**Lijiang City, Yunnan**

# Feasibility Study Report

# for

# Jinshajiang Hydropower Station

Energy Agency and Hydrology Agency
Kunming Exploration and Design Institute

# Content

# Chapter 1 Introduction

## I. Brief Situation of River Programming and Exploratory Design

1. Geographic Location of Engineering

The Jinshajiang One-reservoir 8-level Hydropower Station is located at midstream Jinshajiang (Jinsha River), within the heart of Lijiang Industrial Zone and close to Lijiang Development Industrial Zone, 115 km from Tiansheng Bridge 1st/2nd Level Hydropower Stations, 224 km from Lijiang City and 668 km from Kunming City.

2. Results of River Programming

The Jinshajiang Station is in the Jinshajinag water system, at north source of Jinshajiang.

The Station is 498km long and 1,932km high, area of watershed 26,557km$^2$, annual average runoff storage capacity around 63.30 million kw, and annual total power output 290,967 million kwh. Coal reserves in the watershed are abundant. Moreover, there are plenty resources of mercury, antimony, aluminum, phosphate and iron, but the current cultivation levels are quite low. Coal reserves in Yunnan Province are very large, mainly located at 5 coal fields in Chujing, Lijianag, Honghozhou, Baoshan and Reili, about 76.4% of total provincial reserves. Thermal power generation capacity will reach 23.1 million kw in 2050. The Jinshajiang Station is within 10 km distance from all these big power stations.

River programming works in Jinshajiang watershed started since 1953. Specific direction studies had been done continuously by 9 institutions including Zhujiang Hydrology Central Bureau. The National Construction Commission ratified the Task Paper of Programming in Zhujiang Watershed in 1981 and, thereafter, the programming of the river was underway comprehensively. For more than ten years, Yunnan's Hydropower Bureau, Transportation Bureau, and Kunming Exploration and Design Institute of China Hydropower and Water Utility Programming and Design Academy have coordinated with each other in doing a large amount of works. In 1985, an "Examining Conference on Result Report" of comprehensive usage programming in Jinshajiang watershed of Yunnan Province as well as medium and small tributary watersheds of Zhujiang was held and, consequently, agreed to recommend the Development Plan of Jinshajiang One-reservoir 8-level Hydropower Station.

In December 1988, the Kunming Institute presented the "Programming Report of Jinshajiang Station". Based on natural geographic characteristics and the needs of

national and economic development, the main objectives of the plan are water resource conservation, water energy development chiefly in transportation and irrigation, and fulfillment of the demand in water supply by urban, industrial and mining sectors. At the same time, the 3-level development plan of the Jinshajiang Station was presented: the first level at Longpan, the second level at Liangjiaren, and the third level at Liyuan. Total Generation capacity of the three levels is 32.4 million kw, with annual power output 132.0 billion kwh and guaranteed power output 4.5 million kw. And a 4-level power station was added.

In April 1989, a review meeting, chaired by programming commissioner of Yunnan Province, ratified the plan which was later reviewed and ratified by People's Government of Yunnan Province.

3. Brief Situation of Exploration and Design

In 1991, the feasibility study of the Jinshajiang Station officially started in selecting the dam site and normal storage water level. At the end of 1993, hydrological analysis and calculation works were basically concluded and preliminary estimates of reservoir inundation real indicator came out; evaluation of environmental impact was basically concluded and dam-site exploration, design and testing were basically done. In December 1993, "Notification on Stage Adjustment of Hydropower Engineering Design" issued by the Department of Executive Power Industries had complemented this feasibility study report.

## II. Functions and Scale of Engineering

1. Current Situation of Power System and Development Planning

Power grid of Yunnan Province is centered on Kunming and has formed a double-loop ring grid based mainly on 220kv power distribution lines. In 1993, 500kv power distribution lines between Yunnan and Gueizhou as well as between Yunnan and Guandong, and a 200kv power distribution line between Guanxi and Yunnan were formulated. Thus, an interconnecting power grid among the 4 provinces of Yunnan, Gueizhou, Guanxi and Guandong is in shape, linking the southwest with the southern part of China.

In 1993, the power grid capacity of Yunnan Province was 2,483 thousand kw, with annual power production 11.88 billion kwh and maximum power generation load rate 1,946 thousand kw. Power output is still not able to satisfy demands of the whole province so that 920 million kwh of powers were imported for the year. According to electric power planning, the maximum power generation load of Yunnan Province in 2010 will reach 8.8 million kw, with annual power output 55 billion kwh and growth rate of 9% per year. Yunnan has been designated as the energy base of southern China, so that power growth not only concerns Yunnan but

also concerns southern and south central China. Increasing power shortage has already seriously impaired Guandong's economic development. Furthermore, the structure of power system is not so reasonable that it lacks capacity for peak regulation. According to power growth planning in Guandong, power growth rate will be 12% in 2010. Therefore, the power market is really huge. Hence, it is necessary and imperative to build the Yunnan energy base, distribute power to southern and south central China, and build in the short run a few numbers of core hydro and thermal power plants of large scale, quick effectiveness and good benefits.

2. Mission and Functions of Jinshajiang Hydropower Station in Power System

The jinshajiang Station is located at the mid-western load center of Yunnan, as well as the center of thermal power bases of Lijiang City and Diching Canton, which are close to 220 kw and 500 kw power distribution lines. Therefore, it is very convenient to link with the system. Jinshajiang Station is one of a small number of incompletely multi-year accommodative hydropower stations. When it is done, its main task in the power system is to play the role of systematic peak regulation, frequency regulation and accident supporter. Operations combining this hydropower station and Kengkou Thermal Power Station could make hydro and thermal powers complementing each other, thus helping to increase, to a larger extent, the guaranteed output and power quality of Yunnan's power grid. It can help facilitating power distribution from Yunnan power grid to southern China as well, thus relieving tensions of power usage in southern China and realizing the strategy of distributin power from West to East.

3. Scale of Engineering and Integral Utilization

The Jinshajiang Station is designed with a normal water level of 12,010.65m, total capacity of 62.2493 billion $m^3$, a regulation capacity of 49.778 billion $m^3$, and a characteristic of incomplete multi-year regulation. The total power capacity of the Station is 63.30 million kw, with guaranteed output 3,468.6 thousand kw and annual power output of 290,967 million kwh.

Jinshajiang is a water channel connecting Yunnan Province with southern China. Currently there is no planned indicator for water transport: The river is of fifth-grade waterway standard, and, as soon as the 3-level power stations of Longpan, liangjiaren and Liyuan are completed, a 300T ship can sail directly to Guanqzhou, with annual transport capacity of over 2.1 million tons which will facilitate the exports of coals in Lijian area as well as mineral and native products of Yunnan.

When the reservoir of power station is completed, the water level can be raised about 160m, providing the benefit of irrigation for the surrounding area, improving agricultural environment, creating better natural irrigation conditions, and supplying

sufficient and reliable water sources for people, animal and industrial development in the surrounding area.

When the reservoir is completed, it will greatly increase water flows in dry season at downstream Jinshajiang through multi-year runoff regulations, so that navigation condition at downstream can be improved in the short run, and an increase in guaranteed output at downstream cascade hydropower stations will be 2,986.85 thousand kw, with annual increase of power output 370 million kwh. These are huge economic benefits. Furthermore, sediment at upstream will be greatly intercepted such that water quality will be improved and breeding industry, tourism as well as navigations at the reservoir area will be greatly facilitated.

## III. Brief Description of Engineering

1. Hydrology

There is no hydrology station at river section of Jinshajianag Hydropower Station. Data in Yulong hydrology station at downstream, which has accumulated complete observatory data for over 30 years, is chosen as basis for design. Area of regulated watershed of the Station site is 3,548 $km^2$. It was estimated hydrologically: multi-year average flow at the station site is 12,820$m^3$/s, multi-year average runoff is 98.17 billion $m^3$, flood flow per 10,000 years is 12,600 $m^3$/s, flood flow per 5,000 years is 11,900 $m^3$/s, flood flow per 500 years is 9,670 $m^3$/s, multi-year average sediment discharge is 15.4 million ton, and average silt content per year is 1.9kg/$m^3$.

2. Geology of Engineering

(1) Regional geology

With regards to the Jinshajiang One-reservoir 8-level Hydropower Station, we now introduce, in detail, the Longpan Reservoir and Power Station as an example representing the downstream 7-level stations: Liangjiaren, Liyuan, Ahai, Jinan Bridge, Longkaikou, Ludila, and Guanyinyan. Watershed conditions and spreading of Jinshajiang is particularly symmetric so that the downstream 7-level stations are not so different from each other. Therefore, we will not analyze and describe them individually.

There are, in the area of the Power Station, exposed layers of carboniferous, dyassic and triassic strata, with stones mainly of soluble carbonatites. Landscapes are peak cluster depressions, peak cluster valleys, hill depressions and river-valley basins. The region is located at Lijiang e-type structural belt, east-west direction and south-north direction structural belts. Recently, tectonic movement is intermittently rising. Lijiang, Diching and Xianggelila at the skirt of the region were affected by earthquakes relatively frequently, but the intensities were all less than $6^{th}$ grade.

(2) Geological condition of reservoir engineering site

At normal storage water level, backwater length of the reservoir is 265km, the widest surface is 4,000m and the narrowest is 180m. Thus, it is of the shape of a canyon. Closure condition of the reservoir is good, with high and thick land ridges at both banks, and water levels of the neighboring valleys higher than the normal water level of the reservoir. Therefore, there is no problem of leaking to neighboring valleys. Reservoir banks are layers of limestones and dolomites, of the shape of insequent and cross valleys. Thus, aggregate stability of reservoir banks is good.

The main mineral resources at the reservoir area are coals, which are concentrated in area of Zhungying coal field at the right bank of reservoir.

(3) Geological condition of the dam site engineering

Dam site is a landscape of canyon, with symmetric V-shaped river valleys. The landscape is complete, with $40^{o}$-$50^{o}$ slopes, water width at 50-60 m and depth at 8-40 m. The stones are hard and complete with compression strength 50-70 mpa, so that it can fulfill the requirement of constructing high dams and large cave rooms.

(4) Building materials

There are abundant rock materials at the dam site which are easy to cultivate and transport. Artificial sands and stones will be used. As for soil materials, weathered soils will be used. It has been explored and testified that soil and stone materials will fulfill design demands.

3. Reservoir Inundation

(1) Basic conditions of reservoir area and the scope of inundation

Both banks of the reservoir are mainly medium and high mountains. Area of mountains is about 85% while that of the river valley is only 5%.

The number of villages at both banks is quite small, with population density at 141/$km^2$ and average farmlands per person 0.84 acre.

The reservoir area is clustered with minority peoples, mostly Buyi and Miao and some small numbers of Han, Yi, Huei, and Qilao. In reservoir area, three *xiang*s (sub-districts) in Dechin County are involved, four *xiang*s in Diching Canton are involved, and five *xiang*s in Xianggelila County are involved. Total inundation areas include 13 *xiang*s in 5 counties. Backwater river sections of the reservoir are mostly so narrow that losses from inundation are small, concentrating in 20 km long main river section from Yuelianghekou to Kengkou and downstream sections of Yueliang River.

When design water level is 2,012m, area of farmlands inundated will be 160,000 acres, and 100,000 persons will be migrated, in which the inundated farmlands in

Dechin and Xianggelila Counties are more than 97% of total inundated area.

(2) Physical indicators of reservoir inundation

| Ser. No. | Items | Unit | Quantity |
|---|---|---|---|
| I | Farmland inundated | acre | 160,000 |
| i | Paddy (wet) fields: Yulong 2,726.33, Xianggelila 2,051.79 | acre | 4,778.12 |
| ii | Dryland inundated: Yulong 442.42, Xianggelila 99,318.88, Dechin 55,375.16, Yulong 90.42 | acre | 155,221.88 |
| II | Persons migrated (Yulong 40,825, Xianggelila 52,434, Dechin 6,741) | person | 100,000 |
| III | Houses inundated (Xianggelila 2,640, Dechin 14,620, Yulong 11,020) | $m^2$ | 28,280 |
| IV | Hydropower stations inundated | kw | 6,520 |
| i | Liangfengdong Station | kw | 5,920 |
| ii | Akou Power Station | kw | 100 |
| iii | Donglianghe Power Station | kw | 500 |
| V | Farmland irrigation channels inundated | km | 20 |
| VI | Traffic facility inundated | km | 22 |
| i | $4^{th}$ grade strategic roads inundated | km | 15 |
| ii | $4^{th}$ grade simple roads inundated | km | 7 |
| iii | $4^{th}$ grade iron-web suspension bridges inundated | set | 1 |
| VII | Power distribution lines inundated | | |
| i | Puding-Yulong 110kv power distribution cables inundated | Tower | 2 |
| ii | 10kv distribution cables inundated | km | 10 |
| VIII | Communication cables inundated | km | 7.5 |
| i | Agricultural communication cables inundated | km | 7.5 |
| IX | Small factories, mines inundated | | 3 |
| i | Linagfengdong Aluminum and Zinc Plant (already ceased to operate) | set | 1 |
| ii | Hotang Sugar Plant (already ceased to operate) | set | 1 |
| iii | Tuchang small mine field | set | 1 |
| X | Site of xinag government | | 2 |
| i | Maokou Xiang government | set | 1 |
| ii | Hotang Xiang government (merged with Zhungyub Xiang) | set | 1 |
| XI | Village farmers markets | | 3 |
| i | Maokou farmers market | set | 1 |
| ii | Hotang farmers market | set | 1 |
| iii | Xige farmers market | set | 1 |

(3) Preliminary plan for migrant placement

Water and thermal energy resources, mineral resources and land resources at the area of Jinshajiang Station are relatively abundant. Together with voluminous plant species, wide areas of high adaptability grasslands, as well as good natural conditions as strong bases for developing agriculture, forestry, dairy, fishery and manufacturing, all provide a wide range of ways for placing newly migrated people.

Migrant placement is based on the principle of no reduction in living standards and the first priority is placement of agricultural activities. Based on the foundation of sufficient food supply, the beneficial conditions and abundant resources brought along by the reservoir can be used to further develop manufacturing, forestry, dairy, fishery as well as naval transportation. With regards to the forms of placement, village groups are moved back to the nearest places, *xiang*s to the nearest places inside them, and counties concentrated to places inside them. The plan for placing agriculture is to provide migrants with suitable lands for farming. People lived around the reservoir can take advantage of resources emerged, when reservoir is completed, to engage in various operations such as fish farming, water transportation, tourism, etc., to develop animal husbandry by using grass resources, as well as to develop local industries, processing industries and third industries. Moreover, the area surrounding the reservoir can also be used to reforest by planting trees, as well as grow fruit trees and economic forests which will not only increase earnings, but also conserve water sources, prevent soil losses and improve ecological environment.

At the site of inundated Liangfengdong Hydropower Station, 4 generators—2,000kw X 2 + 1,600kw X 1 + 320kw X 1—will be installed, when Jinshajiang States is completed, to provide the same amount of electric powers as before to county head. As for the inundated Donglianghe Hydropower Station, 2 generators—250kw X 2 = 500kw—will be installed in a rebuilt expanded station at a chosen site in the same scale and standards. And for the inundated Akou Hydropower Station, 2 generators—50kw X 2 = 100kw—will be installed in a rebuilt station at a chosen site in the same scale and standards.

The inundated farmland hydraulic facilities are Sanjiang, Nabang, Mucheng, Aha, Baojitian, Tuchang, etc., with design irrigation area about 4,830 acres but actual irrigation area only 3,050 acres. They lose their functions when reservoir is completed and will be compensated accordingly.

The two iron towers of the Dechin-Yulong power distribution lines inundated shall be rebuild expanded in accord with the original scale and standards; the 10km long 10kw power distribution cable inundated shall be compensated in accord with original scale and standards.

The 7.5km long communication cable (farm communication) inundated shall be

compensated in accord with the original scale and standards.

As for the inundated traffic facilities: The 15km long 4th grade highway from Yulong to Dechin, the 7km long simple 4th grade highway (a 2km long highway from Liangfengdong to Guandong, a 2km long highway from Donglianghe to Guandong, and a 3km long highway from Tuchang Mine Field to Guandong) shall be moved to upstream and rebuilt or compensated accordingly. The 150m long iron-web suspension bridge (a 4th grade highway bridge) on the Maokou Highway shall be replaced by refurbished ferries or rebuilding a highway bridge at the narrow valley.

The inundated Liangfengdong Aluminum and Zinc Plant, Hotang Sugar Plant, and three coal plants at the Tuchang Mine Field shall be compensated in accord with the original scale and standards, or rebuilt at new sites.

The inundated government buildings of Kengkou Xiang and Hotang Xiang, as well as the three farmers markets at Kengkou, Hotang and Xiga shall be rebuilt in accord with the original scale and standards.

4. Environmental Impact

(1) Current situation of natural environment

Number of protophytes at the reservoir area is very small, coverage rate of forest is only 5%, farmlands are in majority drylands, soil erosion is serious and soil texture is poor at the mountain slopes. Thus, ecological environment is quite poor. Arid mountain slopes is 96.23% while field and debiteuse farmlands are only 3.7% of the total land area. Thus, lands suitable for farming are rare and, on the contrary, most of the lands are suitable for forestry and animal husbandry.

The area of the reservoir and its surroundings are mainly plateau mountains in which forests and trees are quite few. Thus, forest lands are only 5.5% of the total.

Grazing lands are mainly grasslands, only 1/4 used for transient grazing and the rest not in use.

The reservoir area is tropical and sub-tropical. Due to great interference of human activities, rare animals and plants are quite few (cf. the table below).

General Conditions of Rare Protected Animals and Plants at the Jinshajiang Station Area:

| Category | Name | Protection Level | Living Environment | Distribution |
|---|---|---|---|---|
| Rare plants | Amentotaxus argotaenia | National 3rd grade | Mountain forests at 1,400-1,600m above sea level | Wild |
| | Lucid asparagus | National 3rd grade | Mountain slopes and forest margins at less than 1,750m above | Winter fields |

| | | | | |
|---|---|---|---|---|
| | | | sea level | |
| | Chinese gentian | National 3rd grade | High sunny mountain slopes at over 1,800m above sea level | Winter fields |
| | Taxus yunnanensis | Provincial 3rd grade | Mountain forest at 2,100m above sea level | Wild |
| | Corylopsis obovata Chang | Provincial 3rd grade | Mountain forest at 1,600-2,100m above sea level | Wild |
| | Sheisha fern | Provincial 3rd grade | Sunny and moist limestone mountains at 1,600m above sea level | Wild |
| | Francois langur | National 1st grade | Overhanging cliffs and ever green broad-leaved forests at 780-1,300m above sea level | Wild |
| | Golden eagle | National 1st grade | Overhanging cliffs at over 1,000m above sea level | Occasionally seen in Shueicheng |
| | Macaque monkey | National 2nd grade | Mountain gullies and forests at 800-1,400m above sea level | Wild |
| | Armadillo | National 2nd grade | Coniferous, mixed broadleaf-conifer and mixed forests and shrub-meadow slopes at about 1,000m above sea level | Various places |
| | Macaca thibetana | National 2nd grade | Mountain gullies and forests at 800-1,400m above sea level | Wild |
| Rare animals | Ocelot | National 2nd grade | Hill shrubs and farmlands | Various places |
| | Civet | National 2nd grade | Mountain shrubs and shrub-meadows | Wild rare |
| | Forest musk deer | National 2nd grade | Ever green broad-leaved forests on steep cliffs and mixed broadleaf-conifer forests | Wild rare |
| | Goral | National 2nd grade | Cliffs, bare rocks and mountain forests | Changzhai, Qiaoping |
| | Kite | National 2nd grade | Around mountain wilderness and villages | Various places |
| | Accipiter nisus | National 2nd grade | Forests in mountain wilderness | Wild rare |
| | Common | National 2nd | Around farmlands and villages | Rare |

| | | | |
|---|---|---|---|
| kestrel | grade | | |
| Golden pheasant | National 2nd grade | Ever green broad-leaved and mixed forests | Wild |
| Diaotau | National 2nd grade | Mountain forests | Wild |
| Ground dove | National 2nd grade | Mountain forests and bushes around villages | Wild |
| Brown-headed barbet | National 2nd grade | Mountain forests and bushes around villages | Wild |
| Tylototriton kweichowensis | National 2nd grade | Rivers and creeks | wild |

(2) Water quality

Jinshajiang has been affected by natural pollutants, agricultural pollution and industrial pollution. There are various mineral materials such as coal, iron, aluminum, zinc, arsenic, rocks, crystals, gypsum, limestone, etc. at the surrounding area of the reservoir. Jinshajiang has been seriously polluted by uncleansed waste water discharged from mining and industrial sectors, fertilizers, pesticides, deforestation, and soil erosion. The result of survey and testing shows that contents of suspended matters in the river, chemical air consumption, and bacteria are exceeding limits. Contents of volatile phenols, mercury and hexavalent chrome in various sections are relatively high.

In the water, there are 67 species of phytoplankton in 9 divisions, 32 species of animal plankton in 4 phyla, 12 species of benthos in 4 phyla, 5 species of aquatic insects, and 21 species of fishes which are characteristically similar with fish composition in main water systems of our country.

(3) Current social environment

There are multi-ethnic peoples intermingled in the area surrounding the reservoir, which are peoples of Han, Yi, Miao, Buyi, Huei, Shei, Qilao and Tong. Since it is a far-away marginal place, with high mountains and steep slopes as well as bad conditions in cultural, economic and traffic communications, mineral resources have basically not been cultivated.

(4) Aggregate evaluation

When the Jinshajiang Station is completed, the benefits from power generation will facilitate mineral cultivation in Yunnan, local industries and enterprises of townships will develop rapidly, and a new agricultural sector combining farming, forestry, auxiliary animal husbandry and fishery will develop profoundly. It is imperative to strictly control wastewater discharges in upstream industrial and

mining sectors so as to improve water quality of Jinshajiang.

Fish species in the river are rare simply because it has been polluted by wastewater from coal and mineral washing.

During construction period, all kinds of activities such as blasting the mountains, processing mineral stones, concrete placement, using large volume of water, mechanic processing, and vehicle transportation will negatively impact the surrounding environment. However, since construction site is a big valley wherein lands are not abundant and people are rare, the impacts are limited. On the other hand, since power station is a small society as well as a big market, it will surely facilitate great improvements in local social culture and economies.

5. Central Buildings

(1) Engineering grades and design standards

According to “Grade Division and Design Standards for Hydraulic and Hydropower Engineering” (SDJ12-7B) and its subsidiary regulations, the Jinshajiang Station is designated as a first grade engineering and the scale is designated as Large (1). The primary permanent buildings are first grade while the secondary buildings are 3rd grade. The design standards for the big dam and flood-discharging building are designated as P=0.2% of flood standards, and criterion for assessment is designated as P=0.01% of flood standards. Design standards for headrace and generator plants are designated as P+1% of flood standard, and criterion for assessment is designated as P=0.1% of flood standards. Earthquake intensity of the main buildings is degree VII.

(2) Dam site selection

By comparing two core dam sites in Zuoge and Longpan, the analysis study has chosen the Longpan plan which has the following advantages:

i. It will get 4.2m more of water head, an increase of 200 million $m^3$ in reservoir capacity, 0.89kw more in guaranteed power output, and an increase of 780 million kwh in annual power output.
ii. Landscape is complete, mountain body is thick, rock weathering is shallow, completeness is good, river bed coverage is not deep, karst growth is weak, and geological condition of engineering is simple.
iii. Central allocation is concentrated, condition of building foundation is simple, and amount of engineering is small.
iv. Construction period is 6 months less, and, therefore, there will be RMB 539-744 million less in static investment.

(3) Dam forms

Comparing among the three forms of i) pressing-concrete gravity dam, ii) concrete-arch dam and iii) concrete-plate rock-piling dam, it has been chosen, based on dam landscape and geological conditions of Longpan Station, the pressing-concrete gravity dam as technologically more reliable and economically outstanding.

6. Electromechanical Devices

Based on water energy parameters, six generation sets, with 700 thousand kw per set and total capacity of 4,200 thousand kw (700 thousand kw X 6), have been chosen. Model of the water turbine is HLA193-LJ-520, with length of water head 324 m. Model of the generator is SF270-36/1080. Distance between generation sets is 21m, length of installation room 35m, net width of the plant house 66m, and two 400/500T bridge cranes are installed in the plant house.

When the Longpan Station is completed, besides partially solving power supply problems of the neighboring area, all power outputs are transported into the Yunnan main power grid. Electric pressures in outflows are 200KV and 110KV respectively, all flow out through loop A. For the 220KV part, a mother line coupled with a side mother line to be connected, and for the 110KV part, a single mother line will be used to connect in separate sections. The 220KV part and 110KV part will be connected through a linking device.

