China: Yangtze Gorge Project - Report [illegible]

PRELIMINARY REPORT
ON
YANGTZE GORGE PROJECT

By

J. L. Savage
Consulting Engineer

PPF

Chungking, China
Nov. 9, 1944

Bx39

Miss

PSF China
Box 29

December 26, 1944

In reply refer to
PR 023.991H/11-3044

My dear Miss Tully:

I am sending herewith a copy of a despatch dated November 30, 1944 from the American Consulate General at Kunming, Yunnan, China, forwarding for the President at the instance of Dr. J. L. Savage, Cultural Relations Program, two copies of his work Preliminary Report on Yangtze Gorge Project together with drawings.

The American Consulate General at Kunming has been requested to thank Dr. Savage on behalf of the President.

Sincerely yours,

Chief of Protocol

Enclosures:

1. From Consulate General, Kunming, no. 119, November 30, 1944.
2. Two copies of Report, with two copies of drawings.

Miss Grace G. Tully,

The White House.

Government of China
Ministry of Economic Affairs
National Resources Commission

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Yangtze Gorge Project

List of Drawings & Studies

Drawing No.	Title	Remarks
RE180c43-B	Five Year Reconstruction Plan for Electric Power Industry in China.	Attached to Dr.Wong's Introduction
RE180c44	Postwar Reconstruction Plan for Electrical Enterprizes in China, Nucleus Plan	Attached to Dr. Wong's Introduction
Y - 1	Study No.1 General Layout	Dam located about 3,000m. downstream from Shih-Pai. Power plant in tunnel.
Y - 2	Study No.1 Dam-Elevation & Sections	
Y - 3	Study No.1 Typical Section	
Y - 4	Study No.1 Sectional Plan	
Y - 5	Study No.2 General Layout	Dam located about 1,800m. upstream from Nan-Tsing-Kwan. Power plant in tunnel.
Y - 6	Study No.2 Dam-Elevation & Sections	
Y - 7	Study No.2 Typical Section	
Y - 8	Study No.3 General Layout	Dam located about 1,200m. upstream from Nan-Tsing-Kwan. Power plant in tunnel.
Y - 9	Study No.3 Dam-Elevation & Sections	
Y -10	Study No.3 Typical Section	
Y -11	Study No.4 General Layout	Dam located at Nan-Tsing-Kwan. Power plant in tunnel.
Y -12	Study No.4 Dam-Elevation & Sections	
Y -13	Study No.4 Typical Section	
Y -14	Study No.4 Sectional Plan	
Y -15	Study No.5 General Layout	Dam located about 500m. downstream from Nan-Tsing-Kwan. Power plant in dam.
Y -16	Study No.5 Dam & Power Plant Sections	

Note: Study No.4 embodies the general plan of development recommended in the Proposal of this Report.

NATIONAL RESOURCES COMMISSION
Ministry of Economic Affairs

Introduction to
Dr. J. L. Savage's Report

(including Post-War Reconstruction Plan
for Electrical Enterprises in China
and
a brief of Power Market)

In the course of our industrial reconstruction, we are most fortunate in being able to invite Dr. J. L. Savage, world authority and designing engineer responsible for the majority of the world famous dams, to advise us on hydro-electric problems with an inspection tour of localities for prospective dam sites. Owing to the limited period which Dr. Savage can spare in our country and the difficulties of travel only following major projects were included in his inspection tour, viz:

Ta Tu Ho and Ma Pien Ho Projects
Upper Ming Kiang and Kwan Hsien Projects
Lung Chi Ho Projects
Tang Long Chuan Projects

The above sites are all confined to the south-west of China, constituting but a small portion of our reconstruction program.

Besides the afore-mentioned projects, our Commission has long cherished in developing hydro-power at the gorge of our famous Yangtze River. An inspection party was dispatched about ten years ago to make a preliminary investigation of the project in view. We are much indebted this time to Dr. Savage for his consent to undertake the observation in person and to formulate a more concrete design.

While his valuable reports will unquestionably be used as the nucleus to our reconstruction program in the districts concerned, we deem it opportune in appending herewith maps and lists showing out tentative plan of Post-war Electrical Enterprises in China and estimates of power requirements compatible to our first stage of five years post-war reconstruction in relation to natural resources and planned industries.

The estimated power required listed below includes requirements of pre-war plants in the occupied zones to be rehabilitated after the enemy's retreat. Of course, this plan is only a tentative layout with a view of gradual expansion and subject to constant revision according to our financial and technical facilities. We are sure that after the first five years' plan is carried out, the power development in ensuing years will be very much accelerated according to the demand of other industrial developments.

For the time being, even the first stage of our program calls for more engineering personnel and expenses than we can muster, so we are hoping that some sort of working principles may be laid down soon by the U.S.government and ours to encourage American engineering and financial institutions in bringing about our plans to the stage of actual construction.

Pending official government arrangement of financial and technical cooperation, preliminary negotiation will be made between our Commission and American institutions to promote immediate construction for some of our urgent installations on the basis of a self-liquidating scheme in terms acceptable to both governments.

Tentative Five-Year Plan for Reconstruction of Electrical Enterprises

District	Natural resources	Planned industries	Estimated power required
Hupei	coal:anthracite bituminous iron manganese salt wheat	iron & steel smeltery salt refinery colliery heavy machineries electrical equipments textile mills flour mills fertilizer	189,000KW
Shangtung	coal:bituminous iron bauxite hemp cotton wheat fruits	aluminium refinery ship-building textile mills liquid fuel chemical industry sugar and starch paper mills	198,000
Honan	coal:anthracite bituminous pyrite wheat cotton	Heavy machineries colliery electrical equipments textile mills flour mills cement	50,000
Shensi-Kansu	coal:bituminous petroleum cotton	machineries liquid fuel textile mills paper mills cement leather processing aircraft manufacturing	62,200
Middle-Kansu	coal:bituminous petroleum bauxite wool pelt and hide	colliery liquid fuel aluminium refinery woolen textile mills chemical industry cement paper mills	30,500

District	Natural resources	Planned industries	Estimated power required
West-Szechuan	coal:bituminous iron copper sulphur petroleum salt sugar timber silk	colliery automobile manufacturing copper industry chemical industry electric furnace products salt refinery sugar refinery timber industry cement paper mills silk industry	154,000 KW
East-Szechuan	coal:anthracite iron sulphur	iron & steel smelting heavy machineries electrical equipments textile mills cement fertilizer chemical industry	164,100
West-Hupeh	coal:anthracite bituminous iron Tung oil cotton	Tung oil textile mills	30,000
Hupei-Kiangsi	coal:anthracite bituminous iron manganese copper	iron & steel smeltery colliery heavy machineries electrical equipments aircraft manufacturing chemical industry Tung oil ship-building paper mills flour mills fat and oil production sugar refinery leather processing	215,000
South-Kiangsi	coal:anthracite bituminous tungsten	machineries chemical industry tungsten mines fuel oil	11,000
Hunan	coal:anthracite bituminous iron manganese tungsten antimony lead & zinc rice cotton	iron & steel smeltery manganese industry colliery liquid fuel tungsten mines heavy machineries railway rolling stock automobile manufacturing electrical equipments cement chemical industry synthetic products textile mills lumber industry paper mills Tung oil flour mills	193,000

District	National resources	Planned industries	Estimated power Required
Kiangsu-Chekiang	coal: bituminous iron rice cotton silk salt	iron & steel smeltery fuel oil machineries colliery ship-building electrical equipments chemical industry salt and products sugar and starch textile mills paper mills silk industry rice mills flour mills leather processing	416,000KW
Kwangtung	coal: bituminous iron tungsten	iron & steel smeltery fuel oil colliery ship-building machineries electrical equipments chemical industry cement salt textile mills paper mills sugar refinery	156,000
Kwangsi	coal: bituminous antimony tin	fuel oil machineries chemical industry cement lumber paper mills sugar refinery	53,000
Yunnan	coal: lignite bituminous iron copper lead and zinc tin bauxite cobalt manganese phosphorous	colliery iron & steel smeltery aluminium refinery copper refinery refinery fertilizer chemical industry cement leather processing textile mills paper mills	227,800
Individual isolated power plants			337,500
Grand total			2,528,400KW

(not including the four north-eastern Provinces and Formosa)

P.S. The above Preliminary five-year plan was suggested at a conference in April 1943. In view of the importance and economy of the Yangtze Gorge Project, it is considered necessary to introduce due modifications in the area within the scope of the new Yangtze Project.

Wong Wen-hao

Wong Wen-hao

Chairman

National Resources Commission

October 1944

WWH

Lungchiho Electricity Works,
Changshow, Szechuan, China.
October 9,1944.

Dr. Wong Wen-hao, Chairman,
National Resources Commission,
Chungking, China.

Dear Dr. Wong,

It gives me one of the greatest pleasures in my forty years of engineering experience to submit this preliminary report on the Yangtze Gorge Project. The study of this project has been extremely interesting because of the unprecedented magnitude of the works to be constructed and also, because of China's great need for the benefits that will accrue from the project.

The report necessarily contains many pages of engineering matter that may not be of particular interest to you. With this in mind, and for the convenience of other readers, I am incorporating in this letter the tentative conclusions that will be found also at the end of the report.

__Tentative Conclusions.__

It is possible to state tentative conclusions relative to the Yangtze Gorge Project on the basis of (1) a brief field inspection of the project area, (2) analyses of available basic data including river discharge records for fifty years, and (3) alternative studies and estimates of five different project sites selected from available aerial topography, as follows:-

1. The Yangtze Gorge Project with a normal reservoir water surface at elevation 200 will develop 10,560,000 kilowatts, of which 6,000,000 kilowatts are firm power and 4,560,000 kilowatts are secondary power. All of this secondary power will be converted ultimately to firm power by upstream storage developments. The project will provide 74,000,000 acre feet of water for the irrigation of 10,000,000 acres of good agricultural lands. About 22,000,000 acre feet of flood storage will be provided, which is sufficient to control the largest flood of record. Also, the project when supplemented by navigation facilities will permit ocean-going vessels to ply inland at least to Chungking. The great Yangtze Reservoir of 50,000,000 acre feet will provide an excellent supply of clear domestic water for many cities and industries, as well as recreational benefits, that are certain to become of utmost importance to China.

2. The relative merits of five alternative studies and estimates and of two alternative general plans of development of Yangtze Gorge Project are shown in the following summary of estimated costs. The costs are given in U.S. dollars.

Alternative Project	Total Field Cost	Investigation right of way Overhd.& Ctgs	Interest during Construction	Grand Total
Study No.1	$860,260,000	$139,039,000	$149,895,000	$1,149,194,000
Study No.2	$730,749,000	$119,612,000	$127,554,000	$ 977,915,000
Study No.3	$740,725,000	$121,109,000	$129,275,000	$ 991,109,000
Study No.4	$698,393,000	$114,759,000	$121,973,000	$ 935,125,000
Study No.5	$835,898,000	$135,385,000	$194,257,000	$1,165,540,000

3. The project is feasible in respect to its construction on the great Yangtze River, and also with regard to prospective repayment of the project cost through revenues accruing from power, irrigation, flood control, navigation, domestic water and recreational resources. Construction of the Yangtze Gorge Dam appears warranted to a large degree by any one of the four big benefits, namely, power, irrigation, flood control or navigation.

4. A plan of development utilizing diversion tunnels for by-passing the river during construction of the dam will cost less and be much more bomb-proof than a plan without diversion tunnels.

5. The total cost for the Yangtze Project including the dam, reservoir and power plant will be well under one billion U.S. dollars. The unit cost for power will be well under one hundred U.S. dollars per kilowatt of installed capacity.

6. On the basis of the fully loaded plant, gross annual revenues from power alone, estimated at two U.S. mills per k.w.h. for firm power and at one half mill per k.w.h. for secondary power, will average U.S.$143,450,000. Annual revenue deductions will include the following:- operation and maintenance on general and special features of the project amounting to U.S.$6,398,000; a replacement reserve of U.S.$2,287,000; and amortization on the basis of 15 years repayment period on a 4% sinking fund, including interest, amounting to U.S.$84,105,000; or a total deduction of U.S.$92,790,000. This leaves a net annual revenue of U.S.$50,660,000.

7. Gross annual revenues or savings and net annual revenues or savings will accrue from power and storage resources of the project as follows:

Power or Storage Resource	Gross Annual Revenue or Saving	Net Annual Revenue or Saving
Power	U.S.$143,450,000	U.S.$ 50,660,000
Irrigation	$ 37,000,000	$ 18,500,000
Flood control	$ 38,240,000	$ 38,240,000
Navigation	$192,500,000	$ 38,500,000
Domestic water	$ 56,600,000	$ 3,000,000
Recreation	$ 50,000,000	$ 5,000,000
Totals	U.S.$517,790,000	U.S.$153,900,000

8. The Yangtze Gorge Project is a "CLASSIC". It will be of utmost importance to China. It will bring great industrial developments in Central and Western China. It will bring widespread employment. It will bring high standards of living. It will change China from a weak to a strong nation. The Yangtze Gorge Project should be constructed for the benefit of China and the World at large.

Respectfully submitted,

J. L. Savage

J. L. Savage.
Consulting Engineer.

Government of China
Ministry of Economic Affairs
National Resources Commission

Preliminary Report
Yangtze Gorge Project
J.L. Savage
Consulting Engineer

Acknowledgments

The writer desires particularly to acknowledge and thank Dr. Wong Wen-hao, Minister of Economic Affairs and Chairman of the National Resources Commission, for his complimentary introduction to this report and for the comprehensive information submitted relative to the Commission's proposed five year post-war industrial program. Also, the writer acknowledges with deep gratitude the cooperation and helpful suggestions received from all of the officials and personnel of the National Resources Commission. It will be obvious from the scope of the report, and particularly from the scope of the exhibits, that the writer has had the fullest cooperation of a number of the Commission's capable engineers. These engineers have made the essential economic studies that form the basis of this report. Their enthusiasm and interest in the work have been an inspiration and a source of keenest pleasure to the writer.

Synopsis

This is a technical engineering report prepared primarily for the guidance of engineering personnel in continuing the investigations, surveys, explorations and studies of the Yangtze Gorge Project. Other important purposes of the present investigation and report are to determine the feasibility, general plan of development, approximate cost of the project and the benefits accruing from the project. It is believed that these purposes are fulfilled in this preliminary report, so far this is possible from the data available at present.

The report will consider five alternative studies of the project as modified by development at different proposed sites. The first four studies (Nos.1,2,3 and 4) will comprise general plans of development that utilize diversion tunnels during construction of the dam. Study No.5 is a plan of development without diversion tunnels, in which the river will be handled by methods similar to those used at Grand Coulee Dam. The alternative sites are located in Ichang Gorge within a reach of about ten Kilometers, namely, between 5 and 15 Kilometers upstream from the city of Ichang. An inspection trip to the project area permitted a careful examination of one of the project sites. However, the other four sites were too close to Japanese military forces to be accessible. Examination of the one site and observation of the gorges between Chungking and a point about three Kilometers downstream from Shih-Pai, gave first-hand general information about geologic formations, topographic conditions, right of way questions and the difficulties inherent in the large discharges and high velocities of Yangtze River.

The proposed general plan that appears most attractive can be illustrated best by reference to the drawings contained in Study No.4. The dam as proposed in this study will cross the Ichang Gorge at a point immediately upstream from the widened channel of the Yangtze River or about 5 kilometers above the city of Ichang. It will be a concrete straight gravity dam designed to raise the water about 160 meters and the length at the top will be about 760 meters. The whole central portion of the dam will comprise an overflow spillway controlled by drum gates and tube valve outlets. A massive hydraulic jump apron designed to pass unprecedented volumes of water will protect the dam against damage from floods.

The power plant will be divided between the two sides of the river and installed entirely underground, utilizing the diversion tunnels and other tunnels and shafts excavated in solid rock, Ten diversion tunnels and two other tunnels on each side of the river will be utilized for the installation of forty eight 110,000 kw. main power units, giving ninety six main power units with a total capacity of 10,560,000 kw. One other tunnel system on each side of the river will be utilized for the installation of two 20,000 kw. station service units giving four station service units with a total capacity of 80,000 kw. Although underground installation of the power facilities will increase materially the cost of the power house feature as compared with an outside power house, the cost per kilowatt of installed power for this project will remain unusually low.

With all power features installed below ground the power plant will be 100% bomb-proof. The ultra-conservative massive dam suggested in the proposed design will be as nearly bomb-proof as possible. While the drum gates are vulnerable, these can be lowered in a few minutes, which would put them under a considerable depth of water, assuming the reservoir to be at a stage well above the permanent spillway crest elevation. During low stages of the reservoir the drum gates would suffer damages from effective bombing but they would provide a large measure of protection to the concrete crest of the dam.

Benefits of the project will accrue from the large capacity of firm and secondary power; and from irrigation, flood control, navigation, domestic water and recreational features. These benefits will be very great even with no upstream storage. With the ultimate development of upstream storage the benefits will be tremendous.

Scope of Preliminary
and Final Reports.

The preliminary report will discuss certain general conditions adopted as fundamental in the proposal of this report. Prior proposals for development of the Yangtze Gorge Project, including that of Dr. Sun Yat-sen, Founder of the Chinese Republic, and that of Mr. G.R. Paschal, Americal Economist and Expert Adviser to the Chinese Government, will be quoted for comparative purposes. A financial analysis of the large fertilizer plant that is included as an auxiliary feature of Yangtze Gorge Project in the proposal of Mr. Paschal has been made by the National Resources Commission. Copy of this analysis is attached hereto and designated "Exhibit No. 1"

The proposal of this report will be outlined in full. The general features of the dam and power plant will be enumerated in considerable detail for each of the two general plans of development. Suggested stage developments of the project will be outlined for the adopted plan of development as embodied in Study No.4. Lists of available and requested additional data will be included. Programs for continuing necessary surveys, explorations and studies of the project will comprise an important section of the report. The benefits inuring from power, irrigation, flood control, navigation, domestic water and recreation will be discussed briefly and evaluated, so far as this is possible from present information. Tentative conclusions will be found at the end of the report.

A final report will be prepared in America, following completion of surveys, explorations and studies of the project. In preparing that report it is proposed to utilize personnel sent from China to America for technical training, and also to utilize personnel of the Bureau of Reclamation providing cooperative arrangements recommended in another report are consummated.

The final report will include general designs and specifications suitable for negotiating a construction contract or for undertaking construction by government forces. Also, the final report will include illustrative matter in the form of exhibits embodying detail designs, standard designs, detail specifications, technical memoranda, engineering reports and other essential data that have been developed and compiled by the Bureau of Reclamation for similar high dam hydroelectric projects. In this manner data pertinent to most of the important details of design and construction can be furnished.

Following completion of the final report, and providing a large development program is authorized for construction, it is proposed that the National Resources Commission will arrange for cooperative assistance from the Bureau of Reclamation and the Tennessee Valley Authority as follows: (1) preparation of detail designs and specifications in America; (2) supervision of construction work in China; (3) training of Chinese technical personnel on design work in America and on construction work in America and China.

General Considerations

In formulating the proposals of this report certain general considerations have been adopted as follows:-

(a) This super-hydroelectric project should be designed on the premise that it may be utilized at some future time for national defense purposes. With such a large concentration of power in one plant, it is considered essential to construct the project as nearly bomb-proof as possible.

(b) Consideration should be given to earthquake effects in the final design of all important structures.

(c) All resources of the river basin should be considered in the ultimate development of the Yangtze River, including hydroelectric power, gravity and pump irrigation, flood control, navigation, domestic water supply and recreational features. All of these resources are of utmost importance in the future development of China and all of them are involved in the proposed Yangtze Gorge Project.

(d) The potential multipurpose benefits of this project are considered to be of such paramount importance that they warrant any additional costs for engineering, labor and materials necessary to procure constructed works of the most modern, permanent and ultraconservative character.

(e) The present inflation makes difficult, if not impossible, the task of preparing cost estimates of the project in Chinese money. For this reason, it is found expedient to make all comparative cost estimates on the basis of U.S. dollars, and also on the basis of work done in America prior to the war. Some idea of after-the-war costs for the project can be had by using cost indexes and exchange rates for years prior to the war.

(f) It is considered very important that arrangements be made as soon as possible for extensive aerial topographic surveys, preferably covering the complete main river and all important tributaries. Conclusion of the war in Europe should make available adequate personnel and equipment for such surveys.

(g) In rehabilitating cities and villages that are to be partly submerged by the reservoir, it is considered advisable to construct modern domestic water systems, sewer systems, public buildings, and other public facilities that will tend to promote a higher standard of living among the people.

(h) The topographic information available for consideration in this preliminary report is limited to sketch topography prepared for military purposes by the Chinese military forces, aerial topography captured from the Japanese military forces, and aerial photographs and topography recently furnished by the U.S.Army. The Chinese and Japanese military maps differ widely and, despite careful field inspection of one of the alternative project sites, it was uncertain whether either of the maps accurately showed the topography of the region in question. With this difference in mind survey parties were organized hurriedly by the National Resources Commission and sent to the region to make check surveys. These surveys ~~probably will~~ indicate that the Japanese aerial topography, although deficient in certain details, is sufficiently accurate for present purposes. The aerial photographs taken by the U.S. Army, viewed through a stereoscope, indicate that the Japanese aerial topography is reasonably accurate. Therefore, this topography has been used as a basis for the studies described in this report.

