports of water loss or other problems.

A tower near the dam commemorating the success of the RCD construction method

(8) Power Station Equipment

The power station equipment consisted of Chinese-made vertical-shaft Francis turbines using direct downflow from the dam. The transformer equipment and the electricity transmission equipment were constructed adjacent to the dam on its downstream side.

2.1.2 Implementation Schedule

(1) Main Preparatory Works (not covered by the JBIC loan)

(i) Construction roads (two roads passing through the site and looping to the north and the south between the site and Xiaoshi. see Figure 5): Completed in August 1989.

(ii) Dedicated Train line connection for delivery of construction materials, and storage yards for materials (a railway laid from Xiaoshi to the site for delivery of construction materials, and a materials yard with an area of 100,000m^2): Completed in July 1989.

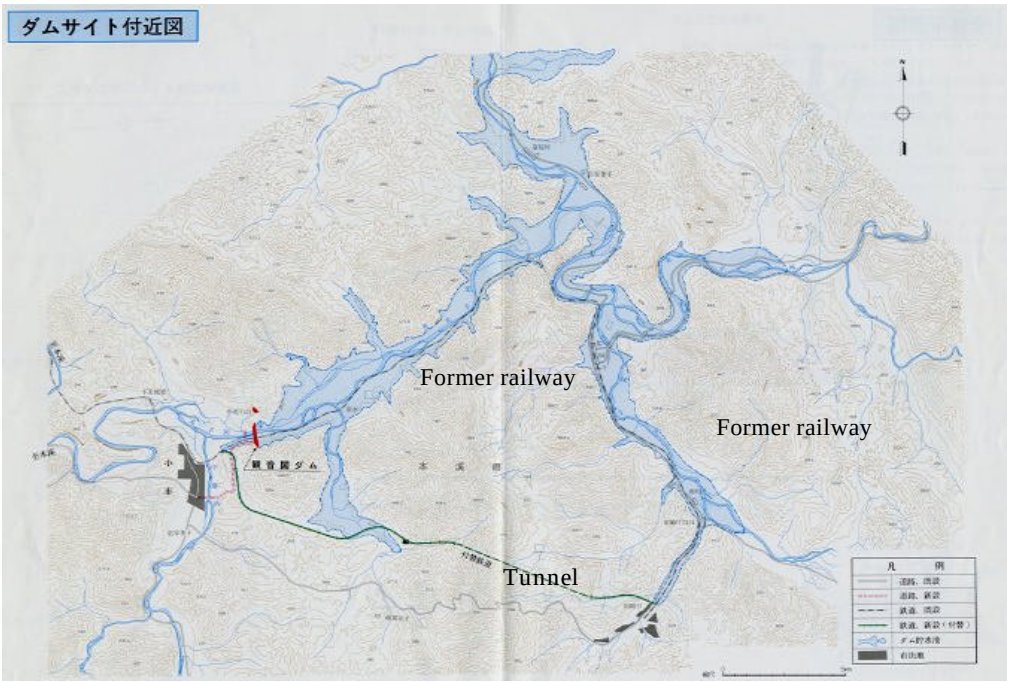
(iii) Rerouting of the existing rail route (construction works to reroute the existing riverside rail route, which was inundated by the dam construction): Completed in January 1993. The works to reroute the Benxi-Tianshifu line, between Benxi and Tianshifu were delayed by approximately three years because the tunnel construction was set back by adverse geological conditions (a fault 170m long in the center of the tunnel). The delay had an impact on the curtain grouting and other construction stages. Therefore the schedule was changed from the original plan, by which the dam wall construction was to start after the railway rerouting was complete. Under the revised plan, only the rerouted section within the dam site was completed before work started on the dam wall.

(iv) Transformer substation (10,000KVA transformer for construction applications and 4.5km of 6,600V distribution cables): Completed in July 1995.

(v) Other works

Two batcher plants: Completed in September 1989.
Aggregate plant: Started production in May 1989.

Figure 9 Map of the Rerouted Railway Line



(2) Dam Construction

Under the initial plan for this project (the Seventh Five-Year Plan from 1985), the dam itself was to be completed by June 1994. That schedule was revised to the end of 1995 when the JBIC appraisal was conducted (March 1988). The main dam-related construction works were in fact completed in December 1995, in line with the revised plan (the completion ceremony was conducted slightly in advance, in September 1995). The delay of eight months in the preparatory works was caused by the difficulties encountered in cutting the tunnel for the rerouted railway line. Most other works were completed ahead of schedule. However, the site for the curtain grouting works overlapped in part with the area used for the rerouted railway line, necessitating an interruption of the works, with a delay of nearly a year.

As mentioned earlier, a comparison was made of the alternative types of flood prediction and warning systems, which delayed the start of procurement by nearly two years. As a result, the system installation works were only completed in June 1998, nearly two years later than planned. Overall, with the exception of the flood prediction and warning system, there were no significant problems with the implementation schedule.

Figure 10 Implementation Schedule

(------Plan, ==== Actual)

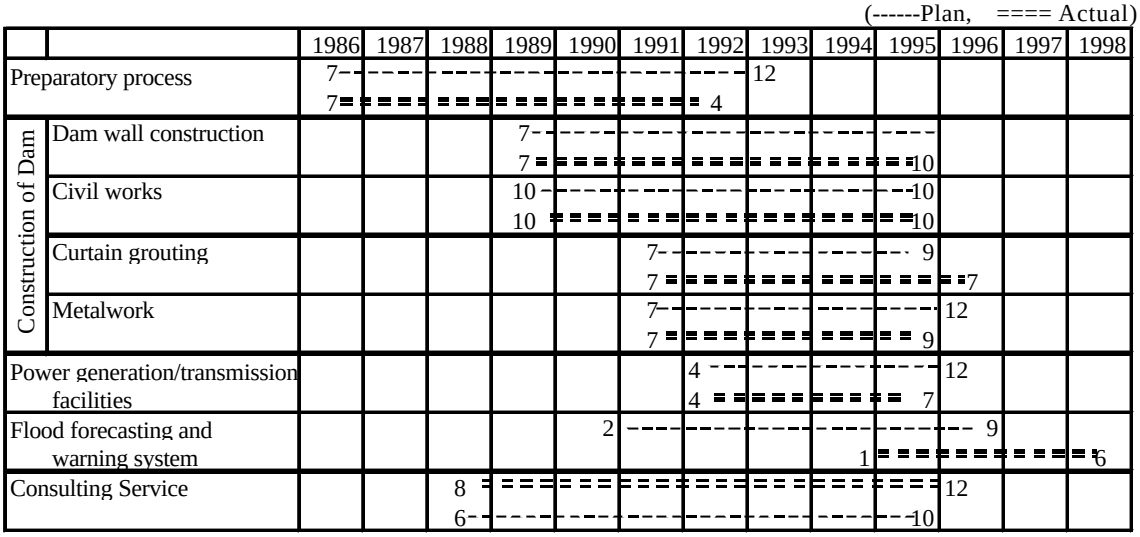


Table 8 Implementation Schedule

	Plan	Actual	Difference*
Preparatory works	Jul. 1986 ~ Dec. 1992	Jul. 1986 ~ Apr. 1992	-8
Dam wall construction	Jul. 1989 ~ Dec. 1995	Jul. 1989 ~ Oct. 1995	-2
Civil works	Oct. 1989 ~ Oct. 1995	Oct. 1989 ~ Oct. 1995	0
Curtain grouting	Jul. 1991 ~ Sep. 1995	Jul. 1991 ~ Jul 1996	10
Metalwork	Jul. 1991 ~ Dec. 1995	Jul. 1991 ~ Sep. 1995	-3
Power generation/transmission facilities	Apr. 1992 ~ Dec. 1995	Apr. 1995 ~ Jul. 1995	-5
Flood forecasting and warning system	Feb. 1991 ~ Sep. 1996	Jan. 1995 ~ Jul. 1998	21
Consultant	Aug. 1988 ~ Dec. 1995	Aug. 1988 ~ Oct. 1995	-2

(*) Unit: month. - (minus) indicates earlier completion than planned and + (plus) indicates delays.

2.1.3 Project Cost

(1) Project Cost

The total project cost of the Guanyinge Dam was 1.2053 billion Yuan in local currency and ¥18.0616 billion in foreign currency. Converting according to the Yuan exchange rate at the time of the JBIC appraisal (1Yuan=¥34.44), the total Yen-based cost comes to ¥59.572 billion. Comparing actual and planned costs, the local currency portion came to 1.205 billion Yuan in local currency, a 13% overrun compared to the planned 1.064 billion Yuan, and the foreign currency portion closely matched the planned ¥18.225 billion. The local currency cost overrun was mainly due to the following problems:

(i) Increased cost for cement and other materials for the main dam construction due to inflation.