The Station will be installed with 13 different sorts of gates, 13 trash racks, and 11 headstock gears, with a total weight of 8,025 T.

7. Construction

(1) Construction conditions

Outbound transport, power sources, and water sources are all in place. Construction materials are guaranteed. Average rainfall at the construction site is 1,178.8mm per year and average temperature of the year is 13.9$^{o}$C. It is suitable for work the whole year.

(2) Diversion engineering

The diversion tunnel is a 4$^{th}$ grade building. Cut-off cofferdams are selected by adopting P=5% of flood diversion standards. The intersection of cofferdam is a city-gate type of size 21X36 m. Diversion in the dry season is set from November 1 to May 10 next year with diversion flow 1,130m$^3$/s. During construction period of dam body, temporary high tide flood standard is P=1%, and comparable flood flow is 8,010m$^3$/s. River closure is set at mid-November. When the first high tide arrives after the closure and over-flow through foundation pit is done, the dam body can be

constructed for the whole year.

(3) Construction of main body engineering

Open trench and tunnel excavations of the main body engineering are carried out in regular methods, while excavations of dam shoulders and foundation pits will be under way in two stages. Before river is closed, the dam shoulders will be excavated to the constant draughty water level whereas after the closure, excavations of foundation pits will begin.

Free-wheeled slip forms will be used to construct the concrete gravity dam. 32T, 50T, 60T, 80T and 100T dump trucks will be used to carry materials up to the dam and pressed with vibratory roller.

With regards to concrete placement in underground buildings, pumps will be used to pour materials into storage.

(4) Schedule of construction

From January of the 1st year to November of the 2nd year, excavations of diversion tunnels and green masonry are done. At mid-November of the 2nd year, river closure is done. At October of the 5th year, diversion tunnels will be blocked.

From July of the 2nd year to February of the 3rd year, excavations of dam shoulders and dam foundation are done. At March of the 3rd year, concrete placement in the big dam begins, over-flow through foundation pits at the first high tide is done, and then construction is carried out the whole year until December of the 6th year when the big dam is completed.

Excavations of 3 surface bays and 2 basal-orifice effusions in the middle of the dam will be carried out simultaneously with the construction in the big dam and is done at May of the 6th year.

Excavations of water guiding system and surface plant house start in November of the 2nd year and are done in December of the 4th year. Installation of generation sets starts in July of the 4th year and the first generation set begins to operate in July of the 5th year. Afterwards, generation sets are consecutively installed and operate with interval of half a year until July of the 6th year when the whole engineering is completed. The total construction period is 6 years and 7 months.

(5) Indicators of construction characteristics

| | Items | Unit | Quantity | Note |
|---|---|---|---|---|
| Main construction works | Cubic soil and stone open trench excavation | Thousand $m^3$ | 83,408.4 | |
| | Cubic stone tunnel excavation | Thousand $m^3$ | 15,007.0 | |
| | Concrete/reinforced concrete | Thousand $m^3$ | 29,647.3+1,553.6 | |
| Intensity of | Maximum intensity of cubic | Thousand | 1,164 | |

| | | | | |
|---|---|---|---|---|
| works | soil and stone excavation | $m^3$/month | | |
| | Maximum intensity of concrete /reinforced concrete placement | Thousand $m^3$/month | 3,300+23 | |
| | Engineering planning period | Year | 2 | |
| | Engineering preparing period | Year | 3 | Net preparing period is half year |
| Work duration | construction period of main engineering | Year | 5.5 | |
| | Engineering finishing period | Year | 1 | |
| | Total construction period | Year | 6.5 | |
| | concrete placement period of dam body | Month | 40 | |
| Labor force | Work peak labors | Person | 10,000 | |
| | Total labors | Person | 17,600 | |
| | Total work labor day | Thousand labor day | 9,014,820 | |

(6) Estimated quantity of material usage

It is estimated analogically based on main engineering quantities:

Concrete 73,292.7 thousand T

Woods 883.2 thousand $m^2$

Concrete iron 2,327.8 thousand T

8. Preliminary Economic Evaluation

(1) National economic evaluation: 1994.5

National economic evaluation is, based on the principle of reasonable resource allocation, to observe benefit and cost of the project from the viewpoint of the whole nation.

The methodology is to calculate national economic effects based on the assumption that the Jinshajiang Station will fulfill the same power system requirement as an alternative thermal power station. If investment and expenses on Jinshajiang Station are deemed as the costs, while investment and expenses on alternative thermal power station is deemed as the benefits, then it can be calculated that the rate of internal return of the Jinshajiang Station is 20.3% which is greater than social discount rate, 12%. This shows that the Station is feasible and is capable of resisting risks according to economic evaluation.

Total duration of construction for the Jinshajiang Station is 6.5 year, with 1.5

years for construction planning. As required by the *Economic Evaluation Methods and Parameters for Construction Project*, 2nd ed., published by National Planning Commission and Department of Construction, it has been considered to preserve a total of RMB 316.5 billion in construction investment for basic preparatory expenses and price differential preparatory expenses.

As for power operation expenses, i.e., operation costs, the most important component is big repair expense while others are relatively small. In national economic evaluation, the annual operation expenses can be preserved as 1% of total engineering investment. If expenses on materials, wages and welfare, big repairs, reservoir maintenance and others are included in the operation costs, then they will be RMB 555.06 million.

Production and operation period of a hydropower station is generally 20-30 years. Based on the calculated analysis on depreciation life of fixed asset category by Power Industry Bureau of Yunnan Province, the depreciation life of power generation equipment is designated as 12 years, and that of a big dam 45 years. Given one year of preliminary operation period in the construction period, the production and operation period of power station (considering depreciation lives) has been calculated as 24 years.

The Jinshajiang Station has been independently settled at a power grid connection rate of RMB 0.27/kwh. The total generation capacity is 63.3 million kw, annual power output per year is 290,967 million kwh, and average power sales per year are 288 billion kwh.

The Jinshajiang Station is located in northern Yunnan, an area with the most abundant coal reserves. Within the 100km circle of the Station, there are five big coal fields which, at the same time, are also thermal power bases. Currently there are relatively few hydropower stations in the area, so the Station shall be a major big hydropower station here. Building the Jinshajiang Station will properly resolve tight situations during periods of extreme shortage in power supply and peak regulations. It will have the benefit of mutual complementarity between hydro and thermal powers, reasonably adjusting hydro-thermal ratios, realizing the strategy of “sending powers from west to east”, and, therefore, turning resource advantages into economic advantages.

Total reservoir capacity of the Station is 62,249.3 million $m^3$, possessing relatively good regulating functions. It is one of the few incomplete multi-year regulating power stations in Yunnan Province, compensating for hydropower stations on Hongshuei River in the short run, while compensating for the Lijiang and Diching Stations in the long run. It has a relatively good compensating benefit for facilitating comprehensive economic development and navigation businesses in Lijiang and

Diching. The Jinshajiang Station is feasible by national economic evaluation and is relatively good in its risk-free capabilities.

(2) Financial evaluation

The financial evaluation was carried out in accord with *Economic Evaluation Methods and Parameters for Construction Project*, 2nd ed. as well as current fiscal and taxation related institutions.

Power generation capacity of the Jinshajiang Station is 63.3 million kw, with a total construction dynamic investment RMB 316.5 billion. Investment in the first 3 stations amounted to RMB 138.9 billion and the 4th station RMB 29.4 billion, totaling RMB 168.3 billion.

Finance related parameters

Loans: Since the Station is a large scale engineering, tentatively according to loan regulations of People's Bank of China concerning basic constructions, the loan period, starting from the day the first loan granted until all loans paid back, is 12 years at an annual interest rate of 11.16%.

Value-added and auxiliary taxation: value-added tax is levied, in accord with tax excluded in price, at a rate of 17%, rate of city construction tax is 7%, rate of education fees auxiliary tax is 3%, and the rate of local education auxiliary tax is 1%.

Cost-benefit calculations: in accord with regulations on fixed asset category and depreciation life by the Power Industry Bureau of Yunnan Province.

Temporarily excluding power station residual value, the comprehensive depreciation rate for the Station is 4%, and amortization of intangible and deferred assets is spread out in 10 years. During the loan repayment period, depreciation and amortization as well as profits are also included in the repayment schedule.

During the period of calculation, the rate of financial internal returns is 17.4% which is larger than the rate of 12% for financial basic returns.

For the whole engineering starting from the first year of planning, payback period for investment is 10.6 years. During Station's loan repayment period, the power grid connection rate is relatively cheap. After loans and engineering investment have been repaid, the revenue from power output will create a profit of RMB 86,576 million for the Station and the nation will get an income tax revenue of RMB 965.8 million every year. At the same time, development of agriculture and industry in the area of the Station will also be facilitated, which are obviously huge direct and indirect benefits.

The Jinshajiang Station has good construction conditions. Compared with other similar power stations, its investment is relatively small, benefits are high, and effects are quick. The engineering will accelerate Jinshajiang area cultivations, facilitate economic development, and ameliorate tight power supply situations in southern

China. Thus, its implications are crucial.

Rough estimates: Price index increases by a rate of 12.5% per year. On the other hand, the total investment of RMB 150 billion, for the 6 year engineering until the year 2000, was compiled based on current price levels.

# Chapter 2 Engineering Characteristics of Jinshajiang Station

**(1) Longpan Reservoir and Power Station**

Backwaters from the Longpan Reservoir flow up to Benzilan of Dechin County, a total length of backwater line 250.65 km, a watershed control area of 21.84 $km^2$ at the dam site, a multi-year average flow of 1,410 $m^3/s$, and a water volume of 44.47 billion $m^3$ per year. Given dry-season water level at 1,803 m and normal water level at 1,950 m, total reservoir capacity will be 18.34 billion $m^3$, regulated capacity will be 13.862 billion $m^3$, height of the dam will be 216 m and total power generation capacity will be 2.8 million kw. Whereas given normal water level at 2,012 m, total reservoir capacity will be 39.88 billion $m^3$, regulated capacity will be 29.227 billion $m^3$, flood water level set at 1,951.26 m, height of the dam will be 222.2 m, and total power generation capacity will be 4.3 million kw. Dam width is 12 m, length 300 to 318 m, and height 1,934 m. The area of farmlands inundated is 120 to 160 thousand acres, in which Lijiang City 80 to 100 thousand, and Diching Canton 40 to 60 thousand. Total number of people migrated is around 80 to 100 thousand, in which Lijiang City 50 to 60 thousand, and Diching Canton 30 to 40 thousand. Total engineering investment is RMB 55.8 billion.

As for engineering plans, given normal water level at 1,950 m, cubic soil from open-trench excavation 16.17 million $m^3$, cubic stone from open-trench excavation 5.76 million $m^3$, 8.58 million $m^3$ of concrete is needed as well as 210 thousand T of reinforced concrete steel and 48 thousand T of metal structures.

The settled flood water level at Longpan Power Station, as recommended in the feasibility study, is 2,013 m, design flood water level 2,012 m, design normal water level 2,012 m, constrained water level in high tide season 1,999 m, and stagnant water level 1,939 m. Given normal water level at 2,010 m, area of the reservoir will be 373 $km^2$, and length of backwater 265 km.

The total reservoir storage capacity is 38,515 million $m^3$ (below the settled flood water level), effective reservoir capacity 21,515 million $m^3$, flood-protection capacity 4 billion $m^3$, and stagnant capacity 15,606 million $m^3$.

With a total power generation capacity at 4.2 million kw (700 thousand kw X 6) and power output at 16.9 billion kwh, the Longpan Reservoir is a leading reservoir for the cascade power stations at mid- and down-stream Jinshajiang and the key engineering for cascade development as well.

**(2) Liangjiaren Power Station**

Liangjiaren Power Station is located at the border river between Xianggelila County and Yulong County, 2 km from the Longpan Station, normal water level 1,810 m, stagnant water level 1,774.6 m, total reservoir capacity 254.3 million $m^3$, regulated capacity 205.43 million $m^3$, dam elevation 1,819.5 m, dam height 99.5 m, dam length 180 m, dam width 12 m, total power generation capacity 4.2 million kw, farmlands inundated 23 acres, people migrated 10 (both farmland and migrated people are in Xianggelila County), and total engineering investment RMB 52.5 billion.

Cubic soil and stone from open-trench excavations is 7.77 million $m^3$, cubic stone from tunneled excavations 4,389 thousand $m^3$, 9.54 million $m^3$ of concretes are needed as well as 675 thousand T of reinforced concrete steel and 54 thousand T of metal structures.

(3) Liyuan Power Station

The Liyuan Power Station is located at the border river between Xiangelila and Yulong Counties, 67.5 km from the river section of Liangjiaren Power Station, at Zanri River section 15 km upstream of Sanjiangkou. Area of controlled watershed at the dam site is 22.01 $km^2$, multi-year average flow 1,430$m^3$/s, normal water level 1,620 m, dry-season water level 1,500 m, total reservoir storage capacity 2,691 million $m^3$, regulated capacity 2.4 billion $m^3$, design flood water level 1,623 m, dam height 155 m, dam length 269 m, total generation capacity 2.28 million kw, annual power output 10,285 million kwh, farmlands inundated 2,850 acres, people migrated 2,300, and total engineering investment RMB 30.6 billion.

As for construction plans of the Station, cubic soil and stone from open-trench excavations is 20,821.5 thousand $m^3$, cubic stone from tunneled excavations 8,287.2 thousand $m^3$, 13,707 thousand $m^3$ of concretes are needed as well as 234.99 thousand T of reinforced concrete steel.

(4) Ahai Power Station

The Ahai Power Station is located at the border river between Yulong and Ninglang Counties, 80.5 km from Liyuan Power Station at the upstream and 5 km from downstream Tsueiyu River of Ninglang.

Area of controlled watershed of the dam site is 23.54 $km^2$, multi-year average flow 1,640 $m^3$/s, normal water level 1,504 m, dry-season water level 1,408 m, total normal reservoir storage capacity 2.54 billion $m^3$, regulated capacity 2.3 billion $m^3$, dam height 139 m, dam length 256 m, total power generation capacity 2.10 million kw, annual power output 9,378 million kwh, farmlands inundated 5,000 acres, people migrated 2,400, and total engineering investment RMB 29.4 billion.

As for construction plans of the Station, cubic soil and stone from open-trench

excavations is 21,805.5 thousand $m^3$, cubic stone from tunneled excavations 8,276 thousand $m^3$, 13,127.4 thousand $m^3$ of concretes are needed as well as 226.8 thousand T of reinforced concrete steel.

(5) Jinan Bridge Hydropower Station

The Jinan Bridge Hydropower Station is located at the border river between Gucheng District of Lijiang City and Yungsheng County, 73.7 km from Ahai Station at upstream river section. Area of controlled watershed of the dam site is 23.74 $km^2$. The big dam is a roller compacted concrete gravity dam, maximum dam height 160 m, length of dam top 640 m, normal water level 1,418 m, total reservoir storage capacity 2,847 million $m^3$, and regulated reservoir capacity 2,656 million $m^3$. Given stagnant water level at 1,398m, total power generation capacity is 2.40 million kw, and annual power output 13,213 million kwh. It was planned to install the first generation set in 2009 with total investment RMB 42.6 billion.

Station inundation involves 8 *xiang*s/towns and 20 village committees which include 65 villager groups in Gucheng District of Lijiang City, Yungsheng County, Ninglang County, and Yulong County. Areas inundated are 25.142 $km^2$, which include land area 17.06 km2, and water area 8.082 $km^2$. Farmlands inundated are 2,491 acres, garden lands 755 acres, forest lands 8,777 acres, unused lands 12,988 acres and construction lands 130 acres.

Placement of migrated people

Number of people for productive placement is 2,479: Gucheng District 962, Yungsheng County 901, Ninglang County 368 and Yulong County 248.

The number of non-farm people for self-placement is 1,005.

As for construction plans of the Station, cubic soil and stone from open-trench excavation is 22,179.6 thousand $m^3$, cubic stone from tunneled excavations 6,137.4 thousand $m^3$, 14,718 thousand $m^3$ of concretes are needed as well as 315.3 thousand T of reinforced concrete steel.

(6) Longkaikou Power Station

The Longkaikou Power Station is located at the border river between Yungsheng county and Hoching County, 42.1 from the river section of Jinan Bridge Hydropower Station at upstream.

Area of controlled watershed of the dam site is 23.97 $km^2$, multi-year average flow 1,710 $m^3/s$, normal water level 1,293.65 m, dry-season water level 1,218 m, design flood water level 1,294.5 m, total reservoir storage capacity 2,065 million $m^3$, regulated capacity 1,990 million $m^3$, dam height 113 m, dam length 246 m, total power generation capacity 1.80 million kw, annual power output 7.89 billion kwh, farmlands inundated 4,400 acres, people migrated 2,000 (Gucheng District,

Yungsheng County and Hoching County involved), and total engineering investment RMB 27.9 billion.

As for construction plans of the Station, cubic soil and stone from open-trench excavations is 29,131.8 thousand $m^3$, cubic soil and stone in piling placement 8,276 thousand $m^3$, 10,726.2 thousand $m^3$ of concretes are needed as well as 240.3 thousand T of reinforced concrete steel.

(7) Ludila Power Station

The Ludila Power Station is located at border river between Yungsheng County and Binchuan County, 99.1 km from river section of Longkaikou Power Station at upstream, and 28 km from Jinjiang Grand Bridge. Area of controlled watershed at the dam site is 24.73 $km^2$, multi-year average flow 1,750 $m^3/s$, normal water level 1,221 m, comparable reservoir storage capacity 6,099 million $m^3$, regulated capacity 5.4 billion $m^3$, design flood water level 1,223 m, dam height 120 m, dam length 385 m, total power generation capacity 2.10 million kw, annual power output 9,359 million kwh, farmlands inundated 31,300 acres, people migrated 16,900 (Yungsheng County, Hoching County and Binchuan County involved), and total engineering investment RMB 30.6 billion.

As for construction plans of the Station, cubic soil and stone from open-trench excavations is 15,344.4 thousand $m^3$, cubic stone from tunneled excavations 9,547.2 million $m^3$, 8,935.2 thousand $m^3$ of concretes are needed as well as 221.1 thousand T of reinforced concrete steel.

(8) Guanyinyan Power Station

The Guanyinyan Power Station is located at border river between Huaping County and Panzhihua City, 97.8 km from the river section of Ludila Power Station at upstream and 27 km from Panzhihua. Area of controlled watershed at the dam site is 25.65 $km^2$, multi-year average flow 1,830 $m^3/s$, normal water level 1,132 m, dry-season water level 1,015 m, design flood water level 1,134 m, normal reservoir storage capacity 5,873 million $m^3$, regulated capacity 5.6 billion $m^3$, dam height 183 m, dam length 398 m, total power generation capacity 3 million kw, annual power output 13,149 million kwh, farmlands inundated 14,100 acres, people migrated 8,810 (Huaping County, Yungsheng County, Renho District, Yungren County and Dayao County involved), and total engineering investment RMB 47.1 billion.

As for construction plans of the Station, cubic soil and stone from open-trench excavations is 72,403.2 thousand $m^3$, cubic stone piling placement 36,556.5 million $m^3$, 7,086.3 thousand $m^3$ of concretes are needed as well as 431.1 thousand T of reinforced concrete steel.

# Chapter 3 Necessity and Development Mission of the Engineering Construction

## I. Necessity of the Engineering Construction

1. Economic Situation of Yunnan Province

According to the spirit of the "Notification of Regional Programming Outline on the Area of Southwestern and Southern China Provinces as Ratified by State Department and Transferred to National Planning Commission", ND [1993] No. 56 (issued June 29, 1993), the direction and focus in Yunnan's development are "based on comprehensive cultivation of water energy resources, gradually and fully developing energy, raw materials, transportation, agriculture, forestry, tourism, etc., to construct Yunnan into an important energy and raw material industrial base relying principally on electric power, coal, aluminum, phosphate, iron and metals". It has been emphasized that the energy industry will follow the route of developing simultaneously thermal and hydro power as well as coordinated development of coal and power, so as to fulfill the demands of the area's high-energy product development and sending powers outwards.

Mineral resources of Yunnan are very abundant. There are 82 categories of mineral resources discovered by now which include 3,000 mine fields and mine sites. Reserves of 74 mineral products have been verified wherein reserves of 28 mineral products are at the top five places in the nation. Reserves of aluminum are 410 million T—2$^{nd}$ in the nation; those of phosphate are 2.57 billion T—3$^{rd}$ in the nation, average grade 22.1% and its rich mine about half in the nation; those of manganese are 8,530 thousand T, antimony 295 thousand T, mercury 33 thousand T, barite 110 million T, and rare earth over 1.44 million T. These mineral products are currently seldom cultivated and the industrial structures are not so reasonable that most of them are in the state of raw material cultivation or preliminary processing with low value-added. Therefore, it is very important for the mineral products to take advantage of cheap electric powers from hydropower stations so that such mineral resources as aluminum, phosphate, etc. can be deeply processed and the current backward status of primary product production in Yunnan could be changed. These all desperately need to develop Yunnan into an important energy base.

At 2010, Yunnan is expected to provide 40 million T of coals and 40% of the province's grid powers to other provinces. This is the only way that the advantage of

Yunnan's resources can be transformed into economic advantages. Thus, the rise of Yunnan's economy should depend on the cultivation of water energy as the leading sector. Jinshajiang Station is one of the large hydropower stations of good construction conditions in Yunnan's hydropower resources.

2. The Programming of Jinshajiang Station

Jinshajiang is the largest river in Yunnan Province. It belongs to Xijiang water system in the watershed of Zhujiang (Zhu River) and is the northern source of Hongshuei River. Total length of Jinshajiang Station is 498 km, with a natural drop of 1,932 m and area of watershed 26,557 $km^2$. The preliminary feasibility report was prepared by Kunming Design Institute organized by Planning and Design Academy of the Hydraulic Power Department which was compiled in December 1988 and has passed review in April 1989. As a consequence, the one-reservoir 8-level cultivation plan has been selected.

The Longpan Hydropower Station is located at midstream Jinshajiang. Left bank of dam site is an area in Lijiang, Yunnan and the right bank is an area in Diching Canton, Yunnan. The Yungsheng County Power Station in the reservoir area is located in the interior of Lijiang Industrial Zone. The Jinshajiang Station is an important large hydropower station here and can complement the Lijiang Thermal Power Station and share some of the tasks in peak regulation, frequency regulation and raising power energy quality. On the other hand, the Longpan Power Station is the mainstay hydropower station and leading power station on main stream Jinshajiang. Its cultivation will not only facilitate economic development in those poor counties of Yulong, Ninglang, Yungsheng and others, but also facilitate hydropower cultivation and navigation development in the whole Jinshajiang area.

3. Completion of Jinshajiang Stations Will Ameliorate Tight Power Situation in Southern China

According to *Area Programming Studies of Southwestern and Southern Provinces*, the situation of shortage in electric power balance in 2000-2010 is that Guandong Province's power shortage in dry season is between 3.03 million kw and 17.9 million kw, with power output at 8-62 billion kwh, while power shortage in rain season is between 5.02-25.64 million kw with power output at 14.3-90 billion kwh. The Jinshajinag Station are at the front edge of sending power from west to east such that they can connect with southern China power grid and distribute powers to Guandong and Guanxi Provinces, through the Tiansheng Bridge First and Second Level Hydropower Stations, relieving tight power situations in southern China.

## II. The Mission of Construction Cultivation

1. Power Development Programming in Yunnan

Yunnan's power grid has already become a 220kv double-loop ring network, centered on Kunming and radiating outwards along the 4 railways of Gueizhou-Kunming, Hunan-Gueizhou, Xichuan-Gueizhou and Gueizhou-Guanxi. Now a 500kv super high pressure Tian-Guei power distribution line has been completed. Therefore, electric power from Gueizhou and Yunnan can be directly, through Tian-Guan Line, distributed to southern China.

Until 2020, power grid load in Yunnan will reach 16.8 million kw and power demand will be 103 billion kwh. Therefore in that time, total power generation capacity of hydro and thermal powers within the grid will be over 20 million kw. At the end of 1992, power generation capacity in Yunnan was 2.15 million kw, in which hydropower capacity was 882 thousand kw, including 630 thousand kw in Zhujiang, 252 thousand kw in Maotiaohe Cascade, and 510 thousand kw in Dongfeng under building.

The Jinshajiang Station is a large scale and one of few well functioned regulating power stations in Yunnan. Its geography is relatively close to the load center, convenient to connect with the system, capable of complementing the nearby Kengkou Thermal Power Station, and helpful in raising volatility and power-supply quality in Yunnan's power grid.