(i) Any conclusions formulated on the basis of present available data must be considered tantative. However, the conclusions in this report are made on the basis of wide experience in similar high dam construction on large rivers and it is believed that this experience warrants difinite conclusions, for example, regarding the feasibility of the project in respect to its construction on such a great river. Construction of the project is unquestionably feasible on the premise that adequate provisions are made for diversion of the river during construction of the dam. This premise is met in all of the proposed plans of development by providing a diversion capacity sufficient for passing the one hundred year flood. This liberal diversion capacity appears warranted, not only for insurance against disaster, but also because the diversion tunnels or the diversion channels are needed also for power purposes.

Proposal of Dr.
Sun Yat-sen

Dr. Sun Yat-sen, Foundar of the Chinese Republic, one of China's greatest leaders and benefactors, is believed to have submitted the first concrete proposal for extensive development of the Yangtze Gorges. Dr. Sun's proposal has been translated into English from certain paragraphs in his third lecture. The proposal is quoted for convenient reference, as follows:

"Principle of People's Livelihood"

"The second method of increasing agricultural production is the use of fertilizers. So far only faeces of human beings and animals, and decayed vegetable matters are used as fertilizers in China. Chemical fertilizers were only introduced recently. In certain places south of the Pearl River in Kwangtung where Chili saltpeters have been used as fertilizers in planting sugar cane's, the rate of growth has been doubled and the size of the products also increased several times. But the saltpeters, being imported from Chili in South America, are high in cost and sold at such high prices that only sugar cane-planters can afford to buy and utilize them.

"Besides saltpeters, the phosphorus from the shell family in the sea and calcium from the mineral materials are good fertilizers; and when nitrates, phosphorus and calcium are mixed in proper proportions, a very suitable fertilizer is formed, which, used in the planting of any vegetation, will increase both the quantity and rate of production. For example, one mow of rice field, which produces five baskets of grains without fertilizer, will yield two to three times the production if suitable fertilizers are applied. Therefore, if we wish to increase the agricultural production, fertilizers should be used, and scientific methods of manufacturing chemical fertilizers should be adopted. The raw materials for making artificial fertilizers are obtainable everywhere in China, and something similar to Chili saltpeter was used in the making of gunpowder a long time ago.

"Formerly the majority of the fertilizers used in the world has been produced in Chili, South America; but recently, due to the advancement of science, a new method of making fertilizers anywhere by the use of electricity has been invented. The artificial fertilizer so produced, being equally effective as the natural fertilizer but much cheaper, are being increasingly used. How is electricity produced? In general, high price electricity has been produced by steam power, but recently low price electricity is being produced by water power. In many foreign countries, an enormous amount of electric power is produced by the development of water falls and river rapids, and cheap energy thus obtained is used in the manufacture of artificial fertilizer, resulting in a very cheap product.

"There are many such falls and rapids in China; for example, many rapids exist along the West River upstream of Ngochow, the most treacherous being Foo-Po Rapid, near Nanking very dangerous to navigation. If the river is dammed up and a navigation channel is constructed, power and benefits to navigation will both be obtained. It was estimated by some one that one million horsepower could be developed from the rapid. Many rapids also exist in Foo-Ho and Red River and can be used for development of water power. Also, according to surveying by engineers, tens of thousands of horsepower could be produced from Yungkiang in the northern part of Kwangtung; and used for lighting Canton and neighbouring cities, running the mathines of the factories, and even electrifying the Canton-Hankow railway.

"Still more splendid is the water power at the Feng-Shang (Wind Box) Gorge on Upper Yangtze River. It was estimated by some one that more than 30 million horsepower could be developed from the river from Ichang to Wanhsien. The above power, being bigger than that produced anywhere in the world, could not only supply all the railways, train cars and factories in the whole country, but produce enormous amount of fertilizers. Again, at the Lung-Men (Dragon Gate) on Yellow River, electric power amounting to tens of thousands of horsepower could be developed. It can be seen that China is rich in natural resources. If modern methods are used to develop the water power resources in Yangtze River and Yellow River, about 100 million horse power could be produced, which will be equivalent to the power of 800 million strong men, as 1 horsepower is about equal to the power of eight men. Futhermore, more than 8 hours work is harmful to the workmen, but horsepower can work 24 full hours in a day, that means 1 horsepower used in a day will be equivalent to the work of 24 men. If full use is made of the water power from Yangtze and Yellow Rivers, producing 100 million horsepower, we will have 2,400 million workers to work for us, running our trains, operating our factories, and producing fertilizers.

"According to Han-Yu (an ancient Chinese writer), if one worker produces for 6 consumers, the country will grow weaker. Just think how many are actually working among the 400 millions in China? Not only the young children, and the old cannot work, but many young strong persons, like the land owners, live on the work of others. So many Chinese are not working and non-producing, resulting in a weak country. If we can develop the water power of Yangtze and Yellow Rivers, to produce 100 million horsepower, equivalent to 2,400 million manpower, and utilize this enormous am unt of electric power to work for us, large production will certainly be the result, and China will change from a poor to rich country. Therefore, if we wish to increase agricultural production, machinery must be utilized to increase the production power of human labor, and moreover, electric power must be utilized to produce fertilizer."

<u>Proposal of G.R. Paschal, Economist</u>

Mr. G.R.Paschal, an American Economist and Expert Adviser to the Government of China, has made a proposal for the development of Yangtze Gorge that warrants most careful consideration. Mr. Paschal's proposal is quoted for convenient reference as follows:-

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"The Building of Hydroelectric Power Plants in China under U.S.Government Loan and a Suggested Mode of Repayment Therefor"

"China urgently needs large amounts of electric power to build up post-war industries, the total need being three or four million kilowatts immediately post-war, but rising to 20,000,000 kw. or more at the end of ten to twenty years, as industrialization progresses and the standard of living rises. But China has very little foreign exchange with which to purchase equipment and to pay for the building of plants, and she needs exchange for other urgent tasks, such as reconstruction work, building of railroads, opening of mines, etc. She can not hope to acquire enough exchange through ordinary exports to finance the desired program, and she is particularly handicapped in trade with the United States, which will probably have to supply most of the equipment and trained personnel needed, due to the urgent needs in other industrial countries for domestic reconstruction. It is suggested that this impasse may be broken by the United States building power plants in China for the Chinese Government and taking payment in certain products which these plants can produce, but which China has not exported hitherto. An example of one possibility is given below.

"The United States has an annual fertilizer bill of large size. In 1942 it was $354,000,000. Yet, in spite of this figure, American farms do not get enough fertilizer, and hence are decreasing in fertility year after year. The loss of nitrogen is several million tons per year, and at present the nitrogen added in replacement is only a little over 400,000 tons per annum. Phosphates and potash are replaced in much large measure, but American farmers tend to skimp on nitrogen due to its high cost. There are 340,000,000 acres in crops in the United States. On at least 200,000,000 acres of this, nitrogen additions would be desirable, and on 100,000,000 acres they are essential to the production of really paying yields. If nitrogen could be supplied at prices less than half the existing figures, crop yields could be improved and agricultural subsidies through conservation on payments and parity payments (amounting to $653,000,000 in 1941) could be reduced. High fertilization could reduce the cost per acre for crops very notably, since it would allow the retirement to pasture of the poorer land, with concentration of labor on the better acres. Low cost fertilizers should be very popular politically, and there are no tariff barriers to imports of nitrogen products.

"If 100,000,000 acres of American land received 100 pounds of nitrogen per acre per year, this would require 5,000,000 tons. This might mean 7,000,000 to 15,000,000 tons of nitrogen fertilizer, depending on the chemical made. Let us assume here that the product produced is calcium cyanamide, which contains 35% nitrogen. It is probable that other nitrogen products could be produced and shipped cheaper, and hence the assumption that this is the product made is conservative on the score of cost. Calcium cyanamide production requires considerable amounts of electric power (8,000 kilowatt hours per ton of contained nitrogen) and hence could not be produced in the quantity and cost desired in the United States. It demands cheap power, and American power is generally not cheap, and is also needed for general lighting and industrial purposes.

"The fixing of 5,000,000 tons of nitrogen would demand 5,000,000 kilowatts years of power,- a figure which the United States could not afford to meet from existing plants, considering demands of other industries. Let us see whether China could meet this, in terms of quantity, cheapness and mutual profit. The Yangtze River flows for several hundred miles above Ichang in a narrow gorge, then opens out abruptly into a wide river below Ichang. A dam 400 feet high could be easily build at Ichang, and this would flood very little agricultural land and few villages, but would on the contrary greatly improve navigation up to Chungking. The river has a low water flow of close to 400,000 cubic feet per second, giving a potential power output of about 10,500,000 kilowatts. Could the United States afford to build a dam here for the Chinese Government, install equipment and take repayment over say 15 years in nitrogen fertilizer? The answer is yes. Likewise, could the Chinese Government afford to make this fertilizer and deliver it to the United States at Ichang, and still make a profit out of the plant? The answer is again yes. In the first place, a dam would cost about U.S.$130,000,000. Generating equipment would cost U.S.$735,000,000 for 10,500,000 kilowatts. Cost of nitrogen plant etc., might be roughly estimated at U.S.$ 35,000,000. Total cost would then be U.S.$900,000,000. For this figure, China would get immediate use for her own industrial program of 5,250,000 kilowatts (an amount much larger than most planners have hitherto believed feasible), and would use the other half of the power to make the fertilizer which would pay for the whole plant. At the end of 15 years, the whole plant would revert to China for such use as she pleased, and any subsequent sales of fertilizers to the United States would be entirely a matter of business profit. Some figures as to the economics of the proposal are given below:

"Let us assume that the plant, equipment and dam cost $900,000,000. Let us pay $90,000,000 to the United States each year on interest and amortization of the principal at say 4% interest on the unpaid balance, with the remainder of the $90,000,000 going for the reduction of the principal. Then, with payments of this type, the entire amount will be paid off in 15 years or less. Let us deliver to the United States fertilizer containing 5,000,000 tons of combined nitrogen as the equivalent of the $90,000,000, making the cost $18 per ton. The United States can afford to transport this fertilizer from Ichang to America and distribute it, and still reduce nitrogen fertilizer costs by perhaps 50% as compared with present figures.

"It can be seen that this scheme, amounting to a barter deal, avoids the otherwise insurmountable obstacle of lack of dollar exchange. What are the costs in Chinese national currency? To make cyanamide, the ingredients are coal, limestone, air and electric power. One ton of coal might be required for each ton of calcium carbide (the first product made), and this might cost U.S.$3,00, after allowing for by-product coal tar, benzol, gas, etc., extracted in a preliminary coking process. Incidentally, these would furnish the raw materials for insecticides, dyes, medicines and industrial chemicals needed by China in its development, as well as much benzol for motor fuel. The limestone needed would cost about U.S.$ 0.50 per ton of product. Labor and miscellaneous items might be roughly U.S.$2,50 making a total of US.$6.00. Add U.S.$1.00 for repair of equipment, and this will make a total cost of $7.00 per ton for carbide. Four tons of carbide will make, by direct reaction with the nitrogen of the air, five tons of cyanamide, and 14,300,000 tons cyanamide are needed to provide 5,000,000 tons of nitrogen. On this basis, production cost for materials and labor will amount to $80,080,000 per annum. This means that in selling to the United States for $90,000,000 the Chinese Government makes a profit. But it is not necessary to tax the Chinese public to earn even this sum. There remains the sale of the 5,250,000 kilowatts of power not required in the cyanamide plant. This can be sold to government or private industry for any figure over the exceedingly minute production costs, since the other half of the power is paying for the plant itself. I suggest that a figure of two-tenths of a U.S. $ cent per kilowatt hour would be sufficient and on this basis the annual revenue (at 8,000 kilowatt hours per year per kilowatt of power) would be $84,000,000, which is just about enough to cover the cyanamide costs and the operating costs of the unallocated power production. The result would be that 5,250,000 kilowatts of very cheap power would be provided immediately for the use of Chinese government and private industry at no cost whatever to the Chinese Government, and that a going power and fertilizer business of equal magnitude would be turned over to Chinese use free in fifteen years.

"Possibilities for the sale of synthetic rubber, industrial chemicals and possibly aluminum and magnesium and ferroalloys also exist, which might give China a positive trade balance with the United States, through operation of this dam, and hence allow the import of more machinery and equipment for other phase of China's construction program".

<u>Proposal of this Report</u>

Two alternative general plans of development for the Yangtze Gorge Project have been studied, namely, a dam with diversion tunnels and a dam without diversion tunnels. Development by a dam with diversion tunnels is believed to be possible at four of the five alternative project sites selected from the Japanese Aerial topography, namely, at sites considered in Studies Nos.1,2,3 and 4. Development by a dam without diversion tunnels appears to be possible at only one of the selected project sites, namely, the site considered in Study No.5.

General Features of
Dam and Power Plant

(Studies 1,2,3 and 4)

The general features of the dam as proposed in Studies Nos. 1,2,3 and 4 will include the following: a concrete straight gravity dam about 225 meters high above assumed elevation of foundation rock, which will raise the reservoir water about 160 meters above low water surface in the river; an overflow spillway controlled by structural steel drum gates; outlet works comprising eighty to one hundred and four tube valve conduits, in two tiers, protected by trashracks and bulkhead gate facilities; and a hydraulic jump apron suitable for discharging unprecedented flood volumes. All of these features will be of ultra-conservative design, particularly the dam and hydraulic jump apron.

The general features of the power plant as proposed in Studies Nos.1,2,3 and 4 will include twenty combined diversion and power tunnels, all of which may be on one side of the river, or they may be divided between the two sides. These tunnels will be utilized first for diversion of the river during construction of the dam and later for tail water tunnels. An additional six tunnels will be needed for power purposes, four of which will be used for main generating units and the remaining two for station service units. Each of these power tunnel systems will incluide the following: a combined concrete tunnel plug and power house substructure; a power inlet tunnel with bulkhead gate seat at the entrance; a vertical intake shaft in which trashracks and bulkhead gate facilities are installed; an access tunnel with travelling crane and gantry crane facilities that serves all intake shafts; an inclined power tunnel, which, combined with the intake shaft, serves also as a head-water surge tank extending in effect from the top of intake shaft to the power penstock inlets; four steel lined penstocks leading from the bottom of inclined power tunnel through four butterfly valves to four 150,000 h.p. turbines driving four 110,000 kw. main generators, or two steel lined penstocks leading from the bottom of inclined power tunnel through two butterfly valves to two 27,000 h.p. turbines driving two 20,000 k.w. station service generators, all installed in the power house tunnel; four draft tubes leading from the main turbines, or two from the station service units, to the downstream portion of diversion tunnel that servies as a tail water tunnel; a combined vertical bulkhead gate shaft and tail water surge tank extending upward from the tail water tunnel to a main access tunnel that is provided with travelling crane and bulkhead facilities for unwatering the turbines of any power tunnel system; a tail water tunnel and downstream portal with bulkhead gate seat; a tail race channel leading to Yangtze River; a vertical hoist shaft and cross tunnel leading from the main access tunnel to the power house tunnel for every two power tunnel systems; three or five vertical elevator shafts from cross tunnels to the transformer tunnel and lightning arrester tunnel that will serve the power systems; a pedestrian gallery and stairway leading from the main access tunnel to the power house tunnel for every two power tunnel systems; a vertical cable shaft leading from each generator to its bank of transformers in the transformer tunnel; a shaft and tunnel outlet for each outgoing high tension circuit; a ventilation duct from top of power house tunnel to low tension cable shaft.

(Study No.5)

The general features of the dam as proposed in Study No.5 will include the following: a concrete straight gravity dam about three Kilometers long and about 225 meters high above the assumed elevation of foundation rock, which will raise the reservoir water about 160 meters above low water surface in the river; a concrete straight gravity portion of dam comprising an overflow spillway controlled by structural steel drum gates located in the Yangtze River channel; outlet works comprising one hundred and four tube valve conduits protected by trashracks and bulkhead gate facilities installed on the upstream face of dam; and a hydraulic jump apron suitable for discharging unprecedented flood volumes.

The power plant as proposed in Study No.5 will utilize the left non-overflow straight gravity end portion of dam, which will contain a power installation of ninety six main units each of 110,000 kw. capacity, and four station service units, each of 20,000 kw. capacity, making a total installation of 10,560,000 kw. for the main generating units and of 80,000 kw. for the station service units. Each power unit system will include the following main features: trashrack and bulkhead gate facilities installed on the upstream face of dam; a steel lined penstock extending a short distance horizontally, thence vertically downward, then horizontally to a 150,000 h.p. turbine that drives a 110,000 kw. main generator, or a 20,000 kw. station service generator, all installed in a power house gallery in the dam; a butterfly valve installed in the lower horizontal leg of the penstock; a draft tube extending to tail water at downstream face of dam; a longitudinal access gallery above the downstream toe of dam with travelling crane and bulkhead gate facilities for unwatering the draft tubes, and with a cross access gallery and a pedestrian gallery leading from the longitudinal gallery to the power house tunnel for every eight main power units; a cable shaft leading upward from each generator to its bank of transformers in a transformer gallery near the top of dam; and an outlet slot for each outgoing high tension circuit.

Switchyard

The switchyard necessary for such a large installation of power units will be unusually long and at some of the alternative project sites this feature will offer a difficult problem. At site No.1 where all of the power units would be installed on one side of the river the switchyard might be placed on the opposite of left side with the outgoing lines crossing the river in parallel alinements normal to the transformer gallery. Another arrangement would be to carry the lines to a switchyard located on top of the ridge on the same or right side of the river. At project sites Nos. 2 and 3 the switchyards on the right side of the river will be located at a suitable location on the ridge of the same side. The switchyards on the left side of the river can be placed on the opposite side of the headrace with parallel outgoing lines normal to the lightning arrester gallery, or they can be carried to a suitable switchyard location above and back of the lightning arrester gallery. At project site No.4 the switchyards will be located on the same side of the river as the respective power plants. At project site No.5 the switchyard can be located immediately downstream from and parallel to the power plant.

Fertilizer Plant

No attempt has been made to determine the best location for the fertilizer plant at the various project sites. However, there appears to be no question that a suitable location will be available at any of the sites. Consideration should be given to the possibility of providing bomb-proof construction for this all-important feature of Yangtze Gorge Project by underground installation so far as this is possible. This construction would be particularly desirable if nearly 50 percent of the power capacity of Yangtze Gorge Project is utilized for nitrogen fixation as proposed by Mr. Paschal.

Outline of Stage
Developments

Although the plans of development embodied in Studies No.2 and No.3 are nearly as satisfactory as the plan embodied in Study No.4, this latter plan appears to be slightly more economical than either of these two plans. All of the four plans that utilize diversion tunnels are more economical and much more bomb-proof than the plan without diversion tunnels, namely, that embodied in Study No.5. With these conditions in mind Study No.4 has been adopted for the following outline of stage developments:

(First Stage)

(a) Complete the excavation and concrete lining of all (twenty six) tunnel and shaft systems. These systems include the diversion and power tunnels, intake tunnels, intake trashracks and bulkhead gate shafts, inclined power tunnels, bulkhead gate shafts for tail water tunnels, intake access tunnel, power house tunnel, main power house access tunnel, cross tunnels and pedestrian galleries, transformer tunnel, transformer elevator shafts, low tension cable shafts, and the high tension outlet shafts and tunnels.

(b) Construct upstream and downstream earth and rock fill cofferdams. Unwater and excavate the foundations of dam. Complete the construction of a concrete dam and appurtenant works. Bulkhead the diversion tunnels at intakes and construct the combined concrete tunnel plugs and power house tunnel substructures.

(c) Install in six tunnel systems (four main and two station service systems) the travelling cranes for power house tunnel, travelling cranes and trashracks and bulkhead gates for intake shafts, travelling cranes and bulkhead gates for tail water tunnels, elevators for transformer and lightning arrester tunnels, and travelling gantry cranes for the transformer tunnel.

(d) Install sixteen main power units and four station service units including turbines, generators, auxiliary hydraulic and mechanical and electrical equipment, transformers, high tension switches and switchyard - utilizing four of the main unit tunnel systems and two station service unit tunnel systems.

(e) Estimated Costs and Assumed Distribution:

Total including power features		US$653,697,000
Total for power features only		$278,697,000
Total excluding power features,	100%	$375,000,000
Chargeable to power............	50%	$187,500,000
Chargeable to irrigation.......	10%	$ 37,500,000
Chargeable to flood control....	20%	$ 75,000,000
Chargeable to navigation.......	15%	$ 56,250,000
Chargeable to domestic water...	2%	$ 7,500,000
Chargeable to recreation.......	3%	$ 11,250,000

(f) Assumed Annual Revenues:
Firm power (gross) 15.4 b.k.w.h.@$0.002 US$30,800,000
Secondary power (none)

(Second Stage)

(a) Install twenty power units including turbines, generators, auxilirary hydraulic and mechanical and electrical equipment, transformers, high tension circuits and switchyard.

(b) Estimated Cost:
Total for second stage US$ 70,357,000

(c) Assumed Additional Revenues:
Firm power 19.3 b.k.w.h.@ $0.002 US$ 38,600,000
Sec. power (none)

(Third Stage)

(a) Install twenty power units including turbines, generators, auxiliary hydraulic and mechanical and electrical equipment, transformers, high tension circuits and switchyards.

(b) Estimated Cost:
Total for third Stage US$ 70,357,000

(c) Assumed Additional Revenues:
Firm power 19.3 b.k.w.h.@ $0.002 US$ 38,600,000
Sec. power (none)

(Fourth Stage)

(a) Install twenty power units including turbines, generators, auxiliary hydraulic and mechanical and electrical equipment, transformers, high tension circuits and switchyards.

