SHANSI WATER CONSERVANCY
COMMISSION STUDIES

Preliminary Report on Hydro-Electric Development in Shansi 1934

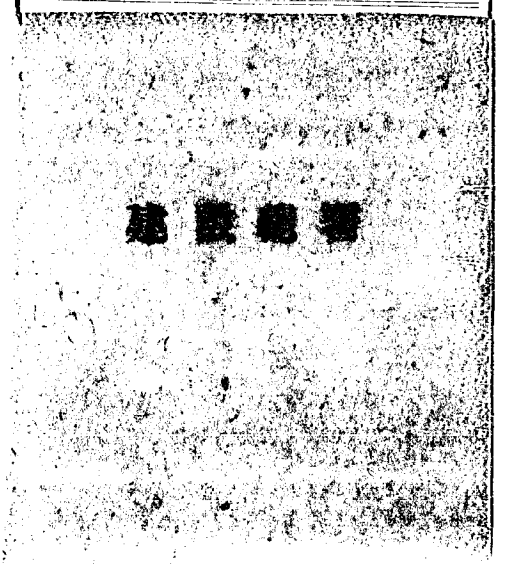
From surveys and estimates made under direction of China International Famine Relief Commission.

Peiping, November, 1934.

書卡

期限表

書號	登記號



DEVELOPMENT OF WATER POWER AT THE YELLOW RIVER FALLS AND ELSEWHERE IN SOUTH AND CENTRAL SHANSI TO AID IN IRRIGATION AND INDUSTRIAL EXPANSION

A REPORT PREPARED FROM SURVEYS MADE IN 1934

FOR

SHANSI WATER CONSERVANCY COMMISSION

UNDER DIRECTION OF

O. J. TODD,

Chief Engineer,

China International Famine Relief Commission

NOVEMBER, 1934.

TO

GENERAL HSU YUNG CHANG, CHAIRMAN OF

THE SHANSI WATER CONSERVANCY COMMISSION.

Sir,

I have the honor to submit herewith a report on investigations made during the past year in connection with hydro-electric development in Shansi Province, particularly as it concerns the Yellow River Falls at Hu-k'ou, Shansi. These studies have been carried out at your request for the Shansi Water Conservancy Commission by members of our staff who have also helped carry out the Fen Ho studies. This report has been prepared in the offices of the China International Famine Relief Commission which organization you have invited to undertake and supervise these studies. As Chief Engineer of that Commission I have employed such of its staff as seemed best qualified to aid in the compilation of this report, based on field studies and surveys made under my direction.

Respectfully submitted,

O. J. Todd,

Chief Engineer.

Peiping,

November, 1934.

The Yellow River falls at Hu-k'ou 70 feet drop.

壺口之黃河瀑布高七十呎

PRELIMINARY REPORT ON WATER POWER DEVELOPMENT IN SHANSI

In order to present in a concise review the possibilities of water power development in the Province of Shansi this report has been prepared based on studies made supplementary to the main surveys for water conservancy in this province. Since the chief object in mind is to furnish cheap power to pump water for irrigating plateau lands in the Hotung region of south-west Shansi and to furnish low priced power for industrial development along the Fen Ho, this report does not cover all parts of Shansi. It centers around the problem of conserving the potential power of the famous Hu-k'ou Falls of the Yellow River along the western border of the province. The other three minor water power developments are of little importance in comparison, but the figures prepared in connection with their utilization will interest all those in Shansi who favor an extensive development of her hydro-electric power.

For centuries water power has been used to grind grain into flour or wood into incense powder along the many streams of China where fall is rapid. These water power developments are of rather low efficiency being wooden wheels of the horizontal type on a vertical shaft that is attached to grinding stones located in a small mill-room a few feet above. The head of water used varies from four to eight feet as a rule. Many such mills operated by water wheels are seen along the Yeh Ho as one travels from Shih-chiachwang to Taiyuanfu. Immediately below Chintze Springs, Kwang Sheng Sze Springs and Chu Wo Falls are found many such mills operated by water flowing through channels that also act as irrigation main canals.

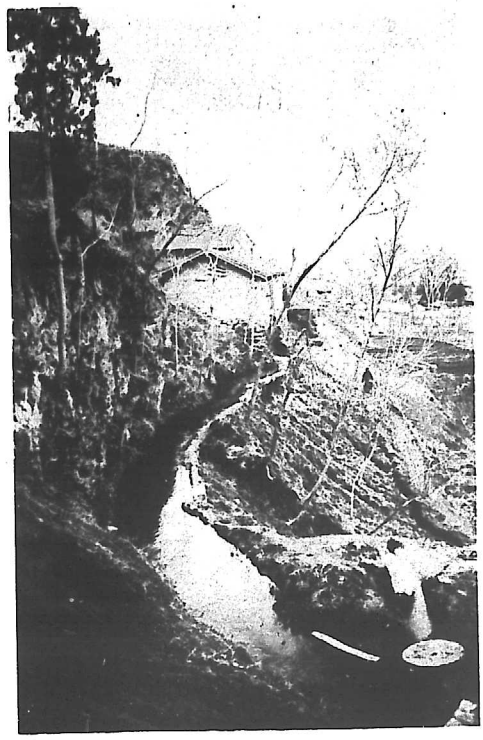
Our recent investigations show that these old type water wheels are as wasteful here in China as they have been in other countries, though they have served a useful purpose and have been the logical forerunners of modern hydro-electric plants using steel turbines of high efficiency. The principle of "highest use" applies to flowing water as much as it does to pasture lands and

forest. Therefore the matter of utilizing to the full the water power such as is found at Chintze, Kwang Sheng Sze and Chu Wo is recommended.

In searching for data on these several power projects little was found from which to start. As yet no hydro-electric development has been undertaken in Shansi as far as our investigations could determine. Cheap labor and cheap coal have furnished such low priced power that few felt the development of water power was worthy of attention beyond the primitive methods that have prevailed for many hundreds of years. An attempt had been made to develop the potential water power at Chintze Springs in one small hydro-electric plant, but owners of small mills would not permit this, demanding exhorbitant prices for their holdings and their water rights. This was but a few years ago and discouraged the promoters. The State will be obliged to take over such development and condemn such properties as may interfere with the best interests of the community as a whole.

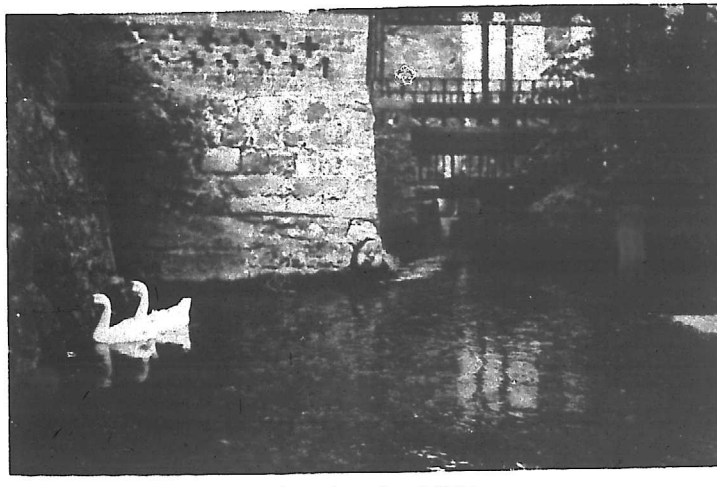
Two minor investigations of Hu-k'ou Falls on the Yellow River were made in late 1932. One was by a foreign engineer who spent a day or two at the falls and drew up a tentative plan for development of power basing his figures on such measurements as he made himself on that short trip. The other investigation was by two young men in the Geological Survey of China who spent more than a month taking topography in the vicinity of these falls. Both of these studies were of a very preliminary nature but such data as they furnished aided in checking against further data collected by our engineers when they conducted more thorough studies.

Since the work undertaken by the Shansi Water Conservancy Commission is entirely connected with the problem of food supply and the improvement of living conditions within the province, this report aims to bring attention of both Chinese and foreigners to the economic benefits of the work proposed by the plans discussed herein. It is not a problem of flood control but one of power utilization to the end that more good farm lands may be irrigated so that more grain, cotton etc. may be produced, and more local industries developed at costs that permit competition with districts outside the province. It will have a distinctly modernizing effect on this part of China and revolutionize living conditions in this region. From a famine prevention standpoint these developments seem to be quite as important as the storage of winter flow in the Fen Ho for spring irrigation though much less attention has been given the problem. The two undertakings are of



Irrigation and power canal near Chu Wo falls, Shansi.

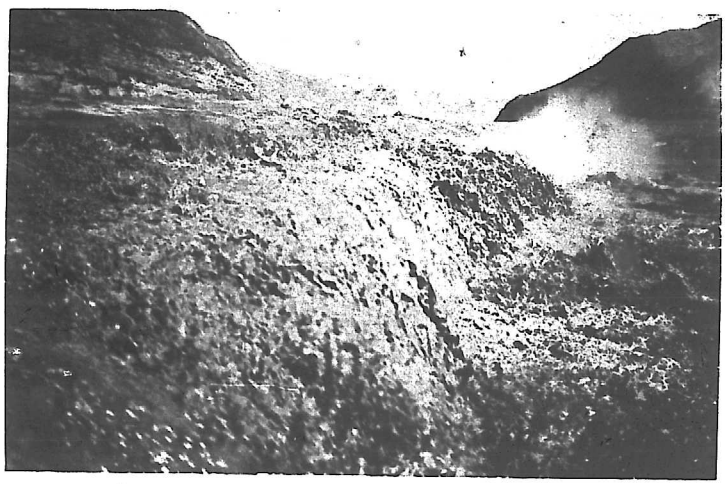
山西曲沃瀑布附近之灌溉及水力渠道



At the main spring of Chintze.

晉祠水泉

Where a 100 second-foot flow comes from the Kwang Sheng Sze springs.
廣勝寺水泉，水量爲每秒一百立方尺



A close-up view of Hu-k'ou falls from west bank of Yellow River.
Oct. 25, 1934.

自黃河西岸視壺口瀑布之近影，二十三年十月廿五攝

such vital importance to the province that they may well go forward at the same time in an effort to insure this province permanently against famine hazards.

HISTORY OF INVESTIGATIONS

The great fluctuation in flow from dry season to wet and the heavy silt load in most of Shansi's rivers have mitigated against hydro-electric development. Storage of flood waters was impractical due to the danger of rapid silting up of reservoirs. Therefore of Shansi's many streams those had to be selected that were either spring fed or had ample low water discharge. Development of power on a large scale along the Fen Ho seemed impractical, when the costs were considered, due to this problem of storage, though there are good dam sites in the gorges just above Lantsun. The low water flow seemed too small to warrant power development by an expensive masonry dam when coal for steam power was so convenient and low in price.

The falls and rapids in the Yellow River on the west border of Shansi have been known chiefly to boatmen until very recently. This region is so difficult of access that few engineers have ever been in the immediate vicinity. Upon the formation of the Shansi Water Conservancy Commission, however, there was a desire on the part of officials to know more about this source of power and I was requested to make preliminary studies.

My first visit to these falls was in April, 1933 when President L. H. Wang of Shansi University accompanied me. My second trip was made last month when Mr. T. E. Armstrong (Mining Engineer) and Mr. M. T. Li (Civil Engineer) accompanied me to make certain check measurements, take further photographs of the falls and the proposed power house site, and inspect the rapids from there to Yumenk'ou by boat. My own observations were supplemented by detailed surveys made early this year by the Commission's regular survey staff aided by a trained geologist.

Road surveys have been made to these falls both from Pingyangfu and Hotsin in order to work out the most practical means of ingress when materials of construction and machinery must be hauled to the site. A survey was also made from the falls to Yumenk'ou and the mouth of the Fen Ho in order to tie up with the more extensive Fen Ho surveys. This furnished the necessary information concerning a second possible power development at the lower end of the Yellow River gorges near Yumenk'ou.

Based on these 1934 surveys made by our own staff a plan has been worked out for developing 50,000

horsepower at these Hu-k'ou Falls by the use of the most modern type of turbine and utilizing a fall of approximately 100 feet over a stretch of less that 5,000 feet from the diversion dam above the falls to the selected power house site. The details of the plan have been worked out during the past three months in our Taiyuanfu office.

The other water power developments studied are three, being located at springs that feed into the Fen Ho. They are all rather small projects but illustrate what may be done in Shansi to conserve water power that is now used in a wasteful manner or but partially. The surveys of these projects have been made by our regular surveyors during 1934 and the plans for developing this power have been worked out from the data thus obtained.

In connection with the development of the Yellow River Falls, studies were also made of three pumping projects for using this new power to help irrigate three districts in the Hotsin area. A complete topographical survey was made of one of these areas, but in the case of the other two old maps were used for getting approximate heights and areas. One line of levels was run to check contours of military maps. Further surveys on these areas will follow. The projects were laid out in recent weeks by our engineers, utilizing all dependable data extant.

These studies therefore cover the following projects:

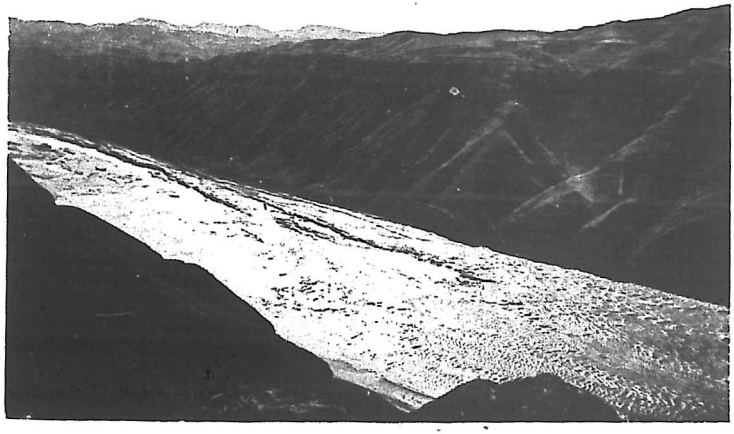
1. Yellow River Falls
   50,000 horsepower installation
2. Kwang Sheng Sze Springs
   1,400 horsepower installation
3. Chu Wo Falls
   400 horsepower installation
4. Chintze Springs
   250 horsepower installation
5. Hotung Pumping Plant
   266,400 gallons per minute
6. Yumenk'ou Pumping Plant
   8,623 gallons per minute
7. Lungmenchu Pumping Plant
   134,640 gallons per minute

THE YELLOW RIVER FALLS PROJECT

In considering economical hydroelectric developments in China probably there is no other project as attractive as the Hu-k'ou Falls of the Yellow River, 125 miles north of Tungkwan, Shensi where the river bends to the east forming a great elbow. It should be a bi-provincial undertaking or one where special rights are granted by the national government since the river is on the boundary between Shansi and Shensi at the falls and for many miles above and below that point. The project is, therefore, of national importance in certain respects. The power developed there would certainly be

Rough country to cover between Chi Hsien and the Hu-k'ou falls of the Yellow River.