2. Power Development Programming in Guandong Province, Southern China

At the end of 1990, power generation capacity in Guandong Province was 8.28 million kw, in which hydropower capacity was 2.68 million kw. Power output in the whole province was 34.4 billion kwh, in which hydropower output was 7.7 billion kwh. Generation capacity of the main power grid was 61.8 billion kwh in which hydropower capacity was 1 million kw. Local grid and self-generation by enterprises occupied a certain proportion with power generation capacity at 2.1 million kw. In 1990, it purchased 350 thousand kw/1.79 billion kwh of power output from Hong Kong. In 1991, the purchased amount was 750 thousand kw/3.06 billion kwh.

In recent years, power loads in Guandong grew rapidly such that power shortage reached 30%. Many factories and mines have installed, in high costs, diesel power generators of their own to ensure production. Power grid in Guandong has already cover the whole province, 98 km long in 500kv cables, 3,802 km long in 220kv cables, and 8,186 km long in 110kv cables. Guandong power grid connects, in 220kv cables, with Guanxi and Hong Kong respectively and, in 110kv cables, with Macao.

Growth of power system loads in Yunnan:

| Items | Unit | 2000 | 2005 | 2010 | 2020 |
|---|---|---|---|---|---|
| Loads | Thousand kw | 4,200 | 6,350 | 8,800 | 16,800 |
| Power output | Billion kwh | 26.5 | 40.0 | 55.0 | 103.0 |

Growth of power system loads in Guandong:

| Items | Unit | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|---|
| Loads | Thousand kw | 11,000 | 22,000 | 40,500 | 75,000 |
| Power output | Billion kwh | 65 | 130 | 240 | 440 |

3. Integrated Utilization

According to development policies for Jinshajiang main river sections, the development targets of Jinshajiang Stations are: Power production is primary, navigation is secondary, and to care for irrigation, water supply and others at the same time.

(1) Power production

The Power Station has good regulating functions and, therefore when completed, shall be another peak regulating power station in Yunnan's power system. Coal resources in the watershed are abundant and concentrated so the potential for thermal power is great. It can, on one hand, fulfill the demand for rapid growth in Yunnan's power loads, and, on the other hand, transport high-quality powers to other provinces.

(2) Navigation

Jinshajinag is a water channel connecting Yunnan with southern China. Currently, a 85 km long river section from Baiwu to Shaujiangkou has been dredged so that 100T motor boats are navigable but navigation rate is low with only about 4,000 T per year. The upstream river section from Baitseng to Zhaotong is interrupted by such big beach lands as Bailong Beach so that it is only navigable with 10T wooden motor boat.

Cultivation of abundant mineral resources within the watershed are limited by poor transportation conditions and navigating abilities, so that the development of industrial production is seriously restricted. According to the navigation plan of Yunnan's Transportation Bureau, the inner rivers of Yunnan shall principally be channelized, combining comprehensive utilization of water resources with construction of hydropower stations. Jinshajiang will reach the standard of $4^{th}$ degree navigation route, navigable with 500T ships, along the section from Longpan downwards, and reach the standard of $5^{th}$ degree navigation route, navigable with 300T boats, along the 500km long section from Xianggelila to Kunming with annual navigation capacity of 2.1 million T. Navigation at midstream Jinshajinag will fulfill the

design criteria only when hydropower stations at Longpan, Liangjiaren, Liyuan, Ahai, Jinan Bridge, Longkaikou, Ludila and Guanyinyan have been completed.

(3) Irrigation, flood prevention and others

Farmlands in Yunnan are mostly rained paddy fields so that it is very difficult to engage in gravity irrigation. When engineering of reservoir in the power station is completed, water level will be raised 100-160 m and, thus, conditions for providing drinking water for people and animals, electric power development, irrigation and land reforms will be much more improved. Moreover, it will provide sufficient water resources and electric power for industrial development in the area surrounding the reservoir.

The completed reservoir will block sediment from upstream river so that water quality will be improved and aquaculture around the reservoir can be developed.

# Chapter 4 Hydrology

## I. Overview

1. Overview of the Watershed

The watershed of Jinshajiang suitable for building hydropower stations is in the midstream. Total length of the river is 498 km, with a natural drop of 1,932 m and average rate of dropping 4.37%. The watershed is located at 24°50'-26°50' north and 103°50'-106°15' east, an area of 26,557 $km^2$.

Tributaries of the watershed are Niulanjiang, Hengjiang and Sanchaho at the upstream of Hengjiang which connects southward with Daguan River. The terrain is high at northwest and low at southeast with drastic droppings. The upstream areas at Xuanwei, Weining and Jinshajiang have elevations of over 1,800 m. The sites suitable for building power stations are generally at elevations of 700-1,200 m which are transitory sloping areas between Yunnan-Gueizhou Plateau and Guanxi hills. The valleys are deep so elevations of the river are only about 300m. Soils there are mainly red and yellow soils where plants are rare and covering rate of forests is 6%, mountains 85%, hills 10%, and plains 5%. Water net in the watershed is relatively high, subterranean stream is dark which is widespread. Thus, underground water is abundant and distribution of tributaries is symmetric.

2. Weather Characteristics

At areas above the dam site of Longpan have all kinds of rainfalls. 10 weather stations and 7 hydrology stations basically form a controlling net in which the Yulong Station was established in 1939 and Xingren Station in 1943. Most of the observational data are quite reliable so that the whole data can fulfill the requirement for design.

The watershed is of subtropical plateau monsoon climate wherein winter is impacted by north rapid current of west winds, while summer mainly influenced by Pacific subtropical high pressure and southwest warm and wet winds in Bay of Bengal at Indian Ocean. The climate is slanting from the long winter-short summer cold and dry area in the northwest (Xuanwei, Weining and Diching Canton) toward the long summer-short winter, warm and wet area near the southeast dam sites. Therefore, difference in weather at the high altitude plateau and the lower valleys is significant.

Rainfalls in the watershed are quite abundant with multi-year average rainfall at 1,178.8 mm and very uneven rain distribution. Climate at the dam sites is warm. Based on statistics at Yungsheng Weather Station, the average temperature per year

is 13.9°C, with the highest average at 14.7°C (1963 and 1973), and lowest at 13.1°C (1976) while the extreme high temperature was 33.4°C (May 4, 1969), and the extreme low temperature was -6.2°C (January 3, 1977). Climate at the watershed is wet, with multi-year average relative humility, in general, over 74%.

3. Overview of Observational Stations and Data

The Yulong Hydrology Station is a main-stream hydrology station at Jinshajiang, located in Malu *Xiang* of Yulong County, with catchment area 14,356 $km^2$. It was established by Zhujiang Hydrology Bureau as Station One in April 1945 and dissolved in 1946. In September 1951, the Yunnan Hydrology Central Station of the Hydrology Department of the Southwest Military Government rebuilt it as Station Two. In June 1963, the basic gauge was moved from 680m downstream of suspension bridge to 610m upstream, named as Station Three.

Station Two has measured the flows, from 1951 to 1968, with intensive method while, for the other years, simple method and float method were adopted so that precision was relatively low.

Station Three started to measure the flows in 1983, 1984, 1987 and 1988 with intensive method, of which the number of intensive measuring points was the highest in 1984. An integrated water flow relational line below the water level at 572m was set derived from observing points in Station Three by adopting intensive method. Viewed from the relational line, it was visible that, at middle to high water levels for the past 30 years, the gauging point was basically on the line whereas, at low water levels, there was a relatively large discrepancy. By analyzing water surface velocity coefficients and float coefficients below the water level of 568m, it has been found that whenever water level is rising the velocity coefficients are also increasing, while, at water level of 568m, the velocity coefficient is 1.17. Thus, the tentative integrated H-Q line flow measurement was adopted (for water levels above 568m). In 1960 -68, velocity meter was used to set gauging points with intensive method, but these gauging points were all below the 568m water level. Thus, for those below the 568m level, the data were reorganized before the results were published.

## II. Runoff

1.

With respect to the measured hydrological data for the Longpan dam site, runoff was extrapolated based on the runoff measured at Yulong Hydrology Station at 19.5 km downstream. The data in that station were incomplete before 1952, thus the series of runoff were calculated starting from 1952. Rain water harvesting area at Longpan dam site is 13,548 $km^2$, whereas the area at Yulong site is 14,356 $m^2$ which is 5.96% larger than the former. Since rainfalls and bearing surfaces in the two sites

are not different from each other, the multi-year average flow at Longpan was calculated by extrapolating the 38 hydrological yearly data, which came from one-square correction, in proportion to areas, of those from June 1952 to May 1990. As a consequence, it is 1,410 $m^3/s$ and the relevant multi-year average runoff is 1,320 $m^3$.

2. Analysis of Runoff Series

The 38 hydrological yearly data series have the following sequence of changes:

i. The data series include two complete dry-season water sections and two complete rain-season water sections, as well as one incomplete dry-season section and one incomplete rain-season section. Thus, representativeness is relatively good.

ii. It can be seen from forward-backward sequence accumulated means and moving means that: the variance of forward-backward sequence accumulated means in more than 17 years is within 10%, which implies relatively good verifiability of the data.

Therefore, the data series fulfill the requirement for hydrological calculations.

3. Runoff Frequency Calculations

The 38 hydrological yearly runoff series of Yulong Hydrology Station, from June 1952 to May 1990, were regarded as continuous measured series, with no historical survey results added. Empirical frequency was then calculated according to the formula, Pm=M/(N+1). The results are listed in the table below.

| Statistical parameter | | | unit | Comparable frequency designed flow | | | | | | | | | | Data years |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| mean | Cr | Cn/Cr | | 1 | 2 | 5 | 10 | 20 | 30 | 50 | 75 | 90 | 95 | 1952.5 |
| 274 | 0.28 | 2 | $m^3/s$ | 483 | 453 | 411 | 376 | 336 | 308 | 267 | 219 | 182 | 161 | 1990.5 |

4. Runoff Characteristics

As the watershed of Jinshajiang is of subtropical plateau monsoon climate, runoffs are principally to replenish precipitation. Since precipitation is distributed unevenly between, as well as within, years, runoffs, as a sequence, also vary. As extrapolated from the 38 hydrological years, multi-year average flow is 274 $m^3/s$, comparable multi-year runoff flow is 86.5X108 $m^3$, multi-year average runoff modulus is 19.1 $DM^3/(S.K\ m^2)$, multi-year average runoff depth is 602.3 mm, the largest average flow per year is 403 $m^3/s$ (june 1954 to May 1955), and the smallest average flow per year is 156 $m^3/s$ (June 1989 to May 1990). The variation of runoffs between years is relatively small, with the largest average flow per year as 2.56 times of the smallest average flow per year. Rain season is usually from June to November of the year while dry season is from December to May next year. Multi-year average flow in rain season is 83.9% of the whole year, with the total ratio of flow in June,

July and August about 55.0%, while average flow in dry season is 16.1% of the whole year. The largest multi-year average runoff per month is in July, about 20.9% of the whole year, while the smallest runoff is in March, about 1.8% of the whole year. The largest amount is 11.4 times of the smallest.

5. Interregional Comparison of Runoff Hydrological Characteristics

Runoff modulus in the watershed of Jinshajiang is smaller than Daguan River in the south and Hengjiang in the north. Dabang River in the watershed is close to Sanpin River, and Wudu River is close to Wubie River, both rivers are located at midstream of Jinshajiang. Therefore, the runoff moduli in Gaoche Station on Dabang River and Tsaopingtou Station on Wudu River are the largest in watershed of Jinshajiang. Along the main stream of Jinshajiang, the runoff moduli are of concave shape which reflected the natural conditions of the watershed.

## III. Design Flood

1. Characteristics of Floods

The largest flood peaks concentrate in June-July of the year, followed by August, September and May while they seldom occurred in October.

The measured peak styles of flood at Yulong Hydrology Station have shown that the probabilities for occurrence of single peak and double peaks are basically the same, the main peak usually came later. The progression of floods is usually rising fast and falling slow. A progression of floods is generally 5-7 days, with sustaining peak for 2-3 hours. Flood amount is mainly focused in 3 days, about 60% of the whole amount in 7 days.

2. Review of Flood History and Analysis of Reappearance Periods

In February 1989, the Diching Hydrology Station has surveyed the flood history and published the result in March of the same year.

i. In Tunzhi 11$^{th}$ year, Ching Dynasty (1872), a big flood in Yulong and iron cable half broken.
ii. In Guanxu 11$^{th}$ year, Ching Dynasty (1885), a flood in Upper Sanma.
iii. In Guanxu 13$^{th}$ year, Ching Dynasty (1887), Yulong inundated by flood, iron bridge destroyed completely, and farmlands in Dongho inundated completely.

It has been extrapolated from an integrated water level flow curve, measured at Zhedong Hydrology Station at downstream, that in 1872 the peak of historical flows was 9,360 $m^3/s$ and in 1833 the peak was 9,150 $m^3/s$.

There was no historical flood data in Yulong river section, thus the following two methods were used to extrapolate its flood history.

First of all, the correlations of flood peak flows for Yulong and Zhedong Hydrology Stations were used to move historical floods in Zhedong to Yulong so that the 1872 historical flood peak at Yulong has been estimated as 8,100 $m^3/s$.

Next, elevation of water surface in Yulong was measured as 583.559 m. The relative drop between Yulong Stations Two and Three in 1954, 0.73%, was used to extrapolate the flood elevation in 1872 as 585.204 m. The water level flow relation curve was then checked and the flood peak value of historical flood in 1872 came out as 7,480 $m^3/s$.

Difference between the two extrapolated values for 1872 flood peak is relatively small and thus they are reliable. Therefore, the reappearance period for the 1872 historical flood peak value is 105 years.

3. Calculation of Peak Value Statistical Relations and Frequencies

In estimating frequencies, the 1-day and 3-day flood volumes were estimated by combining the 1872 historical flood and the measured flood series of the past 35 years, whereas the 5-day, 7-day and 10-day flood volumes were estimated by using measured flood series of the past 35 years and adopting the P-III curve method—visually estimated optimal curve to calculate frequencies. Parameters for calculations are listed in the table below.

| | Flood peak | 1-day flood vol. | 3-day flood vol. | 5-day flood vol. | 7-day flood vol. |
|---|---|---|---|---|---|
| Mean | 3,750 | 2.82 | 6.31 | 8.79 | 10.79 |
| Cv | 0.37 | 0.37 | 0.39 | 0.39 | 0.39 |
| Cs/Cv | 3.5 | 3 | 3 | 3 | 3 |

Note: Flood peak was measured in $m^3/s$, and flood volume measured in X $108m^3$.

4. Reasonableness Verification for the Estimated Results

In estimating flood frequencies, the 1872 and 1933 historical floods were used together with the measured series from 1952-1988. Distribution order of the single station peaks and design parameters for flood volumes, in various time sections, estimated in Dadukou and Yulong Zhedong Stations on Jinshajiang as well as Gaoche Station on Dabang River is relatively reasonable. So is the regional distribution of design parameters in various stations. With regards to the design mean value, 3-day/7-day flood volume mean values, and relation curve of catchment area for the gauging points in four stations, except the smaller value for Dadukou Station which is located at a less-rain region, the distribution of the gauging points along upstream and downstream is even and reasonable as well as suitable for regional orders. Thus, it was verified that the design flood result in Yulong Station was reasonable.

5. Dam Site Design Flood

When the design flood result for Yulong Station was moved to Longpan dam site

19.5 km upstream of Jinshajiang, and, due to smaller catchment area 5.96% less, only correction for area proportions was considered, then, by using peak volume mean value area ratio coefficients in Zhedong Station, the design floods in Longpan dam site could be extrapolated as in the following table.

| Frequency (%) | 0.01 | 0.02 | 0.1 | 0.2 | 1 | 2 | 5 | 10 |
|---|---|---|---|---|---|---|---|---|
| Flood peak ($m^3/s$) | 12,600 | 11,900 | 10,400 | 9,670 | 8,010 | 7,270 | 6,260 | 5,470 |
| 3-day flood vol. (million $m^3$) | 2,131 | 2,019 | 1,754 | 1,638 | 1,362 | 1,237 | 1,068 | 933 |
| 7-day flood vol. (million $m^3$) | 3,616 | 3,426 | 2,977 | 2,780 | 2,311 | 2,100 | 1,813 | 1,584 |

## 6. Construction Design Floods

The watershed of Jinshajiang is of subtropical plateau monsoon climate. In summer, the Pacific subtropical high pressure moves northward and extends westward, so the southeast seasonal wind brings thick, warm and wet currents into the watershed, leading to hot, rainy summer and fall in mid and downstream sections, whereas in winter, it is impacted mainly by north branch of swift west winds.

It can be observed from the maximum flow data in Yulong Station during the period from October 1 to May 31 next year, for various years, that it is still possible to have larger floods in October, November and mid/late May. This should be taken into consideration in deciding on plans for construction design floods and the actual construction time sections.

In order to be safe and saving money for the construction, the flood frequencies of construction design floods have been estimated for the 10 different construction periods respectively. The frequencies in Longpan Hydropower Station were estimated based on the principle of minimizing design values, with P=2% and P=5%, and by adopting area correction method to move construction design flood results in Yulong Hydrology Station to Longpan dam site. They were recorded in the table below.

| Construction period | Start/end date | Frequency design value ($m^3/s$) | | | | |
|---|---|---|---|---|---|---|
| | (month. day) | 1% | 2% | 5% | 10% | 20% |
| 5 months | 11.21-4.20 | 534 | 467 | 330 | 312 | 245 |
| 5 months and 10 days | 11.21-4.30 | 989 | 819 | 603 | 447 | 303 |
| 5 months and 20 days | 11.21-5.10 | 1,170 | 971 | 714 | 530 | 360 |
| 6 months | 11.11-5.10 | 1,980 | 1,560 | 1,030 | 678 | 388 |
| 6 months and 10 days | 11.1-5.10 | 2,070 | 1,650 | 1,130 | 767 | 461 |
| 6 months and 20 days | 11.1-5.20 | 3,050 | 2,390 | 1,580 | 1,040 | 595 |
| 7 months | 10.21-5.20 | 4,850 | 3,700 | 2,300 | 1,410 | 728 |
| 7 months and 10 days | 10.11-5.20 | 5,230 | 4,080 | 2,660 | 1,720 | 958 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 7 months and 20 days | 10.1-5.20 | 6,160 | 4,840 | 3,200 | 2,110 | 1,200 |
| 8 months | 10.1-5.31 | 6,220 | 4,990 | 4,460 | 2,400 | 1,480 |

Note:

1. F Longpan=13,548 $km^2$; F Yulong=14,356 $km^2$.

2. Longpan=(F Longpan/F Yulong) a·Q Yulong.

3. Area ratio coefficient: a=1.62

## IV. Sediment

1. The Data

There is no measured sediment data at the Longpan Hydropower Station dam site. On the other hand, the six hydrology stations in up- and down-stream sections at Yulong County, Gaoche on Dabang River, Baitseng on Jinshajiang, and Zhedong on Jinshadong, etc. have in possession of data on measured suspending sediment. However, lengths of data series are not the same, but, through checking and analyses, quality of the data was deemed as reliable.

River beds of most sections in Jinshajiang are strewn with rocks and small numbers of loads. Thus, only suspending sediments were taken into consideration.

2. Extrapolated Estimates of Dam Site Sediment

In calculating and analyzing sediment series in Longpan dam site, the data on sediments in Tsaopintou Station together with Gaoche Station, corrected by area ratio, for the periods from January 1959 to July 1964 and from January 1967 to December 1988; the data on the sediments in Dadukou, Tsaopingtou, Gaoche and Zhedong Stations, searched by areas, for the period from August 1964 to December 1966; as well as the data on sediments in Yulong Station, corrected by area ratio, for the period from January 1989 to December 1990 were used.

3. Key Statistics of Suspending Sediments

(1) Average sand content per year

Multi-year mean: 1.895 $kg/m^3$ (1959-1990)
Maximum: 3.08 $kg/m^3$ (1959)
Minimum: 0.972 $kg/m^3$ (1964)

(2) Sediment transport per year

Multi-year mean: 1,540 X 104 T (1959-1990)
Maximum: 3,073 X 104 T (1983)
Minimum: 499 X 104 T (1989)

(3) Sediment transport modulus: 1,140 T/km$^2$ (1959-1990)

4. Characteristics of Sediments

The multi-year average sediment transport at Longpan dam site is 1,540 X 104 T (1959-1990), while that at Dadukou Station on upstream is 1,200 X 140 T (1959-1990) and that at Tsaopingtou Station on upstream tributary is 113 X 104 T (1959-1988), which are 77.9% and 7.1% with respect to Longpan in the same series. The ratios for runoff are 46.5% and 8.3% respectively, and ratios for watershed areas are 60.3% and 8.1% respectively. The multi-year average sediment transport at Zhedong dam site, on downstream, is 2,350 X 106 T (1959-1988), while that at Longpan dam site is 68.1% with respect to Zhedong, the ratio for runoff is 69.4%, and the ratio for watershed areas is 67.3%. It is evident that sediments in sites above Longpan Station mainly come from upstream areas. Sediments in the watershed of Jinshajiang mainly come from upstream areas, sediments in the watershed above Longpan Station are more voluminous than those between Longpan and Zhedong, and watershed of Jinshajiang above Longpan dam site is high volume area in terms of sediment transport moduli and sand contents, higher than those in Pudingsuoshai and Hungyandu dam sites because plant coverage is relatively few and soil erosion is serious.

Suspending sediment distribution, during the year, in Longpan dam site is quite uneven. Sediment production is concentrated in rain season of June-November, about 89.14% of the whole year, wherein that in June, July and August is 74.6% of the whole year. June's ratio in the whole year is 34.8%. In dry season, from December to May of next year, volume of sediment transport is relatively small, a ratio of 10.86% of the year. Variation in volume of sediment transport is relatively large between years—the largest, 3,073 X 104 T (in 1983) is 7.4 times of the smallest, 499 X 104 T (in 1989).

Table of Multi-year average quantity of sand-transport in Longpan Dam Site

| Month | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Rain season | Dry season | Year total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Quantity of sand-transport | 0.82 | 0.73 | 0.76 | 12.1 | 152 | 527 | 407 | 208 | 151 | 68.8 | 4.12 | 1.16 | 1,375.9 | 167.56 | 1,543.5 |
| % of year | 0.05 | 0.05 | 0.05 | 0.73 | 9.85 | 34.8 | 26.4 | 13.5 | 9.78 | 4.46 | 0.27 | 0.08 | 89.14 | 10.86 | 100 |

Two sand-sample analyses for 1991 have revealed that: The primary mineral components are such clay minerals as kaolinites, illites and smectites, which are followed by chlorites, quartz, feldspars, apatites, biotites, and muscovites.

The watershed above Longpan dam site has relatively large content of sands, and a certain proportion of the minerals are sands of larger particles and higher hardness.

## V. Dam Site Water-Level Flow Relation

There are water level data since April 1990 until now at the dam site. The integrated water level flow relations in the Yulong Station have been transferred, based on correlations, to Longpan dam site.

The maximum water level in July 1991 was 1,950 m, with comparable flow 5,570 $m^3/s$ of a big flood. The relevant parameters of the 1985 big flood water levels and flows were indicated on a graph of water level flow relations, a relatively good match of points and lines. It is evident that the calculated results can properly represent the current river sections and intersections.

# Chapter 5 Construction Site Geology

## I. Regional Geology

1. Lithology

The exposed strata in the area include Paleozoic, Mesozoic and Caenozoic strata. In reservoir tail, those exposed are mainly coal measure, permian and triassic strata. Areas below Kengkou and of the dam site are mainly covered by dyassic and triassic strata.

Coal measure (C)

The Baizuo Group (C1jx) at downstream is exposed on mud slopes of reservoir tail which are medium thick to block layers of matrix limestones in light grey colors. The Huanglong Group (C2hm) at midstream is exposed in area of Luodong Dam above Kengkou, which are medium thick to thick layers of limestones in gray, dark grey and greyish black colors. The Maping Group (C3mp) at upstream is exposed in areas of Kengkou and Hotang, which are medium thick layers of limestones and grey dolomites in dark grey and grey black colors.

Permian system P—downstream P1

The Liangshan Group (P1L) is exposed in area of Nanshepo at downstream of Maokou, which are medium thick layers of quartz sandstones in greyish white and greyish yellow colors, as well as shales in taupe, greyish yellow and black colors inter-mingled with limestones, disconformablly contacting with the coal measure at downstream. Thickness of the strata is 29-249 m.

The Qixia Group (P19) is exposed in area of Nanshepo, which are medium thick to block layers of limestones in grey, dark grey and greyish black colors, containing a small amount of siliceous concretion and dolomitic clots. Grey calcareous shales are inserted in the strata. Thickness of the strata is 67-228m.

The Kengkou Group (P1m) is exposed in areas of Jinan Bridge and Longkaikou Power Stations which are thick layers of limestone blocks in dark grey color, containing dolomitic clots or mixed with dolomite rocks, whereas the top is often covered with thin layers of silica rocks invaded by bedrock type of gabbro and the bottom is layered with stripes of cherty limestones. Thickness of the strata is 286-700m.