(b) Estimated Cost:
Total for fourth stage US$ 70,357,000

(c) Assumed Additional Revenues:
Firm power 14.1 b.k.w.h.@ $0.002 US$ 28,200,000
Sec. power 3.2 b.k.w.h.@ $0.0005 $ 1,600,000

(Fifth Stage)

(a) Install twenty power units including turbines, generators, auxiliary hydraulic and mechanical and electrical equipment, transformers, high tension circuits and switchyards.

(b) Estimated Cost:
Total for fifth stage US$ 70,357,000

(c) Assumed Additional Revenues:
Firm power 0.3 b.k.w.h.@$0.002 US$ 600,000
Sec. 10.1 b.k.w.h.@$0.0005 US$5,050,000

(Completed Project)

(a) Estimated Cost:
Total for all stages. US$935,125,000.

(b) Assumed Annual Revenues or Savings:

Firm power (gross)	68.4 b.k.w.h.@$0.002	US$136,800,000
Sec. power (gross)	13.3 b.k.w.h.@$0.0005	$ 6,650,000
Irrigation (gross)	74.0 m.a.f. @$0.50	$ 37,000,000
Fl. control (net)		$ 38,240,000
Navigation (net)		$ 38,500,000
Dom. water (net)		$ 3,000,000
Recreation (net)		$ 5,000,000

(c) Gross annual revenues or savings and net annual revenues or savings will accrue from the power and storage resources as follows:

Power or Storage Resource	Gross Annual Revenue or Saving	Net Annual Revenue or Saving
Power	US$143,450,000	US$ 50,660,000
Irrigation	$ 37,000,000	$ 18,500,000
Flood control	$ 38,240,000	$ 38,240,000
Navigation	$192,500,000	$ 38,500,000
Domestic water	$ 56,600,000	$ 3,000,000
Recreation	$ 50,000,000	$ 5,000,000
Total	US$517,790,000	US$153,900,000

Note: The total net annual revenue or saving, namely, U.S. $153,900,000, is exclusive of amortization and interest on project costs.

Economic Limits of Yangtze Gorge Project

The Yangtze Gorge Project is unquestionably the most important hydro-project ever conceived, when considered in relation to the untold benefits that will accrue to ancient but undeveloped China from the resources of Yangtze River and its tributaries.

Although no adequate appraisal of some of these resources and benefits can be made in this preliminary report due to lack of basic data, it is believed that the unprecedented magnitude of the combined power, irrigation, flood control, navigation, domestic water and recreational benefits of the project will be obvious from the subject matter of the report.

It is proposed that sufficient basic data will be obtained during the coming year to permit much more comprehensive analyses of the resources and benefits of Yangtze Gorge Project, than are possible using present limited information. In collecting the necessary additional data and in analyzing the economic limits of the project, it is suggested that certain general principles followed by the U.S. Federal Power Commission in its comprehensive analyses of similar projects, should be adopted. The general principles are illustrated by reports of the U.S. Federal Power Commission contained in Volume XV of the Bureau of Reclamation Data File, copies of which are in the files of the National Resources Commission. Also, these principles are discussed in a recent memorandum by John. S. Cotton, Principal Engineer, U.S. Federal Power Commission. Mr. Cotton's memorandum is quoted below for convenient reference as follows:

"ECONOMIC LIMITS IN THE DESIGN AND SELECTION OF FEDERAL PROJECTS

"Introduction

Federal projects differ primarily from private or local public projects in that all benefits, to whomever they may accrue, may be taken into account in the economic analyses (policy set forth in Flood Control Act of 1936). It is considered herein that:

1. the Congress in making appropriations does not anticipate profits;

2. the appropriations are not in the interest of governmental agencies or local groups, but are for the general welfare and betterment of the population of the nation; i.e., for rendering the greatest service to the most people at the least cost;

3. the national wealth is to be increased by the conservation and development of national resources.

The simplest way to classify and compare projects is to compare the rates of return on the investments; or compare the ratios of the average annual benefits and the average annual costs.

"Definitions

A project, as considered herein, may be a highway or railroad; an irrigation, flood-control, navigation, or power development, or combination thereof; erosion control, recreational facilities, mineral development, etc., etc. All projects, with the possible exception of monuments and the like, are constructed to render service in one form or another. In performing service, benefits accrue locally and to the nation as a whole.

A benefit is whatever promotes the happiness and well-being of a person, or adds to the value of property. Direct benefits are those to which dollar values can be more or less readily attached. Indirect benefits are those which are known, yet difficult to evaluate. Intangible benefits are generally far-reaching, are unknown, and are exceedingly difficult to estimate.

Value is the present worth of all future earnings (or benefits) and is not related to development cost. The value of a project or a benefit may be more or less the cost of developing it. In perpetuity, value is equal to the annual net return, capitalized. Value, however, may be approximated by considering the costs of service from alternative schemes.

Capital Cost is the expenditure for materials, resources, labor, energy, lands, and losses, necessary in the construction of a project. In addition to construction costs there may be acquisition and severance costs, and losses due to complete or partial supersession of existing facilities.

In federal projects the annual cost consists of interest on expenditures (whether or not charged by law to the project); depreciation or its equivalent, i.e., amortization* plus replacements during the amortization period; payments in lieu** of taxes; and operating and maintenance expenses. Local public projects would have similar annual costs.

The annual cost of private projects consists of interest on loans, taxes (local and federal), depreciation, insurance, and operating and maintenance expenses. Capital costs of private projects are seldom amortized. The difference between the legal annual return and the annual costs, in the case of private projects, is profit and not a cost.

The benefit-cost-ratio is the average annual benefits to whomever they may accrue, divided by the average annual cost of obtaining the benefits.

Optimum design (Kelvin's law) is that degree of development where the sum of the annual cost and the annual loss (of service or benefits) is a minimum. This design gives the greatest return (or benefits) on the investment.

The "Over-all" benefit-cost ratio method of economic analysis takes into account the over-all total benefits and costs of a project or group of projects. The over-all ratio is ordinarily less than indicated by the optimum-design ratio, as the ratio for certain increments of construction, or for certain projects in the case of a group, may be relatively small or less than unity. This results from obtaining the maximum return rather than the maximum rate of return.

The "Incremental" benefit-cost ratio method of economic analysis applies to any single increment of construction. In the case of a dam for instance, the ratio of the annual benefit increment to the annual cost increment is usually greater for an increment near the bottom than for an increment near the top. If the dam is carried high enough the ratios for increments at the top will be less than unity. This method is used a great deal by private companies and local public bodies, the limiting incremental expenditure usually being such that the ratio is unity or greater.

"Basis of Determining Benefits

In order that a project*** or projects may best fit into the ultimate plan and be fully useful and economical, the estimate of benefits should be based on:

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* Amortization is not a cost but only a method of accounting, i.e., a temporary arbitrary obligation. After amortization, full depreciation should be charged.

** This is open to question and purely arbitrary, as the taxes may be collected by other methods.

*** A river development is shown only as an example.

1. The ultimate development of the river system, when full use is made of all the water and other resources in an integrated plan;

2. the ultimate development of the region and benefits;

3. the ultimate impaired flows caused by upstream storage, transmountain diversions, diversions of irrigation, etc.;

4. taking into account future benefits to all downstream plants and projects;

5. taking into account all indirect and intangible benefits as well as direct benefits, to whomever they may accrue.

To apply the above, it may be desirable to take into account the present worths of future earnings and benefits. Care must be taken in order to not have duplication of benefits.

Gross returns should not be considered as direct benefits. Direct benefits may be approximated by subtracting all costs incurred in owning and operating the project from the gross return.

The total benefits (direct, indirect, and intangible) are sometimes approximated by assuming that these total benefits equal the gross return. This may give benefits which are too great.

"Planning

Since construction on the basis of optimum design yields the greatest return on money spent, all projects, of whatever nature, having benefit-cost ratios greater than unity should be constructed first in the order of their desirability, to the point of optimum return. It is realized that limitations of topography, area to be served, and other factors may limit the size of a project. If further development is possible in the future, the designs in all cases should be such that the project can be added to or paralleled with units of construction. (There are several instances in California and elsewhere where perfectly good dams have been or will be demolished to provide sites for higher dams. If care had been taken in the original design, this loss in value could have been avoided. To consider that such demolition is justified merely because the original project has been amortized is fallacious, since the existing value in most instances is about equal to the original cost, and perhaps more.)

After all possible projects of every nature have been constructed on the above basis, further projects should be started and the projects already constructed in part should be added to and extended if further benefits can be developed to the point where the benefit-cost ratio for the project, group of projects, or the development of a river system or area equals unity. This would necessarily include projects not initiated previously, but would contemplate the orderly development of all reservoirs. Again, provision should be left for possible enlargement if further benefits can be developed, as the cost of money to the government has always had a general downward trend and on this basis it may be possible to again add to projects in the future, keeping the benefit-cost ratio at unity.

The objective of resource development is to extend benefits on the broadest possible base, to increase the wealth of the nation, to make homes for people, and to provide for their earning a livelihood. The last step in the distant future will be to construct projects not now feasible under the above criteria but then justifiable under the then over-all benefit-cost ratio.

The final complete development of the country on the basis of the over-all benefit-cost ratio equalling unity is equitable to all, allows the greatest development, benefits the most people with no sacrifice of total amount of benefits, and allows all obligations and expenses to be met. The over-all benefit-cost ratio could not economically be less than unity if all of the benefits are evaluated. If the indirect or intangible benefits are not estimated, a ratio less than unity is justified.

"These principles are being carried out practically in this country. For instance, nonprofit street car lines use the excess earnings of certain lines to carry lines which do not earn their own way, the over-all benefit-cost ratio being unity or nearly so.

"It is realised that many practical, special, and political factors must be considered, but ultimately the complete development would be reached. The primary requirement in carrying out such a plan is to see to it that all designs are such that any construction can be made a part of the ultimate plan without compromise or loss."

John S.Cotton
Principal Engineer
U.S.Federal Power Commission"

<u>Resources and Benefits
of Yangtze Gorge Project</u>

It will be noted from the information contained in the Proposal of this Report that the resources of Yangtze Gorge Project - including those from power, irrigation, flood control, navigation, domestic water and recreation - are extraordinarily great. Basic data is available for appraising the power resources quite definitely. Also, the storage capacity available for irrigation and flood control can be determined quite closely from available data. However, definite information about prospective irrigable areas and also about flood damages below Ichang at different stages of Yangtze River are lacking. Likewise, no information is available regarding present or prospective local domestic water supplies and facilities. It will be obvious, however, to people living in China and to foreign visitors travelling in this country that all cities, towns and villages in Central and Western China are in need of better domestic water supplies and of modern water systems. Although recreational benefits are considered to be very important, these are intangible and difficult to appraise. No useful information appears to be available regarding these benefits at the present time. However, it is possible to make certain assumptions based on experience in America and to arrive at approximate values.

With the above general comments in mind, it may be of interest to discuss certain phases of these different resources and benefits, particularly, the methods used in approximating gross annual revenues or savings and net annual revenues or savings of the completed project. Also, the necessary further studies and certain special problems will be discussed in the following paragraphs:-

Power

Reservoir operation and power studies show that the completed Yangtze Gorge Project will have power outputs as follows:

Minimum firm power................	6.0	million k.w.
Average firm power................	7.8	" "
Minimum secondary power...........	1.4	million k.w.
Average secondary power...........	2.7	" "
Minimum firm energy	52.6	billion k.w.h.
Average firm energy	68.4	" "
Minimum secondary energy..........	7.1	billion k.w.h.
Average secondary energy..........	13.3	" "
Minimum total energy	70.8	billion k.w.h.
Average total energy..............	81.7	" "

The gross annual revenues for the completed project from firm power at \$0.002 per k.w.h., and from secondary power at \$0.0005 per k.w.h., are estimated as follows:

Firm power,	68,400,000,000 k.w.h.@ \$0.002	\$136,800,000
Secondary power,	13,300,000,000 k.w.h.@ \$0.0005	\$ 6,650,000
Total gross average annual revenue.............		\$143,450,000

Irrigation

The benefits from irrigation have been tentatively analysed as indicated in the following paragraphs:

Irrigable Area

No definite data are available at present relative to the area and character of irrigable lands below the proposed Yangtze Gorge Reservoir. However, oral statements by engineers who are familiar with that part of the country indicate that the lands eastward from Ichang, south of Siang-Yang, north of Changteh and west of Hankow, are largely under irrigation. If high-line canal systems are built to assume an irrigation supply from Yangtze Gorge Reservoir, this vast area, comprising about 60,000,000 mows (10,000,000 acres) could produce two crops of rice yearly.

Water Supply.

The two growing seasons for rice are from April to July and from July to October. The natural discharges of Yangtze River increase in close unison with the demand of water for rice irrigation. Likewise, the river discharges are more than sufficient for power development during and after May and, therefore, the excess water can be diverted through high-line canal systems for irrigation purposes. Reservoir operation studies show that the minimum annual diversion available from the reservoir for irrigation from April to October is about 74,000,000 a.f., which is just about enough for two crops of rice on the area described. The studies show a slight deficiency of water supply during seeding time in April but the rainfall at this season of the year will make up this deficiency.

Value of Irrigation

With two crops, the rice production per acre per year will average 36 Tan (72 bushels). At the pre-war price of C$6.00 per Tan or U.S.$1.00 per bushel, the gross return per acre per year would be U.S. $72.00. If we assume that 5% of the annual gross return from crops is allotted for repayment of the irrigation system costs, as is usual in America, the annual charge will be U.S.$3.60 per acre or about U.S.$0.50 per acre foot of stored water. With a minimum annual diversion of 74,000,000 acre feet the gross annual revenue from irrigation will be U.S.$37,000,000.

Flood Control

The only record of large flood damages, on Yangtze River below Ichang is that for the flood of August 1931, and any evaluation of flood control benefits necessarily will be made on the basis of this single flood. Before discussing flood benefits it will be advisable to describe several of the larger floods. This will be done in the next few paragraphs.

Magnitude of Floods

The discharge of the 1931 flood was over 40,000 c.m.s. (1,412,000 s.f.) from August 7th. to 14th., also on the 17th. and 18th. The maximum mean daily discharge was 58,500 c.m.s. (2,060,000 s.f.). The total flood volume from August 7th. to 18th. was 50,000,000,000 c.m. (40,500,000 a.f.). If the flood discharge below the proposed Yangtze Dam is to be limited to 40,000 c.m.s., a flood storage of 8,800,000,000 c.m. (7,140,000 a.f.) will be required. (There were two days with discharges less than 40,000 c.m.s.)

The discharge records at Ichang show that there were three floods greater than that of 1931 during the period from 1890 to 1939, namely: the flood of 1896 with maximum daily discharge of 64,800 c.m.s. (2,290,000 s.f.); the flood of 1921 with maximum daily dischafge of 60,000 c.m.s. (2,120,000 s.f.); and the flood of 1905 with maximum daily discharge of 59,100 c.m.s. (2,090,000 s.f.). There were twenty two smaller floods with mean daily discharges greater than 50,000 c.m.s. (1,765,000 s.f.).

However, some of these floods had greater flood volumes and longer durations than the 1931 flood. The maximum flood volume was 160,000,000,000 c.m. (130,000,000 a.f.) for the July 22 to August 30,1922, flood and the discharge was considerably over 40,000 c.m.s. (1,412,000 s.f.). The flood volume above the 40,000 c.m.s. discharge was 21,800,000,000 c.m.(17,700,000 a.f.), which was two and one half times that of the 1931 flood. The maximum mean daily discharge was 56,400 c.m.s. (1,990,000 s.f.).

Reservoir Operation
for Flood Control

Although the floods in the lower Yangtze Valley have been due to the combined flood peaks of Yangtze River above Ichang, the Han River and others, there is no doubt that the largest part of the flood discharges are contributed by Yangtze River above Ichang. The Yangtze Gorge reservoir can be used to regulate the river discharge and eliminate practically all of the floods below Ichang. It is tentatively assumed that the safe limit of Yangtze River discharge below Ichang is 40,000 c.m.s. (1,412,000 s.f.). During flood peaks of Han River or other major rivers the discharge from Yangtze Reservoir can be further reduced, so that the flood discharge below Hankow will be within a safe limit.

The hydrographs of the Yangtze River show that the discharges at Ichang were always above 10,000 c.m.s. (353,000 s.f.) after June 1, except on a very few occasions when the discharges were slightly below 10,000 c.m.s. for periods of a few days. This condition will not affect the power output. The reservoir will be drawn down to elevation 177 (the average water surface for power) or flood storage purposes every year. With such operation, the flood of 1922 would raise the reservoir to elevation 202 causing an encroachment of 2 meters on the designated free-board of the dam. The large floods of Yangtze River always occur in July or August. Therefore, the reservoir will always begin to fill by the middle or latter part of September and there will be enough flow to fill the reservoir and provide for power development during the winter season every year.

Benefits of
Flood Control

Available information indicates that the damages caused by one of the large floods of record, namely, that of 1931, were authentically estimated by the Yangtze River Commission. The estimate, which included damages to crops, fodder, stored provisions, fuels, buildings, furniture, clothing, farm tools, cattle, other livestock, and dikes - but excluded losses in cities, towns and public investments, amounted to C$1,304,600,000. Adding 10% to this amount for losses in cities, towns and public investments gives a total loss of C$1,435,000,000. At the pre-war rate of exchange of about three Chinese dollars to one U.S. dollar this amount becomes U.S.$478,000,000.

If it is assumed that the damages of the 1896, 1905, and 1921 floods were of about the magnitude of the 1931 flood, giving four damaging floods in a period of 50 years or one flood in a period of 12.5 years, the average damage per year would be U.S.$478,000,000 ÷ 12.5 or U.S.$38,240,000. No information is available regarding the damages caused by any floods except that of 1931.

It is believed that the above assumption should be adopted for the purposes of this report, but it should be recognized that the unknown damages of other larger floods than that of 1931 if included in this Study would materially increase that annual savings.

Navigation

The greatest benefit from improved navigation, namely, the saving of lives, can not be given a money value. However, it can be stated that many lives including passengers and personnel will be saved every year by the proposed improvements in navigation.

An analysis of the navigation benefits other than the loss of life has been made, using data taken from the Reconnaisance Report dated January 1939, on Navigation of Yangtze River, by the Ministry of Economic Affairs, as follows:-

Shippings in 1936:

Chungking to Ichang:271,156x806=218,000,000t.mi.=350,000,000 t.k.
Wan-Hsien to Ichang:490,134x400=198,000,000t.mi.=314,000,000 t.k.
Total: 416,000,000t.mi.=664,000,000 t.k.

Freight Rates Upstream
between Chungking and Ichang:

During high water season:C$0.08 to 0.11/t.k. - ave. C$0.095/t.k.
During low water season :C$0.16 to 0.23/t.k. - ave. C$0.195/t.k.
ave. C$0.145/t.k.
or. US$0.0482/t.k.
Downstreamffreight rates are 50% of upstream rates orUS$.0241/t.k.
Average of upstream and ownstream rates US$.0361/t.k.

Freight below Ichang:

During full year C$0.015 to 0.02 - ave. C$0.0175 or US$0.0058/t.k.

Saving in Freight with
Improved Navigation:

Assuming freight rate between Chungking and Ichang to be the same as that below Ichang, the savings in freight will be US$0.0361 - 0.0058 = US$0.0303/t.k. or a total saving of (664,000,000 t.k. x 0.0303) US$20,100,000 for the year 1936.

Assuming that the transportation rate upstream and downstream from Ichang on completion of the project will be the same as the pre-war rate downstream from Ichang, namely, US. $0.0058, and assuming that the volume of shipping between Chungking and Ichang will be increased many times, the gross annual freight revenues for increased cargos of varying percentages over that of 1936 will be as follows:-

Gross Annual Freight
Revenues for Increased
Cargo over 1936:

Increases	Ton-Kilometers	Annual Savings
3000%	19,920,000,000	US$ 115,500,000
4000%	26,560,000,000	US$ 154,000,000
5000%	33,200,000,000	US$ 192,500,000

It is believed that the assumed 5000% increase of cargo over that of 1936, after completion of navigation improvements, should be adopted for the purposes of this report. This increase gives a gross annual revenue of U.S. $192,500,000.

If it is assumed that the navigation facilities can be provided, maintained and operated for 80% of the gross annual revenue, namely, (U.S.$192,500,000 x .80) or U.S.$154,000,000 the remaining 20% becomes a net annual revenue of (U.S.$192,500,000 x .20) or U.S.$38,500,000.

Navigation Facilities

Navigation facilities will become a most important auxiliary development of the Yangtze Gorge Project. Only general consideration of the facilities have been possible in this preliminary investigation and report, due principally to lack of basic data. However, it is proposed to make careful studies of navigation facilities in the final report to be prepared in America. An effort will be made to design a new type of lock gate that will permit the construction of a single lock basin at Yangtze Gorge Dam, in lieu of a series of conventional locks. If this construction proves feasible it will be much more economical than conventional locks.

Some of the special problems to be considered in the study of navigation facilities that are auxiliary to Yangtze Gorge Project will be discussed in the following paragraphs:

Navigation During Construction of dam.