自吉縣至壺口瀑布地形錯雜



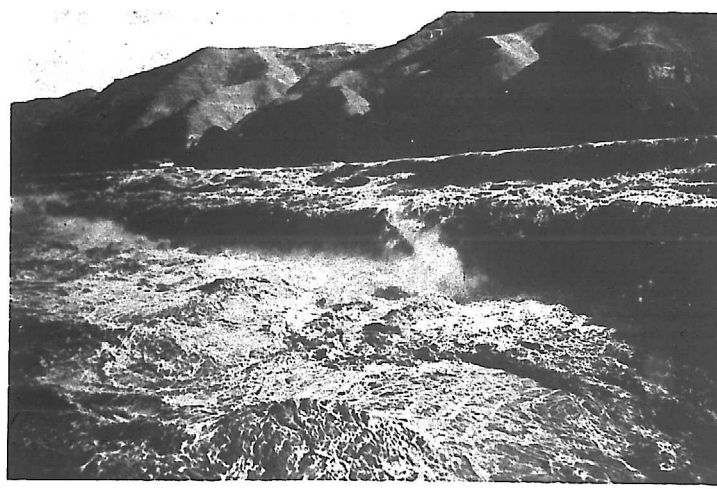
Looking down on Hu-k'ou falls from the trail on the east. Here the Yellow River drops into a deep slot in the limestone river bed. Oct. 24, 1934.

自東岸向下看壺口瀑布．黃河此流入一石灰石之深槽中．

二十三年十月廿四攝

Looking across the Yellow River from the west bank toward Hu-k'ou village just above the falls. Oct. 25, 1934.

在瀑布以上自黃河西岸隔河看壺口之形狀．二十三年十月二十五攝



Yellow River water boiling in the narrow slot at Hu-k'ou falls. Oct. 25, 1934.

壺口瀑布處之河水在狹槽中翻滾之情形．二十三年十月廿五攝

needed in both Shansi and Shensi provinces. But the development may be made by Shansi under federal grant and part of the power sold to Shensi according to agreements made when special rights are assigned by Shensi to the lands on the western bank of the river at and near the falls.

The present proposal is for development of a part only of the potential power at these falls. Even in the lowest stages of the Yellow River 50,000 horsepower may be developed at this point. Without the use of an auxiliary steam plant to take care of the very low water periods these falls may be developed to double this capacity. Also there are opportunities for developing another 50,000 horsepower of hydro-electric energy throughout the year by damming the river near Yumenk'ou at the lower end of the gorges, 60 miles south of the falls.

A recent writer on power development has placed the potential water power of China at 20,000,000 horsepower. Much of this is on the upper Yangtze and inaccessible to localities where it can be used to advantage under present conditions of transport. While the proposed development of Yellow River power on the Shansi-Shensi border is less than 1% of the total available undeveloped water power of China, it is of great significance because of its availability, being reasonably close to good farm lands that need cheap power for pumping water for irrigation and also convenient for supplying cheap electrical power for industrial development in regions from 60 to 125 miles to the south.

As an engineering undertaking this project rivals many large plants in Europe, Africa and America. There are special problems arising in the study of the design for the most practical and efficient development of this power. The occurrence of ice and silt and extreme fluctuations of flow all tend to complicate the problem. Then there is the question of use in a region which heretofore has never used power of this kind or even steam power except in a very limited degree.

That the benefits of this development would soon be far reaching and favorably effect the general living conditions and prosperity of the Chinese people in this part of the country is apparent to every student of rural improvements. A part of the power thus developed would go to increase yields of farm crops on the Hotung plain and in the Chiangchow and Hotsin districts in the vicinity of the mouth of the Fen Ho. Such insurance to crops in this locality would not only greatly decrease drought losses but would aid greatly in preventing famine in adjacent territory and even in districts far removed.

Aside from farmers there will be many other users of this new power. Its use in such industries as the Fixation of Atmospheric Nitrogen and its many allied chemical industries will be but a matter of a few years and such use will have a marked effect in benefitting the country thus served. Even the petroleum bearing strata of north-central Shensi may find this power so low priced as to warrant its use in large quantities. Mills for the spinning of cotton yarn are already awaiting the development of this power as also are many municipalities that would use it for lighting purposes. Suitable use may be found for this new power without going far afield. Before many years a greater demand will likely require a further development of the potential power of these falls and the rapids between them and Yumenk'ou.

PRELIMINARY HYDRAULIC DATA

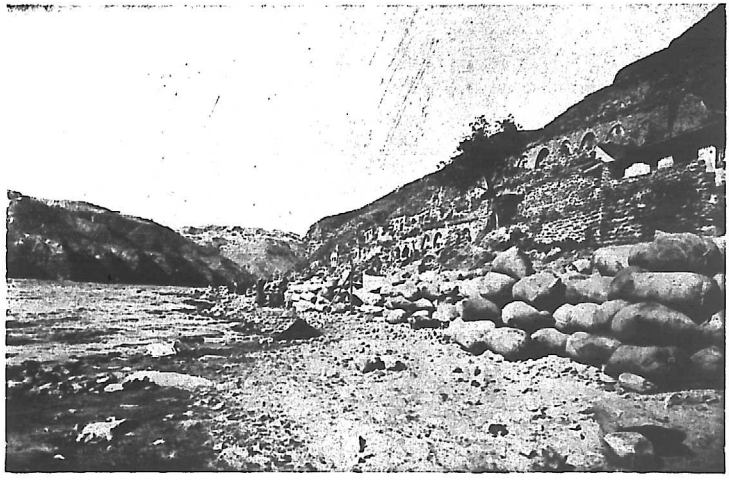
In the usual design of hydro-electric plants, flow duration curves or discharge tables covering a period of several years form the basis for determining the primary and secondary power (power available all of the time and power available only part of the time). These curves combined with the probable load factors indicate, in a general way, the design, performance and probable return on the investment. Past studies of the Yellow River have not been sufficiently extensive to furnish us with as much detailed information as we would like. However, our engineers have had experience on the design and construction of the Saratsi Irrigation Project for several years past and during that period we have made careful studies of the flow of the Yellow River at the Intake near Tengk'ou, Suiyuan. Our present studies and investigations, therefore, are guided by a conservative comparison with the characteristic curves of the Yellow River at Tengk'ou and such flow data as have recently been gathered by the Yellow River Commission. We base our plans on the best data available from all sources supporting our own observations and measurements on the ground.

The Saratsi (or Tengk'ou) duration curve indicates a minimum flow of 10,000 second-feet at that point during the comparatively dry year of 1930. The extreme minimum is likely something lower than the 1930 records show for Tengk'ou. But there are other feeders between Tengk'ou and Hu-k'ou, a distance of nearly 400 miles. These other feeders will bring the Hu-k'ou minimum flow up to 10,000 second-feet in the driest years, in our opinion. For the sake of safety the minimum flow at Tengk'ou has been used in estimating the possibilities of these falls.

Engineer Todd on the lower western rim of Hu-k'ou falls, Yellow River.
Oct. 25, 1934.

塔德工程師站於壺口瀑布下端之西岸．二十三年十月廿五攝

At the power house site one mile below Hu-k'ou falls on the Yellow River.
水電廠之地址在黃河瀑布以下三里



Where the boats from north Shansi are unloaded and floated around Hu-k'ou falls.

自山西北來之船在此處卸貨空船繞過壺口瀑布

Where Yellow River boats are again loaded 3 miles below Hu-k'ou falls.

在壺口以下三里之處船隻復行裝貨

With no other dependable flow data than that which our own engineers have gathered at Tengk'ou in recent years we are justified in basing our estimates on those results which indicate the following assured flow for Hu-k'ou:

Minimum flow = 10,000 second-feet .....Primary power

Average flow = 30,000 second-feet .....Secondary power (available 8 months per year)

Flood flow = 130,000 second-feet .....Not all available without storage.

Maximum Flood flow = 360,000 second-feet (few days duration only)

At the power site at the Yellow River Falls measurements show that a head of a little over 100 feet can be obtained by use of a diversion dam 30 feet high and by going downstream 5000 feet for the power plant installation. The difference in available head between low and high water periods will be approximately 20 feet. In developing 50,000 horsepower in the first step little over half of the low water flow of the river will be used.

$$HP = Q \times H/11$$
$$50{,}000 = Q \times 100/11$$
$$Q = 5{,}500 \text{ second-feet flow.}$$

PLAN OF DEVELOPMENT

The general plan of developing these falls is to divert something over half of the low water flow of the Yellow River by means of a low head masonry diversion dam of overflow gravity type into a short open canal head race and then through a tunnel more than 4000 feet in length to a forebay and through five penstocks to an equal number of turbines, then discharging the water through draft tubes directly into the river.

The plant for this first stage of development will be of 50,000 horsepower capacity or approximately 37,300 kilowatts. There will be five units of 10,000 hp. each. Propeller type turbines having adjustable pitch blades are to be used in order to maintain maximum power production during flood periods when high tail water causes certain losses in head. This rather modern type of turbine is so designed as to be free from danger of destruction of shaft bearings by gritty river water when the silt load is heavy.

The available head has been taken as 100 feet, though in low water there will be 122 feet and in high water 102 feet inclusive of that created by a diversion dam with crest 30 feet above low water surface. For a 50,000 hp. installation this will produce 438,000,000 horsepower-hours or 326,748,000 kilowatt-hours in a "no shut-down year" of 365 days running 24 hours per day.

The dam is to be located about 600 feet above the falls. It will have a slight angle upstream where the intake is to be located in order to induce flowing ice to shear away from the gates, rake and racks. Also it will tend to divert silt from the locality of the intake. This structure will be cyclopean masonry with rich concrete on the outer two feet throughout to protect it against abrasion from ice and large rocks carried down stream in high water. Also heavy steel rails will be imbedded near the surface of the top face and crest as further insurance against damage particularly from ice flows.

The length of the crest of the dam will be approximately 1300 feet provided with ample spillway section to handle extreme flood flows. It will be imbedded five feet into good rock foundation. The greatest height of section will be 45 feet at mid-channel. Chutes will be built on the east side of the river valley to put cargo boats over the dam, thus improving present difficult conditions of portage.

As to the rock structure at the dam site our Geologist makes the following statements after a careful survey of the locality. "The foundation material consists of Ordovician sediments of limestone and shales. The limestone is further differentiated as a calcareous grit (or sandstone) on the higher elevations above the river. Although no borings have been made as yet a surficial inspection indicates a fairly thick layer of limestone at the elevation of the dam site which will provide an adequate foundation and anchorage for the structure".

A study of the topography and comparative costs shows that the head-race should be chiefly in tunnel rather than in open channel. The tunnel section will be approximately 30 feet high by 50 feet wide and between 4000 and 5000 feet in length depending on more detailed rock studies. Canal velocity will be approximately 5 feet per second. Regulation of flow in the canal or tunnel will be by intake gates when the water level is such that throttling is necessary. Two sets of gates at the lower end of the head-race will also be provided so the flow may be diverted into the main river when it is necessary to close the plant.

Design of the power plant has been worked out in sufficient detail to get fairly reliable preliminary cost estimates. These include penstocks, powerhouse, turbines, generators, transmission line etc. Account has been taken of the main details of intake design as well. A road survey taking many weeks has been completed from near Pingyangfu to Hu-k'ou in order to compute freight costs. Another survey is being made of a road from Hotsin

(near Yumenk'ou) to the falls in the hope of finding a less expensive route over which to build. Our engineers have made broad enough investigations to warrant the drawing up of this preliminary plan that is subject to certain alteration but points the way to the economical development of this unused power.

COSTS

As is shown in some detail in Appendix I, the cost for developing these Yellow River Falls is very reasonable. For the proposed primary stage of development where the plant will produce 50,000 horsepower the cost totals a little over $6,000,000.00 exclusive of interest on the capital. If this must be borrowed for two years at 8% then the item of nearly $1,000,000.-00 for interest should be added. It is likely, however, that the work can be so laid out that the main construction expense will be incurred in less than two years time.

Our computations show that this plant running full capacity all the time can produce electric energy and transmit it 60 miles to the Yumenk'ou region for pumping or industrial purposes selling it for 0.3 cents per kilowatt-hour. This is on the assumption of complete use of all power so produced. It is the ultimate minimum rate toward which the builders of this power utility may hope to work. The cost per horsepower will be slightly over $140.00 for plant construction etc.

The annual charges against this project are calculated at $990,000.00. These include "Capital" charges of 6% and "Depreciation and Obselescense" charges of a like amount, as noted in Appendix I. Lands and riparian rights are taken at a low figure as the country is practically uninhabited around the falls and following down river to Yumenk'ou. Though our engineers have carefully surveyed the 100 mile road reaching the dam site from the east and find it will cost fully $700,000.00, other surveys may show a saving on this item. Cement costs are predicated on present methods of supply. If Shansi has her own cement plant operating next year and her railway materially reduces transport costs, a saving can be made on the cost of the dam below the $1,000,-000.00 provided in the estimate. It should be noted that a contingency factor of 15% is allowed over all construction costs. That is low enough in figuring work in such isolated regions of China.