The Ermeishan Basalt (P2B) is exposed in areas around Jinan Bridge and Wanho, which are greyish green and dark green basalts, tholiitic basalts inserted with laminar

flow layers of volcanic rubbles, as well as conglomerates and laminar flow layers of tuffaceous rocks with a little amount of micro-deteriorated sandstones. The strata are inserted with a layer of tholiitic basalts at the top, bottom and middle. The thickness of the strata is 120 m.

The Lontan Group (P2L) is exposed in areas of Lawu and Bingchang which are thin to medium thick layers of sandstones in grey, dark grey and yellowish brown colors as well as a little amount of limestones and marls. The strata contain several to tens of layers of coals and the thickness of the strata is 350-600 m.

The Changxing Group (P2C) is exposed in the area of Banpo which are grey, yellowish grey and taupe mud shales and medium thick layers of combined fine sandstones and arenaceous shales. When the strata are in the state of lenticle thin layers of coals are inserted. Thickness of the strata is 20-100 m.

Dalong Group (P2D) is exposed in the areas of Bangdang and Banpo which are grey, dark grey and yellowish brown arenaceous shales, calcareous shales and cherty shales. Thickness of the strata is 10-30 m.

Triassic system T—downstream T1

The Feixianguan Group (T1f) is exposed in areas of Bangdang and Banpo. At the upper section, the strata are greyish green, yellow and purplish red shales, medium layers of arenaceous mud stones, and thin layers of fine sandstones mixed with limestones and dolomite rocks. At the middle and bottom sections, the strata are thin to medium thick layers of arenaceous mud rocks in greyish green color and siltstones mixed with shales. The thickness is 700 m.

Yungning Town Group (T1yn) is exposed in areas of Binglu and Xialonggu. At the upper section, the strata are thin to medium thick layers of dolomite rocks in dark grey color as well as layers of various thickness of argillaceous dolomites and greyish yellow shales mixed with a little amount of limestones. At the middle and bottom sections, the strata are thin to medium thick layers of limestones in light grey and dark grey colors, mixed with argillaceous stripes of limestones as well as greyish yellow and yellowish green arenaceous mud rocks and shales. The thickness is 651 m.

Midstream T2

The Kuanling Group (T2K) is exposed in the areas of Longkaikou, Ludila and Ahai. At the upper section, the strata are medium thick to thick layers dolomites in grey color and brecciform dolomites mixed with a little amount of argillaceous dolomites. At the middle section, the strata are medium thick to thin layers of limestones in dark grey color mixed with a little amount of dolomitic limestones and vermiform limestones. At the lower section, the strata are thin to medium thick layers of

dolomitic limestones in light grey and greyish white colors as well as greyish green limestones mixed with a little amount of dolomitic and argillaceous limestones. At the bottom, there is a 0.2-1.7 m layer of yellow pisolitic monzogranites. Thickness of the strata is 867 m.

Quaternary system (Q4)

They are mainly alluvial sands, gravels, residual sola and clay, as well as gravity-collapse blocks and gravels. The thickness is 0-15 m.

2. Geological Structure

(1) Regional tectonic structure

The reservoir area straddles two 1st level geotectonic units—Yangzihuai Terrace and Yunnan Fold Belt, mostly in the former.

i. Tectonic belt in northwest direction. It is the Ziyun-Rangdu deep and big fault belt, located at the northeast side of reservoir area. It was formed in Jiaheidong period, alignment in N50°W and extended 300 km into inland of Yunnan. It is a high angular deep fault and fault amplitude is over 3,000 m. The northeast side is a tectonic structure in the directions of northeast and north-northeast and the southwest side is in the direction of northwest.

ii. The Puan epsilon type tectonic structure. The vertebral column is located in the areas from Puan Guanziyao to Fala Guanyin Mountain, with length from south to north at 60 m and width at 10 km, which is formed by a group of shear and compressional structures. The frontal arc is located in areas of Xuanwei Yangchang, Puan Guanziyao and Yungsheng, with a length of 120 km, which is formed by a group of parallel/compacted contorted and thrust faults in the direction of nearly east-west. Spreading over right bank of reservoir area, part of the vertebral column and the east side reflex arc cross over Jinshajiang and mitered with the tectonic belt in the direction of northwest, forming a triangular land block within which most of the reservoir area are located.

iii. Xinhuajia system tectonic structure. It is located at the right bank of Jinshajiang, spreading sporadically, which is formed by a group of short-axis flatly contorted and short extended small faults, which are inserted among the other tectonic systems.

(2) Stability of regional tectonic structure

i. Tectonic structure and earthquake

According to “Review Report on Basic Earthquake Intensity at the Yunnan Jinshjiang Hydropower Station Dam Site” published by Earthquake Bureau of Yunnan Province (March 1994), the three tectonic systems in the region were formed in

Yanshan Period. There had been a medium strong earthquake in Tsiyun-Yadu big fault with a magnitude of 5 3/4, about a dozen earthquakes at Bihenying Fault with magnitudes of 4-5, and the intersection between a group of faults in the direction of northeast-east and a northeast direction tectonic structure developed in pleistocene epoch also had occurred medium weak earthquakes with magnitudes of 4 1/2-5 1/2.

ii. Characteristics of new tectonic movement

Caused by intermittent rising of fault blocks, the magnitude of earthquakes is relatively strong at west and north sides, whereas it is relatively weak at east and south sides. And the reservoir site is located at transitory section between the strong and weak areas.

1.

High frequency of earthquakes happened in early pleistocene epoch and the frequency got lower significantly in mid and late Pleistocene epoch

iv. Evaluation

Those that have the relatively large impact on the dam site and reservoir area are medium strong earthquakes happened at the nearby areas, with the most severe impact at the magnitude of 6.

3. Topography and Physical Geological Phenomena

(1) Topography

The Station is located at the southern Yunnan-Gueizhou Plateau. The plain of the watershed is a long strip, with length 290 km and width 100-120 km. The narrowest is at the border between Dechin and Yulong, with a width of 70 km.

Jinshajiang originates from Zhujiang water system, with elevation of 2,443.9 m. Zhujiang flows in the direction from north to east, forming a dividing crest for Daguan River as well as Hengjiang, Niulanjiang and Nanding River. The altitude of the river descends gradually from northwest to southeast. River valley rises in a form of ladder at the dividing crest. Carbonate rocks and sandstones are alternately distributed. River valley is a wide “V” shape. Topography is composed of peak clusters, marsh lands, knobs, kettles, and river valleys.

Water erosions at soil surface are very serious such that furrows at the banks develop perpendicularly, forming cellular water system. The furrows are very steep, sloping more than $50^{o}$, with width at 1-5 m and depth at 1-3 m. Those furrows at Nanding River, Hengjiang and Niunlanjiang are at the same plane with rivers.

(2) Physical geological phenomena

In the watershed, soluble rocks and sand shales are exposed alternately. There is

no large-scale landslide or collapse.

i. Gravity collapse

Engineering area is located at rive section of hard rocks, with high and deep bank cliffs. At the areas of Wanho and Hungyan where the river turns and the gorge becomes wider, gravity collapses happened at overburdened cliff tops such that the piling bodies and big rocks have turned the river into rapids.

ii. Karst collapse

Soluble rocks are spreading widely in the area. Karst caves, subterraneous streams and underground rivers have developed into strips. In reservoir head at Jinan River and Longkaikou, soluble rock top plates have collapsed, at banks of elevation 1,200 m, and formed into tail-shaped basins which become lakes in rain season and water is leaked, through karst caves, into Jinshajiang.

iii. Serious weathering of rocks

At the section where sand shales are spreading, eroded furrows developed particularly. Weathering of rocks is serious, with depth 5-20 m, such that small scale creeping rubbles and mud avalanches happen frequently. Nevertheless, impact on the reservoir is not big.

4. Karsts and Hydrological Geology

(1) Karsts

The shapes and landscapes of karst topography all reveal particular characteristics of plateau. The topography of dividing crests is peak forests and mud lands. The slopes are flattened and wide in which marsh lands, funnels, avens, and karst caves are spreading extensively. Tributaries and perfusions flow alternately in open and underground fashions.

After the Yanshan movement, rising earth crest was eroded for a long time and rivers were cut deeply, forming into a karst landscape of multi-layered parallel and perpendicular strips alternately revealed.

i. Intensity of karst development has been affected by lithology

Pure carbonate rock areas have developed into large scale cave channels such as in the neighboring areas of Jinan Bridge and Wanho, there appeared relatively large ones with wide karsts and big flows. As for pure quality and thick layered limestones, the karsts have developed particularly and in large scales, with various elevations, such that underground rivers and avens were formed.

ii. Geological tectonic structure has controlled spreading directions of karsts

The direction of karsts in underground river system is mostly consistent with

tectonic structure lines. They are aligned in the direction of northwest which overlaps with tectonic belts also in the direction of northwest.

(2) Hydrological geology

Weather at the watershed area is hot and rainy with multi-year average rainfall as 1,048.7 mm. Rain season is from May to October while dry season is from November to May next year. Tributaries appear alternately in the fashions of open and underground flows, perpendicularly intersected with the main stream. The dynamism of underground waters changes significantly with change in seasons. Their main sources are rains from the sky. There are three categories of underground waters:

i. Underground waters in karsts

These are main part of underground waters and are abundant. Their lodgings are affected by lithology and space. Underground waters mingle at swallies, forming underground rivers and larger springs which flow as karst descending springs along the layers. Their outlets are usually at the surface of the river, with flows at 10-100 L/s.

ii. Crack waters in basement rocks

In strata mainly composed of sand limestones, the underground waters are principally crack waters in basement rocks. Water abundance is related to characteristics, scales and closeness of faults and cracks. Flows are generally smaller at 0.1-10 L/s.

iii. Characteristics of underground water movement

Supply of underground waters are from rain waters from the sky together with soil surface waters. Waters mingle and seep into underground through marsh lands and tunnels. They move in the fashions of water waves, channel flows and crack flows along cracks and karst channels. They are discharged through underground river outlet, karst springs and crack springs.

The average of Jinshajiang's hydraulic gradients is about 50%. The hydrological geology of the watershed is graded layers of banding water-bearing formation. There is no correlation between the water-bearing layers and the soluble rock water-resisting layers.

The quality of water is $HCO_g$-$Ca^-$+$Mg^-$ and salinity is in the range of 0.1-0.4g/L, so it is not erosive to concrete.

## II. Geological Conditions of Reservoir Area Engineering

The reservoir is located at river areas under the jurisdiction of Lijiang, Diching Canton, Lunan and Xingming. Reservoir backwater is up to downstream of

Shueicheng Shangnipo, forming a tree branch-shaped large reservoir. Reservoir basin is at areas of Xingming, Longpan and Hotang Basin, with an area of 373 $km^2$ and steep bank slopes. It is a gorge type reservoir.

1. Seepage of Reservoir

(1) No problem of seepage to neighbors

Jinshajiang neighbors, in the north side, with Luoji River and, in the south side, with Tanglang River. There are successive mountains on the banks which are rich, peak beyond peak and shaped as shields. Elevation of the dividing crest is 2,000-2,200 m. The shortest distance between reservoir and Luoji River is 30 km. Elevation of Luoji River is 1,000 m while elevation of Jinshajiang is 580 m, which is 440 m lower and is the lowest basic level for water drainage. Condition of closure of the reservoir is good. Dividing crests at the north and south sides are high and rich while underground water levels at the scope 2-4 km around the reservoir are all higher than design impoundment level. Therefore, there is no problem for the reservoir to seep to up- and down-stream tributaries of peak valley.

(2) No seepage in reservoir dam section

The section near reservoir dam is a V-shaped valley. At left bank, there is no relatively large cutting furrows so the mountain shape is complete. In front of the right bank, there are farm plants and block shaped Longpan little river city, but the dam section is a horizontal tectonic structure while the rock layer at downstream is a monoclonal structure. The dam strata are reliable water-resistant layers formed by basalts and sandstones which extend to both banks, with good closure condition and stable thickness.

There are karsts along river banks, springs exposed with elevations close to river surface. Flows of springs are relatively voluminous, reaching 420 L/s in March. When water is stored in the reservoir, the natural water-resistant layer formed by basalts and sandstones blocks the passage from reservoir to downstream. Therefore, for the whole dam section, there is no problem of seepage at the reservoir head.

2. Stable Reservoir Banks

Within the reservoir section of 265 km long, bank slopes are formed by limestones, dolomitic limestones and sand shales. Jinshajiang has been enduring a long period of incision, forming steep slopes and cliffs of dropping over 200 m, but there have never been found relatively unstable bad geology and down loading cracks caused by tectonic structural formation incision. There are only small scale gravity collapses but no large scale landslides and loose pilings. Therefore, stability in the whole is good.

3. Other Geological Problems in Engineering Site

(1) Problems related to inundation

There are two relatively large villages of Xingming and Longpan which will be inundated when the reservoir is filled, and there are three large mine fields as well as a small one in Lantian, Xinghua, Lujia and Zhungying which will also be inundated. Gross coal reserves at mine fields in the Longpan Hydropower Station area is 1,221.28 million tons in which 20,273.2 thousand tons below elevation 2,012 m will be inundated, a total economic loss of RMB 291.01 million and tax loss of RMB 29.10 million. These are 1.66% of the gross reserves so that it will not affect aggregate planning and cultivation on coal resources.

(2) Solid sliding matters

i. Bank side recreation

Rock base of the reservoir area is exposed, but there is no large scale collapse or landslide and, furthermore, pilings of sand pebble stones are thin. Therefore, the runoff flow of bed load is small.

ii. Thin plant coverage

There are few plant coverages in reservoir area. Mud and sands are brought in the reservoir by rainfalls, but the covered layers are thin and sporadic. Therefore, sources for suspending materials are rare.

iii. Coal washing wastewater from large scale mine fields in Lijiang is the main source for suspending sediment, as well as pollution, in the reservoir.

## III. Geological Conditions in Engineering of Power Station Main Buildings

The main building section is in horizontal direction wherein strata are exposed orderly, rock body is hard and complete, the strength of physical mechanics is high, and anti-seepage water resistant layers are reliable.

1. Geological Condition of Engineering

(1) Landscape topography

The dam site is located at 4.5 km downstream of Zuoge. Water level in dry season is 1,803 m, width of water surface 80 m, water depth 8-40 m, and no deep furrow at the bottom.

(2) Lithology of strata

At the dam site the Feixian and Yungning Groups of Triassic system are exposed. In Guanling Group at midstream, there are limestones, thin to medium thick layers of bluish grey fine sandstones, medium thick layers of purplish red calcareous

sandstones, thick layers of dark grey argillaceous limestones, and medium thick layers of argillaceous limestones in light grey and flesh pink colors. In Guanling Group at downstream, there are limestones and argillaceous limestones mixed with mud stones. They are not much related to the buildings.

(3) Tectonic geology

The dam site is located at the rising edge of Falang swally, southwest wing of Nengkou anticline, and northeast wing of Datian swally. Intersection angle between the strata and river is 70°. At the dam site, there is a layer of folds and a bedding fault.

The fault is a thrust fault. Direction of mine strip is consistent with the strata which is east-west. Width of the broken zone is 2 m and displacement is 0.2-0.5 m. There are a series of small folds associated with the fault with a developed depth at 30 m.

There are four groups of cracks at the dam site:

i. The crack in east-west direction is relatively long, with width 0.3-1 cm, interval 1.5-2.5 m, dip angle 50-70 °, filled with argillaceous cacites and cutting layers. The crack is straight and smooth as well as shear deep.

ii. The offloading crack in south-north direction is close to soil surface, filled with yellow muds. Its width is getting smaller from soil surface to down under.

iii. The shear crack is located at N67°E in dip angle 20-55°, filled with cacites and at width of 0.01-0.10 m.

iv. The tensional crack is located at N75°W in dip angle 10-85°, filled with yellow muds and cacites.

(4) Geology of karsts and hydraulic

i. Karsts

They are developed in the limestones of Yungling and Guanling Groups, mixed with argillaceous strips, capability of deep drawing is relatively small, karst development is in certain extent limited, and, thus, the scale is small. It has not been found, in drill holes, any karst cave.

ii. Hydraulic geology

(i) Water bearing and water resistant strata

<u>Water bearing strata</u>

The Yungning and Guanling Groups are cracked water-bearing strata. The former's water richness is rather low while the latter is relatively high. Water-bearing strata are distributed in left bank of Wanho, Banpo, Bingwu, ridges of Pohan, half

slopes across Hungyan, Pojiao, Pamei and Jianzhuang.

Water resistant strata

At the dam site, there are two water resistant strata in Feixian and Yungning Groups. The lithology includes sandstones, mud stones and argillaceous limestones, thickness 422 m, 65 m, and 40 m respectively.

(ii) Permeability of the strata

There have been altogether 180 water-pressures tests at the dam site and drill holes on the river bed. It was found that the strata are, within certain ranges, permeable. The permeability is a little bit larger close to soil surface and it becomes smaller deeper down under.

(5) Physical geological phenomena

i. Offloading

There are two groups of offloading cracks, one in the direction of south-north and the other east-west. The rocks were cut into small blocks and toppled. The scale of the cracks is not large and the width is 30 m.

ii. Collapses

Bank slopes are not so deep that there are more collapses than small rock blocks. The collapses developed along offloading cracks , with rather shallow depth of about 5 m and disappeared above elevation of 300 m.

iii. Weathering

The weathering of soluble rocks erodes along structural cracks and is filled with moldable clays.

The weathering of insoluble rocks not only erodes along tectonic cracks and offloading cracks, but is also affected by the component and internal tectonic structures of rocks. It is rather weak at the river bed and widths of micro-weathering strips are 15-50 m.

(6) Strata geology at dam body engineering

Lithology at the reservoir area includes limestones, argillaceous limestone strips as well as argillaceous shales, in thick, medium thick and thin layers. Continuity of the strata is good and thickness is stable.

Component of the inserted soft materials between strata includes carbonate mud rocks, argillaceous shales, slices of cacites, and clays, thickness is 0.1 cm and continuity is weak. Types of causes for the component are primary, secondary, tectonic and combination of the three. The secondary type is formed from the primary inserted layer leached by underground water and weathered into softened

materials as carbonates, muds as well as softened rocks in some cases and clays in other cases.

2. Geological Evaluation of the Big Dam Engineering

(1) Hardness of strata in dam foundation and characteristics of transformation

Strata of the dam foundation are formed from layers of $T^{1-1}$yn, $T^{1-2}$lyn, $T^{1-3}$lyn, $T^{2}$lyn, $T^{3}$lyn, etc. Layer $T^{2}$lyn is composed of sand shales, argillaceous limestones, and mud rocks. It is of category Crv with soft lithology, many inserted layers, low intensity and weak stability. It needs to be dug deeper and processed in particular ways when high concrete dam is built. The other layers are suitable for building high concrete dams.

(2) Skid-resistant stability

To achieve skid-resistant stability at foundation of concrete gravity dams, there are three possibilities:

i. To slide along the contact surface between dam body and foundation rocks;
ii. To slide along the strata and the reverse dip-angle cracks;
iii. To slide along the strata and deep layers of steep dip-angle cracks.

In the above three situations, possibilities i and iii are not high, but only possibility ii is harmful. However, the development of reverse cracks is controlled by strata so that the cutting is not deep. Its possibility is also not high.

(3) Geological condition of engineering in impervious routes

Water resistant layers at the dam site are intended to be at downstream. There are two layers, $T_{1R}$ and $T^{2}$lyn. The fully closed impervious curtain can use the $T_{1R}$ layer. Depth of the curtain is 70-150 m, with impervious cable 1,100 m long, and the area is 137,841 $m^2$. Impervious works on end points of both banks are connected through $T^{2}$lyn layer, with depth 100-250 m and area 190,000 $m^2$. Limestone karsts did not develop in $T^{2}$lyn layer. Thus, the condition for impervious process is relatively good.

3. Geological Evaluation of Water Diversion Tunnel and Plant Engineering

(1) Water diversion tunnel

The tunnel is placed at the right bank, elevation of the entrance is 670 m, and axis is turning from S70$^{o}$W to S20$^{o}$E. Entrance of tunnel and its upstream section are located in a layer of calcareous silt sandstones which is prone to weathering and the tunneling condition is relatively bad. The downstream section is located in a layer of mud limestones and argillaceous limestones which is hard and tunneling condition is good. The tailrace tunnel is located in a layer of mud limestones and mud shales

which is uneven in hardness and tunneling condition is bad. The place where lithology changes could be impacted by a little bit of seepage.

(2) Plant building

It is located at the right bank where lithology includes medium thick layers of limestones and strips of argillaceous limestones. Intensity of rocks is high, there is no underground river and development of karsts is weak, so that the possibility of seepage during cultivation is quite small. However, elevation of plant bottom plane is lower than water level of the river so that it is possible to have river water encroachment.

4. Geological Condition in Engineering of Water Diversion Tunnel

Water diversion tunnel is located at left bank. The entrance is in the layer $T^1$ly of sand shales and the outlet the layer $T^1$lyn of dolomites. The whole diversion tunnel is going through layers of sand shales, sandstones, mud rocks, limestones, mud limestones, thin layer of limestones, mud shales, and dolomites, in which mud rocks, mud shales as well as mud limestones are relatively soft so that tunneling condition is relatively bad, whereas the others are stable so that tunneling condition is relatively good. And since underground waters are not rich, it is beneficial for cultivation works.

## IV. Natural Building Materials

In areas near the core building, distribution of natural sands and pebble stones along the beach is not abundant such that their quality and quantity will not fulfill requirement. Therefore, man-made sands are chosen. The gravel fields selected are: Mawuodi Gravel Field, Hydropower Station Base Gravel Field and Changlinggang Gravel Field which are exploited together and, therefore, both quality and quantity will fulfill design requirement. On the other hand, there is also Jiwushan Quarry at upstream right bank of the dam site as well as Jianzhuang Soil Ground at the area of Jianzhuang on upstream left bank of the dam site which is 4 km from the dam site. The materials there are mainly weathered basalts and sand shales accumulated in collapsed slopes and a small part of collapsed limestones. Length of the soil ground is 3,000 m, width 900 m, thick 23 m, and storage $8.1X10^8$ $m^3$.

## V. Conclusions

1. The new tectonic movement at engineering area is mainly intermittent uprising, in which earthquake activity is relatively weak. As investigated by Yunnan Earthquake Bureau, the basic earthquake intensity at the dam site is level V1.
2. The dividing crests on banks of reservoir are rich, soluble and insoluble rocks spread out alternately, closure condition of the reservoir is good, and water

levels at tributaries on bother banks and dividing crests are all higher than normal reservoir water level. Therefore, there is no problem of seepage to neighboring valleys or seepage at the reservoir head.

Backwater from the reservoir is up to 265 km, reservoir area is a valley in horizontal direction and is composed of limestones and dolomites, and side slopes of the strata are relatively steep. Therefore, there is no landslide at the reservoir head but only small scale partial collapses which are mostly inundated by reservoir waters, so that the buildings will not be affected.

3. The mineral resources inundated are mainly coals, with loss in reserves at 20.36 million tons which is about 1.66 % of the total coal reserves.
4. There is no natural gravel material near the core building site and, therefore, only man-made gravel materials can be exploited. All gravel fields are relatively close by at distances of about 2-5 km whereas both their quality and quantity can fulfill design requirement.
5. The big dam is built on the first section of limestones of Yungning Group where lithology is very even and intensity is high, so that all requirement for building concrete gravity dam will be fulfilled. Furthermore, water level of the reservoir will not be restrained by other conditions. However, entrances of some tunnels are located on layers of sandstones in the Feixian Group in which tunneling condition is relatively inferior.

# Chapter 6 Scale of Engineering

## I. Water Level of the Reservoir

1. Normal Water Storage

By comparing all sorts of schemes, it was found that whenever normal water storage increases power and guaranteed outputs also increase, but at level around 2,012 m the guaranteed output is relatively large. Longpan Hydropower Station is the head power station at downstream Jinshajiang while the major compensating players are Liangjiaren and Ahai Power Stations at downstream which must have functions for multi-year regulations. By comparison with respect to comprehensive functions, it is found that total costs will be the smallest when water level is at 2,012 m.

2. Dead Water Level

Guaranteed output increases when dead water level is lowered, while power output decreases when dead water level is lowered. When dead water level is raised, storage coefficient decreases and regulating function is also lowered. By considering all factors, the dead water level was chosen as 1,939 m.

## II. Scale of Power Generation

1. Power Generation Capacity

Given 2,012 m of normal storage water level, 1,939 m of dead water level, and multi-year regulating function of the reservoir, the power generation capacity has been chosen as 0.7 million kw X 6 =4.20 million kw.