The problem of providing for navigation during construction of the dam will receive careful consideration in the final design of the project. If the single lock structure suggested in a previous paragraph proves feasible, it is believed that such a structure may be adaptable for temporary use during construction of the dam. A provisional installation including a short upstream ship tunnel and conventional lock gates, combined with the permanent lock basin and the permanent downstream ship tunnel, will apparently constitute workable locking facilities. Another alternative plan would include a set of temporary conventional locks located along one of the abutments and passing over the upstream cofferdam, over a low row of blocks in the main dam, and over the downstream cofferdam. This alternative probably would be much more expensive than the plan mentioned first because none of the construction or equipment items could be utilized in the completed project. However, the gates and other mechanical equipment might be used on other auxiliary navigation projects. Such an installation would interfere seriously with construction operations on the main project and in this respect the plan with temporary ship tunnel is preferable.

Navigation between Chungking
and Wan-Hsien During Maximum
Drawdown of Reservoir

Eventually, the upper reach of Yangtze Reservoir, for example, that between Chungking and Wan-Hsien, is certain to present a difficult navigation problem during periods of maximum reservoir drawdown, particularly for navigation of large boats. This difficulty may be postponed for a number of years pending full development of the power and irrigation resources of the river, in other words pending full drawdown operation. Also, this difficulty will ultimately be relieved by increased discharges resulting from upstream storage.

This navigation problem will be given careful consideration in the final report on Yangtze Gorge Project. The most probable means of meeting the difficulty are believed to include the following:

(a) Navigation dams and locks designed for temporary submergence, combined with adequate heavy duty dredging equipment.

(b) River channel control works combined with heavy duty dredging equipment.

(c) River channel flushing during the low water season using large discharges for short periods, following development of upstream storage.

Navigation between Ichang
and Hankow and Shanghai

Presumably the control of Yangtze River for power, irrigation and flood protection will benefit navigation below Ichang. Large flood peaks and low river discharges will be eliminated. Clear water will be released from the reservoir and this may tend to degrade the river channel for a considerable reach below Ichang. However, it appears certain that navigation improvements will be needed in the lower river. These probably will involve navigation dams and locks, and in some reaches constructed navigation channels. It is believed that navigation facilities can be provided and maintained adequate for bringing ocean-going vessels to Ichang and on to Chungking. It is important that comprehensive surveys and data be provided relative to navigation, both upstream and downstream from Yangtze Reservoir, for use in the proposed final report. These navigation problems will need very careful study including hydraulic model tests before final designs can be prepared.

Silting of Power and
Navigation Facilities

Every precaution must be taken in the final design of Yangtze Gorge Project to avoid difficulties due to silt accumulations in front of power intakes and in navigation channels and locks. A large measure of protection will be realized from ultimate upstream storage. However, such relief may be long postponed and otherwhere immediate measures should be taken to avoid these difficulties. The following investigations are suggested for consideration of this problem:

(a) Research should be undertaken to determine what measures have met with success on other great silt laden rivers of the world such as the Mississippi, the Nile and others. Presumably such research may lead to information that will be helpful in planning methods of improving and maintaining navigation channels, for example, in the upper reaches of the reservoir between Chungking and Wan-Hsien during maximum draw-down of Yangtze Reservoir. Also, such research particularly in reference to the Nile should indicate the design and capacity of facilities necessary for sluicing the narrow river channel upstream from Yangtze Dam to keep silt from accumulating eventually in front of the power intakes.

(b) Probably this research should include hydraulic model testing to determine the methods of channel improvement and control best adapted to future silt conditions, and to determine whether navigation dams will be required eventually in the upper reservoir channels as well as in channels downstream from Ichang.

(c) Design studies and hydraulic model tests should be made of different main features of the lock structures to determine the best means of desilting approach channels, ship channels, locks, lock gates and other moving parts in the navigation works. Hydraulic model tests may be useful also in connection with the design of special lock gates.

(d) The silt studies necessarily will have to consider conditions during construction of the dam, as well as those immediately following completion of the dam and those in the distant future.

The silt problems to be solved in connection with China's large water projects are recognized as important and difficult. However, they can be solved and the projects made workable.

Domestic Water

It has been stated that charges for domestic water in certain cities of China vary from C$0.45 to C$0.80, or an average charge of C$0.625 per 1000 imperial gallons. This rate at the pre-war exchange of about three Chinese dollars to one U.S.dollar would be U.S.$0.208 per 1000 imperial gallons or (.208 x 6.25 x 43,560) ÷ 1000 = U.S.$56.60 per acre foot.

This is assumed to be a gross charge sufficient to repay, operate and maintain the pump and distribution systems. Probably such a gross charge would yield a net revenue of at least 5½% or $3.00 per acre foot. Also, it is assumed that the ~~total~~ population to be served in cities, towns, villages and populated rural districts may total 10,000,000. On the basis of 75 imperial gallons per capita per day the total capacity per annum would be (10,000,000 x 75 x 365) ÷ (43560 x 6.25) = 1,000,000 acre feet. The average annual revenue would be (1,000,000 a.f. x U.S.$3.00) or U.S.$3,000,000.

Recreation

A conservative assumption of 500 foreign and Chinese tourists per day for 200 days per year, each spending on the average U.S.$500 in Western China, will give an assumed gross annual revenue of U.S.$50,000,000. If it is assumed that 10% of this amount is a net revenue accruing to Yangtze Gorge Project the net annual revenue becomes U.S.$5,000,000.

Available Data

The available data submitted for consideration of the Yangtze Gorge Project include the following:-

(a) Memorandum on the Upper Yangtze River and its Gorges, Ichang to Chungking, July 1944, prepared by the National Hydro-electric Power Survey of the National Resources Commission. This memorandum contains maps and drawings showing military topography, surficial geology, location of gaging stations, river slopes, rating curves, hydrographs, and flood frequency curves. Also, tables of precipitation, gage reading, discharges, temperatures, evaporation, roughness coefficients, silt contents, and geology of the Gorges. Also, "A Brief Account of Wu-Kiang", extracts from "The Upper River" and "Through the Gorges", by H.G.W.Woodhead; and "The Grandeur of the Yangtze Gorges," by Julius Eigner. Also, "The Grandeur of the Gorges", in 50 photographs (loaned from N.R.C. library). Also, miscellaneous tables of water levels and discharges of the Ming, Chia-Ling, Fu, Chu, Tsa, Ching-I, and King-Sha-Kiang.

(b) Handbook for the Guidance of Shipmasters on the Ichang-Chungking Section of the Yangtze River, by S.C.Plant, Late River Inspector, Chinese Maritime Customs. Revised and enlarged by R.G.Everest, River Inspector, Chinese Maritime Customs. Second Issue.

(c) Geology of the Gorge District of the Yangtze, from Ichang to Tzekuei, with Special Reference to the Development of the Gorges, by J.S. Lee.

(d) Geology of Ichang, Hsienshan, Tzekuei and Patung Districts, Hupeh, by C.Y. Hsieh and Y.T.Chao.

Additional Data Requested
for Preliminary Report

Additional data requested for the preparation of this preliminary report include the following:-

(a) Information conveniently available regarding the location, intersity and damage of recorded earthquakes in Central and Western China.

(b) Check surveys to establish the accuracy or inaccurcy of the Chinese Military topography and of the captured Japanese aerial topography, in the region along the adjacent to Ichang Gorge on the Yangtze River.

(c) Flow sheet and general information regarding the manufacture of fertilizers by the nitrogen fixation process, including available studies by the National Resources Commission and report of Y.C. Lu.

(d) Available information regarding the character and amount of flood damages caused by different stages of the Yangtze during the period of record and particularly the amount of damages from the maximum flood of record.

(e) Available information regarding the difficulties and costs of navigation on the Yangtze River and tributaries under present conditions and estimated savings with the Yangtze Gorge Project completed.

(f) Hydrologic data pertaining to main tributaries of the Yangtze River above Ichang for use in estimating the effects of upstream storage.

(g) Information regarding the location and areas of irrigable lands for gravity and pump irrigation in Yangtze Valley below Ichang, also, areas for pump-irrigation along the Yangtze Gorge Reservoir.

(h) The value of an acre-foot of water for irrigation purposes and for domestic water supply.

(i) The average amount spent in Yangtze Valley per tourist, following completion of the Yangtze Gorge Project.

Program of Surveys

It is suggested that a program of surveys be carried out sufficient for compiling and preparing a file of maps of the Yangtze Gorge Project as follows:-

(a) Map of catchment area showing important physical and geographical features, particularly the mountain ranges, forest areas, rivers, principal cities, and the location of rain gages and stream gaging stations. The scale used for this map should be selected to provide a size of folded map convenient for inclusion in a bound report of U.S. legal size (21½ cm. by 33½ cm.)

(b) Vicinity map showing important present and proposed access roads and railroads, rivers, cities, villages, populated rural districts, and present and potential irrigable areas, that are of interest in connection with the project. The scale of this map should be selected to provide a size convenient for inclusion in the bound report.

(c) Aerial or planetable topographic map of the reservoir area, on a scale of 1 to 5000 and contour interval of 5 meters. Aerial surveys are preferable and more economical.

(d) Aerial or planetable topographic map of the portion of reservoir basin to be cleared of trees and brush, on a scale of 1 to 2500 and contour interval of 2 meters.

(e) Planetable topographic maps showing land and property ownership in the reservoir area, on scales of 1 to 2500 or 1 to 1000, and contour intervals of 2 meters or 1 meter respectively, as found desirable. Special care should be taken in surveying property at Chungking and other important cities and villages.

(f) Topographic alinement map of the river, profile along the center line of river, and profiles on the axes of proposed alternative dam sites. These maps and profiles should extend for sufficient distance longitudinally and laterally to include adjacent alternative dam sites and probable alternative locations of permanent works and of construction plant and operations. This drawing should be on a scale of 1 to 2500 and contour interval of 2 meters. It should include contours up to elevation 300 meters.

(g) Topographic map of each alternative project site including areas needed for all permanent works, areas needed for construction plant and materials and for borrow or wastage of excavated materials. This map should be on a scale of 1 to 1000 and contour interval of 1 meter. The topography should be carried to elevation 350 meters.

(h) Topographic maps of separate natural gravel or rock quarry areas suitable for use as sources of concrete aggregate, including areas needed for processing plant, stock piles or other construction installations, on scales of 1 to 2500 or 1 to 1000, and contour intervals of 2 meters or 1 meter respectively, as found desirable.

(i) Geologic maps, sections and photographs as determined with the aid of a competent engineering-geologist, on scales suitable for illustrating the significant geologic conditions at the locations of principal features of the project, including prospective alternative project sites.

(j) Topographic map of the Yangtze River and adjoining areas downstream from the alternative project areas, including the Ichang area and a region extending about 30 kilometers downstream from Ichang, on a scale of 1 to 2500 and contour interval of 2 meters.

(k) Detail survey and map of irrigable lands available for gravity and pump irrigation, following construction of the project.

(l) Topographic surveys and maps of alternative locations for the construction and operation of a portland cement mill with capacity of 10,000 barrels or more per day, on a scale of 1 to 1000 and contour interval of 1 meter.

(m) Topographic surveys and maps of existing and proposed access roads and railroads, on a scale of 1 to 2500 and contour interval of 2 meters.

(n) Topographic surveys and maps of separate locations for the proposed fertilizer plant, adjacent to each alternative project site, on a scale of 1 to 2500 and contour interval of 2 meters.

(o) Detail survey and report on the character and amount of flood damages caused by different stages of the Yangtze during the period of record and particularly the amount of damage caused by the maximum flood of record. This survey and report should include all basic data necessary to evaluate flood control benefits of the project.

(p) Detail survey and report on present navigation and on proposed navigation following completion of the Yangtze Gorge Project. This survey and report should include all basic data necessary to evaluate navigation benefits of the project.

(q) Detail survey and report on the utilization of stored water for domestic water supply of cities and villages located along the Yangtze Reservoir and along and below the main distributary irrigation canals. This survey and report should include all basic data necessary to evaluate the benefits from domestic water.

(r) Miscellaneous surveys to be determined as investigations, designs, and construction operations progress.

Program of Explorations.

A program of explorations should be carried out at each alternatice project site that is considered to be a prospective site for development, as follows:

(a) The projected layout of the concrete dam should be encircled with 2½-inch core drill holes spaced 25 to 40 meters apart along the projected upstream and downstream faces of the dam. An extra line of core holes should be drilled along the projected center line of the dam, across the river channel and up both abutments for about half the maximum height of dam. Also, an extra line of drill holes spaced 15 to 25 meters apart should be drilled along the downstream edge of the proposed spillway bucket or hydraulic jump apron.

(b) The projected locations of earth and rock fill cofferdams should be encircled with 4 to 6-inch cased drill holes spaced 25 to 40 meters apart and these holes should be drilled to a depth of not less than 5 meters into bed rock. The projected locations of cellular steel pile or timber cribe cofferdams should be explored by one line of 4 to 6-inch cased drill holes spaced 15 to 25 meters apart along the projected center line and drilled to a depth of 10 meters into rock. The overburden materials should be sampled tested and logged with care to determine their suitability for foundations of the cofferdams.

(c) The abutment areas and locations of separate main features and important construction plant installations will be partially explored by the drilling operations described above. However, these areas and locations should be further explored by test excavation methods including pits, trenches and drifts, and by large calyx drills if these become available. Major open joints, fractures, weathered contacts, seams, bed planes, crush zones and faults should be explored preferably by test pits, trenches and drifts prior to and during the progress of excavations.

(d) The projected location of each diversion and power tunnel should be explored by 2½-inch core drill holes as follows:-

(1) A vertical hole intersecting the axis of the intake tunnel at or near the projected upstream tunnel portal and extending down to an elevation 20 meters below the invert of the complimentary diversion tunnel.

(2) An inclined hole on the projected axial center line of each inclined power tunnel and extending down to an elevation 20 meters vertically below the invert of diversion tunnel.

(3) A vertical hole on the axial center line of each cable shaft and extending down to an elevation 20 meters below the invert of diversion tunnel.

(4) A vertical hole intersecting the axial center line of each downstream diversion tunnel portal and extending down to an elevation 20 meters below the invert of the tunnel.

(5) Intermediate vertical holes intersecting the axial center line of each diversion tunnel at intervals of not more than 500 meters between the cable shaft hole and the hole at the downstream portal of the diversion tunnel. All of these holes should extend to an elevation 20 meters below the invert of the tunnel.

(e) Miscellaneous explorations to be determined as investigations, designs, and construction operations progress.

Program of Studies

Five tentative general schemes for the Yangtze Gorge Project have been studied utilizing prospective alternative sites determined from available aerial topography. General features of the dam and power plant have been described in the proposal of this report. The tunnel schemes are applicable to Studies Nos.1,2,3 and 4. In Study No.5 the power plant would be installed in a large gallery in the left end portion of the dam. In this scheme no diversion tunnels would be used. The river would be controlled by stage cofferdams similar to those used at Grand Coulee dam, also, by diversion over low blocks of the dam and through draft tubes and other conduits in the dam. With these general features in mind the preliminary studies can be described briefly as follows:-

Preliminary Study No.1

The project location for this study is along the right bank of Yangtze River downstream from the village of Shih-Pai and upstream from a small tributary entering from the south, named "Soon-Men-Chi". The dam would be located closely upstream from the mouth of Soon-Men-Chi, which stream would be utilized for a tail race channel to Yangtze River. The power house tunnel would parallel the Yangtze. The combined diversion and power tunnels, which are normal to the power house tunnel, would bend to the left a short distance beyond the main access tunnel and extend in generally parallel alinements to Soon-Men-Chi.

Preliminary Study No.2

The project location for this study includes both banks of the Yangtze River in an area immediately upstream from a tributary entering from the north, named "Sha-Law-Chi". The dam would be located closely upstream from the mouth of Sha-Law-Chi. The power house tunnel on the left bank would be nearly normal to the Yangtze River and parallel to a nameless creek about one kilometer upstream from Sha-Law-Chi, which will be utilized as a head race channel. The combined diversion and power tunnels would be normal to the power house tunnel and extend in parallel alinements to Sha-Law-Chi, which will be utilized as a tail race channel to Yangtze River. The power house tunnel on the right bank would parallel the Yangtze and the combined diversion and power tunnels would make a bend to the left a short distance beyond the main access tunnel and extend in parallel alinements to Tze-Kou.

Preliminary Study No.3

The project location for this study includes both banks of the Yangtze River and covers much of the same area described under Study No.2. However, the dam would be placed closely downstream from the mouth of Sha-Law-Chi. The power house tunnel on the left bank would be approximately normal to the Yangtze and woubd parallel the Sha-Law-Chi, which latter stream would serve as a head race. The combined diversion and power tunnels would continue on the same parallel tangents to an unnamed tributary stream (hereinafter called "Unnamed Stream") entering the Chang-Chiao-Chi from the west. Unnamed Stream would serve for a tail race channel to Yangtze River. The power house tunnel on the right bank would parallel the Yangtze and the combined diversion and power tunnels would make a bend to the left a short distance beyond the main access tunnel and extend in generally parallel alinements to Tze-Kou.

Preliminary Study No.4

The proposed location for this study would include both banks of the Yangtze River and place the dam approximately one kilometer farther downstream than proposed under Study No.3 The power house tunnel on the left bank would parallel the Yangtze and the combined diversion and power tunnels would make a bend to the right and extend in generally parallel alignments to Chang-Chiao-Chi or to Unnamed Stream both of which would serve for a tail race channel leading to Yangtze River. The power house tunnel on the right bank would parallel the Yangtze and the combined diversion and power tunnels would make a bend to the left and extend on generally parallel alinements to Tze-Kou.

Preliminary Study No.5

The proposed location for this study would include a strip of land about 3 kilometers long extending from an abutment on the right bank of the Yangtze River to an abutment on the left bank of the Chang-Chiao-Chi, crossing the peninsula between these two rivers in the lowest narrow place. The right end portion of the dam, comprising the Yangtze River channel, would be constructed as a concrete overflow spillway. The left end portion would be constructed as a concrete non-overflow section, in which the power plant would be installed. The two portions of the structure would form a straight gravity dam about 3,000 meters long. The left end portion would include a power house gallery about 2,000 meters long housing ninety six main power units of 110,000 kw. capacity each, of 10,560,000 kw. and four station service units of 20,000 kw. capacity each, or a total installed capacity of 80,000 kw.

Additional Field Studies

Studies should be made of the ultimate power, irrigation, flood control, navigation, domestic water and recreational resources of the complete river basin of the Yangtze River and tributaries in Central and Western China, using methods of the U.S. Federal Power Commission (See Volume XV of Bureau of Reclamation Data File).

Final Studies

Final studies to be made in America for the purposes of a final report will include the following:-

(a) Review of preliminary economic studies to confirm or determine the water supply available for the project; the location, type and height of dam; the location, type and capacity of diversion works, spillways, outlet works, power plant and switchyard.

(b) Hydraulic model tests of the diversion works, spillways, outlet works, power intake systems, power tunnel systems and the power plant complete with all hydraulic features, for the proposed final project and if necessary for alternative projects that appear to be attractive.

(c) Stress and stability studies, design studies and estimates of cost, to confirm or determine the general dimensions, quantity of work and materials, and relative costs for the alternative projects described in the preliminary studies, or for other alternative projects that may be developed in the course of preparing the final studies.

(d) Contract designs and specifications and engineer's estimate of cost for the final project to be authorized for construction. The contract designs and specifications are to be prepared in the form of bound volumes similar to those prepared by the Bureau of Reclamation for construction by either contract or government forces.

(e) Detail designs and specifications for all features of the project to be authorized for construction, including structural, hydraulic, mechanical and electrical features, suitable for manufacture, procurement, installation and construction purposes.

Cooperative Arrangements
for Technical Personnel
and
Training Programs for
Chinese Technical Personnel

If any large program of project construction is authorized, such as that proposed on the Yangtze tributary rivers or that proposed in the Yangtze Gorge Project, the need for foreign technical assistance and for a comprehensive program of training for Chinese technical personnel will become imperative. Also, if a final report on present investigations of the scope proposed in this preliminary report is to be completed in America, cooperative arrangements, with some American engineering organization will be necessary. These matters have been the subject of considerable thought, which culminated in a discussion with Vice Chairman, C.C. Chien of the National Resources Commission on September 14,1944 and resulted in my Memorandum dated September 17,1944, addressed to Mr. Chien. The subject matter of this Memorandum is of sufficient importance to warrant quoting in full as follows:-

"On the occasion of our conference in your office during the afternoon of September 14, we discussed among other subjects the proposed arrangements for cooperative assistance of the Bureau of Reclamation and of the Tennessee Valley Authority; also, the proposed programs for the training of Chinese technical personnel. These arrangements and programs as presented to you verbally are outlined below:-

Completion of Final Report
on Present Investigations.

The final report on present investigations will include comprehensive studies of the projects under consideration and the preparation of general designs and specifications suitable for negotiating a contract for construction of the works or for undertaking construction by government forces.

The cooperative arrangements for assistance in completing the final report should be with the Bureau of Reclamation and these will include the services of about 150 Bureau engineers and certain other personnel for perhaps 6 to 8 months.

The training program under these cooperative arrangements would include the services of about 150 Chinese engineers and a number of geologists, chemists and physicists, all of whom would be utilized on actual necessary engineering work in America.

<u>Detail Designs and Specifications Necessary for Construction</u>

The construction of one large hydroelectric project such as Boulder or Grand Coulee Dam and Power Plant requires the preparation of no less than 15,000 detail design drawings. These drawings usually are prepared during the progress of construction and therefore a sufficient length of time, usually a period of several years, is available for this big task.