BENEFITS AND USES

When the question of hydro-electric power development is raised everyone asks how a large supply of new power will be used in the interior of China, for in most localities it must compete either with low priced hand

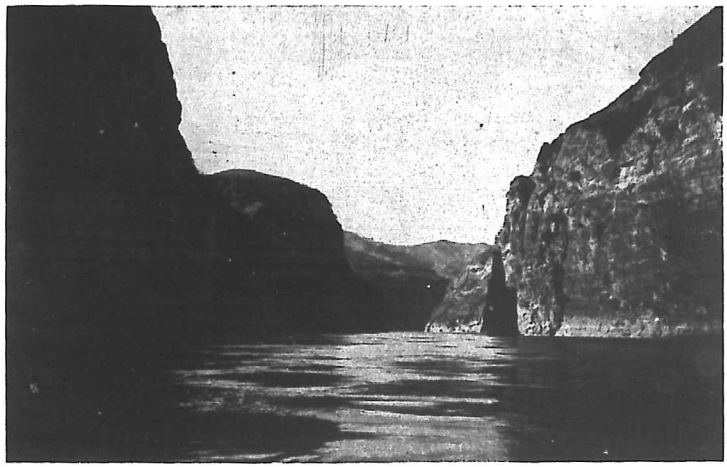
labor or cheap steam power where coal is abundant. A few of the possible markets may be tabulated as follows:

1. Yumenk'ou Pumping Plant for irrigation.
2. Lungmenchu Pumping Plant for irrigation.
3. Hotung Pumping Plant for irrigation.
4. Cotton Spinning Mills at Chiangchow.
5. Other mills and industries to be built nearby.
6. Lighting nearby cities.
7. Tungkwan municipality and railroad shops and industries.
8. Coal mines in south Shansi.
9. Petroleum distillation and refining in central Shensi.
10. Electrochemical industries—
    Fixation of Atmospheric Nitrogen.
    a. Fertilizers
    b. Nitric acid
    c. Pulp products

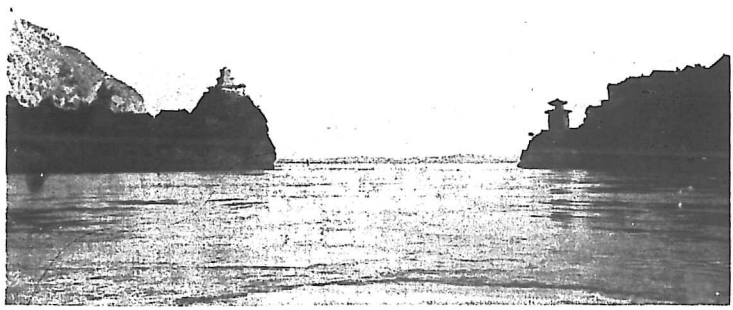
With the many opportunities to dispose of this new power as indicated above it seems likely that the entire output of this first development may be economically employed within less than five years of the completion of the Huk'ou power plant. Though the very important use connected with the new irrigation districts proposed for southwest Shansi will be seasonal, it is likely that a Nitrogen plant could be so operated as to take up the unused power at other times of the year.

The development of these falls of the Yellow River will mean new life for all of south Shansi as well as neighboring regions. This potential power should not continue a complete loss to the State as it has down through the centuries. It is within the ability of Shansi today, with moderate aid from the National Government, to so utilize this power that many millions of her people will benefit by the increased prosperity that will accrue to the province.

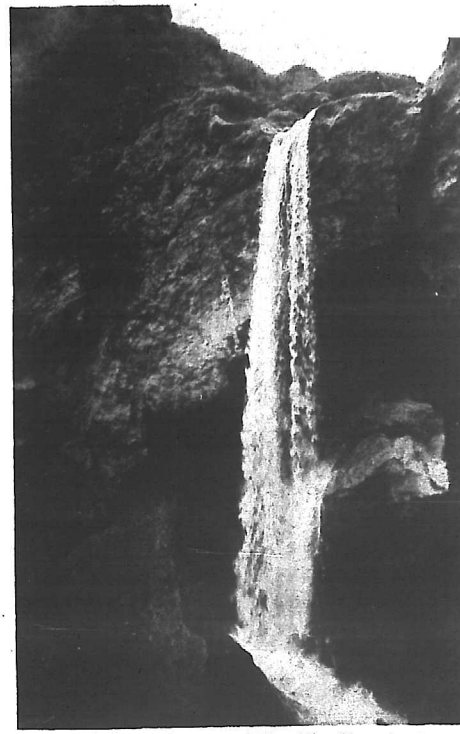
Foreign specialists investigating lands in China have stated that the climate and soil of south-west Shansi is particularly adapted to the growth of cotton. This is a valuable crop bringing in larger revenue to the farmer than do most grain crops. With irrigation cotton does well throughout the Hotung area even including districts as far north as Pingyangfu. To get water to the higher lands of Hotsin and Wanchuan hsiens it is necessary to have cheap power for pumping. To do this pumping, to manufacture the cotton into yarn, to grind grain into flour, to light cities and otherwise modernize this part of Shansi will be a part of the benefits that these Yellow River Falls may confer on the nearby country. Added to these the production of nitrates for use in fertilizers will prove a very important factor in keeping up high production in agriculture.



Gorges of the Yellow River north of Yumenk'ou, Shansi.
山西禹門口北之黃河山峽

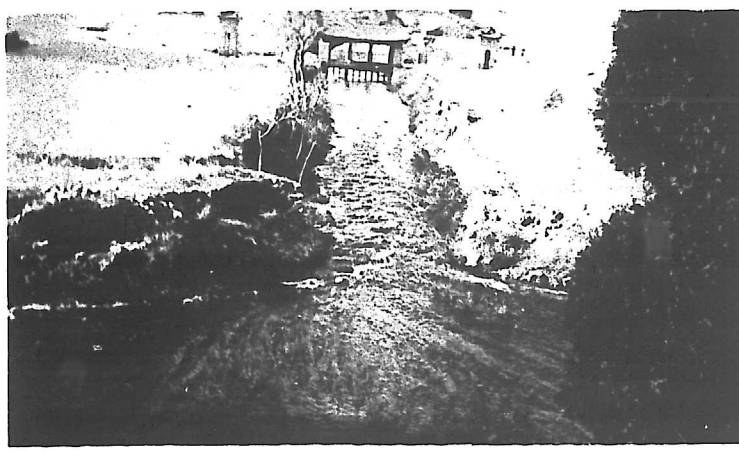


Yumenk'ou, where the gorges of the Yellow River end.
禹門口之形狀，黃河由此出山峽



Lower Chu Wo falls 6 miles east of Chu Wo, Shansi. Apr. 13, 1934.

山西曲沃東十八里處之曲沃瀑布．二十三年四月十三攝



A flow of 100 cubic feet per second from Kwang Sheng Sze springs north-east of Hung Tung, Shansi.

廣勝寺在洪洞城東北，水量爲每秒一百立方尺

KWANG SHENG SZE SPRING PROJECT

The Kwang Sheng Sze Springs, located at the foot of limestone hills, are well above the plain, lying to the west between Hung Tung and Chao Cheng, which they water, and are at an elevation such that the flow of nearly 100 second-feet can eventually be used to develop 2600 horsepower of electrical energy. The first development, however, will furnish only 1400 horsepower.

The flow from the springs is divided into three main canals and along these native mills make use of the power of low drops of four to six feet each. Later the water is released to be used by irrigationists. These small native mills for grinding flour are of low efficiency. A central flour mill operated by power from a hydro-electric plant would do all the work of these many native mills and still leave most of the power for other uses, such as lighting the cities of Pingyang, Hung Tung and Chao Cheng beside operating various industries.

What new industries would likely grow up near this power plant, aside from cotton mills and flour mills, is a matter of speculation. But it is a good farming region. Canneries for vegetables might easily become profitable enterprises here. The manufacture of cloth by modern methods might prove a thriving business also.

For developing the first unit of 1400 horsepower or 1000 kilowatts the entire flow of 100 second-feet would be used with a head of 150 feet at a point 8000 feet west of the springs. The second development would be built later and utilize an available head of 80 feet.

The cost of developing this water power is estimated at approximately $180,000.00, or nearly $130.00 per horsepower. Annual operating costs figured at $40,000.00 would give power at 0.45 cents per kilowatt-hour at the switchboard assuming full use of the power throughout the year. While this is 50% higher in cost than the larger Yellow River Falls development, it is a low rate that should induce enterprising men to build mills or factories in this district.

THE CHU WO FALLS PROJECT

The Chu Wo Falls are located directly below a group of springs in the hills 20 li east from Chu Wo city near the village of Pai Shui Tsun and Ching Ming Tsun in southern Shansi. The flow of the stream fed by these springs seems to vary from 20 to 30 second-feet. For years small native flour mills and cotton seed oil presses have held water rights along the small canals leading from the stream above these

falls. Here, as elsewhere in China, the power of falling water is inadequately conserved or but partially used.

This project has the highest head and smallest flow of any of these covered by this report. The dependable flow has been taken at only 20 second-feet and the head at 223 feet as per surveys and gagings made last spring by our engineers. There will be but one unit of 400 horsepower capacity.

It is proposed to develop these falls by constructing a small low head dam with a 12 hour storage capacity, leading the water from there by an open flume and penstock to a Pelton type impulse wheel from which the water is discharged into the stream channel near the village at the foot of the falls. Below this point the water will again be used for irrigation purposes as it is used at present.

The following uses may be made of the power developed at this plant:

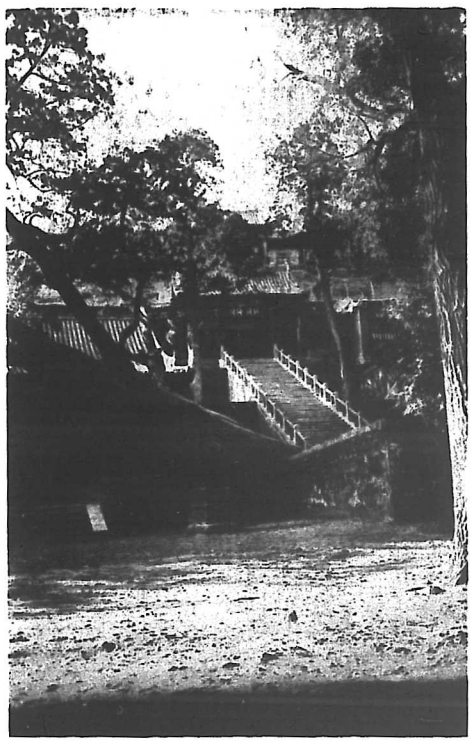
1. Flour milling
2. Cotton spinning
3. Pressing cotton into bales
4. Pressing and refining cotton seed oil and other oils
5. Lighting Chu Wo, 20 li to the west

The cost of this development is estimated at $120,000.00 or $300.00 per horsepower, a rate considerably higher than that for the two previously outlined plants. However, due to the rich farm lands in the vicinity and the general prosperity of this region this higher cost is not excessive. Power is of great value to this community so that this small project may well prove worth the investment.

THE CHINTZE SPRINGS PROJECT

These springs, located close to the town of Chintze, Taiyuan Hsien, are well known for their clear water and regular flow. The temples built around them have made the spot a shrine for centuries. The provincial capital is but 40 li to the north connected by a good motor road. Coming from the hillside on the western border of the Fen Ho valley these springs are particularly valuable for irrigating lands immediately to the east and south where rice and other grains are grown. The 40 feet of fall before the main valley lands are reached has been used, in the native way, to run small flour mills. But here, as at Kwang Sheng Sze and Chu Wo, the power is wasted and efficiency is low.

While this is the smallest development covered by this report it is important because of the location. Though the 70 second-feet of flow would produce but 250 horsepower of electrical energy, still this is valuable



Leaning cedar at Chintze springs.

晋祠之古柏

On the Hotung plateau 310 feet above the Fen Ho and to the south of Hotsin pumping station.

河東高原高於汾河三百一十呎、在河津灌田場之南

Cotton fields on the dry Hotung plateau 310 feet higher than the Fen Ho.

河東乾燥高原之棉花高於汾河三百一十呎

and can be developed without detriment to the farmers who use this water for irrigation. It can be made to do greater work than at present by centralizing the milling in one plant.

The power would be used in two ways as follows:

1. To furnish electric lights to the town of Chintze.
2. To operate a central flour mill superseding the native ones.

In addition the temples around the springs might be lighted and the new park that is being created near the springs may have the benfits of electric lights. Milling might be done in the daytime so that the same power could be used for lighting at night.

The cost of this project is figured at approximately $44,000.00 bringing the cost per horsepower to nearly $176.00. Operation costs and fixed charges are estimated at $8,800.00 per year so that the power may sell at 0.53 cents per kilowatt-hour if it is all consumed and the plant runs continuously.

The necessary field studies have been made for this development and preliminary plans have been worked out in some detail. As soon as the Provincial Government is prepared to take the matter up and exercise the right of "eminent domain" the water may be diverted through new channels to the proposed plant and, after being properly used for power, will go back into the same three main canals that now use it for irrigation.

This improvement will be a distinct benefit to this community and be an example for other districts that have water power that is now wasted. The very prosperous community in and near Chintze can easily finance this work. The initiative, however, should come from the Provincial Government to expedite the work and prevent excessive demands for antiquated water rights that are improperly exercised.

THE LOWER HOTUNG IRRIGATION SCHEME

The district known locally as the "Lower Hotung" lies south of the Fen Ho and east of the Yellow River and consists of a series of plateaus or benches draining off on all sides to the rivers which surround this high land but chiefly draining into the Yellow River. The city of Wanchuan is on the highest of these benches, being something over 1000 feet above the Fen Ho at its mouth. But other lands to the west are lower as indicated by military maps. No recent topographical surveys have been made to check up these maps that are used for our preliminary estimates, except for one line of levels from the Fen Ho to Wanchuan made very recently.