2. Power Output Balance

Load backup has been set as 5% of maximum loads, and accidental backup at 10% of system loads, whereas a hydropower station of good regulating function and close to load center should assume more load backup. Generator overhaul has been scheduled as once per year for each generator, the time span for every overhaul of hydropower station is one month, while that for thermal power station is one and half months.

When hydro and thermal powers are balanced, the operating benefit in hydro-thermal power coordination should be sufficiently fulfilled. The work of systematic peak regulation will be assumed by hydropower stations. In rising tide seasons, given thermal power stations having already fulfilled minimum technical power outputs, they will take part in works of systematic peak regulations. The main

peak loads will be assumed by hydropower stations in implementing waste peak regulations. The minimum technical power output from hydropower stations is 70% of generator output, including spinning reserves, from thermal power stations.

3. Achievement Analysis

Given loads in 2014 and power generation quantities being balanced as designed, setting generation capacity of Longpan Hydropower Station at 5.07 million kw has been verified as appropriate. When all power outputs and quantities are transported into Yunnan power system, there always were spare capacities in times before 2012. And as generation capacity is getting bigger, we will have more spare capacities. Until 2014 when 5.07 million kw of generation capacity has been installed, a peak capacity of 0.7 thousand kw from thermal power stations is needed, which is close to 0. Since peak regulation assumed by thermal power stations is not economically efficient, Longpan Hydropower Station is, therefore, a very good power source after the Silin Station with a generation capacity sufficiently beneficial.

4. Analysis of Outward Distribution

The three provinces in the southwest—Gueizhou, Xichuan and Yunnan as well as the three provinces in the Southern China—Guandong, Guanxi and Hainan are located along the coast and country borders so that their geographic locations are very important. The three southwestern provinces are abundantly endowed with energy resources. Coal reserves are 81.84 billion tons at the end of 1990, about 8.6 % of the whole country's reserves at 954.4 billion tons. Water resources are especially outstanding, with palpable power generation capacity at 175.75 million kw and power output at 975 billion kwh per year which are 46.5% and 50.7% out of the whole country's palpable capacity at 378.53 million kw and 1,923.3 billion kwh. Other than water energy resources, Yunnan is also abundantly endowed in coals as well as such metal resources as aluminum, tins, leads, zincs etc. On the other hand, Guandong is relatively less endowed in energy resources. Hence, if Yunnan's energy resources could be cultivated in large scale, then Guandong would be its main domestic market. Yunnan is a typical inland border province, lacking low-cost, convenient and fast marine outlets which have seriously constrained its resource cultivation and openness inward and outwards. On the other hand, Guandong has a very long coast line and good ports as well as a vanguard in openness outwards so that it has a significant locational advantage. Cultivation of the Jinshajiang one-reservoir and 8-level hydropower station will facilitate decisively navigation from Yunnan to Guandong and development in southwestern and southern China. Until dry season in 2010, power shortage will be at 17.90 million kw and output shortage 62 billion kwh while in rain season, power shortage will be at 25.64 million kw and

output shortage 90 billion kwh. So, when time comes transportation of powers from Longpan Power Station to Guandong will be a reliable way.

5. Generator Models

It has been decided to install three generation sets in Longpan Hydropower Station: hydro-turbine model HLA193-LJ-530 and generator model SY270-36/1080.

# Chapter 7 Reservoir Inundation

For details see 3. “Reservoir Inundation” in Section 3, “brief description of engineering” at Chapter 1, “introduction”.

# Chapter 8 Environmental Impacts

## I. Environmental Situation

For details see 4. “Environmental impacts” in Section 3, “Brief Description of Engibeering” of Chapter 1, “Introduction”.

## II. Predictive Evaluation on Environmental Impact

1. When the reservoir is finished, 160 thousand acres (standard acres) of farmlands will be inundated. These lands are landfills and debiteuses with high maturation of soils. The engineering construction reduces land resources in that area.
2. In the process of people migration, the indices of new plantation and replantation of old farmlands will be raised so as to cause land erosion and fertility loss if land reform and protection are not well implemented. Therefore, only by transforming and reforming lands, rationally adjusting industrial structure as well as developing more categories of operations, the land environment will be improves, land utilizing ratios raised as well as land productivity.
3. In the process of construction, such activities as cultivating and blasting mountains, filling sands and stones, concrete placement, waste pilings, etc. will seriously affect plants, vegetation, animal groups and their ecologies. Therefore, it should be rationally programmed and allocated during construction period so as to ameliorate the impacts.
4. When waters are stored in the reservoir, rising waters will directly inundate fold plains on river banks, lands, tributary creeks, and part of the slopes altogether with all sorts of vegetation and plants in there. The living land animals will be affected such that their living areas will be narrowed. As for rare plants, they all distribute in areas over 2,200 m above sea level so they will not be affected.
5. According to migration planning, majority of the migrants mill be moved back to areas close by. Hence, the impact of migrant movement, production and living activities on animals, plants and their ecological environment will be limited to areas around the reservoir.
6. There are natural protection zones for such rare animals as francois langurs and wild species around the reservoir area. They are all living on steep cliffs at banks of Jinshajiang which are of slopes more than $70^{o}$. Carbonates spread widely in there and limestones developed into karsts forming large numbers of

caves. These animals live in broad-leaved forests over 2,500 m above sea level while normal water level of the reservoir is at 2,012 m which is not in direct danger of being inundated, threatening their livelihood.

7. The main stream of Jinshajiang has been affected by coal-washing wastewaters on the upstream so that the sight is not pretty, contents of suspending materials are high which are seriously above the criteria of chemical oxygen consumption, and bacteria index does not fulfill drinking water standard. Coal-washing wastewaters have polluted jinshajiang for a long time and the measured values of river sediment have been contrasted with standard values which are presented in the table below.

| | aluminum | zinc | arsenic | chromium | mercury |
|---|---|---|---|---|---|
| Standard | 29.0 | 94.0 | 25.4 | 0.19 | 0.194 |
| Measured mean value | 32.0 | 185 | 16.3 | 0.89 | 0.09 |

8. When waters are stored in the reservoir, velocity of flow will fall, temperature will be stabilized and nutritive salts will increase. When the sediment settles, waters will be more transparent. This is good for animal plankton to grow and procreate. Benthos and aquatic vascular plants, affected by deep water and basal conglomerates, will be diverted to reservoir banks and tributaries. Fishery resources are poor in the river and there is no migrating fish. But since reservoir construction will not block the waters, when the reservoir is filled with waters the improved condition will benefit the livelihood of fishes.
9. The benefits from power production in the stations will facilitate economic development in Yunnan. Economy and culture of the region will be greatly promoted, mineral resources cultivated, local industries and district businesses will be rapidly developed. Agriculture will be transformed into a mono-structure concentrating in crop production. The new agriculture, forestry, animal husbandry, auxiliary and fishery will be greatly developed which will have invaluable effects on human resource qualities and employment opportunities.
10. In view of the seriously off-limit contents of such toxic and heavy metals as aluminum, zinc, chromium and mercury, when construction is under way relevant governmental and environmental agencies must be contacted as soon as possible, to strictly control wastewater discharges from mining and manufacturing units at upstream.

<u>The left bank</u>

A ship lock is installed which is composed of surface approach channel at

upstream, #1 tower on land surface, navigating tunnels underground, #2 and #3 towers on land surface and underground approach channel at downstream, with a total length of 1,552 m.

The right bank

(1) The underground diversion tunnel is located at the right bank of elevation 583-581.5 m, with total length of 720 m.

(2) Three pressure tunnels and steel penstocks for water supply in underground water diversion system are located at the right bank. The pressure tunnels placed at elevation 750.5 m-770 m above sea level is of average length, 600 m, in which the gross height of the surge shaft is 103 m, and internal void diameter is Φ21 X 36 m, located at the junction between concrete pressure tunnel and pressure steel penstock. Diameter of the pressure steel penstocks is Φ17 m which are of average length at 296 m, including a 47 m long curving section with inner diameter at 17 m-15 m.

(3) The plant house on shore surface is located at the right bank of elevation 559.57 m above sea level with length, width and height of the main plant at 320, 85.6 and 180 m.

(4) The open style switch station in the surface plant is located at an elevation of 630.00 m above sea level with length and width at 350 and 270 m.

On river surface

A rolled gravity dam is installed, with maximum height 222.2 m, on Triassic limestones at an elevation 584 m above sea level. Maximum length of the dam is 960 m, dam top at an elevation 750.5 m above sea level, volume of rocks cultivated 15,007.03 thousand $m^3$, and concrete placement 29,547.3 thousand $m^3$. 3 surface tunnels and 2 underground tunnels in the big dam are used for flood discharge of which the design discharge flow 9,445 $m^3/s$ and checked flood flow 9,857 $m^3/s$.

# Chapter 9 Electro Mechanics and Metal Structures

## I. Hydrological Mechanics

1. Mechanical Parameters

Total generation capacity of Longpan Power Station is 4.20 million kw in which six 0.7 million kw generators are installed.

Hydroturbines

Model: HLA193-Lj-520

Normal water head: 124 m

Maximum water head: 165 m

Minimum water head: 91 m

Normal flow: 253 m3/s

Normal output: 275 thousand kw

Normal rotation speed: 166.7 r/min

Wheel diameter: Φ5.2 m

Draught height: -5.5 m

Runaway rotation speed: 315 r/min

Maximum efficiency: 94.3%

Gross weight: 700 tons

Generators

Model: SF270-36/1080

Normal output: 2.40 million kw

Synchronous rotation speed: 166.7 r/min

Normal electric pressure: 18 kw

Guaranteed efficiency: 98.5%

Flywheel moment: >30,000 t/$m^2$

Gross weight: 1,540 t

Wheel weight: 770 t

2. Accessories

(1) Bridge cranes in plant house

Type: simple small car

Span: 22 m

Lift weight: 400/500 t

Number: 2

(2) Speed controller

Model: TD-150-40 electrohydraulic / YS-10-40 separated oil pressure device

Normal work pressure: 4.0 mpa

3. Adjustment Guaranty Calculations

According to the unit water diversion plan, when generators are passing the normal flow 253 $m^3/s$, switch-off time is set at 13 s and when generator power is fully loaded, the parameters are as follows:

Maximum pressure rise: 27%

Maximum speed rise: 43%

Draught tube vacuum: +6 m

## II. Electric Main Structure

1. Power Delivery Direction, Outlet Electric Pressure, Loop Number and Power Delivery Distance of the Station

Except for assuming a little amount of power loads of nearby area, the Longpan Hydropower Station is principally responsible for delivering power to the main grid, having based in Yunnan and taken into account of Guandong. To accommodate future development and changes, it was designed to have four 220kv outlet loops—two loops to Puding with delivery distance at 75 km, one loop to Dechin County with distance 85 km, and one loop reserved, as well as four 110kv outlet loops—one to Yulong with delivery distance 20 km, one to Guanling with distance 45 km, and two reserved. If the two 220kv loops to Puding are instead delivered to Lijiang 500/200kv Substation, then the delivery distance will be 90 km.

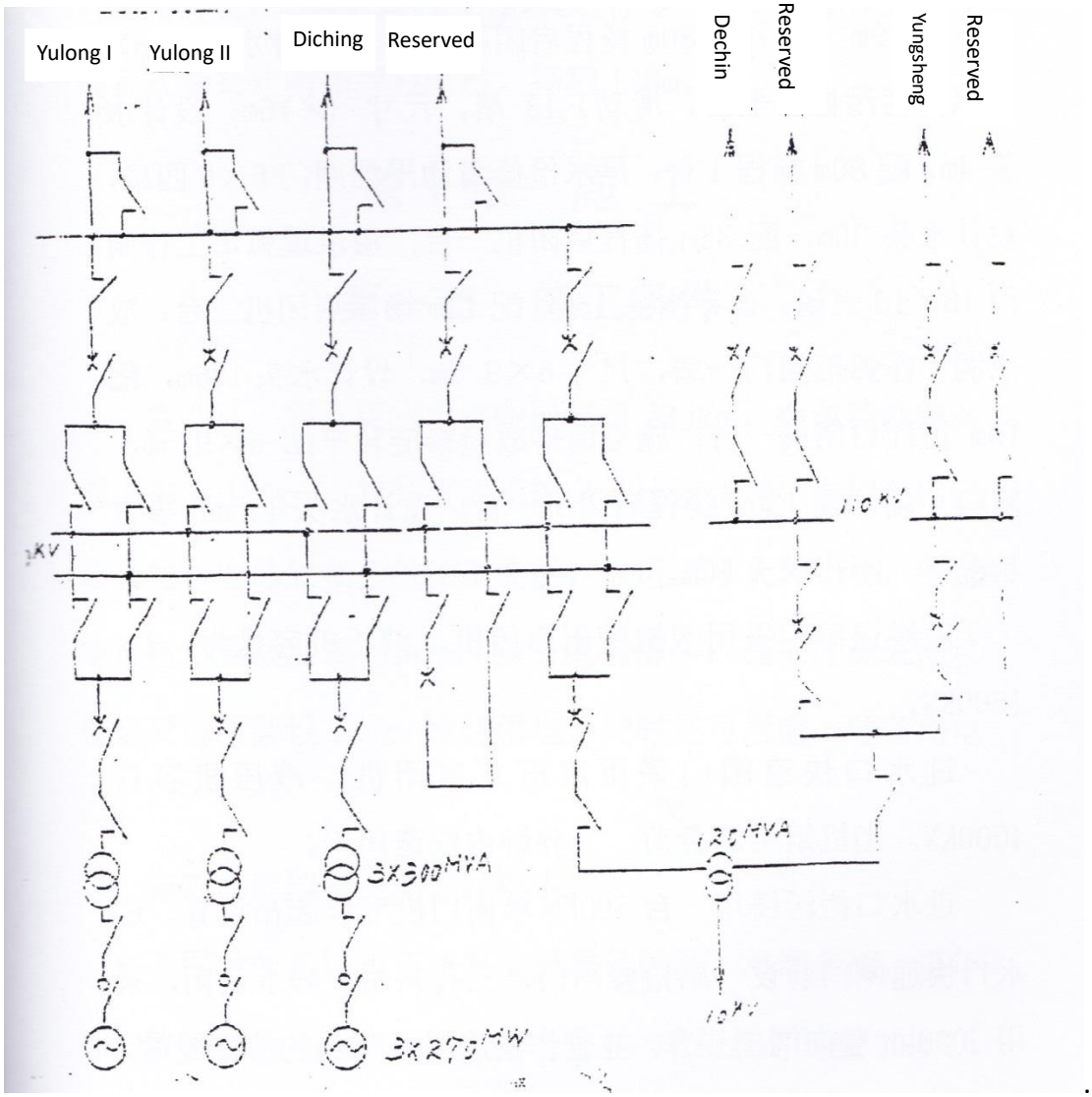
All six generators are connected to the 220 kv cables while the 110kv cables are connected with a joint variation.

2. Main Electric Connections

For the 6 generators, the t/g transformer will use unit interface and load switches were installed between t/g transformers so as to reduce frequent on-and-off of high-pressure switches during periods of peak regulations and to raise reliability of high-pressure powers.

For the 220kv cables, there will be 3 loops of line-ins and 4 loops of line-outs with an additional loop of joint variation. The connection will use double-bus with auxiliary bus configuration and specific purpose auxiliary circuit breakers are used.

For the 110kv cables, there will be one loop of line-in. Single-bus is used to connect for different sections. The connection configuration is as follows:




## III. Metal Structure

Metal structure of the Jinshajiang Station can be categorized into three parts: spillway gate, catchment power generation system and unloading caves. 13 various gates, 13 trash racks, 30 gate/rack grooves and 11 switching devices are installed for a total quantity of 4,025 T, of which include 3 sliding speed plane gates (8.5 X 8 m) at water inlets combined with three 9 m hoist headstock gears, one bulkhead sliding plane gates (6.5 X 9 m) at water inlets combined with one 80 m hoist headstock gear (design water head 75 m), 13 sliding plane trash racks at inlets (3 X 16 m, design head water 4 m) combined with one 80 m hoist headstock gear, 4 tail water bulkhead sliding plane gates (6 X 6 m, design head water 30 m) combined with one 35 m hoist headstock gear, 3 spillway arc main gates (16 X 15 m, design water head 15 m) combined with three 12 m hoist headstock gears, one unloading-cave arc main gate (6 X 9.5 m, design head water 136 m) combined with one 10 m hoist headstock gear, as well as one 6 X 9.5 m plane chain gear for overhauling accidents with one gate

combined with one 130 m hoist headstock gear (design water head 136 m and gate closure water head 60 m when accidents occur).

The spillway gates are installed with double-barrel hydraulic hoists in capacity 2 X 1,600KN.

The speed inlet gates use hydraulic hoists with capacity 4,000 KN. When generators use up all loads, the gates will be quickly closed in 2 minutes.

The inlet trash racks will use one 500 KN baffle-gate special purpose lifting device. In front of each inlet speed gate, a bulkhead gate is installed. The three flow-hole shared still-water hoist headstock gears operate by using 2,000 KN double-action gantry cranes which served as hoist devices for speed-gate hydraulic press.

The arc gates of unloading caves adopt a structural form of double principle-and-subordinate horizontal/upright arms and cylinder hinges. With respect to this kind of upriver valves on deep-hole high-head water gates, special studies should be engaged so as to ensure safety and reliability. In operations of the chosen 5,000KN hydraulic hoists, lowering force is 2,000 KN and stroke is 10 m.

With regards to the accidental overhauling gates for unloading caves, they open in still waters, head water is tall, and hydraulic pressure is high. Thus, special studies should be engaged on their design construction works, sustaining models and sealing patterns. A 5,000KN fixed rolling hoist headstock gear is used, with hoist height 130 m.

# Chapter 10 Construction Works

## I. Construction Conditions

The Jinshajiang Station is 225 km from Lijiang City, 120 km from Yaopu Station on Yunnan-Gueizhou Railways and has a relatively good condition in outward distributions. A rough road on the left bank has already reached the construction site. The power station is inside the Jinshajiang Industrial Zone, close to loading center in eastern Yunnan, and at a linear distance of 65 km from Puding Hydropower Station. Electric powers for construction works are at hand, transported from Puding Substation through 110kv cables. At the same time, some other back-up power sources can also be taken into consideration.

As for water sources for construction, three pumping stations will be built to catch waters.

Watershed of the construction site is of subtropical plateau monsoon climate, wet and rainy, multi-year average rainfall is 1,178.8 ml, average temperature is 13.9$^{o}$C, highest temperature is 30.4$^{o}$C, lowest temperature is -6.2$^{o}$C, and mostly south and northeast winds with maximum wind speed 21 m/s. Hence, construction works can be undertaken for the whole year.

As for engineering construction period, preparing period is 2 years and 6 months, main body engineering construction period is 5 years and 6 months, period from preparing stage to the time the first generator set begins to produce power is altogether 5 years and 7 months, engineering finishing period is 1 year, and gross construction duration is 6 year and 7 months.

## II. Building Materials

Sand and stone materials needed for engineering concrete and placement are produced artificially. The chosen sand and stone factories are fields in Mawuodi, Longpan and Changlinggang, all being limestone strata, with rich reserves and good qualities.

## III. Water Diversion for Construction

1. Diversion Standards

The Jinshajiang Station is a first class engineering. The big dam is a first class building and temporary buildings are of the fourth class. Water diversion design flood standard is one flood in 10-20 years.

2. Intervals and Flows of Diversion

Intervals of diversion adopt dry season diversion plan. Flood flows of the whole year are 5-16 times of those in dry season, and diversion tunnels pass through soft strata (sandstones and mud shales), so that their intersections should not be too large and, therefore, a 21 X 36 m city doorway type is adopted. In dry season diversion, height of cofferdams at upstream is 15.8 m and that at downstream is 9.8 m.

Diversion intervals in dry season are chosen as from November 11 to May 19 next year, with comparable diversion flow (P=1%) at 1,130 $m^2/s$.

3. Diversion Method

The river bed is very narrow and the banks are steep, so a one-time cutoff cofferdam is used. Dam body construction is in work in dry season, so an overflow through foundation pits is adopted in high rain season.

For the cofferdams, earth rocks overflow cofferdams are used to protect the flow surface.

4. Construction Diversion Allocations

The construction diversion tunnels are allocated at the left bank which are of the type of city doorway at size 21X36 m, height of upright flat 23 m, radius of round-arched crown 13 m, central angle 124.423°, and gross section relined at width 0.8 m. Characteristics of diversion buildings allocation are as the following table.

| | Unit | Divers. Tunnel #1 | Divers. Tunnel #2 | | Unit | U'stream c'dam | D'stream c'dam |
|---|---|---|---|---|---|---|---|
| Height of inlet underplate | m | 584.0 | 584.0 | Height of cofferdam top | m | 595.8 | 587.8 |
| Height of outlet underplate | m | 582.0 | 582.0 | Length of cofferdam top | m | 118.0 | 80.0 |
| Length of inlet open channel | m | 100.0 | 180.0 | Maximum cofferdam hgt. | m | 15.8 | 9.8 |
| Length of outlet open channel | m | 58.0 | 60.0 | Maximum cofferdam bed width | m | 103.0 | 92.2 |
| Tunnel length | m | 1,087.0 | 1,246.0 | Maximum depth of water resistant flat | m | 18.75 | 15.0 |
| Bed slope | 0/00 | 1.84 | 1.6 | Cutoff area of water resistant flat | $m^2$ | 1,194.0 | 875.0 |
| Overflow intersection area | $m^2$ | 167.72 | 167.72 | Cofferdam type | | Earth rocks overflow | |

5. Diversion Process and Flood Handling

At the time when diversion caves are constructed, the water surface section of dam shoulders on the banks are also cultivated up to the normal draughty water level before the time of river cutoff. Mid-November of the dry season is chosen to

begin the works of river cutoff. After that, works on construction of cofferdams are under way. When waters in foundation pits have been pumped out, the dam foundation begins to be cultivated. Before May 10, concrete will be filled into the dam body up to a height of 585 m, and dam body flood protection works will also be engaged as well as overflow through foundation pits at high tide period.

At the second dry season in the cutoff valley, construction works on dam body are required to be under way until up to the height of over 625 m so as to fulfill the standard for flood handling in every one hundred years. Thereafter, safety of the dam body and construction in the whole year shall be assured.

6. Blocking of Diversion Caves

Blocking is arranged to be done at the dry season. When pouring of concrete in the dam body has, before certain high tide period, surpassed the height of spillway gate top, blocking of diversion caves can be done right before high tides come. The diversion cave #1 will be blocked at first (to be rebuilt as loading cave) and then cave #2 will be blocked.

## IV. Construction on Main Body Engineering

1. Works on the Big Dam

The volume of soil and stone in cultivating the big dam is large, reaching 15 million $m^3$. Excavation is divided into two stages: excavating to normal dry season water level before river cutoff, and the rest after the cutoff. The construction works will adopt the method of top down bench excavation, with bench height 15 m. The downhole drill, model 150, will be used to blast in the drilling hole. A horizontal air drill is placed to assist the drill blasting. The residues are collected by bulldozers and dumped by using excavators and loaders coordinated with 20T, 50T or 60T autodumpers. The river bed section is excavating blasted with downhole drill coordinated with horizontal air drills, and the residues are dumped with excavators and loaders coordinated with 20T, 50T or 60T autodumpers.

Concrete pouring: Combined with excavations on dam foundation and construction roads, concrete pouring in dam body will be done by pouring on the left and right banks simultaneously with regards to different parts, or pouring on one bank alone. Reinforced concretes are secured directly on the spot.

Concrete placement is done through railless slipforms, by installing plate bending machines on dam tops to haul sliding up for pouring concrete through slipping ledge into storage.

2. Construction Works on Power Generation System

(1) Headrace System Construction

Buildings for headrace system include water inlet, gate well, headrace tunnels and high pressure conduits. Open excavation of water inlet is undertaken by excavating dam foundation roads into working surface in which the downhole drill, model YQ-100, is used to drill holes and to blast, in layers, from top to down. The residues are dumped by loaders equipped with autodumpers.

When open excavations of inlets are done, excavation of horizontal sections on top of the three diversion tunnels starts to work by using multi-boom drills to excavate in full cross-section. Excavations of the shaft for high-pressure conduits and lower horizontal section are carried out by digging side tunnels. When excavation of top and lower horizontal sections are done, the shafts begin to be excavated.

(2) Construction works on plant system

The plant system includes plant on surface, main switching room and tail water channels.

(3) Construction works on navigation building

This building is a visional engineering, allocated elevation is higher and has not much connection with main buildings. Therefore, it can be constructed separately in years. But the approach channels at upstream and the tunnels for vertical ship lifts should be built before waters are stored in the big dam. Excavation of the tunnels for the approach channels could be done simultaneously at upper and downstream.