The cooperative arrangements for the preparation of detail designs and specifications for construction of any large authorization of projects in China should be with the Bureau of Reclamation and the Tennessee Valley Authority. Probably a force of about 500 Bureau and T.V.A. engineers would be needed from these two organizations for carrying out any large project authorization such as that proposed on the Yangtze tributary rivers or that proposed in the Yangtze Gorge Project.

The training program under these cooperative arrangements would include the services of about 500 Chinese engineers and a number of geologists, chemists and physicists, all of whom would be utilized in America on actual necessary work including some field and construction work for training purposes.

<u>Construction of Authorized Projects</u>

Construction under any large authorization of projects such as that proposed on the Yangtze tributary rivers or that proposed in the Yangtze Gorge Project will require the services in China of a considerable force of experienced engineering and construction personnel from America. The cooperative arrangements for this personnel should be with the Bureau of Reclamation and Tennessee Valley Authority. A force of at least of 500 engineers, construction superintendents, general formen, formen and skilled workmen probably would be needed from these two organizations.

The training program under these cooperative arrangements would include the services of a very large number of Chinese engineers, geologists, chemists, physicists, and construction personnel in all classifications from construction superintendent to skilled labor. Probably the training advantages can be extended to as many as 10,000 to 15,000 Chinese workers during the period of construction.

Cooperative Contracts

The cooperative contracts for the above described arrangements with the Bureau of Reclamation and Tennessee Valley Authority should be made flexible in the matter of duration and personnel because the amount of work to be done can not be estimated with certainty in advance. It is believed probable that the cooperation of the Bureau can be secured under present laws, and on the basis of actual necessary services plus a percentage for overhead and other general costs. It is possible that 15% may cover the overhead and general cost. However, these cooperative arrangements will have to be submitted to the Bureau of Reclamation and the Department of the Interior for consideration. It is my intention, if the Officials of National Resources Commission concur, to submit these various cooperative arrangements to the Bureau by cable. With this in mind I am enclosing copy of such a cable and desire that it be dispatched if agreeable to the Commission.

Contract Versus
Government Force Work

The construction of large projects such as those proposed on the tributary rivers of the Yangtze, or such as the Yangtze Gorge Project, can be done successfully either by contract or by government forces. The Bureau of Reclamation has built its super-projects including Boulder, Grand Coulee and Shasta Dams and Power Plants by contract. On the other hand the Tennessee Valley Authority has constructed their great projects by government forces. There are advantages in both methods and in my opinion there is very little choice between them, providing experienced personnel is assured by selecting an organization that has constructed similar and comparable works. For example, if the work is done by contract selection of the construction organization should be by negotiation and not by bidding. Only contractors who have built similar and comparable works should be considered. If the work is done by government forces the construction personnel should be selected largely from the construction organization of the Tennessee Valley Authority.

Economy of Design
and Construction by
Cooperative Arrangement
and Training Program.

It is my opinion that the cooperative arrangements and training programs suggested above will insure sound engineering and construction at minimum cost to the Government of China. The plan takes full advantage of the most experienced engineering and construction personnel on large hydroelectric projects and this personnel happens to be largely U.S.Government personnel. It is believed that the plan proposed for designing and constructing these super-projects is the best that can be arranged."

Tentative Conclusions.

It is possible to state tentative conclusions relative to the Yangtze Gorge Project on the basis of (1) a brief field inspection of the project area, (2) analyses of available basic data including river discharge records for fifty years, and (3) alternative studies and estimates of five different project sites selected from available aerial topography, as follows:-

1. The Yangtze Gorge Project with a normal reservoir water surface at elevation 200 will develop 10,560,000 kilowatts, of which 6,000,000 kilowatts are firm power and 4,560,000 kilowatts are secondary power. All of this secondary power will be converted ultimately to firm power by upstream storage developments. The project will provide 74,000,000 acre feet of water for the irrigation of 10,000,000 acres of good agricultural lands. About 22,000,000 acre feet of flood storage will be provided, which is sufficient to control the largest flood of record. Also, the project when supplemented by navigation facilities will permit ocean-going vessels to ply inland at least to Chungking. The great Yangtze Reservoir of 50,000,000 acre feet will provide an excellent supply of clear domestic water for many cities and industries, as well as recreational benefits, that are certain to become of utmost importance to China.

2. The relative merits of five alternative studies and estimates and of two alternative general plans of development of Yangtze Gorge Project are shown in the following summary of estimated costs. The costs are given in U.S. dollars.

Alternative Project	Total Field Cost	Investigation right of way Overhd.& Ctgs	Interest during Construction	Grand Total
Study No.1	$860,260,000	$139,039,000	$149,895,000	$1,149,194,000
Study No.2	$730,749,000	$119,612,000	$127,554,000	$ 977,915,000
Study No.3	$740,725,000	$121,109,000	$129,275,000	$ 991,109,000
Study No.4	$698,393,000	$114,759,000	$121,973,000	$ 935,125,000
Study No.5	$835,898,000	$135,385,000	$194,257,000	$1,165,540,000

3. The project is feasible in respect to its construction on the great Yangtze River, and also with regard to prospective repayment of the project cost through revenues accruing from power, irrigation, flood control, navigation, domestic water and recreational resources. Construction of the Yangtze Gorge Dam appears warranted to a large degree by any one of the four big benefits, namely, power, irrigation, flood control or navigation.

4. A plan of development utilizing diversion tunnels for by-passing the river during construction of the dam will cost less and be much more bomb-proof than a plan without diversion tunnels.

5. The total cost for the Yangtze Project including the dam, reservoir and power plant will be well under one billion U.S. dollars. The unit cost for power will be well under one hundred U.S. dollars per kilowatt of installed capacity.

6. On the basis of the fully loaded plant, gross annual revenues from power alone, estimated at two U.S. mills per k.w.h. for firm power and at one half mill per k.w.h. for secondary power, will average U.S.$143,450,000. Annual revenue deductions will include the following:- operation and maintenance on general and special features of the project amounting to U.S.$6,398,000; a replacement reserve of U.S.$2,287,000; and amortization on the basis of 15 years repayment period on a 4% sinking fund, including interest, amounting to U.S.$84,105,000; or a total deduction of U.S.$92,790,000. This leaves a net annual revenue of U.S.$50,660,000.

7. Gross annual revenues or savings and net annual revenues or savings will accrue from power and storage resources of the project as follows:

Power or Storage Resource	Gross Annual Revenue or Saving	Net Annual Revenue or Saving
Power	U.S.$143,450,000	U.S.$50,660,000
Irrigation	$ 37,000,000	$18,500,000
Flood control	$ 38,240,000	$38,240,000
Navigation	$192,500,000	$38,500,000
Domestic water	$ 56,600,000	$ 3,000,000
Recreation	$ 50,000,000	$ 5,000,000
Totals	U.S.$517,790,000	US$ 153,900,000

8. The Yangtze Gorge Project is a "CLASSIC". It will be of utmost importance to China. It will bring great industrial developments in Central and Western China. It will bring widespread employment. It will bring high standards of living. It will change China from a weak to a strong nation. The Yangtze Gorge Project should be constructed for the benefit of China and the World at large.

Respectfully submitted,

J. L. Savage

J. L. Savage
Consulting Engineer.

Table I
Yangtze Gorge Project

POWER OUTPUT
(Fourth Stage)

Res. W. S. El. 200 — Eff. storage: 29,200,000. A.F.
Nor. Tail W. S. El. 44 — Inst. Cap. : 8,360,000 kw.

Year	Firm Power, Million Kw.	Secondary Power, Million Kw.	Firm Energy, Billion Kw. hrs.	Secondary Energy, Billion Kw. hrs.	Total Energy, Billion Kw. hrs.
1890	8.4	0	73.6	0	73.6
1891	7.5	0.9	65.7	3.9	69.6
1892	7.1	1.3	62.3	6.6	68.9
1893	8.1	0.3	71.0	1.7	72.7
1894	8.0	0.4	70.1	2.0	72.1
1895	8.3	0.1	72.6	0.6	73.2
1896	8.4	0	73.8	0	73.8
1897	7.5	0.9	65.7	4.6	70.3
1898	8.2	0.2	71.8	1.0	72.8
1899	8.0	0.4	70.1	2.0	72.1
1900	7.8	0.6	68.3	2.6	70.9
1901	7.4	1.0	64.8	4.0	68.8
1902	7.1	1.3	62.1	5.7	67.8
1903	8.0	0.4	70.1	2.0	72.1
1904	8.4	0	73.8	0	73.8
1905	8.3	0.1	72.7	0.5	73.2
1906	8.4	0	73.6	0	73.6
1907	7.4	1.0	64.8	4.6	69.4
1908	8.3	0.1	73.0	0.4	73.4
1909	6.7	1.7	58.7	8.0	67.3
1910	7.5	0.9	65.5	4.6	70.2
1911	8.3	0.1	72.6	0.5	73.1
1912	8.4	0	73.8	0	73.8
1913	7.5	0.9	65.7	4.6	70.3
1914	7.6	0.8	66.6	4.1	70.7
1915	7.3	1.1	64.0	5.6	69.6
1916	8.3	0.1	72.9	0.6	73.5
1917	8.3	0.1	72.7	0.5	73.2
1918	8.4	0	73.6	0	73.6
1919	8.3	0.1	72.7	0.5	73.2
1920	8.0	0.4	70.3	2.0	72.3
1921	8.1	0.3	71.0	1.5	72.5
1922	8.0	0.4	70.1	2.0	72.1
1923	6.7	1.7	58.7	9.8	68.5
1924	6.7	1.7	58.9	8.7	67.6
1925	7.1	1.3	62.1	6.6	68.7
1926	8.3	0.1	72.7	0.5	73.2
1927	8.3	0.1	72.7	0.5	73.2
1928	6.6	1.8	58.0	9.6	67.6
1929	7.3	1.1	64.0	5.6	69.6
1930	8.2	0.2	71.8	0.9	72.7
1931	7.3	1.1	64.0	5.9	69.9
1932	7.5	0.9	65.8	4.6	70.4
1933	7.3	1.1	63.9	5.6	69.5
1934	8.1	0.3	71.0	1.5	72.5
1935	7.4	1.0	64.8	5.1	69.9
1936	7.9	0.5	69.4	2.9	72.3
1937	6.0	2.4	52.6	10.3	62.9
1938	8.2	0.2	71.8	0.9	72.7
1939	7.9	0.5	69.2	2.6	71.8
Average	7.76	0.64	68.1	3.2	71.3

Table II
Yangtze Gorge Project

POWER OUTPUT
(Fifth Stage)

Res. W. S. : El. 200   Live storage: 29,200,000 A.F.
Res. Cap.: 48,600,000 A.F.   Installing cap.:10,560,000 K.W.

Year	Firm Power, Million Kw.	Secondary Power, Million Kw.	Firm Energy, Billion Kw.hrs.	Secondary Energy, Billion Kw. hrs.	Total Energy, Billion Kw. hrs.
1890	8.7	1.8	76.2	10.7	86.9
1891	7.5	3.0	65.7	13.3	79.0
1892	7.1	3.4	62.3	17.5	79.8
1893	8.1	2.4	71.0	13.8	84.8
1894	8.0	2.5	70.1	12.7	82.8
1895	8.3	2.2	72.6	12.1	84.7
1896	8.8	1.7	77.3	8.1	85.4
1897	7.5	3.0	65.7	15.5	81.2
1898	8.2	2.3	71.8	11.9	83.7
1899	8.0	2.5	70.1	11.3	81.4
1900	7.8	2.7	68.3	11.9	80.2
1901	7.4	3.1	64.8	13.0	77.8
1902	7.1	3.4	62.1	15.2	77.3
1903	8.0	2.5	70.1	12.7	82.8
1904	8.4	2.1	73.8	10.4	84.2
1905	8.3	2.2	72.7	10.6	83.3
1906	9.1	1.4	79.6	7.1	86.7
1907	7.4	3.1	64.8	15.0	79.8
1908	8.3	2.2	73.0	8.6	81.6
1909	6.7	3.8	58.7	18.0	76.7
1910	7.5	3.0	65.6	15.6	81.2
1911	8.3	2.2	72.6	11.6	84.2
1912	8.9	1.6	78.2	8.3	86.5
1913	7.5	3.0	65.7	14.8	80.5
1914	7.6	2.9	66.6	15.1	81.7
1915	7.3	3.2	64.0	15.8	79.8
1916	8.3	2.2	72.9	12.0	84.9
1917	8.3	2.2	72.7	11.1	83.8
1918	8.4	2.1	73.6	11.1	84.7
1919	8.3	2.2	72.7	10.3	83.0
1920	8.0	2.5	70.3	12.5	82.8
1921	8.1	2.4	71.0	12.6	83.6
1922	8.0	2.5	70.1	13.1	83.2
1923	6.7	3.8	58.7	19.6	78.3
1924	6.7	3.8	58.9	19.1	78.0
1925	7.1	3.4	62.1	18.1	80.2
1926	8.3	2.2	72.7	11.5	84.2
1927	8.3	2.2	72.7	9.5	82.2
1928	6.6	3.9	58.0	18.6	76.6
1929	7.3	3.2	64.0	15.2	79.2
1930	8.2	2.3	71.8	10.8	82.6
1931	7.3	3.2	64.0	16.6	80.6
1932	7.5	3.0	65.8	15.6	81.4
1933	7.3	3.2	63.9	16.4	80.3
1934	8.1	2.4	71.0	12.2	83.2
1935	7.4	3.1	64.8	15.1	79.9
1936	7.9	2.6	69.4	12.8	82.2
1937	6.0	4.5	52.6	18.2	70.8
1938	8.2	2.3	71.8	10.2	82.0
1939	7.9	2.6	69.2	12.6	81.8
Average	7.8	2.7	68.4	13.3	81.7

Table III

Yangtze Gorge Project

Study No. 1
Power Plant in Tunnel
Dam located about 3,000m. downstream from Shih-Pai

ESTIMATED COST

Item No.	Item	Quantity	Unit Cost U.S.$	Total Cost U.S.$
	(A) River Diversion			319,494,000
1.	Excavation: rock, diversion tunnels	25,200,000 cy	6.00	151,200,000
2.	Excavation: common, cofferdams	533,000 cy	0.15	80,000
3.	Excavation: common, tailrace channel	5,480,000 cy	0.15	822,000
4.	Excavation: rock, tailrace channel	49,320,000 cy	0.75	36,990,000
5.	Earthfill: cofferdam upstream	4,040,000 cy	0.25	1,010,000
6.	Earthfill: cofferdam downstream	2,176,000 cy	0.25	544,000
7.	Rockfill: cofferdam upstream	710,000 cy	1.00	710,000
8.	Rockfill: cofferdam downstream	384,000 cy	1.00	384,000
9.	Riprap: cofferdam upstream	77,200 cy	1.50	116,000
10.	Riprap: cofferdam downstream	61,500 cy	1.50	92,000
11.	Rock barrier, upstream	135,000 cy	1.00	135,000
12.	Rock barrier, downstream	217,000 cy	1.00	217,000
13.	Removal of downstream cofferdam earth	2,176,000 cy	0.15	326,000
14.	Removal of downstream cofferdam rock and rock barrier	662,500 cy	0.50	331,000
15.	Pressure grouting of tunnels	Lump Sum		3,000,000
16.	Concrete: diversion tunnel linings	7,726,000 cy	15.00	115,890,000
17.	Concrete: diversion tunnel plugs	841,000 cy	7.00	5,887,000
18.	Concrete: tunnel inlet structures	30,000 cy	20.00	600,000
19.	Concrete: tunnel outlet structures	33,000 cy	20.00	660,000
20.	Installing bulkhead gates and hoists (4)	Lump Sum		500,000

Study No. 1

ESTIMATED COST

(Continued)

Item No.	Item	Quantity	Unit Cost U.S.$	Total Cost U.S.$
	(B) Dam			82,948,000
1.	Excavation: common, dam foundation	4,830,000 cy	0.15	725,000
2.	Excavation: rock, dam foundation	5,250,000 cy	0.75	3,938,000
3.	Foundation treatment	Lump Sum		2,000,000
4.	Concrete: dam	9,140,000 cy	5.00	45,700,000
5.	Concrete: spillway apron	2,160,000 cy	5.50	11,880,000
6.	Concrete: spillway crest and piers	247,000 cy	11.00	2,717,000
7.	Concrete: gravity training walls	250,000 cy	5.50	1,375,000
8.	Concrete: canti-lever training walls	95,000 cy	12.00	1,140,000
9.	Concrete: trashrack structures	32,700 cy	20.00	654,000
10.	Concrete: parapet walls, side walks and curbs	600 cy	20.00	12,000
11.	Placing reinforce-ment bars and fabrics	25,974,000 lb.	0.04	1,039,000
12.	Cooling concrete, including pipings and fittings	Lump Sum		920,000
13.	Grouting contract-ion joints includ-ing pipings and fittings	Lump Sum		920,000
14.	Installing, steel conduit lining, river outlets	22,500,000 lb.	0.10	2,250,000
15.	Installing tube valves, river outlets	80 sets	45,000	3,600,000
16.	Installing, gate frames, seats, guides, and trash-rack sections, river outlets	10,100,000 lb.	0.075	758,000
17.	Installing drum gates	Lump Sum		2,000,000
18.	Installing, drum gates control mechanism	Lump Sum		500,000
19.	Installing, bulkhead gates (2)	Lump Sum		20,000
20.	Installing, metal sealing strips in contraction joints	800,000 l.f.	0.75	600,000

Study No. 1

ESTIMATED COST

(Continued)

Item No.	Item	Quantity	Unit Cost U.S.$	Total Cost U.S.$
21.	Installing misc. metal works	Lump Sum		200,000
	(C) Power Plant			445,318,000
1.	Excavation: rock, intake tunnels and headworks	752,400 cy	6.00	4,514,000
2.	Excavation: rock, power plant tunnel	3,440,000 by	6.00	20,640,000
3.	Excavation: rock, draft tubes	195,000 cy	6.00	1,170,000
4.	Excavation: rock, power plant main access tunnel	1,136,100 cy	6.00	6,817,000
5.	Excavation: rock, cross tunnels	170,000 cy	6.00	1,020,000
6.	Excavation: rock, intake access tunnel	691,000 cy	6.00	4,146,000
7.	Excavation: rock, tailrace tunnels	1,840,000 cy	6.00	11,040,000
8.	Excavation: rock, transformer tunnel	900,000 cy	6.00	5,400,000
9.	Excavation: rock, transformer tunnel cross galleries	26,300 cy	6.00	158,000
10.	Excavation: rock, high tension outlet shafts	2,060,000 cy	6.00	12,360,000
11.	Excavation: rock, low tension outlet shafts	154,000 cy	6.00	924,000
12.	Excavation: rock, transformer and passenger elevator shafts	146,500 cy	6.00	879,000
13.	Excavation: rock, pedestrian galleries	14,700 cy	6.00	88,000
14.	Excavation: rock, intake trashrack shafts	1302,500 cy	6.00	7,815,000
15.	Excavation: rock, lightning arrester tunnels	625,000 cy	6.00	3,750,000
16.	Excavation: rock, inclined power tunnels	466,000 cy	6.00	2,796,000
17.	Excavation: rock, ventilation shafts	10,500 cy	6.00	63,000
18.	Concrete: intake tunnel lining and headworks	236,500 cy	15.00	3,548,000

Study No. 1

ESTIMATED COST

(Continued)

Item No.	Item	Quantity	Unit Cost U.S.$	Total Cost U.S.$
19	Concrete: intake trashrack shaft lining	300,000 cy	15.00	4,500,000
20	Concrete: trashrack structures	33,000 cy	20.00	660,000
21	Concrete: inclined power tunnels	171,500 cy	11.00	1,887,000
22.	Concrete: intake access tunnel lining	127,500 cy	15.00	1,913,000
23.	Concrete: power plant tunnel lining	590,000 cy	15.00	8,850,000
24.	Concrete: power plant substructures	545,000 cy	20.00	10,900,000
25.	Concrete: draft tubes	188,000 cy	20.00	3,760,000
26.	Concrete: power plant main access tunnel lining	200,000 cy	15.00	3,000,000
27.	Concrete: cross tunnel lining	66,500 cy	15.00	998,000
28.	Concrete: pedestrian tunnel lining	5,500 cy	15.00	83,000
29.	Concrete: transformer tunnel lining	300,000 cy	15.00	4,500,000
30.	Concrete: transformer tunnel cross gallery lining	9,700 cy	15.00	146,000
31.	Concrete: high tension outlet shaft lining	1,025,000 cy	15.00	15,375,000
32.	Concrete: low tension cable shaft lining	66,000 cy	15.00	990,000
33.	Concrete: lightning arrester tunnel lining	119,000 cy	15.00	1,785,000
34.	Concrete: tailrace tunnel lining	586,000 cy	15.00	8,790,000
35.	Concrete: transformer & passenger elevator shaft lining	45,200 cy	15.00	678,000
36.	Concrete: ventilation shaft lining	4,300 cy	15.00	65,000
37.	Placing reinforcement bars & fabrics	400,670,000 lb.	0.04	16,025,000
38.	Installing penstocks	17,800,000 lb.	0.10	1,780,000
39.	Power plant, including electrical, mechanical & hydraulic equipment and high tension switching equipments	10,640,000 kw.	25.00	266,000,000
40.	Installing: cranes and gantries	Lump Sum		280,000

Study No. 1

ESTIMATED COST

(Continued)

Item No.	Item	Quantity	Unit Cost U.S.$	Total Cost U.S.$
41.	Installing: gantry rails	883,000 lb.	0.06	50,000
42.	Installing elevators	Lump Sum		760,000
43.	Installing: intake gate seats, guides, trashrack guides and sections	11,000,000 lb.	0.075	825,000
44.	Installing: intake coaster gates and hoists	Lump Sum		660,000
45.	Installing: tailrace bulkhead gates	Lump Sum		430,000
46.	Pressure grouting tunnels & shafts	Lump Sum		500,000
47.	Installing: misc. metal works	Lump Sum		500,000
48.	Drainage system	Lump Sum		1,000,000
49	Ventilation system	Lump Sum		500,000
	Total Cost from A to C			847,760,000
	Construction Camp			5,000,000
	Freight			5,000,000
	Communication Roadways			2,500,000
	Total Field Construction Cost			860,260,000
	Right of Way and Investigations			10,000,000
	Overhead and Contingencies 15%			129,039,000
	Total			999,299,000
	Interest during Construction 15% (completed in 6 years)			149,895,000
	Grand Total			1,149,194,000

Note: Unit Cost indluding labor and materials.