The good farm lands of these plateaus are estimated to total 3,000,-000 mou of which probably 1,000,000 mou lie on an average of less than 250 feet above the mouth of the Fen Ho. It is this area that this project aims to serve. The pumping system to be installed near the junction of the Fen Ho and the Yellow River will be operated by low priced power from the Hu-k'ou hydro-electric plant described in this report. Water from the Yellow River will be pumped to various levels as the topography permits without the necessity of lifting all of it to the upper plateaus. Likely two or more sub-stations will be required in connection with this pumping. The number, size and location of these stations will be dependent on surveys to be made next year.

Without having the topographic sheets that are necessary before a comprehensive report can be made on the costs and returns of this major irrigation project that so many residents desire, it is possible to work out from the somewhat meagre data the probable costs and returns in an approximate way. Estimates prepared by our engineers and checked against those of other engineers who have considered this project indicate a probable outlay in pumping plant of nearly $500,000.-00, plus an equal amount for the canal system. This should bring in an annual income of $1,000,000.00 from 1,000,-000 mou of land served. Annual operation and upkeep of the system is estimated at $350,000.00, figuring power costs at twice the theoretical minimum.

The benefits of this project would be chiefly in the increase to crop yields, increase to land values, and insurance against drought famines. These benefits would amount to several million dollars each year in the Hotung area alone. As a business enterprise it will pay well, according to calculations made from present maps and figuring on cheap power from Hu-k'ou.

YUMENK'OU IRRIGATION PROJECT

This project is small but worth while. It embraces an area of 16,390 mou of fertile farm land that requires irrigation to insure good crops annually. Cotton grows well here as also do many grains. The lands lie close to the Yellow River immediately north of the Fen Ho near its mouth. The maximum height it is proposed to lift water to this area from the Yellow River by electrically driven centrifugal pumps is 185 feet. Part of the area is very low and can be irrigated without pumping. A two stage pumping scheme will take care of the rest of the area. It is proposed to pump water to this land so that every 15 days it will all get an irrigation of from 3 to 4 inches. It is plan-

ned to have the first stage a lift of 85 feet. The second stage would be a lift of 100 feet. Details of pumps, motors etc. have been prepared for this project.

The cost of this plan exclusive of canals is estimated at $164,000.00. The canal system should not cost over $20,000.00. The cost of power from Hu-k'ou would be a very small item, or little over 5% of the total annual charges of $50,000.00 against puming plant, interest and depreciation, salaries etc. It is figured that a plant of 800 horsepower would handle this project. The annual water tax here would have to be $3.00 per mou to warrant the investment in plant. This rather high charge is due to the small area to be served. However, it is valuable land that should yield $20.00 per mou annually from cotton.

The topography here is favorable to the construction of a canal system and the cost of excavation should be moderate. The cost of the pumping equipment is the main item to consider in this undertaking.

LUNGMENCHU IRRIGATION PROJECT

In the region of Hotsin and Chi Shan an area of approximately 300,000 mou of good farm land lying well above the Fen Ho valley is in need of irrigation. It has been urged by the local people that Yellow River water should be pumped to these plateau lands. The plan is to pump the water from the river at Yumenk'ou and bring it by canal at an elevation of less than 100 feet above the river to the vicinity of Hotsin where a booster station would take care of the additional lift to lands of varying height up to 300 feet above the river.

Surveys are not yet made giving correct topography on which to base a close estimate of costs. With such data as are available estimates have been worked out showing that this project will cost approximately $1,000,000.00. Annual charges are estimated at $350,000.00 so that the water tax must be something over $1.00 per mou. However revenues from cotton crops would so increase that the land could stand a tax of $3.00 per mou each year.

This project would improve conditions in the Hotsin and Chi Shan districts bringing up the price of land served by these canals at least another $10.00 per mou in value. The annual increase in crop value should average $5.00 per mou through the region served. The benefit derived by insuring this region against drought would have a marked stabilizing effect on the community.

These three irrigation projects that would be served by pumping plants

near Yumenk'ou with power from the Hu-k'ou hydro-electric development are all worthy of consideration. The carrying through of the general plan herein outlined in a preliminary way would mean many millions of dollars of revenue annually to the province above the present income. This plan would so increase land values and crop values that the people's living conditions would be entirely changed within a few years. Prosperity on a scale not heretofore seen in these regions would come to south-west Shansi as a result of these improvements through irrigation.

Respectfully submitted,

O. J. Todd,

Chief Engineer.

APPENDIX I

HU-K'OU FALLS HYDRO-ELECTRIC PLANT

COSTS

A.	Construction Costs.	
1.	Pingyangfu to Hu-k'ou Road	$ 700,000
2.	Masonry Dam	1,000,000
	a. Gates and Gatehouse	100,000
	b. Racks and Rake	50,000
3.	Forebay and Controls	50,000
4.	Tunnel, Gates and Spillway	600,000
5.	Penstocks and Valves	100,000
6.	Powerhouse	
	a. Substructure	50,000
	b. Superstructure	50,000
	c. Equipment	
	1. 5 Turbines and Appurtanences (wt. 450 tons.)	480,000
	2. 5 Generators and Appurtanences (wt. 300 tons.)	900,000
	3. 2 Transformers and Switchboard	200,000
7.	Freight on machinery from Tientsin $200 per ton	180,000
8.	Transmission Line (60 miles)	600,000
		$5,060,000
B.	Other Costs.	
1.	Land and Riparian Rights	$ 50,000
2.	Engineering 5%	255,500
3.	Contingencies 15%	766,500
	Total	$6,132,000

Interest During Construction (8% for 2 years)		981,120
	Total	$7,113,120
Cost per horsepower	$142+	
Weight of largest piece of equipment	15 tons.	

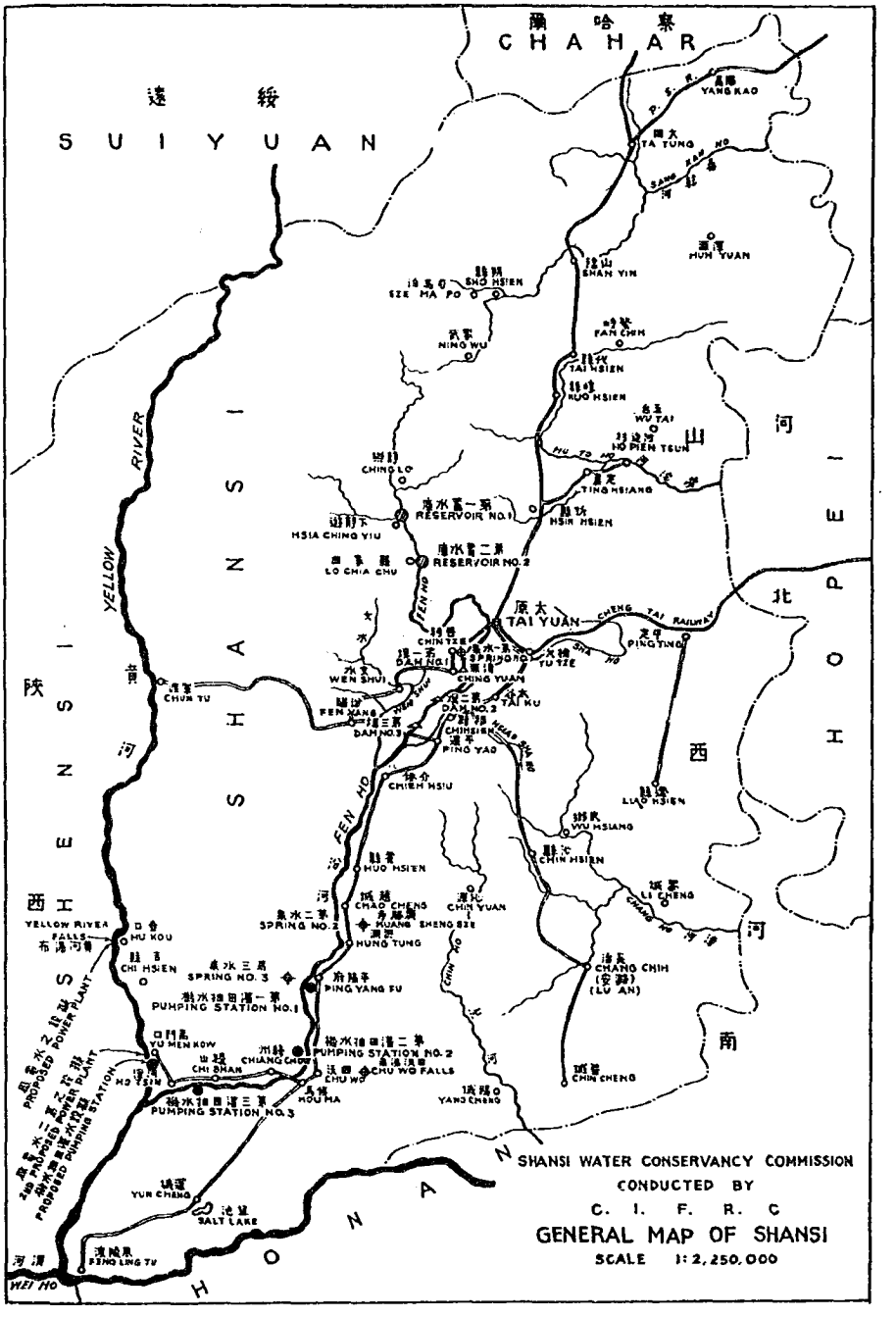
Assuming plant operation for 365 days of 24 hours each the plant will produce annually 37,300 kilowatts for 8760 hours or 326,748,000 kilowatt-hours.

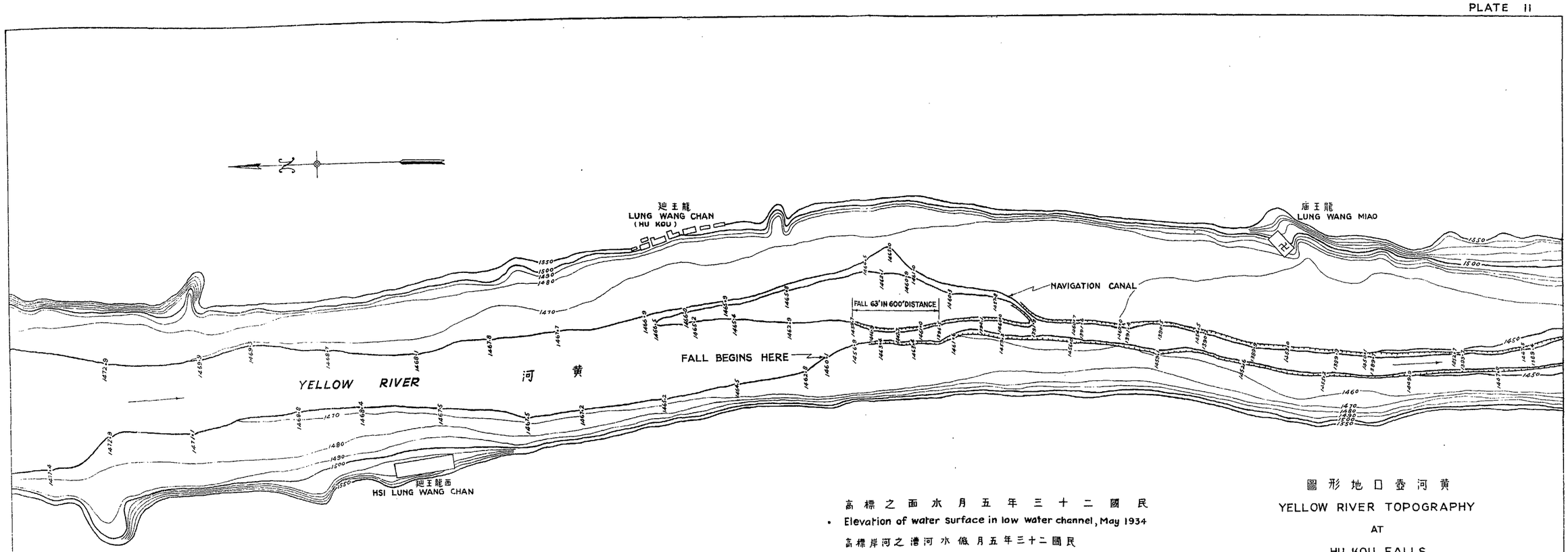
Expenses per annum

1. Lubricants		$ 50,000
2. Engineers' Salaries and Wages		50,000
3. Maintenance		50,000
	Total	$ 150,000
Capital Charges 6%		420,000
Depreciation and Obsolescense 6%		420,000
	Total	$ 990,000

The power can be sold for 0.3 cents per kilowatt-hour at switchboard if fully utilized.