(ii) Increased unit cost per relocated resident compared to the initial plan, which increased the total cost of resident relocation.

The first problem was unavoidable and also affected other ODA loan projects carried out in China in the same period. The second was due to the cost of more generous compensation payments and was not a problem (details on the content and unit cost of compensation paid appear in "2.2.4 Relocation of Residents").

Table 9 Planned and Actual Local and Foreign Currency Portions of Project Cost

	Local currency			Foreign currency			Total		
	Plan (million Yuan)	Actual (million Yuan)	Difference (million Yuan)	Plan (¥ 1million)	Actual (¥ 1million)	Difference (¥ 1million)	Plan (¥ 1million)	Actual (¥ 1million)	Difference (¥ 1million)
Preparatory costs	226.48	247.93	21.45				7,799.97	3,064.41	-4,735.56
Indirect costs	199.39	167.17	-32.22	1,036.00	925.51	-110.49	7,902.99	2,991.73	-4,911.26
Equipment costs				1,810.00	1,810.00	0.00	1,810.00	1,810.00	0.00
Materials costs				5,141.00	6,189.74	1,048.74	5,141.00	6,189.74	1,048.74
Main earthworks	198.70	271.27	72.57	5,418.00	5,689.66	271.66	12,261.23	9,042.56	-3,218.67
Curtain grouting	53.30	58.90	5.60	1,787.00	1,786.15	-0.85	3,622.65	2,514.15	-1,108.50
Metal parts	1.50	1.50	0.00	501.00	325.30	-175.70	552.66	343.84	-208.82
Electrical equipment	1.47	1.47	0.00	777.00	490.35	-286.65	827.63	508.52	-319.11
Measurement systems	20.88	19.66	-1.22	1,169.00	844.84	-324.16	1,888.11	1,087.84	-800.27
Compensation for burial	237.15	437.40	200.25				8,167.45	5,406.26	-2,761.18
Contingency	124.90		-124.90	586.00		-586.00	4,887.56	0.00	-4,887.56
Total	1,063.77	1,205.30	141.53	18,225.00	18,061.55	-163.45	54,861.24	32,959.06	-21,902.18

Note The conversion from local to foreign currency was made on the basis of the one Yuan = ¥34.44 rate from the time of the plan. The rate at the time of the recorded figures was one Yuan = ¥12.36.

(2) Fund Plan

The funds for this project were provided from the ODA loan for all the foreign currency portion and from the domestic government budget for the local currency portion. The borrower for the ODA loan was the Foreign Trade and Economic Cooperation Dept. of Government of the People's Republic of China, and the loan was transferred from Ministry of Foreign Trade and Economic Cooperation through its wholly-owned Chinese gateway bank to the Liaoning Provincial Water Resources Department. The terms of the sub-loan were identical to those of the ODA loan.

The cost overrun of 142 million Yuan in the local currency portion was covered by a supplementary loan from the China Construction Bank and had no impact on the implementation of the project.

Table 10 Loan Disbursed Results by Fiscal Year

	Local currency (million Yuan)	Foreign currency (¥ 1 million)
1986	25.00	
1987	45.00	
1988	58.00	
1989	77.00	905.00
1990	100.00	987.00
1991	111.50	1,451.00
1992	127.00	3,028.00
1993	254.50	2,911.00
1994	234.60	3,051.00
1995	146.30	5,375.00
1996	26.40	353.55
Total	1,205.30	18,061.55

2.1.4 Implementation Scheme

(1) Procurement Method and Construction Method

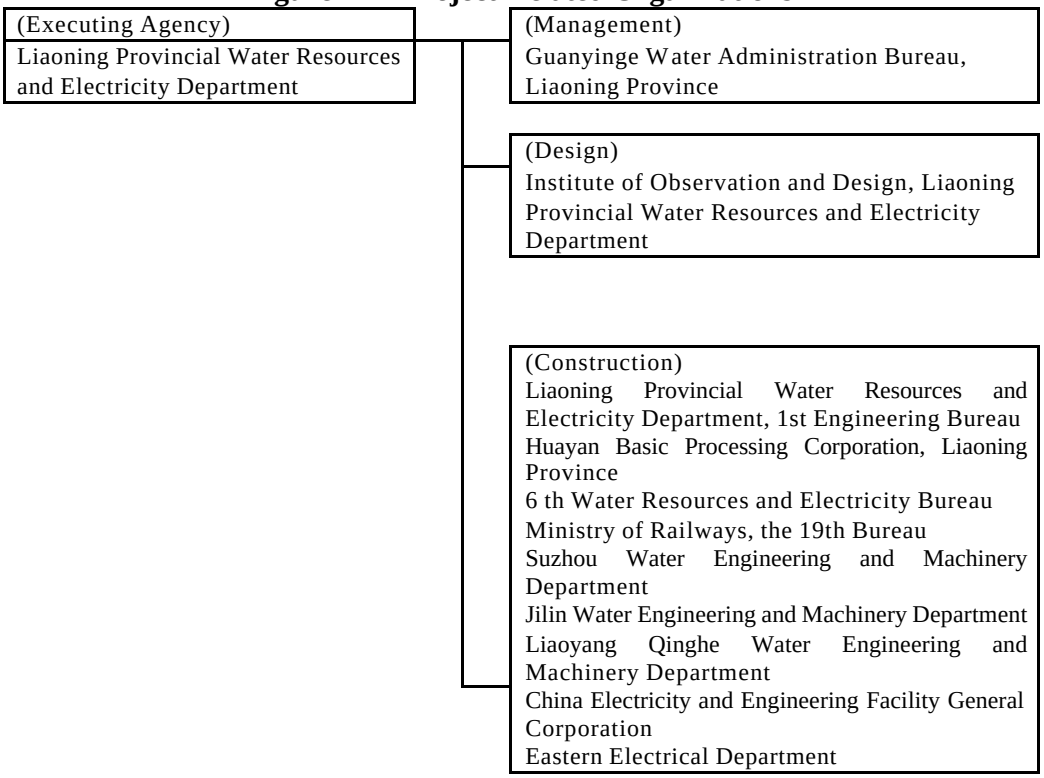
Procurement method and construction method are summarized as follows.

(i) The procurement method was international competitive tender. The procurement conditions for the equipment, materials and services (excluding the consultants) were general untied.

(ii) The construction method was limited contracting (some construction equipment was provided. Materials were provided by the project executor).

(iii)