## V. Gross Allocation for Outward Transportations and Construction Plane

1. Outward Transportations

The Longpan Hydropower Station is located within Xianggelila and Yulong Counties, 680 km from Kunming City, 60 km from Lijiang City, 40 km from Yungning which is closest to National Highway 214, 18 km from Liangshueiying, 120 km from Yaopu Station on Gueizhou-Yunnan Railway, and 64 km from Xinyao Rail Station.

## VI. Gross Schedules of Construction

1. Engineering Preparing Period

Works of Engineering needed to be done in this period are: inbound roads for water diversion engineering and internal temporary roads, sand and stone procession system, concrete stirring and systems as well as construction plant. The works start from beginning of January in the first year to end of November in the second year, for a total of 22 months.

2. Main Engineering Construction Period

(1) Big dam

Excavation of big dam shoulders starts from July 1 in the first year until November 30 in the second year. Excavation stops when dry season water level reaches 582 m, with total excavated cubic soil and stones 684.6 thousand $m^3$ and average intensity 40.3 thousand $m^3$/month. Excavation of big dam foundation pits starts from beginning of December in the 2nd year until fully finished at end of February in the 3rd year, with total excavated cubic soil and stones 300 thousand $m^3$ and average intensity 100 thousand $m^3$/month.

Concrete pouring in the dam body is carried out in five stages. In the first dry season after river has been cut off, toe board concrete placement, river bed toe board consolidation and curtain placement, as well as concrete placement for part of the dam body will be done, with total poured concrete 550 thousand $m^3$ and average intensity 238 thousand $m^3$/month. The duration is from March 1 to mid-May in the 2nd year.

From December 11 in the 3rd year to May 10 in the 4th year at the dry season for a total of 5 months, the temporary low-tide intersection at the front end of dam body needs to reach elevation standard of 652 m to avoid flood occurred in every one hundred years. Afterwards, construction can be done for the whole year, even during flood periods, with total volume of concrete 1.30 million $m^3$ and average intensity 260 thousand $m^3$/month.

From May 11 to December 10 in the 4th year, concretes are placed for the dam body up to elevation at 652 m, with total volume of concretes 1.9 million m3, duration 7 months, and average intensity at 266 thousand $m^3$/month.

From December 11 in the 4th year to April 10 in the 5th year which is the third dry season after the river has been cut off, Concretes are placed for the dam body up to elevation 652 m, total volume of concrete placement 1.05 million $m^3$, duration for 4 months, and average intensity at 266 thousand $m^3$/month, in which volume of concretes 20 thousand $m^3$ and concrete pouring for the curtain 25 thousand $m^3$.

From April 11 in the 5th year to April 10 in the 6th year, concrete placement for the dam body is up to elevation of 700 m, total volume of concrete placement 3.48 million $m^3$ and average intensity 290 thousand $m^3$/month.

From April 10 to July 10 in the 6th year, dam body concrete placement is done up to elevation 730 m, total volume of concrete placement 900 thousand $m^3$ and average intensity 300 thousand $m^3$/month.

From July 11 to August 31 in the 6th year, works on dam body are finished, with total volume of concrete placement 343.3 thousand $m^3$.

Construction period for the whole big dam is from July 1 in the 1st year to December 31 in the 6th year, a duration of 66 months.

(2) Construction on land surface generation plant system

The land surface plant will not be affected by flood and, therefore, is suitable for construction in the whole year. From November 1 in the 2nd year to June 30 in the 6th year when the first generator starts to generate powers, the total duration is 66 months, total volume of cubic soil and stones excavated 670.3 thousand $m^3$, and that of concrete placement as well as pouring is 128.9 thousand $m^3$.

(3) Engineering Finishing Period

Engineering finishing period begins from the date when the first generator starts to produce powers, which is July 1 in the 6th year, to end of June in the 7th year. During this period, the main work is to install the 2nd and 3rd generators. It is planned that the 2nd generator starts to generate power in the end of December of the 6th year, and the 3rd generator will start to generate powers in the end of June of the 7th year.

(4) Main indicators for gross construction schedules:

| | Item | Unit | Quantity | Note |
|---|---|---|---|---|
| Main engineering volume | Open excavation of cubic soil and stones | Thousand $m^3$ | 83,408.4 | |
| | Tunnel excavation of cubic stones | Thousand $m^3$ | 15,000 | |
| | (cubic stones) concrete | Thousand $m^3$ | 9,647.3 | |
| | Concrete | Thousand $m^3$ | 553.6 | |
| Construction intensity | Maximum excavation intensity of cubic soil and stones | Thousand $m^3$/month | 164 | |
| | Maximum intensity of concrete placement (cubic stones) | Thousand $m^3$/month | 300 | |
| | Maximum intensity of placement (cubic stones) | Thousand $m^3$/month | 23 | |
| Construction duration | Engineering planning period | Year | 2.0 | |
| | Engineering preparing period | Year | 3.0 | Preliminary preparing period for half year |
| | Main body engineering construction period | Year | 5.5 | |
| | Engineering finishing period | Year | 1 | |
| | Gross duration | Year | 6.5 | |
| Labor force | Dam body placement period | Month | 40 | |
| | High production peak | Person | 10,000 | |
| | Total laborers | Person | 17,600 | |
| | Total labor days | Thousand labor day | 20,000 | |

| | | |
|---|---|---|
| Cement | Thousand T | 20,351.2 |
| Woods | Thousand $m^3$ | 830 |
| Reinforced concrete | Thousand T | 1,390 |
| Steel | Thousand T | 450 |

# Chapter 11 Investment Estimates

## I. Engineering Overview

See the first chapter.

## II. Main Economic Indicators

These estimates were prepared in constant price levels of 2006. Total engineering investment is RMB 316.5 billion, unit kw total investment is RMB 5,890, and static total investment is RMB 268,509 million.

## III. Basis for Estimation

1. These estimates were based on current *Simple Rules for Preparing Investment Estimates*. Civil engineering adopts general fixed budget of FY 2006 expanding 20%, while electric mechanical engineering adopts general fixed budget of FY 2006 expanding 10%.
2. Basic data were determined in reference to other engineering together with actual situations of this engineering: power rate RMB 0.6/degree, wind price RMB 0.18/$m^3$, sand price RMB 70/$m^3$, and rubble price RMB 60/$m^3$.
3. Permanent housing building engineering was estimated at 4% of the first part of main body building engineering.
4. Other permanent building engineering was estimated at 4% of the first part of main body building engineering.
5. For electric mechanical equipment and installation engineering, water turbines at RMB 28 thousand/T, power generators at RMB 26 thousand/T, and other electric mechanical equipment at RMB 350/kw.
6. Reservoir expenses were listed according to plan.
7. Other expenses were estimated at 19.2% of parts 1 to 4 of construction allocations.
8. Explanation:
   1. Basic preparing expenses were estimated at 10%, and price difference preparing expenses were estimated based on annual increase of price index, 6%.
   2. Investments for various years were estimated taking into account the impacts during planning period. See the following table for their estimates:

Gross Table for Power Station Investment Estimates

| Ser. No. | Items | Estimates (in RMB thousand) | Ser. No. | Items | Estimates (in RMB thousand) |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| | Part 1: Building engineering | 71,022,970 | | Part 4: Temporary engineering | 12,913,700 |
| 1 | River cutoff engineering | 24,706,300 | 1 | Flow diversion engineering | 1,151,340 |
| 2 | Flood discharge engineering | 11,727,000 | 2. | Transportations engineering | 1,548,000 |
| 3 | Water diversion | 28,123,000 | 3 | House building engineering | 10,470,700 |
| 4 | Power generation plant engineering | 21,341,900 | 4 | Power distribution cables engineering | 165,000 |
| 5 | Booster substation engineering | 9,475,300 | 5 | Other temporary engineering | 9,814,700 |
| 6 | Transportation engineering | 16,663,000 | | Part 5: Reservoir expenses | 21,332,200 |
| 7 | House building engineering | 21,141,400 | | Part 6: Other expenses | 22,764,100 |
| 8 | Other building engineering | 8,362,500 | | | |
| | Part 2: Electrome-chanical equipment and installation engineering | 24,702,000 | | Basic preparing expenses | 2,256,000 |
| | Part 3: Metal structural equipment and installation engineering | 8,618,100 | | Price difference preparing expenses | 7,025,400 |
| 1 | Overflow engineering | 9,188,800 | | Interest payment during construction period | 11,149,460 |
| 2 | Water diversion engineering | 8,343,300 | | Static total investment | 268,509,000 |
| 3 | Power generation plant engineering | 1,929,500 | | Total investment | 316,500,000 |
| 4 | Interests for equipment preservation loans | 861,400 | | Unit kw static investment (in yuan) | 5,700.06 |

## Budget of Building Construction

| Ser. No. | Item | unit | quantity | Unit price (yuan) | Total price (thousand yuan) |
|---|---|---|---|---|---|
| | Part 1: Building engineering | | | | 11,022,966.2 |
| 1 | River cutoff engineering | | | | 5,470,626.7 |
| (1) | Barrage engineering | | | | 4,470,626.7 |
| | Cubic stone excavation | $m^3$ | 984,600 | 18.06 | 917,781.9 |
| | Cubic stone tunnel excavation | $m^3$ | 12,300 | 102.29 | 91,258.2 |
| | Stone landfill | $m^3$ | 8,961,100 | 35.00 | 8,313,638.5 |
| | Transit materials | $m^3$ | 368,500 | 29.85 | 910,999.7 |
| | Filter landfill | $m^3$ | 193,700 | 69.64 | 713,489.2 |
| | Concrete | $m^3$ | 65,700 | 442.14 | 829,048.6 |
| | Spraying concrete | $m^3$ | 500 | 609.53 | 12,304.8 |
| | Reinforced concrete | T | 5,000 | 6,286.01 | 831,430.1 |
| | Anchor bolt | Stick | 700 | 105.92 | 974.1 |
| | Consolidating grouting | m | 4,600 | 158.34 | 8,728.4 |
| | Curtain grouting | m | 71,200 | 632.93 | 745,064.6 |
| | Other engineering | $m^3$ | 9,589,500 | 0.71 | 96,808.5 |
| 2 | Flood discharge engineering | | | | 2,172,699.6 |
| (2) | Spillway engineering | | | | 9,128,926.4 |
| | Cubic stone excavation | $m^3$ | 1,728,300 | 18.06 | 831,213.1 |
| | Backfill concrete | $m^3$ | 24,300 | 280.00 | 76,804.0 |
| | Concrete | $m^3$ | 189,700 | 338.32 | 664,179.3 |
| | Spraying concrete | $m^3$ | 1,800 | 600.00 | 91,080.0 |
| | Consolidating grouting | m | 2,000 | 87.55 | 9,175.1 |
| | Reinforced concrete | T | 3,200 | 6,285.01 | 820,115.2 |
| | Anchor bolt | Stick | 5,800 | 105.92 | 614.3 |
| | Temperature control measures | $m^3$ | 215,800 | 10.00 | 2,153.0 |
| | Other engineering | $m^3$ | 215,800 | 11.99 | 2,587.4 |
| | Unloading caves engineering | | | | 943,773.2 |
| | Cubic stone open excavation | $m^3$ | 60,200 | 30.94 | 2,921,862.6 |
| | Cubic stone tunnel excavation | $m^3$ | 115,030 | 64.04 | 3,867,366.5 |
| | Concrete | $m^3$ | 37,620 | 509.76 | 1,219, 177.2 |
| | Spraying concrete | $m^3$ | 3,900 | 559.36 | 92,181.5 |
| | Consolidating grouting | m | 16,810 | 87.55 | 81,471.7 |
| | Reinforced concrete | T | 1,510 | 6,286.01 | 2,679,491.9 |
| | Anchor bolts | Stick | 9,760 | 105.92 | 651,033.8 |

| | | | | | |
|---|---|---|---|---|---|
| | Backfill grouting | $m^3$ | 13,040 | 58.85 | 265,767.4 |
| | Other engineering | $m^3$ | 41,520 | 10.13 | 34,420.6 |
| 3 | Water diversion engineering | | | | 56,781,230.6 |
| (1) | Diversion tunnels engineering | | | | 56,781,230.6 |
| | Cubic stone excavation | $m^3$ | 670,300 | 30.94 | 34,520,739.1 |
| | Cubic stone tunnel excavation | $m^3$ | 167,730 | 64.04 | 30,210,741.4 |
| | Concrete | $m^3$ | 49,400 | 509.76 | 8,725,182.1 |
| | Concrete spraying | $m^3$ | 8,796 | 559.36 | 564,916.8 |
| | Consolidating grouting | m | 27,700 | 87.55 | 452,425.1 |
| | Backfill grouting | $m^3$ | 12,920 | 58.85 | 362,760.3 |
| | Reinforced concrete | T | 1,970 | 6,286.01 | 82,012,383.4 |
| | Anchor bolts | Stick | 32,230 | 105.92 | 1,853,413.8 |
| | Other engineering | $m^3$ | 58,190 | 11.49 | 2,816,688.6 |
| 4 | Generation plant engineering | | | | 10,134,186.4 |
| | Underground plant engineering | | | | 592,518.6 |
| | Cubic stone tunnel excavation | $m^3$ | 179,300 | 55.59 | 109,967.3 |
| | Concrete | $m^3$ | 79,500 | 497.41 | 2,039,544.1 |
| | Concrete spraying | $m^3$ | 3,000 | 630.86 | 101,892.6 |
| | Consolidating grouting | M | 1,700 | 87.55 | 20,148.8 |
| | Backfill grouting | M | 6,200 | 58.85 | 40,364.9 |
| | Reinforced concrete | T | 4,800 | 6,286.01 | 2,030,172.8 |
| | Anchor bolts | Stick | 6,100 | 203.92 | 501,243.9 |
| | Steel | Stick | 300 | 4,500.00 | 651,350.0 |
| | Brick wall | $m^3$ | 7,600 | 400.0 | 423,040.0 |
| | Other engineering | m | 90,100 | 53.21 | 604,794.2 |
| | Drainage tunnel engineering | | | | 522,636.7 |
| | Cubic stone tunnel excavation | $m^3$ | 13,200 | 64.04 | 87,845.3 |
| | Concrete spraying | $m^3$ | 1,500 | 559.36 | 69,839.0 |
| | Anchor bolts | Stick | 3,500 | 79.20 | 98,277.2 |
| | Drainage hole | $m^3$ | 8,800 | 75.00 | 20,660.0 |
| | Other engineering | $m^3$ | 1,500 | 10.13 | 6,515.2 |
| | Ventilating tunnel engineering | | | | 2,320,190.7 |
| | Cubic stone tunnel excavation | $m^3$ | 48,700 | 82.21 | 314,003.6 |
| | Concrete | $m^3$ | 1,500 | 683.32 | 201,025.0 |
| | Concrete spraying | $m^3$ | 2,400 | 600.21 | 151,440.5 |
| | Anchor bolts | Stick | 2,900 | 105.92 | 64,307.2 |
| | Reinforced concrete | T | 200 | 6,286.01 | 251,257.2 |
| | Other engineering | $m^3$ | 3,900 | 10.31 | 6,039.5 |

| | | | | | |
|---|---|---|---|---|---|
| | Traffic tunnel engineering | | | | 2,320,190.7 |
| | Cubic stone open excavation | $m^3$ | 6,600 | 30.94 | 40,204.2 |
| | Cubic stone tunnel excavation | $m^3$ | 76,900 | 82.44 | 626,339.6 |
| | Concrete | $m^3$ | 9,000 | 560.71 | 755,046.4 |
| | Concrete spraying | $m^3$ | 4,600 | 615.27 | 842,830.2 |
| | Reinforced concrete | T | 800 | 5,286.01 | 655,028.8 |
| | Anchor bolts | Stick | 5,700 | 105.92 | 69,603.7 |
| | Other engineering | $m^3$ | 13,600 | 10.13 | 87,137.8 |
| (5) | Outlet tunnel engineering | | | | 6,510,767.4 |
| | Cubic stone tunnel excavation | $m^3$ | 51,800 | 82.44 | 874,270.4 |
| | Concrete | $m^3$ | 3,400 | 260.71 | 781,906.4 |
| | Concrete spraying | $m^3$ | 3,700 | 615.27 | 962,276.5 |
| | Reinforced concrete | T | 300 | 6,286.01 | 981,885.8 |
| | Anchor bolts | Stick | 4,500 | 79.20 | 79,356.4 |
| | Other engineering | $m^3$ | 7,100 | 10.13 | 8,071.9 |
| 5 | Booster substation engineering | | | | 2,647,533.9 |
| (1) | Underground substation engineering | | | | 6,547,533.9 |
| | Cubic stone open excavation | $m^3$ | 383,200 | 30.94 | 7,811,856.2 |
| | Cubic stone tunnel excavation | $m^3$ | 53,600 | 55.59 | 652,979.6 |
| | Concrete | $m^3$ | 19,500 | 430.09 | 648,386.8 |
| | Concrete spraying | $m^3$ | 4,000 | 630.86 | 562,523.4 |
| | Reinforced concrete | T | 1,200 | 6,286.01 | 797,543.2 |
| | Steel | T | 1,300 | 4,500.00 | 895,850.0 |
| | Anchor bolts | Stick | 3,100 | 105.92 | 20,328.4 |
| | Brick wall houses | $m^2$ | 1,000 | 400.00 | 90,400.0 |
| | Backfill cubic coil and stone | $m^3$ | 96,800 | 15.00 | 971,452.0 |
| | Brick wall | $m^3$ | 1,600 | 400.00 | 89,640.0 |
| | Frame | $m^3$ | 10,500 | 500.00 | 865,250.0 |
| | Other engineering | $m^3$ | 25,100 | 12.92 | 84,324.3 |
| 6 | Transportation engineering | Thousand yuan | | | 2,966,300.0 |
| | Transportation engineering | Thousand yuan | | | 1,966,300.0 |
| 7 | House building engineering | | | | 2,014,137.9 |
| | House engineering | Thousand yuan | 906,277.2 | 1.56% | 9,214,137.9 |
| 8 | Other engineering | | | | 6,536,251.1 |
| | Other engineering | Thousand yuan | 906,277.2 | 4% | 5,836,251.1 |

| Ser. No. | Equipment names and specification | Unit | Quantity | Total price (thousand yuan) | |
|---|---|---|---|---|---|
| | | | | Equipment expense | Installation expense |
| | Part 2: Electromechanical equipment and installation engineering | | | 371,467.7 | 998,727.7 |
| | Electromechanical equipment and installation engineering | set | 1 | 371,467.7 | 998,727.7 |

## Budget of Metal Structural Equipment and Installation Engineering

| Ser. No. | Equipment names and specification | Unit | Quantity | Unit price (thousand yuan) | | Total price (thousand yuan) | |
|---|---|---|---|---|---|---|---|
| | | | | Equipment expense | Installation expense | Equipment expense | Installation expense |
| | Part 3: Metal structural equipment and installation engineering | | | | | 8,736,433.8 | 6,025,373.1 |
| 1 | Flood discharge engineering | | | | | 2,016,104.3 | 602,277.7 |
| (1) | Spillway engineering | | | | | 88,278.1 | 9,812.9 |
| i | Gate and embedment | | | | | 75,393.5 | 7,748.1 |
| | 3 operation (arc) gates | T | 600 | 75,000.0 | 9,563.2 | 94,500.0 | 9,573.8 |
| | Gate embedment | T | 90 | 50,000,0 | 19,370.8 | 7,450.0 | 8,174.3 |
| | Freight and miscellaneous expense (8.96%) | | | | | 50,443.5 | |
| ii | Headstock gear | Set | | | | 20,886.2 | 964.8 |
| | Headstock gear 30T | Set | 3 | 2,700,000.0 | 216,120.0 | 7,810.0 | 5,064.8 |
| | Freight and miscellaneous expense (8.96%) | | | | | 2,072.6 | |
| (2) | Unloading cave | | | | | 9,828.2 | 1,464.8 |
| i | Gate and embedment | | | | | 7,082.4 | 1,353.8 |
| | 1 operation (arc) gate | T | 400 | 75,000.0 | 11,560.0 | 3,000.0 | 464.2 |
| | Gate and embedment | T | 100 | 50,000.0 | 20,090.0 | 500.0 | 200.9 |
| | Freight and miscellaneous expense (8.96%) | | | | | 582.4 | |
| ii | Headstock gear | | | | | 2,755.8 | 111.0 |
| | Headstock gear 80T | Set | 1 | 7,200,000.0 | 435,930.0 | 720.0 | 43.6 |
| | Headstock gear 200T | Set | 1 | 18,000,000.0 | 673,970.0 | 1,800.0 | 67.4 |
| | Freight and miscellaneous expense (8.96%) | | | | | 225.8 | |
| 2 | Water diversion engineering | | | | | 11,800.3 | 22,534.4 |
| (1) | Gate equipment and installation | | | | | 3,987.9 | 921.4 |
| | Gate and embedment | | | | | 3,987.9 | 921.4 |
| | 3 speed (plain) gates | T | 300 | 60,000.0 | 11,048.4 | 1,800.0 | 331.5 |
| | Gate embedment | T | 120 | 50,000.0 | 19,518.8 | 600.0 | 234.2 |
| | 1 bulkhead (plain) gate | T | 110 | 60,000.0 | 11,048.4 | 660.0 | 121.5 |
| | Gate embedment | T | 120 | 50,000.0 | 19,518.8 | 600.0 | 234.2 |
| | Freight and miscellaneous expense (8.96%) | | | | | 327.9 | |
| (2) | Headstock equipment and installation | | | | | 5,687.7 | 749.5 |
| i | Headstock equipment | | | | | 5,687.7 | 258.1 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Headstock gear 50T | Set | 3 | 4,500,000.0 | 2,690,022.2 | 1,350.0 | 80.7 |
| | Headstock gear 350T | Set | 1 | 31,500,000.0 | 1,338,051.5 | 3,150.0 | 133.8 |
| | Headstock gear 80T | Set | 1 | 7,200,000.0 | 435,932.1 | 720.0 | 43.6 |
| | Freight and miscellaneous expense (8.96%) | | | | | 467.7 | |
| ii | Equipment rail | | | | | | 491.4 |
| | Rail | Double 10m | 8 | | 258,870.2 | | 206.9 |
| | Rail | Double 10m | 11 | | 258,870.2 | | 284.5 |
| | Freight and miscellaneous expense (8.96%) | | | | | | |
| (3) | Garbage discharge equipment / installation | | | | | 2,124.7 | 428.2 |
| i | Drain grating | | | | | 2,124.7 | 428.2 |
| | Drain grate | T | 195 | 50,000.0 | 3,759.6 | 975.0 | 73.3 |
| | Grating slot | T | 195 | 50,000.0 | 18,201.5 | 975.0 | 354.9 |
| | Freight and miscellaneous expense (8.96%) | | | | | 174.7 | |
| (4) | Steel penstock fabrication and installation | | | | | | 20,435.3 |
| i | Steel pipe | | | | | | 20,435.3 |
| | Fabrication / installation | T | 2,150 | | 95,048.1 | 2,386.2 | 20,435.3 |
| 3 | Power generation plant engineering | | | | | 1,801.7 | 561.0 |
| (1) | Gate equipment and installation | | | | | | 413.9 |
| i | Gate embedment | | | | | 1,801.7 | 413.9 |
| | 4 gates | T | 120 | 60,000.0 | 10,272.7 | 720.0 | 123.3 |
| | Gate embedment | T | 150 | 50,000.0 | 19,370.8 | 750.0 | 290.6 |
| | Freight and miscellaneous expense (8.96%) | | | | | 131.7 | |
| (2) | Headstock equipment and installation | | | | | 784.5 | 43.6 |
| i | Headstock equipment | | | | | 784.5 | 43.6 |
| | Headstock gear 80T | Set | 1 | 7,200,000.0 | 435,932.1 | 720.0 | 43.6 |
| | Freight and miscellaneous expense (8.96%) | | | | | 64.5 | |
| ii | Equipment rail | | | | | | 103.5 |
| | Rail | Double 10m | 4 | | 258,670.2 | | 103.5 |
| | Freight and miscellaneous expense (8.96%) | | | | | | |
| 4 | Interests for equipment preservation loan | | | | | 6,143.0 | |