Table IV

Yangtze Gorge Project

Study No. 2
Power Plant in Tunnel.
Dam located about 1,800 m. upstream from Nan-Tzin-Kwan

ESTIMATED COST

Item No.	Item	Quantity	Unit Cost U.S.$	Total Cost U.S.$
	(A) River Diversion			196,411,000
1.	Excavation, rock, diversion tunnels	14,560,000 cy	6.00	87,360,000
2.	Excavation, common, cofferdams	425,000 cy	0.15	64,000
3.	Excavation, common, headrace channel	5,400,000 cy	0.15	810,000
4.	Excavation, rock, headrace channel	16,300,000 cy	0.75	12,225,000
5.	Excavation, common, tailrace channel	14,000,000 cy	0.15	2,100,000
6.	Excavation, rock, tailrace channel	37,000,000 cy	0.75	27,750,000
7.	Earthfill, coffer-dam upstream	3,705,000 cy	0.25	926,000
8.	Earthfill, coffer-dam downstream	1,759,000 cy	0.25	440,000
9.	Rockfill, coffer-dam upstream	655,000 cy	1.00	655,000
10.	Rockfill, coffer-dam downstream	311,000 cy	1.00	311,000
11.	Riprap, coffer-dam upstream	58,000 cy	1.50	87,000
12.	Riprap, coffer-dam downstream	41,000 cy	1.50	62,000
13.	Rock barrier up-stream	342,000 cy	1.00	342,000
14.	Rock barrier down-stream	170,000 cy	1.00	170,000
15.	Removal of down-stream cofferdam earth	1,759,000 cy	0.15	264,000
16.	Removal of down-stream cofferdam rock and rock barrier	522,000 cy	0.50	261,000
17.	Pressure grouting of tunnels	Lump Sum		2,200,000
18.	Concrete diversion tunnel lining	3,500,000 cy	15.00	52,500,000
19.	Concrete, diversion tunnel plugs	882,000 cy	7.00	6,174,000
20.	Concrete, tunnel inlet structures	29,000 cy	20.00	580,000
21.	Concrete, tunnel outlet structures	31,500 cy	20.00	630,000

Study No. 2

ESTIMATED COST

(Continued)

Item No.	Item	Quantity	Unit Cost U.S.$	Total Cost U.S.$
22.	Installing bulkhead gates and hoists	Lump Sum		500,000
	(B) Dam			97,104,000
1.	Excavation, common, dam foundation	5,781,000 cy	0.15	867,000
2.	Excavation, rock, dam foundation	2,144,000 cy	0.75	1,608,000
3.	Foundation treatment	Lump Sum		2,000,000
4.	Concrete, dam	11,780,000 cy	5.00	58,900,000
5.	Concrete, spillway apron	2,280,000 cy	5.50	12,540,000
6.	Concrete, spillway crest and piers	247,000 cy	11.00	2,717,000
7.	Concrete training walls	350,000 cy	12.00	4,200,000
8.	Concrete, trashrack structures	32,700 cy	20.00	654,000
9.	Concrete, parapet walls, sidewalk & curbs	900 cy	20.00	18,000
10.	Placing reinforcement bars and fabrics	28,060,000 lb.	0.04	1,122,000
11.	Cooling concrete including piping & fittings	Lump Sum		1,200,000
12	Grouting contraction joints including pipings and fittings	Lump Sum		1,200,000
13.	Installing steel conduit lining river outlet	22,500,000 lb.	0.10	2,250,000
14.	Installing tube valves, river outlets	80 sets	45,000	3,600,000
15.	Installing gate frames, seats, guides and trashrack sections, river outlets	10,100,000 lb.	0.075	758,000
16.	Installing drum gates	Lump Sum		2,000,000
17.	Installing drum gates control mechanism	Lump Sum		500,000
18.	Installing bulkhead gates (2)	Lump Sum		20,000
19.	Installing metal sealing strips in contraction joints	1,000,000 l.f.	0.75	750,000
20.	Installing misc. metal works	Lump Sum		200,000

Study No. 2

ESTIMATED COST

(Continued)

Item No.	Item	Quantity	Unit Cost U.S.$	Total Cost U.S.$
	(C) Power Plant			424,734,000
1.	Excavation, rock, intake tunnels and headworks	647,000 cy	6.00	3,882,000
2.	Excavation, rock, power plant tunnels	3,440,000 cy	6.00	20,640,000
3.	Excavation, rock, draft tubes	195,000 cy	6.00	1,170,000
4.	Excavation, rock, power plant, main access tunnels	1,670,000 cy	6.00	10,020,000
5.	Excavation, rock, cross tunnels	170,000 cy	6.00	1,020,000
6.	Excavation, rock, intake access tunnel	600,000 cy	6.00	3,600,000
7.	Excavation, rock, tailrace tunnels	1,880,000 cy	6.00	11,280,000
8.	Excavation, rock, transformar tunnel	675,000 cy	6.00	4,050,000
9.	Excavation, rock, transformer tunnel cross galleries	26,300 cy	6.00	158,000
10.	Excavation, rock, high tension outlet shafts	780,000 cy	6.00	4,680,000
11.	Excavation, rock, low tension cable shafts	154,000 cy	6.00	924,000
12.	Excavation, rock, transformer and passenger elevator shafts	200,000 cy	6.00	1,200,000
13.	Excavation, rock, pedestrian galleries	14,700 cy	6.00	88,000
14.	Excavation, rock, intake trashrack shafts	1,302,500 cy	6.00	7,815,000
15.	Excavation, rock, lightning arrester tunnels	588,000 cy	6.00	3,528,000
16.	Excavation, rock, inclined power tunnels	488,000 cy	6.00	2,928,000
17.	Excavation, rock, ventilation ducts	10,500 cy	6.00	63,000
18.	Excavation, common open cut for intake control house, transformer bay, and roadway to intake access tunnel	120,000 cy	0.15	18,000

Study No. 2

ESTIMATED COST

(Continued)

Item No.	Item	Quantity	Unit Cost U.S.$	Total Cost U.S.$
19.	Excavation, rock, open cut for intake control house, transformer bay and roadway to intake access tunnel	230,000 cy	0.75	173,000
20.	Backfill for intake control house, transformer bay and roadway to intake access tunnel	420,000 cy	1.00	420,000
21.	Pressure grouting, tunnels and shafts	Lump Sum		500,000
22.	Concrete intake tunnel lining and headworks	233,000 cy	15.00	3,495,000
23.	Concrete intake shaft lining	300,000 cy	15.00	4,500,000
24.	Concrete trashrack structures	33,000 cy	20.00	660,000
25.	Concrete inclined power tunnel lining	180,000 cy	15.00	2,700,000
26.	Concrete intake access tunnel lining	104,000 cy	15.00	1,560,000
27.	Concrete power plant tunnel lining	590,000 cy	15.00	8,850,000
28.	Concrete, power plant substructures	545,000 cy	20.00	10,900,000
29.	Concrete draft tubes	188,000 cy	20.00	3,760,000
30.	Concrete power plant main access tunnel	230,000 cy	15.00	3,450,000
31.	Concrete cross tunnel lining	66,500 cy	15.00	998,000
32.	Concrete, pedestrian gallery lining	5,500 cy	15.00	83,000
33.	Concrete transformer tunnel lining	225,000 cy	15.00	3,375,000
34.	Concrete transformer house, intake control house, etc.	158,000 cy	20.00	3,160,000
35.	Concrete transformer tunnel cross gallery lining	9,700 cy	15.00	146,000
36.	Concrete, high tension outlet shaft lining	208,000 cy	15.00	3,120,000
37.	Concrete low tension cable shaft lining	66,000 cy	15.00	990,000
38.	Concrete lightning arrester tunnel lining	130,000 cy	15.00	1,950,000
39.	Concrete, tailrace tunnel lining	436,000 cy	15.00	6,540,000

Study No. 2.

ESTIMATED COST

(Continued)

Item No.	Item	Quantity	Unit Cost U.S.$	Total Cost U.S.$
40.	Concrete, elevator shaft lining	60,000 cy	15.00	900,000
41.	Concrete, ventilation duct lining	4,300 cy	15.00	65,000
42.	Placing reinforcement bars and fabrics	310,280,000 lb.	0.04	12,411,000
43.	Installing penstocks	17,800,000 lb.	0.10	1,780,000
44.	Power plant including electrical, mechanical and hydraulic equipments, and high tension switching equipments	10,640,000 kw.	25.00	266,000,000
45.	Installing cranes and gantries	Lump Sum		280,000
46.	Installing gantry rails	1,150,000 lb.	0.06	69,000
47.	Installing elevators	Lump Sum		920,000
48.	Installing intake gate seats, guides, trashrack guides and sections	11,000,000 lb.	0.075	825,000
49.	Installing intake coaster gates	Lump Sum		660,000
50.	Installing tailrace bulkhead gates	Lump Sum		480,000
51.	Installing misc. metal works	Lump Sum		500,000
52.	Drainage System	Lump Sum		1,000,000
53.	Ventilation System	Lump Sum		500,000
	Total Cost from Item A to C			U.S.$718,249,000
	Construction Camp			5,000,000
	Freight			5,000,000
	Communication Roadways			2,500,000
	Total Field Construction Cost			U.S.$730,749,000
	Right of Way and Investigations			10,000,000
	Overhead and Contingencies 15%			109,612,000
	Total			U.S.$850,361,000
	Interest during Construction 15% (completed in 5 years)			127,554,000
	Grand Total			U.S.$977,915,000

Note: Unit Cost including labor and materials.

Table V

Yangtze Gorge Project

Study No. 3
Power Plant in Tunnel
Dam located about 1,200 m. upstream from Nan-Tsin-Kwan

ESTIMATED COST

Item No.	Item	Quantity	Unit Cost U.S.$	Total Cost U.S.$
	(A) River Diversion			216,914,000
1.	Excavation, rock, diversion tunnels	16,390,000 cy	6.00	98,340,000
2.	Excavation, common, cofferdams	400,000 cy	0.15	60,000
3.	Excavation, common, headrace channel	9,000,000 cy	0.15	1,350,000
4.	Excavation, rock, headrace channel	27,000,000 cy	0.75	20,250,000
5.	Excavation, common, tailrace channel	10,000,000 cy	0.15	1,500,000
6.	Excavation, rock, tailrace channel	30,000,000 cy	0.70	22,500,000
7.	Earthfill, coffer-dam upstream	2,840,000 cy	0.25	710,000
8.	Earthfill, coffer-dam downstream	1,360,000 cy	0.25	340,000
9.	Rockfill, coffer-dam, upstream	500,000 cy	1.00	500,000
10.	Rockfill coffer-dam, downstream	250,000 cy	1.00	250,000
11.	Riprap, cofferdam, upstream	50,000 cy	1.50	75,000
12.	Riprap, cofferdam, downstream	30,000 cy	1.50	45,000
13.	Rock barrier, upstream	400,000 cy	1.00	400,000
14.	Rock barrier, downstream	300,000 cy	1.00	300,000
15.	Removal of down-stream cofferdam earth	1,360,000 cy	0.15	204,000
16.	Removal of down-stream cofferdam, rock, and rock barrier	1580,000 cy	0.50	290,000
17.	Pressure grouting of tunnels	Lump Sum		2,500,000
18.	Concrete, diversion tunnel lining	3,940,000 cy	15.00	59,100,000
19.	Concrete, diversion tunnel plugs	920,000 cy	7.00	6,440,000
20.	Concrete, in tunnel inlet structures	30,000 cy	20.00	600,000
21.	Concrete, in tunnel outlet structures	33,000 cy	20.00	660,000
22.	Bulkhead gates and hoists (4)	Lump Sum		500,000

Study No. 3

ESTIMATED COST

(Continued)

Item No.	Item	Quantity	Unit Cost U.S.$	Total Cost U.S.$
	(B) Dam			88,112,000
1.	Excavation, common, dam foundation	5,000,000 cy	0.15	750,000
2.	Excavation, rock, dam foundation	5,500,000 cy	0.75	4,125,000
3.	Foundation treatment	Lump Sum		2,000,000
4.	Concrete, dam	9,630,000 cy	5.00	48,150,000
5.	Concrete, spillway apron	2,280,000 cy	5.50	12,540,000
6.	Concrete, spillway crest and piers	247,000 cy	11.00	2,717,000
7.	Concrete, training walls	350,000 cy	12.00	4,200,000
8.	Concrete, trashrack structures	32,700 cy	20.00	654,000
9.	Concrete, parapet walls, sidewalks and curbs	400 cy	20.00	8,000
10.	Placing reinforcement bars and fabrics	28,010,000 lb.	0.04	1,120,000
11.	Cooling concrete, including pipings and fittings	Lump Sum		960,000
12.	Grouting contraction joints, including pipings and fittings	Lump Sum		960,000
13.	Installing steel conduit lining, river outlets	22,500,000 lb.	0.10	2,250,000
14.	Installing tube valves, river outlets	80 sets.	45,000	3,600,000
15.	Installing gate frames, seats, guides, and trashrack sections, river outlets	10,000,000 lb.	0.075	758,000
16.	Installing drum gates	Lump Sum		2,000,000
17.	Installing drum gate control mechanism	Lump Sum		500,000
18.	Installing bulkhead gates (2)	Lump Sum		20,000
19.	Installing metal sealing strips in contraction joints	800,000 l.f.	0.75	600,000
20.	Installing misc. metal works	Lump Sum		200,000

Study No. 3

ESTIMATED COST

(Continued)

Item No.	Item	Quantity	Unit Cost U.S.$	Total Cost U.S.$
	(C) Power Plant			423,199,000
1.	Excavation, rock, intake tunnels and headworks	487,000 cy	6.00	2,922,000
2.	Excavation, rock, power plant tunnels	3,440,000 cy	6.00	20,640,000
3.	Excavation, rock, draft tubes	195,000 cy	6.00	1,170,000
4.	Excavation, rock, power plant access tunnels	1,500,000 cy	6.00	9,000,000
5.	Excavation, rock, or cross tunnels	170,000 cy	6.00	1,020,000
6.	Excavation, rock intake access tunnels	810,000 cy	6.00	4,860,000
7.	Excavation, rock tailrace tunnels	1,020,000 cy	6.00	6,120,000
8.	Excavation, rock, transformer tunnel	900,000 cy	6.00	5,400,000
9.	Excavation, rock transformer tunnel cross galleries	26,300 cy	6.00	158,000
10.	Excavation, rock, high tension outlet shafts	1,500,000 cy	6.00	9,000,000
11.	Excavation, rock, low tension cable shafts	154,000 cy	6.00	924,000
12.	Excavation, rock, transformer and passenger elevator shafts	224,000 cy	6.00	1,344,000
13.	Excatation, rock, pedestrian galleries	14,700 cy	6.00	88,000
14.	Excavation, rock, intake trashrack shafts	1,302,500 cy	6.00	7,815,000
15.	Excavation, rock, lightning arrester tunnels	743,000 cy	6.00	4,458,000
16.	Excavation, rock, inclined power tunnels	488,000 cy	6.00	2,928,000
17.	Excavation, rock, ventilation ducts	10,500 cy	6.00	63,000
18.	Pressure, grouting, tunnels & shafts	Lump Sum		500,000
19.	Concrete, intake tunnel lining and headworks	180,000 cy	15.00	2,700,000
20.	Concrete, intake shaft lining (trashrack)	300,000 cy	15.00	4,500,000
21.	Concrete, trashrack structures	33,000 cy	20.00	660,000
22.	Concrete, inclined power tunnels lining	180,000 cy	15.00	2,700,000
23.	Concrete, intake access tunnel lining	122,000 cy	15.00	1,830,000

Study No. 3

ESTIMATED COST

(Continued)

Item No.	Item	Quantity	Unit Cost U.S.$	Total Cost U.S.$
24.	Concrete, power plant tunnel lining	590,000 cy	15.00	8,850,000
25.	Concrete, power plant substructures	545,000 cy	20.00	10,900,000
26.	Concrete, draft tubes	188,000 cy	20.00	3,760,000
27.	Concrete, power plant main access tunnel lining	207,000 cy	15.00	3,105,000
28.	Concrete, cross tunnel lining	66,500 cy	15.00	998,000
29.	Concrete, pedestrian gallery lining	5,500 cy	15.00	83,000
30.	Concrete, transformer tunnel lining	300,000 cy	15.00	4,500,000
31.	Concrete, transformer tunnel cross gallery lining	9,700 cy	15.00	146,000
32.	Concrete, high tension outlet shaft lining	400,000 cy	15.00	6,000,000
33.	Concrete, low tension cable shaft lining	66,000 cy	15.00	990,000
34.	Concrete, lightning arrester tunnel lining	170,000 cy	15.00	2,550,000
35.	Concrete, tailrace tunnel lining	240,000 cy	15.00	3,600,000
36.	Concrete, elevator shaft lining	60,000 cy	15.00	900,000
37.	Concrete, ventilation duct lining	4,300 cy	15.00	65,000
38.	Placing reinforcement bars and fabrics	324,700,000 lb.	0.04	12,988,000
39.	Installing penstocks	17,800,000 lb.	0.10	1,780,000
40.	Power plant, including electrical, mechanical and hydraulic equipments and high tension switching equipments	10,640,000 kw.	25.00	266,000,000
41.	Installing cranes and gantries	Lump Sum		280,000
42.	Installing gantry rails	1,150,000 lb.	0.06	69,000
43.	Installing elevators	Lump Sum		920,000
44.	Installing intake gate seats, guides trashrack guides and sections	11,000,000 lb.	0.075	825,000
45.	Installing intake coaster gates and hoists	Lump Sum		660,000

Study No. 3

ESTIMATED COST

(Continued)

Item No.	Item	Quantity	Unit Cost U.S.$	Total Cost U.S.$
46.	Installing tailrace bulkhead gates	Lump Sum		430,000
47.	Installing misc. metal works	Lump Sum		500,000
48.	Drainage system	Lump Sum		1,000,000
49.	Ventilation system	Lump Sum		500,000
	Total Cost from Item A to C			$728,225,000
	Construction Camp			5,000,000
	Freight			5,000,000
	Communication Roadways			2,500,000
	Total Field Construction Cost			$740,725,000
	Right of Way and Investigations			10,000,000
	Overhead and Contingencies 15%			111,109,000
	Total			$861,834,000
	Interest during construction 15%			129,275,000
	Grand Total			$991,109,000

Note: Unit Cost including labor and materials.