Figure 11 Project-Related Organizations



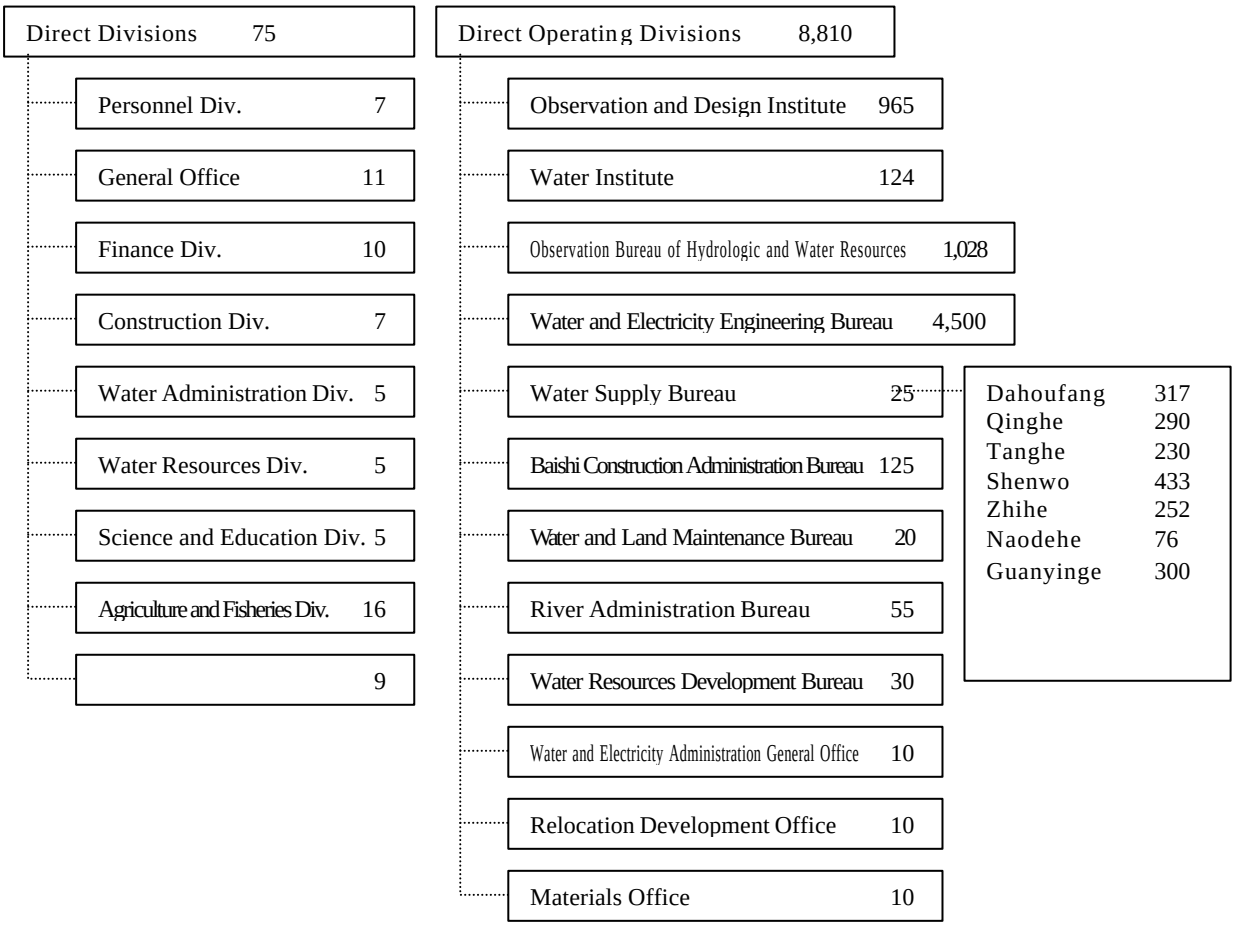
(2) Executing Agency

The executing agency for this project was the Liaoning Provincial Water Resources and Electricity Department. It has now changed its name to the Liaoning Provincial Water Resources Department. The change was made because State Council/Ministry of Water Resources and Electricity was split into two parts in 1988, becoming the Ministry of Water Resources and the Ministry of Electricity. However, although the tasks have been separated at the state level, in Liaoning province the change was only nominal and the organizational content

is entirely unchanged. Originally, the organization was established in 1954 as the Liaoning Provincial People's Government Water Resources Bureau when the provinces of Liaodong and Liaoxi were merged. In 1958 the Water Resources and Electricity Construction Bureau, Liaoning Province was established to handle large-scale construction works, and the two organizations were merged in 1961.

As Figure 13 shows, the Liaoning Provincial Water Resources Department has a small staff of 75 people in directly attached departments, but it is a large organization with a further 8,810 staff in directly attached project departments. It is directly involved in nearly all dams in the province and it has abundant experience. Following its success with the RCD construction method in this project, the Water Resources Department was able to win the order for the construction of the Taolinkou Dam in Hebei province by the RCD method.

Figure 12 Organization Chart of Liaoning Provincial Water Resources Department



(Note) Figures indicate the number of staff.

At the time of the project construction, Water Resources and Electricity Department, as it then was, was in charge of the development and use of water resources, water defenses, flood drainage, urban and industrial water supplies, irrigation water supplies, measurement of water use for power generation etc., planning, design, management of construction works, personnel

development and other matters. It had a staff of 2,051 engineers, of whom 260 were high-level (senior) engineers, 850 were mid-level engineers and 941 were assistant engineers. By field of work, 800 were involved in water-related construction, 800 in rice paddy water usage, 300 in hydrology, 50 in civil engineering, 50 in mechanical and electrical engineering and 51 in other fields.

The Institute of Observation and Design, Liaoning Provincial Water Resources and Electricity Department, handled the F/S (in June 1984), the first draft design and the detailed design for this project. The Institute was established in 1954 as the Shenyang Branch Institute, Beijing Institute of Observation and Design, Ministry of Water Resources. It was transferred to the jurisdiction of Liaoning province in 1958 and given its present name. It has 965 staff, of whom 390 are engineers, comprising 120 high-level, 170 mid-level and 100 assistant engineers. Its main tasks are:

(i) Planning and consultancy work concerning the overall usage of the province's water resources.
(ii) Planning of various water and power-related works, F/S reconnaissance and design and consultancy.

The institute has carried out reconnaissance designs for over 100 projects in China and abroad.

(3) Contractors

As Figure 12 showed, the contractors for the construction of this project were nine bureaus and corporations under the Hydroelectric Section, Water and Hydroelectric Engineering Bureau, Liaoning Province. Contractor selection was carried out through a two-step evaluation method with prequalification (P/Q) according to the criteria stated in Table 12. In the primary appraisal the Hydroelectric Section was ranked poorly, in eighth place of nine participating companies (one French, two Italian, one Japanese and five Chinese), but it passed through the secondary appraisal because it was evaluated favorably on the following points:

(i) It had experience of large-scale concrete construction.
(ii) Its location is close to the project site.
(iii) It could obtain the necessary personnel, equipment and funding.
(iv) The main reason it scored poorly on the first evaluation was that it lacked engineers with experience of the RCD construction method, but it intended to remedy the problem by hiring new engineers.

In subsequent bidding, the Hydroelectric Section made the winning bid.

While the Hydroelectric Section performed satisfactorily in the end, there was an air of opacity about the P/Q process. As transparency was meant to be important in this contractor selection process, we cannot say that it was conducted correctly.

Table 11 Criteria for Contractor Prequalification (P/Q) Appraisal

Aspects evaluated	Points available	Content
General experience	15	Legal position: Limited liability, joint stock, state owned Years registered Specialist fields Nominal capital Number of workers Engineers (with 15+ years of experience) Specialists (with 15+ years of experience) Number of prime construction projects International activity China Elsewhere Number of engineers Value of construction projects executed per year
Experience of similar projects	45	Concrete dams Construction by the RCD method Power stations Grouting River redirection
Personnel experience	15	
Suitability of construction equipment	10	
Financial capacity	15	Value of construction orders received each year Authorized capital Deposited capital Total assets Total liabilities Net capital Value of construction orders currently received Bonding ability
Total	100	

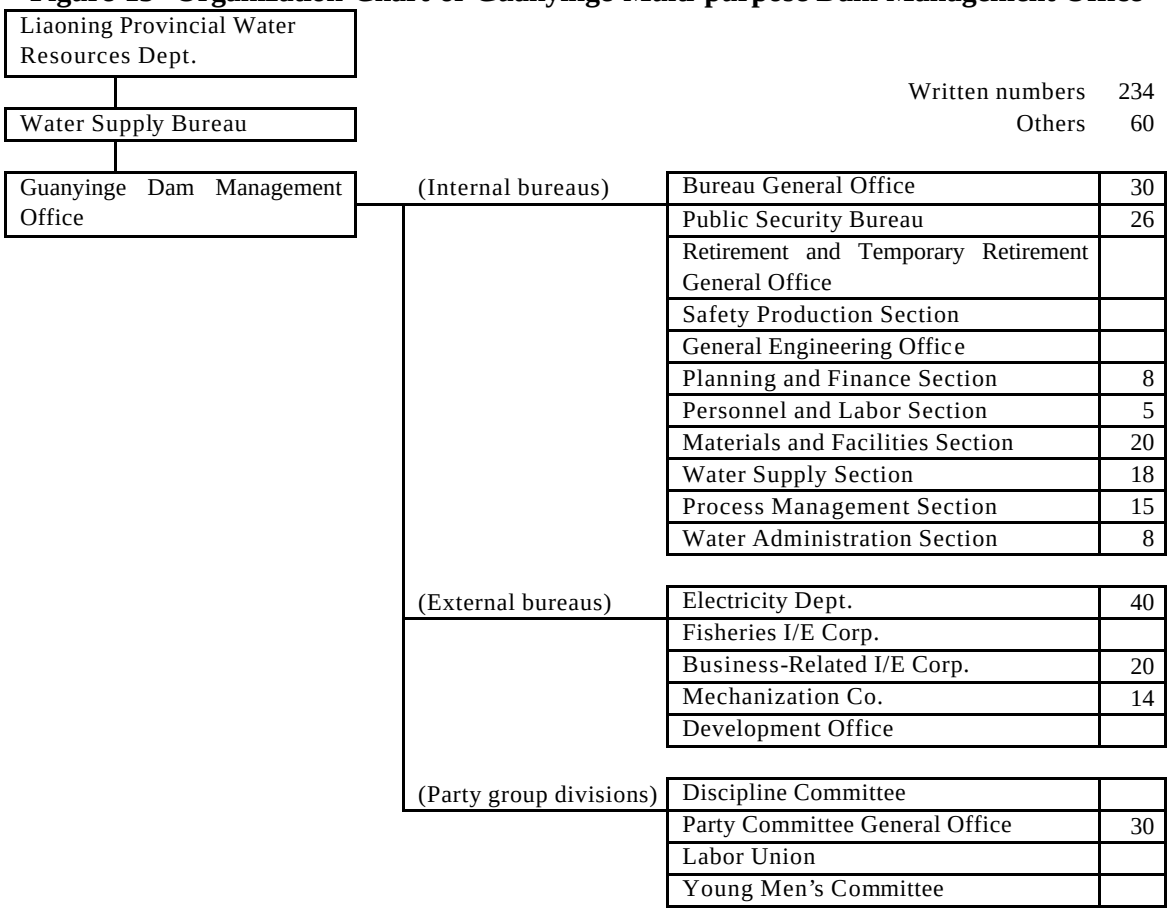
2.2 Evaluation on Operation and Maintenance

2.2.1 Operations and Maintenance Scheme

(1) Organization

After this project was completed, Liaoning Provincial Water Resources Development, Water Supply Bureau established Guanyinge Dam Management Office (referred to below as the Dam Management Office) in February 1989 to handle the management and operation of the dam. The office was planned to have a staff of approximately 350, but in fact the staff is approximately 300 (the flood prediction and warning system is managed by the Taizi River Valley Flood Control Supplies Center ("Control Center"), which is a provincial agency, rather than by the Dam Management Office).

