RECONNAISSANCE REPORT
ON
RESERVOIR SITES
IN
TAIWAN

Vol. I

(North & Central Taiwan)

Edited & Printed
By
Joint Commission on Rural Reconstruction
November, 1957

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Preface

The reconnaissance survey covered in this report was financed by the Joint Commission on Rural Reconstruction (JCRR) with a grant of NT$298,072.70 and US$1,513.33. This covered all expenses except for the salaries of the Taiwan Power Company engineers and the Taiwan Water Conservancy Bureau engineers who respectively carried on the work for North and East Taiwan and for Central and South Taiwan. The field work was performed between January 2, 1953 and January 31, 1954. The rather voluminous report was prepared by the party chiefs following the completion of the field work. Preparation of this condensed report in English was made by JCRR engineers.

The 92 reservoir projects investigated have been arranged in the report by river basins. A general description of the river basin and data precedes the reservoir project presentation. Sources of data and their locations have been indicated herein.

All known reservoir sites, both existing and proposed are included. Any known modification to the Reconnaissance Party's report have been included in the editing remarks.

The original information or opinions of each party has been retained although they may not coincide with those of the editing staff.

The area each reconnaissance party covered, date of field work; the party personnel are:

Reconnaissance Party	District	Field Work	Personnel
1	North Taiwan	3 months, from Feb. 2, 1953 to April 30, 1953	Shi-shan Lee, Chief Ching-chang Lai Chin-yu Chen Han-tsing Peng
2	Central Taiwan	3 months, from Jan. 2, to March 31, 1953	Te-pei Chin, Chief Sze-chun Lee Kwan-feng Lin, Jung-pin Chu
3	South Taiwan	3 months, from July 1, 1953 to Sept. 30, 1953	Te-pei Chin, Chief Sze-chun Lee Kwang-feng Lin Jung-pin Chu
4	East Taiwan	3 months, from Nov. 1, 1953 to Jan. 31, 1954	Shi-shan Lee, Chief Tsung-chow Chang Chin-yu Chen Ting-mao Wang

An index has been prepared, in which reservoir sites are arranged both alphabetically and according to their containing prefectures. English translations of Chinese geographic names have also been listed in alphabetical order.

November 1957

T. R. Smith, Chief
Irrigation & Engineering Division
JCRR

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List of Reservoirs Arranged Alphabetically

NORTH TAIWAN

Name of Reservoir	Series No.	Location			Function
		Hsien	Tributary	Main Creek	
Chih-hu	16	Miao-li	Lao-tien-liao Chi	Hou-lung Chi	Irrigation
Ching-tsao-hu	12	Hsin-chu	—	Ke-ya Chi	Irrigation & Scenery
Cho-lan	21	Miao-li	—	Ta-an Chi	Irrigation & Power
Chu-keng	2	Tai-pei	Pei-shih Chi	Tan-shui River	Multiple purpose
Ha-pen	3	Tai-pei	Nan-shih Chi	Tan-shui River	Power
Hsiang-pi	19	Miao-li	—	Ta-an Chi	Multiple purpose
Hsi-ho	14	Miao-li	O-mei Chi	Chung-kang Chi	Irrigation
Kwei-chu-lin	18	Miao-li	—	Hou-lung Chi	Irrigation
La-hao	5	Tai-pei	Nan-shih Chi	Tan-shui River	Power & Flood Control
Li-mao-kan	4	Tai-pei	Nan-shih Chi	Tan-shui River	Multiple purpose
Li-yu-tan	22	Miao-li	To-lo-ku Chi	Ta-an Chi	Irrigation
Mai-fu-ping	20	Tai-chung	—	Ta-an Chi	Multiple purpose
Ming-tch	17	Miao-li	Lao-tien-liao Chi	Hou-lung Chi	Irrigation
Nuan-nuan	1	Kee-lung C.	Kee-lung River	Tan-shui River	Water Supply
San-chu-hu	15	Miao-li	O-mei Chi	Chung-kang Chi	Irrigation
Sha-hu-li	11	Hsin-chu	Unknown	Tou-chien Chi	Irrigation
Shang-ping	10	Hsin-chu	—	Tou-chien Chi	Multiple purpose
Shih-men	8	Tao-yuan	Ta-ko-kan Chi	Tan-shui River	Multiple purpose
Shuang-chi	6	Tai-pei	Shuang Chi	Tan-shui River	Water Supply
Ta-chien	23	Tai-chung	—	Ta-chia Chi	Multiple purpose
Tao-shan	9	Hsin-chu	—	Tou-chien Chi	Multiple purpose
Ta-pu	13	Miao-li	O-mei Chi	Chung-kang Chi	Irrigation
Tien-leng	24	Tai-chung	—	Ta-chia Chi	Irrigation
Wu-lai	7	Hsin-chu	Ta-ko-kan Chi	Tan-shui River	Power

CENTRAL TAIWAN

Name of Reservoir	Series No.	Location			Function
		Hsien	Tributary	Main Creek	
Chi-chi	37	Nan-tou	—	Cho-shui Chi	Multiple purpose
Ching-shui-chi	38	Nan-tou	Ching-shui Chi	Cho-shui Chi	Multiple purpose
Li-yu-ku	28	Nan-tou	Mei Chi	Wu Chi	Irrigation
Lung-shen-chiao(Cho-shui)	36	Nan-tou	—	Cho-shui Chi	Multiple purpose
Ma-hsi-to-pang	25	Nan-tou	Pei-kang Chi	Wu Chi	Power
Nan-kang-chi	29	Nan-tou	Nan-kang Chi	Wu Chi	Irrigation & Power
Pei-kang-chi	27	Nan-tou	Pei-kang Chi	Wu Chi	Multiple purpose
Pu-li	30	Nan-tou	Nan-kang Chi	Wu Chi	Power
Shih-kang	26	Nan-tou	Nan-kang Chi	Wu Chi	Power
Sun-moon Lake (Jih-yueh-tan)	35	Nan-tou	Hsin-shih Chi	Cho-shui Chi	Power
Ta-keng	33	Tai-chung	Ta-keng Chi	Wu Chi	Irrigation
Tou-pien-nan-keng	32	Tai-chung	Tou-pien-keng Chi	Wu Chi	Irrigation
Wu-chi	31	Nan-tou	—	Wu Chi	Multiple purpose
Wu-she	34	Nan-tou	Wu-she Chi	Wu Chi	Power

List of Reservoirs Arranged in Various Prefectures

NORTH & CENTRAL TAIWAN

Nau-tou Hsien

Tan-shui River Basin

General Description

The Tan-shui river is the largest in North Tai-wan. It originates from the northern part of the Central Range. Below the confluence at Tai-pei of the three tributaries, Kee-lung River, Hsin-tien Chi, and Ta-ko-kan Chi, it is called Tan-shui River. It has a total drainage area of 2,705 sq. km, a length of 144 km, and an average slope of about 1/56.

Some hydrological stations were established, but the records were incomplete. Some of them had only one or two years of record and discharges were recorded only in low stages.

The location of the gaging stations and hydrological stations are shown in Fig. 1 and Fig. 2.

There is now available only scanty data concerning geology of dam sites. It is contemplated that a minimum of 6 or 8 diamond drill holes will be required. The holes should be drilled to a depth equal to 60% of the height of the dam.

Flood Control

According to the Japanese plan, the total length of dikes along Tan-shui is 85,890 m. The designed floods at Shih-men, Tai-pei Bridge, and Kwan-tu were 6,800 cms, 11,300 cms and 12,500 cms, respectively. The designed slopes at Shih-men, Ta-ko-kan Railway Bridge, and Tai-pei Bridge were 1/200, 1/1200 and 1/4,000 respectively. ~~The designed width~~ between dikes at Shih-men, Ta-ko-kan Railway Bridge, Tai-pei Bridge, and the river mouth was 200m, 700m, 900m, and 1,300m respectively. The top width of the dike is 3m for stone section and 5.5m for earth section. The free board is 1.8m for stone section and 1.6m for earth section. The side slopes are all 1:2. A total of 12 spur dikes of either wire cylinders or concrete blocks were planned. For lack of fund, only 18% or 15,371m of the river work was completed.

Irrigation

The irrigation in this basin was developed to a great extent. Some of the present important canals were ~~built~~ two hundred years ago.

In this Basin there are five hydraulic associations administering a total irrigated area of 32,363 ha.

According to the reconnaissance survey, the duty of water is about 800 ha. per cms. The maximum is 1,000 ha in the Ta-ko-kan Chi basin and Tao-yuan Canal system. The return flow in the creeks is revised for irrigation by a series of diversion weirs. There are many ponds, the area of which is about one tenth of the whole area. The regulation of the ponds help reduce the waste and thereby increase the duty. In the Hsin-tien basin, the duty of water is as low as 323 ha. per cms.

During low stages of the river, the discharge is less than that required and water disputes occur. Such is the case of the irrigation systems along the Ta-ko-kan Chi. To settle disputes, the government uses to limit the intake of each system by proportion of the irrigated area. Rotational irrigation method is also used to minimize the difficulty.

The irrigation in Chung-li and Hu-kow area is incomplete due to lack of definite water resource. After completion of the Shih-men Reservoir project, most part of the region may become double cropping field.

It is possible that some area along the Ta-ko-kan such as Hai-shan District could be irrigated by sources from the Hsin-tien Chi, thus leaving a larger supply from the Ta-ko-kan to irrigate the Chung-li and Hu-kow area.

Too many ponds were built in Tao-yuan and Chung-li. Some are 2 - 3 m deep. Some have a depth of less than one meter. It is suggested that small ones be reclaimed and large ones be improved. This is to increase the capacity and reduce the loss.

A combination of these hydraulic associations would help greatly reduce the water disputes.

Power Development

The first hydro-electrical power plant was the 600 kw plant installed in 1903 at Kwei-shan near Tai-pei. This plant is not functi ning. The newly completed plant in this basin is the 2-unit plant at Wu-lai. The first 11,250 kw unit was installed in 1950 and the second unit in 1953. At present, there are three hydro-electric plants as follows:

Hydro-electric Power Plants in Tan-shui Basin

Plant	Source of water	Head (m) Max.	Head (m) Min.	Q (cms) Max.	Q (cms) Ave.	Q (cms) Min.	Installed Capacity (kw)
Wu-lai	Nan-shih Chi	93.4	91.8	29.0	-	11.0	22,500
Hsin-kwei-shan	Nan-shih Chi	54.95	54.04	29.0	26.3	11.0	13,000
Hsiao-tsu-keng	Hsin-tien Chi	22.6	16.97	27.08	-	20.93	4,400

In the northern part of Tai-wan, the plentiful rainfall in the winter increases the river flow. Thus the fluctuation of power output is less in North Tai-wan than in other places. A large portion of the mountainous region is covered with forest. Generally speaking, the condition of the forests is quite good.

The Hsin-tien Chi possesses the best characteristics in Tai-wan for hydro-electric power generation. The flood peaks are not too high, and the minimum discharge is not very low. The silt problem is not serious. The watershed area is well covered. The rainfall in the winter is abundant. The transmission distance to the load center is short. All these factors are the reasons why the existing plants are along the Hsin-tien basin.

In the Hsin-tien basin, three reservoirs were proposed, Chu-keng Reservoir on Pei-shih Chi and Ha-pen Reservoir and Li-mo-kan Reservoir on Nan-shih Chi. After the completion of the reservoirs the existing plants would also be benefited and the amount of firm power would be increased.

The proposed Shih-men Dam is situated on the lower Ta-ko-kan. is a multiple purpose project.

There may be a reservoir site near Wu-lai. The reservoir elevation of this site is about 800 m above sea level. The usable head below the reservoir is about 650 m.

Other Developments

Steep slopes of the river make it impossible to have any inland navigation development by canalization. After completion of storage reservoirs the flood peaks would be reduced. The cross sections of the river in the lower stretch may also be reduced. It is estimated that at least 500 ha may be reclaimable. Beautiful scenic spots are found at a number of places in the basin. The headwater regions are truly beautiful. Serious considerations should be given to development of such regions for recreational uses. The culture of fishes in the Tao-yuan ponds is another possibility.

Summary

1. Water Resources

The rainfall stations in this basin are uniformly distributed as shown in Fig. 1. Some stations were established in 1897. The average rainfall in the basin is 3,100 mm, that at Hwo-shao-liao is 6,570 mm and that in the Central Range is about 3,000 - 4,000 mm.

The hydrological data is not sufficiently systematic and most records are found incomplete. Some have only one to four years of record.

Some stations, though equipped with self-recording gage, were suspended for lack of fund.

The proposed stations are shown in Fig. 2. All these stations should be of the self-recording type and the rating curves should be constructed by actual gaging at various river stages, including floods. The rating curves should be checked from time to time.

For rough estimate the following data may be used:

Area of the basin . . . . 2,705 Km^2
Average annual rainfall . . . . 3,100 mm
Coefficient of runoff 0.80

Then the available average discharge of the river is roughly estimated to be 213 cms. $\left(\frac{3.1 \times 2705 \times 1000^2 \times 0.8}{365 \times 86400}\right)$

2. Feasibility and Priority of Projects

Name of Project	Purpose	Feasibility	Priority
Nuan-nuan	Water supply	Completed	
Chu-keng	Multiple use	Feasible	A
Ha-pen		B/C = 1.6	A
Li-mo-kan		Feasible	B
La-hao		Further study	B
Shuang-Chi		Under construction	
Wu-lai		B/C = 1.1	B
Shih-men		Feasible	A

3. Multiple Uses

It seems more advantageous to develop water power together with flood control and irrigation. It is true that multiple projects would take longer period of time and larger sum of money, so large projects may not be started at once. But hydrological, topographical and geological surveys for comprehensive planning is urgently in need and strongly recommended.

Nuan-nuan Reservoir (No. 1)

General Description

The Nuan-nuan Reservoir, located on a branch of the Kee-lung River, was built by the Japanese for the water supply of the Kee-lung City. Above the reservoir the watershed area is covered with dense forest, and is very little cultivated. The geologic formation of the dam site is thick compact strata of sandstone.

There are four coal mines. Two adit tunnels are contiguous with the reservoir.

There had been a plan of elevating the dam another five meters but was not realized.

Engineering Features

1. Dam

Type	Concrete Gravity
Maximum height	26.26 m
Top width	2.3 m
Base width	21.8 m
Top length	131.0 m
Concrete volume	19,500 m^3

2. Reservoir

Watershed	6.5 sq. km
Reservoir Area	85,300 M^2
Maximum drawdown	12.5 m
Total storage capacity	576,197 m^3
Effective storage capacity	542,000 m^3

3. Spillway

Spillway length	45.5 m
Designed capacity	No data

Chu-keng Reservoir (No. 2)

General Description

The proposed reservoir is on Pei-shih Chi, one of the two tributaries of Hsin-tien Chi. It has an average ~~slope of 1/200.~~ It drains 310 sq. km. of mountainous region well covered with forest. The basin is about 30 km in length and 15 km in its widest breadth. Within the reservoir area, only 0.3 sq. km will be paddy fields. In the basin, Ping-lin is the only town with a population of 7,700. The most important product in the basin is timber. Rice comes next. Tobacco and tea are insignificant.

The geologic formation at the dam site is sandstone striking N 55° - 60° E and dipping 32° - 35° toward the right bank. The river bed here has a slope of 1 in 220.

The flood area of the reservoir will cover five villages with a total number of 82 houses, 93 families and 750 people. In addition, 80.7 ha. of paddy field, 1.3 ha. of dry farming land, 12.5 ha. of tea farm, and 26.7 ha. of forest land will be also covered.

Concrete aggregates are available in the region from the dam site to Hwo-shro-liao.

There are small land slides within the reservoir area and in the watershed upstream from the reservoir.

Engineering Features

1. Dam

Type: Straight gravity concrete dam with overflow spillway

Maximum height of spillway section	73 m
Width of dam at base: Excluding apron	84.7 m
with apron	110.0 m
Length of dam at crest	150 m
Clear crest legnth of spillway	80 m
Designed spillway capacity	4,000 cms
Concrete volume	240,000 cu.m.
Movable gates	8 - 10 X 7.2 m radial gates

2. Reservoir

Watershed	258 sq. km

Reservoir area . . . . 4.13 sq. km

Max. drawdown . . . . 28.6 m

Total storage capacity . . . . 111×10^6 cu. m.

Effective storage capacity . . . . 81×10^6 cu. m.

3. Intake

Type: Reinforced concrete vertical shaft attached to the dam.

Gate: One vertical lift caterpillar gate.

4. Penstock

	Diameter	Length
Main	6.0	260
Branch	3.0	30 - 50 m

5. Powerhouse

Type: Indoor type, reinforced concrete structure

Turbine: 4 vertical Francis turbines @ 36,600 hp.

Generator: 4 units each rated at 29,500 kva
(26,500 kw with p.f. of 0.9), 3 phase, 60 cycle

Cost Estimate:

According to the cost estimate made by the Taiwan Power Company in 1952, the total project cost amounted to NT$313,000,000 (or US$20,100,000) of which 170 million is local currency. The cost consists of the following items:

	NT$	US$
Dam	86,500,000	
Spillway gates and hoists	10,800,000	
Intake	10,500,000	
Waterway	1,500,000	590,000
Mechanical and Electrical Equipment, Sending and receiving stations, Transmission line		6,973,700
Power house	8,200,000	
Highway	6,480,000	
Earth dam at saddle	5,000	

Flood damage and right of way	3,730,000	
Total field construction cost:	127,715,000	7,563,700
Indirect cost (10%)	12,770,000	
	140,485,000	
Contingencies (10%)	14,050,000	756,300
	154,535,000	8,320,000
Overhead and interest	15,450,000	832,000
Total construction cost	169,985,000	9,152,000
Total equivalent cost	NT$312,875,000	

Benefit

The proposed Chu-keng Reservoir is mainly for power development. There will be minor benefits for flood control, irrigation, and water supply.

The maximum flood discharge was estimated to be 4,000 cms and the maximum flood discharge on record at the dam site was 1,610 cms. The storage capacity will not be large enough for a flood of 4,000 cms but for a flood of 1,610 cms a large percent of reduction can be expected.

After reservoir regulation, there will be a flow of 20 cms in the dry season. With this increase of dry season flow, there will be dependable supply for the irrigation of the existing 3,300 hectares.

For power generation, the proposed installation is 106,000 kw. With a maximum drawdown of 28.6 m., and a daily peaking period of 3 hours, the dependable peaking capacity will be 73,000 kw. In an average year, the firm energy output is estimated at about 80 million kwh and the secondary energy output, 28 million kwh.

The water supply of the Tai-pei City can be provided from this project provided that a conservation pool is constructed.

Ha-pen Reservoir (No. 3)

General Description

This proposed reservoir is on Nan-shih Chi and drains a water-shed of 52.7 sq. km above it. The riverbed has a slope of 1/50 at the dam site. The rock is hard massive slate, about five meters thick, stricking N45° - 50° E and dipping 35° toward the upstream.

The whole watershed is mountainous and is densely covered with forest. The valley is deep and steep.

Engineering Features

1. Dam

Type	Gravity Concrete
Maximum height	62 m
Top width	4 m
Base width	52 m
Top length	108 m
Concrete volume	75,000 m^3

2. Reservoir

Watershed	52.7 sq. km
Reservoir Area	640,000 M^2
Maximum drawdown	36 m
Total storage capacity	$15.48 \times 10^6 M^3$
Effective storage capacity	$14.1 \times 10^6 M^3$

3. Spillway

Crest elevation	542.6 m
Spillway length	145 m
Designed spillway capacity	470 cms

Economic Analysis

The cost estimate, in 1940, of the project was ¥2,327,000 of Japanese Currency, equivalent to US$1,670,000 in 1953.

The river discharges at the dam site are estimated as follows:

Duration	100%	90%	70%	50%	30%	20%	10%
Discharge (cms)	1.6	2.6	3.5	4.8	6.8	8.3	10.8

The minimum regulated flow is 4.09 cms, the maximum usable flow is limited to 7.05 cms with an average of 5.3 cms.

There will be six plants, of which Wu-lai, Hsin-kwei-shan, and Hsiao-tsu-keng are already completed, benefited by the Ha-pen Reservoir. The completion of this project will bring about an additional firm energy amounting to 67,300,000 kwh among the six plants with a decrease of secondary energy of 41,000,000 kwh.

The annual cost is estimated to be 10% of the capital investment, or US$167,000. The annual benefit is calculated to be US$267,000 assuming six and three mills for each kwh of firm and secondary energy respectively, and deducting 5% for energy loss. This would result in a benefit to cost ratio of 1.6.

Li-mo-kan Reservoir (No. 4)

General Description

The proposed Li-mo-kan reservoir is below the junction of three small branches on the headwater of Nan-shih Chi. The dam site is about 15 km. above Wu-lai.

The whole region is steep and mountainous, and is densely covered by forests. The slope from the origin to Li-mo-kan is 1/10 - 1/50. The area is extensively covered by sandstone, black shale and slate. The rock at the dam site is hard slate, about 5 m. thick, striking N45° - 50° E and dipping 32° toward the upstream. No data are available about the investigation made during the Japanese occupation.

The silt problem is believed not serious since soil erosion and sedimentation are not prominent in this area.

Available Data

1. River Flow

A gaging station was established at Li-mo-kan by the Taiwan Power Company. Records during 1937 - 1945 are available. The minimum flow occured in March 1940 was 5.12 cms. The average flow in an average year is 20.5 cms and is 15.2 cms in a dry year. The Maximum flood at Li-mo-kan is estimated to be 1,500 cms.

2. Meteorological Data

33 years' records of rain fall and 10 years' records of average temperature are available from the Water Conservancy Bureau. The maximum, average and minimum temperatures are 28.7°C, 21.6°C and 11.3°C respectively. The average yearly evaporation is estimated to be 700 mm. The maximum, average and minimum yearly precipitations at Li-mo-kan are 4,530.6 mm, 2,955.8 mm, and 1,246.8 mm. respectively.

Engineering Features

1. Dam

Type	Concrete gravity
Maximum height	130 m
Top width	5 m
Base width	95 m
Top length	300 m
Concrete volume	650,000 m^3

2. Reservoir

Watershed . . . . 165 sq. km.

Reservoir area . . . . 2.93 sq. km.

Maximum drawdown . . . . 70 m

Total storage capacity . . . . . . $137.3 \times 10^6 m^3$

Effective storage capacity . . . . $117 \times 10^6 m^3$

Flood: 60 families, 300 people, 9 ha. of paddy, 4.6 ha. of dry land, 5 ha. of bamboo, 6.5 ha. of forest

3. Spillway

Crest elevation . . . . 480 m

Length . . . . 50 m

Design spillway capacity . . . . . 1,500 cms

Cost

The construction cost of this project is estimated to be about US$15,000,000 on 1953 basis.

Benefit

1. Power

The total head below the reservoir is about 400 m., of which 170 m have already been used by the three completed plants, namely, Wu-lai, Hsin-kwei-shan, and Hsiao-tsu-keng. The Nan-shih Project is under planning. The total installed capacity of the four plants is about 60,000 kw. The firm power totals 24,900 kw only. By regulation of the Li-mo-kan Reservoir. The firm power of the four plants could be doubled. The total energy output would also be increased.

2. Flood Control

The reservoir will hold about one fifth of the yearly inflow. The effective depth was designated from the elevation 480 m. to 410 m. A reduction of the flood to a large percentage can be expected.

3. Irrigation

By proper operation of the reservoir, a minimum flow of 20 cms in the dry season would be expected. With this increased flow, the lower irrigation could be appreciably benefited. Moreover, this water may be diverted to Hai-shan and Hsin-chuang district to improve the existing irrigation systems.

4. Water Supply

The Tai-pei City water supply is in bad need of additional water. The completion of this reservoir would solve the water supply problem of Tai-pei, since the minimum flow of the river would be greatly increased.

La-hao Reservoir (No. 5)

General Description

The proposed La-hao Reservoir is on Nan-shih Chi of the Hsin-tien Chi. The dam site is about 30 kilometers south of Tai-pei. The rock is of massive slate, over 5 meters in thickness, with a strike of N40°W and a dip of 72°-75°. The riverbed at the dam site has a slope of 1 in 60. Small amounts of gravel around 5 centimeters in diameter can be found.

There is an existing road highway leading from Wu-lai to Lao-hao. Power Transmission lines are available. The reservoir will flood about 2 hectares of dry farm land, and about 6 hectares of tea farm, waste land and forest area.

Engineering Features

1. Dam

Type	Concrete gravity
Maximum height	140 meters
Top width	5 meters
Base width	101 meters
Top length	150 meters
Concrete volume	400,000 m^3

2. Reservoir

Watershed	210 sq. km.
Reservoir Area	1.96 sq. km.
Maxmimum Drawdown	80 meters
Total Storage Capacity	100 x 10^6 m^3
Effective Storage Capacity	90 x 10^6 m^3

3. Spillway

Crest elevation	350 meters
Length of spillway	150 meters
Design spillway discharge	1,700 cms

Cost and Benefit

The total construction cost on 1953 basis of the project is estimated at US$12,500,000.

The benefit for power is large. Three power plants below the servoir would be generating more power both firm and peaking. The three plants use a total head of 170 meters and have a total installed capacity of 39,900 KW.

The flood control for the recorded flood would be effective.

Shuang-chi Reservoir (No. 6)

General Description

The purpose of this project is to increase the water supply for Tai-pei City. A stone masonry dam with a maximum height of 22.9 meters and a top length of 181 meters was planned to be built across Shuang Chi, a small tributary of Kee-lung River. At the dam site, the rock is composed of thick alternate layers of fine grained sand stone and dark gray sandy shale. The reservoir will flood 4.58 hectares of land of which 3.36 hectares are paddy field.

The drainage area above the dam site is 16.5 sq. km. The general river bed slope at the dam site is about 1/100. Stream flow data for eight months are available. The estimated maximum flow is 263 cms. The minimum flow is 0.47 cms. The maximum, minimum, and average yearly rainfall are 3,171.4 mm., 1,503.9 mm. and 2,103 mm. respectively.

The capacity of Tai-pei City Water Supply has been repeatedly extended as follows:

Original capacity . . . . 23,962 m^3/day

In 1946, by additional installation of 1-100 H.P. pump, capacity raised to . . . . 27,188 m^3/day

In 1949, by addition of another 100 H.P. pump, capacity raised to . . . . 31,634 m^3/day

In 1952, by installation of rapid filters, capacity raised to . . . . 63,134 m^3/day

Two other sources at Tsao-shan and Wan-hwa offer daily amount of 28,844 m^3 and 5,000 m^3 respectively. The total capacity from the three sources is 96,978 m^3 per day and the effective capacity is 85,478 m^3 per day. However, the required capacity was estimated to be 103,179.5 m^3, and a capacity of 17,701.5 m^3 is urgently needed.

Engineering Features

1. Dam

Type	Stone masonry gravity dam
Maximum height	22.9 meters
Top width	2.74 meters
Base width	16 meters
Top length	181 meters
Volume	65,000 m^3

2. Reservoir

Watershed	16.5 sq. km
Reservoir Area	72,000 M^2
Maximum drawdown	19.27 meters
Effective storage capacity	1,040,000 m^3

3. Spillway

Crest elevation	126.57 meters
Design spillway discharge	263 cms

Pipe line

Length of reinforced concrete pipe	3,545 meters
Length of cast iron pipe	3,116 meters
Diameter of pipe	0.6 meter
Capacity	44,000 m^3/day

5. Water works

Dividing well: 4.6 meters in diameter, 4 meters deep

Settling basin: 2 units @ 45 x 30 x 5 meters,
Total capacity 12,500 m^3

Filter bed: 8 compartments @ 60 x 24 x 2.82 m

Filter well: 2.5 meters in diameter, 4 meters deep

Collecting well: 6 meters in diameter, 4.5 meters deep

6. Estimate

The estimate made by the Construction Office of Tai-pei City Government was NT$9,890,000. After completion of the project, an increase of 40,000 m^3 is expected. This would bring the total capacity of the three sources to 125,478 m^3, which may supply the need at the end of 1957.

Wu-lai Reservoir (No. 7)

General Description

This proposed project is for hydro-electric power development. The rock at the dam site is hard, massive sand stone. The two sides of the valley are steep. The river bed slope at the dam site is about 1/80. There are three years of river flow record, with a minimum of 2.79 cms. The flow is relatively uniform and the water is usually clear. The watershed is well covered with forest. The proposed dam site is near the Wu-lai Police Office.

Engineering Features

1. Dam

Type	Concrete Gravity
Maximum height	66 meters
Top length	103.5 meters
Concrete Volume	83,000 m^3

2. Reservoir

Watershed	308 km^2
Reservoir Area	1.44 km^2
Maximum Drawdown	25 meters
Total Storage Capacity	39,500,000 m^3
Effective Storage Capacity	27,200,000 m^3

3. Spillway

Crest elevation	860 meters
Length	88 meters
Design Capacity	2,860 cms.

4. Power Plant

Total maximum available head (860 - 280)	580 meters
Total effective head	500 meters
Total installed capacity	75,000 KW
Firm power	29,100 KW
Average power	58,750 KW
Total energy output	515,000,000 KWH
Firm energy output	255,000,000 KWH

5. Estimate

The estimate made by Japanese engineers in 1935 was ¥20,000,000 of Japanese Currency. Reduced to 1953 basis it amounts to US$17,500,000. Transmission lines and substations cost about US$2,500,000. The total cost would be about US$20,000,000.

According to the study made by the Japanese, the minimum regulated flow would be 6.97 cms. If the maximum usable flow were limited to 15 cms, the average flow to be used would be 12.2 cms.

The annual cost and annual benefit are estimated as follows:

Total cost estimate	US$ 20,000,000
Annual cost at 10%	US$ 2,000,000
Income from firm energy 255 x 10^6 x 0.006 =	US$1,530,000
Income from Secondary energy 260 x 10^6 x 0.003 =	US$780,000
	US$2,310,000
loss (5%)	115,000
Annual benefit . . .	US$2,195,000

Benefit cost ratio = $\frac{2,195,000}{2,000,000}$ = 1:1

Shih-men Reservoir (No. 8)

(Note: The report here made by the Reconnaissance Party in July 1953 gave all planning features up to that time. The definite planning report as finally adopted is also given at the end of the report under the heading "Definite Plan" for reference).

General Description

The Shih-men dam site is on Ta-ko-kan Chi, the largest branch of the Tan-shui River. The headwater originates from the Central Range at an elevation higher than the 3,500 meters. The watershed above the dam site is about 764 km^2 and the average river slope is 1/170. The rock at the dam site is massive sand stone with a dip of $60^o - 70^o$ and a strike of N 75^oE. The Hsin-tien Fault is located downstream from the dam site.

The planning work was started by the Japanese in 1924. The main purpose was for irrigation of the table land above the Tao-yuan Canal. In order to irrigate the land above elevation 220 meters, a 160-m dam was planned.

The created reservoir would flood ten villages occupied by 280 families with 2,103 people. In addition, 231 hectares of paddy field, 3 hectares of dry farming land, 30 hectares of tea farm, 52 hectares of forest land, and one tea factory will also be flooded.

Engineering Features

1. Dam

Three different types have been studied, i.e. gravity, arch, and rock fill.

a. Gravity section

Maximum height	160 meters
Top width	16 meters
Base width	295 meters
Top length	383 meters
Concrete volume	1,750,000 m^3

b. Arch section

Maximum height	165 meters
Top width	9 meters
Base width	94 meters

Top length	349.1 meters
Concrete volume	1,550,000 m^3

c. Rockfill

Maximum height	165 meters
Top width	10 meters
Base width	322 meters
Top length	400 meters
Total volume	4,700,000 m^3

2. Reservoir

Watershed	764.3 sq. km.
Reservoir Area	13.8 sq. km.
Maximum drawdown	70 meters
Total Storage Capacity	690 x 10^6 m^3
Effective Storage Capacity	580 x 10^6 m^3

3. Spillway

Crest elevation	270 meters
Length of spillway	Under planning
Design capacity	6,680 cms

4. Irrigation

a. Shih-men Canal (to be built)

Area to be irrigated	23,000 hectares
Maximum discharge	14.2 cms.
Diameter of tunnel	3.0 meters
Slope of main tunnel	1/1,000
Velocity of water	2.01 m/sec.
Length of canal	34 km

b. Taoyuan Canal (existing)

Irrigated Area	23,000 hectares
Maximum discharge	16.7 cms

c. Ta-chi and Hsin-chuang District

Irrigated Area	5,500 hectares
Maximum discharge	8.3 cms

5. Power Plant

Total maximum available head	135 meters
Total installed capacity	Under planning
Energy output for average year	276×10^6 KWH
Energy output for dry year	193×10^6 KWH
Average Capacity	35,000 KW
Firm Capacity	29,000 KW

Cost Estimate

According to the cost estimate of the Taiwan Water Conservancy Bureau, the Shih-men Project costs US$48,930,000, US$46,680,000, and US$38,900,000 for the gravity, arch, and rockfill section respectively. However, the Taiwan Power Company estimated that it would cost US$64,800,000.