Table VI

Yangtze Gorge Project

Study No. 4

Power Plant in Tunnel
Dam at Nan-Tsin-Kwan

ESTIMATED COST

Item No.	Item	Quantity	Unit Cost U.S.$	Total Cost U.S.$
	(A) River Diversion			152,614,000
1.	Excavation: rock, diversion tunnels	12,600,000 cy	6.00	75,600,000
2.	Excavation: common, cofferdams	522,000 cy	0.15	78,000
3.	Excavation: common, tailrace channel	10,800,000 cy	0.15	1,620,000
4.	Excavation: rock, tailrace channel	21,600,000 cy	0.75	16,200,000
5.	Earthfill: cofferdam upstream	3,020,000 cy	0.25	755,000
6.	Earthfill: cofferdam downstream	2,550,000 cy	0.25	638,000
7.	Rockfill: cofferdam upstream	550,000 cy	1.00	550,000
8.	Rockfill: cofferdam downstream	450,000 cy	1.00	450,000
9.	Riprap: cofferdam upstream	50,000 cy	1.50	75,000
10.	Riprap: cofferdam downstream	51,000 cy	1.50	77,000
11.	Rock barrier upstream	215,000 cy	1.00	213,000
12.	Rock barrier downstream	485,000 cy	1.00	485,000
13.	Removal of downstream cofferdam earth	2,550,000 cy	0.15	383,000
14.	Removal of downstream cofferdam rock	986,000 cy	0.50	493,000
15.	Pressure grouting of tunnels	Lump Sum		2,000,000
16.	Concrete diversion tunnel lining	3,030,000 cy	15.00	45,450,000
17.	Concrete diversion tunnel plug	841,000 cy	7.00	5,887,000
18.	Concrete diversion tunnel intake structure	28,000 cy	20.00	560,000
19.	Concrete diversion tunnel outlet structure	30,000 cy	20.00	600,000
20.	Installing bulkhead gates and hoists	Lump Sum		500,000

Study No. 4

ESTIMATED COST

(Continued)

Item No.	Item	Quantity	Unit Cost U.S.$	Total Cost U.S.$
	(B) Dam			115,790,000
1.	Excavation: common dam foundation	9,200,000 cy	0.15	1,380,000
2.	Excavation: rock dam foundation	2,200,000 cy	0.75	1,650,000
3.	Foundation treatment	Lump Sum		2,000,000
4.	Concrete: dam	13,800,000 cy	5.00	69, 000,000
5.	Concrete: spillway apron	2,940,000 cy	5.50	16, 170,000
6.	Concrete: spillway crest and piers	312,000 cy	11.00	3,432,000
7.	Concrete: training walls	340,000 cy	12.00	4,080,000
8.	Concrete: trashrack structures	42,500 cy	20.00	850,000
9.	Concrete: parapet walls, sidewalks, and curbs	600 cy	20.00	12,000
10.	Placing reinforcement bars and fabrics	35,450,000 lb.	0.04	1,418,000
11.	Cooling concrete, including pipings and fittings	Lump Sum		1,380,000
12.	Grouting contraction joints including pipings and fittings	Lump Sum		1,380,000
13.	Installing steel conduit lining, river outlets	29,200,000 lb.	0.10	2,920,000
14.	Installing tube valves, river outlets	104 sets	45,000	4,690,000
15.	Installing gate flames, seats, guides, and trashrack sections, river outlets	14,100,000 lb.	0.075	1,058,000
16.	Installing drum gates	Lump Sum		2,600,000
17.	Installing drum gates control mechanism	Lump Sum		650,000
18.	Installing bulkhead gates (2)	Lump Sum		20,000
19.	Installing metal sealing strips, in contraction joints	1,200,000 l.f.	0.75	900,000
20.	Installing misc. metal works	Lump Sum		200,000

Study No. 4

ESTIMATED COST

(Continued)

Item No.	Item	Quantity	Unit Cost U.S.$	Total Cost U.S.$
	(C) Power Plant			417,489,000
1.	Excavation: rock intake tunnels	700,000 cy	6.00	4,200,000
2.	Excavation: rock power plant tunnels	3,440,000 cy	6.00	20,640,000
3.	Excavation, rock draft tubes	195,000 cy	6.00	1,170,000
4.	Excavation: rock, power plant main access tunnel	1,500,000 cy	6.00	9,000,000
5.	Excavation: rock, cross tunnels	170,000 cy	6.00	1,020,000
6.	Excavation, rock, intake access tunnel	810,000 cy	6.00	4,860,000
7.	Excavation: rock, tailrace tunnels	1,390,000 cy	6.00	8,340,000
8.	Excavation, rock, transformer tunnel	900,000 cy	6.00	5,400,000
9.	Excavation: rock, transformer tunnel cross galleries	26,300 cy	6.00	158,000
10.	Excavation: rock, high tension outlet shafts	600,000 cy	6.00	3,600,000
11.	Excavation: rock, low tension cable shafts	154,000 cy	6.00	924,000
12.	Excavation: rock transformer and passenger elevator shafts	190,000 cy	6.00	1,140,000
13.	Excavation, rock, pedestrian galleries	14,700 cy	6.00	88,000
14.	Excavation: rock, intake trashrack shafts	1302,500 cy	6.00	7,815,000
15.	Excavation: rock, lightning arrester tunnels	742,600 cy	6.00	4,456,000
16.	Excavation, rock, inclined power tunnels	405,000 cy	6.00	2,430,000
17.	Excavation, rock, ventilation ducts	10,500 cy	6.00	63,000
18.	Pressure grouting, tunnels & shafts	Lump Sum		400,000
19.	Concrete: intake tunnel lining	229,000 cy	15.00	3,435,000
20.	Concrete: intake trashrack shaft lining	300,000 cy	15.00	4,500,000
21.	Concrete: trashrack structure	33,000 cy	20.00	660,000

Study No. 4

ESTIMATED COST

(Continued)

Item No.	Item	Quantity	Unit Cost U.S.$	Total Cost U.S.$
22.	Concrete: inclined power tunnels lining	152,000 cy	15.00	2,280,000
23.	Concrete: intake access tunnel lining	122,000 cy	15.00	1,830,000
24.	Concrete: power plant tunnel lining	590,000 cy	15.00	8,850,000
25.	Concrete: power plant substructure	545,000 cy	20.00	10,900,000
26.	Concrete; draft tubes	188,000 cy	20.00	3,760,000
27.	Concrete: power plant main access tunnel lining	207,000 cy	15.00	3,105,000
28.	Concrete: cross tunnel linings	66,500 cy	15.00	998,000
29.	Concrete: pedestrian gallery lining	5,500 cy	15.00	83,000
30.	Concrete: transformer tunnel lining	300,000 cy	15.00	4,500,000
31.	Concrete: transformer tunnel cross gallery	9,700 cy	15.00	146,000
32.	Concrete: high tension outlet shaft lining	180,000 cy	15.00	2,700,000
33.	Concrete: low tension cable shaft lining	66,000 cy	15.00	990,000
34.	Concrete: lightning arrester tunnel lining	146,200 cy	15.00	2,193,000
35.	Concrete: tailrace tunnel lining	335,000 cy	15.00	5,025,000
36.	Concrete: elevator shaft lining	60,000 cy	15.00	900,000
37.	Concrete: ventilation duct lining	4,300 cy	15.00	65,000
38.	Placing reinforcement bars and fabrics	297,520,000 lb.	0.04	11,901,000
39.	Installing penstocks	17,800,000 lb.	0.10	1,780,000
40.	Power plant including electrical, mechanical, and hydraulic equipments and high tension switching equipments	10,640,000 kw.	25.00	266,000,000
41.	Installing cranes and gantries	Lump Sum		280,000
42.	Installing gantry rails	1,150,000 lb.	0.06	69,000

Study No. 4

ESTIMATED COST

(Continued)

Item No.	Item	Quantity	Unit Cost U.S.$	Total Cost U.S.$
43.	Installing elevators (12 freight 22 passenger)	Lump Sum		920,000
44.	Installing intake gates seats, guides, trashrack guides and sections	11,000,000 lb.	0.075	825,000
45.	Installing intake coaster gates and hoists	Lump Sum		660,000
46.	Installing tailrace bulkhead gates	Lump Sum		430,000
47.	Installing misc. metal works	Lump Sum		500,000
48.	Drainage system	Lump Sum		1,000,000
49.	Ventilation system	Lump Sum		500,000
	Total Cost from A to C			$685,893,000
	Construction Camp			5,000,000
	Freight			5,000,000
	Communication Roadways			2,500,000
	Total Field Construction Cost			$698,393,000
	Right of Way and Investigations			10,000,000
	Overhead and Contingencies 15%			104,759,000
	Total			$813,152,000
	Interest during Construction 15% (completed in 6 years)			$121,973,000
	Grand Total			$935,125,000

<u>Note</u>: Unit Cost including labor and materials.

Table VII

Yangtze Gorge Project

Study No. 5
Power Plant in Dam
Dam located about 500 m. downstream from Nan-Tsin-Kwan

ESTIMATED COST

Item No.	Item	Quantity	Unit Cost U.S.$	Total Cost U.S.$
	(A) River Diversion			103,903,000
1.	Excavation: common, diversion channel	5,350,000 cy	0.15	802,500
2.	Excavation: rock, diversion channel	126,500,000 cy	0.75	94,875,000
3.	Excavation: common, cofferdams	838,000 cy	0.15	125,700
4.	Earthfill, cofferdam upstream	3,277,000 cy	0.25	819,300
5.	Earthfill, cofferdam downstream	5,410,000 cy	0.25	1,352,500
6.	Riprap, cofferdam upstream	47,000 cy	1.50	70,500
7.	Riprap, cofferdam downstream	80,000 cy	1.50	120,000
8.	Rockfill, cofferdam upstream	693,000cy	1.00	693,000
9.	Rockfill, cofferdam downstream	1,200,000 cy	1.00	1,200,000
10.	Rock barrier upstream	473,000 cy	1.00	473,000
11.	Rock barrier downstream	1,280,000 cy	1.00	1,280,000
12.	Removal of downstream cofferdam earth	5,410,000 cy	0.15	811,500
13.	Removal of downstream cofferdam rock	2,560,000 cy	0.50	1,280,000
	(B) Dam			405,081,000
1.	Excavation: common, dam foundation	12,950,000 cy	0.15	1,942,500
2.	Excavation: rock, dam foundation	51,600,000 cy	0.75	38,700,000
3.	Riprap paving, downstream of dam	120,000 cy	1.00	120,000
4.	Foundation treatment	Lump Sum		7,000,000
5.	Concrete: dam	60,500,000 cy	5.00	302,500,000
6.	Concrete: Spillway apron	2,940,000 cy	5.50	16,170,000
7.	Concrete: spillway crest and piers	312,000 cy	11.00	3,432,000
8.	Concrete: training walls	413,000 cy	12.00	4,956,000

Study No. 5

ESTIMATED COST

(Continued)

Item No.	Item	Quantity	Unit Cost U.S.$	Total Cost U.S.$
9.	Concrete: trash-rack structures	42,500 cy	20.00	850,000
10.	Concrete: parapet wall, side walks and curbs	8,000 cy	20.00	160,000
11.	Placing reinforcement bars and fabrics	36,250,000 lb.	0.04	1,450,000
12.	Cooling concrete, including pipings & fittings	Lump Sum		6,050,000
13.	Grouting contraction joints including pipings and fittings	Lump Sum		6,050,000
14.	Installing steel conduit lining, river outlets	29,200,000 lb.	0.10	2,920,000
15.	Installing tube valves, river outlets	104 sets	45,000	4,690,000
16.	Installing gate frames, seats, guides, and trash-rack sections	14,100,000 lb.	0.075	1,058,000
17.	Installing river outlets bulkhead gates (2)	Lump Sum		20,000
18.	Installing drum gates	Lump Sum		2,600,000
19.	Installing drum gates control mechanisms	Lump Sum		650,000
20.	Installing metal sealing strips in contraction joints	4,350,000 l.f.	0.75	3,262,500
21.	Installing elevators (5 passenger, 5 freight)	Lump Sum		300,000
22.	Installing misc. metal works	Lump Sum		200,000
				314,414,000
	(C) Power Plant			
1.	Excavation: common, for tailrace channel	37,700,000 cy	0.15	5,655,000

Study No. 5.

ESTIMATED COST

(Continued)

Item No.	Item	Quantity	Unit Cost U.S.$	Total Cost U.S.$
2.	Excavation: rock, for tailrace channel	13,000,000 cy	0.75	9,750,000
3.	Excavation: all classes for main access tunnel	352,000 cy	8.50	2,992,000
4.	Excavation: all classes for power plant gallery	47,000 cy	8.50	400,000
5.	Excavation: all classes for transformer gallery access tunnel	19,000 cy	8.50	161,500
6.	Concrete: substructure of power plant gallery	150,000 cy	15.00	2,250,000
7.	Concrete: crane girders and columns	85,000 cy	20.00	1,700,000
8.	Concrete: power plant lining	14,000 cy	15.00	210,000
9.	Concrete: power plant main access tunnel lining	111,000 cy	15.00	1,665,000
10.	Concrete: lining of transformer gallery access tunnel & headworks	10,000 cy	15.00	150,000
11.	Concrete: trashrack structures	164,000 cy	20.00	3,280,000
12.	Placing reinforcing bars	52,400,000 lb.	0.04	2,096,000
13.	Installing crane and gantries	Lump Sum		312,000
14.	Installing intake gate seats, guides trashrack guides and sections	55,200,000 lb.	0.075	4,140,000
15.	Installing intake bulkhead gates (8)	Lump Sum		400,000
16.	Installing tailrace bulkhead gates (4)	Lump Sum		80,000
17.	Installing penstocks	121,000,000 lb.	0.10	12,100,000
18.	Installing gantry rails	1,200,000 lb.	0.06	72,000
19.	Power plant, including electrical, mechanical, and hydraulic equipment and high tension switching equipments	10,640,000 kw.	25.00	266,000,000

Study No. 5

ESTIMATED COST

(Continued)

Item No.	Item	Quantity	Unit Cost U.S.$	Total Cost U.S.$
20.	Installing misc. metal works	Lump Sum		500,000
21.	Ventilation system	Lump Sum		500,000
	Total Cost from A to C			823,398,000
	Construction camp			5,000,000
	Communication roadways			2,500,000
	Freight			5,000,000
	Total Field Construction Cost			835,898,000
	Right of Way and Investigations			10,000,000
	Overhead and Contingencies 15%			125,385,000
	Total			971,283,000
	Interest during Construction 20%			194,257,000
	Grand Total			1,165,540,000

Note: Unit cost including labor and materials.

Table VIII

Yangtze Gorge Project

Study No. 4

ESTIMATED COST FOR DIFFERENT STAGES

Item	Total Cost U.S.$
(First Stage)	
(A) River Diversion	152,614,000
(B) Dam	115,790,000
(C) Power Plant	204,689,000
	473,093,000
Construction camp	5,000,000
Freight	5,000,000
Communication Roads....................	2,500,000
Total Field Cost................	485,593,000
Right of Way and Investigations........	10,000,000
Overhead and Contingencies 15%.........	72,839,000
Total..........................	568,432,000
Interest During Construction...........	85,265,000
Grand Total....................	653,697,000
(Second Stage)	
(C) Power Plant (Including Overhead and Interest)	70,357,000
(Third Stage)	
(C) Power Plant (Including Overhead and Interest)	70,357,000
(Fourth Stage)	
(C) Power Plant (Including Overhead and Interest)	70,357,000
(Fifth Stage)	
(C) Power Plant (Including Overhead and Interest)	70,357,000
Grand Total	U.S.$ 935,125,000

Table IX

Yangtze Gorge Project

Study No. 4

YEARLY REVENUES

Electrical operating income

a. Firm Power Revenues:
68,400,000,000 x 0.002 — U.S.$136,800,000

b. Secondary Power Revenues:
13,300,000,000 x 0.0005 — $ 6,650,000

$143,450,000

Operating Revenue Deductions:

a. Operating & maintenance

General Features.
0.50 x 10,640,000 — US$5,320,000

Special Features.

Dam & Res.	29,200,000 x 0.01	US$ 292,000
Penstocks.	338,000 x 0.015	$ 5,100
Tunnels.	166,400,000 x 0.00025	$ 41,600
Metal Works	15,750,000 x 0.01	$ 157,500
Misc. O & M	10%	$ 581,600
		US$6,397,800

b. Replacement Reserve
217,345,000 x 0.01052 — US$2,286,500

c. Amortization including interest.
938,125,000 x 8.994% — US$84,105,100

Total operating Revenue Deductions — U.S.$ 92,789,400

Net Operating Revenues — U.S.$ 50,660,600

A PRELIMINARY STUDY OF UTILIZING HYDRO POWER AT YANGTZE GORGE FOR MANUFACTURING FERTILIZERS

Power Available	10,500,000 kw
Estimated Power for Manufacturing Fertilizers	5,000,000 kw

SUMMARY (VALUE IN U.S. DOLLARS)

Estimated cost of Hydro Project by Dr. Savage	US$ 987,281,600
Navigation Equipment including overhead and interest (roughly estimated by Dr. Savage, to be confirmed later)	200,000,000
Fertilizer Plants including overhead and interest (to be confirmed later)	120,000,000
Total cost of project	US$1,307,281,600
Profit from selling fertilizers at 7th - 10th yrs. incl.	194,000,000
Obligation at end of 10th year	1,113,281,600
Value of fertilizers to be exported to U.S.A. to pay interest at 2½% compound and pay part of principal, liquidating the whole obligation in 25 years	90,000,000 per annum

The plan requires a total capital of US$1,307,281,600, but the actual capital required would be round US$1,113,000,000, because beginning from the 7th year a part of the power equipment and fertilizer plant would be completed and fertilizers could be sold to earn a profit for paying the interest and part of the scheduled work.

It is estimated by Dr. Savage that the firm power would amount to 6,000,000 kw and secondary power 4,500,000 kw. Power utilized to make fertilizers would be 5,000,000 kw. leaving a surplus power (during the 7th - 10th years inclusive) to earn additional income. But other industries that could utilize this power may not be ready during this period. For conservative estimate, this income is not counted in our calcultions.

INTRODUCTION

There are several outstanding factors worthy of serious considerations. First of all, such an enormous power requires an astounding supply of raw materials. For example, if the cynamide process were exclusively adopted for the utilization of half of the power, say 5,000,000 kw, about 7,300,000 tons of coal and 16,500,000 tons of lime stone would be required. On the other hand, if the synthetic process alone were used, and ammonium sulphate were manufactured, an enormous quantity of sulphur (to form sulphuric acid) or gypsum would be required. It is evident that these easily accessible and cheap supply of several vital raw materials would be exhausted with amazing rate which would threaten the very possibility of this industry itself. The storage quantity of coal in China is by no means rich and its demand by industries in general will be enormous in future. The cynamide process takes an unreasonable quantity in coal, it would certainly drain on our national resources. So it is suggested that several known processes are to be used at the same time, so the demand of raw materials may be diversified in nature and drain on the supply of any particular kind may be minimized.

The second consideration is: that industries are inter-dependent on each other. No single industry can prosper alone; one must depend on the others from which it can draw its necessary starting materials and to which it can economically dispose of its by-products. Since no industry of appreciable size has yet been developed in China, and if we plan to establish any one, we have all by ourselves to manufacture the starting materials on the one hand and to find utilization for the by-products on the other. So it is the present case here. With the industry of nitrogen fixation as a neucleus, a series of closely related industries should developed, so that they may be mutually benefited.

With the above points of view, we proceed to examine the raw materials and products of each known process, finding the cost and prices, before we decide on the size of various manufacturing plants.

This study is based upon the memorandum submitted by Mr. George Reed Paschal of F.E.A, collaborated by Prof. F. O. McMillan of Oregon State College (Specialist sent to China in 1943), with a few corrections on the figures.

PROCESS

(For some what detailed description,
the appendix may be referred to)

Cynamide Process - In this process, coke and lime are reacted in electric furnace to form calcium carbide. If carbide is heated in a stream of nitrogen, obtained from liquified air, calcium cynamide is formed and will be used directly as fertilizer. For each ton of fixed nitrogen, the materials and electric energy required are:

Lime stone	7.40 tons.	@ US$0.50/ton	US$ 3.70
Coal	3.28 tons	@ 3.00/ton	9.84
Electric energy	18,000 kwh	@ 0.002/kwh	36.00
Labor and misc. costs at 10%			5.00
Total production cost			US$54.54/ton nitroge

Cynamide produced = 5.20 tons/ton nitrogen fixed

It is to be noted that the valuable by-products from the coal distillation process (for obtaining coke to make carbide) are not counted. The above is therefore conservative estimate.

Electrolytic Water and Direct Synthetic Process - In this process, water is electrolized to form oxygen and hydrogen, the latter is used in direct contact of nitrogen to form ammonia. Electric energy required is 16,000 kwh per ton nitrogen. This amount of energy cost US$32 and adding 10% for labor and miscellaneous expenses the total is US$35.20 per ton nitrogen.

Electrolytic Caustic and Direct Synthetic Process - In this process, common salt is electrolized and hydrogen formed is collected and brought directly in contact with nitrogen to form ammonia. Caustic soda and chlorine are the valuable by-products. To fix one ton of nitrogen, the materials and products are:

Salt 18 tons (at CNC 0.16/Kg or US$48/ton)	US$864.00
Electric energy 28870 (at US$0.002/kwh)	57.74
Labor and Misc. costs	10.00
Total production cost	US$931.74
By-products	
Caustic soda 9.52 tons (at US$65.70/ton)	US$625.00
Chlorin 8.32 tons (at US$37.40/ton)	311.00
Total price for by-products	US$936.00

Note: From Chemical Guide Book, 76% pure caustic soda costs US$2.90 - 3.00/100 lb in U.S.A. For conservative estimate, assume the price US$2.50/100 lb. for 76% pure or 65.70/ton for 100% pure caustic soda. From Chemical Guide Book, average price for chlorine US$1.70/100 lb. or 37.40/ton.

It can be seen from above that the price of by-products has exceeded the cost of production. So, it is a conservative estimate to assume that hydrogen would be obtained by this process at no cost. But the extent of this process is limited by the difficulty of evaporating a large volume of caustic solution and by the available market for caustic soda and chlorine.

Ammonium Sulphate Manufacturing Process - Ammonia obtained from the direct synthetic process is in liquid form which can not be used directly as fertilizer and is hard to transport. It is necessary to convert ammonia into some other products which can be used directly as fertilizer and is easy for transportation. Ammonium sulphate is one of the desirable products because it is in crystal form and not hydroscopic (not absorbing water), thus making it easy to transport. (most of ammonium products have disadvantage of absorbing water making them unfit for transportation and storage)

To make ammonium sulphate from ammonia, either sulphuric acid (H_2SO_4) or gypsum ($CaSO_4$) will be used. Due to Scarcity of sulphur in China and the use of sulphur in other industries, more gypsum which is abundant in both Hupeh and Hunan will be used. The process employing sulphuric acid will be shown in the appendix. Only the materials and products per ton of nitrogen for the process using gypsum is shown as follows:

		Using Ammonia from Electrolytic Water Process	Using Ammonia from Electrolytic Caustic Process
Ammonia	1.21 tons	US$35.20	US$ ----
Gypsum	6.80 tons @ $5.10	$34.70	$34.70
Labor & Misc. costs at 10%		$ 7.00	$ 7.00
Total production cost		US$76.90/ton nitrogen	US$41.70/ton nitrogen

Ammonium sulphate produced in each case is 4.80 tons.