Figure 13 Organization Chart of Guanyinge Multi-purpose Dam Management Office



(2) Training

The Dam Management Office uses almost no on-the-job training (OJT) for staff training and education, and the Department of Water Conservancy has no affiliated school. Even the concept of OJT appears to be unfamiliar. Therefore the central elements of staff training consist of dispatching staff to study at external schools or using distance learning. Financial support is also provided for the acquisition of state qualifications and university master's degrees. Overall, the Dam Management Office says it is satisfied with the ability of its workers.

(3) Number of Engineers

Of the 300 people working for the Dam Management Office, 95 are university graduate engineers, which is an adequate number of engineers. The graduate engineers include 17 high-level, 31 mid-level and 47 novice engineers. Due to the nature of the project, the staff of the Dam Management Office is heavily weighted towards engineers, with only around 50 manual workers.

2.2.2 Maintenance Scheme and Status

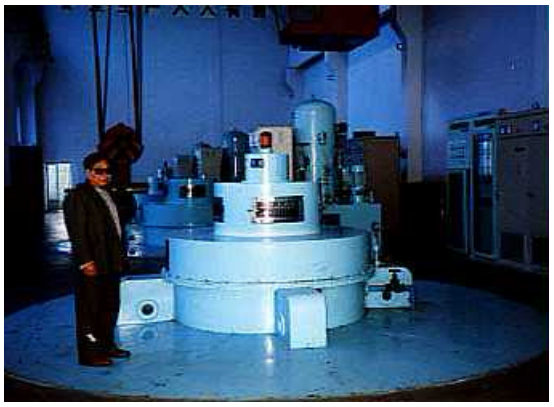
Liaoning Provincial Water Resources Department has a management office for each dam, and the Guanyinge Dam Management Office, under the authority of the Water Supply Office, handles the maintenance and maintenance of the dam. The cost of this maintenance amounts to around 50 million Yuan per year (including depreciation). The majority of the cost is covered directly by revenue from the dam's water supply, power generation and aquatic produce raising functions, with the shortfall made up by the provincial government. At present the burden of spare parts and similar costs is small because the equipment is still new. The maintenance of the project is handled by eight mechanical specialists and eight electrical specialists and no problems have been reported. Two specialist staff are on hand to monitor leaking and two manual checks are made every month, in addition to automatic measurements. The volume of leakage was 106l/m in 1996, falling to 95l/m in 1997 and 79l/m in 1998, which is a good record.

Figure 14 Income and Expenditures of Guanyinge Dam

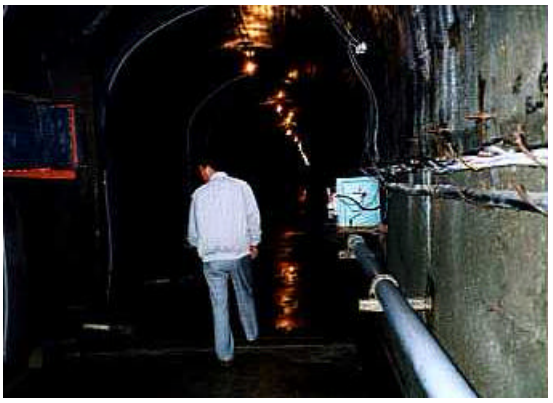
(Unit: million Yuan)

		1995	1996	1997	1998
Power generating volume (million KWH)		**60.00**	**86.00**	**102.00**	**104.20**
Electricity unit price (Yuan/kwh)		**0.18**	**0.18**	**0.18**	**0.18**
Income	Electricity		15.48	18.36	18.76
	Water		9.80	10.56	14.27
	Fish farming, tourism		13.86	14.89	15.01
	Total		39.14	43.81	48.04
Expenditures	Depreciation cost		28.00	32.00	33.00
	Power generating cost		3.24	3.42	3.35
	Repair cost		1.00	1.05	1.10
	Maintenance cost		11.59	12.00	12.14
	Labor cost		0.10	0.11	0.13
	Retirement pension		0.41	0.48	0.45
	Others		2.20	2.31	2.14
	Total		46.54	51.37	52.31
Profit			-7.40	-7.56	-4.27

(Source) Guanyinge Water Management Office



Three generators



The inspection tunnel which passes through the dam (the tunnel is equipped with devices to detect distortion of the dam, water loss and other problems)

One chief engineer for environmental problems has been appointed to monitor such problems, with particular reference to waste water discharged from factories and farms. Waste water is managed according to the "People's Republic of China Surface Water Quality Standard".

The Dam Management Office is considering tourist development of hot springs and limestone caves in the area as a measure against the overmanning typical of state-owned enterprises. There is the problem of funding and the ideas have not yet been put into practice, but as part of this avenue of development, efforts are being made to refurbish the old water guest house, which was originally a lodging attached to the dam management office. It is to be made available as accommodation for ordinary tourists[1].

2.2.3 Environmental Problems

(1) Standards for Environmental Evaluation

Dam projects in China are under the jurisdiction of the State Council, Ministry of Water Resources and Water Resources Divisions in regional People's Governments. The environmental assessment which precedes dam construction can be conducted by either the State Council, Ministry of Water Resources or Water Resources Divisions in regional People's Governments, depending on the size of the project. An environmental impact assessment report is prepared according to the criteria contained in the "Technical standards for assessment of the environmental impact of water supply and hydroelectric construction" (in effect from 1986). The report is studied and approved by the relevant environmental protection body, which is the National Environmental Protection General Bureau at the national level and the Environmental Protection Bureau at the provincial level.

The specific points to be evaluated include hydrological changes, flood prevention, the

[1] In China it is becoming common for wealthier urbanites to make sightseeing tours of famous sites and ruins. A tour group was staying at the guesthouse when we made the field study for this evaluation.

ecological environment, local climate, water temperature, quality and eutrophication, cement quality, environment geology, soil and land use, valuable species, health and disease, cultural protection, and environmental impact during construction. The current technical standards are now being revised in light of the experience of the last ten years, and also to bring them into line with international standards now that the number of foreign projects in China is increasing.

Environmental assessments can also be made by any executing agency whenever necessary. To date, State Council, Ministry of Water Resources has conducted environmental assessments of the Sanmen Xia Dam in the Huang He valley and the Dongjiang Dam in Hunan province. These assessments investigated various related problems, such as environmental impact, and the public health environment, standard of living and productivity of relocated residents, and countermeasures are prepared where necessary.

This dam was a regional project under the authority of the Liaoning Provincial Water Resources Department, and the environmental assessment investigations and approvals were conducted by the Environmental Protection Office Liaoning Province. JICA conducted an environmental survey in the F/S prior to the implementation of the ODA loan, and the findings of the survey are included in the "Guanyinge Dam Construction Plan Investigation". The following six points were checked during the JBIC appraisal.

(i) Impact during construction.
(ii) Impact on the natural environment.
(iii) Changes in water temperature and quality, both in reservoir water and downstream.
(iv) Impact on historic and cultural relics.
(v) Impact on existing infrastructure.
(vi) Relocation of residents.

The sections below describe these six aspects of the environmental and social impact of this project, based on the report from the Liaoning Provincial Water Resources Department. The relocation of residents will be described in section 2.2.4.

(2) Impact During Construction.

The environmental risks posed during the construction period included the following:

- Waste water from construction.
- Waste water and sewerage from the construction teams themselves.
- Degradation of river water quality by large amounts of particulate materials washing into the water.

Considering the topography of the site and the distribution of pollution sources, a number of water purification facilities were built or improved downstream from the dam. Some were permanent facilities and others were temporary. As a result, over 40 million tons of contaminated water were treated during the construction period, bringing water quality at waste water discharge points within national standards. The water satisfied demand for urban and rural supplies further down the valley.