Benefit to be Expected

1. Irrigation

The reservoir water will supply full irrigation to the 28,500 ha. of existing irrigated area within the districts of Tao-yuan, Hsin-chuang and Hai-shan Hydraulic Associations. In addition, 23,000 hectares of dry farming land and one-crop land will also be converted into 2-crop paddy field. An annual increase of 80,000 tons of paddy rice per year was estimated.

2. Flood Control

The maximum flood was estimated to be 8,200 cms. The largest recorded flood was 4,725 cms. After completion of the reservoir, the flood would be reduced to 2,990 cms, or a reduction of 37% would be expected.

3. Water Power

The Taiwan Water Conservancy Bureau, basing on the 1926 - 1951 records, estimated that for a tailrace elevation of 135 meters the annual salable power would average about 256,000,000 KWH. In addition there could be developed another 20 million KWH from the new irrigation intake and canal for pumping irrigation.

Another power study of the project was made by the Taiwan Power Company. The result was that with a minimum reservoir elevation of 235 meters the maximum firm power would be 29,000 KW.

The Definite Plan

Reservoir:

Maximum water surface elevation	248 meters
Maximum water surface area	8.5 sq. km.
Gross storage capacity	316,000,000 cu. m.
Effective storage capacity	251,000,000 cu. m.
Maximum drawdown	55 meters
Dam Crest Elevation:	250 meters
Dam Height:	125 meters
Total Construction Cost:	NT$616,398,000) including one NT$ 14,937,000) power unit.
Irrigable Land:	54,600 hectares Increased rice production 69,000 MT of brown rice per year
Power Development:	
One unit	198,220,000 KWH
Two units	208,890,000 KWH
Annual Cost:	NT$90,945,000
Annual benefit:	
Irrigation	NT$75,800,000
Power	NT$41,924,000
Flood control	NT$ 9,228,000
Water supply	NT$ 8,250,000
	NT$135,202,000
Total Net Annual Benefit:	NT$ 44,257,000
Overall Benefit-Cost Ratio:	1.48:1

Tao-shan Reservoir (No. 9)

General Description

This proposed reservoir site is on the upper Tou-chien Chi, near Tao-shan Police Station. The width of the river bed is only 20 meters. The slope of the river is about 1/60. The rock is composed of sand stone and shale. The rock stratum is over ten meters thick striking N12°E and dipping 36° to the right bank. The site commands a drainage area of 166 sq. km. covered with dense forest.

There was a gaging station at Shih-pah-erh above which there lies a watershed of 179 km^2. Records of this station for the years 1934 - 1939 are available.

An 100-m dam would flood no village nor any large farm land except about 1.5 hectares of paddy field and about one hectare of dry farming land.

Engineering Features

1. Dam

Type	Gravity dam
Maximum height	100 meters
Top width	10 meters
Top length	110 meters
Volume	170,000 m^3
Base width	72 meters

2. Reservoir

Watershed	166 km^2
Reservoir Area	1.17 km^2
Maximum Drawdown	50 meters
Total Storage Capacity	45 x 10^6 m^3
Effective Storage Capacity	37 x 16^6 m^3

3. Spillway

Length of Spillway	80 meters
Design Spillway Capacity	1,400 cms

4. Estimate

The construction cost of this project was estimated to be about NT$70,000,000. Besides the benefit on flood control by reducing the flood peak of 1,400 cms, the regulated flow would be sufficient to supply irrigation water to the 12,000 hectares lying below and to generate 12,000 KW of firm power with a total annual energy output of 105 million KWH.

Shang-ping Reservoir (No. 10)

General Description

The proposed dam site is on the upper Tou-chien Chi near the Shang-ping Tsun. The rock stratum is mostly of sand stone, 0.5 - 1.0 m thick, striking N60^{o}E and dipping 48^{o} - 50^{o} toward the upstream. The rock at this site is not so hard as that at the Tao-shan site. The river bed is about 65 meters wide and has a slope of about 1/100. The watershed area above the dam site is 232 km^2.

With the planned height for the dam, there will be 7 km of highway requiring relocation. The Shang-ping Tsun will be under water. In this village there are 225 families with 220 houses and a population of 1,500. The reservoir will also flood 65 hectares of paddy field, 12 hectares of dry farming land, 15 hectares of tea farm and 11 hectares of forest area.

Engineering Features

1. Dam

	Layout 1	Layout 2
Type	Concrete gravity	Concrete gravity
Maximum Height	70 meters	90 meters
Top Width	10 meters	10 meters
Base Width	50 meters	65 meters
Top Length	160 meters	190 meters
Volume	180,000 m^3	320,000 m^3

2. Reservoir

Watershed	232 km^2	232 km^2
Reservoir Area	3.0 km^2	4.3 km^2
Maxmimum Drawdown	40 meters	60 meters
Total Storage Capacity	98.5 x 10^6 m^3	171.6x10^6 m^3
Effective Storage Capacity	80.4 x 10^6 m^3	153.5x10^6 m^3

3. Spillway

Length	120 meters
Design Spillway Capacity	2,000 cms

Cost and Benefit

The construction cost of this project was estimated to be NT$130,000,000 for the 90-m dam, and NT$70,000,000 for the 70-m dam.

Besides the benefit in reducing the flood peak of 2,000 cms, the regulated water will supply irrigation water to 12,000 hectares and will develop a firm power of 14,000 KW with a total annual energy output of 123 million KWH.

Sha-hu-li Reservoir (No. 11)

General Description

The proposed reservoir site is located at Sha-hu-li, a village in Chu-tung, Hsin-chu. Its purpose is to store water for irrigation of 784 hectares in Chin-shan-mien area. The water would be diverted from the Chu-tung Canal into the reservoir through a waterway of about 2,900 meters long. It is planned to divert the river flow through the Chu-tung Canal Intake whenever there is surplus flow in the Tou Chien Chi.

The average yearly rainfall in the project area is 1,466 mm. The minimum flow in the Tou-chien Chi at the Chu-tung Canal Intake is 2.07 cms.

The reservoir would flood about 36 houses accomodating 45 homes. Another 36 hectares of paddy field would also be under water. About 1.5 km of highway will have to be relocated.

The material for the proposed earth dam is available near the dam site. An existing highway leads from the dam site to Hsin-chu.

Engineering Features

1. Dam

Type	Earth Dam
Maximum Height	28 meters
Top Width	8 meters
Base Width	180 meters
Top Length	125 meters
Volume	150,000 m^3

2. Reservoir

Watershed	285 hectares
Reservoir Area	0.35 km^2
Maximum Drawdown	15 meters
Total Storage Capacity	2,180,000 m^3
Effective Storage Capacity	2,180,000 m^3

3. Spillway

Crest Elevation . . . . 135.0 meters

Length of Spillway . . . . 26 meters

Design Spillway Capacity . . . . 55 cms.

Cost and Benefit

The PWCB's estimate for the construction cost of this project is US$1,000,000.

Annual Cost (10%) . . . . US$100,000

Income after project completion . . . . . US$470,400

Income before project completion . . . . US$ 80,000

Increase . . . . US$390,400

Net benefit (assume 50%) . . . . US$195,200

Benefit Cost ratio 1.95

Ching-tsao-hu Reservoir (No. 12)

General Description

This project is under construction. The purpose of the project is to store water to supply 600 hectares of paddy field in the Hsiang-shan area near Hsin-chu. The reservoir is formed by a dam across the Ke-ya Chi near Ching-tsao-hu. A waterway of about 2 kilometers long will be built to connect the reservoir to the existing Ting-pu Canal. The slope of the river bed is about 1/1,000. No discharge data are available. The maximum, minimum, and average annual rainfall are 2,375.3 mm, 877.6 mm., and 1,845.2 mm. respectively. The annual evaporation is 1,353.1 mm. The maximum and minimum monthly mean temperatures are 27.8°C and 14.6°C respectively.

An existing highway leads the dam site to Hsinchu. The material for the earth dam is also available at the dam site. No relocation of communication lines, nor flood of property is involved.

Engineering Features

1. Dam

Type	Earth dam
Maximum Height	13 meters
Top Width	6 meters
Base Width	87 meters
Top Length	140.5 meters
Volume	50,000 m^3

2. Reservoir

Watershed	30 km^2
Reservoir Area	248,510 m^2
Maximum Drawdown	4.5 meters
Total Storage Capacity	1,100,000 m^3
Effective Storage Capacity	845,000 m^3

3. Spillway

Crest Elevation	34.5 meters
Length	36 meters
Design Spillway Capacity	320 cms

Cost and Benefit

The cost estimate for the project made by the PWCB in 1952 was NT$2,030,000 with the following breakdown:

Reservoir	NT$822,210
Waterway	268,090
Miscellaneous	64,320
Cement & Reinforcing Bar	705,380
Right of Way	100,000
Supervision	70,000
Total:	NT$2,030,000

The annual cost, assumed at 10% of the total cost is NT$203,000. The completion of the project will effect an annual increase of crop yield amounting to NT$2,160,000 (NT$3,600,000 - NT$1,440,000). Assume 50% of the annual increase is net gain, the benefit cost ratio will be 5.3 (1,080,000 ÷ 203,000). In addition to the benefit from a better crop, there is an estimated benefit from fishery amounting to NT$390,400. This would raise the benefit cost ratio from 5.3 to 7.3.

Editor's Note : The final completed project has a total construction cost of about NT$5,600,000. The original plan has been much strengthened and improved in the following ways. The dam has been provided with a parapet wall and the spillway has been so modified that a much larger flood could safely be taken care of.

The two ends of the spillway and the thin hill section encircling the reservoir have been strengthened. The dike slope on the reservoir side has been provided with protection. A new intake structure has replaced the old one, which failed due to poor construction. The intake tunnel has been grouted. Part of the new canal from the reservoir to the existing Ting Pu Canal has been relocated and strengthened.

Ta-pu Reservoir (No. 13)

General Description

The area of cultivated land near Tou-feng and Chu-nan is about 1,800 hectares most of which is dry land. The purpose of the project is to store water by constructing a dam across the O-mei Chi near Shih-erh-liao above the Si-ho Dam for irrigation of 1,400 ha. A canal system and a pumping station would be built. The canal system will consist of 10 kilometers of main canal and 25 kilometers of laterals. The ponds in this region will also be improved.

No flow records were available. The maximum flood is estimated from maximum daily rainfall. The maximum, minimum, and average annual precipitations are 2,893.6 mm., 1,337.4 mm., and 2,097 mm. respectively.

At the proposed dam site some thick outcrop of soft sand stone can be seen. The earth is reddish and sandy. The river bed slope is 1 in 240 at the site. The proposed reservoir would flood about 25 hectares of paddy field, and 25 hectares of grass and forest area.

Engineering Features

1. Dam

Type	Concrete Gravity
Maximum Height	14 meters
Top Width	4.2 meters
Base Width	15 meters
Top Length	80 meters
Concrete Volume	7,500 m^3

2. Reservoir

Watershed	100 km^2
Reservoir Area	115 hectares
Maximum Drawdown	7 meters
Total Storage Capacity	6.44×10^6 m^3
Effective Storage	5.05×10^6 m^3

3. Spillway

Crest Elevation . . . . 67 meters

Length of Spillway . . . . 80 meters

Design Spillway Discharge . . . . 444 cms

Cost and Benefit

The 1952 estimate of the project made by the Chu-nan Hydraulic Association was NT$10,000,000 composing of NT$3,872,540 for the reservoir, NT$5,666,362 for the canal system, NT$150,000 for supervision of construction, and NT$311,098 for miscellaneous work.

The completion of the project will raise the annual production from NT$6,350,000 to NT$20,550,000. One half of this increase may be assumed as the net benefit. Considering 10% of the total construction cost as the annual cost, the benefit cost ratio will be 7.1.

Editor's Note: This project has been started in August 1956. The main features decided as of now consist of a reservoir of 8,500,000 m^3, of which 6,400,000 m^3 is effective; a concrete dam, 18.6 meters high, with an overflow section of 48.1 meters provided with 5 spans of 8m x 8m taintor gates and two spans of sluice gate; and a canal system constituting 13 kilometers of main canal and 37 kilometers of laterals. The main canal includes 2.6 kilometers of tunnel in 4 stretches and 10.4 kilometers of open canal. The intake from the reservoir has a capacity of 2.2 cms. The area to be irrigated is 1,230 hectares. The total project is estimated to cost NT$40,000,000 and is to be finished in three years. The benefit cost ratio is 1.97.

Hsi-ho Reservoir (No. 14)

General Description

The Hsi-ho Dam, on the O-mei Chi, a branch of Chung-kang Chi, was completed in 1951. It is 5 meters high and has a crest length of 90 meters. Nine vertical-lift gates were provided. The reservoir capacity is about 1,000,000 m^3. The stored water is to supplement irrigation water to 2,500 hectares of paddy field during dry season.

A study was made by the Taiwan Water Conservancy Bureau to increase the reservoir capacity by heightening the dam. An additional height of 2 meters would double the capacity. With the aid of the improved pond storage of about 2,500,000 m^3, the irrigation water for the 1,000 hectares under Ta-pu Canal can be supplied.

Engineering Features

1. Dam

Type	Concrete Gravity
Maximum Height	5 meters
Top Width	1.6 meters
Base Width	10 meters
Top Length	90 meters

2. Reservoir

Watershed	120 km^2
Reservoir Area	33 hectares
Maximum Drawdown	5 meters
Total Storage Capacity	980,000 m^3

3. Spillway

Crest Elevation	55.3 meters
Length of Spillway	90 meters
Design Spillway Discharge	444 cms

4. Extension of Reservoir

Height of Crest Gates	2 meters
Storage Capacity Increased	840,000 m^3
New Irrigation System (Capacity 3 cms) . .	14 km

<u>Cost and Benefit</u>

The estimated cost for the extension work is NT$4,324,000 with the following breakdown:

1.	2 meters movable dam	NT$ 292,000
2.	Irrigation System	2,236,000
3.	Pond Improvement	741,000
4.	Cement	398,000
5.	Steel Reinforcement	317,000
6.	Supervision	240,000
7.	Miscellaneous	100,000
	Total:	NT$4,324,000

The completion of the extension work would raise the annual production from NT$6,350,000 to NT$14,670,000. Considering 10% of total cost of extension as the annual cost and 50% of the annual increase of production as the net benefit, the benefit cost ratio is 9.6.

San-chu-hu Reservoir (No. 15)

General Description

This is another project proposed for the improvement of the irrigation of the Ta-pu district. Two earth dams were proposed to be built across the O-mei Chi near San-chu Tsun. A waterway of about 11.5 km long will convey the water from the reservoir to the intake, where a new irrigation system is to be built to take the water to 1,400 hectares of dry land.

Rainfall records for 39 years are available. The maximum, minimum, and mean annual rainfall records are 2,654.4 mm., 1,337.4 mm., and 2,081.7 mm respectively. There was only one-year flow record. The maximum, minimum and average flow records were 7.93 cms., 0.31 cms and 2.69 cms respectively. The relation between the runoff and rainfall showed a runoff factor of 0.87.

The proposed dam site is 11 km from Chu-nan, having a watershed of 5.8 square kilometers. The rock outcrop is bluish sandstone.

The reservoir will flood 30.5 hectares of paddy field, 38.5 ha. of dry farming land, and 80 hectares of forest area.

Engineering Features

1. Dam

Type	Earth Dam
Maximum Height	25.76 meters
Top Width	8 meters
Base Width	140 meters
Top Legnth	208.5 meters

2. Reservoir

Reservoir Area	1.1 km^2
Maximum Drawdown	8 meters
Total Storage Capacity	4.3×10^6 m^3
Effective Storage Capacity	3.8×10^6 m^3

3. Spillway

Crest Elevation	99 meters
Length of Spillway	18 meters
Design Spillway Discharge	57 cms

4. Intake

Tower Height	23.3 meters
Intake Discharge	2.1 cms
Waterway from Intake to Reservoir	11.5 km

Cost and Benefit

The 1950 estimate made by the Taiwan Water Conservancy Bureau for the total project was US$1,932,000. The completion of the project would raise the annual revenue from production from US$1,510,500 to US$2,079,000. Considering 10% of the total construction cost as the annual cost and 50% of the annual increase of production as the annual net benefit, the benefit cost ratio is 1.5.

Chih-hu Reservoir (No. 16)

General Description

This proposed project is to build a dam across the Lao-tien-liao Chi of the Hou-lung Chi to create a reservoir for irrigation of 2,900 hectares in Miao-li Hsien between Hou-lung Chi and Chung-kang Chi. The elevation of the land is from 4 meters to 50 meters above the sea level. The general slope of the land surface is about 1/50 - 1/170

The proposed dam site near the Chih-hu Tsun has a river bed slope of about 1 in 100. The forest covered watershed accounts for the clear water. The rock is snadstone, about one meter thick, striking N23° - 25°E and dipping 40° toward the upstream. The created reservoir will submerge about 53 hectares of land. In addition, 720 meters of highway and a 100-m span suspension bridge will have to be relocated and rebuilt

Engineering Features

1. Dam

Type	Concrete Gravity
Maximum Height	47 meters
Top Width	5 meters
Base Width	36 meters
Top Length	83 meters
Concrete Volume	50,000 m^3

2. Reservoir

Watershed	20 km^2
Reservoir Area	47 hectares
Maximum Drawdown	30 meters
Total Storage Capacity	5,764,000 m^3
Effective Storage Capacity	5,724,000 m^3

3. Spillway

Crest Elevation	128 meters
Length of Spillway	100 meters
Spillway Discharge	450 cms

Cost and Benefit

The Taiwan Water Conservancy Bureau estimated the cost of the project at NT$19,642,000, about 68% of which is for the reservoir and the remaining for the waterway and irrigation system. The completion of the project will effect an increase of annual production amounting to about NT$6,620,000. Based on an annual cost estimated at about 10% of the total cost and an annual benefit estimated at about 50% of the gross annual increase of production, the benefit cost ratio would be 1.7.

Ming-teh Reservoir (No. 17)

General Description

This is an alternative proposal of the Chih-hu Reservoir Project. The dam site is below Chih-hu near Ming-teh Tsun. The rock stratum is soft sand rock, a meter thick, with a strike of N25°E and a dip of 39° toward upstream. The river bed slope is about 1/120.

There is a gaging station at Jen-lung, Tou-wu Hsiang. Records for the years 1941, 1942, 1944 and 1950 are available. The minimum flow is 0.45 cms.

The created reservoir would flood 70 hectares of land. About 7 kilometers of highway with a 30-ft span bridge have to be relocated.

Engineering Features

1. Dam

	Layout 1	Layout 2
Type	Earth dam	Concrete
Maximum Height	31 meters	29 meters
Top Width	8 meters	8 meters
Base Width	140 meters	66 meters
Top Length	135 meters	136 meters
Volume	127,000 m^3	51,000 m^3

2. Reservoir

Watershed	25 km^2
Reservoir Area	70 hectares
Maximum Drawdown	11 meters
Total Storage Capacity	4,480,000 m^3
Effective Storage Capacity	4,060,000 m^3

3. Spillway

Crest Elevation	50 meters
Length of Spillway	100 meters
Design Spillway Discharge	540 cms

Cost and Benefit

The Taiwan Water Conservancy Bureau had the following constructi estimates:

	Layout 1 (earth dam)	Layout 2 (Concrete dam)
Reservoir	NT$7,300,000	NT$9,770,000
Water-way	2,741,000	2,741,000
Irrigation system	3,606,000	3,606,000
Total	NT$13,647,000	NT$16,117,000

The annual increase of production brought about by this project amounts to about NT$6,620,000 shown in detail as follows:

Before Completion of Project

	Area (ha.)	Production Per Ha.(kg)	Total Production	Unit Cost (NT$)	Total Cost (NT$)
Double Crop	1,184	6,000	7,104,000	0.92	6,535,000
Single Crop	316	3,000	948,000	0.92	872,000
Dry Land	311.2	2,100	1,493,500	0.92	1,374,000
Dry Land	479.2	5,000	2,396,200	0.25	699,000
Others	226.4	-	-	-	-
Total	2,916.8	-	-	-	9,480,000

After Completion of Project

Double Crop	2,916.8	6,000	17,500,000	0.92	16,100,000

The annual increase is therefore NT$6,620,000. Assuming 10% of the total construction cost as the annual cost and 50% of the annual increase as the annual benefit, the benefit cost ratio will be 2.4 for the earth dam and 2.1 for the concrete dam.

Kwei-chu-lin Reservoir (No. 18)

General Description

Along the Hou-lung Chi there are five irrigation systems with a total irrigated area of 2,156 hectares. In dry seasons, 50% of the area along the lower end of the canals is short of water. It is proposed to build a dam across the Hou-lung Chi near Kwei-chu-lin Tsun, Shih-tan Hsiang, Miao-li Hsien. The earth material for the proposed earth dam is available near the dam site.

The proposed layout shows a 3-span intake gate and a sluice gate on the left bank and a siphon spillway on the right bank. The reservoir will flood five families and 26 hectares of paddy field. About 1.5 kilometer of highway will have to be relocated.

Engineering Features

1. Dam

Type	Earthdam
Maximum Height	23 meters
Top Width	8 meters
Base Width	126 meters
Top Length	100 meters
Volume	89,600 m^3

2. Reservoir

Watershed	22 km^2
Reservoir Area	320,000 m^2
Maximum Drawdown	19 meters
Total Storage Capacity	2.94×10^6 m^3
Effective Storage Capacity	2.94×10^6 m^3

3. Spillway

Crest Elevation	252 meters
Spillway Capacity	156 cms

Cost and Benefit

The cost of the project was estimated by the Miao-li Hydraulic Association at NT$2,250,000 with the following breakdown:

Dam		774,000
Intake		25,300
Gates		71,000
Spillway		317,000
Hoist Room		5,770
Bridge		3,800
Culverts		3,800
Roadway		89,100
		1,289,770
Land	15 ha. @ 18,000	270,000
	8 ha. @ 5,000	40,000
	6 ha. @ 3,000	18,000
	1 ha. @ 5,000	5,000
		1,300
Removal of Houses		128,000
Cement and Reinforcing Bars		438,000
Supervision of Construction		54,300
		2,244,370
	Say	2,250,000

The completion of the project will raise the value of annual production from NT$3,111,450 of rice and NT$137,885 of potato to NT$5,204,775 of rice, a difference of NT$1,955,440. Assuming 10% of the construction cost as the annual cost and 50% of the annual increase as the benefit, the benefit cost ratio will be 4.4.

Hsiang-pi Reservoir (No. 19)

General Description

Ta-an Chi is one of the most steep and torrential rivers in Taiwan. It originates from the western part of Mt. Tsu-kao and Mt. Ta-pa-chien of the Central Range and has headwaters of about 3,500 meters above mean sea level. The general slope of the lower portion is greater than 1/90. Most portion of its drainage area is mountainous and is covered with forest.

The proposed Hsiang-pi Reservoir site is situated on the upper stream of the Ta-an Chi near the Hsiang-pi Police Station. The geologic formation at the dam site is mainly sand stone with some shale. The rock strata is 3 - 5 meters thick striking N5^{o} - 20^{o}E. Material for concrete aggregate is available.

The annual rainfall in the upper drainage basin is 3,700 mm at Kao-ling and 3,200 mm at Chiu-kang. A gaging station had been established near the dam site. Seven years records starting from 1937 are available. The maximum recorded flood is 758 cms and the minimum flow is 5.19 cms.

The reservoir will flood 130 families with 650 people, and 4,000 square meters of building. In addition, the flooded area will include 35 hectares of paddy land and 60 hectares of dry farming land.

There are several slides on the headwaters of Ta-an Chi and Nan-keng Chi. Between Hsiang-pi and Erh-pen-sung, the land below elevation 800 is either cultivated by the aborigines or occupied by bamboo forest. Above elevation 800 are hardwoods. Upstream from Erh-pen-sung are mixed forests of hardwoods and conifers.

Engineering Features

1. Dam

Type	Concrete Gravity
Maximum Height	100 meters
Top Width	10 meters
Base Width	80 meters
Top Length	290 meters
Concrete Volume	700,000 m^3

2. Reservoir

Watershed	441 square kilometers
Reservoir Area	3.9 square kil-meters
Maximum Drawdown	40 meters
Total Storage Capacity	175 x 10^6 m^3
Effective Storage Capacity	146 x 10^6 m^3

3. Spillway

Crest Length	250 meters
Designed Spillway Capacity	3,500 meters

Cost and Benefit

Since this is a multiple project, the benefit is also multiple. The benefit on flood control depends on the flood. For the designed flood of 3,500 cms, the benefit would be small. For the maximum recorded flood of 758 cms a large percentage of flood reduction could be expected. The irrigation benefit is appreciable. The regulated flow is estimated to be about 25 cms in the dry season. It would be adequate to supply the 12,000 hectares of existing irrigated area and 13,000 hectares of dry land. The generated power is estimated at 12,500 kw of firm power with an annual output of about 110 million kwh. If the plant is to be used as a three-hour peaking station, the installed capacity may be around 100,000 kw.

Mai-fu-ping Reservoir (No. 20)

General Description

The proposed dam site is located on the upper Ta-an Chi, about 15 kilometers downstream from Hsiang-pi, Ho-ping Hsiang, Tai-chung Hsien. The rock is shale and sandstone, 2 - 5 meters thick, striking N30°W, and dipping 35° - 45° downstream. The left bank has an overburden of 1 - 2 meters on the right bank, there can be seen some rock outcrop. The river bed slope here is 1:80. Cobbles around 0.50 meter in size are seen. The river bed below here is much wider. The river flows from north to south above Mai-fu-ping, and then makes a right angle turn to the west.

During low stages there are lumbers and bamboo rafts in the river, Cho-lan is accessible from the river bed in low water.

Within the watershed area above the dam site there are no large slides. Two small slides were seen about 5 kilometers upstream from the dam site. Further upstream there are more slides, but none of them is extensive. The aborigines cultivate an area of 4,000 hectares. The forest is being managed by the Pa-hsien-shan Lumber Yard. Most of the miscellaneous wood have been cut by private lumber companies.

A self - recording gaging station near the dam site was established by Japanese, but no record is available. The minimum flow is 7 centimeters and the maximum is 4,400 centimeters. The serious flood on July 18, 1943 broke the Hwo-yen-shan Dike, washed 700 hectares of paddy land, buried another 600 hectares, destroyed 381 houses, broke 400 meters of railway, 600 meters of highway and caused a death of 157 people. It was estimated that the total loss was ¥ 10,000,000 Japanese Currency.

The proposed reservoir will flood six villages, Hsueh-shan-keng, Ta-kwan, Chu-lin, Shih-ling, Hsiang-pi, Mai-fu-ping. In the flooded area, there are 220 families with 1,296 population. In addition, 132 hectares of paddy field and 3,854 hectares of dry farming land would also be submerged. About 3 kilometers of highway will have to be relocated.

Engineering Features

1. Dam	Layout 1	Layout 2	Layout 3
Type	Concrete Gravity	Concrete Gravity	Concrete Gravity
Maximum Height	65 meters	150 meters	170 meters
Top Width	8 meters	10 meters	10 meters
Base Width	50 meters	105 meters	120 meters

	Top Length	260 meters	550 meters	600 meters
	Concrete Volume	280,000 m^3	3.3×10^6	4.2×10^6
2.	Reservoir			
	Watershed	441 sq. km.	441 sq. km.	441 sq. km.
	Reservoir Area	2.3 sq. km.	7.0 sq. km.	9.9 sq. km.
	Maximum Drawdown	35 meters	80 meters	100 meters
	Total Storage Capacity	$71.5 \times 10^6 M^3$	349×10^6	682×10^6
	Effective Storage Capacity	59×10^6	316×10^6	610×10^6
3.	Spillway			
	Designed Capacity	4,400	4,400	4,400

Cost and Benefit

Due to lack of foundation information, the estimated cost for excavation and foundation treatment is quite uncertain. The costs for the layouts 1, 2, and 3 have been roughly estimated to be NT$100 million, NT$1,000 million and NT$1,200 million respectively. The benefits are from the multiple functions.

The reservoir will have a storage capacity equal to two-thirds of the annual flow of the Ta-an Chi. The flood control benefit could be large. The regulated flow would be a great help to the lower area now in shortage of water. The estimated firm power to be generated is 45,000 kw and the annual energy output will be about 394 million kwh. A large peaking power generation can be expected.

Cho-lan Reservoir (No. 21)

General Description

This project proposed in 1936 is for irrigation of about 15,000 hectares along the lower Ta-an Chi. The main feature is to divert the water through a 4-km water-way from the Ta-an Chi at a point about 3.5 kilometers above Nei-wan Tsun and to store the water in a reservoir on the Lao-chuang Chi created by an earth dam across the creek. At the site of the proposed earth dam, the river bed slope is 1/80. The rock is sand stone with thick overburden. The created reservoir will flood 40 families accomodating 300 people. In addition, 27 hectares of paddy field, 43 hectares of dry farming land, and 56 hectares of forest area. Another waterway of 10 kilometers will be built from the reservoir outlet. Four power plants will be built with a total installation of 32,500 kw, one just below the desilting basin, one below the storage dam, the other two at the end of the lower waterway. The water to be used in No. 3 and No. 4 power plant is 45% and 55% respectively of the total. A tunnel of 1.5 km long would be necessary to divert water from main water-way to the No. 4 plant.

This project was revised by the FWCB in 1952. The waterway below the reservoir was omitted. Some changes in the dam height and volume were made and only two power plants were proposed.

Engineering Features

1. Dam

Type	Earth dam
Maximum Height	49.5 meters
Top Width	10 meters
Base Width	290 meters
Top Length	350 meters
Volume	1,000,000 m^3

2. Reservoir Area . . . . 128 hectares

Maximum Drawdown	30 meters
Total Storage Capacity	27×10^6 m^3
Effective Storage Capacity	23×10^6 m^3

3. Spillway

Crest Elevation . . . . 395 meters

Length of Spillway . . . . 20 meters

Design Spillway discharge . . . . 80 cms

Cost and Benefit

The 1952 estimate by the WCB for the total project is NT$60 million (29.9 million for the reservoir, 15.7 million for the waterway and 14.4 million for the new irrigation system).

The benefit of this project has been estimated by the PWCB at NT$58 million, based on the assumption that the completion of the project will raise the annual income from the 15,512 ha. from NT$102 million to NT$160 million.

Assuming 10% of the total cost as the annual cost and 50% of the total benefit as the net annual benefit, the benefit - cost ratio would be 4.8.

Li-yu-tan Reservoir (No. 22)

General Description

This is a proposed project to irrigate about 8,000 hectares along the lower Ta-an on the right bank. Though Cho-lan Reservoir has been proposed to supply irrigation water for Yuan-li and Tung-hsiao districts, its capacity is not enough. Therefore this project is proposed.

The proposed dam site is at Li-yu-tan, Cho-lan Hsiang, Miao-li Hsien on the To-lo-ku Chi, a tributory of Ta-an Chi. The intake is proposed to be built on the right Ta-an bank at the inlet of Lao-chuang Chi. The length of the water-way from the intake to the reservoir is 2 kilometers of which 1.25 kilometer is a tunnel. The reservoir will flood 15 families accomodating 100 people, 25.3 hectares of paddy field, 10 hectares of dry farming land and 20 hectares of forest area.