PLATE I


CHAHAR
SUIYUAN
SHANSI
HOPEI
YELLOW RIVER
FEN HO
TAI YUAN
CHENG TAI RAILWAY
SHANSI WATER CONSERVANCY COMMISSION
CONDUCTED BY
C. I. F. R. C
GENERAL MAP OF SHANSI
SCALE 1: 2,250,000



民國二十三年五月水面之標高

• Elevation of water surface in low water channel, May 1934

民國二十三年五月傾水河槽之河岸標高

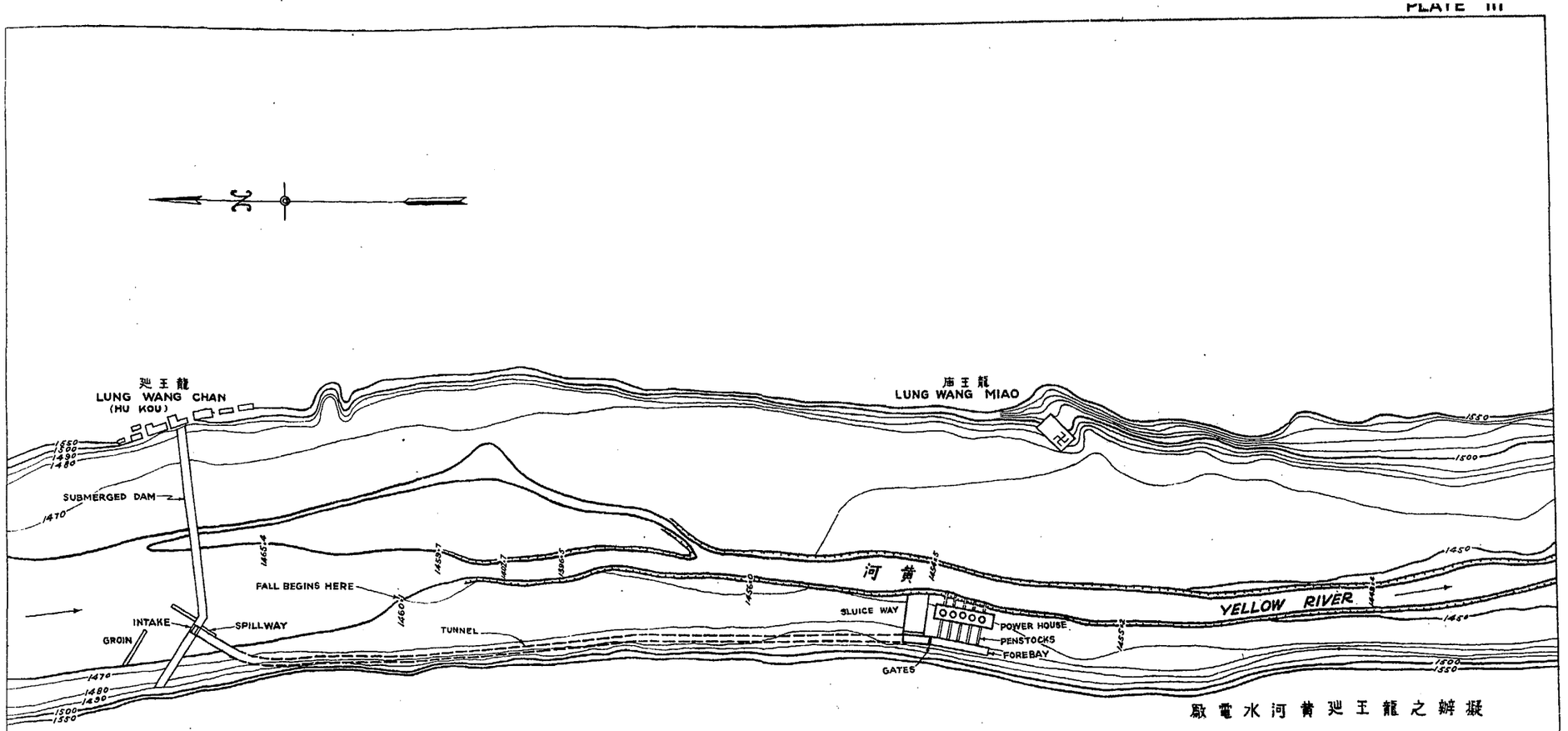
x Crest of low water channel, May 1934

黃河壺口地形圖

YELLOW RIVER TOPOGRAPHY AT HU KOU FALLS

SCALE 1: 6,000

PLATE III



民國二十三年五月底水位之標高

* Elevation of water surface in low water channel, May 1934.

民國二十三年五月底水位河岸之標高

* Cresr of low water channel, May 1934.

擬辦之龍王迟黃河水電廠

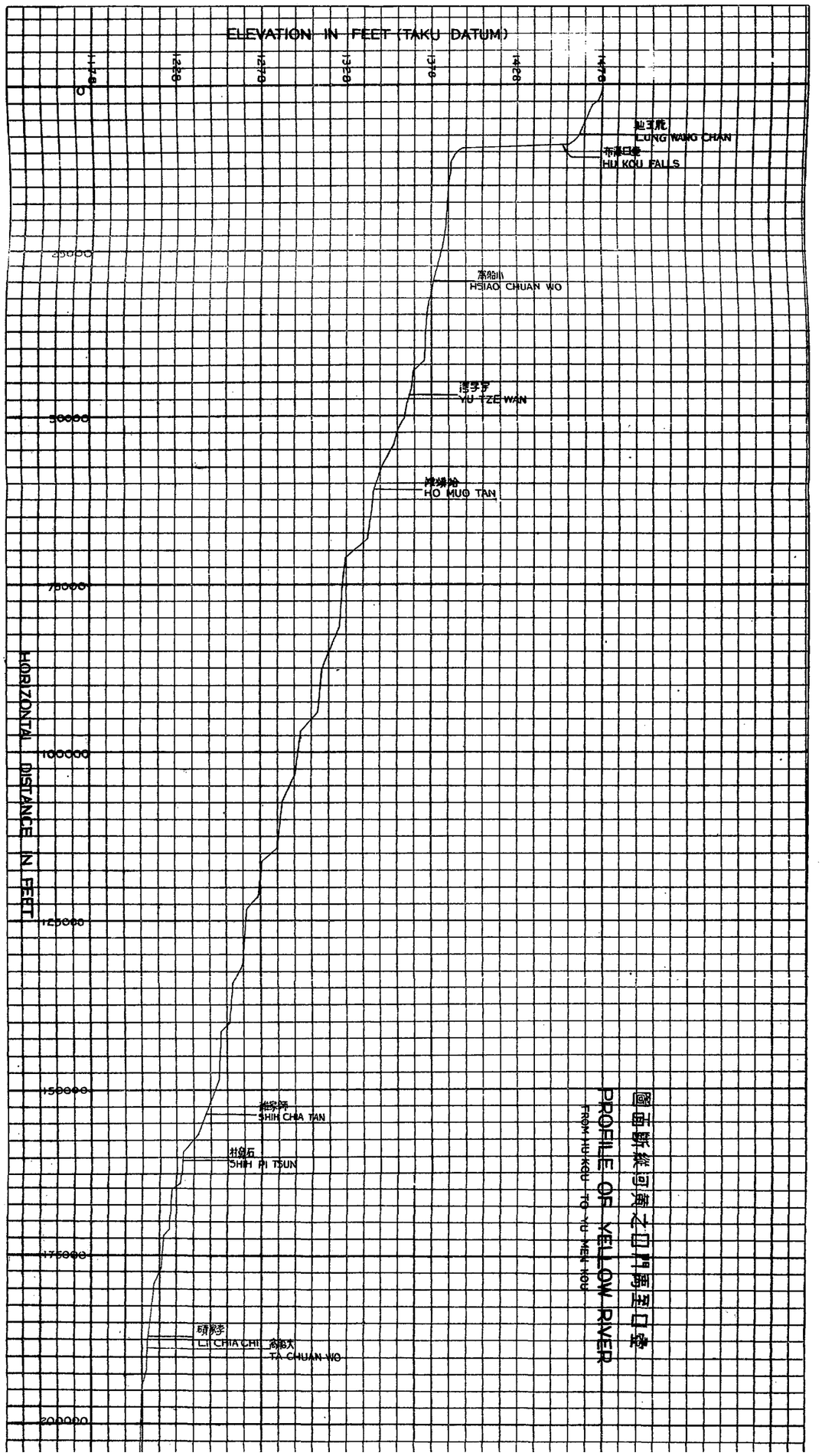
PROPOSED
YELLOW RIVER FALLS HYDROELECTRIC PLANT

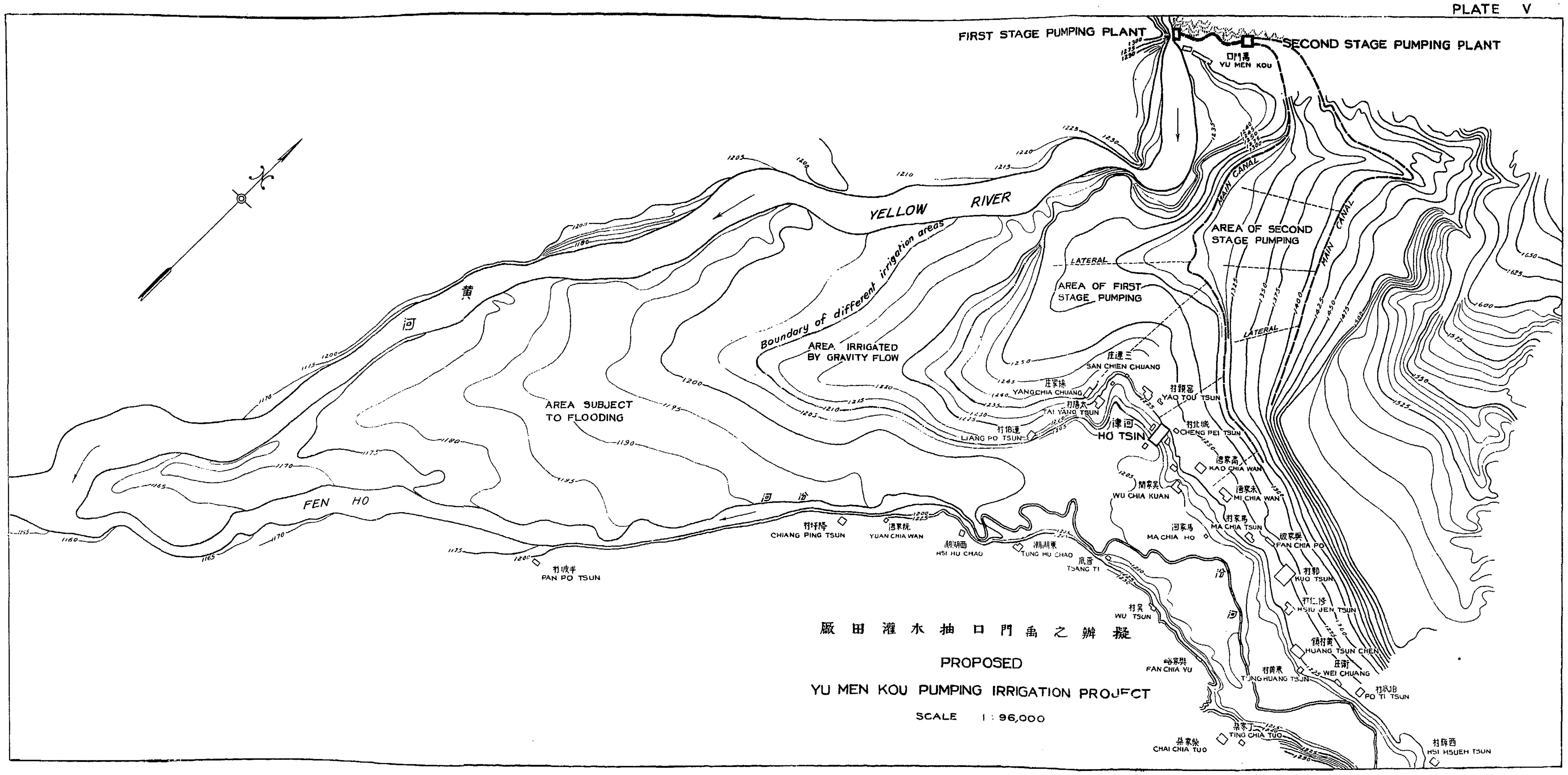
LUNG WANG CHAN

OCTOBER, 1934 SCALE 1: 6,000

黃河壺口瀑布至禹門口段縱斷面圖

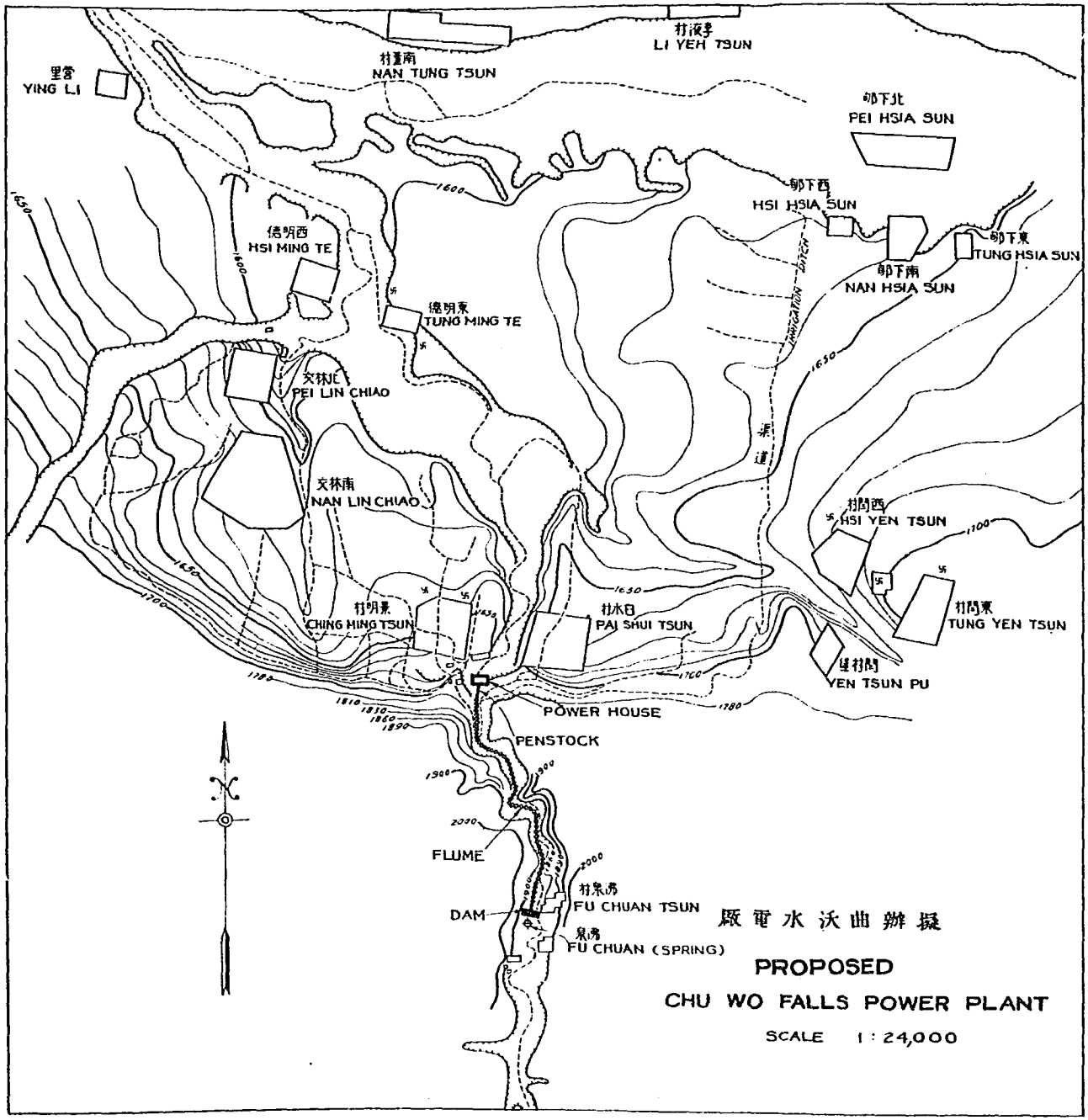
PROFILE OF YELLOW RIVER FROM HU KOU TO YU MEN KOU