(3) Impact on the Natural Environment

The direct impact of the dam's construction on the natural environment is the destruction of vegetation. The area of destroyed vegetation was 187 Mu (approximately 12.5ha). In order to restore vegetation in the affected areas as soon as possible, the Dam Management Office commissioned Reforestation Plan from the province's Park Regulation and Design Institute in 1992. Replanting of the dam area got under way in 1993 and the planted area reached 7.9ha by the end of 1997, restoring 63.4% of the damaged area. The Guanyinge Dam area has already been officially designated as a tourist area by the Benxi Tourism Office.

When the dam was completed, the reservoir inundated 2.32ha of farmland and 990ha of forest, as well as 49 factories, 35km of railway, 52.3km of power transmission lines and 135km of national roads.

There are no protected zones, such as forest reserves or natural environment conservation zones, around the dam area. There have not been any reports of habitation of the area by animals designated as in need of protection or in danger of extinction, or by animals of special scientific interest, and it has been judged that no grave damage will be inflicted on the ecology of the area. No severe negative impact from this project has been reported. Conversely, as the reservoir has filled up, it has become a lake which attracts large numbers of wildfowl.

(4) Changes in Water Temperature and Quality, both in Reservoir Water and Downstream

Water quality tests at the dam are conducted twice on every second day at four points: at the water inflow point, in the reservoir, around the dam, and where the water is released from the reservoir. At present the water quality at the dam conforms to the Type II National Standard. The quality of the water is suitable for the protection of potable water resources and of valuable types of fish. However, compared to the time of the appraisal, the standard of the water has deteriorated by one rank, from Type I to Type II as the area of cultivated land upstream from the dam has increased.

Hotels and tourist facilities are now being built around the dam site and water quality conservation measures will have to be strengthened to cope. The land upstream from the Guanyinge Dam is 80% forest, but mining and building stone quarrying operations are cutting into mountainsides, causing topsoil runoff. At present there does not appear to be any risk of this soil runoff having a major impact on the dam's water quality or its basic functions, but continued action for appropriate land use and soil conservation are required.

There have been no significant reports of environmental health impact, such as increased disease incidences, since the dam was built.

Table 13 Surface Water Quality Standards in China (Example Values)

(Units: mg/l, no units for pH)

		Type I	Type II	Type III	Type IV	Type V
pH	<	6～9	6～9	6～9	6～9	6～9
Sulfates	<	250	250	250	250	250
Chlorinated compounds	<	250	250	250	250	250
Dissolved iron	<	0.3	0.3	0.5	0.5	1.0
Manganese	<	0.1	0.1	0.1	0.1	0.1
Copper	<	0.01	0.01	0.01	0.01	0.01
Zinc	<	0.05	1.00	1.00	2.00	2.00
Nitrates	<	10	10	20	20	25
Nitrites?	<	0.06	0.10	0.15	1.00	1.00
Nitrogen	<	0.5	0.5	1.0	2.0	2.0
Phosphorous	<	0.02	0.10	0.10	0.20	0.20
COD	<	15	15	15	20	25
BOD	<	3	3	4	6	10

(Note) Type I Headwaters, national natural conservation zones etc.
Type II Grade one protected zones, such as water sources for concentrated potable water supplies.
Type III Grade two protected zones, such as water sources for concentrated potable water supplies.
Type IV Water zones for industrial supplies and leisure uses etc.
Type V Agricultural water supplies etc.

Source People's Republic of China Surface Water Quality Standard (promulgated in April 1988, in force from June 1988).

(5) Impact on Existing Infrastructure

The relocation, repair and construction of infrastructure for transport, electrical distribution and other applications which was inundated around the dam, was conducted in parallel with the relocation of residents. The affected infrastructure was restored to the level it was at before the construction of the dam. Further improvements to the area around the dam can be expected to accompany the future development of the tourist industry there.

(6) Problems with Relics

The area inundated by the dam includes areas with ancient historical and cultural aspects. The area was the cradle of numerous ancient peoples. The province's archaeological survey team conducted surveys, measurements, excavations, studies and relocations of cultural relics in the area facing inundation in an effort to enhance the management and protection of cultural relics in the area. A three year survey filled in gaps in previous knowledge of culture in the Liaodong region before the Age of Warring States. Important archaeological materials of great historical value were gathered which advanced research into the primitive cultures of barbarian and Koguryo peoples.

Neolithic and bronze age historic remains were discovered at nine locations around the project

site, as well as bronze age caves and cremation burial sites at over 200 locations. The nine historical sites have been relocated and the tumuli were scheduled for investigation by the "Liaoning Province Guanyinge Dam Cultural Treasures and Archaeology Engineering Team", followed by conservation measures where necessary. In interviews conducted for this survey, we heard that there was nothing of extraordinary worth in the area, and almost no conservation measures were taken beyond relocation of fossils dating back over 4,000 years.

2.2.4 Relocation of Residents

(1) Previous Resident Relocations

In China, 86,000 reservoirs have been built since 1950, forcing the relocation of over 12.2 million people. Relocation of residents under China's dam projects can be divided into three periods:

(i) From the founding of the state to the Great Leap Forward (1949~1957): The scale of relocations was not great and relocated people faced no great problems after relocation.

(ii) The period of political turmoil from the Great Leap Forward to the Cultural Revolution (1958~1977): particularly at the time of the Great Leap Forward, large dams were built through the mass mobilization of labor, and the relocations of residents were also larger in scale. No adequate consideration was given to the environmental capacity of the relocation destination areas and, in many cases, the relocated people faced great hardship in rebuilding their lives.

(iii) The reform and openness period, from the end of the Cultural Revolution to the present (1978~): Systems were devised based on the experience and lessons learned from previous relocations. Due consideration is now given to the standard of living of residents after relocation.

The "Rules Concerning Land Acquisition, Compensation and the Relocation of Residents in Connection with the Construction of Medium and Large-scale Water and Hydroelectric Projects" (promulgated by the State Department in 1991) clearly stated that the state proposed and supported developmental relocation of residents. Developmental resident relocation goes beyond moving people away from areas facing inundation and restoring their standard of living to previous levels. Instead, the policy is to consider the whole way of life of the people after relocation and to employ them to positively support productive activity.

(2) The Relocation of Residents for this Project

The number of residents to be affected by the construction of the Guanyinge Dam was put at 5,405 households (23,446 people) at the planning stage of the project, but in fact the final numbers were 7,501 households (up 38.8%) and 28,580 people (up 21.9%).
The relocation of residents was carried out by the people's governments of Benxi and Shenbin districts between 1991 and 1997, when relocation was completed. By 1995 the relocation had covered 2 districts, 5 towns , 23 villages, 184 companies and 54 work units. The total number of

people relocated by that stage was 26,744 in 6,981 households. After the dam reservoir filled, most of the farmland for the two villages of Nandian Zhen 溝口村 and Qinghecheng 前央村 in Benxi district was below the water level. The situation prompted the relocation of 187 people in 49 households in 1997. A further relocation was conducted following consideration of relocated residents' actual way of life and other factors, bringing the final total of relocations to 28,580 people in 7,501 households. According to the Liaoning Provincial Water Resources Department and the District Relocation Office, the difference between planned and actual relocation numbers was due to the following factors:

(i) The population increased.

(ii) A portion of the farmland owned by people from Nandian Zhen Ditacun and Qinghecheng Qianyingcun was inundated, forcing relocation to maintain the livelihoods of the affected landowners.

However, we must point out that surveys conducted on the Chinese side at the planning stage were inadequate.

Housing and substitute farmland were obtained for relocated residents (0.1ha per person, which roughly equals the land before relocation), and various subsidies were paid (see table 15 for house compensation etc.). There was also a plan to build various factories to employ at least 5,300 people, enough to employ at least one person from each household that stops farming. Actual factory construction fell considerably short of the plan. Thus the area of farmland was reduced by around 80% and the factories only created 400 new jobs (making 1,200 jobs, including those at previous factories).

The cost of relocation compensation comes to 380.777 million Yuan, of which 359.961 million Yuan was paid from the Liaoning province People's Government to the District Relocated Residents Office. According to the Liaoning Provincial Water Resources Department, budgetary arrangements have been completed for the payment of the remainder. The relocation compensation cost includes 97.4 million Yuan paid directly to relocated residents as compensation and subsidy, which comes to a simple average of approximately 3,408 Yuan per person.

Table 14 Relocation of Residents and Land Acquisition Associated with the Construction of the Guangyinge Multi-purpose Dam

Extent of effects		Plan	Actual
Households	Household	5,405	7,501
Population	Persons	23,446	28,580
Cultivated land	ha	2,783	2,320
Forest	ha	1,188	990
Jobs	Factory employees	5,300	1,200

(Source) Liaoning Provincial Water Resources Department materials.