Engineering Features

1. Dam

Type	Earth dam
Maximum Height	42 meters
Top Width	8 meters
Base Width	206 meters
Top Length	180 meters
Volume	350,000 m^3

2. Reservoir

Watershed	4,800 hectares
Reservoir Area	84 hectares
Maximum Drawdown	28 meters
Total Storage Capacity	12 x 10^6 m^3
Effective Storage Capacity	11 x 10^6 m^3

3. Spillway

Crest Elevation	260 meters

Length of Spillway . . . . 25 meters

Design Spillway Discharge . . . . 100 cms

Cost and Benefit

The estimate by the PWCB in 1953 was NT$15.4 million consisting of NT$6 million for the reservoir, NT$1.4 million for the waterway and NT$8 million for the irrigation system. It is also estimated that the completion of the project will raise the annual income from NT$22,815,000 to NT$34,517,000. Assuming 10% of the total cost as the annual cost and 50% of the annual benefit as the net annual benefit, the benefit cost ratio will be 3.8.

Ta-chien Reservoir (No. 23)

General Description

Ta-chia Chi is one of the most important power development rivers on the island. It originates from Mt. Tzu-kao, Mt. Nan-hu and Mt. Ho-huan of the Central Range, with a headwater elevation of more than 3,000 meters. The total drainage area is 1,272 sq. km, while the average river slope is 1 to 60.

The planning work was started in 1938 by the Japanese. It calls for the construction of a concrete gravity storage dam of 201 meters high at Ta-chien. It was planned to build 8 power houses downstream from the dam utilizing a total head of 1,200 m. within a distance of 60 kilometers. By the regulation of the reservoir, the low flow will be greatly increased. The total firm power and installed capacity are estimated to be 312,000 kw and 458,500 kw respectively. The main design features are tabulated as follows:

Project	Dam Height (m)	Tunnel Length (km)	Tunnel Dia. (m)	Effective Head	Proposed Plant Capacity (kw)	Firm Power (kw)
Ta-chien *1	201	0.25	4.5	Max. 187.1 Nor. 147.0	66,200	35,600
Lower Ta-chien		4.96	4.7	181.5	64,200	43,600
Upper Ku-kwan		4.81	4.9	117.6	46,800	32,700
Ku-kwan	14	6.74	4.9	173.1	71,000	52,600
Tien-leng *2	34	10.13	5.1	171.0	84,500	56,500
Feng-yuan No. 1	12	9.18	5.2	106.9	51,200	36,700
Feng-yuan No. 2		10.90	5.2	94.8	44,700	31,600
Feng-yuan No. 3		8.39	5.2	66.8	29,900	22,700
				1,098.8	458,500	312,000

*1 The 30 km road from Ku-kwan to Ta-chien is in bad shape. The foundation exploration is not yet completed.

*2 Completed.

The dam site is of a V-shape, composing of rock cliffs of hard slate and rock with a strike of N20°-30°E and a dip of 70°. The river bed slope at the dam site is 1 in 90. The reservoir will flood a total of 116 families in the villages Chia-yang, Huan-shan, and Tao-yuan. These families accomodate 515 people.

Only 2.5 hectares f paddy field and 18 hectares of dry farming land will be flooded. There are frequent slides about 1 kilometer up-stream from the dam site. Beside this, there are two or three minor slides.

Engineering Features

1. Dam

Type	Concrete Arch-gravity
Maximum Height	201 meters
Top Width	10 meters
Base Width	176 meters
Top Length	230 meters
Free Board	6 meters
Volume of Concrete	1,500,000 cubic meters

2. Reservoir

Watershed	526 square kilometers
Reservoir Area	5.1 square kilometers
Reservoir Perimeter	40 kilometers
Maximum Drawdown	120 meters
Total Storage Capacity	310×10^6 cubic meters
Effective Storage Capacity	290×10^6 cubic meters

3. Spillway

Crest Elevation	1,414 meters
Length of Spillway	140 meters
Design Spillway Capacity	4,000 cms

4. Intake Tunnel

Diameter . . . . 4.5 meters

Length . . . . 250 meters

5. Transport

Road . . . . . 69 km from Tung-shih to Ta-chien

Railway . . . 14.4 kilometers from Feng-yuan to Tung-shih only earthwork completed.

Cableway . . . 69 kilometers from Tung-shih to Ta-~~chien~~, only 20% completed.

<u>Cost</u>

According to the original estimate made by the Japanese in 1942, the total cost of the reservoir would require $135 million of Japanese Currency (or US$34 million) of which 100 million was planned to be borne by the Government and 35 million by the Taiwan Power Company. The cost of the reservoir composes of US$21,500,000 for the dam, US$1,100,000 for the road, US$10,900,000 for the railway, and US$500,000 for overhead. The cost of the 8 power plants was estimated at ¥240,000,000 or US$60,000,000. The total cost for the dam and power plants was US$94,000,000 on 1942 basis or US$212,000,000 on 1953 basis.

<u>Benefit</u>

The Ta-chien Reservoir project is not only for water power development, but also for irrigation, and flood control, etc.

The effective storage between elevation 1,420 and 1,300 is about equal to one-third of the annual inflow. The maximum flood discharge on record at the dam site was 2,503 cms. The maximum flood discharge of the Ta-chia Chi was estimated to be 10,600 cms with a total drainage area of 1,272 square kilometers of which 92% or 1,167 square kilometers is mountainous district. The dam site controls 45% of the total mountainous district. After the completion of the reservoir the flood discharge of the Ta-chia Chi and flood damages could be appreciably reduced.

According to the plan of water power development, the release from the lowest plant is about 33.3 cms in the dry season which is adequate to supply supplementary water to the existing 25,000 hectares of irrigated area and full supply to another 6,330 hectares of dry land.

The available head to be consumed and the power to be generated by the 8 plants have been listed in the above table. The firm energy output was estimated to be 2,733,100,000 kwh and the secondary energy output. 68,100,000 kwh.

A new industrial center was planned at the district between lower Ta-chia Chi and Wu-chi. The water supply for this industrial center would also be provided by this project.

__Editor's note:__ This project has been planned and investigated in greater detail after the reconnaissance survey was made. The planning work was carried out successively by the Ta-chia Development Commission and the Water Resources Development Commission. The scale of power development and the layout for the dam and the power plants have been modified by the French Engineer Mr. Keine after his visit.

Tien-leng Reservoir (No. 24)

General Description

This proposed project is for irrigation. The irrigated land along Ta-chia Chi is about 26,000 hectares under four hydraulic associations. During dry seasons, about 7,500 hectares of the area will suffer insufficient irrigation. Another 4,000 hectares receive no irrigation. The minimum flow of the Ta-chia Chi was only 9.7 cms.

The proposed dam site is near the Tien-leng Suspension Bridge across the Ta-chia Chi. The width of the river-bed is about 200 meters and the river bed slope is about 1/80. The rock formation composes of alternate layers of quartz sandstone and sand rock 1.5 - 3.0 thick, with a strike of N70°-75°W and a dip of 40°-44° toward the downstream.

The reservoir will flood 85 families situated in the villages Nan-shih, Fu-hsin, and Ma-chu-keng. These families have a total population of 818. In addition, 47 hectares of paddy field will also be flooded.

Engineering Features

1. Dam

Type	Concrete Gravity
Maximum Height	40 meters
Top Width	4 meters
Base Width	29 meters
Top Length	200 meters
Volume	95,000 m^3

2. Reservoir

Watershed	967 km^2
Reservoir Area	2.52 km^2
Maximum Drawdown	40 meters
Total Storage Capacity	38×10^6 m^3
Effective Storage Capacity . . .	38×10^6 m^3

Cost and Benefit

The PWCB's 1952 estimate for this project is NT$56,000,000 consisting of NT$1,200,00 for dewatering, NT$48,700,000 for dam, NT$350,000 for house, NT$250,000 for power line, NT$300,000 for gate and hoists, NT$2,900,000 for spillway and other construction, NT$300,000 for right-of-way and NT$2,000,000 for overhead. The total annual benefit was estimated to be NT$23,500,000. Assuming 10% of total cost as the annual cost and 50% of the total benefit as the net annual benefit, the benefit cost ratio will be 2.1.

Wu Chi Basin

(See Fig. 16 & 17)

General Description

Wu Chi originates from Mt. Ho-huan (El. 3,416 m). The headwater is called Pei-kang Chi. It flows westward and below the confluence with Nan-kang Chi, at Shuang-chi-tsui, Kuo-hsing Hsiang, the river is known as Wu Chi. The lower reach in which another two tributaries, Mao-lo and Ta-li, join, flows through the central part of Taiwan and then empties into the sea at Ko-chueh, Lung-ching Hsiang. The whole river is 113 km. long and has a drainage area of 2,070 sq. km. of which 73 per cent is mountainous. The maximum flow estimated in the past was 9,230 cms. above Wan-tou-liu and 13,900 cms. at the main railway bridge. The levee along the lower course was built during 1931-1939. Since the completion of the levee, the flood damage has been greatly reduced but the deposit of sand and gravel carried from upstream is getting to be a serious problem.

Precipitation

The river originates in a region of heavy rainfall. The records are as follows:

Station	No. of yrs. of Record	Max. Annual (mm.)	Average Annual (mm.)	Max. Daily (mm.)
Sung-ling	21	4,833	3,100	367.0
Ho-huan-shan	8	5,703		466.8
Chui-fen	29	4,476		312.0
Tsui-luan			3,400	
Chuan-chung-tao			3,080	
Ta-tu			1,500	
Pu-li			2,400	
Nan-tou			1,700	

There are about 158 rainy days a year in the upper watershed area; 120 days in the middle reach, and 80 on the plain.

River Flow:

In Pei-kang Chi, there are a 5-year record at Chuan-chung-tao starting 1937, and a 2-yr. record at Kuo-hsing. In Nan-kang Chi, there is a 3-yr. record at Pei-shan-kang starting 1937. The flow records are listed below:

	Pei-kang Chi		Nan-keng Chi
	Upper and Middle Reach	Lower Reach	
High flow/100 sq.km. (1)	11.70 cms	11.60 cms	6.68 cms
Ordinary flow/100 sq.km. (2)	5.40 cms	4.62 cms	2.80 cms
Low flow/100 sq.km. (3)	2.50 cms	1.51 cms	1.97 cms
Very low flow/100 sq. km. (4)	1.45 cms	1.10 cms	1.14 cms
(3)/(4)	1.72	1.73	1.72
(2)/(4)	3.72	4.20	2.45
(1)/(4)	8.08	10.60	5.85
Ann. Ave. Q	10.55 cms	9.50 cms	5.83 cms
Ann. Min. Q	1.3 cms	-	0.97 cms
Ann. Max. Q	-	-	58.27 cms

The "high", "ordinary", "low" and "very low" flows are the respective discharges that are equaled or exceeded in 95 days 185 days, 275 days and 355 days in a year.

Geology

Most of the watershed is of Tertiary formation. The headwater region is of Wu-lai Series, composed of medium grained sandstone and black shale. The central region is of gray sandstone, shale and soft sandstone. The lower reach in the plain is of clay and gravel.

Forest

In the headwaters of the Pei-kang Chi, above Elev. 2,000 m., virgin forests of conifers as cypress, red cypress, spruce and pine and virgin forests of hardwoods can be seen. In the Nan-kang Chi watershed, hardwoods occupy about 70 percent of the forest area with only thinly scattered conifers.

Temperature

In this basin, the lowest annual average temperature is 10.70°C at Sung-ling, 23.3°C at Ta-tu, and 23.7°C at San-kwai-tso, Nan-tou Hsien. The eastern watershed is a region of comparatively low temperature, the max. monthly average temperature is about 30°C.

The lowest recorded temperature is 4.7°C in January at Sung-ling and the highest recorded temperature is 29.8°C in July at Ching-shui.

Evaporation

Evaporation record can only be found for Tai-chung. The record covered 42 years starting from 1900. The record shows an average of annual evaporation of about 1,500 mm. The range is from 1200 mm to 2000 mm. An estimated of 800 mm for the yearly evaporation in the mountainous district might not be far off. The evaporation is high in June, July and August, the max. for this period being 230.2 mm. It is low in January and February.

Basin Development

The hydrologic and topographic phenomena make it possible that this river has a plentiful ordinary flow and is one of the best rivers for development of cheap hydro-power.

An area of 26,600 hectares under the Nan-tou, Ta-tun, Neng-kao, Chang-hwa, Feng-jung, and Ta-chia hydraulic Associations is irrigated by this river water. (Fig. 19) of this area, 24,400 hectares are two-crop paddy fields. There is no shortage of irrigation water in this basin.

For development of this basin, the good characteristics of the river ought to be fully utilized, and measures of preventing the future flood menance ought to be developed.

Projects for Development

There were three proposals for development of the Wu-chi basin: the first and second are alternate hydro-electric development plans and the third consists of other development plans.

First Proposed System of Hydro-power Development

The first proposed system consists of 5 plants at Tung-feng, Kwan-tao, Shih-kang, Pu-li No. 1 and Pu-li No. 2. Each plant is explained as follows:

1. Tung-feng Power Plant

This scheme covers a 30-meter high concrete dam on the headwaters of Pei-kang Chi, about one kilometer downstream from the confluence of Ho-shui Chi to divert 12 cms through a horse-shoe tunnel of 1.4 m radius in the right bank with a length of 5,600 m. The tunnel will reach the Yu-sheng region of the Mei-yuan She and the plant is to be located about 800 m downstream from the confluence of Tung-feng Chi. It is estimated that 14,094 kw of power could be generated with an effective head of 141 m. The tail water discharges back into the river.

2. Kwan-tao Power Plant

At the canyon 1,800 m downstream from the Tung-feng plant, another concrete dam, 30 m high, as planned to intercept the tail water from the Tung-feng Plant and the nearby tributaries and to divert a flow of 17 cms through a tunnel 8,100 m long in the left bank. The plant is to be situated at Pei-pa-la and will generate 27,709 kw under an effective head of 198 m.

3. Shih-kang Reservoir Power Plant

Shih-kang is 6.50 km northwest of Pu-li, on the Shih-kang-keng Chi, which has a drainage area 12.90 sq km above Shih-kang. It was proposed that an earth dam, 35 m high, and containing 590,000 M^3 of earth work be built across the gorge near Shih-kang to store 16,000,000 m^3 of water. This reservoir filled to capacity has a water elevation of 490 m and will have 1.30 sq km of water area.

This reservoir will have its intake from Pei-kang Chi. A diversion dam, 20 m high, is to be built on Pei-kang Chi upstream from Mei-yuan She, 1,500 m downstream from the Kwan-tao Plant. This 20-meter dam will control a watershed of 370 sq km. Any flow of Pei-kang Chi below 30 cms will be diverted through a 2,150-m tunnel into Shan-shan Chi (drainage area 16.10 sq km) where the water after passing a desilting basin, will enter another 5,450-m tunnel, which will feed into the Shih-kang Reservoir. Water will be taken from the reservoir through a pressure tunnel, 500 m long, to a surge tank, and then flow through 2 steel penstocks each 100 m long to the plant. The tail water will go to Nan-kang Chi.

The plant estimate follows:

Effective head	38 m
Max. power	6,200 kw
Firm power	2,500 kw
Average power	4,600 kw

4. Pu-li Plant I

A 53-meter dam, to be built 800 m downstream from the junction of Mei Chi and Nan-kang Chi, will create a reservoir with a total storage of 205,495,000 M^3. This reservoir will submerge the westerly fifth of the Pu-li basin. A power intake 29 m below the reservoir surface will give an effective storage of 170,000,000 M^3. The reservoir fully described in a following section will control a total watershed of 637 sq km of which 237.7 sq km is for Nan-kang Chi watershed. The plant will be located at Ta-mao-pu, Kuo-hsing. The pertinent figures follow:

Maximum Q	52.50 cms	Ordinary Q	33.80 cms
Effective head	10 6 m	Maximum power	46,000 kw
Firm power	29,700 kw		

5. Pu-li Plant II

This plant takes water from the tail-race of the Pu-li First Plant. The same water is taken through a 8,850 m long tunnel on the left of Nan-kang Chi to Tsu-kow-keng, Tsao-tun Hsiang, Nan-tou Hsien, where the forebay, penstock and power plant will be built. Here the max. effective head is 124 meters. The max. power is 54,000 kw and the firm power is 34,800 kw.

Second Alternate System of Hydro-power Development

The second system is an alternative plan and consists of 5 plants, the upper two being the same as the first system. The other three are Pei-kang Chi Plant, Kuo-hsing Plant and Tou-pien-keng Plant (Fig. 17) which are explained as follows:

1. Pei-kang-chi Plant (Plant (3') in Fig. 17)

The plant will be of run-of-river type. A 40-meter high concrete dam to be built in the narrow gorge of the Pei-kang Chi will intercept the tail water of the Kwan-tao Plant and the tributaries below the upper dam. This reservoir at full stage will have a water surface area of only 0.08 sq.km. The space behind the dam will soon be filled by silt deposit. Hence only a very minor regulating effect can be expected. A max. flow of 23.31 cms will be diverted by this dam through a 7,350 m long runnel on the left bank. A round power intake tunnel 1.92 m in diameter will take the water to a surge tank where the water enters the perstock to the Plant. Power of 33,590 kw can be generated with an effective head of 173 m.

2. Kuo-hsing Power Plant (Plant (4') in Fig. 17)

In Kuo-hsing, a concrete gravity dam, 55 m high, can be built to create a reservoir with a maximum water surface area of 3.96 sq km and an effective storage of 92,500,000 m^3 above the max drawdown of 30 meters. The plant located downstream from the dam will generate 14,800 kw with an effective head of 49 m and a discharge of 36 cms. The tail water flows back to the Pei-kang Chi.

3. Tou-pien-keng Power Plant (Plant 5' of Fig. 17)

The plant would be located at Tou-pien-keng 7 km east of Taichung City. The intake would be effected by a diversion dam 30 m high at Shuang-chi-tsui on Wu Chi below the confluence of Pei-kang Chi and Nan-kang Chi. This is also the site of the Wu-chi Reservoir Dam described in a later section. The water would be taken through a 10-km tunnel to the headwater of Nan-kang Chi, in the region of Ta-chien-chiao. A discharge of 41.30 cms with an effective head of 80 m will generate a maximum power of 27,000 kw. The tail water flows into a lower reservoir described in a subsequent section, where the water is regulated to 46 cms and flows to another plant (plant 6' of Fig. 17) right below the reservoir to generate 23,000 kw. at an effective head of 60 m. The tail water can be conveyed into canals irrigating 30,000 ha. between Ta-chia Chi and ~~Wu-Chi.~~

The distribution of irrigation water among Chang-hwa and other hydraulic Associations requires studying before project implementation since there are 9,800 ha. on the other (south) bank of Wu Chi now being supplied with irrigation water from Wu Chi.

Other Development Projects

Other development projects involve construction of multiple or single purpose reservoir projects. The possible dam sites, (Fig. 18) function, feasibility and priority are shown in the next table:

Reservoir	Function	Feasibility	Priority
Ma-hsi-to-pang	Power	Requires further study	A
Shih-kang	Power	Requires further study.	A
Pei-kang-chi	Multi-purpose	Requires further study	A
Li-yu-ku	Irrigation	Feasible	A
Nan-kang-chi	Irrigation and power	Requires further study	A
Pu-li	Power	ditto	A
Wu-chi	Multi-purpose	ditto	B
Tou-pien-nan-keng	Irrigation	ditto	A
Ta-keng	Irrigation	Feasible	B

For the following data, please refer to the tables in the Chinese version of the report:

Irrigated area under the various hydraulic associations

Information of 16 weather stations in the basin such as latitude, longitude, elev. date intervals of recording.

Monthly rainfall (from starting date to 1941)

Ave. monthly rainy days (some sta. up to 1941, some to 1935)

Flow records of two gaging stations (Chuan-chung-tao and Kuo-hsing) on Pei-kang Chi and one (Pei-shan-keng) on Nan-kang Chi

Temperature of eight stations in the Wu Chi basin

Tai-chung evaporation records (1900-1941)

The details of the above nine projects follow:

Ma-hsi-to-pang Reservoir (No. 25)
(See Fig. 20 - 24)

The dam site is located at Ma-hsi-to-pang, on the upper reach of the Pei-kang Chi. A storage of 92,540,000 m^3 can be obtained by building a 100-m high dam. An 800-m head can be developed. The project is primarily for power generation. The reservoir will control a watershed of 157.5 sq.km. The rainfall in this watershed is abundant and has a fairly uniform distribution. The average annual precipitation is 3,240 mm and the maximum daily is 339 mm. The 5-yr. record (1937-41) of Chuan-chung-tao River Gauging Station shows a maximum record of 284 cms., a minimum of 1.74 cms and an average of 17.9 cms. The maximum flood has been estimated to be 4,330 cms by using the rational formula.

Fig. 20 and 21 show that a 100-m high dam will have an effective storage of 68,340,000 with a drawdown of 40 meters. During the low stage period, October - February, the reservoir regulated flow will increase the low discharge from 1.74 cms to 10 cms. This increase would benefit greatly the lower power plants. The flow used for power generation ranges between 10 and 21 cms. The amount of power generation has a maximum of 16,500 kw and a firm power of 6,650 kw.

This reservoir will have a large capacity and the dam site is the only site on the headwater of Pei-kang Chi. If the power of the Wu Chi were to be developed, this project would be required to regulate the flow as well as to benefit the lower power system. The dam site region is not of easy access and very thinly populated. This situation would of course increase the construction difficulties. Due to the inconvenient access and shortage of camps, the Reconnaissance Party was unable to visit the site. The above study was based on 1 in 50,000 topographic map.

Shih-kang Reservoir (No. 26)

(See Fig. 25 - 28)

The proposed dam site is on Shih-kang Chi, a small tributary of the Ma-kang Chi. There have been two projected sites, Hsiao-pu She and Shih-kang-keng. (Fig. 25)

In Japanese time, it was proposed to build an earthdam at Hsiao-pu She on the Shih-kang Chi to form a reservoir which is also supplied by water diverted from Pei-kang Chi. It was reported by the local people that this damsite had been surveyed and a development plan had been made around 1943. Some bench marks were found near the foothill at Shih-kang-keng. This project was not built because World War II broke out.

Geology:

The dam site is at a region of rolling country and low hills. No rock outcrop was found. The Puli basin is of the Eocene Series of the Tertiary System, composing of alternate layers of sandstone and shale.

Reservoir Planning:

The drainage area at the Shih-kang Reservoir is only 11.58 sq. km. Therefore it is planned to divert a maximum of 20 cms from Pei-kang Chi water at Mei-yuan She where the drainage area is 341.60 sq.km. The diverted flow would go through 2 tunnels, 2.60 km and 3.50 km. before reaching the reservoir. The 2.6 km tunnel takes the water to a desilting basin on Shan-shan Chi, a small tributary of Pei-kang Chi. The desilting basin catches another water-shed area of 16.11 sq. km. of the Shan-shan Chi. Other engineering features are as follows (based on 1:50,000 topographic map)

Type of dam	Earthdam
Crest elevation	494 m.
Base elevation	454 m.
Height of dam	40 m.
Crest length	380 m.
Max. water level	490 m.
Dead water level	474 m.
Total storage	23,500,000 M^3
Effective storage	15,900,000 M^3
Dead storage	7,600,000 M^3
Earthwork	600,000 M^3

The original data are not available. Detailed survey is required.

Benefits:

The reservoir regulated flow has a minimum of 8 cms and an average of 20 cms. The maximum power to be generated is 6,200 kw. of which 2,500 kw is firm power.

Other information

A total of 130 ha. of land will be covered by the reservoir. Of these, 13 ha. are of paddy field, 78 of dry farming land and 39 of waste land. In addition, 60 families will have to be removed and 2 km. of highways will have to be relocated.

An existing highway and a Sugar Coorporation railroad lead from Pu-li to the damsite at Mei-yuan She. Earthdam material is locally available.

Although this project has only a small power benefit, it will greatly benefit the lower two projects of the Pu-li power system.

Pei-kang-chi Reservoir (No. 27)

(See Fig. 29 - 32)

The proposed dam site is near the intake of the Kuo-hsing Canal in Ta-an, Kuo-hsing Hsiang, about two kilometers upstream from the junction of Shui-chang-liu Chi and Pei-kang Chi. Based on the 1:50,000 map, the elevation of the riverbed at the site is 262 m. About one kilometer upstream from the site, the valley opens out into a table land about 40-50 meters above the riverbed. In order to create a large reservoir capacity, a dam must be higher than the table land. (Fig. 29)

Geology

The geologic formation is essentially of hard black shales and white siliceous sandstone of the Tertiary Age. The strike is approximately N 80°E. The dip is 15°-35°. No fault is found in the dam site.

Precipitation

The following rain gauge records are available.

Station	Period	Years
Sung-lung	1923-1944	21
Ho-huan-shan	1936	
Chui-fen	1935	
San-chio-feng	1912-1934	24
Wu-she	1936-1944	8
Pu-li	1902-1937	35
Ta-tu-cheng	1914-1944	30
Pei-kang-chi	1902-1943	41

Some of the above stations are too far apart and some are too close.

River flow

Gauging Station	Location	Period	Drainage A (Sq.Km.) above station
Chuang-Chung-tao	10 Km. above dam site	1937-1941	382.92
Kuo-hsing	2 Km. below dam site	1939-1940	518.79 (Pei-kang dam drainage area 430.54 KM^2)

The above discharge record shows that the discharge at Chuan-chung-tao for January-June, 1939 is larger than that of the lower station at Kuo-hsing. Whether this is a mistake or due to other reasons is not known.

The Kuo-hsing record is used for water study since it is very close to the proposed dam site (Fig. 30)

Flood Estimate

The flood at the confluence of Pei-kang Chi and Nan-kang Chi is estimated by the rational formula. Above the confluence, the drainage area is 527.50 Sq. Km. The estimated flood is 5,280 cms based on a daily rainfall of 466 mm. Since the drainage area above the dam site is only 430.54 sq.km the 5,280 cms for the flood discharge is considered satisfactory.

Regulated Flow

Based on an effective storage of 412,000,000 m^3, and the mass curve, the minimum regulated flow will be 33 cms and the maximum, 46 cms (Fig. 30)

Proposed Reservoir Features

Type of dam	Straight Gravity Concrete
Crest Elevation	404 m.
Base Elevation	262 m.
Height of Dam	142 m.
Crest Length	500 m.
Max. Flood Level	400 m. (Fig. 31-33)
Full Water Surface Level	390 m.
Total Storage	445,000,000 m^3
Dead Storage (Below Elevation 306 m)	33,000,000 m^3
Effective storage	412,000,000 m^3
Max. Spillway Capacity	2,940 cms
Spillway crest length	43 m.

Benefits

a. Power Maximum 39,000 kw. Average 28,000 kw.

b. Flood Control

Automatic Control Gates 10 m. high if installed above the spillway crest will hold 52,000,000 m^3 of water. Ordinary floods could be eliminated. Extraordinary floods could be reduced by 44.3% (Fig. 31-33).

c. Irrigation

The minimum flow recorded is 4.5 cms. After completion of the dam, the regulated flow could be 33 cms. This increased flow will greatly benefit the lower land. The proposed reservoir will inundate 297 hectares of land (287 hectares of double crop and 10 hectares of single crop), 200 family homes and involve the relocation of 3,000 meters highway.

Communication and Engineering material

There is a rural highway leading to the dam site from Kuo-hsing where it is connected with the provincial highways. The nearest large city is Tai-chung which is about 30 kilometers away.

Conclusion

Pei-kang Chi is the main stream of Wu-Chi and controls a large drainage area. The upper valley is narrow and steep. Landslides are prevalent. There is no good reservoir site. The central reach is wider, but there is not a good site in this stretch either. The proposed site controls four fifths of the drainage area and might be worthy of further investigation.

Li-yu-ku Reservoir (No. 28)

(See Fig. 34 - 48)

The proposed site at Li-yu-ku, 4 km east of Pu-li, is at the south end of a dry creek, where rain water collected in a depression makes a natural lake. During rainy season the amount of water in this lake may reach 500,000 M^3. During the reconnaissance on January 16, 1953, in the dry winter, the lake still contains considerable water. The local people report that the lake water is still abundant even in the driest year. This indicates that the underground strata is rather impervious and this location might be a good dam site.

Here the drainage area is only 3.40 sq. km. It has been suggested by the Neng-kao Hydraulic Association that water of Mei Chi, a tributary of Nan-kang Chi, may be diverted from the left bank of Nan-kang Chi at Shih-tzu-tou to this reservoir as a supplementary supply.

Geology

The proposed site is covered by brownish soil of disintegrated shale. No rock outcrop can be found. The geologic formation of the Mei Chi valley contiguous to this region is composed of lustrous, medium and coarse grained sandstone, and black shale of the Tertiary Formation. The dam site should be drilled to determine the silt deposit.

Stream Flow

There is no record for the creek water at Li-yu-ku. If the Mei Chi water is to be diverted, the following 5-year record of Mei Chi at Shih-tzu-tou would be of value.

Average Flow of Mei Chi in cms

	1940	1941	1942	1943	1944
January		1.94	1.94	1.48	2.15
February		2.12	1.60	1.52	1.16
March		6.96	1.24	1.71	2.00
April	3.08	9.89	1.31	6.89	35.03
May	9.49	16.32	4.30	2.14	5.27
June	20.69	27.45	5.48	7.03	17.56
July	12.70	10.06	6.85	22.72	8.14
August	8.31	7.95	11.27	19.67	7.88

	1940	1941	1942	1943	1944
September	16.16	5.95	7.22	6.55	3.87
October	5.01	3.94	4.34	3.45	2.30
November	2.53	2.56	1.86	2.98	3.26
December	1.47	2.85	1.56	2.30	2.60

Reservoir Planning

Two dam sites (A and B, Fig. 34) are proposed by the Reconnaissance Party. Three alternate plans, all based on the idea of diverting Mei Chi water through a 4.50 km canal and a 350 m. tunnel are tabulated as follows:

	1st Plan	2nd Plan	3rd Plan
Drainage area (sq.km)	3.40	3.40	20.20
Type of dam	earth dam	earth dam	earth dam
Elev. max. water surface	542	562	560
Free board (m)	3	3	1.66
Crest elev.	545	565	563.5
Base elev.	520	520	515
Max. height (m)	25	45	48.5
Crest length (m)	400	480	950
Earth volume (M^3)	750,000	2,920,000	6,730,000
Storage capacity (M^3)	8,240,000	22,300,000	85,000,000
Dead storage (M^3)	540,000	300,000	15,500,000
Effective storage (M^3)	7,500,000	22,000,000	69,500,000
Max. flood (cms)	110	110	1,390
Max. spillway capacity (cms)	23.5	23.5	150
Diversion canal capacity (cms)#	4.00	7.80	20.00

Including 1.43 cms for the existing irrigation canal, Shou-cheng Canal.

Benefits

	1st Plan	2nd Plan	3rd Plan
Irrigation (ha.)	1,503	1,800	1,800
Power (kw)		1,700	1,700

Conclusion

The natural lake and some dry land and some uncultivated land will be under the reservoir. The communication is convenient. Highways lead from Pu-li to Tai-chung, Sun-moon Lake and Wu-she. The dam site is only 500 m. from the Pu-li Wu-she Highway. Barth dam material can be collected nearby.

In the Pu-li basin, there is a total area of 3,800 ha., part of which is not yet irrigated and depends on this reservoir for supply of irrigation water.

The silt trouble will not be so serious since the reservoir depends largely on the flow diverted from Mei Chi.

The water storage capacities per cubic meter of earth dam for the above three plans are 11.00, 7.70, and 12.70 M^3 respectively. The first plan is the easiest one to build because it involves the lowest dam and the smallest amount of fund.

Nan-kang-chi Reservoir (No. 29)

(See Fig. 49 - 64)

This proposed site is at Wai-chia-tao-keng, five kilometers south of Pu-li. A concrete gravity dam is proposed to be built at the gorge. The Nan-kang Chi originates from the Mt. Shui-she-ta and Mt. Mao-lan, of the Mt. Hsin-kao. The small tributaries from Yu-chih, Ta-lin, Mao-lan, Mu-li-lan and Nei-chia-tao-keng meet at a point upstream from the site, forming a fan-shaped basin collecting a watershed of 76.3 square kilometers.