FIRST STAGE PUMPING PLANT
SECOND STAGE PUMPING PLANT
YU MEN KOU
YELLOW RIVER
MAIN CANAL
AREA OF SECOND STAGE PUMPING
LATERAL
AREA OF FIRST STAGE PUMPING
Boundary of different irrigation areas
AREA IRRIGATED BY GRAVITY FLOW
AREA SUBJECT TO FLOODING
FEN HO
HO TSIN
SAN CHIEN CHUANG
YANGCHIA CHUANG
TAI YANG TSUN
LIANG PO TSUN
YAO TOU TSUN
CHENG PEI TSUN
KAO CHIA WAN
WU CHIA KUAN
MI CHIA WAN
MA CHIA HO
MA CHIA TSUN
FAN CHIA PO
KUO TSUN
HSIU JEN TSUN
HUANG TSUN CHEN
WEI CHUANG
PO TI TSUN
WU TSUN
FAN CHIA YU
TUNG HUANG TSUN
TING CHIA TUO
CHAI CHIA TUO
HSI HSUEH TSUN
CHIANG PING TSUN
YUAN CHIA WAN
HSI HU CHAO
TUNG HU CHAO
TSANG TI
PAN PO TSUN
擬辦之禹門口抽水灌田廠
PROPOSED
YU MEN KOU PUMPING IRRIGATION PROJECT
SCALE 1 : 96,000

PLATE VI

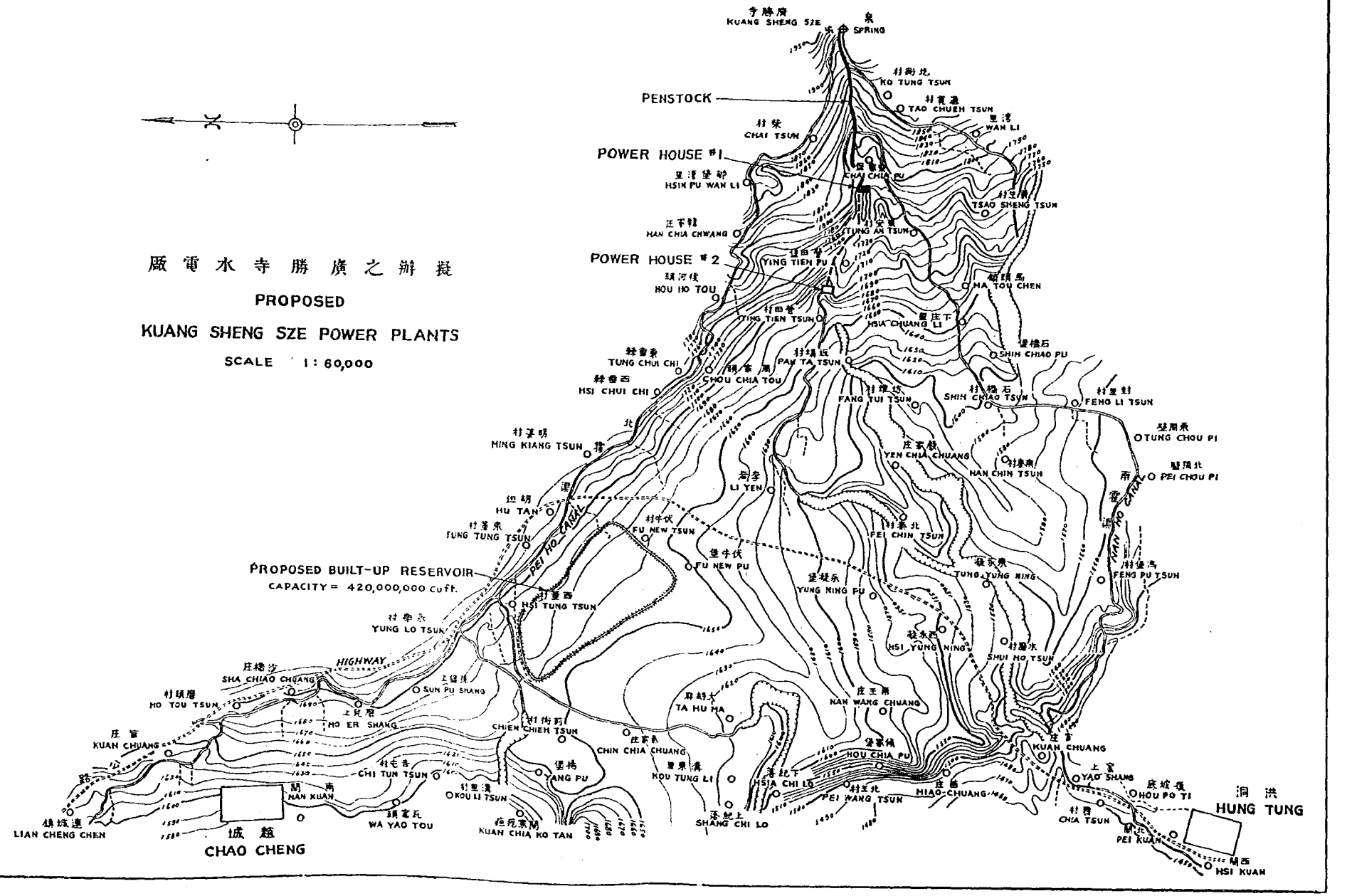


擬電水沃曲辦廠

PROPOSED

CHU WO FALLS POWER PLANT

SCALE 1:24,000



廣勝寺水電廠之擬辦

PROPOSED

KUANG SHENG SZE POWER PLANTS

SCALE 1 : 60,000

晉祠附近詳圖

DETAIL MAP OF CHIN TZE SPRING AREA

SCALE 1:24,000

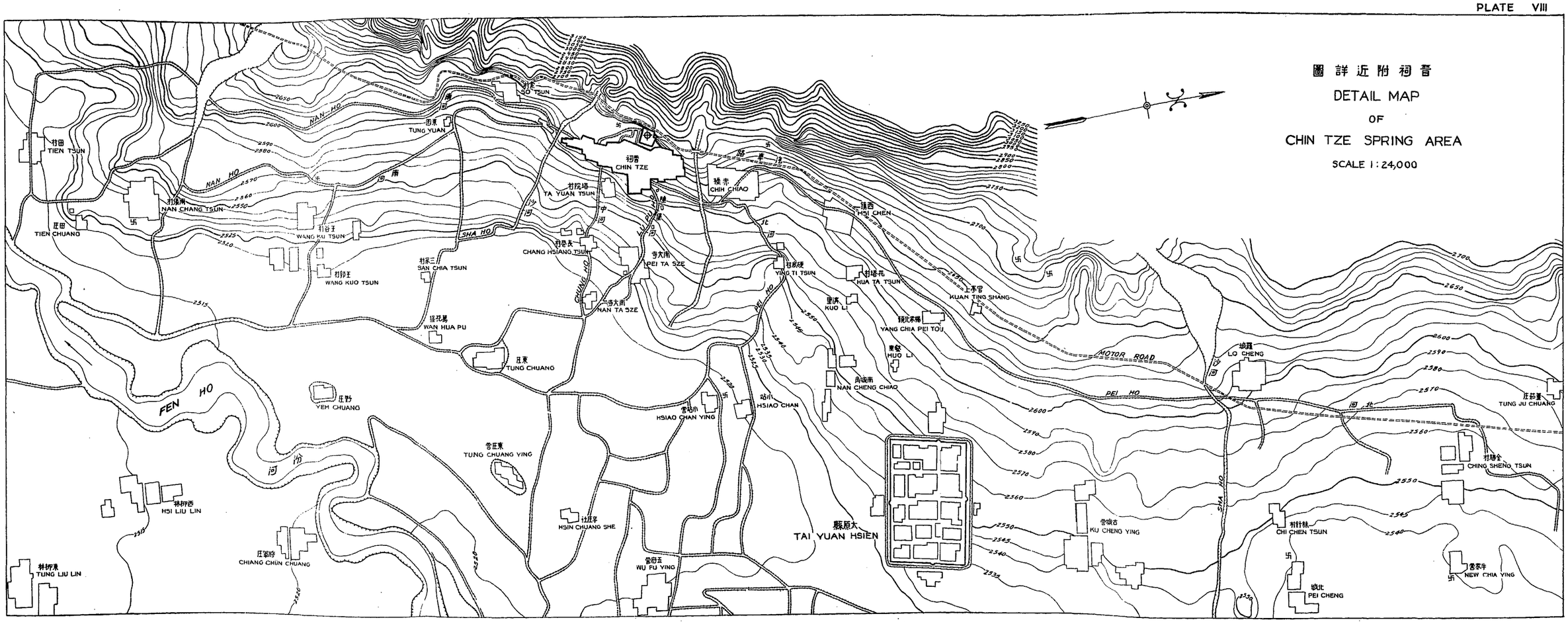
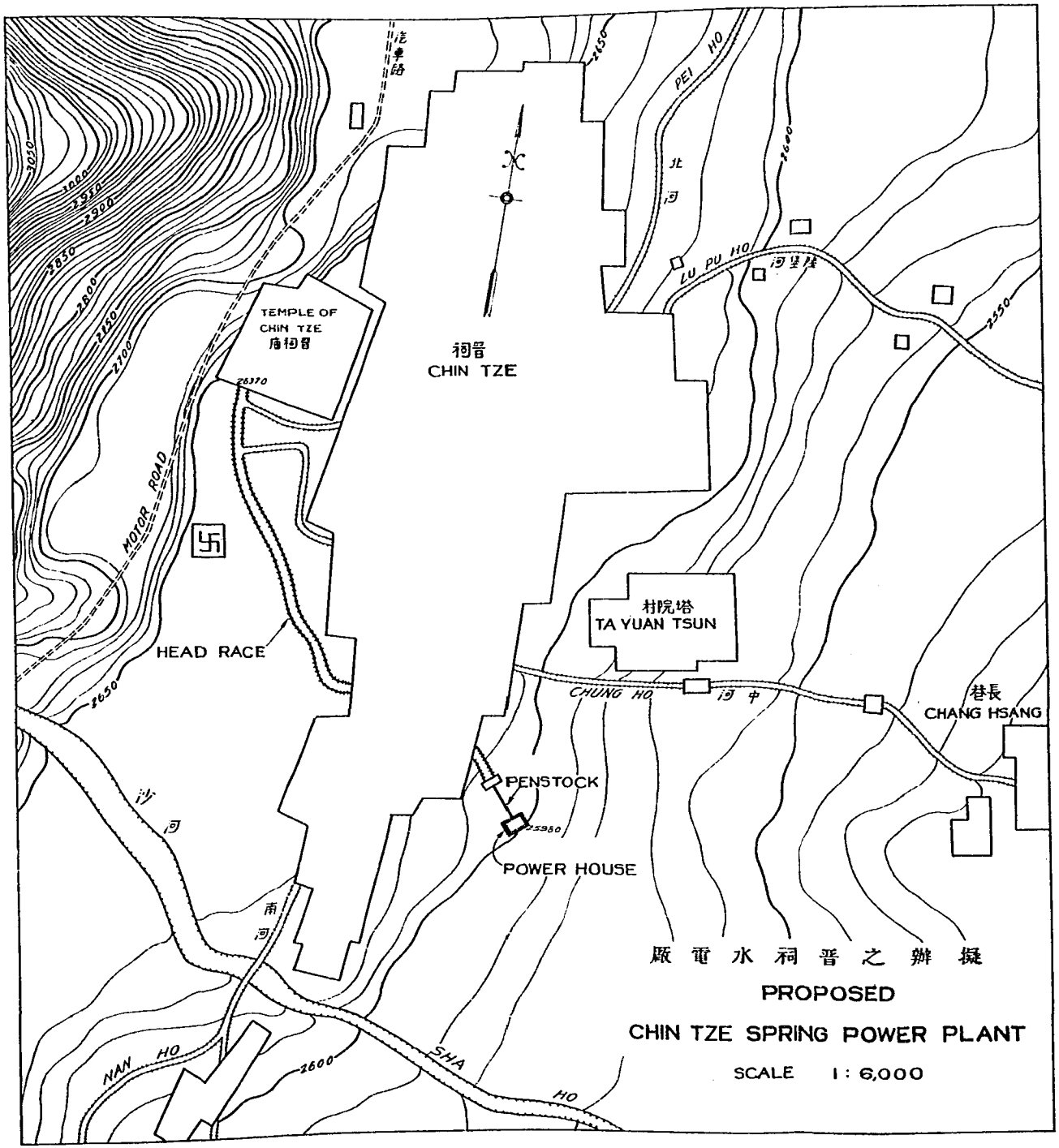