Table 15 Unit Cost Table for Relocation Compensation

	Units	Old budget	New budget	Difference	Reason for difference
Compensation cost for land	Yuan/ are	698	1,806	1,108	Policy 739, prices 369
Relocation subsidy	Yuan/ person	272	719	447	Policy 298, prices 149
Compensation cost for wooded land	Yuan/ are	306	1,675	1,369	Policy 1024, prices 342
Personally-owned trees	Yuan/ tree	5	20	15	Prices
Fruit trees	Yuan/ tree	48	78	30	〃
Fish farming pools	Yuan/ are	800	1,600	800	〃
Brick houses	Yuan/ m^2	45	110	65	〃
Thatched house	Yuan/ m^2	37.5	80	43	〃
Barn	Yuan/ m^2	12	48	36	〃
Relocation cost	Yuan/ household	350	560	210	〃

(Source) Liaoning Provincial Water Resources and Electricity Department materials

(Note) The unit price table was revised in 1990. In the "Reason for differences" column, "Policy" refers to revisions in consideration of matters other than price rises.

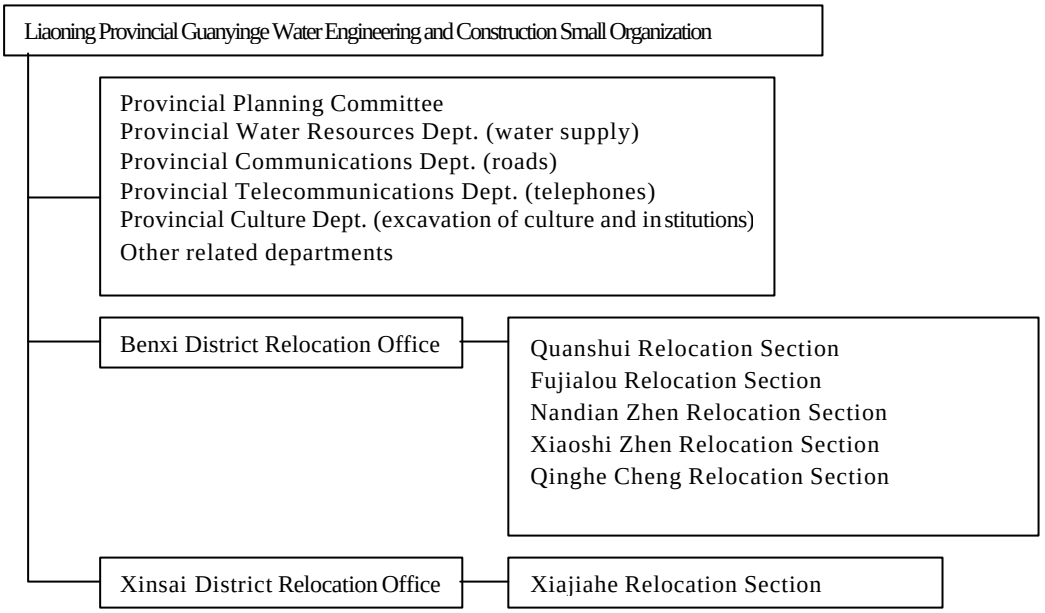
(3) The Status of Resident Relocation in Benxi District

Nearly all (96%) of the residents relocated for this project were from Benxi district. In this section we will examine the situation in that district.

Of the 27,333 people (7,175 households) relocated in Benxi district, 21,660 (5,791 households) were relocated elsewhere in the district and the remaining 5,673 (1,384 households) went elsewhere. Thus around 80% of the residents were relocated within the district. Among the relocations within the district there are two types: Relocations to higher ground, which moved people to areas behind their original land but above the inundation line, and neighborhood relocations to other land near the dam. As Table 17 shows, the split between the two relocation types is approximately three against seven, with relocation to higher ground for 6,486 people (1,665 households) and neighborhood relocations, the more numerous type, for 15,174 people (4,126 households). The relocations within the district were carried out in a planned manner by the District Relocated Residents Office.

The organizations responsible for the relocation of residents under this project are listed in the diagram below.

Figure 15 Organization for Relocation of Residents



(Source) Liaoning Provincial Water Resources Department

At the planning stage of the resident relocation operation, "engineering teams" were organized by districts, towns and villages and tasks such as land surveys and allocation or relocation sites were carried out. The demands of individual members of the public were heard at this stage and efforts were made to win their approval. The relocation operation for Guanyinge Dam proceeded through relocation to newly prepared land near the dam and reallocated land in existing villages. In cases where there was demand from relocated residents and the land was feasible, relocation to land above the inundation line was permitted. In this area, relocation above the new waterline can easily lead to poor land conditions, inconvenient transport and worsened living conditions. Nevertheless, many people chose that option, particularly those who received little compensation because they had few assets and wanted to save relocation costs, the physically weak (particularly the elderly), and those with a strong emotional attachment to the land.

Those who relocated outside the district turned to their relatives and others for help and moved further by choice. They moved to other parts of the province, and beyond the provinces of Heilongjiang, Hebei and Shandong.

Looking at the relocation in terms of the organizational form, nine villages (12,216 people) relocated as groups, six villages (11,316) relocated partially in groups, and 7 villages (3,801 people) dispersed completely. In terms of the numbers of people, the vast majority (86%) relocated in groups consisting of whole or partial villages. This form of relocation is convenient for the preparation of land and facilities at the relocation destination, and it is also effective in reconstructing rural communities which are built on neighborhood connections. Therefore a general rule in the implementation of resident relocations is to avoid dispersed relocations.

In the case of partial group relocations, the key task in the formation of the new community is to

build relationships between established residents and the new arrivals. In China the villagers' committees are a form of self-government for villagers. The District Relocation Office says that when there are large numbers of new residents an organization called a villagers' union is sometimes established under the villagers' committee. The head of the villagers' union then serves as the deputy head of the villagers' committee. This arrangement makes it easier for the actions of the villagers' committee to reflect the wishes of the new residents.

Table 16 Types of Resident Relocations (Benxi District)

	Relocation area			Organizational form		
	In district, to higher ground	In district, neighborhood	Outside district	Partial group relocation	Group relocation	Complete dispersal
Villages	-	-	-	9	6	7
Households	1,665	4,126	1,384	2,947	3,316	912
People	6,486	15,174	5,673	11,316	12,216	3,801

(Source) Benxi District Relocation Office

(4) Readiness of Relocation Areas

Houses are built by the relocated residents themselves, using the relocation compensation and subsidies paid to them under the standards set by the urban and rural planning and administration departments. Three types of land plot were available, being, from the smallest, 15m x 18m rectangles ($270m^2$), 18m x 20m rectangles ($360m^2$) and 20m x 30m rectangles ($600m^2$). In general, the first two types were more commonly used. Within the plot, the house occupies $40m^2$ or more, with most of the remainder being used as a field. If the land is used as a field, some of the occupants brought the cultivated topsoil from their previous land with them and used it to improve the soil of their new land.

The new villages in relocation areas differed from the previous villages, which had evolved naturally. They are dense residential clusters due to restrictions on available land area and the convenient provision of services such as electricity and water.

In addition to land and housing, water, electricity, communications and roads are also provided. First, to solve problems with water supply, simple water mains were installed in 76 locations. This was a major labor-saving improvement for people moving to the new villages with simple water mains from upstream areas, where they sometimes had to go to the river to gather water.

For electricity, 150km of high-voltage distribution lines and 250km of low voltage distribution lines were constructed. Electricity supplies have been connected to 4,612 households, which is approximately 80% of the households relocated within the district. A 64km optical fiber communications cable has been laid and 113 telephones installed, together with cable television and other amenities. Care has been taken to make life much more convenient in the new villages.

Roads provided comprise 86.7km of public roads (national and district roads) and 66.5km of feeder roads to link the new villages of relocated residents to the public roads.

Thirteen schools have been refurbished or newly built (twelve elementary schools and one

junior high school) with a total floor area of over 20,000m^2. In addition to one new hospital, public health centers have been built in each new village that can provide simple medical treatment.

Another social welfare facility is the home for the elderly, which is located in the town of Quanshui Zhen and has a total floor area of 2,000m2. It is designed for a population of 40 people. In addition to the necessary facilities for life, such as a dining hall, toilets and entertainment facilities, the home is provided with 40 Mu (approximately 2.7ha) of farmland and a livestock farm, where the more robust residents can work. The residence fee is six Yuan per year and the home now has 18 residents (of whom 16 are relocated residents).

Thus the facilities needed in the relocation areas have largely been provided smoothly.

However, when we talked to people in the area during the field survey[2], we heard of the following problems from people who had relocated above the inundation line in the furthest upstream end of the inundated area:

(i) Housing for some residents had still not been completed. Just before the dam was completed, the area was hit with torrential rains. As an emergency countermeasure, the Department of Water Conservancy closed the dam. Villages at the furthest upstream point, which were planned to be the last evacuation, had to be evacuated before all the preparations for their relocation were ready. Many materials were lost to flooding. The government responded by providing assistance in obtaining and transporting the necessary replacement materials, but some houses have still not been built due to lack of funds. In follow-up discussions with the executing agency, we heard that the funding shortfall had been made up using the provincial budget from the end of FY 1998 and the remaining houses had been built.