Geology

The geologic formation of Nan-kang Chi basin is largely of Wu-lai Series of the Tertiary, composing of medium grained sandstone, black slate, and dark gray shales. The outcrops near the dam site are black slate and dark gray shale with a strike of N40°E and a dip of 75°. The left abutment is good, but the right abutment is comparatively poor, crevices and joints being prevalent.

Site Problem

During the reconnaissance of this region on January 20, 1953, the discharge was estimated to be 1.20 cms. The water looked clear. The farmers reported that the flow was dirty during floods but clear during ordinary or low flows. No silt data are available. The silt trouble could be reduced by work of watershed management.

Precipitation

No rain gauge records are available in the Nan-kang Chi basin. Data for the three nearby stations at Shui-she, Pu-li and Ta-tu-cheng can be used for reference. The maximum daily and yearly average rainfall is listed as follows:

	Shui-she	Pu-li	Ta-tu-cheng
Max. daily rainfall (mm)	315	379.70	451.70
Yearly average rainfall	2727.90	2317.40	2471.20
Years of record	8	33	30

River Flow

No flow records are available upstream from the proposed dam site. Some measurements are available at a lower station named Pei-shan-keng. The flood has been estimated by the three following methods.

a. By synthetic unit hydrograph method (Fig. 52-54)

$q=3.12$ cms/1mmR (R=Max. daily rainfall)

R=451.7 mm.

$Q=qR=3.12 \times 451.7 = 1,410$ cms.

b. By rational formula

Q=3,340 cms.

c. By Creager's equation (Creager & Justin: Hydroelectric Hand-book, p 62)

C=100

A=76.5 sq. km. = 29.5 sq. mi.

q=2000 cfs/sq. mi. = 56.6 cms/sq. mi.

$Q = qA = (56.6)(29.5) = 1,670$ cms

Planning Reservoir Features

Type of dam	Ogee type concrete gravity
Crest elevation (Fig. 50)	540 m.
Base elevation (Fig. 50)	491.50 m.
Height of dam (Fig. 50)	48.50 m.
Crest length	70.00 m.
Drainage area	76.50 sq. km.
Max. water surface area	3.24 sq. km.
Spillway crest length	50 m.
Spillway capacity (Fig. 55-59)	1,030 cms.
Estimated concrete volume of dam	85,000 M^3

Benefits

a. Power: From a mass curve based on the Pu-li records, it is estimated that a regulated flow of 2.65-4.10 cms might be obtained. Assuming a maximum drawdown of 25 m. and a tail-race elevation of 470 m., a maximum head of 70 m. can be obtained. Then

$$\text{Minimum power} = \frac{2.65 \times 1000 \times 57.5}{102} = 1,500 \text{ KW}$$

$$\text{Maximum power} = \frac{4.10 \times 1000 \times 57.5}{102} = 2,300 \text{ KW}$$

b. Irrigation: Assuming a duty of water of 538 hectares/cms (JCRR 1951 Annual Report) a total area, 2210 ha., can be supplied with the regulated flow for irrigation. This would solve the water problem in the Pu-li basin.

c. Flooded Area: The flooded area will include 123.6 ha. of rice field, 30.9 ha. of dry land, 23 ha. of forest and waste land, and 126.5 ha. of public land. In addition, 50 families occupying about 2 ha. will have to be removed, four km. of Taiwan Sugar Cooperation light track railroad from Wai-che-cheng to Pu-li, another 15 km. from Pu-li to Yu-chih and 5 km of power and telephone lines have to be relocated.

d. Transportation and Engineering Material:

Highways from Pu-li to Tai-chung and Shui-li-keng and light railroads from Pu-li to Yu-chih and Wai-che-cheng can be used for transportation of engineering materials. Aggregates can be collected from both upstream and downstream of the dam site. The concrete aggregates for Wu-she Dam are being collected from Chu-tzu-shan, about one kilometer downstream from the proposed dam site.

Pu-li Reservoir (No. 30)
(See Fig. 65-70)

The proposed dam site is about 800 m. downstream from the confluence of Mei Chi and Pei-kang Chi, and about 300 m. upstream from the existing intake of Pei-shan-keng Hydro-plant. The site is very good because a low and narrow dam would create a reservoir of large capacity. (Fig. 65) The only drawback is that the reservoir would flood about twenty percent of the Pu-li basin which is agriculturally prosperous. The possible power house at this location is described in a preceding paragraph.

Reservoir Planning

The proposed dam is a 53 m. concrete dam. The power plant is to draw its supply from an intake tower in the reservoir near the right bank through a 1.8 km. tunnel, using an effective head of 106 m. The flow through the plant will be 52.5 cms as a maximum and 33.80 cms as an average. The tail water goes to Nan-kang Chi. The general features of the reservoir are as follows:

Type of dam	Ogee type concrete gravity
Maximum water surface elev.	430 m.
Elevation of river bed	377 m.
Height of dam	53 m.
Length of dam	160 m.
Max. drawdown	29 m.
Total storage	205,490,000 M^3
Effective storage	170,000,000 M^3
Dead storage	35,490,000 M^3
Max. flood (estimated by using rational formula)	3,390 cms
Crest length of spillway	150 m.
Head on spillway crest	3.10 m.
Concrete volume of dam (estimated)	180,000 M^3
Drainage area - direct	349.68 sq. km.
indirect	341.60 sq. km.

Other Information

The power to be generated is 29,700 kw as firm power. The maximum power is 46,000 kw and the average 34,000 kw. The reservoir formed by a 53-meter dam would flood 1,000 hectares of cultivated land, 800 families and 12.50 km. of transportation line.

The Tai-chung Pu-li Highway runs through the site. Good concrete aggregates are available in the vicinity.

If a 123-meter dam is to be built, the capacity would be 2,985,000,000 M^3. This site is the best on this island, as far as the reservoir capacity is considered. It would not be economical if the reservoir is solely used for power, since there are many good sites for power development.

Wu-chi Reservoir (No. 31)
(See Fig. 71-79)

(This is also the Tou-pien-keng Power Plant)

The proposed reservoir will have a dam at Shuang-chi-tsui, Kuo-hsing Hsiang, Nan-tou Hsien, about 200 m. downstream from the junction of Pei-kang Chi and Nan-kang Chi. This dam site is in a narrow gorge and the valley upstream from it widens out to form a large storage capacity. A hydropower project was proposed during Japanese Occupation period for a 40-meter dam here diverting a flow through a 1,200 m. tunnel along the left bank for generation of 12,200 kw at a head of 49.5 m. A high dam would for a reservoir large enough for multiple purposes of power, flood control, and irrigation.

Geology

In the vicinity of the dam site, the geologic formation is of Ma-an-liao Strata (Miocene Series) of the Tertiary. There is the Ta-heng-ping-shan Syncline in a north and south direction. The formation just upstream from the junction of Pei-kang Chi and Nan-kang Chi is of the Pai-mao Strata, also of the Miocene Series of the Tertiary. Here is the Kuo-hsing Anti-syncline also in a north and south direction. About 800 m. east of the junction are the Kuo-hsing Fault and the Chu-keng Fault in north and south direction across the reservoir. About 2 km. downstream from the dam site are the Ta-heng-ping-shan Fault Chien-kow and Shuang-tung Fault. Ma-an-liao Strata is composed of thick layers of sandstone and alternate layers of sandstone and shale. Pai-mao Strata is composed of dark shales intruded by sandstone. The rock outcrop at the dam site is composed of thick layers of sandstone intruded by shale, with a strike of N40°E and a dip of 50°. The rock is hard and massive, but the dip changes abruptly due to the syncline. Whether the geologic condition is favorable for a reservoir site requires further investigation.

Precipitation

There are eleven rain gauging stations in Wu Chi, Ta-chia and Cho-shui valleys. (PWCB Bulletin No. 9) The periods of record are as follows:

Station	Years of Record	Station	Years of Record
Sung-ling	1923-1944	Shui-she (Cho-shui Chi)	1932-date
Wu-she (Cho-shui Chi)	1937-1939 1951-date	Shui-ti-liao (Ta-chia Chi)	1902-1945
Ta-tu	1922-date	Pei-kang-chi	1902-1943
Nan-tou	1920-date	Chung-liao	1933-date
Chui-fen (Cho-shui Chi)	1955-date	San-kwai-tso	1918-date
Ta-tu-cheng	1914-1944		

The maximum precipitation for the watershed above the dam site has been calculated to be 401.70 mm. (by Thiessen's method) This was used in flood estimate. (Fig. 73)

Stream Flow

The available stream flow data are 5 years (1937-1941) records of Chuan-chung-tao Station, 3 years (1937-1939) of Pei-shan-keng Station, and 2 years (1939-1940) of Kuo-hsing Station. The mass curve in Fig. 74 and duration curve in Fig. 75 are based on these records.

The flood was estimated by using the "rational formula".

$Q = 0.2778\ frA$ (See PWCB Bulletin #9, P. 154)

$A = 959.8\ km^2$

$H = 1.81\ km^2$

$L = 60\ km$

$$W_2 = 72(\frac{H}{L})^{0.6} = 72(\frac{1.81}{60})^{0.6} = 72(\frac{1}{33.2})^{0.6} = 8.78$$

$$T = \frac{L}{W_2} = \frac{60}{8.78} = 6.83\ hrs.$$

$$r_o = 401.7/24 = 16.72\ mm/hr.$$

$$r = r_o(\frac{24}{T})^{2/3} = 38.7\ mm.$$

$$Q = 0.2778\ (0.8)\ (38.7)\ (959.8) = 8,230\ cms.$$

Reservoir Features

Type of dam	Concrete arch gravity
Top elevation	344 m.
River bed elevation	220 m.
Height of dam	124 m.
Top length	580 m.
Full water level	330 m.
Maximum flood level	339.90 m. (Fig. 78)
Total capacity	710,000,000 M^3 (Fig. 72)
Effective capacity	600,000,000 M^3 (Fig. 72)
Dead storage	110,000,000 m^3 (Fig. 72)
Max. spillway capacity	3,500 cms (Fig. 77-79)
Spillway crest length	50 m.

Benefits

a. Power

The regulated flow to be used by the hydro-plant will be 54 cms. The maximum is 77 cms. (Fig. 74-76). The firm will be 44,500 kw and the maximum output will be 63,400 kw.

b. Flood Control

A total volume of 180,000,000 m^3 is available for flood control. This would reduce 58.1% of the uncontrolled flood peak.

c. Irrigation

The tail water can be used for irrigation.

Conclusion

The reservoir controls 959.76 sq. km. of watershed and is an ideal site for a thorough solution of flood control problem in Wu Chi basin. One disadvantage of this site is the large area flooded by the reservoir, which includes villages named Shuang-chi-tsui, Kan-tzu-lin, Lung-tu-sheh, Chu-keng, Kuo-hsing, Mei-tzu-chi, Ta-mao-pu, Chung-kwa-keng, Wai-pan-an, etc., 750 hectares of paddy field, and 1,100 hectares of hilly ground. The existing Pei-shan-keng Hydro-power Plant will also be under water. In addition, 12 km. of highway have to be relocated. The geologic condition of this site is another phase worthy of further investigation.

This site and the Pei-kang-chi-Reservoir site are the two good sites in the Wu Chi basin. The latter site is inferior in flood control benefit and superior in geologic formation.

For the method of estimation of maximum and average power generation by use of "duration curve" and "duration area curve", see H. L. Foster's article in ASCE Transaction Volume 99 (1934), pp. 1213-1267.

Tou-pien-nan-keng Reservoir (No. 32)

(See Fig. 80 - 88)

A plain area of 2,500 ha lies east of Tai-chung City on the east bank of Ta-li Chi, west of the foot of the hill, south of Chun-kung-liao, and north of Wu-feng, about 3 km in the east and west direction and 12 km in the north and south direction. Only small areas of low elevation along the creeks are being irrigated. In order to irrigate the 2,500 ha. and to supply domestic water supply for the 10,000 people in this region, two reservoir projects, Tou-pien-nan-keng Reservoir Project and Ta-keng Reservoir Project are proposed.

Tou-pien-nan-keng Chi is a branch of Ta-li Chi, a tributary of Wu Chi. (Fig. 80) It drains 74 sq. km. The low flow is only nominal and enough for irrigation of over ten hectares. It was proposed during the Japanese Occupation period to build an earth dam in the gorge on the Tou-pien-nan-keng Chi. After Restoration in 1948 the PWCB Tai-chung Construction Office made a prelininary plan. Topographic Maps of 1:25,000 scale are available.

Geology

The rock outcrop is brownish, soft, and medium grained sandstone intruded by shale, striking N 82° E with a dip of 40° upstream. The geologic condition is in general good but borings are necessary.

Precipitation

No rainfall record is available in the Tou-pien-keng valley. Records from the following rain gauging stations are available.

Station	Location	Elev.	Yrs. of record
Tai-chung City	7 km. West of dam site	-	1928-1952
Ta-nan Nursery, Hsin-she-chuang	12 km N. E. of dam site	500 m.	1933-date
Ta-tun Hydraulic Assn., Wu-feng	8 km S. W. of dam site	-	1952-date
Shui-ti-liao	11 km N. E. of dam site	520 m.	1902-1944

Stream Flow

Tou-pien-kang River Gauging Station was established in April, 1940 and dropped in December 1943. It was reestablished in January 1947 and dropped again in September 1948. During the observation periods, records of June, July and August are incomplete due to washing out of the gauges. The following records are missing.

1940	June 5 - September 18.
1941	April 5 - 30.
1942	June 25 - July 4, July 13 - 21.
	August 9 - 31, September 13 - 21.
1943	June 22 - July 23.
1947 - 48	Only gauge records available.

In view of the incomplete flow record, some study was made on the relation between rainfall and stream flow. In the above rain gauging stations the Tai-chung Station was considered too low (Elev. 80 m.) to be applicable. The Wu-feng Station record is too short. The Shui-ti-liao Station is too far from the area concerned. Hence date from Ta-nan Station was selected for such study. The rainfall in millimeters and the runoff in cms-days for each month of each year in the period 1941-1947 were studied. The runoff coefficient for these years is found to be ranging between 0.57 and 0.77. The stream flow data for 1941, 1942, and 1947 used for the computation are measured records and that for 1943, 1944, 1945 and 1946 are estimated figures.

The catchment basin of the Tou-pien-nan-keng Dam site is 60.4% of that of the Tou-pien-keng Gauging Station. The flow hydrograph at the dam site is obtained by applying a correction factor to the figures for the Tou-pien-keng Gauging Station. (For detailed computation see the Chinese version of the report).

Flood Estimate

The flood is estimated by using the rational formula:

$Q = 0.2778 f r A$

A (Drainage area) = 44.60 sq. km.

f (Runoff coeff.) = 0.33

r_o (Max. rainfall) = 485.3/24 = 20.2 mm (Shui-ti-liao Rain Gauging Station)

L (Length of basin) = 11.94 km.

H (Diff. of elev. in the basin) = 0.91 km.

$W_2 = 72(\frac{H}{L})^{0.6} = 15.30$ km/hr.

$T = \frac{L}{W_2} = 0.782$ hrs.

$r = r_o(\frac{24}{T})^{2/3} = 198.2$ mm.

$Q = frA = 2,040$ cms.

The time base of the hydrograph (Da) has been found to be 14 hours. (For the method used, see Hydroelectric Handbook by Creager and Justin, p. 79)

Water Requirement

The total water requirement is estimated for 2-crop paddy field. The first crop (Feb. 1-Jun. 26) requires 949.6 mm. and the second crop (Jun. 15 - Oct. 31) requires 1,006.5 mm. The green manure in September requires 45 mm. The total requirement is 2001.1 mm. The monthly requirement per 10,000 ha. is tabulated in the following:

Water Requirement

Month	Depth (mm)	10^6M^3/10,000 ha.	CMS (Ave.)
January	-	-	-
February	51.6	5.16	2.13
March	241.0	24.10	9.00
April	270.0	27.00	10.40
May	279.0	27.90	10.40
June	146.2	14.62	5.64
July	225.8	22.58	8.48
August	279.0	27.90	10.40
September	270.0	27.00	10.40
October	193.5	19.35	7.25
November	45.0	4.50	1.73
December	-	-	-

The effective rainfall data from the Tai-pei Agriculture Experiment Station are shown below:

January - 90%	May - 60%	September - 90%
February - 75%	June - 60%	October - 90%
March - 60%	July - 75%	November - 90%
April - 75%	August - 75%	December - 90%

The net monthly water requirement for each of the seven years 1941 - 1947 is thus obtained by subtracting the effective rainfall from the total water requirement. Assuming 900 ha. of land to be used as two-crop paddy field, the maximum storage capacities required for the following dry periods are shown in the following:

Period	Eff. Storage Required
Oct. 1941 - Apr. 1942	3,830,000 M^3
Sept. 1942 - Apr. 1943	1,800,000 M^3
Aug. 1943 - May 1944	2,800,000 M^3
Sept. 1944 - Apr. 1945	1,900,000 M^3
Sept. 1945 - May 1946	2,300,000 M^3
Oct. 1946 - Apr. 1947	1,900,000 M^3

Including 20% for evaporation and percolation loss, the maximum storage required for 900 ha. of 2-crop paddy field is 4,600,000 m^3 (3,830,000 x 1.2).

Another arrangement of the total 2,500 ha. is 500 ha. of 2-crop, 1,000 ha. each of first and second crop. This arrangement would require a total effective storage capacity of 5,800,000 M^3. Including evaporation and percolation the required storage is 7,000,000 m^3.

The curve in Fig. 83 shows an effective storage of 4,800,000 m^3 at an elevation of 158 m. assuming dead storage below 140 m. If an automatic gate, 3 m. high, is installed on the spillway crest, an additional effective storage of 2,200,000 m^3 could be obtained, raising the total effective storage to 7,000,000 m^3, which would be adequate for the irrigation of the 2,500 ha. of land.

Reservoir Features

Location	Tou-pien-nan-keng
Watershed	44.60 sq. km.
Type of dam	earth dam
Top elevation	165.80 m.
Base elevation	127.00 m.
Height of dam	38.80 m.
Crest length	240.00 m.
Spillway crest elevation	158.00 m.
Max. water surface elev. (Gate closed)	161.00 m.
Dead water elevation	140.00 m.
Total storage (Gate opened)	5,400,000 m^3
Total storage (Gate closed)	7,600,000 m^3
Dead storage	600,000 m^3
Effective storage (Gate closed)	7,000,000 m^3
Max. flood elevation	163.8 m.
Max. spillway capacity	1,500.00 cms.
Earth dam volume	1,118,000 M^3

About 30 family homes will be inundated. Very little paddy field will be submerged.

Ta-keng Reservoir (No. 33)

(See Fig. 89-95)

The proposed dam site is on Ta-keng Chi, the headwater of Ta-li Chi, about 300 m. upstream from the Ta-keng Tsun. The site controls a watershed of 19.30 sq. km. Topographic maps for the dam site (1:500) and reservoir (1:2,500) had been made. During the reconnaissance in March 1953, the PWCB had a party there to make further survey and to draft a preliminary plan for irrigation.

Geology

The rock outcrop is brownish, soft sandstone intruded by alternate thin strata of shale and sandstone. This shale resembles slate. When soaked in water, very fine powder can be scratched off the shale with the finger nail. The rock strata dip downstream, indicating necessary consideration of possible leakage.

Precipitation and Stream Flow

No rain gauging station in this small basin is available. The three stations at Tai-chung, Ta-an Nursery, and Shui-ti-liao mentioned in the Tou-pien-nan-keng Reservoir Project may be used.

The Ta-keng-chi River Gauging Station was established in 1940 and abolished in 1949. The record was incomplete. There was no record in 1945 - 46. The gauge was occasionally washed out. Only stages were recorded during 1948 - 49. The cross-section at the station changes greatly during floods. The records in CMS are as follows:

Year / Month	1940	1941	1942	1943	1944	1947	1948	1949
1	-	3.42	1.97	1.63	1.86	2.25	-	-
2	-	5.68	1.72	5.34	0.95	2.07	-	-
3	-	23.24	0.75	6.53	2.87	2.92	-	-
4	15.89	17.24	1.45	6.62	18.83	9.12	-	-
5	51.04	11.68	5.54	2.70	80.49	36.71	-	-
6	112.85	71.52	5.65	53.04	170.78	168.34	-	-
7	24.54	123.05	15.84	56.16	18.90	48.91	-	-
8	10.38	24.99	7.61	33.26	11.93	42.23	-	-
9	0.84	18.53	24.29	5.45	5.72	7.16	-	-
10	3.82	1.42	3.69	0.81	1.63	6.59	-	-
11	2.20	3.58	17.30	1.59	1.77	2.45	-	-
12	1.36	5.56	1.58	2.30	3.90	2.30	-	-

NOTE: Records underlined are incomplete.

The flood has been estimated to be 928 cms. by using rational formula.

$$Q = 0.2778 f r A$$

$A = 19.30$ sq. km. $f = 0.80$ . . $L = 9.72$ km.

$H = 0.627$ km. $r_0 = \frac{485.3}{24} = 20.2$ mm./hr.

$T = \frac{L}{W} = 0.685$ hrs. $r = (\frac{24}{T})^{2/3} = 216.50$ mm.

$Q = 928$ CMS.

Area to be Irrigated

Due to the insufficient water supply of the Ta-keng Chi, only a part of the 2,500 ha. in the Che-lung-pu district can be included in this project. The proposed plan has been to convert single crop into double crop paddy field and to convert dry farming land into single crop paddy field. The total that could be thus converted is 520 ha., of which 220 ha. (100 of single crop and 120 of dry farming) belong of Pu-tzu and 300 ha. (50 of single crop and 250 of dry farming) belong to San-pien.

A study of water demand and supply shows that a demand of 1,400,000 m^3 during 1941-42 is a maximum. Including 20% for evaporation and percolation, the required reservoir storage will be 1,650,000 m^3 (Fig. 95)

Reservoir Features

Earth dam top elevation	188 m.
Earth dam base elevation	163 m.
Dam height	25 m.
Length of dam	170 m.
Full water level	183 m.
Dead water level	176 m.
Total storage	2,550,000 m^3
Dead storage	650,000 m^3.
Effective storage	1,900,000 m^3
Max. flood level	186 m.
Spillway capacity	800 cms.
Earth dam volume	319,000 m^3.

Other Considerations

The stored water is adequate for the irrigation of 520 ha. and the domestic supply for 10,000 people. The reservoir flooded area will include about 30 families with little paddy field. The flooded-area consists of dry farming land, waste land, and forest.

The transportation is convenient. Clayey material for the earth dam has to be located.

The small watershed is a drawback to this project. Ta-keng is only about 8 km. away from the Ta-chia Chi. Diversion of Ta-chia water to Ta-keng might be considered for irrigation as well as power development.

Conclusion

A review of the two projects reveals that the Tou-pien-nan-keng Reservoir is superior to the Ta-keng Reservoir. But both sites will have the silt problem. The life of the reservoir should be investigated.

The water supply of the two reservoirs could be increased by diverting the Ta-chia Chi and Wu Chi into them. Diversion of the Ta-chia from a place about 2 km. upstream from the Ta-nan Third Nursery through an 8-km. tunnel to the Ta-keng Reservoir will develop a head of 240 m. Diversion of the Wu Chi from Kuo-hsing through a 10-km. tunnel to the Tou-pien-nan-keng Reservoir will develop a head of 100 m.

Cho-shui Chi Basin

(See Fig. 96)

General Description

Cho-shui Chi, in a total length of 170.10 km, drains a watershed of 3,114 sq. km. Along its headwater tributaries, Wu-she Chi and Wan-ta Chi, and the main stream down to Wu-chieh Dam, hydro-power has been developed, constituting the major portion of the Tai-wan power system. The central reach is mostly undeveloped. The lower stretch is an alluvial plain. On the two banks of the lower portion, dikes have been built for flood control.

An area of 107,000 ha. in the plain under the administration of five local hydraulic associations is supplied by Cho-shui for irrigation. Of this area, 43,800 ha. are of two-crop paddy field, the remaining being one-crop paddy field, rotation plantation field, etc. It is estimated that there are another 42,000 ha. of dry farming land and tidal land. Due to the vast area to be irrigated and the low flow during low stages, (Minimum Q at Lin-wei 23.09 cms) there have been serious water shortage and disputes have been very complicate.

During floods, the turbulent current washes away levees, floods low land, and carries large quantities of sand, gravel and debris resulting in numerous unstable streams. The riverbed in the lower reach is gradually rising. The government has to invest immense amount of money for dike maintenance and flood control. Yet the menace of flood is ever increasing.

The geologic formation along the upstream tributaries Wan-ta, Tan-ta, Chun-ta, etc. is black slate, brittle, weak and easy to disintegrate. The following table gives the appearance of the water at various places during reconnaissance survey:

River	Place	Appearance of water	Remarks
Wu-she	Just above Wu-she Dam	Clear	
Wan-ta	Ao-wan-ta	Muddy	
Cho-shui	Wan-ta junction	Muddy	Due to muddy Wan-ta
Cho-shui	Just below Wu-chieh Dam	Clear	Due to desilting effect.
Cho-shui	Su-hsi Chi junction	Clear	Su-hsi Chi is clear during dry season.

River	Place	Appearance of water	Remarks
Cho-shui	Chia-she Chi junction	Clear	Chia-she Chi is clear during dry season.
Cho-shui	Chun-ta junction	Muddy	Tan-ta and Chun-ta are both muddy.
Cho-shui	Lung-shen-chiao	Muddy	Chen-yu-lan Chi is clear during dry season.

In view of the above situation it is obvious that Cho-shui basin development would involve projects of two categories: (a) those for control of silt in the headwaters and (b) those in the middle stretch for multi-purpose development.

Trpography

Cho-shui, running through Nan-tou, Chang-hwa, Chia-yi and Yun-lin of West Taiwan, is the second largest river on this island. The upper and central valleys belong to three high ranges of the island, Central Range, Mt. Hsin-kao and Mt. A-li. The eastern end of the Cho-shui basin is the divide of Cho-shui Chi and Ta-chia Chi headwaters. The northern boundary extends from the east peak of Mt. Ho-huan (3,418 m.) in a south west direction to connect with San-chio-feng (2,374.6 m.), Mt. Kwan-tou (1,534.8 m.), Mt. Tui-wan, Mt. Mai-hou Mt. Ta-chien, etc. to adjoin Wu-chi, Pei-kang Chi, and Nan-kang Chi. Starting from Mt. Ta-chien, the range rises again to join Mt. Shui-she-ta (2,057.6 m.) and Mt. Pu-chi (1,351 m.). The divide range ends in the headwater of the Shui-li Chi.

The northeastern portion of the basin, from Mt. Ho-huan to the north peak of the Mt. Chi-lai-chu, adjoins Li-wu Chi. From here to Mt. Chi-lai-chu (3,558.90 m.), Mt. Neng-kao (3,261.40 m.), Kwan-men, Mt. Ta-shih-kung (3,048.5 m.), Mt. Tan-ta (3,370.9 m.) etc., the divide adjoins Hwa-lien Chi valley on the east. The boundary then turns southwest to Mt. Mei-po-la-sze (3,806.10 m.) and Mt. Hsiu-ku-luan (3,803 m.) to divide the Hsiu-ku-luan Chi valley and Cho-shui Chi valley. The dividing range then runs through Pa-tung-kwan (2,840.6 m.) to Mt. Pai (3,833 m.) and Mt. Yu of Mt. Hsin-kao and Mt. Erh-yu of Mt. A-li (2,588 m.) to adjoin the Hsia-tan-shui valley. This portion of the range runs through the highest peak (3,950 m.) on this island. The divide then runs north to Mt. Wan-sui (2,467 m.) and westward to peaks (above 1,500 m.) near Shui-che-liao. Here the boundary is adjacent to Tseng-wen Chi valley on the south. From here the range slopes toward the plain.

The basin consists of the most mountainous and precipitous slopes where detritus avalanches are prevalent. Along the river, there are gentle basins as the Sun-moon Lake.

Geology

The geologic formation within the basin is mostly Tertiary. The rocks near Tan-ta Chi are graphite stone and laminated sandstone of Tertiary. Westward from Tan-ta Chi the rocks are slate and lustrous, medium-grained sandstone, and black shale. Further downstream, the rocks are lustrous coarse grained sandstone lying southward from north of Sun-moon Lake. Still further downstream the rocks are dark gray sandstone and shale, and soft, lustrous sandstone. The formation west of Chi-chi and in the coastal plain is all of sand-gravel-clay of the Quaternary.

Forest

In the headwater region above 3,000 m. there are forests of conifers, hardwoods or both. The watershed is fine. In the Wu-she district, at the northwest side of the river there are aborigines who use to clear the mountain slopes by fires to plant sweet potato and German Millet. In the center reach, only conifers grow on Mt. Chih-mao and Mt. Luan-ta. Around Sun-moon Lake forests are almost all hardwoods. Along the river cultivated lands are sometimes seen. At Chien-cho-wan She and Jen-lun She, irrigated land can be seen. The lower basin is all cultivated. Bamboos are abundant in Chu-shan.

Rainfall

The annual rainfall in the upper stream of the basin where mountains, about 3,000 m. stand, reaches 4,800 mm., the central basin, 2,500 mm., the lower basin 1,500 mm., and the estuary, 1,270 mm. Rains are abundant in May through August, scarce from November through January. The rain is maximum in June and minimum in November. The abundant rainfall in the summer is due to the monsoon from the southwest, thunderstorms, and typhoons. The number of rainy days in a year in this basin is 100-150 days. The northeastern basin near Ying-feng, Wei-shang, Meng-kao may have around 180 days of rain.

There are 28 rain gaging stations of which 6 started recording from 1903; 5 from 1912-1913, 8 from 1922-1928, and 9 from 1930-1937. Six stations were discontinued. The elevations of these stations range from 10 m. to 3,416 m. above the sea level.

Discharge

Considering the river above the confluence of Ching-shui with Cho-shui, the change of river flow is about the same. Stated in discharge per 100 sq. km., the figures are as follows:

Very low flow	1.50 cms
Low flow	2.60 cms (1.7 times very low flow)
Ordinary flow	5.10 cms (3.4 times very low flow)
High flow	8.70 cms (5.8 times very low flow)
Yearly average	8.80 cms

Considering Ching-shui Chi and the lower Cho-shui Chi, the ordinary flow is usually small and the high discharge is about the same as in the upper-stream. The yearly average is 12.53 cms.

There are five river gaging stations, one on Tan-ta Chi, one on Chun-ta Chi, two on Chen-yu-lan Chi, and one on Ching-shui Chi. The longest record is only 4 years.

Temperature

The yearly average temperature in the lower basin is between 23°C - 24°C. It decreases gradually with increase of elevation.

Temperature records for 19 stations in this basin are available. The period of record ranges from 2 to 60 years.

Location	Elevation	Temperature (°C) Annual Ave.	Jan.	Feb.	July
Pa-tung-kwan	2818	9.4	4.3	4.9	12.9
She-tou	40	24.8	19.2	18.5	29.6
Ma-hsi-ta-lun She	1573	17.3	12.1	13.0	21.2

Evaporation

Evaporation records for A-li-shan (2406 m.) in the period 1934-1941 are available. The yearly and monthly averages (mm) are listed as follows:

January	62.3	May	65.1	September	58.5
February	59.5	June	62.8	October	73.3
March	60.3	July	59.0	November	73.0
April	69.3	August	58.6	December	73.1

Yearly Average 774.6

Communication

The communication in the lower basin downstream[1] from Chi-chi is convenient since there are existing highways and railroads. A railroad branch was built from Erh-shui to Wai-che-cheng through Shui-li-keng for the construction of the Sun-moon Lake Power System. On the main river, a highway leads to Lung-shen-chiao. On the tributary, another highway was built leading from Pu-li to the Wu-she Dam and Wan-ta Power Plant. On other tributaries as Wan-ta Chi, Su-hsi Chi, Chia-she Chi, Tan-ta Chi, Chen-yu-lan Chi, etc. Only trails are available. Communication in the headwaters and the central stretches of tributaries Tan-ta and Chun-ta is especially inconvenient since the aborigines moved away to the tributary Chen-yu-lan Chi. Above Chih-mao very few people appear. Accidentally few wood cutters go there. On Chen-yu-lan Chi, a highway leads up to Nei-mao-pu. Above Nei-mao-pu, there is only temporary highway for shipment of lumber. Upstream from Tung-pu only trails are available.