## Budget of Temporary Engineering

| Ser. No. | Name of engineering or expense | Unit | Quantity | Unit price (yuan) | Total price (thousand yuan) |
|---|---|---|---|---|---|
| | Part 4: Temporary engineering | | | | 291,368.1 |
| | Water diversion engineering | | | | 151,529.5 |
| (1) | Diversion tunnel engineering | | | | 127,443.5 |
| i | Diversion tunnel #1 | | | | |
| | Cubic soil and stone excavation | $m^3$ | 34,258 | 18.06 | 618.7 |
| | Cubic stone tunnel excavation | $m^3$ | 144,990 | 64.04 | 9,285.2 |
| | Concrete | $m^3$ | 9,000 | 400.00 | 3,600.0 |
| | Concrete pouring and placement | $m^3$ | 8,845 | 509.76 | 4,508.8 |
| | Backfill grouting | $m^3$ | 941 | 58.85 | 55.4 |
| | Reinforced concrete | T | 1,160 | 6,286.01 | 7,291.8 |
| | Caulking concrete | $m^3$ | 11,000 | 450.00 | 4,950.0 |
| | Other engineering | Thousand yuan | 30,309.9 | 10% | 3,031.0 |
| ii | Diversion tunnel #2 | | | | 94,102.6 |
| | Cubic soil and stone excavation | $m^3$ | 198,622 | 18.06 | 3,587.1 |
| | Cubic stone tunnel excavation | $m^3$ | 299,012 | 64.04 | 19,148.7 |
| | Concrete | $m^3$ | 16,123 | 400.00 | 6,449.2 |
| | Concrete pouring and placement | $m^3$ | 57,913 | 509.76 | 29,521.7 |
| | Backfill grouting | $m^3$ | 16,077 | 58.85 | 946.1 |
| | Reinforced concrete | T | 3,332 | 6,286.01 | 20,945.0 |
| | Caulking concrete | $m^3$ | 11,000 | 450.00 | 4,950.0 |
| | Other engineering | Thousand yuan | 85,547.8 | 10% | 8,554.8 |
| (2) | Cofferdam works | | | | 18,688.3 |
| i | Upstream cofferdam | | | | 12,135.5 |
| | Mixed soil and stone cofferdam filling | $m^3$ | 86,589 | 56.00 | 4,849.0 |
| | Concrete | $m^3$ | 7,960 | 350.00 | 2,786.0 |
| | Concrete impermeable wall | $m^3$ | 1,194 | 750.00 | 895.5 |
| | Reinforced concrete | T | 398 | 6,286.01 | 2,501.8 |
| | Other engineering | Thousand yuan | 11,032.3 | 10% | 1,103.2 |
| ii | Downstream cofferdam | | | | 6,552.8 |
| | Concrete | $m^3$ | 4,692 | 350.00 | 1,642.2 |
| | Soil and stone piling | $m^3$ | 37,614 | 56.00 | 2,106.4 |
| | Impermeable wall | $m^3$ | 975 | 750.00 | 731.3 |
| | Reinforced concrete | T | 235 | 6,286.01 | 1,477.2 |
| | Other engineering | Thousand yuan | 5,957.1 | 10% | 595.7 |

| | | | | | |
|---|---|---|---|---|---|
| (3) | Metal structure fabrication and installation | | | | 5,397.7 |
| i | Gate and embedment | | | | 5,397.7 |
| | Gate | T | 350 | 7,010.00 | 2,453.5 |
| | Gate embedment | T | 350 | 7,010.00 | 2,453.5 |
| | Other | Thousand yuan | 4,907.0 | 10% | 490.7 |
| 2 | Traffic engineering | | | | 4,800.0 |
| (2) | Roads | | | | 4,800.0 |
| i | Roads | Km | 8 | 600,000.00 | 4,800.0 |
| ii | Other | Thousand yuan | | | 47,071.6 |
| 3 | House building engineering | | | | 47,071.6 |
| (2) | Office, living and cultural welfare buildings | | | | 47,071.6 |
| 4 | Power supply cables engineering | | | | 6,500.0 |
| (1) | Power supply cables | Km | 50 | 130,000.00 | 6,500.0 |
| 5 | Other temporary engineering | Thousand yuan | 1,357,783.0 | 6% | 81,467.0 |

Investment in Various Years (in thousand yuan)

| Engineering and expenses | Total investment | Investment in various years | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1st yr | 2nd yr | 3rd yr | 4th yr | 5th yr | 6th yr | 7th yr | 8th yr |
| Part 1: Building engineering | 1,022,970 | 40,920 | 51,150 | 102,300 | 255,740 | 236,430 | 204,590 | 61,380 | 20,460 |
| Part 2: Electromechanical equipment and installation engineering | 470,200 | | | | | 164,570 | 211,590 | 94,040 | |
| Part 3: Metal structure equipment and installation engineering | 61,310 | | | | 11,130 | 37,080 | 11,740 | 1,360 | |
| Part 4: Temporary engineering | 291,370 | 5,830 | 72,840 | 101,980 | 58,270 | 29,140 | 14,570 | 8,740 | |
| Part 5: Remuneration expense for reservoir inundation handling | 133,220 | | | 19,980 | 33,310 | 33,310 | 26,640 | 19,980 | |
| Part 6: Other expenses | 276,410 | 41,400 | 55,280 | 69,100 | 55,280 | 27,650 | 13,820 | 13,820 | |
| Total of parts 1-6 | 2,255,970 | 88,210 | 179,270 | 293,360 | 413,730 | 578,170 | 282,960 | 199,820 | 20,460 |
| Basic reserve funds | 225,600 | 8,820 | 17,930 | 29,340 | 41,370 | 57,820 | 48,300 | 19,980 | 2,040 |
| Price difference reserve funds | 702,540 | 5,290 | 22,160 | 56,040 | 108,590 | 195,550 | 202,130 | 100,630 | 12,150 |
| Reserve funds in preparing period | | | | | | | | | |
| Price difference reserve funds in construction period | 702,540 | 5,200 | 22,160 | 56,040 | 108,590 | 195,550 | 202,130 | 100,630 | 12,150 |
| Interest payment for loans in construction period | 1,149,480 | 4,000 | 17,010 | 42,270 | 83,800 | 147,640 | 225,250 | 291,550 | 337,950 |
| Static total investment | 2,481,560 | 97,030 | 197,200 | 322,700 | 455,100 | 635,980 | 531,250 | 219,800 | 22,510 |
| Total investment | 4,333,560 | 106,320 | 266,360 | 421,000 | 647,490 | 979,180 | 958,630 | 811,980 | 372,610 |
| Static total investment in period from work start to the date 1st generator begins generating powers | 2,459,060 | 97,030 | 197,200 | 322,700 | 455,100 | 635,980 | 531,250 | 219,800 | |
| Total investment in period from work start to the date 1st generator begins generating powers | 3,960,950 | 106,320 | 236,360 | 421,000 | 647,490 | 979,180 | 958,630 | 611,980 | |

## IV. Tentative Plan for Fund Raising

Static total investment for the Jinshajiang Stations is RMB 316.5 billion, price difference reserve funds RMB 60,895 million, while interest payment for loans during construction period will be RMB 16,420.8 if interest rate is 10%, or RMB 1,149.46 million if interest rate is 7%.

In view of provincial situation in Yunnan, characteristics in the location of the Jinshajiang Station, and current national investment policies, investment intentions

of Electric Power Bureau of Yunnan Province toward the Jinshajiang Station are: investment in 30% by Yunnan Province, and the rest 70% will tentatively be invested by National Government. With the above proportions, Yunnan Province will invest RMB 90 billion and National Government will invest RMB 226.5 billion.

Since the Jinshajiang Stations are located at northwestern Yunnan where main reserves of coals are distributed, they can coordinate with the nearby thermal power stations to form a large scale power base, so as to transport powers toward southern China. Therefore, the above mentioned 70% part of investment tentatively shouldered by national government could be considered by soliciting relevant provinces in southern China as shareholders or creditors.

# Chapter 12 Preliminary Economic Evaluation

## I. Preliminary National Economic Evaluation

National economic evaluation is based on the principle of reasonable allocation of resources and examines benefits and costs of the project from the viewpoint of the whole country.

When the Jinshajiang one-reservoir 8-level Hydropower Station was under economic evaluation, an alternative thermal power station of proper scale, which can fulfill the same power system requirement, was used. In calculations, the investment expenses of the Jinshajiang Station were regarded as costs, while the investment expenses of the alternative thermal power station as benefits so as to evaluate economic rationales of the Jinshajiang Station.

1. Hydropower

(1) Engineering investment

Total construction period of the Jinshajinag Station is 6.5 years, with planning period at 1.5 years. According to the requirement in *Economic Evaluation Method and Parameters for Construction Projects*, 2nd ed. published by National Planning Commission and Ministry of Construction, basic reserve funds and price difference reserve funds were considered.

(2) Operation expenses

Operation expenses of the Jinshajinag Station are operational costs, in which big repair expenses occupy the largest ratios relative to other expense. In national economic evaluation, annual operation expenses of the hydropower station can be estimated as 1% of total engineering investment.

(3) Production and operation period

The production and operation period for the Jinshajiang Station is in general 20-30 years. Calculated according to regulations of “Categorical Depreciation Years of Fixed Assets” published by Yunnan Power Industry Bureau, production and operation period of the Station is 24 years.

2. The Alternative Power Station

The Jinshajiang Station is located at coal and hydropower base in northwestern Yunnan. An alternative thermal power station will be used to evaluate economically the Jinshajiang Station.

(1) Scale and benefits of the alternative power station

In ascertaining scale and benefits of alternative power station, the principle of "whether or not" the Jinshajiang Station can fulfill the same load demands is based.

If we take the difference of the necessary capacity for the "whether or not" Jinshajiang Station and further consider such characteristics as power utilization of the thermal power station, then multiply it by 1.1, we will get the power generation capacity of the alternative thermal power station. The presently planned additional power generation set has single-generator capacity, in general, as 700 thousand kw. Therefore, the generation capacity of the alternative thermal power station is 6 X 700 thousand kw.

Taking the power output difference of "whether or not" the Jinshajiang Station being included in the system, and further considering power utilization situations of thermal power stations, then multiplying them by 1.05, we will get the annual power output of the alternative power station. By calculations, the annual power output of the additional alternative thermal power station is 29,096.7 thousand kw.

(1) Relevant indicators of the alternative power station

Taking into account situations of the comparable design-stage thermal power station in Yunnan, dynamic investment unit kw power construction price of the thermal power station is taken as RMB 3,500/kw, standard coal consumption as 360g/kw, and standard coal price as RMB 180/T. By regulations, depreciation years for thermal power stations are 12 years, so that, for convenience of calculation, the power station will be reinstalled, in original values, after 12 years.

(2) Operation expenses

Other than fuel expenses, a thermal power station also incurs operation expenses, in which big repair expenses occupy the largest ratios while those of the other expenses are relatively small. By economic calculations, operation expenses of thermal power stations can be estimated as 3% of total investment of the engineering.

3. National Economic Evaluation

The construction and production/operation periods of both Jinshajiang Hydropower Station and the alternative thermal power station are long, so that their calculated periods in national economic evaluation were taken as 32 years. Considering systematic efficiency and calculating based on same period inputs of thermal and hydro power stations, beginning of the 1$^{st}$ year of Jinshajiang Station construction was taken as the base year for calculations.

If social discount rate is 12%, then net current economic value is RMB 88,140

million, in which current value of investment for the Jinshajiang Station is RMB 79.1 billion, current value of operation expenses is RMB 11,125.6 million, while current value of investment for the thermal power station is RMB 82,058.8 million, current value of operation expenses is RMB 40,334 million and current value of fuel coal expenses is RMB 50,890 million.

The rate of economic internal returns is 20.3%, which is larger than social discount rate. This justifies the feasibility of constructing the Jinshajiang Station according to national economic evaluation.

4. Aggregate Analysis

The Jinshajiang One-reservoir 8-level Hydropower Station is located at northwestern Yunnan which is the area of the most abundant coal reserves in Yunnan Province. The 100 km circular area surrounding Longpan Station include such large scale coal bases as Lijiang, Yungsheng, Xianggelila, Yulong, Diching and Baoshan which will also be bases for thermal power production. At present, hydropower in the area are relatively few. Thus, the Jinshajiang One-reservoir 8-level Hydropower Station will be an important large scale hydropower station. Construction of the Jinshajiang Station will relatively properly solve the problem of shortage in power supply and peak regulations. At the same time, it will also facilitate a reasonable adjustment in proportions between hydro and thermal powers, realizing the strategic goals of transporting powers from west to east and transforming resource advantages into economic advantages.

The reservoir at Longpan Hydropower Station is relatively better in its regulating functions. In the short run, it can compensate for deficiency in hydropower stations on Hongshuei River while, in the long run, it will compensate for shortages in hydropower stations at Ahai and Liangjiaren. Therefore, the Longpan Station will also have compensating effect as well as facilitating effects for accelerating development in watershed of Jinshajiang.

It is obvious from national economic evaluation on the Jinshajiang Station that: in average the rates of internal economic returns from various plans are larger than social discount rate so that the Jinshajiang One-reservoir 8-level Hydropower Station is feasible as justified by national economic evaluation and possesses a certain risk resistant capabilities.

Summing up all the above, construction of the Jinshajiang One-reservoir 8-level Hydropower Station is economically reasonable and can relatively efficiently facilitate national economic development, so it is better to build it as soon as possible.

## II. Preliminary Financial Evaluation

Financial evaluation was proceeding according to *Economic Evaluation Methods*

*and Parameters for Construction Projects*, 2nd ed. and present fiscal and taxation related systems.

1. Engineering Progress and Estimates of Fixed Asset Investment

The engineering of Jinshajiang One-reservoir 8-level Hydropower Station, in capacity of 63.3 million kw, has dynamic total investment at RMB 316.5 billion.

2. Fund Raising

In fulfilling the requirement of bank loans, investors generally have to infuse self-owned funds in about 30% of total investment while the rest of the investment can be settled by way of loans and issuance of bonds.

The Jinshajiang Station is at the stage of starting to construct, such that the investors and sources of investment are still unclear. Therefore, all investment, during the process of financial evaluation, will be estimated based on interest rate for electric power loans and repayment durations as published by national government.

3. Parameters of Related Finance and Taxations

(1) Loans

Construction of the Jinshajiang One-reservoir 8-level Hydropower Station is a large scale engineering and, therefore, the loan repayment period is 12 years as required by loan regulations, i.e., the period beginning from the date the first loan is granted until the date when all loans have been repaid is 12 years. According to regulations in basic construction loans by People's Bank of China, annual interest rate is 11.16% and the unpaid interests of the past year will be charged with more interests.

(2) Value-added tax and surcharges

The value-added tax will be one not included in the calculated prices with a rate of 17%. Surcharges of city maintenance and construction as well as education expenses will be subject to comparable proportions with rates at 5% and 2% respectively.

(3) Income tax

Income tax is levied at 33% of gross profits while loan repayment will be done out of after-tax profits.

4. Calculation of Earnings

(1) Production/operation period

According to regulations in *Fixed Asset categorization and Depreciation Periods* published by Electric Power Industry Bureau of Yunnan Province, the depreciation

period for power generating equipment is 12 years and that for big dams of hydropower stations is 45 years. As a consequence of calculation and analysis, the aggregate depreciation period of the Jinshajiang One-reservoir 8-level Hydropower Station is designated as 25 years which means, taking the 1 year of preliminary operation in construction period into account, its production/operation period is 24 years.

(2) Operation costs

Operation costs include material expenses, wage and welfare, big repair expenses, reservoir maintenance expenses and other expenses. Cost calculation has been referred to related regulations and statistics in recent years and, thus, the operation costs in regular operation period of the power station are RMB 655.06 million.

(3) Depreciation and amortization

The aggregate depreciation period of the power station is 25 years, which means, temporarily not counting power station residual values, the depreciation rate is 4%.

Invisible and deferred assets will be amortized in 10 years.

# Organization's Credit Code Certificate

No. 0014499363

Code: G10530111015599990J

Name: Yunnan Jialixiang Hydraulic and Hydropower Development Co., Ltd.

Address: 336 Jinzhi Rd., Guandu District, Kunming City, Yunnan Province

Valid until 26 August 2017

Issued by Credit Reference Centre, The People's Bank of China

# Permission for Opening Account

Permission No.: J7310015599901 Ser. No.: 7310-00260627

It has been verified that Yunnan Jialixiang Hydraulic and Hydropower Development Co., Ltd. fulfills conditions for opening account and is permitted to open a basic deposit account.

Legal Representative (organization's chief): Huang Chengtsai

Bank of Account: Operation Office, Operation Department, Yunnan Province Branch, China Industry and Business Bank

Account No.: 2502010339200131458

Issuance Organization (Seal)

9 July 2010

# Organization's Code Certificate

## People's Republic of China

Code: 55777379-9

Name of Organization: Yunnan Jialixiang Hydraulic and Hydropower Development Co., Ltd.

Type of Organization: Enterprise Legal Person
Legal representative: Huang Chengtsai
Address: 336 Jinzhi Rd., Guandu District, Kunming City

Period of validation: From 3 June 2014 until 2 June 2018

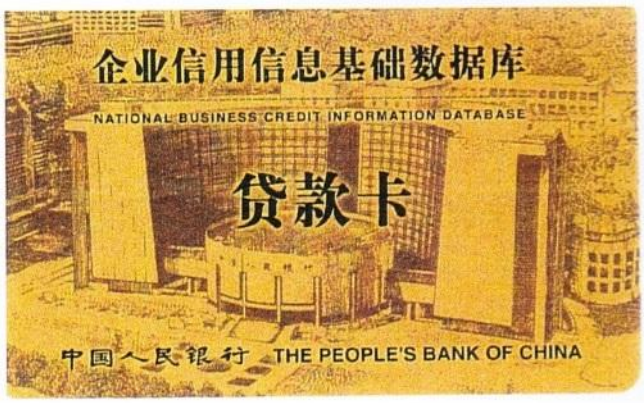
Issued by Quality and Technology Monitoring Bureau, Yunnan Province

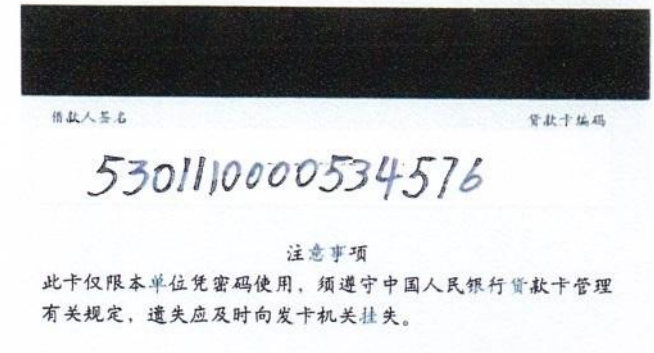
Registration No.: SC 530000-086561

Note:

1. The organization's code certificate of the People's Republic of China is an unchanging legal coding symbol and certificate for legal coding symbol of the organization which is divided into the original and the copy.
2. "Organization's code certificate of the People's Republic of China" is not permitted for renting, lending, fraud, transfer, forgery, falsification or sale illegally.
3. When the registered items in the "organization's code certificate of the People's Republic of China" have changed, it is obliged to apply to issuing agency for correction.
4. Each organization concerned is obliged to be reviewed annually by issuing agency in accord with relevant regulations.
5. When the organization concerned has been written off or rescinded, it is obliged to apply to issuing agency for registration write-off and return all code certificates.

National Quality Monitoring, Examination and Quarantine Agency, the People's Republic of China.




(Copy of loan card)



(Copy of ID card of organization’s chief)


(copy of the organization’s IC card)

# Operation Certificate

Registration No.: 530000100048109

Name: Yunnan Jialixiang Hydraulic and Hydropower Development Co., Ltd.

Category: Limited liability company funded by natural person(s)

Address: 336 Jinzhi Rd., Guandu District, Kunming City, Yunnan Province

Legal Representative: Huang Chengtsai

Registered Capital: RMB 11.68 million

Date established: 8 July 2010

Period of Operation: from 8 July 2010 until 8 July 2020

Scope of Operation: investment in hydraulic and hydropower, traffic energy; sales in mechanical electric equipment, electric wires and cables, hardware and electric materials, construction materials, car accessories (items permitted by legal authorities and operations started only with permission from relevant authorities)

Issued by Industry and Business Administrative Management Agency, Yunnan Province

8 July 2010

# Tax Registration Certificate

(copy)

YLT 530171557773799

Name of Tax Payer: Yunnan Jialixiang Hydraulic and Hydropower Development Co., Ltd.

Legal Representative (organization's chief): Huang Chengtsai

Address: 336 Jinzhi Rd., Guandu District, Kunming City, Yunnan Province

Registered Category: private limited liability company

Scope of Operation: investment in hydraulic and hydropower, traffic energy; sales in mechanical electric equipment, electric wires and cables, hardware and electric materials, construction materials, car accessories

Establishment Permission Agency: Industry and Business Agency, Yunnan Province

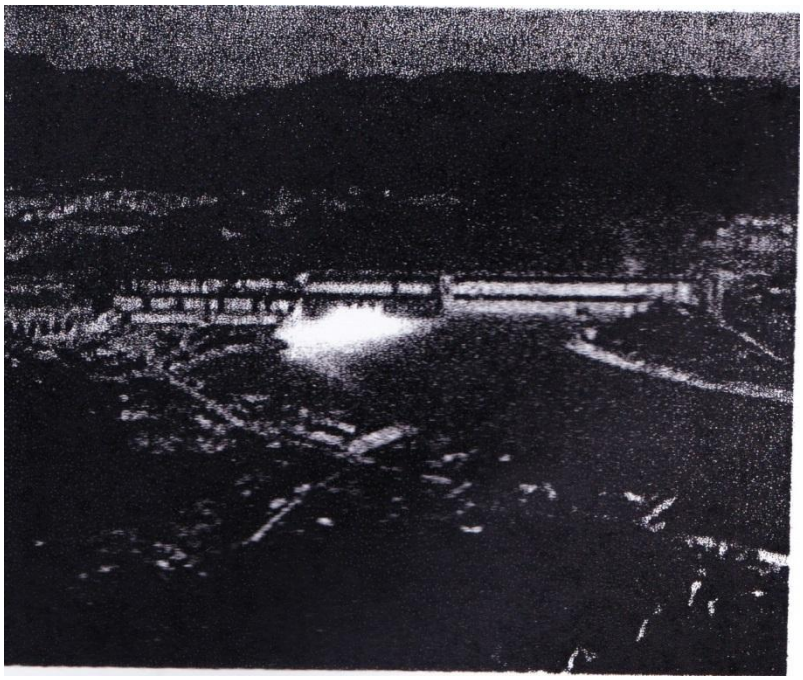
Withdrawal obligation: ascertained legally

Issued by District Taxation Bureau, Guandu District, Kunming City

8 July 2010

# One-reservoir Eight-level Hydropower Station at Midstream Jinshajiang, Lijiang City

## Project Information



Yunnan Wenjie Dacheng Traffic Energy Development Co., Ltd.

October 2010

# Project Compilation of Yunnan Jialixiang Hydraulic and Hydropower Development Co., Ltd.

Head Company: Yunnan Jialixiang Hydraulic and Hydropower Development Co., Ltd.

Head Project: Lijiang One-reservoir Eight-level Hydropower Station, Yunnan Province

Legal Representative: Huang Chengtsai

Total Money Value of Compiled Project: RMB 112.5 billion

Total Money Value of Registered Investment: RMB 130.5 billion (based on ratification in 2012, there is an increase of 6% in 2 years, 3% for each year, and an unpredictable safety coefficient of 10% is added so that a total increase of 16%)

Date of registration: 24 July 2014

# Bank-Enterprise Cooperative Project/Legal Person Verification Registration

## Head Company: Yunnan Jialixiang Hydraulic and Hydropower Development Co., Ltd.

Registered date: 24 July 2014

| Ser. No. | Company Name | Name of project | Doc. of Ratification | Registered funds (billion yuan) | Ratified funds (billion yuan) | province | Bank account No. of the company | Tel. No. | Legal Repre-sentative | Note |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Yunnan Jialixiang Hydraulic and Hydropower Development Co., Ltd. | One-reservoir Eight-level Hydropower Station at Midstream Jinshajiang, Lijiang City | NDCE (2009) 367, YDRE (2010) 27/28, EM (2010) 66 | 116.8 | 130.5 | Yunnan | Yunnan Province Branch of China Industry and Business Bank account No.: 2501010339200131458 | | Huang Chengtsai | |
| Total | | | | | 130.5 | | | | | |

Note: 1. Unpredictable safety coefficient is 10%. 2. Price and wage inflation rate is 6% (3% X 2).

**Yunnan Jialixiang Hydraulic and Hydropower Development Co., Ltd.**

# Authorization Letter of Loan Application

To: Mr. Chen Tsunhuang, chairman of Taipei Dongxinag Technology Co., Ltd.

1. Mr. Chen Tsunhuang, chairman of Taipei Dongxinag Technology Co., Ltd., has been authorized to represent our company in handling the engineering project ratified by Yunnan provincial government.
   Title of the Project:
   Construction works on three hydropower stations undertaken by Yunnan Jialixiang Hydraulic and Hydropower Development Co., Ltd., Yunnan Province, with total investment of RMB 130.5 billion.
2. Mr. Chen Tsunhuang, chairman of Taipei Dongxiang Technology Co., Ltd., has been fully authorized, as decided in our company's board of directors, to undertake loan application for our company and pay the expenses simultaneously along with progress of the engineering.
3. Two copies of loan application for our company have been attached as appendices.