(ii) In rainy weather the roads linking the villages to the public roads turn into quagmires, making it difficult to get out. (Relocations to higher ground reduced the area of cultivated land, forcing some residents to go out to work elsewhere to make ends meet. Therefore they need the roads much more than they did before they were relocated).

(5) Relocated Residents' Adaptation to New Lives and Production Activities

As described above, steady progress has been made in the building of basic infrastructure in the relocation areas. However, for some relocated residents it has become more difficult to make ends meet. That is particularly true of those who relocated to higher ground and those who were originally in a poorer position.

In 1997 the District Relocation Office conducted an interview survey of approximately 3,300 people in 820 households in a representative sample of ten relocated villages, asking people about their way of life since relocation (Table 18). The survey revealed that around 50% of

[2] The Benxi District Relocation Office and persons connected with the government of Nandian Zhen town arranged for the discussions to take place in Nandian Zhen Macun on 27th May 1998. The event was attended by six residents, of whom three had been relocated to higher ground. Specifically there were three residents from Nandian Zhen Macheng, (one of whom was relocated to higher ground), one from Nandiancun (relocated to higher ground), and two from Beidiancun (one relocated to higher ground).

respondents said their income had increased, but 20% said their income had decreased. Around 60% of the relocated residents still worked in agriculture, and the main reason for their loss of income was the smaller area of land they had for cultivation. In particular, many of those who relocated to higher ground suffered from a smaller area of land for cultivation, compounded by reduced land productivity. The Liaoning Provincial Water Resources Department says that those households with numerous elderly people or children, those which did not have large amounts of assets eligible for compensation, and others in socially weaker positions were hit harder by relocation.

On the other hand, residents were highly satisfied with the extension of water mains, electrification, roads, educational facilities and other infrastructure.

Interviews[3] held at the time of the field survey found that in Nandian Zhen Beidiancun, the average area of cultivated land held by those who relocated to higher ground had fallen by around two thirds, from 1.5 Mu (0.1ha) per household before relocation to 0.5~0.6 Mu (0.033~0.4ha) afterwards. The villagers had to work at jobs such as coal mining, cargo shipping and construction to recoup the income lost by the reduction in their land area. However, the economy has been performing poorly lately and even when people work in coal mining they are not paid on time. Working away from home has certainly not stabilized their livelihoods.

In the course of the field survey, we observed from the car window that many fields below the inundation line were under cultivation. The District Relocation Office says that all the relocated residents cultivate crops below the inundation line. The land can be used by registering a contract with the village, in the case of relocation to higher ground, or with the town in the case of neighborhood relocation. Of course, the risk of inundation is higher than it was before, but the residents already received compensation for inundation when they were relocated. Therefore if they lost crops due to flooding, they would not receive further compensation. Nevertheless, many residents, seeking to compensate for the reduction in their arable land area, are growing crops that can be planted and harvested between rainy seasons (such as potatoes and wheat). In this way, each farmer can pay 12 Yuan per Mu per year and do as they please with the harvest.

Until now the villagers have been free to fish from the river, but as the river has been inundated the villagers have received compensation based on the Fishing Act. After that, they can buy tickets from the dam management office in order to fish from a certain position for a certain period of time. According to the District Relocation Office, some villagers refuse to accept this kind of management, but recently the numbers buying the tickets to fish have been increasing and the method appears to be winning acceptance.

[3] Refer to footnote 2.

Table 16 Survey of the Position of Residents After Relocation

Satisfaction with relocation	Satisfied/ somewhat satisfied	80%	Didn't change	10%	Dissatisfied/ somewhat dissatisfied	10%
Change in income	Increased	50%	Didn't change	30%	Decreased	20%
Change in employment	Agriculture		Industry		Commerce, others	
Before relocation		70%		20%		10%
After relocation		60%		10%		30%
Water supply diffusion	Improved	70%	Didn't change	20%	Worsened	10%
Progress in electrification	Improved	90%	Didn't change	10%	Worsened	0%
Roads projects	Improved	70%	Didn't change	15%	Worsened	15%
Educational facilities	Improved	80%	Didn't change	20%	Worsened	0%

People who continued farming

Income	Increased	50%	Didn't change	30%	Decreased	20%
Area of farmland	Increased	20%	Didn't change	30%	Decreased	50%
Main crops	No. 1		No. 2		No. 3	
Before relocation	Corn		Rice		Beans	
After relocation	Corn		Beans		Rice	

(Source) Liaoning Provincial Water Resources Department materials.

2.2.5 Examples of How Relocated Residents Have Rebuilt Their Lives

(1) Policies for Rebuilding Residents Livelihoods

Most of the residents of the inundated areas made their living from farming, but the relocation reduced the average area of arable land per household from 1.5 Mu to less than one Mu. This lack of land hampered their efforts to re-establish their livelihoods. In particular, many of those who relocated to higher ground suffered worsened cultivation conditions. To deal with this problem, the district communist party committee and the district government began organizing the relocated residents in 1991 to clear and prepare a total of 560 Mu (approximately 37.3ha) for individual use and 1,200 Mu (approximately 80ha) for group use. They are also working to improve the soil of farmers with farmland of low productivity.

The construction of new factories has provided jobs for 310 relocated residents, and support is also provided for diversified farming operations. Relocated residents are setting up operations for raising chickens, ducks, rabbits, pigs and other animals. In 1997 their production amounted to 400,000 chickens, 7,000 ducks and 1,200 rabbits. Other measures include support for planting of lucrative crops of fruit and vegetables.

The district Communist Party Committee and the district government have adopted a preferential policy for relocated residents in the form of tax cuts when they find jobs in tertiary industries, such as commerce, catering, transport and services. As a result, the total annual value of benefits enjoyed by relocated residents has climbed to around one million Yuan.

The findings of an interview survey conducted in 1997, concerning residents' lives after relocation, showed that the proportion saying their income had declined has risen to 20%. This prompted the Benxi district government to take the measures listed below in an effort to

improve the lives of relocated residents.

(i) Provision of 2,360 Mu of new farmland.
(ii) Continued tax reductions or exemptions for residents who have found jobs in commerce or founded their own businesses.
(iii) Continued encouragement for livestock raising and cultivation of vegetables and fruit trees etc.

(2) Agriculture

The district Communist Party Committee and the district government have adopted two methods to overcome the reduction in arable land area and decline in income caused by the relocation.

(i) Greenhouse cultivation is typical as a simple technique to introduce. At its simplest, tree branches gathered from the surrounding hills can be stuck into the earth and covered with plastic sheeting bought in town. Tomatoes and peas are being cultivated on farmland in Xiaoshi Zhen Shangbucun using this kind of simple greenhouse.

(ii) The District Relocation Office provides a subsidy of 400 Yuan per Mu (approximately 6.7 ares) of newly cleared land. Villagers in Quanshui Zhen Sanguangecun have expanded their land from only 4 Mu at the start to 15 Mu by clearance, and have started keeping sheep and pigs as well as growing fruit trees and vegetables. To improve the soil of the cleared land, they used a tractor to bring relatively well fertilized soil from their previous arable land.

The above are attempts at agricultural production operation on "owned" land (land on which cultivation of crops for personal consumption is permitted). In some cases it is possible to contract larger areas of arable land from the town or village to grow crops as commercial products. One villager in Xiaoshi Zhen Xiabucun has contracted 125 Mu (approximately 8.3ha) from the town and employed 22 relocated residents to grow vegetable seedlings such as Chinese cabbage and Chinese white radish for a South Korean company. The contract charge is 15,000 Yuan per year, and annual production is worth 100,000 Yuan (of which 40,000 is post-tax income).

Similarly, a villager in Xiaoshi Zhen Xiaoshicun operates an orchard of 32 Mu (approximately 2.1ha). The land is contracted from the town for six years, and the orchard includes pears, apple and apricot trees. Saplings are sold commercially for 60~70,000 Yuan per year. Saplings have been bought from the Liaoning Provincial Fruit Tree Research Center and used in trials, with technical assistance from the Center, to find cold-resistant and early-yielding varieties.

The district and town relocation offices are also central to new moves to organize stock raising operations among the relocated residents. In Xiaoshi town, the District Relocation Office organized 20 households to use the remains of temporary buildings erected for the dam construction as a stock-raising farm for 400 pigs. Each household keeps 20 pigs, and the former village mayor actually runs the farm, representing the 20 households. Fertilizer and feed are bought jointly through the District Relocation Office.

In Nandian Zhen, two households of relocated residents are running a chicken farm. In one year

they make four shipments of 1,300 hundred chickens for an annual turnover of 15,600 Yuan. They started the chicken farm to compensate for the loss of farmland, because the area they farmed was halved after the relocation. The site and buildings are the old station site and buildings, which were left disused after the dam was built.