Along Ching-shui a highway leads up to Lao-shui-keng; however, this road is always subject to flood because it runs along the riverbed. On the Ching-shui headwater, the Provincial Water Conservancy Bureau built a road to Tsao-lin Natural Reservoir. That road was cut after the failure of the natural reservoir in 1951.

Basin Development

The basin development may be considered in the following four districts:

1. The Sun-moon Lake Hydro-power Development Region

The region consists of (a) the area upstream from Wu-chieh, controlling a watershed of 501.20 sq. km., (b) the Sun-moon Lake Watershed, 82.50 sq. km. and (c) a portion each of the Su-hsi Chi (41 sq. km.) and the Chia-she Chi (125 sq. km.). The development of this region is primarily for power generation.

2. Cho-shui Multi-purpose Development Region

This region will control a total watershed 1553.50 sq. km., covering the area downstream from Wu-chieh, part of Chia-she Chi, part of Su-hsi Chi, Tan-ta Chi, Chun-ta Chi, and Chen-yu-lan Chi. One or two reservoirs could be built for flood control, power generation and irrigation.

3. Ching-shui Chi valley

Ching-shui Chi is a large tributary on Cho-shui Chi. It control 413.80 sq. km.

The development of the above 3 regions will be further described separately later.

4. Dike Protected Region

The lower Cho-shui alluvial plain, 150,000 hectares is now protected by existing dikes.

Wu-she Dam Project (No. 34)

(See Fig. 97-108)

The Wu-she Dam was originally designed by Mr. Nishiyama, a Japanese Engineer and the construction was started in 1938 but discontinued in 1945. The finished work consists of all prepara-tory work, communication lines, plant installation and 5% of dam construction. The work was resumed in 1951 by the Taiwan Power Company. Due to the long period of discontinuation some installed facilities have to be replaced or repaired.

The original design features are listed as follows:

Drainage area: 217.9 sq. km.

Weighted mean annual rainfall: 3,807 mm.

Flood estimate:	By Creager equation	3,360 cms.
	By T. N. Hsu's formula	3,500 cms.
Design flood:	(Spillway capacity)	3,500 cms.
Maximum flood on record:		1,200 cms.

Dam: 97 m. high, 185 m. long, of which 100 m. is Ogee type spillway, concrete volume 350,000 cu. m.

Storage capacity: Gross 115,000,000 cu. m., effective 94,500,000 cu. m. drawdown 43 m.

Effective head used by plant: 62 - 109 m.

Discharge: 8.78 - 22.60 cms.

Intake: $8^{m\phi}$ vertical shaft, 64.15 m. long, controlled by 2 high pressure gates @ $4^m \times 5^m$.

Pressure tunnel: Circular, 369 m. long, of which 231^m is 3.5 m. in diameter and 138 m. is 2.89 m. in diameter.

Power house: Reinforced concrete, indoor type, built in 1943. Two turbines, vertical Francis type, Japanese made each rated capacity 11,200 kw; 2 generators each 11,500 KVA.

Tailrace: 4 m. in diameter, concrete lined, 976 m. long.

Total cost estimate (November 1952): US$1,314,600 & NT$133,000,000.-

If the Wu-she Reservoir is to be so operated as to produce maximum benefit for the Sun-moon Lake, the total increase of firm power in average year is 172 x 10^6 kwh, and that of secondary energy is 20.4 x 10^6 kwh. Assuming a power rate of NT$0.16 for firm energy and NT$0.08 for secondary energy, the annual benefit is NT$29,110,000. With 6% interest, 2.5% depreciation, and NT$41.3/KW of annual operation and maintenance cost, the total annual cost is NT$13,100,000. This would give a benefit cost ratio of 2.22.

The Reconnaissance Party checked the estimated flood by using "synthetic unit hydrograph" (Fig. 106). Flood routing diagrams were also prepared. (Fig. 107).

The Party did not think it proper to estimate the flood by merely basing on two empirical formulas, nor did it think reliable to estimate the life of the reservoir by merely basing on the silt data in one year period. Based on this meager data, the dead storage was estimated to be filled in about 30 years. The silting situation of Wu-chieh dam indicated an annual silt of 2,100,000, two-thirds of which was estimated by Japanese engineer to be from Wan-ta Chi and one-third from Wu-she Chi. Recent observation indicated a smaller portion from Wu-she Chi. The party also noticed that the Wu-she Chi is much more cheater than the Wan-ta Chi. After the Wu-she Dam is completed, the stability of the sumberged slopes will be reduced by reservoir drawdown and more deposit is expected.

The Present Features of Sun-moon Lake (No. 35) Power Development and Its Future Extension
(See Fig. 109 - 111)

Existing Plants

Wan-ta Plant

A 13-m dam, of concrete gravity type, 46 m long, was built on Wan-ta Chi at Ao-wan-ta to divert the flow through a 6.30 km tunnel and 575 m penstock into the plant. With a net head of 276 m and a flow of 2.4 - 6.6 cms, the capacity of the Pelton wheel is 16,500 kw. The plant was built in 1943. Due to the leakage in the tunnel lining cuased by a fault, the generated power was reduced to 5,000 kw. During the Reconnaissance Party's visit (January 1953) the repairing work was progressing.

Sun-moon Lake No. 1 Plant (Ta-kwan Plant)

This plant was finished in 1934. The intake is at Wu-chieh on Cho-shui Chi where a 48-m concrete dam, 91 m. long, was built with 11 spans of taintor gate installed on dam. In addition, three flood tunnels were provided. The watershed above the Wu-chieh Dam is 501.2 sq. km. The spillway capacity is 5,000 cms. The storage capacity is 12,600,000 cu. m. with the gates opened, and 17,400,000 cu. m. with the gates closed. The space below the spillway crest was all silted in about six years after completion. The flow from the intake was diverted in a 15-km channel, 14-km of which is of tunnel section and has a capacity of 40 cms, to a lake formed by two earth dams. One is Shui-she Earth Dam built of rolled fill with clay and reinforced concrete core wall. This dam is 6 m on top, 30 m above ground and 364 m long. The other is Tou-she Earth Dam 6 m on top, 19 m above ground and 164 m long. The Sun-moon Lake has a total effective storage of 124,000,000 cu m with a maximum drawdown of 21 m. The lake water goes through a 3 km pressure tunnel and a surge tank into the plant. The plant uses a discharge ranging from 23.18 to 41.53 cms and a head ranging from 305 to 320 m. The plant has five units of 20,000 kw each.

Sun-moon Lake No. 2 Plant (Chu-kung Plant

This plant takes the tail water from the Ta-kwan Plant through a 4.20 km waterway. The head used ranges from 123.50 to 125 m. Two Francis wheels with a total installed capacity of 43,500 kw were installed. The plant was started in 1935 and finished in 1937.

Plants Under Construction and Other Proposed Projects

Wu-she No. 1 Plant

This work was started by the Japanese but was left unfinished. The intake is to be from the reservoir behind the Wu-she Dam, the plant was already installed in the Wan-ta power house. With the Wu-she Dam completed, the runoff from 217.90 sq. km. of watershed will be regulated and the low flow will be increased from 2.70 to 11.30 cms. The regulated flow by the Wu-she Dam would greatly benefit all lower plants in the system. The generated firm power for the Sun-moon Lake No. 1 Plant would be raised from 58,800 KW to 84,000 KW and that for the Sun-moon Lake No. 2 Plant from 26,640 KW to 33,000 KW.

The Wu-she Dam will be separately reported later.

Wu-she No. 2 Plant

The proposed plan is to divert the tail water of the Wan-ta and Wu-she No. 1 Plant through an 8.05 km. tunnel to Chu-ping She, Tzu-mei-yuan at the left bank of Cho-shui Chi. The maximum power output is 27,000 KW with 12,700 KW of firm power. The effective head is 113 m.

Sun-moon Lake No. 3 Plant

The plan is to divert the tail water of the Sun-moon Lake No. 2 Plant through a 12 km. tunnel to a power plant at Lin-wei. An effective head of 77 m. would generate a maximum output of 26,500 KW with a firm power of 15,000 KW.

Su-hsi Chi Diversion Project (Fig. 109)

This project is aimed to increase the inflow of the Sun-moon Lake. An 8-m dam on Su-hsi Chi about 2 km upstream from its confluence with the Cho-shui was proposed by Japanese to divert 0.5 - 2.50 cms through a 4.50 km. tunnel to Wu-chieh. The elevation of the top of the dam is 771 m. and that of the diversion intake is 766 m. The watershed above the dam is 41 sq. km.

Chia-she Chi Diversion Project (Fig. 109)

Also to increase the inflow of the Sun-moon Lake, another low dam was proposed to be built on Chia-she Chi 4.5 km upstream from its confluence with the Cho-shui. The watershed above the dam site is 125 sq. km. A flow of 1.80 - 7.50 cms is to be diverted through a 9.5 km. tunnel to the Su-hsi Chi.

Sun-moon Lake Capacity Extension Heightening Project

Some engineers of the Taiwan Power Company suggested increasing the capacity of the Sun-moon Lake by 20% by heightening the dam. This would involve enlarging of the 15 km intake tunnel since its capacity is limited to about 40 cms. Such proposal should be carefully investigated before adopted.

The maximum reservoir surface could be raised 1.60 m by encroaching the 3 m. freeboard without heightening the dam. An increase of 12,800,000 cu. m. of effective storage and 12,800,000 kwh of energy could be effected.

Lung-shen-chiao Reservoir (No. 36)

(See Fig. 112 - 121)

Two alternate dam sites were proposed near Lung-shen-chiao, the junction of the Cho-shui and its tributary Chen-yu-lan Chi. One site is upstream from the junction, (B' in Fig. 112). The other is downstream from it. (A in Fig. 112). During 1951-53 the PWCB made some investigation. The following data is available:

1. Reconnaissance report.
2. A Preliminary report for multi-purpose development of Cho-shui basin.
3. Trpographic maps: 1:5,000 for the reservoir and 1:500 for the dam site.
4. Geological report of the dam site and the reservoir.

The geologic survey in 1953 revealed that the axis of the lower site (including Chen-yu-lan Chi) is located on the Shui-li-keng Fault, the biggest fault on this Island. About 500 m. to the west, there are two other faults. These faults result in very much distorted geologic formation. The upper site, losing the catchment area of the Chen-yu-lan Chi, is geologically much better. Both sites have the disadvantage of losing the tailrace flow of 23.2 - 46.2 cms from the Sun-moon Lake No. 2 Plant. The site suggested by the Reconnaissance Party (B in Fig. 112) is between the upper and the lower sites mentioned above.

Geological Features

The whole vicinity is composed of metamorphic rocks derived from sedimentary rocks of the Tertiary of the Cenezoic Era. The bed rocks, of Eocene formation are hard and compact quartzite sandstone with white and gray colors. The upper portion consists of thick layers of sandstone mingled with thin layers of slate. The lower portion consists of alternate layers of sandstone and slate. The dip is 20^{o} - 45^{o}. The strike is between N30^{o}W and N10^{o}E. The geologists are certain that the chance of percolation of water from the reservoir would be very small.

Water Study

The flood has been estimated to be 8,320 cms using synthetic unit hydrograph method. The flow mass curve was prepared using the record from the Lin-wei Station. Adjustments were made for difference of catchment area by proportion (Lung-shen-chiao catchment area = 1712 km^2, Lin-wei catchment area = 2,304 km^2). For lower estimate, duration curve and duration area curve were plotted.

Reservoir Features

Catchment area	1,712 km^2
Flood level	390 m.
Ordinary high water level	380 m.
Dead water level	360 m.
Dead water capacity	93,000,000 m^3
Effective storage	207,000,000 m^3

Dam (top width 5m, central angle 104°, radius 200 m.) — Concrete arch gravity

River bed elevation	310 m.
Elev., top of dam	395 m.
Height of dam	85 m.
Top length	350 m.

Spillway crest: Elevation 380 m; Length 160 m.

Top elevation of the gate on spillway: 390 m.

Benefits

The regulated flow will range from 32 to 63 cms. The power output is 20,000 kw of firm power. The maximum power will reach 39,000 kw. Benefits could be increased by joint operation of this reservoir with the lower Chi-chi Reservoir. Large amount of water in the Lung-Shen-Chiao Reservoir may be released in a short interval, and reregulated by the Chi-chi Reservoir downstream, so irrigation action will still be retained. If the reservoir is especially designed for irrigation, large amount of water may be discharged in the very dry season, such as March each year, the benefit caused by irrigation would be much more enlarged. What would be the most economical operation of the two reservoirs deserves careful planning. The operation of the movable gates on the spillway and the use of diversion tunnel as auxilliary flood tunnel can be made most effective to flood control. This reservoir, due to its upstream location, would necessarily catch the silt deposit and thereby lengthen the life of the lower reservoir.

Other Information

The submerged area will be about 187 hectares of paddy field along the river bed. About 100 families will have to be moved. A highway leads up to the dam site. A railway branch line comes within 4 km. of the site. The quartzite sandstone at the site is good concrete aggregate. Good sand has to be shipped in from outside. One disadvantage is that the height of the dam will be limited to 85 m. as the saddle on the right bank is low, (395 m.) If the top of the dam could be brought up to elevation 420 m. the total storage capacity would be 600 x 10^6 cu. m.

Chi-chi Reservoir (No. 37)

(See Fig. 122-153)

General Description

The site is at Lin-wei, Nan-tou, near the Cho-shui Suspension Highway Bridge. Here the Cho-shui narrows from 3,500 m. to 500 m. The controlled drainage area is 2,304 sq. km. An 80-m high dam here would create a reservoir of 1,170,000,000 cu. meters in capacity, with a water surface 4 km. wide and 10 km long. However, the submerged area would include over 10 villages, of which Chi-chi, Lin-wei, Chai-tou-chiao, Tung-chio, Shui-li-keng etc. are on the north of Cho-shui, Kwei-tzu-tou, Fan-tzu-liao, Ping-tzu-ting, Ta-chiu-yuan, Wai-cheng are on the south.

Geology

Geologists believe that the Cho-shui gorge at Lin-wei was formed after the fault movement of the recent geologic era. The Cho-shui formerly run through the Nan-tou plateau from Ta-shih-kung. The geologic formation of this site, being Cho-lan Strata of the Tertiary is composed of alternate layers of grayish yellow sandstone and dark gray sandy shale, dipping 35° and striking N15°W. The layers are clear and regular with a thickness of two to three meters. The rock should be capable of withstanding all pressures of an 80-meter gravity dam.

The Chi-lung-shan Fault is found about 800 meters downstream from the suspension bridge. East of the fault the rock strata are badly distorted. This fault, being outside of the reservoir and the dam site, will probably not effect its stability, provided core drilling will be investigated.

Meteorological Data

The monthly average temperature for 1926-1936 at the Chi-chi Station ranges from 17.3°C in January to 27.5°C in July. A record of 41 years here shows a yearly average of 116.3 rainy days. In this Cho-shui valley as a whole, the rainy days in a year varies from 150 days in the upper region and 100 days in the lower region. The amount of precipitation in Chi-chi within the July-September typhoon period reaches 2,374 mm., averaging 1,614 mm., or 67.7% of the annual average precipitation.

The maximum daily precipitation in the 41 year record of Chi-chi Station is 418.1 mm. (August 11, 1929) and that in the 21 year record of Niu-wen-lu Station is 445.6 (July 19, 1913).

Hydrological Data

There were 14 rain gauging stations, - None self-recording - in the Cho-shui basin, all established during the Japanese Occupation period. Records of 20 - 30 years are available. The average yearly precipitation of the whole basin is 2,520 mm. varying from 4,800 mm for the mountainous region, 2,500 mm for the central region and 1,270 mm for the lower region. The rain season is May - October. Typhoon prevails in June - October. The Isohyet map (Fig. 129) is based on maximum daily records (at different times) and the average maximum daily precipitation in the basin is found to be 440 mm which is used for flood estimate.

In the year 1951 - 1952 the evaporation was 845.5 mm. Basing on this data, the evaporation loss of the reservoir is $0.845\ m \times 26,000,000\ M^2 / 365 \times 86,400 = 0.684$ cms.

Stream Flow

The Lin-wei Station has stream flow records for 1941 - 1944 and 1948 - 1952. The Niu-wen-lu Station keeps records for 1926 - 1937. Float method was used. It was reported that the river stages were recorded three times in low stage and six times in high stage.

The recorded maximum was 3,152 cms (1947) and the minimum was 23.09 cms (1942).

The monthly discharges vary from 1,001 - 25,026 cms days (Fig. 131). The seven-year average is 138 cms, varying from 94 - 181 cms. The run-off mass curve and the required storage is shown in Fig. 133, 134 and 148.

The flood was estimated by different methods as follows:

Rational method $Q = 0.2778\ frA = 12.000$ cms

$$f = 0.78, \quad r = r_o \left(\frac{24}{T}\right)^{2/3} \quad T = \frac{L}{W_2}, \quad W_2 = 72\left(\frac{H}{L}\right)^{0.6}$$

$$r_o = \frac{440}{24}$$

Creager's equation (refer to Creager and Justin: Hydroelectric Handbook, p. 62)

$$Q = Aq = 10,400 \text{ cms} = (q = 410 \text{ cfs/sq. mile} = 4.5 \text{ cms/km}^2, \; A = 889.2 \text{ Mile}^2 = 2,303.3 \text{ km}^2)$$

T. N. Hsu's flood formula for Tai-wan

$$Q = 2100 \left(\frac{A}{100}\right)^{2/3} = 16,600 \text{ cms}$$

Schwarz and Taylor: Synthetic unit hydrograph

qPR= 23.9 cms/1mmR(Fig. 126)

Q = 23.9 x 440 = 10,600 cms

Silt Content

The silt content by % in weight of Cho-shui at Lin-wei is shown in Fig. 138 - 140. The three - year average is 0.927%, and the maximum is 4.854%. The samples were taken at half depths.

Four year record at the Wu-chieh Reservoir showed an average annual deposit of 0.18% of annual runoff

Discharges and silt contents were plotted but showed no definite relationship. There were no data to show the density of the silt and the silt distribution in a cross section. Thus ~~the study~~ on the life of Chi-chi Reservoir is based on the record of the Wu-chieh Dam.

Reservoir Planning

Catchment basin	2,304 sq. km.
Ordinary flood level	275 m.
Ordinary full water level	265 m.
Dead water level	247 m.
Dead storage	385×10^6 cu. m.
Effective storage (to be subject to silt study)	375×10^6 cu. m.
Flood storage	265×10^6 cu. m.

Dam - concrete gravity; top elev. 277.5 m; Height 77.5 m; top length 620 m, of which 110 m. is spillway with crest elevation at 265 m.

Concrete volume - (300,000 M^3 for spillway section 1,360,000 M^3 for dam)................1,660,000 M^3

Flood Control

Due to lack of data for study of flood frequency, the maximum probable flood can not be estimated. The flood routing was based on the flood estimated by the Synthetic Unit Hydrograph. The spillway was assumed to have free fall. With a crest spillway length of 110 m. the maximum spillway capacity is 7,700 cms with a surcharge of 10 m. The flood would be reduced by 27%. The flood storage is 265,000,000 m^3

There should be an economical balance between the loss from the reservoir flooded area and the gain from a corresponding increase of effective storage. Figs 146 and 147 were intended for this study.

No flood damage data are available. It is difficult to estimate the flood control benefit. Portion of the river bed downstream from the dam could be reclaimed, but would be subject to extraordinary flood.

The spillway section is to be at the middle of the dam with movable gates installed on the crest. The use of sluice pipes used in Shasta Dam may be considered in this plan.

Power Generation:-

Assuming a tail water elevation of 200 m and power plants installed on both banks, the power output to be expected is as follows:

$$P_{max} = \frac{1000 \times 120 \times 0.85 \times 57}{102} = 57{,}000 \text{ KW}$$

$$P_{primary} = \frac{1000 \times 66 \times 0.85 \times 57}{102} = 31{,}000 \text{ KW}$$

A total energy of 3.46×10^8 KWH will be generated.

Irrigation:

The existing irrigation systems supplied by the Cho-shui Chi are as follows:

District	2-crop (ha.)	1-crop(ha.)	3-yr. Rotation (ha.)	Miscel-laneous (ha.)	Total
Chia-nan Canal Cho-shui Main	7,260	2,074	43,512	-	52,846
Tou-liu and Lin-nei Canal	607	1,601	14,566	-	16,774
Ba-pao Canal	19,484	-	-	1,663	21,147
Pei-tou	15,069	1,428	708	-	17,205
Nan-tou	1,334	-	-	976	2,310
Total:	43,754	5,103	58,786	2,639	110,282

The possible extension area in the various districts are as follows:

District	Coast land (ha.)	Dry land (ha.)	High land (ha.)	Submerged land (ha.)	Total
Chia-nan Canal	6,000				6,000
Tou-liu Canal		10,000			10,000
Ba-pao Canal					
Pei-tou Canal	8,300			14,871	23,171
Nan-tou			3,000		3,000
Total:	14,300	10,000	3,000	14,871	42,171

The main crops are rice, sugarcane and miscellaneous crops. The duty of water for the 2-crop paddy field in the Chia-nan area is 900 ha./c.m.s. The water for sugarcane is 1/4 of that for rice and miscellaneous crops take ½ of that for sugarcane. Better utilization of rainfall might raise the duty of water to 1,100 ha./cms.

The mass curve based on the seven-year runoff record at Lin-wei indicated that the regulated flow in low flow period (October - March) is 66 cms. and 120 cms. in the remaining period of the year. Proper operation of the reservoir would be able to supply full irrigation to 42,171 ha. to be developed and supplementary irrigation to 110,282 ha. of existing irrigated area.

Other Information

The area submerged by the reservoir will include 800 ha. of paddy field, 700 ha. of dry land and land in the riverbed, 10 km of railroad, 15 km of highway, and about 5,000 families in over ten villages mentioned under "General Description."

Life of Reservoir

The percent in volume of silt in Cho-shui at Wu-chieh is 0.18%. If this percent of silt is applied to Lin-wei, the silt carried in an average year would be $4,320 \times 10^6 \times 0.18/100 = 7.78 \times 10^6\ m^3$. The above reservoir planning assumes to provide a dead storage of $385 \times 10^9\ M^3$ which will be enough for 50 years.

Another approach as shown following will result in a much shorter life.

Silt content (by weight, at Lin-wei) = 0.00927 (1948-52)

Silt content (by weight, at Wu-chieh) = 0.00463 (1916-18)

Silt carried in Cho-shui at Lin-wei = $4,320 \times 10^6\ m^3$/year

Let S = Silt content in M^3/year

p = Density of silt in tons/m^3

B = Rate of deposit

V = Yearly deposit

Q = Yearly flow in m^3/year

P_w = Ratio of silt content in yearly flow by weight.

$$S = P_w Q$$

$$V = \frac{BS}{P}$$

$$\frac{V}{Q} = P_w \frac{B}{P}$$

B can be considered constant before the reservoir is 50% silted. At Wu-chieh,

$$0.00183 = \frac{0.00463B}{P} \qquad \therefore \frac{B}{P} = 0.396$$

Assuming same $\frac{B}{P}$ for Chi-chi as for Wu-chieh,

Then at Wu-chieh, $\frac{V}{Q} = \frac{0.00927B}{P} = 0.00367$

$$V = 0.00367Q = 15.8 \times 10^6 \ M^3/\text{year}$$

$$\text{Effective life} = \frac{385 \times 10^6}{15.8 \times 10^6} = 24.4 \text{ yrs}$$

The life of the reservoir could be increased by reforestation, ample provision of sluicing device, and compacting the deposit by periodic emptying of the reservoir. Without effective measures, the life of the reservoir would be very short and the economy of reservoir would be highly questionable.

Within the long reservoir surface area large particles will deposit in the upper portion and fine ones in the lower portion. The power intake should be placed below the dead storage level. To provide for later silting, it should be made possible to place the intake at different levels. No effective means of sluicing the reservoir silt is known. Sluicing device can only sluice the silt near the gate. The possibility of utilizing density current for sluicing during floods ought to be thoroughly investigated and studied.

Backwater Effect

Due to incomplete flow records and lacking detail survey, backwater can only be studied basing on 1:50,000 topographic map. (Fig. 150). The backwater curve obtained is also based on the assumption that the loss of head due to friction and turbulance is the same as the mean velocity head between the two sections. The effect of the tributaries on the backwater is also neglected. Therefore the backwater obtained is only a rough one. This backwater indicates that the proposed dam with the spillway crest at elevation 265 m. would not affect the tail water (elev. 276) of the power plant at Shui-li-keng. If the Chi-chi Dam is to be increased in height by 10 m., the effective reservoir storage would be increased by $2.6 \times 10^8 \ m^3$, the regulated flow by 14 cms, the average head by 5 m. and the power output by

$$\frac{1000 \times 94 \times (\frac{275+247}{2} - 200) \times 0.85}{102} - 37,300 = 10,500 \text{ KW}$$

In the mean while, reduction of the power output of power house at Shui-li-keng, due to ten-meter increase of the Chi-chi Dam would be 2,500 kw. Obviously there should be a balanced study between the increase in cost of a higher dam and the cost of removing the power plant on the one hand and the increase of power output on the other.

Soil Conservation of Watershed

The main reasons for the heavy silt content in Cho-shui are weak geologic formation, and uncontrolled deforestation. Landslides are prevalent on the headwaters. In order to prevent soil erosion, the following three measures are vitally important:

1. Checking burning and cultivating the mountain slopes. The aborigines are to be removed away to facilitate administration and direction of work.

2. Improving farming method: Better terracing and adopting contour plowing.

3. Forestation: In order to check or reduce landslides, the following measures are necessary:

    a. Constructing check dams, not for storing deposit, but for improving the river bed slope and slowing down the river velocity.

    b. Providing proper plant coverage.

    c. Investigating effective measure for top soil conservation.

    d. Studying erosion and weathering of clay slate for reference of river control design.

Ching-shui-chi Reservoir (No. 38) and Ching-shui-chi

(See Fig. 154 - 159)

The Ching-shui Chi is a large branch on the lower Cho-shui Chi. The east of the watershed boundary is Chen-yu-lan Chi with the Mt. A-li running between in north and south direction. The south is neighboring Tseng-wen Chi. On the west is the headwater of the Pei-kang Chi. On the Ching-shui Chi headwater, the watershed condition is good and the forest is well preserved. Cliffs and big landslides are common in the upper and central region.

Above Chang-hu and Mei-liao the river flows between gorges with many rock cliffs and slides. Below Chang-hu, the river bed opens up to nearly one kilometer. It gets still wider at Lao-shui-keng. The whole Ching-shui valley has a total watershed of 413.80 sq km, 70% of which is forest.

Geology

The upper and central region is mostly of dark gray sandstone and shale of the Tertiary. The lower basin is of soft, lustrous sandstone. The gravelly clayey formation at the confluence of Ching-shui with Cho-shui is more recent. The basin as a whole has a formation of soft sedimentary rock. In December 1941, a serious earthquake caused an avalanched mass of about 120,000,000 m^3. This big mass choked the river and formed a natural reservoir holding 150,000,000 m^3 of water with a maximum water depth of 117 meters. This mass had an average height of 160 m and a crest length of 1.2 km. It is 100-200 m wide on the top and 4.8 km wide on the bottom.

Hydrologic Data

The yearly precipitation on the headwaters of the Ching-shui basin ranges from 3500 - 4500 mm. The highest precipitation reached 7,000 mm. The lower basin has a yearly precipitation of about 2,000 mm.

The average flow records at Tung-tou Station follows:

Very low flow/100 sq km of catchment area	0.45 cms
low flow/100 sq km of catchment area	0.77 cms
Ordinary flow/100 sq km of catchment area	3.46 cms
High flow/100 sq km of catchment area	8.53 cms

The meteorologic and hydrographic stations in the Ching-shui basin are listed below:

1.	A-li-shan (rain gauging)	35 yrs. (1910-1944)
2.	Yu-yeh-lin (rain gauging)	41 yrs. (1904-1944)
3.	Tsao-ling (rain and stream gauging)	5 yrs. (1947-1951)
4.	Tung-tou (stream gauging)	29 yrs. (1913-1941)
5.	Erh-wan-ping (rain gauging)	15 yrs. (1913-1927)
6.	Chiao-li-ping (rain gauging)	3 yrs. (1913-1915)

Project of Development

Due to the fact that the change in seasonal flow is tremendous, the low flow is extremely small, and the slope of the middle portion is comparatively flatter, there is little chance of developing power by construction of runoff river plants. However, reservoir regulated flow could be used to irrigate high land in Chu-chi, Hsiao-mei, Ta-lin, Tou-liu, etc. as well as to develop power. The existing irrigated area is about 2,700 ha as follows:

Name of Canal	Area Irrigated (ha.)	% of flow entitled in dry yrs.	Hydraulic Association
Lung-an	29.83	-	Chu-shan
Lao-shui-keng	12.58	-	"
Shan-pien	26.69	-	"
Szu-chueh-tan	16.17	-	"
Ko-tzu-keng	22.93	6%	"
Ho-chi-tso	97.25	16%	"
Tou-liu	2,383.00	-	Tou-liu
Others	160.00	78%	
Total	2,748.45	100%	

In February, March and April, the river flow is often less than 1 cms, which is far from being enough. Water stealing cases and serious water disputes resulted. The PWCB often had to dispatch a squad of men to distribute the water and to settle the disputes. But the most effective and fundamental measure would call for water storage and regulation by reservoirs.

Above Nei-liao, the river flows through narrow gorges, but no good reservoir site of large capacity is available. The natural reservoir at Tsao-lin was washed in May, 1951.

Geologically Yun-tai-chiao, can be considered as a good dam site but the storage capacity is small. The storage capacity is based on 1 in 50,000 topographic map. (Fig. 155) It is to be noted that the topography had a remarkable change since the failure of the Tsao-lin Reservoir. More exact planning of the reservoir would necessitate a resurvey of the topography. Fig. 156 shows a storage of 5,000,000 m^3 at a dam of 80 m height, 16,500,000 m^3 at 120 m height, and 137,000,000 m^3 at 200 m height.

The minimum inflow to the reservoir is only 0.5 cms. The estimated flood is 4,800 cms. After construction of the reservoir, the minimum regulated flow will be 8.00 cms. This regulated flow, after generating power, could be released to supply irrigation in the lower basin or be diverted to the Shih-tzu-tou Reservoir to supply irrigation water to the Chia-yi plain.

During the Japanese occupation period, a detailed survey of the whole river was made. (Report on the survey of Ching-shui possible power sites, 1940). However no plant was built. This may be due to the serious avalanche and other disadvantages.

Chen-yu-lan Chi Basin

Topography

Chen-yu-lan Chi is the largest tributary of Cho-shui and has a catchment area of 453.81 sq. km. The east boundary borders the Chun-ta watershed. On the south, the divide line links the peak of Mt. Pa-tung-kwan, Mt. Pei, Mt. Hsin-kao, Mt. Hsi, Mt. Chien, Mt. Lu-lin, Mt. Shih, Mt. Erh-yu, etc. and borders Lao-nung Chi and Nan-tzu-hsien Chi, of the Hsia-tan-shui Chi system. The west watershed boundary is Mt. Ta-ta, Mt. Sung, Mt. Wu-yi-lung, Mt. Chin-kan-shu, Mt. Feng-huang dividing Chen-yu-lan Chi on one side and Tseng-wen Chi and Ching-shui Chi on the other.

The watershed slopes northward. There are practically no level ground on the two banks. Cultivated area by the aborigines can be frequently seen. There are also many cliffs and avalanches.

Geology

The geologic formation is of Tertiary. In the south east basin, lustrous and medium grained sandstone and black shale are found. In the central basin, the rock is mainly lustrous, coarse grained sandstone. The rock in the western part of the watershed is almost all of dark gray sandstone and shale. Along the river bank of the headwater some igneous rocks are found. There are many slides. The river debris is abundant in flood. However, the flow is fairly clear in low stages.