PLATE IX



廠電水祠晉之辦擬

PROPOSED CHIN TZE SPRING POWER PLANT

SCALE 1 : 6,000

(甲)滑機品　五〇、〇〇〇元

(乙)薪金及工資　五〇、〇〇〇元

(丙)修理費　五〇、〇〇〇元

共計　一五〇、〇〇〇元

每年利息按全本六厘計　四二〇、〇〇〇元

每年損廢按全本六厘計　四二〇、〇〇〇元

以上常年經費　九九〇、〇〇〇元

註●每馬力之建築費一百四十二元強

最大之器件重十五噸

設電廠每年工作三百六十五日每日二十四點鐘則每年之總產量爲八千七百六十點鐘每點發電三七●三〇〇瓦共合三二六●七四八●〇〇〇瓦點鐘

設電力完全用之則按閘盤處計算合每瓦點鐘值洋三厘

渦輪機五副及附屬物（重四百五十噸）	四八〇、〇〇〇元
發電機五副及附屬物（重三百噸）	九〇〇、〇〇〇元
轉電機及閘盤二副	二〇〇、〇〇〇元
（庚）機器運費自天津起按每噸二百元	一八〇、〇〇〇元
（辛）電線（長六十英里）	六〇〇、〇〇〇元
以上共	五、〇六〇、〇〇〇元
（二）其他費	
（甲）購地及河岸權	五〇、〇〇〇元
（乙）薪金按用費百分之五計	二五五、五〇〇元
（丙）意外費按用費百分之十五計	七六六、五〇〇元
以上連建築費共	六、一三二、〇〇〇元
加建築期二年之八厘利息	九八一、一二〇元
以上總共	七、一一三、一二〇元
（三）常年經費	

副錄一

壺口瀑布水電廠之用費

（一）建築費

（甲）平陽府至壺口之路工　七〇〇、〇〇〇元

（乙）石壩　一、〇〇〇、〇〇〇元

（一）閘門及閘房　一〇〇、〇〇〇元

（二）水篦及清理機　五〇、〇〇〇元

（丙）靜水池及啟閉機關　五〇、〇〇〇元

（丁）山洞閘門及洩水道　六〇〇、〇〇〇元

（戊）引水管及活塞　一〇〇、〇〇〇元

（己）機器房

（一）下部工程　五〇、〇〇〇元

（二）上部工程　五〇、〇〇〇元

（三）內部設備

此高原之議，其法擬在禹門口，抽水達一百呎，以渠引至河津附近，再設二級抽水站，按地形之高下，抽水灌溉，其最高處，高於河身三百呎，

此地尚未測量，確切之預算，無從依據，但以現有之材料而計算之，則用費約一百萬元，常年之養護費，約三十五萬元，故將來之水租，必須每畝一元而後可，但以棉花之收入將如此之大，即每年每畝出三元之稅，亦可行之事也，

此計劃實可改進河津稷山兩縣之生活狀況，其灌溉區之地價，每畝至少增值十元，農產之增值，每年每畝平均約五元，既得灌溉又可免除旱災，其對於穩固地方之利益亦大矣。

以上三灌田計劃，以壺口瀑布之電力，在禹門口附近抽水，皆有考究之必要，如此次初步之計劃，能見諸實行，則本省歲入之增加，將達數千百萬元，且以地畝及農產價格之增大，將使本地人民於數年內改變其生活狀況，本省西南部之繁榮。亦將因灌溉之發展，而開以前未有之先例也：

益，將達數百萬元，按現時之地圖及壺口廉價之勤力而計，則此計劃乃甚合算之事業也。

禹門口灌溉計劃

此計劃雖小而頗有價值，其灌溉之面積，約一萬六千三百九十畝，在黃河之邊，汾河口之北，地質肥沃，須灌溉以保障五穀之豐收，此地棉花五穀生長均佳，其灌溉之法，擬用電動遠心力之抽水機，由黃河取水，高達一百八十五呎，其一部之地較低，不須抽水，其餘面積，須分二級抽水，第一級八十五呎，第二級一百呎，所抽之水，擬於每十五日將全面積灌溉一週，其每次灌溉之水量，約三吋至四吋深，所用之抽水機及電機等，業經計劃妥當矣。

此計劃之用費，約須一十六萬四千元，開渠用費，當不過二萬元，壺口之電力，費用甚少，約微過於常年經費五萬元百分之五，常年經費者，係指抽水場，利息，折舊，及薪金而言也，此場所需之動力，約計八百馬力，爲保証投資之利益，又以灌域之狹小，故每年之水租，將爲每畝三元，此數雖大，但每年因而所得棉產之值，將達每畝二十元之譜，亦可貴矣。此處地形頗佳，適宜開渠，其費用將亦不大，其主要之費用，爲抽水機，此不可不察也。

龍門渠灌溉計劃

河津稷山兩縣，有良田約三十萬畝，高出汾河之上，須水灌溉，本地人士，有用黃河之水灌

流注，而以入黃河者爲多，由軍用地圖觀之，此地最高處爲萬泉縣，約出於汾河一千呎，西部地形漸低，此項初步之預算除最近由汾河以達萬泉所測之水平線以爲參考外，並無其他最近之地形測量，以爲校準。

此高原之良田，計約三百萬畝，其中約一百萬畝，高於汾河二百五十呎，乃本計劃擬灌之主要區域也，抽水場將設於汾河黃河滙流之處，以本報告所擬辦黃河瀑布之廉價電力而發動之，其水自黃河抽起，所達之高度，按地形之高下而定，固無須共同抽至最高處，而後用也，抽水之高，或須二個以上之連接抽水機以輔助之，其水機之數目大小及位置，須視明年之測量而後定之。

此計劃爲當地人民之所需要，其詳細之計劃及可得之利益，因無適當之地形圖，殊難確定，但以現有之一部材料，亦可將用費及利益估其梗概，照本會工程師之預算與其他工程家所作之預算比較而計之　則按置灌田場，約須洋五十萬元，開渠之費用，將與此數相同，所灌之面積，爲一百萬畝，每年之收入，當爲一百萬元，每年之用費及修理費，約三十五萬元，其中電力之價格，係按兩倍於理論上最低之價格而估算者也。

此計劃之主要利益，將爲增加農產，增值地價，並防止旱災之復現，計河東一地，每年之利

（一）供給晉祠之電燈

（二）發動代替現有水磨之總麵粉廠

除以上之用項外，如晉祠廟及附近所建之花園，皆可用以燃燈，麵粉廠可於晝間工作，夜間停工，爲供給燈火之用。

此計劃之用費，約四萬四千元，每馬力之費用，約合一百七十六元，常年用費及固定費預計八千八百元，若常年工作，電量完全利用，則每毎點鐘之電價，將爲五厘三毫。

必須之測量業經測過，初步之計劃，及一部之詳細工作，亦已竣就，如政府預備興工，而實行其土地收用權，則此水可先導入新河槽，歸擬設電廠之用，而後再改入舊有之三幹渠，仍可用以灌田。

此計劃，將於本地有極顯明之利益，亦且爲他處有水力而廢棄者之先例，按晉祠及晉祠附近富庶之情形，本可自行籌辦，但應由省府發起促成此舉，以免據有不當之水權者高索價格之弊。

河東灌溉計劃

「河東」乃本地之稱謂也，位於汾河之南，黃河之東，其地形爲階級形之高原，其雨水四下

(三)榨花。

(四)榨棉子油，及提煉棉子油

(五)供給二十里以西曲沃城之電燈

預計本計劃約需費一十二萬元，合每馬力三百元，其價格較以前兩計劃高差殊甚，然附近之地土肥沃，地方富庶，此種價格，尚非太高，對此地而言則動力至爲寶貴，計劃雖小，不無投資之價值也。

晉祠水泉水電計劃

此泉在太原縣晉祠鎮內，以其水清而流量不變著名，晉祠廟蓋於其地，數世以來稱爲名勝，北距省城只四十里，有良好之公路以連貫之，泉水出於汾河西之山坡，東流南流灌溉稻穀，至爲寶貴，自水泉至主要之灌溉區，水位下降約四十尺，爲本地水磨所應用，其能力之耗費及效力之低徵，與廣勝寺曲沃兩地殊無二致也。

此計劃在本報告中爲最小，以其位置之關係，頗爲重要，其水量爲每秒七十立方呎，雖僅可發二百五十馬力之電力，仍屬寶貴，且不傷於農家之灌溉，如將現有之小水磨合建一大機廠而代之，則其效率將增大矣，此電力有兩項用途如下，

廠者計，固甚低廉也。

曲沃瀑布水電廠計劃

曲沃瀑布，在沸泉之下，西距曲沃城二十里，附近有白水景明二村，山西南部之一地也，泉水之大小，似由每秒二十立方呎至三十立方呎之譜，本地人民自瀑布之上，開渠引水，據爲己有，用以磨麵粉磨棉子，但其水溜節用不當，或只用其一部，此種情形非獨此地如是，中國各地莫不如是，在本報告各計劃中，此計劃之水勢爲最高而流量最小，據本會地形測量及水紋測量之結果，其可靠之流量，只每秒二十立方呎，水勢之高，爲二百二十三呎，所生之力量，只四百馬力耳。

發展此瀑布之計劃，擬建一小壩，作成一小蓄水庫，每日蓄水十二時，用橙槽及引水管，將水引至「拍爾敦推進式」之渦輪機，而後流入瀑布以下各村之渠道，仍歸灌田之用，與現時灌田之情形將無變動。

本計劃擬發之電可有以下用途，

(一)磨麵粉

(二)紡紗

灌域也，泉之水量，爲每秒一百立方呎，自其高度計之，可供發展電力二千六百馬力之用，惟初期發展，則僅能供一千四百馬力。

泉水下流，分爲幹渠三道，各渠沿岸，均有土人藉其水力以爲推磨之需，其水勢頗低，僅四呎至六呎。自是而下，則供灌田之用，此種磨麵之小石磨，效率頗低，如設磨麵總廠一處，而以水電機所發之動力供其運用，則不特可盡代各小石磨之勢，且其所餘大部之動力，除舉辦各種工業外，尙可供他項用途，如平陽府洪洞趙城各城市電燈之類是也。

至若此電廠附近，除棉廠及磨麵等業而外，更有何種新工業相繼而起，則全在隨機之審度，惟此處既係良好農區，由蔬菜製造罐頭，當易獲利，或用新法織布，亦易發達。

第一期發展一千四百馬力，卽一千伍之電力，須用每秒一百立方呎之水量，其水勢之高，爲一百五十呎，其地點在泉源之西，約八千呎，第二期當俟將來續辦，其所用之水勢將爲八十呎。

發展此項水力之成本，計約十八萬圓，按每馬力計之，約合一百三十圓之數，如每年經費，按四萬圓計算，而一年之內，所產生之電力，盡量售出，則按發電總表計之，每伍鐘點，可售價四厘五毫，此項計劃所需費用，雖較發展黃河瀑布多百分之五十，然爲此地營謀磨房工

十　各種電化工業，如收取空中淡氣，以製(甲)肥料(乙)硝酸及(丙)各種。

此種新動力，既有如許之銷路，則創辦壺口工廠成立後所產出之動力，不出五年，當可全數供用，其重要用途，爲山西西南部擬設之灌田區域，其每年所用僅有數月，故淡氣工廠之設計，或須於非灌田時期，而將灌田之電力收用之也。

總之黃河瀑布水力之發展，實能爲山西南部全境及鄰近區域立一新生活，此項隱蓄之厚力，不當任其廢棄，以成國家之大損失，致蹈以往之故轍，以今日山西之能力，稍得國民政府之輔助，必能利用此動力，以增本省之繁榮，俾境內數百萬居民將受重惠也。

外國專家，考查中國土地者，曾謂山西西南部之氣候土性，特適于植棉之用，農家種棉獲利之大，有非多種穀類所能及者，如灌溉有方，則河東全境北至平陽府等處，殊可得種棉之利，而引水以灌河津萬泉之高原，則須有廉價動力，以資抽水之用，凡抽水，以至紡紗，磨麵，燃燈，及山西此部一切之新事業，皆將有賴于黃河瀑布所賜一部之惠利，此外更可製造各種硝酸鹽，以供肥料之用，尤爲增加農產之要素焉。

廣勝寺水泉水電計劃

廣勝寺水泉位于霍山之麓，山爲灰石質，下距其西洪洞趙城兩縣間之平原甚遙，是即泉水之

最低之數也

利益及用途

凡聞在中國內地舉辦水電事業之議者，每問此種大批動力，將作何用，蓋以在普通各處，必與省費之手工相競爭，而在產煤旺盛之地，尤必與廉價之汽力相角逐也，茲爲解釋羣疑起見，略舉銷路數處，表列于下，

一　禹門口抽水灌田。

二　龍門渠抽水灌田。

三　河東抽水灌田。

四　絳州紡紗廠。

五　附近擬辦各廠及他項工業。

六　附近城市之燈火。

七　潼關市區及鐵路機廠並各種工業。

八　山西南部各煤礦。

九　陝西中部提煉石油。

費用

開發黃河瀑布之成本，照附錄一所列細數計之，殊不爲多，蓋所擬第一步電廠所產出之動力爲五萬馬力，而其成本總額除資本利息未計入外，僅徵過六百萬圓，如借資本以二年爲期，按年息八釐計算，則應加入之利息，約一百萬圓，實則工作進行時所有主要建築之完成，或尙不需二年之久也。

此項設備，如常日盡量工作，估計所發生之電力，傳送六十英里至禹門口一帶，供給抽水或他項工業用途，每瓦鐘點，可售洋三釐，此係按照所產出之動力全數售出計算，實爲營此項事業者所可望最低之售價，其每馬力之成本，即建設費等項，爲一百四十圓有奇。

每年經費計須九十九萬圓，內有資本項下各費，及折舊費，均係按百分之六計算，（見附錄一）購地及領用河道兩項，因瀑布附近及順流而下以至禹門口一帶，居民甚少，故估費甚廉，自東部以達壩址之地，計程一百英里，據本會工程師之測量，約需費七十萬圓，如另由他處勘測估計，則此項或當稍減，洋灰價格照現在之情形估計，如將來山西自設洋灰廠可屆時出灰供給，鐵路運費亦可核減，則預算內所列築壩費一百萬圓，亦可減少，此外應注意者，爲所有各項建設費用，均加算意外消耗百分之十五，在中國此種偏僻區域，照此估計，實屬