Yunnan Jialixiang Hydraulic and Hydropower Development Co., Ltd. (company seal)

Legal representative: (signature and seal of legal person)

6 September 2014

# Document of National Development and Reform Commission

DRE [2009] 367

## Official Reply to Jinshajiang Midstream One-reservoir Eight-level Hydropower Station of Lijiang City

To: Yunnan Provincial Development and Reform Commission

We have received your request for instruction on *Project of Jinshajiang Midstream One-reservoir Eight-level Hydropower Station, Lijiang City, Yunnan Province* and *Study Report on Feasibility*. We are now replying to the above-mentioned feasibility report and instructing on the approved items of constructing hydropower station as in the following:

1. For the sake of cultivating water energy resources in watershed of Jinshajiang so as to increase power supply in power grid of Yunnan and southern China, raise Yunnan's power utilization, as well as transform local resource advantages into economic advantages, by fulfilling the demand for distributing power from west to east, and greatly facilitate local economic and social development in Yunnan, Lijiang and Diching Canton, we agree to pursue the engineering of constructing Jinshajiang Midstream One-reservoir Eight-level Hydropower Station, Lijiang City.
2. Power generation capacity of the One-reservoir Eight-level Hydropower Station is 63.3 million kw. As for each station at Longpan, Liangjiaren, Liyuan, Ahai, Jinan Bridge, Longkaikou, Ludila and Guanyinyan, they shall be examined by experts appointed by national hydraulic and electric power department on the site and decided, based on the theoretical figures in the feasibility report, how power generation capacities are allocated among them and when they shall be built.

   Total investment in the one-reservoir eight-level hydropower station is RMB 31.65 billion and annual power production is 29,096.7 million kwh.
3. The Jinshajiang Midstream One-reservoir Eight-level Hydropower Station is composed of a water-holding big dam, water-holding buildings for diverting power generation system and switching stations, as well as navigation buildings. The water-holding big dam is a roller compacted concrete gravity dam, with maximum height at 222.2 m and minimum height at 113 m. Normal water levels of the reservoir are different for each level of power station which must be strictly controlled, taking flood effects in high-tide seasons into consideration and doing the best preparation works.

The areas impacted by reservoir inundation and land acquisition for core engineering construction involve Gucheng District and Renho District of Lijiang City, Yulong County, Ninglang County, Yungsheng County, Huaping County, Xianggelila County of Diching Canton, Dechin County, Hoching County of Dali Canton, Binchuan County, Yungren County of Chuxiung Canton and Dayao County. Altogether there are 4 cities/cantons and 12 counties/districts in which 160 thousand acres of farmlands in Longpan Power Station site are inundated and 100 thousand people migrate, 23 acres of farmlands in Liangjiaren Power Station site are inundated and 10 people migrate (both farmlands and migrants are in Xianggelila), 2,850 acres of farmlands in Liyuan Power station site and 1,300 people migrate, 5,000 acres of farmlands in Ahai Power Station site are inundated and 2,400 people migrate (only Yulong County and Ninglang County are involved), 25.142 $m^2$ of areas in Jinan Bridge Power Station site are inundated and 2,479 people migrate, 4,400 acres of farmlands in Longkaikou Power Station site are inundated and 2,000 people migrate (Gucheng District of Lijiang City, Yungsheng County and Hoching County are involved), 31,300 acres of farmlands in Ludila Power Station site are inundated and 16,900 people migrate (Yungsheng County, Hoching County and Binchuan County are involved), as well as 14,100 acres of farmlands in Guanyinyan Power Station site are inundated and 8,810 people migrate (Huaping County, Yungsheng County, Yungren County and Dayao County are involved). Altogether there are 73,650 acres of farmlands and 25.142 $m^2$ land area in One-reservoir Eight-level Hydropower Station site are inundated and 133,899 people migrate.

4. Yunnan provincial commission and government must strictly implement managing procedure on national construction project with respect to the management system of the Hydropower Station, engage in good organizing works and leadership on migration so as not to harm the benefit of mass population, assure at any time safety of construction, as well as utilize reasonably water energy resources of Jinshajiang so as to consolidate cultivations in the Jinshajiang One-reservoir Eight-level Hydropower Station of Lijiang City and spread effectively social benefits of the engineering.
5. With regards to sources of construction funds, fund raising intensity must be strengthened and effective funds in the society must be encouraged to put into shareholding investment. Shortage part in finance shall be solved by incurring loans from Bank of China, China Industrial and Commercial Bank, China Agricultural Bank, China Construction Bank and National Development

Bank.

Keywords: hydropower, project, standard, official reply

Copies delivered to: Ministry of National Land Resources, Ministry of Hydrology, National Environmental Protection Agency, Electric Power Monitoring Commission, People's Government of Yunnan Province, China Industrial and Commercial Bank, China Agricultural Bank, China Bank, China Construction Bank, National Development Bank, China International Engineering Consulting Co., and China Hydropower Engineering Advisory Group Co.

Office of National Development and Reform Commission

10 September 2009

# Document of Yunnan Province Development and Reform Commission

YDRE [2010] No. 28

## Official Reply to Feasibility Study Report on Jinshajiang Midstream One-reservoir Eight-level Hydropower Station

To: Lijiang City Development and Reform Commission

*The Development Plan concerning Jinshajiang Midstream One-reservoir Eight-level Hydropower Station* submitted by Yunnan provincial government, in 18 May 2007, to National Development and Reform Commission has been replied by the Commission with respect to its feasibility study report and transferred to us. We are now officially replying and ask relevant agencies to coordinate properly with the plan. The Provincial Commission and Government request that the construction of Jinshajiang Midstream One-reservoir Eight-level Hydropower Station shall be completed and ready to produce power during the period from 2009 to 2015 so as to ameliorate problems of power shortage in areas bordering the Province and increase intensity of power distribution from west to east. The reply is as follows.

1. Total power generation capacity of the Jinshajiang Midstream One-reservoir Eight-level Hydropower Station of Lijiang City is 63.30 million kw, annual power output is 290,967 million kwh and total investment is RMB 316.5 billion. At the Longpan Reservoir and Power Station, total water storage capacity is 39.88 billion $m^3$, regulating capacity 29,227 million $m^3$, height of dam 222.2 m, length of dam 318 m, 160 thousand acres of farmlands are inundated in which 100 thousand acres in Lijiang City, 60 thousand acres in Diching Canton, as well as 100 thousand people migrated in which 60 thousand in Lijiang City and 40 thousand in Diching Canton. Construction period of Longpan Power Station is 3 years. At Liangjiaren Power Station, total water storage capacity is 254.3 million $m^3$, regulating capacity 205.43 million $m^3$, height of dam 99.5 m, length of dam 180 m, 23 acres of farmlands inundated, 10 people migrated (both farmlands and migrants are in Xianggelila), and construction period is 2 years. At Liyuan Power Station, total water storage capacity is 2,691 million $m^3$, regulating capacity 2,400

million $m^3$, height of dam 155 m, length of dam 269 m, 2,850 acres of farmlands inundated , 2,300 people migrated, and construction period is 2 years. At Ahai Power Station, total water storage capacity is 2.54 billion $m^3$, regulating capacity 2,656 million $m^3$, height of dam 139 m, length of dam 256 m, 5,000 acres of farmlands inundated, 2,400 people migrated, and construction period is 2.5 years. At Jinan Bridge Power Station, total water storage capacity is 2,847 million $m^3$, regulating capacity 2,656 million $m^3$, height of dam 160 m, length of dam 400 m, 25.142 $m^2$ of areas inundated in which land area 17.06 $m^2$ and water area 8.082 $m^2$, 2,491 acres of farmlands inundated, 755 acres of garden lands, 8,777 acres of forest lands, 12,988 acres of unused lands, and 429 acres of construction lands. Gucheng District of Lijiang City, Yungsheng County, Ninglang County and Yulong County, altogether 4 counties/districts, 8 *xiang*s/towns and 20 village commissions which include 65 villager groups are affected by Jinan Bridge Power Station. 2,479 people will have to migrate in which Gucheng District 962, Yungsheng County 901, Ninglang County 368, Yulong County 248 and 1,005 non-farm population will settle by themselves. Construction period of the Station is 2 years.

At Longkaikou Power Station, total water storage capacity is 2,065 million $m^3$, regulating capacity 1,990 million $m^3$, height of dam 113 m, length of dam 246, 4,400 acres of farmlands inundated, 2,000 people migrated (Gucheng District, Yungsheng County and Hoching County are involved), and construction period is 2 years. At Ludila Power Station, total water storage capacity is 6,099 million $m^3$, regulating capacity 5,400 million $m^3$, height of dam 120 m, length of dam 385 m, 31,300 acres of farmlands inundated, 16,900 people migrated (Yungsheng County, Hoching County and Binchuan County are involved), and construction period is 3 years. At Guanyinyan Power Station, total water storage capacity is 5,873 million $m^3$, regulating capacity 5,600 million $m^3$, height of dam 183 m, length of dam 398 m, 14,100 acres of farmlands inundated, 8,810 people migrated (Huaping County, Renho District, Yungren County and Dayao County are involved), and construction period is 3 years.

2. It is agreed that construction of power stations shall be carried out according to aggregate allocation plans on gated dam, pressure tunnels, surge shafts, penstocks, and surface plant reservoir. During construction, models and labels of reinforced concrete and cement shall be selected among the best, the relevant quality certificates be recorded and put into files for future checkup, and important figure data be filed.

3. Construction units, designing units, programming institutions, provincial hydraulic bureau and power monitoring department, together with power grid company and engineering monitoring agencies shall all unite and stick together, as well as shoulder the responsibility toward Party and people in accomplishing their own works.
4. The project owner shall choose the most prominent investors and get loans as soon as possible so as to start construction earlier, gain the benefits sooner and contribute to economic development for Yunnan Province.

Yunnan Province Development and Reform Commission
16 February 2010

Keywrods: hydropower station, project, feasibility report, official reply
Copies delivered to: Provincial Hydropower Bureau, Provincial Finance Bureau, Lijiang City Government, Lijiang City Development and Reform Commission, Lijiang City Hydropower Agency

Processed by Office of Yunnan Province Development and Reform Commission
16 February 2010

# Document of Yunnan Province Development and Reform Commission

YDRE [2012] No. 21

## Authorization Letter

To: Yunnan Jialixiang Hydraulic and Hydropower Development Co., Ltd.

We now authorize you the project on three power stations at Liangjiaren, Liyuan and Ahai of the Jinshajiang Midstream One-reservoir Eight-level Hydropower Station for a total investment of RMB 112.5 billion. The project will be subject to your development and construction, as well as operation and management for 50 years, after which it shall be returned unconditionally to Lijiang City Government.

Your company shall raise the funds by yourself, in any way, including soliciting foreign investment or applying for bank loans. When the funds are in place, you shall inform us immediately so as to carry on procedures of land acquisition, environmental protection, programming, construction and engineering.

The Jinshajiang Midstream One-reservoir Eight-level Hydropower Station is a middle large scale hydropower station. Therefore, it is required that you, the project owner, shall recruit a key team with powerful technology, proficient operational ability and hard spirited endurance. During construction period, it is required to abide by national and hydropower department policies, regulations and related management institutions, so as to contribute to economic development in Yunnan province as well as Lijiang City and Diching Canton.

According to requirement by Provincial Commission and Government, it is hoped that you shall solicit investment and other funds so that the construction can be started sooner and the afterward operation and management works be well prepared.

With this authorization

Yunnan Province Development and Reform Commission

26 April 2012

# Document of Yunnan Province Development and Reform Commission

YDRE [2010] No. 27

## Itemized Reply on Jinshajiang Midstream One-reservoir Eight-level Hydropower Station

To: Lijiang City Development and Reform Commission

The National Development and Reform Commission had sent us itemized reply on the Jinshajiang Midstream One-reservoir Eight-level Hydropower Station. Continuing with this spirit and studying carefully, we, the Provincial Commission, have decided to engage in itemized reply to ensure early start of construction in the Jinshajiang Midstream One-reservoir Eight-level Hydropower Station so as to facilitate regional development in the Province. The reply on related issues is as follows:

1. According to requirement by Provincial Commission and Government, the Jinshajiang Midstream One-reservoir Eight-level Hydropower Station must be constructed and start generating powers in the period from 2009 to 2015. Thus, the time is short and the task is heavy. Completion of the power station shall have invaluable facilitating effects on economic development of Lijiang City and Diching Canton.
2. Total power generation capacity of the Jinshajiang Midstream One-reservoir Eight-level Hydropower Station is 63.30 million kw with annual power output at 290,967 million kwh and total investment estimated at RMB 316.5 billion. Individual hydropower stations will not influence but will complement each other. It shall inflict people migrated and farmlands acquired so that placement of migrants especially is obliged to be carefully implemented and acquisition of farmlands to ensure protection of people's benefits, including compensation for green shoots. Every work shall be practically implemented.
3. The Jinshajiang Midstream One-reservoir Eight-level Hydropower Station is a relatively large hydropower station in the Province which sufficiently utilizes water system resources in Jinshajiang to benefit people and is another large engineering after the Three Gorge Hydropower Station. It is hoped that when the construction has started, leaders of every level will go deep into the front line to inhibit any malevolent behavior, to ensure everything is taken care by specific person, safety first, to prevent every accident which

should not happen and to strictly control quality verification of construction units in the power station.

Yunnan Province Development and Reform Commission
16 February 2010

Keywords: hydropower station, itemized project, official reply
Copies delivered to: Provincial Hydropower Bureau, Provincial Finance Bureau, Lijiang City Government, Lijiang City Development and Reform Commission, Lijiang City Hydropower Agency

# Document of Yunnan Province Environmental Protection Bureau

EM [2010] No. 66

## Reply Letter of Reviewing Opinions Concerning Environmental Impact Report for the Jinshajiang Midstream One-reservoir Eight-level Hydropower Station

To: Lijiang City Environmental Protection Agency

Your document, EM [2009] No. 12, has been received. After studying carefully, we now replying with opinions concerning the environmental impact report for the Jinshajiang Midstream One-reservoir Eight-level Hydropower Station as follows:

1. We agree, in principle, your suggestions. The Station is a multi-level hydropower station which has been itemizationally ratified by National and Provincial Development and Reform Commissions. The economic benefits from utilizing sufficiently Jinshajiang's water resources to store waters and produce powers are magnificent. Considered from the viewpoint of environmental protection, construction of the Power Station is feasible.
2. The adverse environmental impact of the engineering is difficulties in flow regulation during high tide period. Environmental protection of the engineering shall be well planned in the next stage to implement environmental protection measures and environmental monitoring programming as raised in the Report. Environmental protection measures must be focally implemented during construction period, and operation mode during high tide period must be carefully configured so as to ameliorate impact on each level of power station as best as possible.

Yunnan Province Environmental Protection Bureau

17 September 2010

# Document of Yunnan Province Homeland Resource Bureau

YHLR [2011] No. 98

## Opinions Concerning Land Usage by the Project on Linjiang City Jinshajiang Midstream One-reservoir Eight-level Hydropower Station

To: Lijiang City Homeland Resource Agency

Continuing with the spirit imbued in the document of National Development and Reform Commission, DRE [2009] No. 367, the pre-reviewed opinions concerning construction and land usage of the Jinshajiang Midstream One-reservoir Eight-level Hydropower Station have been reviewed by us. The opinions are as follows:

1. Land usage of the Jinshajiang Midstream One-reservoir Eight-level Hydropower Station is in accord with Ministry of Homeland Resources policies on the project's land usage.
2. The project's land usage will occupy farmlands of farmers so that the farmlands occupied shall be compensated in money. The criterion of compensation shall be in accord with national policies and shall not be delayed. The project owner shall adopt the method of reimbursing land usage expenses with guaranteed funds and apply for land usage certificates.
3. Land area utilized by the project shall be delimited jointly by experts from provincial agencies and experts appointed by the Ministry together with local governments.

When funds required on the part of project owner have been in place, he/she shall come to our Bureau to fulfill related procedures.

Yunnan Province Homeland Resource Bureau

3 May 2011

Keywords: hydropower, land, reviewed reply, opinions

Copies delivered to: Provincial Development and Reform Commission, Provincial Hydrology Bureau, Hydropower Bureau, Lijiang City Government, Lijiang City Development and Reform Commission

Prepared by Office of Yunnan Province Homeland Resource Bureau

# Agreement on Grid Connection for the Jinshajiang Midstream One-reservoir Eight-level Hydropower Station

Agreement Parties:

Party A: Yunnan Jialixiang Hydraulic and Hydropower Development Co., Ltd.

Party B: Yunnan Power Grid Co.

Preliminary works for the Jinshajiang Midstream One-reservoir Eight-level Hydropower Station have been basically completed and the construction is going to start right away. Parties A and B have been negotiating on grid connection with respect to the Jinshajiang Midstream One-reservoir Eight-level Hydropower Station and Party B has agreed request for grid connection by Party A. The following agreement articles have been drafted for both parties to implement accordingly.

1. Party B agrees that at the date the Jinshajiang Midstream One-reservoir Eight-level Hydropower Station has been completed it shall be connected with Yunnan Power Grid Co. into synchronized operation.
2. Party B agrees that the Jinshajiang Midstream One-reservoir Eight-level Hydropower Station shall use a 110kv substation as grid connection point and power rate settling point. The connection will be through 110kv (or 35kv) level of electric pressure and connection cables will be newly built by party A.
3. When the Jinshajiang Midstream One-reservoir Eight-level Hydropower Station has completed, the first priority will be to satisfy power demands in Lijiang City and Diching Canton. The rest will be connected to power grid of Yunnan Power Grid Co. and main grid of Southern Power Grid Co. The powers connected to grids shall be subject to power grid regulations.
4. In low-tide season, the Jinshajiang Midstream One-reservoir Eight-level Hydropower Station will operate by daily regulations so as to ensure sufficient output for the demands of late peak weeks. Assessment of grid connection shall be carried out, in principle, according to regulations in [2008] No. 21 document jointly issued by Ministry of Hydropower and Yunnan Provincial Government such that power demands within the grid can be satisfied and the rest can be distributed to power lines from west to east.
5. With regards to electric rate settlement in grid connection, Parties A and B agree that, within five years after the power station starts production, electric rate will be implemented according that ratified by Yunnan

Provincial Government, i.e., 0.27 yuan/kwh, and, after five years, the rate shall be gradually adjusted in accord with market prices. Parties A and B agree that the setting of electric rate of the Jinshajiang Midstream One-reservoir Eight-level Hydropower Station shall fulfill 4 basic principles of cost compensation, reasonable profits, fair burdens and endurance of the society. Loan repaying capability is in accord with the settled power sale price, within loan repayment period (10 years starting from the date of investment), by deducting tax payment and regular retained earnings (a 15% rate of return for the part of capital funds) from the power station/grid.

6. As negotiated by Parties A and B, the power output of the Jinshajiang Midstream One-reservoir Eight-level Hydropower Station connected to grid shall be assessed in accord with 0.8 of power factor.
7. Both Parties agree that the power quality electric pressure of the Jinshajiang Midstream One-reservoir Eight-level Hydropower Station shall be assessed according to deviation rate no more than ±5% of designated pressure and its frequency assessed according to deviation no more than ±5 hz.
8. Grip connecting inlet equipment shall be installed by Jinshajiang Midstream One-reservoir Eight-level Hydropower Station and the property rights belong to the Jinshajiang Midstream One-reservoir Eight-level Hydropower Station. Power meters for grid connection settlement shall be installed by Party B and the property rights belong to Party B.
9. Matters not included in this agreement and clauses needed to be changed afterwards shall be negotiated by both Parties in other occasions and signed into supplement agreements for implementation.
10. The Agreement shall be produced in four copies and each party retains two copies. It is effective since the date representatives of both Parties sign and stamp seals. Both Parties shall implement clauses in the Agreement sincerely.

Party A: (Seal) Party B: (Seal)

Representative of Party A: (Signature) Representative of Party B: (Signature)

Place the agreement signed: Kunming, Yunnan
Date the agreement signed: 8 November 2010

## Yunnan Jialixiang Hydraulic and Hydropower Development Co., Ltd.

# Brief Description of the Project

According to Document of **Yunnan Province Development and Reform Commission**, YDRE [2010] No. 21, authorized to our Company three hydropower stations of Liangjiaren, Liyuan and Ahai: power generation capacity 8.58 million kw, and total investment RMB 112.5 billion.

**Liangjiaren Hydropower Station**

The liangjiaren Hydropower Station is located at border river between Xianggelila County and Yulong County, normal water storage level 1,810 m, dry season water level 1,774.6 m, total reservoir storage capacity 254.3 billion $m^3$, regulating storage capacity 205.43 billion $m^3$, dam top elevation 1,819.5 m, dam height 99.6 m, dam length 180 m, generation capacity 4.20 million kw, total investment RMB 52.5 billion and period of construction 8 years.

**Liyuan Hydropower Station**

The Liyuan Hydropower Station is located at border river between Xianggelila County and Yulong County, 67.5 km from river section of Liangjiaren Hydropower Station, normal water storage level 1,620 m, dry season water level 1,500 m, total reservoir storage capacity 2,691 million $m^3$, regulating reservoir capacity 2.4 billion $m^3$, dam height 155 m, dam length 269 m, total generation capacity 2.28 million kw, total investment RMB 30.6 billion, and construction period 6 years.

Ahai Hydropower Station

The Ahai Hydropower Station is located at border river between Yulong County and Ninglang County, 80.5 km from river section of Liyuan Hydropower Station, normal water storage level 1,504 m, dry season water level 1,408 m, total reservoir storage capacity 2.44 billion $m^3$, regulating reservoir storage capacity 2.3 billion $m^3$, dam height 139 m, dam length 256 m, total generation capacity 2.10 million kw, total investment RMB 29.4 billion, and construction period 5 years.

Yunnan Jialixiang Hydraulic and Hydropower Development Co., Ltd.

22 July 2014

## Yunnan Jialixiang Hydraulic and Hydropower Development Co., Ltd.

# Fund Usage Plan

**The fund usage plan is in accord with actual situation of fund infusion:**

| | |
|---|---|
| 1. Preliminary works: exploration, design, environmental evaluation, soil and water conservation. | Tentative expenses: RMB 6 billion |
| 2. Land acquisition, migrant placement | Tentative expenses: RMB 15 billion |
| 3. Engineering preparation period, temporary facilities, roads, water and electricity, communications | Tentative expenses: RMB 15 billion<br>Total: TMB 36 billion |
| 4. Engineering construction period: The 2nd to the 4th year | Tentative expenses: RMB 50 billion<br>Total: RMB 50 billion |
| 5. Purchase of electromechanical equipment, etc. | Tentative expenses: RMB 15 billion<br>Total: RMB 15 billion |
| 6. End period settlement | Tentative expenses: RMB 11.5 billion<br>Total: RMB 11.5 billion |
| | Gross total: RMB 112.5 billion |

Yunnan Jialixiang Hydraulic and Hydropower Development Co., Ltd.

22 July 2014

## Sensibility Analysis

This sensibility analysis mainly considers changes in power station investment, loan repayment period, loan interest rates and income taxes. The impact on financial indicators can be seen in the following table:

| Scenario | Investment | Repayment period (year) | Loan interest rate (%) | Income tax rate (%) | Loan repayment power price (yuan/kwh) | Internal return rate (%) | Net current value (thousand yuan) | Payback period of investment (year) |
|---|---|---|---|---|---|---|---|---|
| 1 | Basis | 12 | 11.16 | 33 | 0.537 | 17.4 | 1,056,760 | 10.6 |
| 2 | -20% | 12 | 11.16 | 33 | 0.634 | 17.4 | 1,268,540 | 10.6 |
| 3 | +10% | 12 | 11.16 | 33 | 0.590 | 17.4 | 1,162,650 | 10.6 |
| 4 | -10% | 12 | 11.16 | 33 | 0.484 | 17.4 | 950,880 | 10.6 |
| 5 | Basis | 12 | 8.28 | 33 | 0.465 | 15.4 | 654,680 | 11.3 |
| 6 | Basis | 10.5 | 11.16 | 33 | 0.685 | 18.8 | 1,302,320 | 9.9 |
| 7 | Basis | 12 | 11.16 | 22 | 0.498 | 17.8 | 1,185,000 | 10.6 |
| 8 | Basis | 12 | 11.16 | 11 | 0.469 | 18.1 | 1,313,200 | 10.6 |
| 9 | Basis | 12 | 11.16 | 0 | 0.445 | 18.5 | 1,441,370 | 10.6 |
| 10 | Basis | 12 | 8.28 | 0 | 0.380 | 16.6 | 993,550 | 11.2 |