Forest

Up on the headwaters, conifers are found. At lower elevations, are red cypress and cypress, etc. Around elevation 1,500, is seen beautiful forest of conifers and hardwoods. Below this, are beautiful forest of hardwoods. Along the Mt. A-li, there are forests of the cold zone as well as those of the tropic zone.

Gaging Station

1.	A-li-shan (rain)	35 years record (1910-1944)
2.	Nan-tzu-chiao-wan (rain)	32 years record (1913-1944)
3.	Tung-pu (rain)	(1923-1937, 1948-date)
	(flow)	5 years record (1938-1942)
4.	Pa-tung-kwan (rain)	22 years record (1923-1944)
5.	Nei-mao-pu (flow)	(1937-1938, 1948-date)

River Course

Chen-yu-lan Chi originates from Mt. Pei of Mount Hsin-kao, Pa-tung-kwan, etc. It meets the tributary Sha-li-hsien Chi at Tung-pu, Ho Chi at Ho-she, and other small tributaries in the lower course. It joins Cho-shui Chi at Lung-shen-chiao.

The lower course is fairly wide with small islands which are now gradually cultivated. The river upstream from Ho She has slope of 1/20 to 1/60. The lower stretch has an average gradient of 1/60 to 1/80, and the river is 800-1,000 meters wide. No good reservoir site is found. Along the lower course, there are some paddy fields on the two banks, the irrigation water for which is taken from the creeks nearby. Downstream from Nei-mao-pu, the terraces and mountain slopes are all planted to banana tress, which are producing ill effect on soil conservation.

Hydro-power Development Plan

The following run-of-river plants are cited below:

1. A low concrete diversion weir is proposed to be built ~~about~~ 30 m. below the junction of Ho-she Chi and Chen-yu-lan Chi to divert 12.2 cms through a tunnel, 11.2 km. long on 1:900 slope, to the plant in the forest of National Taiwan University at Nei-mao-pu. The power to be generated is 25,900 K.W. for an effective head of 249 m. The tail water is diverted to the lower plant.

2. The above tailrace flow of 12.2 cms. is diverted through a tunnel, 10,550 m. long, to a plant at Niu-wen-lu on the left bank of the Cho-shui Chi. The power is 18,951 kw for an effective head of 162.5 m. using a flow of 14 cms of which can be intercepted from two tributaries in the amount of 1.2 and 0.60 cms. The tunnel is 2.80 m. in diameter on 1/900 slope for the upper stretch. For the lower stretch the tunnel is 3 m. in diameter on 1/1000 slope. The open channel for the supplementary supply is 4000 m. long, having a bottom width of 1 meter and a gradient of 1 in 300.

Silt Control Plan

There is a plan for silt control in this basin. (refer to The Silt Control Plan of the Taiwan Water Conservancy Bureau)

Silt Problem in Choshui Basin

Available Data

The four stations from which some silt data are available are listed in the following table:

Station	Observation Period	No. of observation
Lin-wei	1948, 1951, 1952	2 - 5 per month
Niu-wen-lu	Sept. 11, 1915 - Jan. 1, 1917	457 days
Tzu-mei-yuan	Dec. 1, 1919 - Sept. 30, 1923	Every day
Tzu-mei-yuan	July, 1917 - June 1918	Unknown

Silt content recorded at Lin-wei Station

	Yearly runoff cms day	Solid matter in yearly runoff (Ton/s) day	Silt % (Wt.) Annual Average
1948	34,682	238	0.688
1951	66,316	374	0.564
1952	38,844	591	1.523
Total:	129,842	1,203	
Average			0.927

Silt Content Recorded at Niu-wen-lu Station

Month	Run-off cms Days	Sediment Run-off Ton/s - Days		Sediment Concentration % by wt.
1	1261.8	0.635		0.050
2	1218.6	1.155		0.095
3	2972.2	5.669		0.191
4	3120.5	4.739		0.149
5	2238.2	2.426		0.108
6	3977.7	7 389		0.186
7	3689.2	3.582		0.097
8	7446.3	53.703		0.721
9	9191.8	54.393		0.592
10	6578.5	15.081		0.229
11	3604.6	1.971		0.055
12	2872.8	0.497		0.017
Total	48,172.2	151.240	Average	0.314

Note: Samples of 700 cc. were taken but the method of sampling is unknown.

Silt Content ~~Recorded at Tzu-mei-yuan~~ Station
(Wu-chieh Dam)

(Based on the monthly averages between April 1920 - Sept. 1923)

Month	Q (cms)	Sediment Runoff (Ton/day)	Sediment Runoff (Ton/month)	Silt & (wt.) #
January	9.74	342	10,610	0.0406
February	17.4	1,938	54,295	0.1290
March	28.8	2,400	81,103	0.0965
April	21.6	2,311	69,340	0.1240
May	70.5	26,375	817,590	0.4330
June	60.7	18,038	541,150	0.3440
July	60.1	26,222	812,877	0.5060
August	48.1	28,367	879,270	0.6830
September	70.1	57,745	1,732,370	0.9550
October	28.0	11,517	356,946	0.4770
November	15.65	1,705	51,030	0.1264
December	13.85	675	20,929	0.0565
Total:	444.54	177.631	5,427,510	
Average	37.0	14,803	452,293	0.463

Note: Method of observation is unknown.

Source: Hydro-electric Power Development Plan of Cho-shui
Taiwan Power Company

Not shown in the above source of information.

Silt Content Recorded at Tzu-mei-yuan

(Based on record from July 1917 - June 1918)

Month	Discharge (Q) cms	cms-days	Silt Percentage by Volume (P_v)	Sediment Run-off (QP_v)
1	9.34	289.54	0.0221	0.0639
2	9.71	271.88	0.0466	0.1260
3	21.70	672.70	0.1170	0.7875
4	26.29	788.70	0.0502	0.3950
5	34.00	1046.29	0.0442	0.4620
6	54.31	1630.30	0.0792	1.2900
7	64.19	1989.89	0.2145	4.2700
8	64.75	2007.25	0.2260	4.5300
9	52.92	1587.60	0.1097	1.7400
10	30.69	951.39	0.0695	0.6600
11	22.73	681.90	0.0421	0.2870
12	14.66	456.46	0.0472	0.2140
Total:		12,371.90		13.8254

Average: $\frac{13.8254}{12,371.90} \times 100 = 0.117\%$

Source: Taiwan Water Conservancy Bureau's series No. 6 "Essential Hydraulic Works in Taiwan" P. 258.

Methods of observation is not known.

Silt Content Recorded at Tzu-mei-yuan

(Based on a study made by Mr. Yu Masu Tani in June 1930)

Month	Discharge (Q) cms	Discharge (Q) cms-days	Silt Percentage by Volume (P_v)	Sediment Run-off (P_vQ)
1	9.74	301.94	0.025	0.075
2	18.1	496.8	0.075	0.372
3	29.5	914.5	0.058	0.530
4	21.8	654.0	0.074	0.485
5	70.5	2,185.5	0.260	5.68
6	60.7	1,821.0	0.206	3.75
7	58.4	1,810.4	0.306	5.54
8	48.1	1,491.1	0.410	6.11
9	69.8	2,094.0	0.568	11.9
10	28.8	892.8	0.275	2.45
11	15.7	471.0	0.076	0.358
12	13.2	409.2	0.032	0.131
Total		15,542.24		37.39

Average $\frac{37.39 \times 100}{15,542.24} = 0.2405\%$

Source: A paper entitled "Problem of Desilting Basin" in "Hydro-electric Power Development Plan of Cho-shui", Taiwan Power Company.

Method of observation is not known. No record of specific gravity for the sediment is available. Mr. Yu Masu Tani estimated that 6,000,000 tons of suspended load were carried per year. Adding another 16.7% for bed load, the total yearly sediment is 7,000,000 tons. The average annual runoff is 874,200,000 m^3. The silt percentage by weight is 0.8%. The drainage area is 458 km^2. The sediment has a rate of $\frac{7,000,000}{458}$ = 15,300 tons per sq. km. per year, or 15.3 kg. per m^2 per year. This estimate is based on an assumption that one m^3 of sediment weighs 1.66 tons.

Rate of Wu-chieh Reservoir Sedimentation

Year	Annual Runoff ($10^6 M^3$) (1)	Annual Intake ($10^6 M^3$) (2)	Space Silted (10^6 M^3) (3)	Trap Efficiency (%) (4)=(3)/(1)	Intake Ratio (%) (5)=(2)/(1)
1935	1,218.522	427.647	3.429	0.281	35.1
1936	819.338	491.023	1.284	0.157	59.9
1937	901.063	565.958	0.881	0.0979	62.8
1938	1,085.311	508.669	1.768	0.163	46.9
Total	4,024.234	1,993.297	7.362		
Average	1,006.059	498.324	1.841	0.183	49.5

Source: "Tseng-wen Chi Reservoir Survey Report" by Mr. Suehiko Miyagi P. 5 published by Tainan District Office.

Annual Runoff and Annual Rate of Sediment Flow

Station	Catchment Area above Station	Average Annual Runoff
Wu-chieh	501 Km^2	1,006 x $10^6 m^3$
Lung-shen	1712 Km^2	2,625 x $10^6 m^3$
Niu-wen-lu	2172 Km^2	3,330 x $10^6 m^3$
Lin-wei	2304 Km^2	4,320 x $10^6 m^3$

Station	Sediment Concentration	Description	Unit Rate of Sediment Flow
Lin-wei	0.927% (wt)	1948, 1951, 1952	17.4 $kg/m^2/yr.$
Niu-wen-lu	0.314% (wt)	1916	6.03 $kg/m^2/yr.$
Wu-chieh	0.463% (wt)	1920 - 1923	9.30 $kg/m^2/yr.$
Tzu-mei-yuan	0.117% (Vol)	1917 - 1918	2.34 $1/m^2/yr.$
Tzu-mei-yuan	0.2405% (Vol)		4.83 $1/m^2/yr.$
Tzu-mei-yuan	0.8% (wt)	Yu Masu Tani	16.1 $kg/m^2/yr.$

It is to be noted that between Lin-wei and Niu-wen-lu there are no large tributaries, yet the sediment at Lin-wei is 2.9 times that at Niu-wen-lu. Hence the sediment study of Lung-shen-chiao Reservoir ought to be based on the silt data of the nearer station Lin-wei.

Prediction of Annual Reservoir Sediment

Let ρ_s = Dry weight of unit volume of sediment in reservoir, and assume all sediment settles in the reservoir, then the following table stands:

ρ (Ton/M^3)	Porosity (%)	Void Ratio	Annual Sediment $10^6 M^3$ Chi-chi	Lung-shen-chiao	Rate of Sedimentation (%) Chi-chi	Lung-shen-chiao
0.208	92.15	11.75	192.5	117	16.45	13.77
0.5	81.90	4.34	80.0	48.6	6.84	5.72
1.0	62.20	1.65	40.0	24.3	3.42	2.86
1.5	43.40	0.77	26.7	16.2	2.28	1.905
1.87	29.30	0.41	21.4	13.0	1.825	1.53

In the United States, Actual records on ρ values of reservoir sediment range from 13 - 117 lbs/ft^3 or 0.208 - 1.87 $tons/M^3$, and the effective life of a reservoir is considered to be 60% of its original capacity.

Records at Wu-chieh showed that the trap effeciency or the ratio of reservoir space occupied to annual run-off is 0.183%. Assuming. the same ratio be applied to Chi-chi and Lung-shen-chiao then the following results:

Annual reservoir sediment

Chi-chi $4320 \times 10^6 \times 0.00183 = 7.9 \times 10^6\ m^3/yr.$

Lung-shen-chiao $2625 \times 10^6 \times 0.00183 = 4.8 \times 10^6\ m^3/yr.$

Percentage of Annual Sediment to Capacity

Chi-chi $\frac{7.9}{1170} \times 100 = 0.675\%$

Lung-shen-chiao $\frac{4.8}{850} \times 100 = 0.565\ \%$

This problem may be investigated in a different way as follows:

Let S = Total sediment carried in the flow (Ton/yr.)

E = Percentage of total sediment deposited in the reservoir

V = Reservoir space occupied per year.

Q = Annual runoff, in m^3 per yr.

P_w = Percentage by wt. of sediment

$$S = QP_w$$

$$V = \frac{QP_w E}{\rho} = \frac{ES}{P}, \quad \frac{V}{Q} = \frac{EP_w}{\rho}$$

In Wu-chieh $\frac{V}{Q} = \frac{0.00463E}{\rho} = 0.00183$

$$\frac{E}{\rho} = 0.396$$

Assuming same $\frac{E}{\rho}$ = be applied to Chi-chi and Lung-shen-chiao,

$$\therefore \frac{V}{Q} = 0.396 \times 0.00927 = 0.00367$$

$$V = 0.00367Q$$

For Chi-chi, $V = 0.00367 \times 4320 \times 10^6 = \underline{15.8} \times 10^6 \; m^3/yr.$

For Lung-shen,chiao, $V = 0.00367 \times 2625 \times 10^6 = \underline{9.63} \times 10^6 \; m^3/yr.$

Rate of Capacity reduction:

For Chi-chi $\frac{15.8}{1170} \times 100 = 1.35\%$ per yr.

For Lung-shen-chiao $\frac{9.63}{850} \times 100 = 1.13\%$ per yr.

The factors affecting ρ, are distribution of particle size, the drawdown condition, and years of service. The factors affecting E are width of reservoir area, length of back water, and velocity of flow; The relation of ρ and years of service is often represented by $\rho_T = \rho_o + K \log T$ where P_o is value of in the initial stage, $_T$ is value of ρ after T years of service. Mr. Brown, in his study on control of reservoir sediment, indicated that when the reservoir is emptied, the reservoir sediment, after long exposure under sunshine will shrink to one half of its original volume.

Conclusion:

It may be seen from the above that the effective life of Chi-chi Reservoir (60% of total Capacity) would vary from 3.65 to 88.9 years and that of the Lung-shen-chiao Reservoir from 4.36 to 106 years. Necessity for further collection of silt data is indicated.

GEOGRAPHICAL NAMES

(North & Central Taiwan)

North Taiwan

A

A-yu 阿玉

C

Central Range (Chung-yang-shan-mai) 中央山脈
Chia-nan 甲南
Chia-yang 佳陽
Chia-yi 嘉義
Chieh-cheng 結城
Chih-hu Reservoir 紙湖水庫
Chih-hu Tsun 紙湖村
Ching-chuan 清泉
Ching-tsao-hu 青草湖
Chin-shan-mien 金山面(金山里)
Chio-pan-shan 角板山
Chiu-kang (Ti-kang) 萩岡 (荻岡)
Chiu-liang-hsi 久良栖 (和平)
Cho-lan 卓蘭
Cho-lan Hsiang 卓蘭鄉
Cho-lan Reservoir 卓蘭水庫
Chu-keng 竹坑
Chu-keng Reservoir 竹坑水庫
Chu-kwang-keng 出礦坑
Chu-lin 竹林
Chu-nan 竹南
Chu-nan Hydraulic Association 竹南水利委員會
Chung-kang Chi 中港溪
Chung-li 中壢
Chu-tung 竹東
Chu-tung Canal 竹東大圳
Construction Office of Taipei City Government 臺北市政府工務局

E

Erh-chung-pu 二重埔
Erh-pen-sung 二本松

F

Feng-yuan No 1 豐原一號
Feng-yuan No 2 豐原二號
Feng-yuan No 3 豐原三號
Fu-hsin 福興

H

Hai-shan 海山
Ha-pen 哈本
Ha-pen Reservoir 哈本水庫
Heng-chun 恆春
Heng-lung-shan Station 橫龍山測站
Ho-ping Hsiang 和平鄉
Hou-li 后里
Hou-lung 後龍
Hou-lung Chi 後龍溪
Hsiang-pi 象鼻
Hsiang-pi Police Station 象鼻警察派出所
Hsiang-pi Reservoir 象鼻水庫
Hsiang-shan 香山
Hsiao-li 霄裡
Hsiao-tsu-keng 小粗坑
Hsi-ho Dam 西河壩
Hsi-ho Reservoir 西河水庫
Hsin-chu 新竹
Hsin-chuang 新莊
Hsin-kwei-shan 新龜山
Hsin-kwei-shan Plant 新龜山電廠
Hsin-tien 新店
Hsin-tien Chi 新店溪

Hsin-tien Fault	新店斷層
Hsi-shui-shan Station	洗水山測站
Hsuan-yuan	萱原
Hsueh-shan-keng	雪山坑
Huan-shan	環山
Hu-kow	湖口
Hwa-lien	花蓮
Hwo-shao-liao	火燒寮
Hwo-yen-shan Dike	火炎山堤防

I

I-lan	宜蘭

J

Jen-lung	仁隆
Jih-nan	日南
Juan-chiao	軟橋
Jui-fang	瑞芳

K

Kan-kow	乾溝
Kao-hsiung	高雄
Kao-kang (San-kwang)	高崗（三光）
Kao-ling	高嶺
Kao-yi-lan	高義蘭
Kee-lung City	基隆市
Kee-lung River	基隆河
Ke-ya Chi	客雅溪
Ku-kwan	谷關
Kwan-hsi	關西
Kwan-tu	關渡
Kwan-yin	觀音
Kwei-chu-lin Reservoir	桂竹林水庫
Kwei-chu-lin Tsun	桂竹林村
Kwei-shan	龜山

L

Lao-hao	喇號，拉號
La-hao Reservoir	拉號水庫
Lao-chieh Chi	老街溪
Lao-chuang Chi	老庄溪
Lao-tien-liao Chi	老田寮溪
Li-mo-kan	利莫干（利莫岸）
Li-mo-kan Reservoir	利莫干水庫
Li-yu-tan	鯉魚潭
Lower Ta-chien (Hsia-ta-chien)	下達見
Lu-chang	鹿場
Lung-tan	龍潭

M

Ma-an-liao	馬鞍寮
Ma-chu-keng	麻竹坑
Mai-fu-ping Reservoir	埋伏坪水庫
Ma-li-ko-wan	馬利可萬
Ma-lun	馬崙（巴崚）
Ma-mei (Ma-ming)	麻梅（馬鳴）
Miao-li Hsien	苗栗縣
Miao-li Hydraulic Association	苗栗水利委員會
Ming-teh Reservoir	明德水庫
Ming-teh Tsun	明德村
Mt Ho-huan	合歡山
Mt Nan-hu	南湖山
Mt Ta-pa-chien	大壩尖山
Mt Tsu-kao	次高山（雪山）

N

Nan-chuang	南庄
Nan-kan	南崁
Nan-keng Chi	南坑溪
Nan-shih	南勢
Nan-shih Chi	南勢溪
Nei-wan Tsun	內灣村

Nuan-nuan 暖暖
Nuan-nuan Reservoir 暖暖水庫

O

O-mei 峨眉
O-mei Chi 峨眉溪

P

Pa-chieh 八結
Pa-hsien-shan 八仙山
Pa-hsien-shan Lumber Yard 八仙山林場
Pa-hsien-shan Railway 八仙山鐵路
Pai-leng 白冷
Pa-kuai 八塊
Pa-tu 八堵
Pei-pu Thermal Power Plant 北部火力電廠
Pei-shih Chi 北勢溪
Ping-chen 平鎮
Ping-lin 坪林
Pi-ya-nan-an-pu 壁亞南鞍部

S

San-chu-hu Reservoir 珊珠湖水庫
San-chu Tsun 珊珠村（珊珠湖）
San-hsia 三峽
San-i 三義
Sha-hu-li 沙湖壢
Shang-ping Tsun 上坪村
Sheh-liao-chio 社寮角
Shih-erh-liao 十二寮
Shih-kang 石岡（石崗）
Shih-ling 司令
Shih-men 石門
Shih-men Reservoir 石門水庫
Shih-pah-erh 十八兒
Shih-tan Hsiang 獅潭鄉
Shih-ti 石底
Shih-ting 石碇
Shou-feng 壽豐
Shuang-chi 雙溪
Shuang-chi Reservoir 雙溪水庫
Shui-ti-liao 水底寮
Sung-shan 松山
Sung-shu-chiao 松樹脚

T

Ta-an Chi 大安溪
Ta-chi 大溪
Ta-chia Chi 大甲溪
Ta-chia Chi Development Commission 大甲溪開發委員會
Ta-chien 達見
Ta-chien Reservoir 達見水庫
Ta-hsi 大溪
Ta-hu 大湖
Tai-chung 臺中
Tai-chung Hsien 臺中縣
Ta-ko-nan (Ta-ku-nan) 大閣南（大古南）
Tai-nan 臺南
Tai-pao-chiu 太保久
Tai-pei Bridge 臺北橋
Tai-pei City 臺北市
Tai-tung 臺東
Tai-wan Power Company 臺灣電力公司
Tai-ya-kan 泰亞干（泰野關）
Tai-yu-ku 鯉魚堀
Ta-ko-kan Chi 大嵙崁溪
Ta-ko-kan Railway Bridge 大嵙崁鐵橋
Ta-kwan 大觀
Ta-nan-pu 大湳埔
Tan-shui River 淡水河
Tao-shan 桃山

Tao-shan Police Station	桃山警察派出所
Tao-yuan	桃園
Tao-yuan	桃源
Tao-yuan Canal	桃園大圳
Tien-leng	天冷
Tien-leng Reservoir	天冷水庫
Ti-kang (Chiu-kang)	荻岡（萩岡）
Ting-pu Canal	汀埔圳
To-lo-ku Chi	哆囉咽溪
Tou-chien Chi	頭前溪
Tou-fen	頭份
Tou-wu Hsiang	頭屋鄉
Tsao-shan (Grass Mountain)	草山
Tu-cheng	土城
Tung-hsiao	通霄
Tung-shih	東勢

U

Upper Ku-kwan (Shang-ku-kwan)	上谷關

W

Wai-shih-tan	外獅潭
Wan-hwa	萬華
Water Conservancy Bureau	水利局
Water Resources Development Commission	水資源開發委員會
Wu-lai	（新店溪）烏來
Wu-lai Police Office	烏來警察派出所
Wu-lai Series (Urai Series)	烏來系
Wu-lai Reservoir	（大料炭溪）烏來水庫
Wu-tu	五堵

Y

Yuan-li	苑裡
Yuan-shan	圓山
Yuan-tung-tzu	員東子
Yu-cheh-kou	油車口
Yueh-mei	月眉

Central Taiwan

A

A-leng Chi 阿冷溪
A-li-shan Chi 阿里山溪
A-li-shan Station 阿里山測站
Ao-wan-ta 奧萬大

C

Central Range (Chung-yang-shan-mai) 中央山脈
Chai-tou-chiao 柴頭橋
Chang-hu 樟湖
Chang-hwa 彰化
Chang-nao-liao 樟腦寮
Chao-an-liao 詔安寮
Chao-jih 朝日
Che-lung-pu (Kwang-lung Tsun) 車籠埔（光隆村）
Chen-yu-lan Chi 陳有蘭溪
Chia-nan Canal 嘉南大圳
Chiao-li-ping 交力坪
Chia-tsou-liao Chi 加走寮溪
Chia-yi 嘉義
Chia-yi Hsien 嘉義縣
Chi-chi 集集
Chi-chi Reservoir 集集水庫
Chi-chow 溪洲
Chien-cho-wan She 千卓萬社
Chien-kow 墘溝
Chien-kow Fault 墘溝斷層
Chien-pu-tso 前埔厝
Chih-kan 赤崁
Chih-mao 治茆
Chi-lung-shan Fault 雞籠山斷層
Ching-pu 菁埔
Ching-shui 清水
Ching-shui Chi 清水溪
Ching-shui-chi Reservoir 清水溪水庫
Chi-tou 崎頭
Chiu-chiun-lin (Chiu-hsiung-lin) 九芎林
Cho-lan 卓蘭
Cho-lan Strata 卓蘭層
Cho-shui Chi 濁水溪
Cho-shui Main Canal 濁水幹渠
Chuan-chung-tao 川中島
Chu-chi 竹崎
Chui-fen 追分
Chu-keng 竹坑
Chu-keng Fault 竹坑斷層
Chu-kung 鉅工
Chung-kwa-liao 種瓜寮
Chung-kwei 銃櫃
Chung-liao 中寮
Chung-niu-keng 刣牛坑
Chun-kung-liao 軍功寮
Chun-ta 郡大
Chun-ta Chi 郡大溪
Chu-ping She 曲水社
Chu-shan 竹山
Chu-tzu-shan 珠子山

E

Erh-shui 二水
Erh-wan-ping 二萬坪

F

Fang-li 房里
Fan-tzu-liao 番子寮
Fen-chi-hu 奮起湖

Feng-jung	豐榮
Feng-yuan	豐原
Fu-hsing	福興
Fu-shih	富士

H

Ho Chi	和溪
Ho-chi-tso Canal	和溪厝圳
Ho-huan-shan Station	合歡山測站
Ho-she	和社
Ho-she Chi	和社溪
Ho-shui Chi	合水溪
Hsiao-mei (Mei-shan)	小梅（梅山）
Hsiao-pu She	小埔社
Hsia-tan-shui Chi	下淡水溪
Hsi-lo	西螺
Hsin-chu	新竹
Hsin-she-chuang	新社庄
Hsiu-ku-luan Chi	秀姑巒溪
Hu-wei	虎尾

I

I-na-kuo	伊那果（親愛）

J

Jen-lun She	人倫社

K

Kan-chi-kow	乾溪口
Kan-tzu-lin	柑子林
Kao-hsiung	高雄
Kee-lung	基隆
Keng-tou-tso	坑頭厝
Keng-tzu-liao-ping	㹃子寮坪
Ko-chueh	葛掘
Ko-tzu-keng Canal	柯子坑圳
Ku-keng	古坑
Kuo-hsing	國姓
Kuo-hsing Anti-syncline	國姓背斜軸
Kuo-hsing Canal	國姓圳
Kuo-hsing Fault	國姓斷層
Kuo-hsing Hsiang	國姓鄉
Kuo-shan (Kai-yuan-hou)	過山（開元後）
Kwan-men	關門
Kwan-tao	關刀
Kwei-tzu-tou	龜子頭

L

Lao-nung Chi	荖濃溪
Lao-shui-keng	勞水坑
Lao-shui-keng Canal	勞水坑圳
Li-hsing	力行
Lin-nei	林內
Lin-nei Canal	林內大圳
Lin-tzu-cheng	林子城
Lin-wei	林尾
Li-wu Chi	立霧溪
Li-yu-ku	鯉魚窟
Li-yu-ku Reservoir	鯉魚窟水庫
Lu-kang	鹿港
Lu-ma-chan	鹿麻產
Lung-an Canal	籠庵圳
Lung-ching Hsiang	龍井鄉
Lung-shen-chiao	龍神橋
Lung-shen-chiao Reservoir	龍神橋水庫
Lung-tu-sheh	龍吐舌
Lun-pei	崙背
Lu-tso-wa	鹿厝挖

M

Ma-an-liao	馬鞍寮
Ma-an-liao Strata	馬鞍寮層

Ma-hsi-ta-lun She 馬西達輪社
Ma-hsi-to-pang Reservoir 馬西托邦水庫
Mao-lan 貓囒
Mao-lo Chi 貓羅溪
Mao-tzu-pu 茅子埔（太南村）
Ma-sheh-lung 麻舌隆
Mei Chi 眉溪
Mei-shan 梅山（小梅）
Mei-tzu-chi 梅子崎
Mei-yuan 眉原
Mei-yuan Chi 眉原溪
Mei-yuan She 眉原社
Men-pai-tan 門牌潭
Min-hsiung 民雄
Mt. A-li 阿里山
Mt. An-ying 暗影山
Mt. Chi-lai-chu 奇萊主山
Mt. Chien 前山
Mt. Chih-mao 治茆山
Mt. Chi-lung 雞籠山
Mt. Chin-kan-shu 金甘樹山
Mt. Erh-yu 兒玉山
Mt. Feng-huang 鳳凰山
Mt. Ho-huan 合歡山
Mt. Hsi 西山
Mt. Hsin-kao 新高山
Mt. Hsiu-ku-luan 秀姑巒山
Mt. Kwan-tou 關頭山
Mt. Luan-ta 巒大山
Mt. Lu-lin 鹿林山
Mt. Mai-hou 埋后山
Mt. Mao-lan 貓囒山
Mt. Neng-kao 能高山
Mt. Pai 白山
Mt. Pa-tung-kwan 八通關山
Mt. Pei 北山
Mt. Pu-chi 卜吉山
Mt. Shih 石山
Mt. Shui-she-ta 水社大山
Mt. Sung 松山
Mt. Ta-chien 大尖山
Mt. Ta-heng-ping 大横屏山
Mt. Tan-ta 丹大山
Mt. Ta-shih-kung 大石公山
Mt. Ta-ta 大塔山
Mt. Tou-ko 頭嵙山
Mt. Tui-wan 對萬山
Mt. Wan-sui 萬歲山
Mt. Wu-yi-lun 五義崙山
Mt. Yu 玉山
Mu-li-lan 木屐囒

N

Nan Chi 南溪
Nan-kang Chi 南港溪
Nan-kang-chi Reservoir 南港溪水庫
Nan-tou 南投
Nan-tou Hsien 南投縣
Nan-tzu-chiao-wan 楠子脚萬
Nan-tzu-liao 楠子寮
Nei-chia-tao-keng 內加道坑
Nei-liao 內寮
Nei-mao-pu 內茅埔
Nei-pu-tzu 內埔子
Nei-ta-lin 內大林
Neng-kao 能高
Niu-chow Chi 牛綢溪
Niu-hsiang-chu 牛相觸
Niu-wen-lu (Yung-hsing Tsun) 牛轀轆（永興村）

P

Pai-leng 白冷
Pai-mao Strata 白毛層

Pai-yeh-keng 白葉坑
Pa-ku 八股
Pa-pao 八寶
Pa-pao Canal 八寶圳
Pa-tung-kwan 八通關
Pei Chi 北溪
Pei-kang Chi 北港溪
Pei-kang-chi (Tsun) 北港溪(村)
Pei-kang-chi Reservoir 北港溪水庫
Pei-pa-la She 貝拔拉社
Pei-shan-keng 北山坑
Pei-shan-keng Hydro-power Plant 北山坑水力發電廠
Pei-tou 北斗
Pìng-tzu-ting (Ping-ting Tsun) 坪子頂(坪頂村)
Po-tzu-pu 朴子埔
Pu-li 埔里
Pu-li Reservoir 埔里水庫
Pu-tzu 廍子

S

San-chio-feng 三角峯
San-kwai-tso 三塊厝
San-pien 三汴(坪林村)
San-tieh Chi 三疊溪
Sha-li-hsien Chi 沙里仙溪
Shan-pien Canal 山邊圳
Shan-shan Chi 山杉溪
Shan-tzu-chiao 山子脚
Shasta Dam (美國加州)夏士塔壩
Sheng-fan-keng 生蕃坑
Sheng-mao-shu 生毛樹
Sheng-mao-shu Chi 生毛樹溪
Shih-i-fen 十一份
Shih-kang 史港
Shih-kang-keng 史港坑
Shih-kang-keng Chi 史港坑溪
Shih-kang Reservoir 史港水庫
Shih-tzu-tou (Shih-yeh Tsun) 獅子頭(獅埜村)
Shou-cheng Canal 守城圳
Shuang Chi 雙溪
Shuang-chi-tsui 雙溪嘴
Shuang-liao-kan-chiao 雙寮崁脚
Shuang-tung 雙冬
Shuang-tung Fault 雙冬斷層
Shui-chang-liu Chi 水長流溪
Shui-che-liao 水車寮
Shui-li Chi 水裡溪
Shui-li-keng 水裡坑
Shui-li-keng Fault 水裡坑斷層
Shui-liu-tung 水流東
Shui-she 水社
Shui-ti-liao (Tung-hsing Tsun) 水底寮(東興村)
Shui-tou 水頭
Shui-wa-ku 水娃堀
Shui-wei 水尾
Su-hsi Chi 粟栖溪
Sung-ling 松嶺
Sun-moon Lake 日月潭
Sun-moon Lake Reservoir 日月潭水庫
Szu-chueh-tan 四掘潭
Szu-chueh-tan Canal 四掘潭圳