Note: From "Catalogue Industry in Hunan" Gypsum costs CNC$17 or US$5.10/ton.

Other Processes - Other processes of converting and absorbing ammonia are to form (1) calcium nitrate, (2) ammonium mitrate, (3) ammonium phosphate, and (4) urea etc. These processes may be adopted at the same time in proportion to the demand in American market. For simplicity, they are not described here but show briefly in the appendix.

PROPOSED PLAN

	Electric Power kw	Products in Terms of Nitrogen	Cost per ton Nitrogen US$	Total Cost US$	Products
Cynamide Process	1,500,000	$\frac{1,500,000 \times 8,000}{18,000}$ = 667,000 tons	54.54	36,300,000	Calcium Cynamide 3,470,000 tons
Electrolytic Water & Direct Synthetic Process	2,500,000	$\frac{2,500,000 \times 8,000}{16,000}$ = 1,250,000 tons	76.90	96,000,000	Ammonium sulphate 6,000,000 tons
Electrolytic Caustic & Direct Process	1,000,000	$\frac{1,000,000 \times 8,000}{28,870}$ = 278,000 tons	41.70	11,600,000	Ammonium sulphate 1,335,000
Total	5,000,000	2,195,000 tons		143,900,000	

$$\text{Average cost} = \frac{143,900,000}{2,195,000} = \text{US\$65.60/ton nitrogen}$$

From the Maritime Customs record, we found the following:

Import to China of Ammonium Sulphate

	1934 Ton	1934 Value G.U.	1935 Ton	1935 Value G.U.	1936 Ton	1936 Value G.U.
Total	49,948.4	3,148,170	68,630.8	4,134,022	124,000	6,553,598
from USA	1,054.9	70,749	3,038.9	144,470	1,293.7	59,298

The average value of the three years' import from all countries = 57.10 gold units per ton ammonium sulphate
= 57.10 x 0.67 = US$38.20 per ton ammonium sulphate
= 38.20 x 4.80 = US$183 per ton nitrogen.

The average value of the three years' import from U.S.A.
= 51.00 gold units per ton ammonium sulphate
= 51.00 x 0.67 = US$34.20 per ton ammonium sulphate
= 34.2 x 4.80 = US$164 per ton nitrogen.

The "value" here means CIF value, exclusive of import duty. Usually the actual cost is 10-20% higher. For conservative estimate, only "values" here are taken for reference.

Suppose we sell fertilizer to the U.S.A. at ordinary production cost, say US$70/ton nitrogen, which is less than half the price of what U.S.A. sold to China, and sell to the Chinese market at US$90/ton nitrogen, then

Nitrogen exported to U.S.A. to cover payment of

US$90,000,000 = $\frac{90,000,000}{70}$ = 1,295,000 tons/year

Remaining nitrogen for Chinese market

2,195,000 - 1,295,000 = 900,000 tons/year

Returns from the above amount of nitrogen

= 90x 900,000 = US$81,000,000/year

There remains a firm power of 1,000,000 kw and secondary power of 4,000,000 kw. These may be sold to other industries. Suppose we sell the firm power at 8000 hours per year and US$0.002 per kwh and sell the secondary power at 4000 hours/year and US$0.005 per kwh, then income from this sources.

1,000,000 x 8000 x 0.002 + 4,000,000 x 4,000 x 0.0005
= US$24,000,000/year

FINANCIAL STATUS (VALUE IN U.S. DOLLARS)

Expenditures

Production cost of 2,195,000 tons of nitrogen at $29.2 per ton excluding power cost§	64,000,000
Operating and Maintenance expenses = 0.80 x 10,500,000	8,400,000
Replacement reserve 939,400,000 x 55.6% x 0.02401†	12,000,000
Total expenditure	84,400,000

Income

Revenue from selling 900,000 tons nitrogen in China in addition to what is needed to export to U.S.A. for liquidating obligations	81,000,000
Revenue from selling remaining power to other industries in addition to what is needed in making fertilizers	24,000,000
Total income	105,000,000

Profit

105,000,000 - 84,400,000 = US$20,600,000

CONCLUSION

Besides the profit of US$20,600,000 per annum, the following benefits may obtain:

(1) There is the very cheap and available firm power of 1,000,000 and secondary power of 4,500,000 kw, all of which will serve as a priming force to other industrial and agricultural developments.

(2) The whole plant (power and fertilizer manufacturing plants) will be free of charge after 25 years.

(3) All other conclusions of the alternative proposal.

At the same time, the U.S. financial institution would receive dependable amount of at less than half the market price. It is a plan beneficial to both U.S.A. and China.

As it has pointed out thatsome other fertilizing products may be manufactured besides cynamide and ammonium sulphate. But this will depend on the market in America and the available raw materials. Detailed investigation will have to be made as to the natural resources and means of transportation for these materials. Whatever other process adopted will not effect materially the conclusion drawn above.

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* Production cost of nitrogen
$$\frac{143,900,000 - 5,000,000 \times 8,000 \times 0.002}{2,195,000} = \text{US\$29.2 per ton}$$

+ Annual sinking fund at 4% interest for a period of 25 years

ALTERNATIVE PROPOSAL

This proposal is to build the project on a less elaborate scale, allowing, however, for later expansion to its full kw. capacity as orginally proposed, so that total sum of US$850,-000,000 will be sufficient to cover the entire cost. Of this sum, US$600,000,000 will have to be borrowed from the U. S. Government, while the remainder, i.e. US$250,000,000 will be secured by floating a gold dollar bond in China and foreign markets. The basic idea is still that the repayment of principal and interest could be met by the manufacturing of fertilizer. By the application of fertilizer to our land, we will be able to increase our farm products and save the US$49,000,000 we had been paying for our imports every year before the war. We may even export our farm products and our very cheap fertilizer, thus adding quite a sizable amount to our foreign exchange reserve. It is clear then that our Government could afford to pay off our loan and bond within a reasonable number of years after the completion of this Gorge project.

To liquidate US$600,000,000 loan at 3% interest and a US$250,000,000 bond at 5% in 30 years, we have to pay an annual sum of US$55,000,000 starting from the 8th year until the end of the 30th year. This China could do easily, as shown in the following paragraphs.

With the investment of US$850,000,000 we could build 5,000,000 kw hydro power, as estimated below:

River diversion	US$140,800,000	
Dam & Appurt. Works	124,100,000	
Power Plant	270,000,000	
Road	2,500,000	
Camp	5,000,000	
Freight	3,000,000	
	US$545,400,000	US$545,400,000
Right of Way & Investigation	US$ 10,000,000	
Overhead & Contingency 15%	81,800,000	
Interest during construction	64,000,000	
	US$155,800,000	US$155,800,000
Over-dam boat-lifting structure and equipment	US$ 60,000,000 *	
Fertilizer and other plants	90,000,000 *	
	US$150,000,000	US$150,000,000
		US$851,200,000
	say	$850,000,000

* These figures are just assumed values but we believe they are ample.

Suppose power utilized and fertilizers manufactured are reduced to 50 % of the first plan, then,

Power required = 5,000,000 x .5 = 2,500,000 kw
Fertilizers produced = 2,195,000 x .5 = 1,100,000 tons nitrogen

In order to promote the use of fertilizers in China as well as export to foreign countries, we will sell at 50% of its pre-war price of US$180 per ton nitrogen. So income from selling nitrogen = 1,100,000 x 180 x .5 = US$99,000,000.

Suppose 20% of this fertilizer could be exported, then actual U.S. dollar income or its equivalent would be

= 99,000,000 x .2 = US$19,800,000

while the income in US$ equivalent in Chinese currency from local sales would be

= 99,000,000 x .8 = US$79,200,000

Since by the application of fertilizer, we could save yearly the 49,260,000 actual U.S. dollars we had been paying for imported rice, wheat, cotton, etc. before the war, it is not unreasonable to figure that our Government would be able to sanction a yearly payment, of 25,000,000 actual U.S. dollars for the whole duration of payment, after receiving its equivalent in Chinese currency out of the proceeds from local sales.

Now let us examine the economic side of fertilizer application. From TVA Chemical Engineering Report of 1943, it can be inferred that one ton of fertilizer would increase production of about four tons of cereals of half a ton of cotton. But we will assume that in China three fourth of the above results would be obtained. Then,

Price of 1 ton of nitrogen = 180 x .5= US$90
Price of 1 ton of fertilizer = 90 ÷ 5= US$18
with 20% nitrogen

Adding 70% for freight and distribution charges,

Cost of 1 ton of fertilizer to the farmer
= 18 x 1.7 = US$30.60

while the increase of yield from 1 ton of fertilizer will be

In the case of cereals = 3 x (76‡ ÷ 3.3) = US$69
In the case of cotton = 3/8 x (500‡ ÷ 3.3) = US$57

The profit to the farmer for one ton of fertilizer used will be 69-30.60 = US$38.40 and 57-30.60 = US$26.40 respectively. Actually, the profit may be even greater as it is borne out by the fact, that even with fertilizer at US$180 per ton of nitrogen c.i.f. Shanghai including import duty, there had been a mounting for ammonium sulphate every year before the war. So, there is sufficient ground to believe that at US$90 per ton of nitrogen all its production could be easily sold.

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‡ The figure CN 76 per ton of cereals is based on Customs record 99,000,000 ÷ 1,294,000 = 76, while a lower figure of CN500 per ton of cotton is assumed, the Customs Average being 55,770,000 ÷ 70,600 = CN789.

FINANCIAL STATUS OF WHOLE PROJECT

Expenditures:	In Actual U.S.dollars	In U.S.dollar Equiv. of Chinese currency
Repayment of principal and interest	55,000,000	-----
Production cost of 1,100,000 tons nitrogen at US$29.20 per ton excluding power cost	-----	32,120,000
Depreciation of power plant and other equipments at 4% (659,000,000 x .50 x .02401)	6,000,000	2,350,000
Production cost of electrical energy. 1/3 paid in U. S. dollars. (5,000,000 x 1.2)	2,000,000	4,000,000
	63,000,000	38,470,000

Total = 63,000,000 + 38,470,000 = US$101,470,000

Income		
Export of fertilizers	19,800,000	-----
From sales of fertilizer in China	25,000,000	54,200,000
Revenue from selling 2,500,000 kw in addition to what is needed in making fertilizer, at 0.002 per kwh (2,500,000 x 6,000 x .002)	-----	30,000,000
	44,800,000	84,200,000

Total = 44,800,000 + 84,200,000 = US$129,000,000

Profit

129,000,000 - 101,470,000 = US$27,530,000

There is, however, a deficit of foreign exchange to the extent of 63,000,000 - 44,800,000 = US$18,200,000 of which US$6,000,000 is depreciation reserve and not immediate layout. So the actual deficit is US$12,200,000. This deficit can easily be made up by further savings in import and increases of export and by promoting tourist trade as will be explained later.

CONCLUSION

Besides the net profit of US$27,530,000 per annum, the following benefit may be obtained:

(1) The entire project will be free of any encumberance after 30 years.

(2) There is the very cheap firm power of 2,500,000 kw. available for industrial uses. From Chungking in the West to Wu-han and Changsha in the East, industries will sprout out everywhere by themselves due to the presence of this vast source of cheap power.

(3) Any future extension of power plant may be achieved at very little additional cost of civil work. The ultimate power will be 10,500,000 kw, of which 6,000,000 kw is firm power.

(4) Most of lakes in Hupei Province could be reclaimed to the extent of at least 4,000,000 mow.* (total area of lakes = about 6,600,000 mow), which will more than offset areas flooded above the dam. This means an annual cereal production of at least 1,500,000 tons, worth US$35,000,000.

(5) Irrigation above and below the Gorge on a vast scale could be attempted, which will also increase our agricultural production considerably.

(6) Import of electric furnace products, such as carbide, ferro-silicon, etc., as well as aluminum could be reduced greatly. This will save depletion of our foreign exchange reserve.

(7) The use of soyabean cakes as fertilizer could be stopped, and the soyabean crop increased, thus providing greater export of this product to foreign countries. This will again help building up our foreign exchange reserve.

(8) Tourist trade could be promoted to obtain more foreign exchange. This project will remain to be the biggest of its kind on earth for many years to come. This fact, added to the famous scenery along the Gorge, the oldest salt producing district at Tseliutsin, the ancient irrigation project at Kwanhsien, the city of Chengtu and the Mount Omei, could be incorporated into a very attractive tourist program. It would not be a surprise if the income from this source reaches the sum of twenty or thirty million U.S. dollars a year. The tourist service should be conducted by the Gorge project administration.

(9) Part of the yearly profit could be appropriated for the reforestation of the entire Yangtze valley on a vast scale.

(10) The last and the most important of all is that the navigation and flood control would be immensely improved. By this project, the water flow to Ichang would be greatly increased and properly regulated, and, by improving the river channel below Ichang at not very big cost, any large ship that could formerly reach Hankow will be able to sail straight to Ichang all the year around. Besides, medium size ships up to 2000 tons could travel between Ichang and Chungking without anymore of the dangers of the numerous rapids of the Gorge. People in Szechuan, Hupei and other areas would no longer depend on the mercy of heaven for their food and living. With the profit derived from this project, dams could be built on important tributaries such as Black River, Gold Sand River and Hanshui, and the flood of the mighty Yangtze could be brought under control, saving the loss of millions of lives and properties for centuries to come.**

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* 1 mow = 1/6 Acre.

** The loss of properties due to the flood of the Yangtze valley in the provinces of Hunan, Hupeh, Anhwei, Kiangsi and Kiangsu in 1931 amounted to CNC 1,288,600,000 according to the esti[mate] made by Yangtze River Commission.

With the Yangtze River as a shining example, high dams could be built on the Yellow River, not only controlling completely its recurrent floods, but also giving life blood of water to the provinces of Ningsha, Kansu, Shensi and Hupei. Moreover, with a common purpose for the salvation of our nation and enabling our people to have vastly more chances to earn a good living, we will have politically a more stable government. The benefits of this project as well as its economical and political effects are indeed beyond words of description.

APPENDIX

1/ Cynamide Process

Carbide is made by heating coke and lime in electric furnace according to the following formula:

$$2CaCO_3 + 5C \rightarrow 2CaC_2 + 3CO_2$$

The biggest unit is built at Hafslund (Norway), in which each furnace consumes 15,000 kw at 80% power factor. The energy consumption is 4 - 4.2 kwh per kg of carbide. The purity varies between 72 to 83%. For one ton of carbide, 900 kg of lime, 600 kg of coke and 30 kg of graphite electrode are used.

If carbide is heated in a stream of nitrogen, cynamide is formed according to the following:

$$CaC_2 + N_2 \rightarrow CaCN_2 + C$$

The continuous furnaces of Calson Process can be built to deal with charges of eighteen tons per day, each ton of carbide will furnish 1.4 tons of calcium cynamide. The product contains about 19 - 19.5% of nitrogen. The electrode consumption is about 5 kg per ton. According to Caro, the total energy necessary for the fixation of one ton of nitrogen by this method, including the production of carbide, machine driving, grinding and crushing, mechanical charging and air liquefaction, amounts to 3 hp year.

From the above, we have the following calculations:

$$\text{Lime stone required (80\% pure)} = .9 \times \frac{100}{56} \times \frac{1}{.8} \times \frac{1}{1.4} \times \frac{1}{.192}$$
$$= 7.40 \text{ tons/ton nitrogen}$$

$$\text{Allow 70\% of coke formed per ton coal, Coal required} = (.6 \times \frac{1}{.7} + .03)\ \frac{1}{1.4} \times \frac{1}{.192}$$
$$= 3.28 \text{ tons/ton nitrogen}$$

$$\text{Electric Energy} = 3 \times .746 \times 8000 = 18,000 \text{ kwh/ton nitrogen}$$

2/ Electrolytic Water Process

In the "Integal Oxygen Co.", a single cell takes normally 600 ampere of current with a voltage of 2.2 - 2.3. The electrolyte is 20% NaOH. The guaranteed purity of hydrogen is 99.5%. 7.2 cu.ft. of hydrogen are produced per kwh, that is 56,000 kwh per ton of hydrogen.

Allow 10% loss in the process, electric energy required

$$= 56{,}000 \times \frac{3}{14} \times \frac{1}{.9} = 13{,}330 \text{ kwh/ton nitrogen}$$

Here only hydrogen is used; oxygen produced is usually uneconomical to be transported to far distances and presumably wasted.

3/ Electrolytic Caustic Process

In this process, aqueous salt solution is decomposed according to the following equation:

$$2NaCl + 2H_2O \longrightarrow 2NaOH + Cl_2 + H_2$$

Although for one ton of hydrogen it takes nearly twice the value of electrical energy, i.e. 110,000 kwh, compared with the electrolytic water, yet it produced in addition 40 tons of caustic soda and 36 tons of chlorine, both of which are valuable.

Allow 10% loss of gases, electric energy required

$$= 110{,}000 \times \frac{3}{14} \times \frac{1}{.9} = 26{,}200 \text{ kwh/ton nitrogen}$$

Allow 10% loss of gases and 30% more salt used in actual process than theoretical, salt required

$$= 59 \times \frac{3}{14} \times \frac{1}{.9} \times 1.3 = 18 \text{ tons/ton nitrogen}$$

Caustic soda produced

$$= 40 \times \frac{3}{14} \times \frac{1}{.9} = 9.25 \text{ tons/ton nitrogen}$$

Chlorine produced

$$= 36 \times \frac{3}{14} \times \frac{1}{.9} = 8.32 \text{ tons/ton nitrogen}$$

4/ Liquefied Air Process - Linde System

In the Linde process about 280 - 780 kwh is used per ton of nitrogen. Taking the mean value and allow 10% loss, the electric energy required

$$= 520/.9 = 580 \text{ kwh/ton nitrogen}$$

5/ Direct Synthetic Process - American System

In the American system, 3 volumes of hydrogen and one volume of nitrogen are carefully mixed and sent into the system. 30% of the gas volume are converted and drawn off as liquefied ammonia and the remaining gasses made to circulate again. There is a loss of 10% of gas through leaks (as mentioned above) and through the loss of unconverted gases when purging the system by argon. The mechanical power is found to be about 2090 kwh/ton nitrogen.

The total electric energy for (1) electrolytic water and direct synthetic process = 13,330 + 580 + 2090 = 16,000 kwh per ton nitrogen, (2) electrolytic caustic and direct synthetic process = 26,200 + 580 + 2,090 = 28,870 kwh per ton nitrogen

Ammonia produced = 1.21 tons/ton nitrogen

6/ Ammonium Sulphate Manufacturing Process

$$2NH_3 + CaSO_4 + CO_2 + H_2O \rightarrow (NH_4)_2SO_4 + CaCO_3$$

Theoretically 4.85 tons of $CaSO_4$ are required per ton of nitrogen. Taking 70% CaSO in gypsum, then gypsum required

= 4.85/0.7 = 6.80 tons/ton nitrogen

Ammonium sulphate produced = 4.80 tons/ton nitrogen

7/ Other Process

a/ Ammonium sulphate from sulphuric acid

$$2NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$$

Materials required per ton nitrogen:

Ammonia 1.21 tons
98% sulphuric acid 3.68 tons
(or 46% pure S. pyrite 2.85 tons)

Cost of production - US$31.20 (ammonia from electrolytic water)

Products ammonium sulphate 4.80 tons/ton nitrogen

b/ Nitric acid and calcium nitrate

$$NH_3 + 3[O] \rightarrow HNO_3$$
$$2HNO_3 + CaCO_4 \rightarrow Ca(NO_3)2 + CO_2 + H_2O$$

Materials required per ton nitrogen

Ammonia 1.30 tons
Lime 3.75 tons

Cost of production - US$81.37 (high cost due to extensive labor required) (ammonia from electrolytic water)

Products calcium nitrate 5.38 tons/ton nitrogen

c/ Nitric Acid and ammonium nitrate

$$NH_3 + 3[O] \rightarrow HNO_3$$
$$NH_3 + HNO_3 \rightarrow NH_4NO_3$$

Materials required 1.21 tons of ammonia/ton nitrogen

Cost of production - US$56.98 (using ammonia from electrolytic water process), which consists of high cost of labor in making nitric acid.

Products ammonium nitrate 2.85 tons/ton nitrogen

d/ Urea Manufacturing

$$2NH_3 + CO_2 \rightarrow (NH_2)_2CO + H_2O$$

Material required 1.21 tons of ammonia/ton nitrogen plus CO_2

Cost of Production - US$70.40 (using ammonia from electrolytic water process) (Labor costs 50% of total)

Products Urea 2.14 tons/ton nitrogen

e/ Ammonium Phosphate

$$Ca_3(PO_4)_2 + 3H_2SO_4 \rightarrow 2H_3PO_4 + 3CaSO_4$$
$$2NH_3 + H_3PO_4 \rightarrow (NH_4)_2PO_4$$

Materials required <u>per ton nitrogen</u>

Ammonia 1.21 tons
Phosphate rock 7.90 tons
Sulphuric acid 5.20 tons

Cost of production - US$125.00 (using ammonia from electrolytic water process)

Products Ammonium phosphate 4.80 tons/ton nitrogen

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