Nursery farm for saplings

Chicken farm in old houses

A newly-built pig farm

A few piglets are reared in each enclosure with modern equipment

A new factory for processing animal feed has been built in the same town. It has a capacity of around 200 tons per year and it is a peripheral industry to chicken farming in the area. It employs five relocated residents with wages of 450 Yuan per month each.

(3) Cottage Companies

One major task for this resident relocation operation is to find jobs to soak up the excess manpower left by the reduced area of arable land. In Benxi district, where the majority of the relocated residents live, three new factories have been built, and older factories expanded to create jobs for relocated residents.

The following is a summary of the four new factories based on discussions held when the factories were visited for this survey.

1) Benxi Axle Factory • Bengang Gearbox Factory

These are town enterprises located in the town of Xiaoshi. They are both located on the same site of 1,600m^2 and are run by one factory manager. They are managed by a board of directors comprising the head of the district relocation office, the president of the town enterprises corporation and the mayor of Sailisai village. The total investment in the factories was five million Yuan, and the investment shares are 40% from the town enterprises corporation, 20% from the District Relocation Office and 10% from the village. The axle factory produces 50,000 axles per year with an annual turnover of 1.5 million Yuan. The gearbox factory produces automobile gearboxes with an annual turnover of two million Yuan. These factories help to employ relocated residents, and thereby qualify for a preferential regional tax exemption.

The two factories employ 120 people between them, of whom 110 are relocated residents. The number of relocated residents employed here is equivalent to nearly half of the population of Sailisai village. Monthly wages are in the range 400~800 Yuan.

The employment process began with advertising in the village for applicants, who passed through scrutiny of their documents and an interview. Those who then passed the occupational training were hired. As most of the relocated residents were farmers who made their livings cultivating farmland, occupational training is a necessity. The pass rate from the training was 90%. Those who failed were not up to the required physical or intellectual level, or could not get used to working according to rules in a factory environment.

Factory Entrance

Metalworking Machinery

2) Quanshui Alloy Factory

This factory is a town enterprise located in the town of Quanshui Zhen. It was completed in 1994 and began operation in 1995. It smelts magnesium and has a design production capacity of 600 tons per year. The products are shipped to the Bentai Cast Iron Factory (a Hong Kong capital venture), but orders from that factory were low last year and shipments only reached 90 tons. In general the annual value of production is five million Yuan, generating a profit of 700,000 Yuan. The raw material is bought from Baotou in the autonomous region of Inner Mongolia.

The factory employs five administrative staff and 51 relocated residents as laborers. The average monthly wage for laborers is 800 Yuan. Working conditions are harsh, so the wage includes a health care allowance which raises the amount.

3) Tiannaxi Furniture Factory

Located in Quanshui Zhen, this furniture factory is a jointly-financed venture between the town and Hong Kong. It was completed in November 1996, with a total investment of over 37 million Yuan. The investment shares are 25% from Hong Kong, 25% from the town and 50% from a domestic private company (Zhongxin). The value of its annual production is five million (this is the figure for 1997, against a planned production value of 6.5 million Yuan). The factory's products are mainly dining tables, writing tables, chairs and wardrobes, which are exported to Taiwan, Japan, Italy and elsewhere.

The factory employs over ten administrative staff and 250 relocated residents as laborers. The average monthly wage is 400 Yuan.

4) Quanshui Cement Factory

This is a town factory that was built in 1984. At one stage it was losing money, but its equipment was refurbished in 1992 and its management strengthened to cut costs. As a result, its losses ceased in 1997. It produces cement with a value of 24 million Yuan per year, generating profits of two million Yuan.

The factory employs 347 people, of whom 187 are relocated residents. Most of the relocated residents come from the villages of Sanguangecun and Yaobucun. The average monthly wage is 450 Yuan for administrative posts and 600 Yuan for laborers. As the working environment is harsh, a health care allowance is paid (50 Yuan per person, per month) and workers are subscribed to injury insurance.

When relocated residents are hired, they are given one month of training in safety, skills and factory labor rules.

2.3 Project Effects and Impacts

2.3.1 Quantitative Effects

The qualitative effects of this project include its contribution to improving the standards of living of the relocated residents through infrastructure improvements. The way of life of the farmers before the dam was built was poorly provided with mains water supply, electricity, gas, communications and roads, as well as facilities such as schools and hospitals. The standard of their housing was also poor. The huge investment involved in the construction of this dam has enabled a major improvement in social and economic infrastructure.

2.3.2 Qualitative Effects

(1) Flood Control

Flood control was the main objective of this project, and it has already yielded concrete effects. In 1995, immediately after the dam was completed, the Taizi valley suffered a flood with a probability of once in 20 years, but the dam regulated the flood waters and there was no flood damage. According to calculations by the Water Resources Department, Institute of Design, if the dam had not existed it would have been impossible to avoid a large release of water from dams downstream and damages of around 860 million Yuan would have been caused.

The completion of the dam has enhanced safety, improving the flood probability from once in 50 years in Benxi to once in 500 years, and in Liaoyang from once in 100 years to once in 500 years. For farmland, the combination of the project with refurbishment of the Taizi River Embankment Project has improved the flood probability from once in five years to once in 50 years. At the Shenwo Dam downstream, the flooding standard has been improved from once in 1,000 years to once in 10,000 years.

(2) Supplies of Urban and Industrial Water and Agricultural Water

Actual amounts of water supplied to urban and rural users and to agriculture since the dam's completion are shown in Table 18. So far the peak supply volume has been 780 million m^3 in 1998, which is two thirds of the planned capacity of 1.18 billion m^3. The plan was that nearly 70% of the initial volume of supplied water should go for urban and agricultural water supplies, with 30% distributed for irrigation, but the share allocated to irrigation in 1998 was higher. The Department of Water Conservancy explains that this happened because the two downstream dams did not contain enough water in April and May, when irrigation is required, and the supply from Guanyinge Dam was increased to compensate.

The four cities in the lower valley, Benxi, Liaoyang, Anshan and Yingkou are supplied with approximately 1.03 billion m^3 per years (Liaoning Statistics Yearbook 1999, for 1998), of which 270 million m^3 is supplied from Guanyinge Dam (1998). Thus this project supplies around one quarter of the total water supply for these cities, making a great contribution to alleviating their water shortages.

Guanyinge Dam also supplies at least one quarter of the volume of irrigation water supplied from the Taizi river system, and the volume it supplies already exceeds the plan. In 1997 there was a severe drought, but it was possible to get enough water from the sowing season in May by releasing water from Guanyinge Dam. The dam began generating effects soon after completion.

The Department of Water Conservancy expects the planned water supply volume (1.179 billion m^3) to be reached in 2003.

Table 18 Annual Water Supply Volumes from the Taizi River System (recorded values, units: 100 million m^3)

	Urban and industrial water supplies		Irrigation water supply		Total	
	River system overall	Guanyinge Dam	River system overall	Guanyinge Dam	River system overall	Guanyinge Dam
1996	4.8	2.1	10	2.6	14.8	4.7
1997	4.4	2.7	12	2.7	16.4	5.4
1998	4.9	2.7	11.7	5.1	16.6	7.8
1999	5.8	2.9	9.8	3.7	15.6	6.6

(Source) Liaoning Provincial Water Resources Department

(4) Power Generation

The project generates 170MWh per year, as planned. The electricity is used for factory power supplies and the electrification of private homes.

(5) Aquatic Produce Raising and Other Applications

The raising of aquatic produce has only just started and only amounts to about one third of the planned volume at present. However, the aquatic produce raising team from Dahoufang Dam is making rapid progress in its efforts to realize the plan.

Fish farm at Dahoufang Dam (management office and fishing pool), and a scene of fish being hauled in.

A refrigerated warehouse attached to the fish farm

When the dam was built, it created an enormous vista across the reservoir lake which has become a new tourism resource. A tourist hotel is already under construction on the lakeside, and plans are underway for a pleasure cruiser and leisure boating facilities.

(6) Internal Rates of Return

As a means of analyzing the effects of this project, the Economic Internal Rate of Return (EIRR) for the project was calculated for a project life of 50 years, taking the benefits as the construction, operation and maintenance costs for alternative facilities and the average value of flood damage. The costs were taken as dam construction cost and operation and maintenance costs. The EIRR was put at 12.6% at the time of the appraisal, but when EIRR was reviewed in 1998 with the benefits limited to the sale revenues, the figure was down 4.5 points, at 8.1%. However, when the EIRR was calculated with all benefits taken into account, EIRR rose to 15.5%. This figure was strongly influenced by the dam's role in preventing flooding in 1997. The rate of return earned by this dam as an infrastructure-related project is running at a favorable level.