T

Ta-an 大安
Ta-chia 大甲
Ta-chia Chi 大甲溪
Ta-chien-chiao 大尖脚
Ta-chien-shan Station 大尖山測站
Ta-heng-ping-shan Fault 大橫屏山斷層
Ta-heng-ping-shan Syncline 大橫屏山向斜軸

Tai-chung	臺中
Tai-chung City	臺中市
Tai-nan	臺南
Tai-niu-keng	蔚牛坑
Tai-ping	太平（中平）
Tai-tung	臺東
Taiwan Power Company	臺灣電力公司
Taiwan Water Conservancy Bureau	臺灣省水利局
Ta-keng	大坑
Ta-keng Reservoir	大坑水庫
Ta-kwan	大觀
Ta-li Chi	大里溪
Ta-li-chuang	大里庄
Ta-lin	大林
Ta-lo-wan Chi	塔羅灣溪
Ta-mao-pu	大茅埔
Ta-nan Nursey	大楠苗圃
Tan-ta	丹大
Tan-ta Chi	丹大溪
Ta-ping	大坪
Ta-ping-ting	大坪頂
Ta-pu	大浦
Ta-shih-kung	大石公
Ta-tsao-pu	大草舖
Ta-tu	大肚
Ta-tu-cheng	大肚城
Ta-tun	大屯
Tien-liao	田寮
To-lu-ku	托洛庫
Tou-liu	斗六
Tou-liu Canal	斗六大圳
Tou-pien-keng	頭汴坑
Tou-pien-keng Chi	頭汴坑溪
Tou-pien-nan-keng Chi	頭汴南坑溪
Tou-pien-nan-keng Reservoir	頭汴南坑水庫
Tou-pien-pei-keng Chi	頭汴北坑溪
Tou-she	頭社
Tsao-hu	草湖
Tsao-ling	草嶺
Tsao-ling Natural Reservoir	草嶺潭水庫
Tsao-tun	草屯
Tsao-tun Hsiang	草屯鄉
Tseng-wen Chi	曾文溪
Tsui-luan	翠巒
Tsu-kow-keng	祖口坑
Tung-chio	洞角
Tung-feng	東峯
Tung-feng Chi	東峯溪
Tung-pu	東埔
Tung-pu-jui Chi	東埔蚋溪
Tung-tou	桶頭
Tzu-mei-yuan	姊妹原

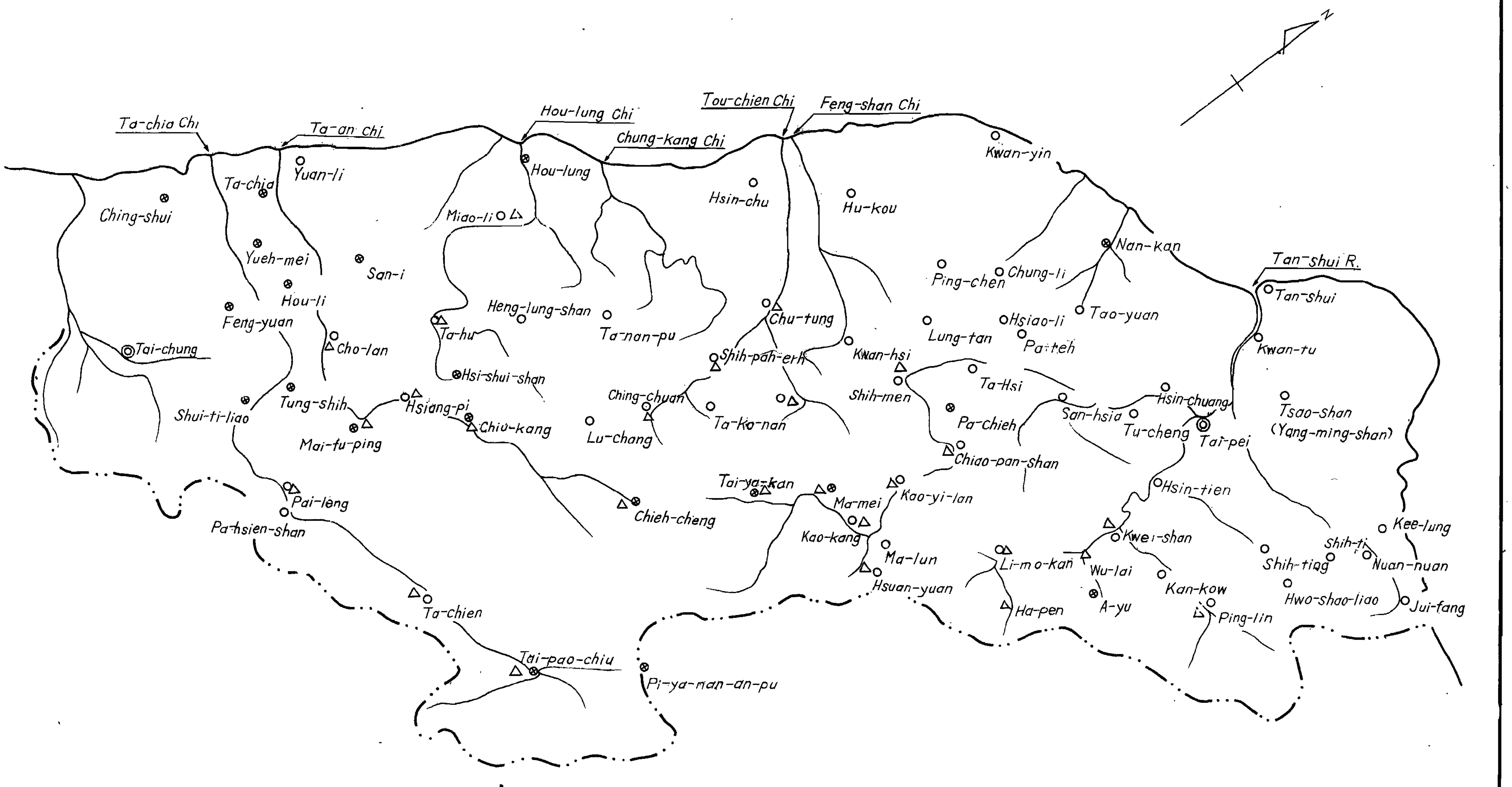
W

Wai-che-cheng	外車埕
Wai-cheng	外城
Wai-chia-tao-keng	外加道坑
Wai-mao-pu	外茅埔
Wai-pan-an	外盤鞍
Wan-ta (Bandai)	萬大
Wan-ta Chi	萬大溪
Wan-tou-liu	萬斗六
Wei-shang	尾上
Wu Chi	烏溪
Wu-chieh	武界（法治村）
Wu-chieh Dam	武界壩
Wu-feng	霧峯
Wu-kung-lun	蜈蚣崙
Wu-lai Series	烏來系
Wu-she Chi	霧社溪
Wu-she Reservoir	霧社水庫

Y

Ying-feng 櫻峯
Yuan-lin 員林
Yu-chih 魚池
Yun-lin 雲林
Yun-tai-chiao 雲帶橋
Yu-sheng 有勝
Yu-yeh-lin 幼葉林

Fig 1



NOTES	
	Rivers
◎	Weather station
○	Rainfall station
▲	Station to be improved
⊗	Abandoned station

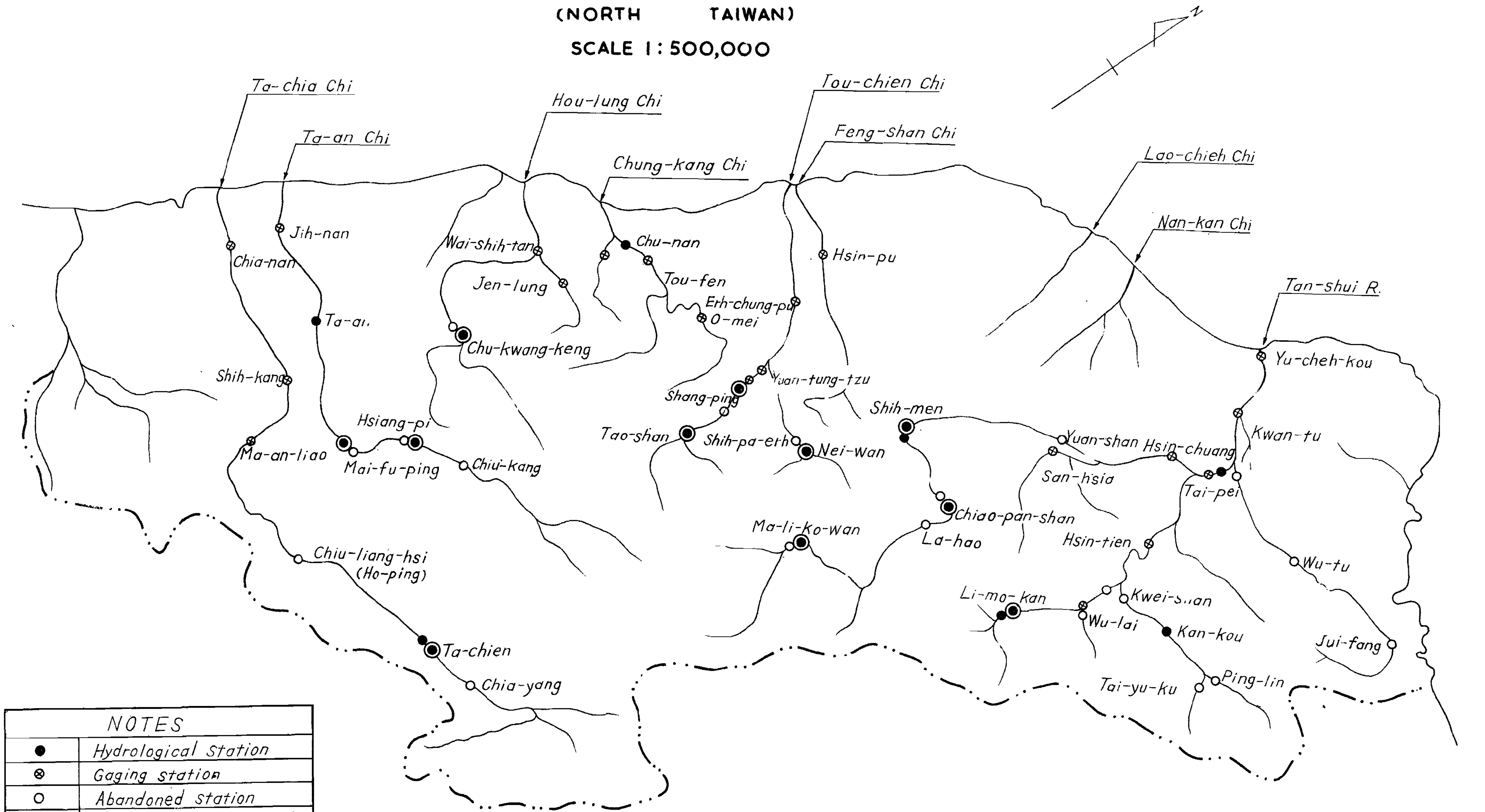
WEATHER STATIONS & RAIN GAUGING STATIONS, NORTH TAIWAN

SCALE 1:500,000

LOCATION MAP OF HYDROLOGICAL STATIONS

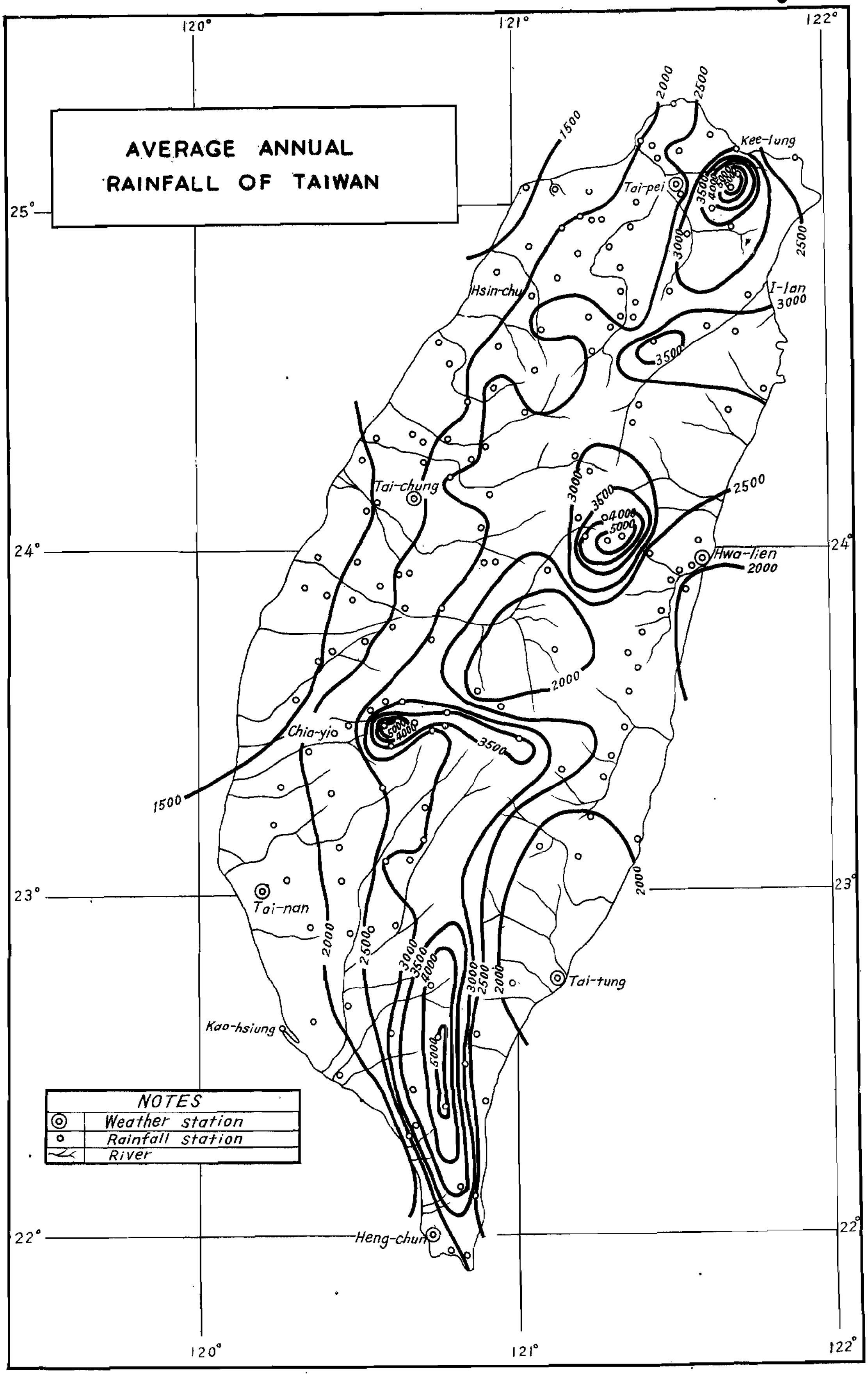
(NORTH TAIWAN)

SCALE 1:500,000



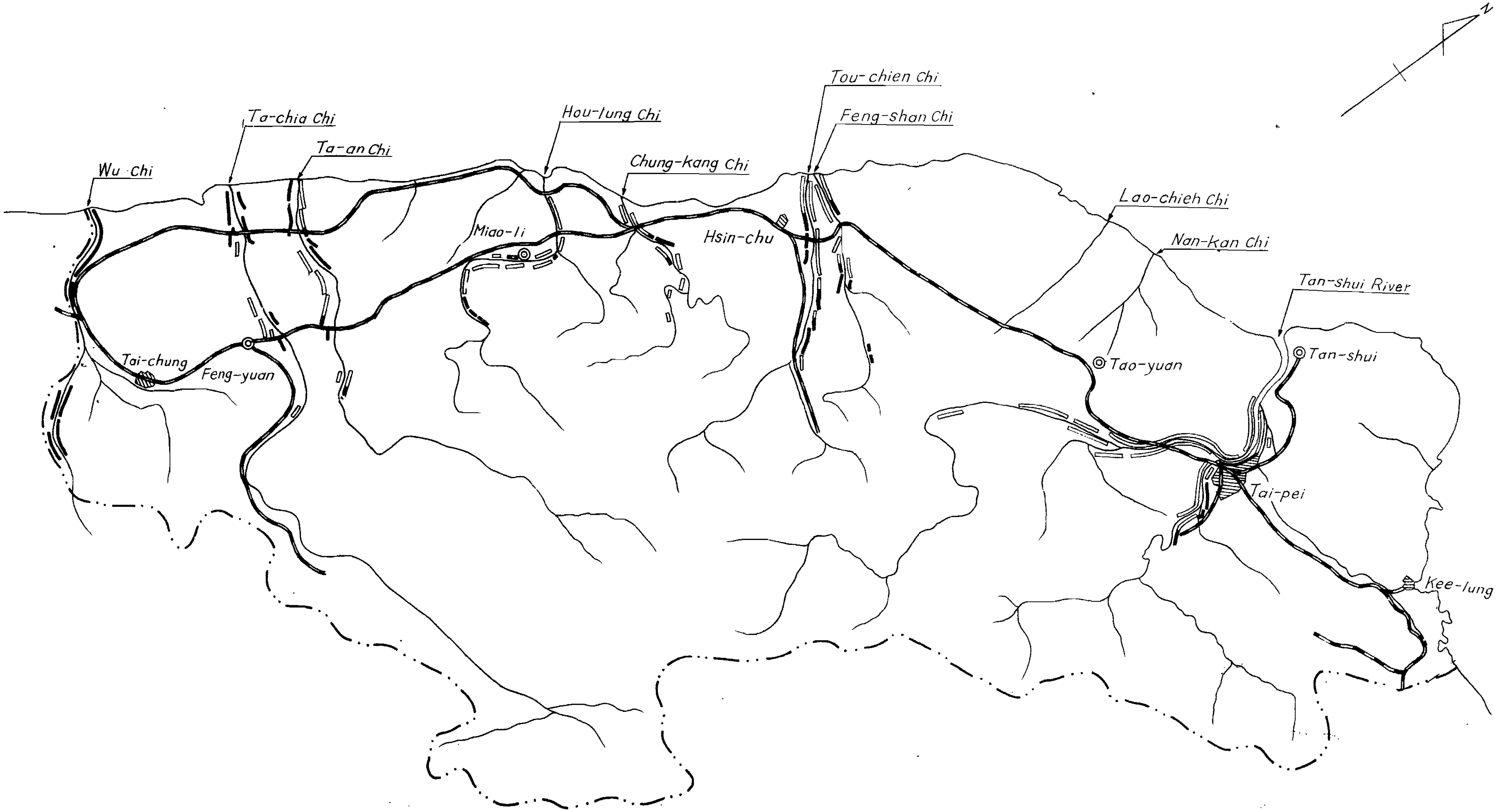
NOTES	
●	Hydrological Station
⊗	Gaging station
○	Abandoned station
◉	Station to be improved

Fig 3



AVERAGE ANNUAL RAINFALL OF TAIWAN
120°
121°
122°
25°
24°
23°
22°
Kee-lung
Tai-pei
Hsin-chu
I-lan
Tai-chung
Hwa-lien
Chia-yio
Tai-nan
Tai-tung
Kao-hsiung
Heng-chun
1500
2000
2500
3000
3500
4000
5000
NOTES
Weather station
Rainfall station
River

Fig 4

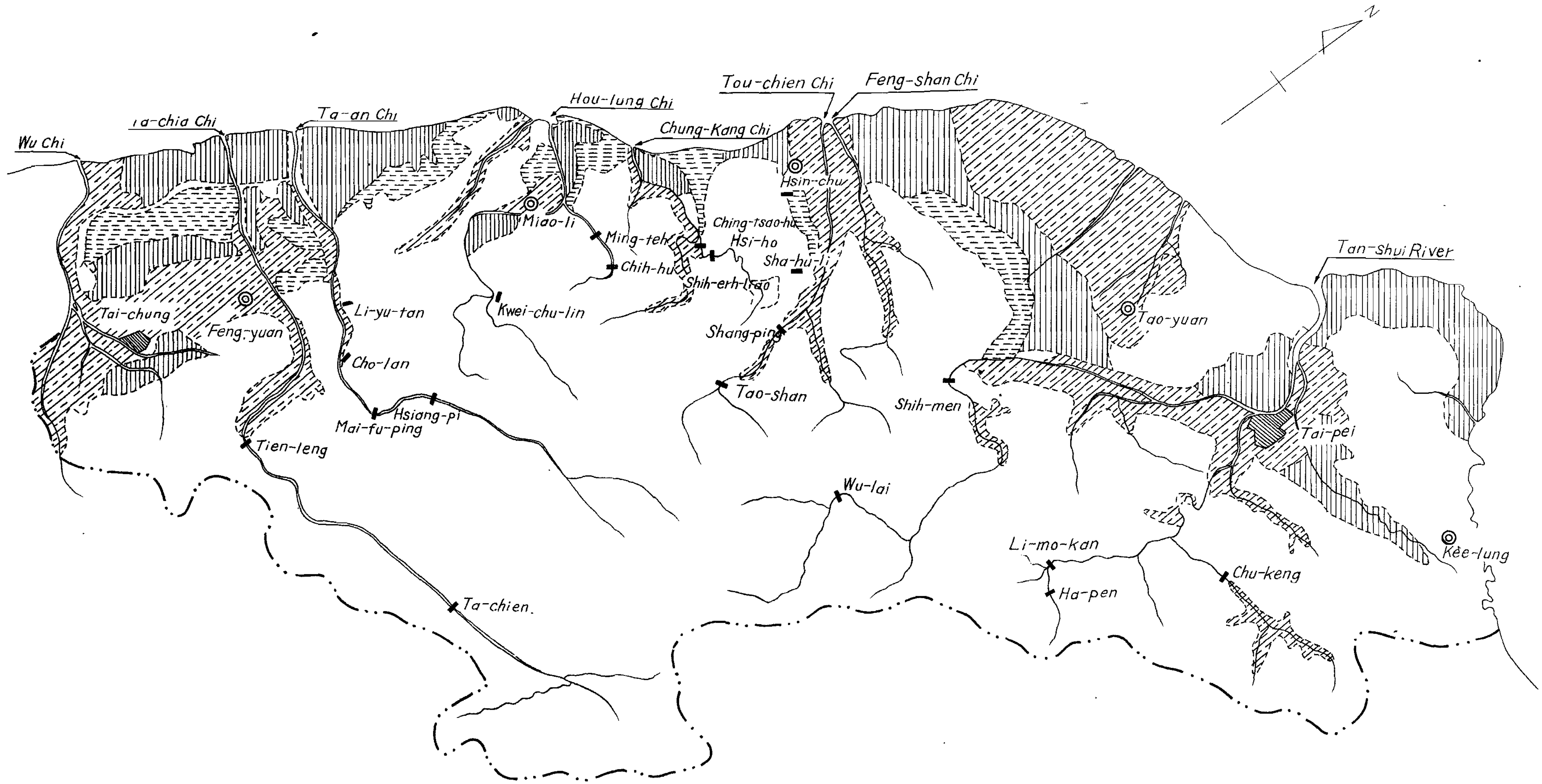


NOTES	
	Rivers
	Railway
	City
	Existing dyke
	Dyke not completed

RIVER WORKS, NORTH TAIWAN

SCALE 1 : 500,000

Fig 5



NOTES	
	River
	City
	Irrigation Area
	Incomplete Irrigation Areas
	Irrigable Area
	Possible Dam Site

IRRIGATION AREAS, NORTH TAIWAN

SCALE 1:500,000

MAP OF ELECTRIC POWER SYSTEM

(NORTH TAIWAN)

SCALE 1 : 500,000

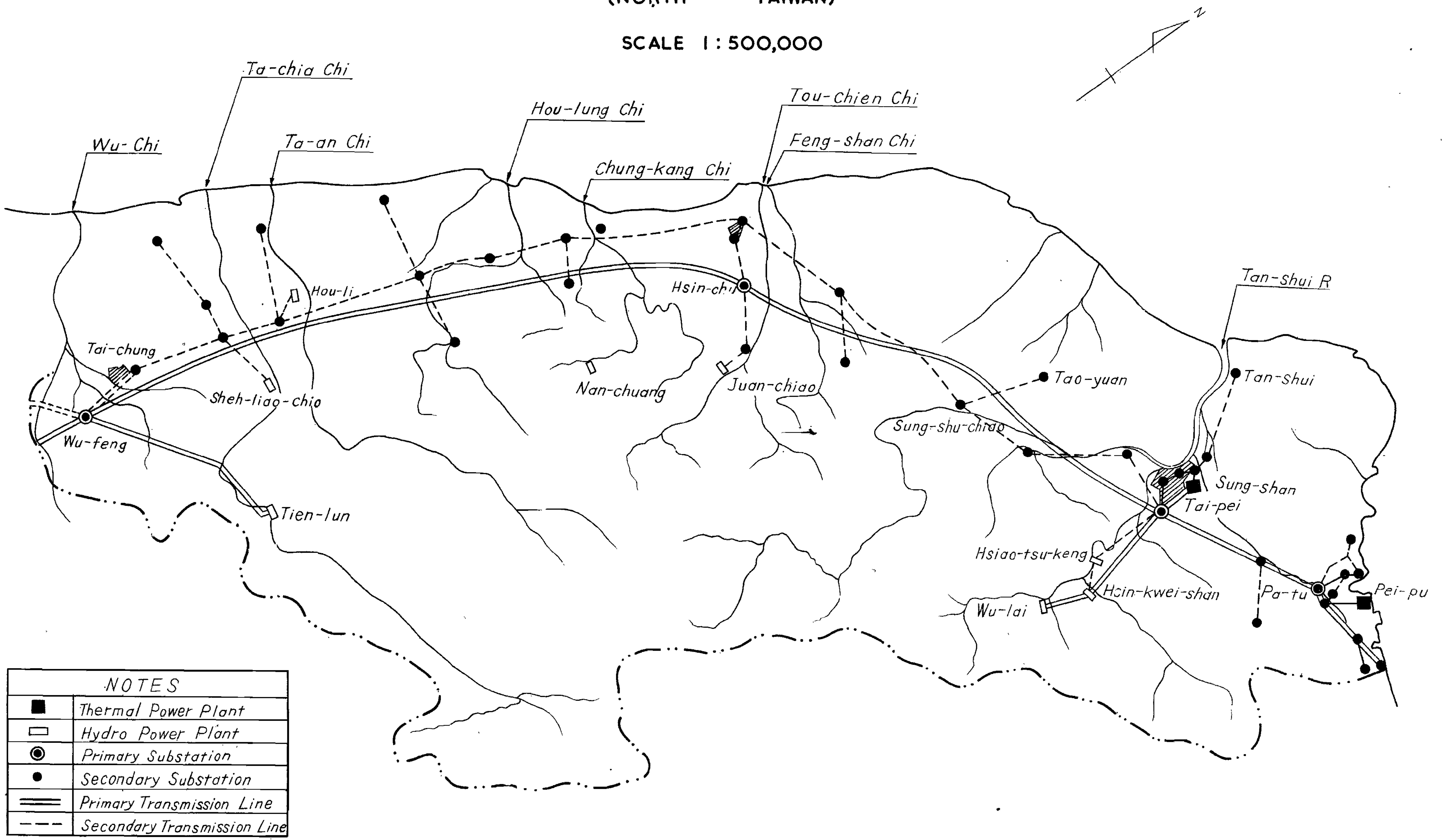
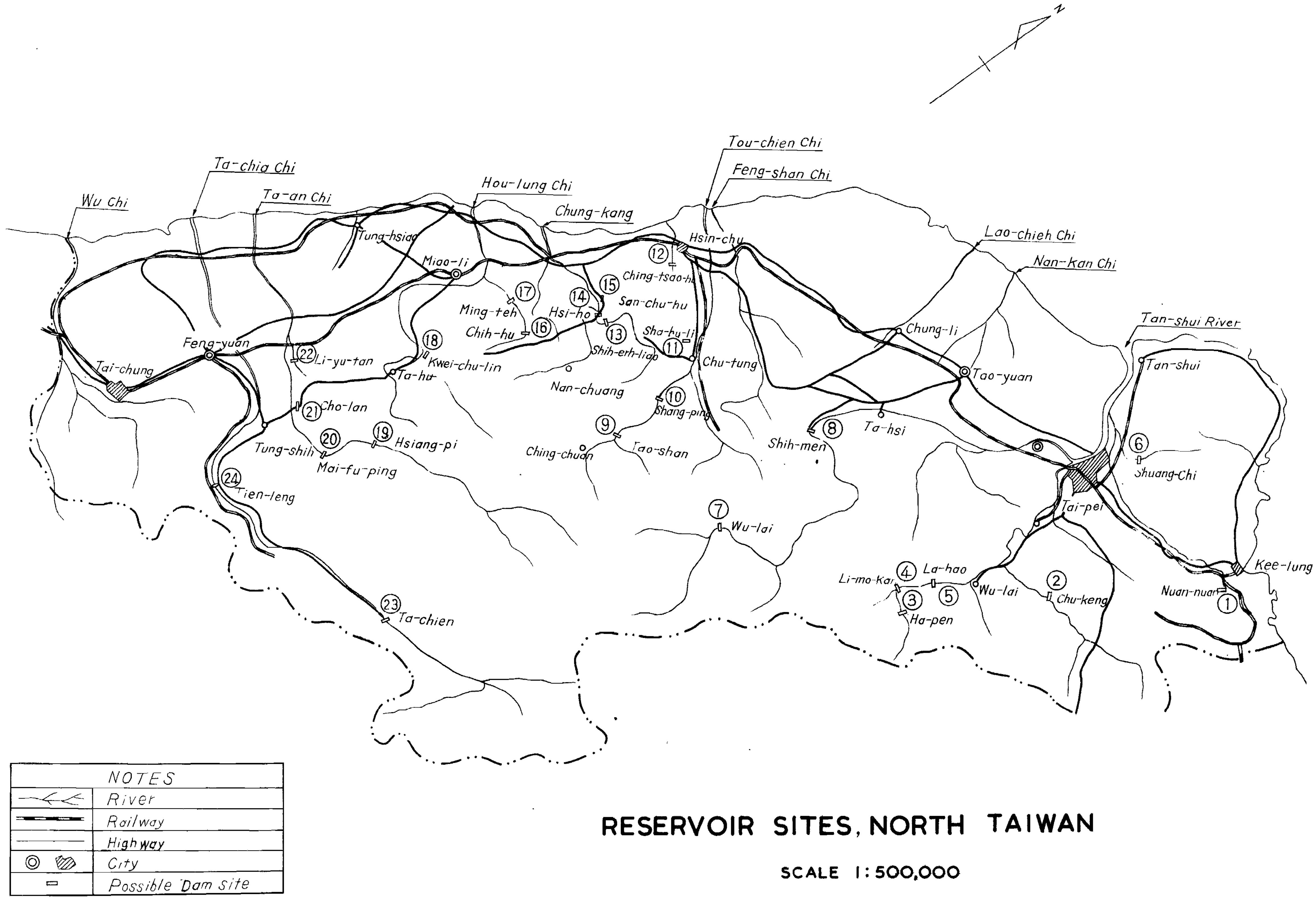