計五呎，在中流處最大之高度，爲四十五呎，在河道之東側設船道，以備貨船過攔面免運輸之困難。

建攔地址之石質，經本會地質家詳加考察，據稱地基之質料，爲沃多維珊系水成岩類之灰石及頁岩，距河面稍高之處，其灰石之質轉變而爲含有灰石之沙石，其內質尙未鑿驗，惟自表面觀察，擬建壩址之地層，灰石頗厚，足固定攔基之用。

自地形及比較川度兩方面審察，則導水槽用隧道式較用明溝式爲宜，隧道之截面，約高三十呎，寬五十呎，其長度在四千呎至五千呎之間，須俟詳查石質後定之。水道之速率，約每秒五呎，如水位過高，以水閘爲節制隧道內水量之具，並在導水槽下端設水門二副，以備發力機須停歇時導水歸河之用。

發力機之規制，已經擬定，頗爲詳密，故所具初步費用之預算，亦甚可據，預算內包有水管，機器房，渦輪機，發電機，及電線之類，進水口設備之要略，亦計在內，自平陽府至壺口之道路，亦以數星期之時間測量完竣，以備計算運費之用，另由河津禹門口附近測路一條，以達壺口瀑布，冀獲一運輸省費之路途，綜核本會一程師考察之範圍，頗爲廣博，藉以擬成此項初步計劃，其中各點，或須稍有變更，然已指明發展此項廢棄動力之途徑矣。

經過四千餘呎長之隧道，以至於停水池，再經通水管五條，而入五架渦輪機，終以洩水管，洩其水逕入河內，第一步發展所用之機械，其發動總量須達五萬馬力，約合三七、三〇〇瓦，共須用一萬馬力之機械五副，其渦輪機須具活動之輪葉，雖值洪水時期壩上壩下之水位差減低，仍可以節制之，以保持其最大發電量，此種新式渦輪機，須妥爲規劃，以防水內泥沙太重時，其軸座有損壞之患。

水勢之高度，茲定爲一百呎，實則在低水時期，其高度可得一百二十二呎，高水時期，可得一百零二呎，由高出低水位三十呎之滾水壩所增多之量數亦在其內，如用五萬馬力之發力機，每日工作二十四點鐘，每年三百六十五日，毫無停歇，所發生之動力，計得四三八、〇〇〇、〇〇〇馬力鐘點，卽三二六、七四八、〇〇〇瓦鐘點。

水壩應建于瀑布上六百呎處，微微傾向上流之進水口，俾可令水內之流氷脫離水閘水篦，且可減少進水口內泥沙之量，建壩石料，應用巨石灌以洋灰漿，外面護以佳質混凝土，厚二呎，以防高汛受水內大石塊氷塊之磨損，并在石壩之頂及邊沿處，嵌入鋼條，以爲抵禦氷塊磨損之助力。

石壩頂沿之長，約一千三百呎，附以寬裕之傾水波，以備洪水之宣洩，壩脚深入堅固石基共

即以鎖口最小水量爲計算壺口水量之標準。

茲將所算壺口各水量列下，

最小水量，　一〇、〇〇〇秒呎，　主要力，

平均水量，　三〇、〇〇〇秒呎，　次要力（每年可用八個月

洪水量，　一三〇、〇〇〇秒呎，　無水庫則不能全用，

最大洪水量　三六〇、〇〇〇秒呎，　爲日無多

據本會測量，如在黃河瀑布建一滾水壩，高三十呎，在下游五千呎之處，設立發力機，則所得之水勢，可微過一百呎，此地低水位及高水位兩時期水位相差，約二十呎，初期發展五萬馬力之水力所需之水量，微過於低水之半數，共計算如下。

馬力＝水量×水勢／11

50,000＝水量×100／11

水量＝5,500秒呎

發展方法

發展瀑布方法之大綱，係建一低水勢石質滾水壩，水由壩上流入短距離之明溝式導水槽，復

紗各廠，具待此項動力之發展，以爲紡織之應用，各處城市，亦需此以供燃燈之用．其用途隨處皆是，固無事於遠求，不過數年需要增大，不特各溜水之水力，須爲進一步之經營，行且併由此至禹門口間各奔湍而利用之矣。

水力預算

尋常計劃水電機械者，先以數年之水量，製爲水流期限圖，或流量表，以爲考定主要力及次要力之依據，（主要力，即終年可用之動力，次要力，即每年一定期間可用之動力，）此種圖表，補以機械之動力率，即可約略指明機械之構造功用，及投資之收穫，以前考察黃河之範圍，殊不足供給所需之資料，幸前數年間，本會工程師，曾從事於薩拉齊水渠計劃，彼時本會曾在綏遠鐙口，詳察黃河之水量，此次考察，即以鐙口附近黃河水流期限圖，互相稽核。並以黃河水利委員會最近所得水量，據爲引導，採取各處所得最確之資料，與本會實地勘測相符者，據以擬定計劃，

薩拉齊（即鐙口）水流期限圖所載，民國十九年時雨量較少，至最小水量，爲一萬秒呎，其極小之限度當更較低於此數，惟自鐙口至壺口，約四百英里，路程之間，尚有其他水源，竊意壺口之水，得此項水源，則雖在極旱之年，其最小水量，亦可達一萬秒呎，茲爲確切起見，

近有論發展水力者，謂中國之水力，共有二千萬馬力之多，其大部在長江上游，惟以運輸之不便，竟不能供需各地之利用，若擬發展山陝兩省邊界黃河之水力，尚不及此數百分之一，惟以其應用之多，故其爲益甚大，蓋附近良田既需廉價動力以供灌溉，且可以廉價電力，供給其南六十英里至一百二十五里一帶發展工業也。

以工程事業論之，此項計劃可與歐美非各洲之大事業相競賽，欲求一易行有效之規劃，遂有種種之特殊事件發生其間，即如水內泥沙，冬時結冰，以及河流漲縮之懸絕，皆足使此事益增煩難，最後則有用途一事，亦屬疑問，蓋以此地不特未嘗使用電力，即蒸汽力亦罕用之也。

至於此項事業，其利益之易于普及，且能使中國此部人民之生計繁榮增進，凡研究發展農村者無不知之，所發展之動力，其一部用以增進河東平原以及汾河口附近及稷山河津兩處之農產，此各處農產之增加，不特能使其本地旱灾大爲減少，且能爲鄰近區域甚至遠處各方防灾之助。

此種新動力，除農事之外，尚有多種用途，如收取空中淡氣，以及各種附屬工業，不數年間，均將見之，此類用途，爲利尤大，即陝西中北部煤油區域，亦將因其價廉而大量取用，紡

二　廣勝寺水泉，　一千四百馬力之水電廠。

三　曲沃沸泉，　四百零五馬力之水電廠。

四　晉祠水泉，　二百五十馬力之水電廠

五　河東抽水灌田機　每分鐘排水　二六六、四〇〇、加侖

六　禹門口抽水灌田機　每分鐘排水　八、六二三、加侖

七　龍門渠抽水灌田機　每分鐘排水　一三四、六四〇、加侖

發展黃河瀑布計劃

在中國而言水電事業，其最有價值者殆無過於黃河壺口之瀑布，此地在陝西潼關北一百二十五英里，上下數百里之內，河流於山陝之間，此種事業，應爲兩省共同或政府特許之事業，故於國家頗有關係，所發之電力：固爲兩省所必須，惟其事可由兩省會商，交由山西辦理，由陝西許以黃河兩岸及瀑布附近用地之特權，而將電力之一部，訂立合同，售與陝省。

今所擬發展之水力，僅爲其全量之一部，此地當黃河水位最低時期，可發展五萬馬力之水力，實則此地可發之電力，在最低水位不需汽機之補助，可兩倍于此數，若在其南六十英里山峽之下游河水流近禹門口之處築壩逼水，則更可得五萬馬力經年工作之電廠。

並自壺口測至禹門口及汾河口與汾河測量相聯接，由是遂知禹門口附近黃河峽之下游，更有可以發展水力者。

以本會二十三年間之測量爲依據，曾擬有用最新式渦輪機，利用黃河瀑布，發展五萬馬力之計劃，其水勢之下降，約一百呎，自上端之滾水壩以達所擬工廠之地址，計長不及五千呎，至於詳細條款，已於過去三月中在本會太原分會擬就矣。

此外所考察之水力，計有三處，均係汾河來源之泉水，其規模頗小，然亦足示現今晉省所未盡用及虛糜之水尚有發展之法，其測量事宜，已於民國二十三年由本會測量員執行，至其計劃，亦由所得資料擬就矣。

關於黃河瀑布水力之發展，曾擬有利用此項新動力抽水灌溉河津區內三處田畝之計劃，其內一處之地形，曾經完全測量，其餘二處，則係依據舊有地圖，約略定其高度面積，另測水平線一條，藉以稽核軍用圖之等高線，三處之詳測，尚待舉行，最近數星期間，已由本會工程師根據所得可靠之資料，擬定進行計劃矣。

茲將各次考查所定之計劃綜列於下，

一　黃河瀑布，　五萬馬力之水電廠。

時進行，以永免災荒于異日焉。

考察之經過

晉省大多數之河流，因其雨旱兩季水量懸殊，且泥沙甚重，頗有碍於水電之發展，儲存洪水，則有水庫迅即淤塞之患，殊不可行，故山西多數河流，其僅可選用者，非泉水所注之河，即淺水時期流量較大者也，在汾河沿岸，作大規模電力之發展，似亦難行，蘭村以上山峽之中，雖有良好之壩址，惟以儲水之難，需費頗大，且其淺水期內水量太小，況在此汽機用煤便利價廉之地，以巨款修築石壩，殊難得利，省之西界黃河內瀑布奔湍，曩昔僅見知於舟子，以其險阻難行，故其附近之地，工程家鮮有至者，自山西水利工程委員會成立以來，本省當局，欲詳知此項水力之情狀，乃以著者任其初步調查之事。

著者初到壺口時為民國二十二年四月，同行者為山西大學王錄勳校長，第二次為本年十月，由雅振華（礦師）李茂唐（土木工程師）同往，舉行覆測，並增製瀑布及工廠地址之照片，復乘船至禹門口，視察奔湍，所視察各事，均參加本年初間本會測量隊由地質專家輔助詳測所得，以資詳密。

由平陽府及河津兩處以達壺口之路，亦經勘測，以為將來運送材料機械，謀一最便之途徑，

關於各項計劃之材料，歷經搜覓，殊少可資依據者，據本會所知，山西省內，尚無水電工業之建設，蓋以晉省人力煤炭，價格低廉，足供廉價之動力，故除數百年來所沿用簡陋成法外，鮮有知發展水力者，曾有人擬利用晉祠水泉，試辦水電小工廠，卒以各小水磨房，羣起阻撓，藉其所有財產及水道權，索取重價，其事竟因此而中輟，此數年前事也，竊意此種事業，應由官方擔任之，其有害羣衆公益之營業，概應廢棄。

從事考察壺口瀑布者，民國廿一年之末，曾有二次，其一爲一外國工程師，在其地停留一二日，曾擬有試行發展水力之計劃，其各項預算，即以其旅行測量所得者爲依據，又一次爲地質調查所之二少年，居其地月餘，曾在附近測其地形，此兩次考察均甚粗略，惟其所供之資料，足爲稽核本會工程師詳察結果之一助。

茲以山西水利工程委員會之設施，係純爲供給民食，提高生計，故本報告之目的，即在以所擬各項計劃之利益，引起中外人士之注意，其主旨不在防災，而在利用水力，以期多灌良田，增加棉穀之產量，兼以發展地方工業，俾其成本可與省外各處之貨相競爭，其結果能令中國此部煥然更新，而一變其境內生活之狀態，即以防災而論，此各項計劃，亦與汾河水庫之存儲冬水春日灌田者同爲重要，特人少注意之耳，此二事之關係晉省者既如此其大，似應同

晉省水電測量報告

山西省內之水力，頗有可發展者，茲特將各主要水力測量之結果，加以探討，具此簡括報告，以示概略，其要旨，係在以廉價之動力，供給晉省西南部河東境內抽水灌溉高原，及汾河沿岸發展工業之用，故不涉及全省，本報告之主要事件，爲利用本省西界著名之黃河壺口瀑布之水力，其餘三項水力事業，則遠遜之，然所具各項預算，亦足資晉省主張大興水電工業者之參考焉。

數百年來，中國多數河流陡急之處，常有藉水力磨製麵粉香麵者，惟其設備僅係平置木輪，貫以直立木軸，以接於高距數尺水磨房內之石磨，故效率頗小，其水之懸勢，大率自四尺以至八尺，凡旅行石家莊太原之間者，即可見冶河沿岸，設有此種水磨甚多，晉祠水泉，廣勝寺水泉，及曲沃瀑布之下游，亦多有之，所用之水，來自水溝，即灌田所用之總渠也。

此種舊式水輪，固有其功用，且亦爲現代水電機所用鋼製渦輪機之先導，惟據本會近日調查，則其糜費之多，在中國與他國殊無二致也，畜牧造林，本有「務盡地利」之原則，利用流水，自應援據此理，此本會所以建議盡量利用晉祠廣勝寺曲沃等處之水力也。

山西水利工程委員會徐委員長勛鑒：自

貴會商請中國華洋義賑救災總會担任測量工作。僕謬承委託，任總工程師之職。曾囑測查山西水電事業，即以原在汾河之工作員司，進行工作，而於黃河之壺口瀑布，特加詳細。茲以測查之結果，在華洋義賑救災總會，聘有經驗之員司，助理彙編。僅此報告，幸祈

垂察

總工程師塔德謹啟　二十三年十一月

山西省水利工程委員會出版

（所有測繪計算等工作悉由中國華洋義賑救災總會指導實施）

開發黃河瀑布及晉南晉中各處水力用以灌田及發展工業之初步計劃

二十三年十一月刊行

晉省水電測量及初步計劃報告