Fig 7



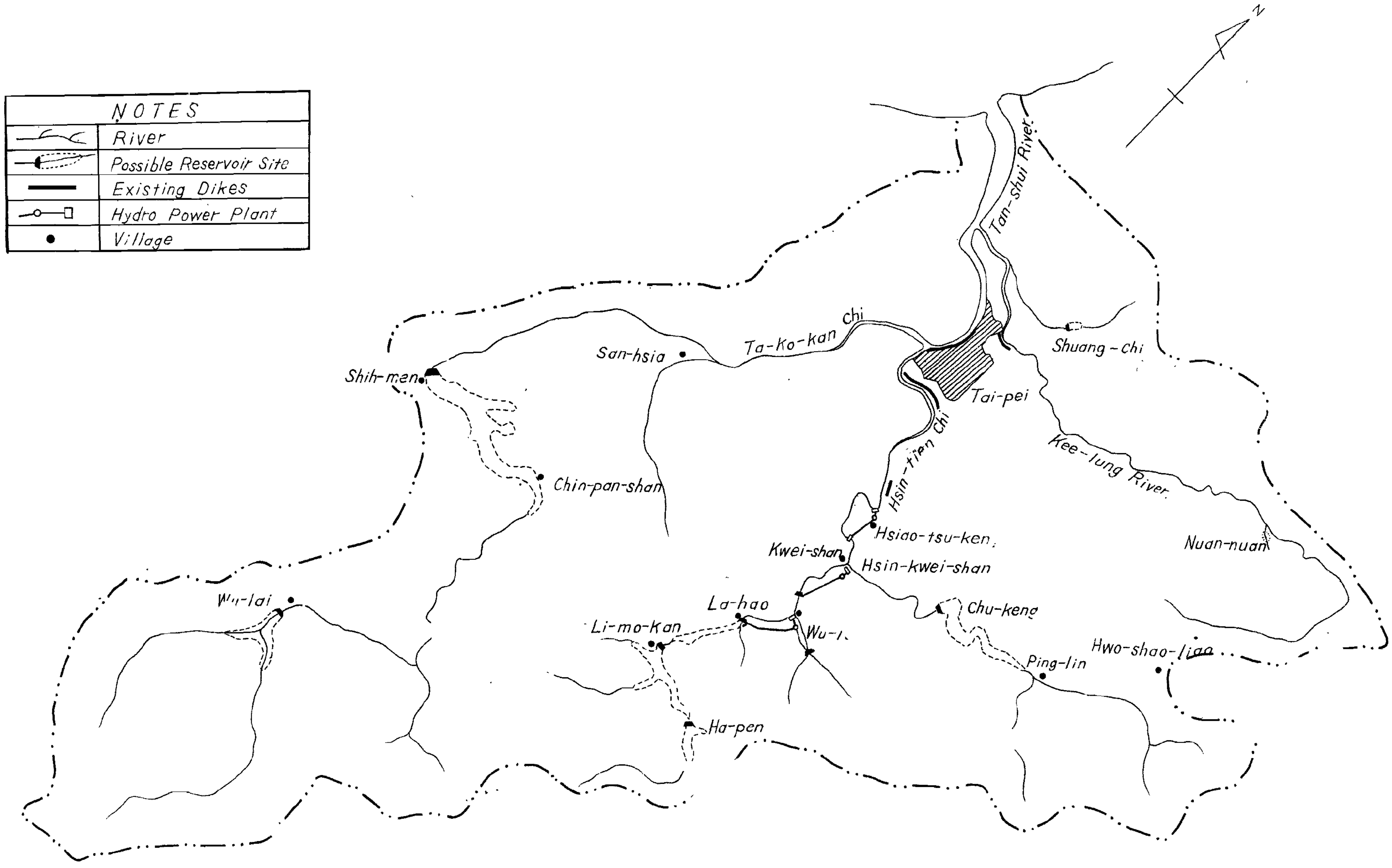
RESERVOIR SITES, NORTH TAIWAN

SCALE 1:500,000

Fig 8

TAN SHUI RIVER BASIN

SCALE 1:300,000

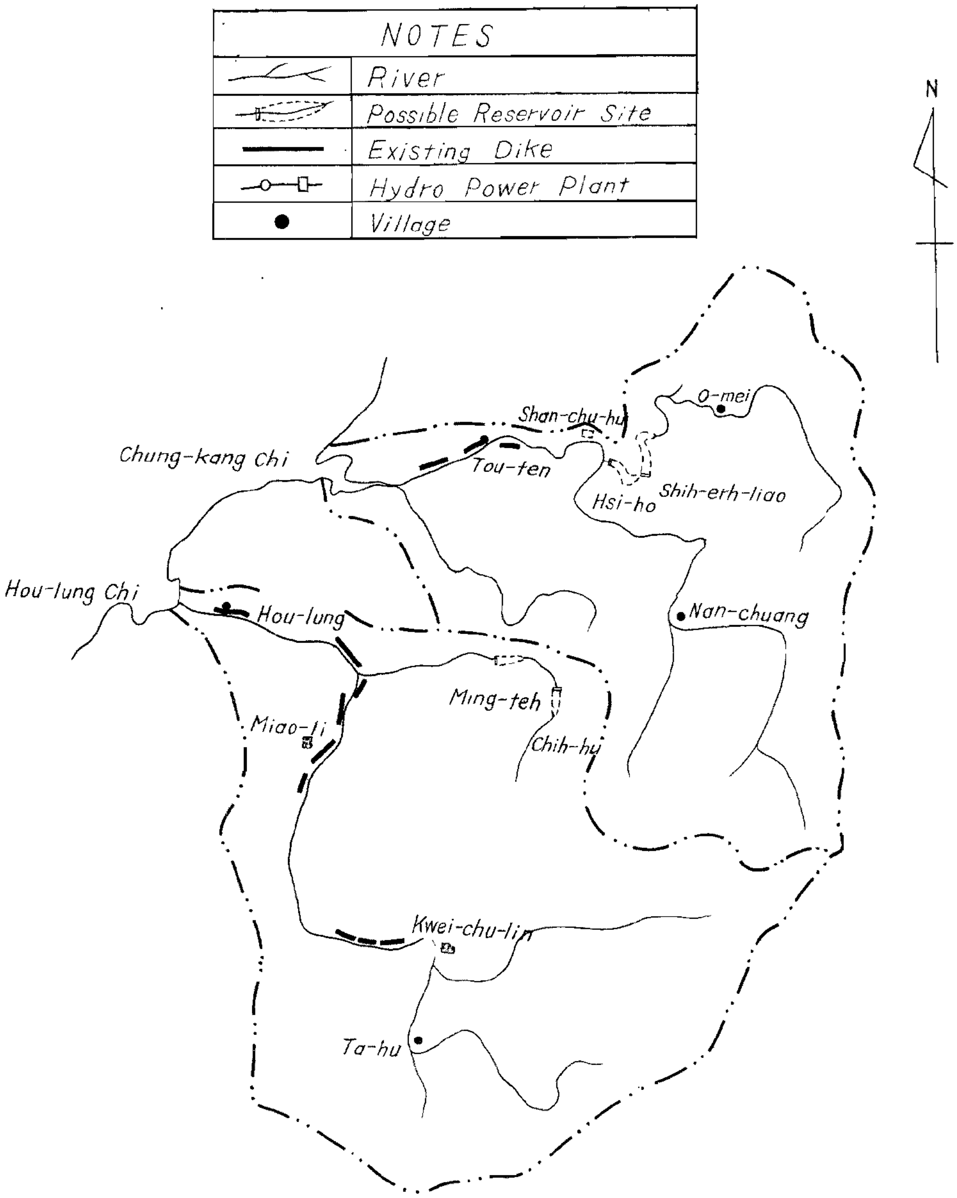


FENGSHAN & TOUCHIEN CHI BASIN

SCALE 1:300,000

CHUNGKANG & HOULUNG CHI BASIN

SCALE 1:300,000



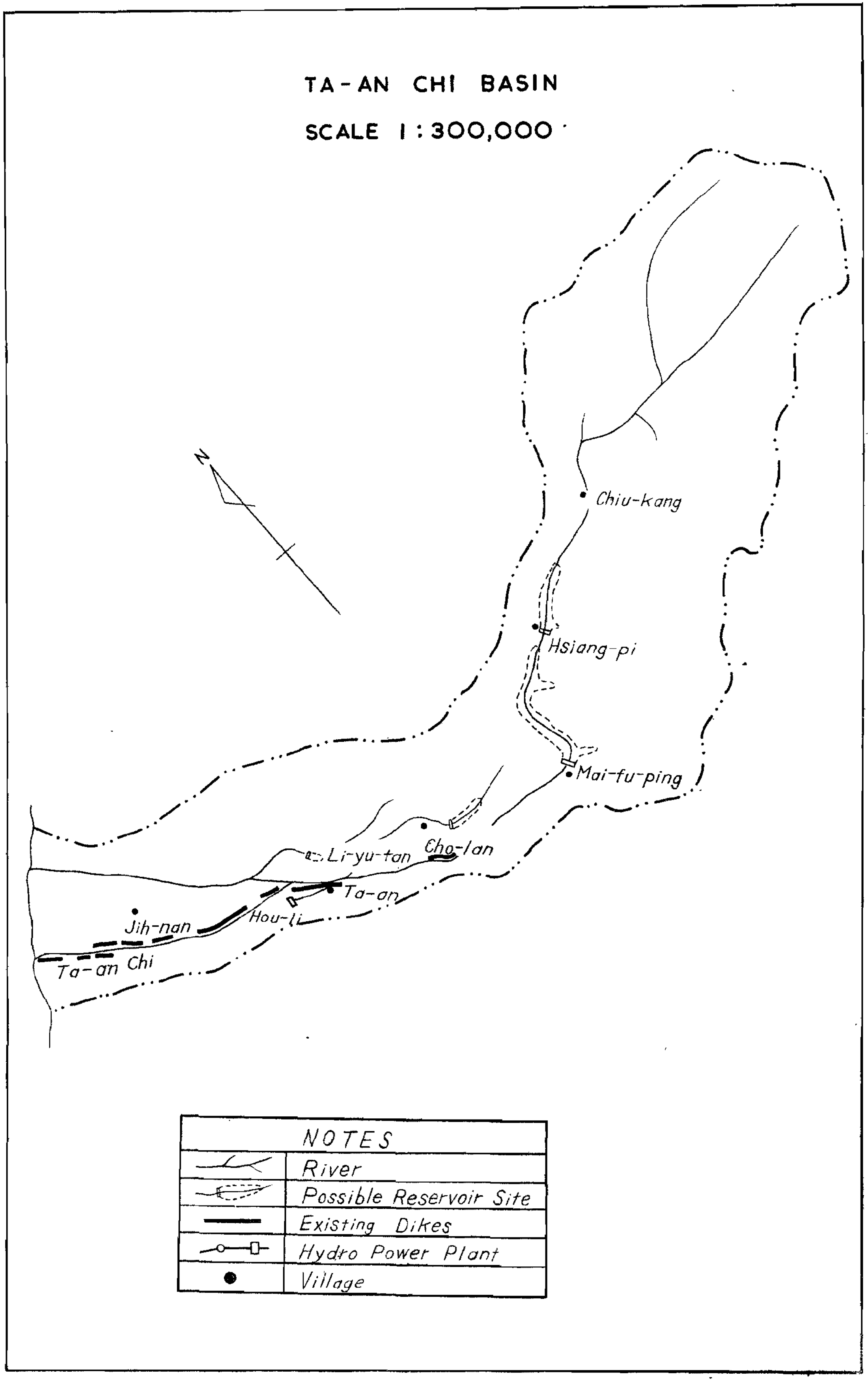
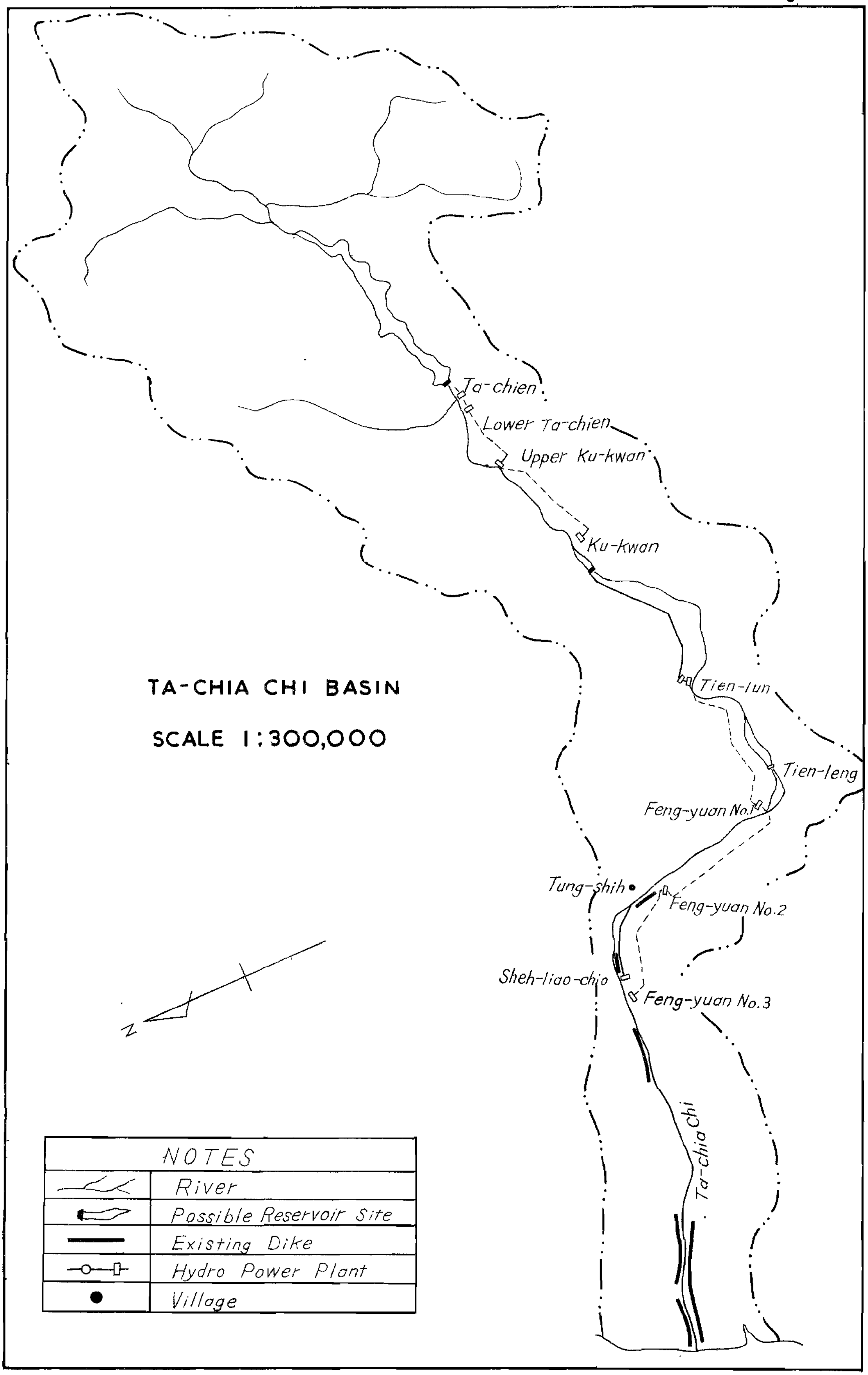

TA-AN CHI BASIN
SCALE 1:300,000
N
Chiu-kang
Hsiang-pi
Mai-fu-ping
Cho-lan
Li-yu-tan
Ta-an
Hou-li
Jih-nan
Ta-an Chi
NOTES
River
Possible Reservoir Site
Existing Dikes
Hydro Power Plant
Village

Fig 12



TA-CHIA CHI BASIN
SCALE 1:300,000
Ta-chien
Lower Ta-chien
Upper Ku-kwan
Ku-kwan
Tien-lun
Tien-leng
Feng-yuan No.1
Tung-shih
Feng-yuan No.2
Sheh-liao-chio
Feng-yuan No.3
Ta-chia Chi
N
NOTES
River
Possible Reservoir Site
Existing Dike
Hydro Power Plant
Village

Fig 13

NUAN-NUAN DAM SITE
Scale 1:1,000
131.0 M
45.5 M
85.5 M
HA-PEN DAM SITE
Scale 1:1,000
145.0 M
NWL 542.6
LI-MO-KAN DAM SITE
Scale 1:2,000
41°
45°
WL 352 M
CHU-KENG DAM SITE
Scale 1:1,000
150 M
8~10 M x 7.2 M Radial gates
EL 175 M
NWL 170 M
WL 98 M
LA-HAO DAM SITE
Scale 1:2,000
50°
50°
Baby Track 307 M
67°
66°
WL 216 M
SHUANG-CHI DAM SITE
Scale 1:1,000
129 M
WL 106 M
SHIH-MEN DAM SITE
Scale 1:2,000
383 M
SHANG-PING DAM SITE
Scale 1:1,000
65½°
50°
223.6 M Highway
56°
WL 204.7 M
WU-LAI DAM SITE
Scale 1:1,000
103.5 M
EL 860 M
TAO-SHAN DAM SITE
Scale 1:1,000
110 M
70°
60°
80°
63°
WL 418 M

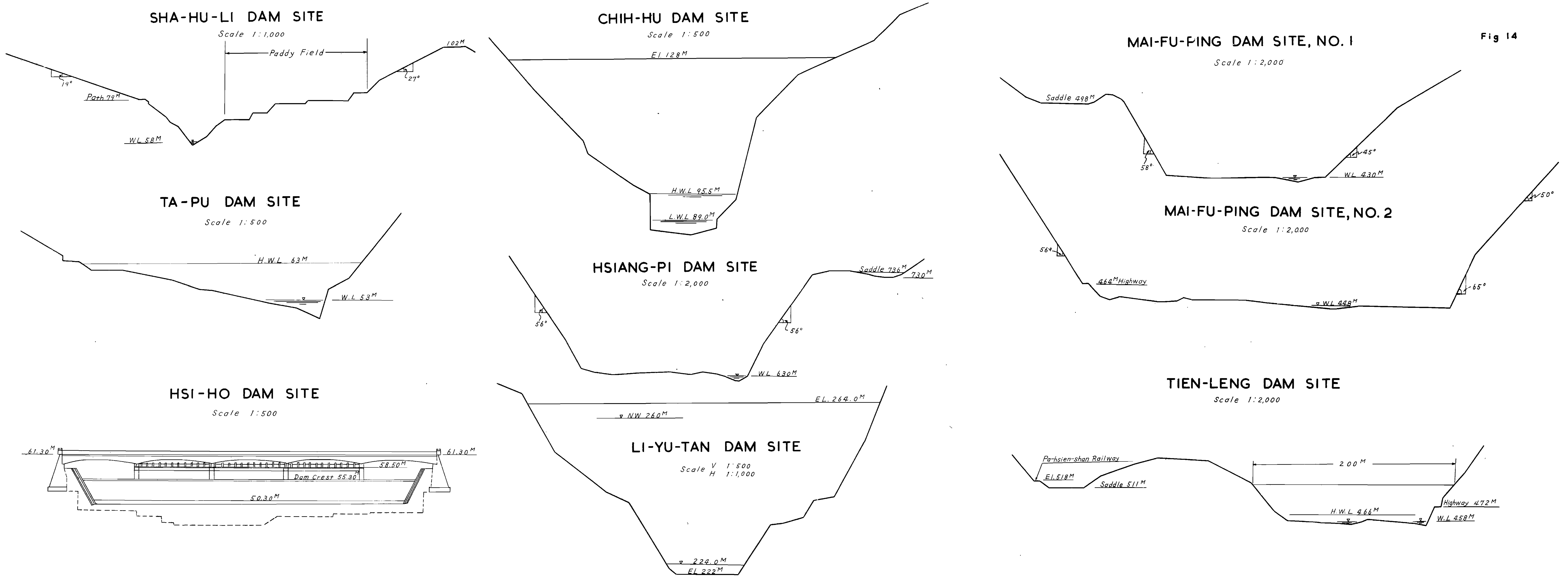
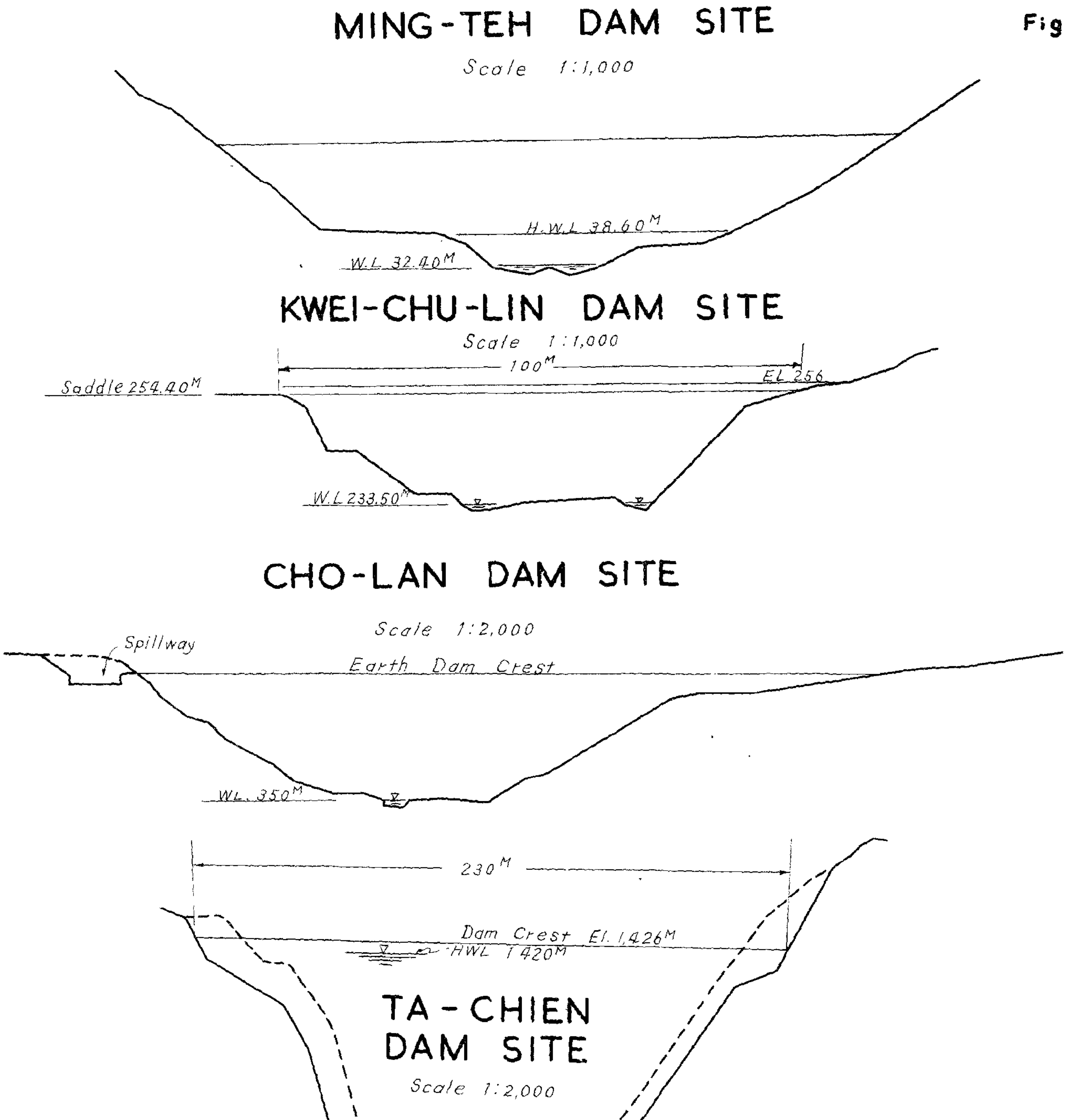

SHA-HU-LI DAM SITE
Scale 1:1,000
Paddy Field
102M
27°
19°
Path 79M
WL 58M
TA-PU DAM SITE
Scale 1:500
H.W.L 63M
W.L 53M
HSI-HO DAM SITE
Scale 1:500
61.30M
61.30M
58.50M
Dam Crest 55.30
50.30M
CHIH-HU DAM SITE
Scale 1:500
El 128M
H.W.L 95.5M
L.W.L 89.0M
HSIANG-PI DAM SITE
Scale 1:2,000
Saddle 736M
730M
56°
56°
WL 630M
LI-YU-TAN DAM SITE
Scale V 1:500 H 1:1,000
EL. 264.0M
NW 260M
224.0M
EL 222M
MAI-FU-PING DAM SITE, NO. 1
Scale 1:2,000
Saddle 498M
58°
45°
WL 430M
MAI-FU-PING DAM SITE, NO. 2
Scale 1:2,000
56°
464M Highway
WL 448M
65°
50°
TIEN-LENG DAM SITE
Scale 1:2,000
Pa-hsien-shan Railway
El 518M
Saddle 511M
200M
H.W.L 466M
Highway 472M
W.L 458M

Fig 14

Fig 15



MING-TEH DAM SITE
Scale 1:1,000
H.W.L 38.60M
W.L. 32.40M
KWEI-CHU-LIN DAM SITE
Scale 1:1,000
100M
EL 256
Saddle 254.40M
W.L 233.50M
CHO-LAN DAM SITE
Scale 1:2,000
Spillway
Earth Dam Crest
WL. 350M
230M
Dam Crest El. 1,426M
HWL 1,420M
TA-CHIEN DAM SITE
Scale 1:2,000
El 1,250M

Fig 16

RECONNAISSANCE SURVEY ON RESERVOIR SITE
(PARTY NO. II)

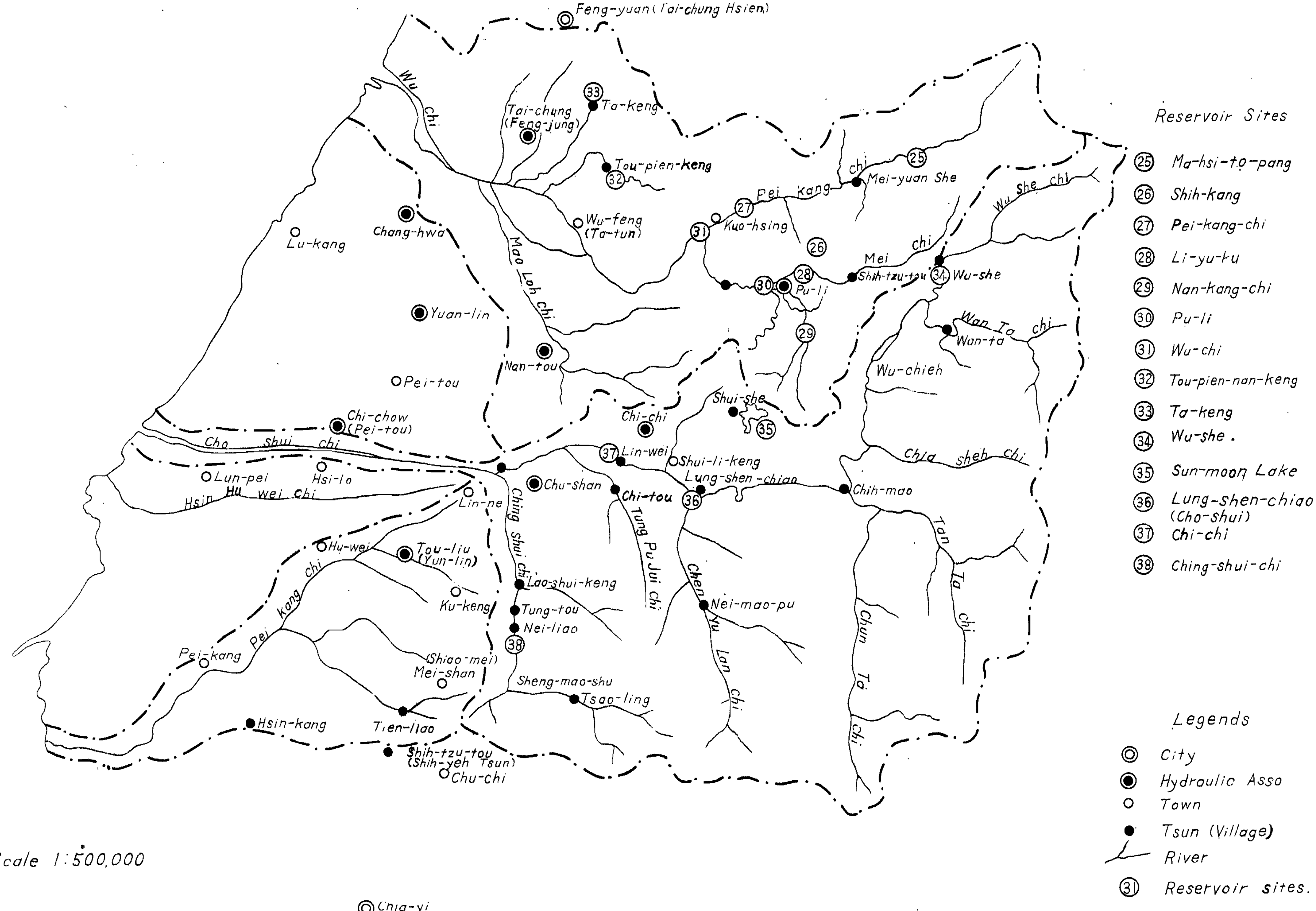
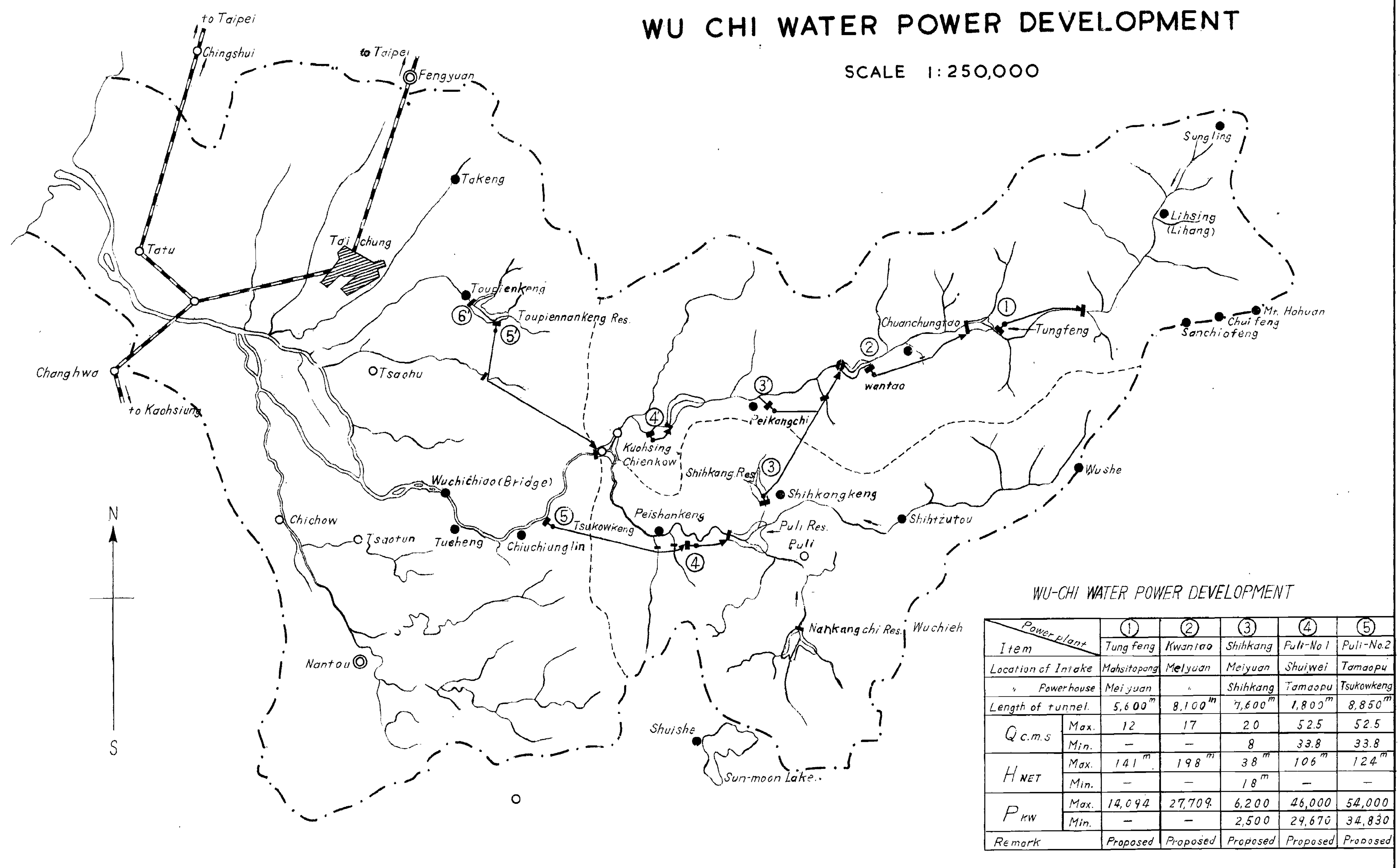


Fig 17

WU CHI WATER POWER DEVELOPMENT

SCALE 1:250,000



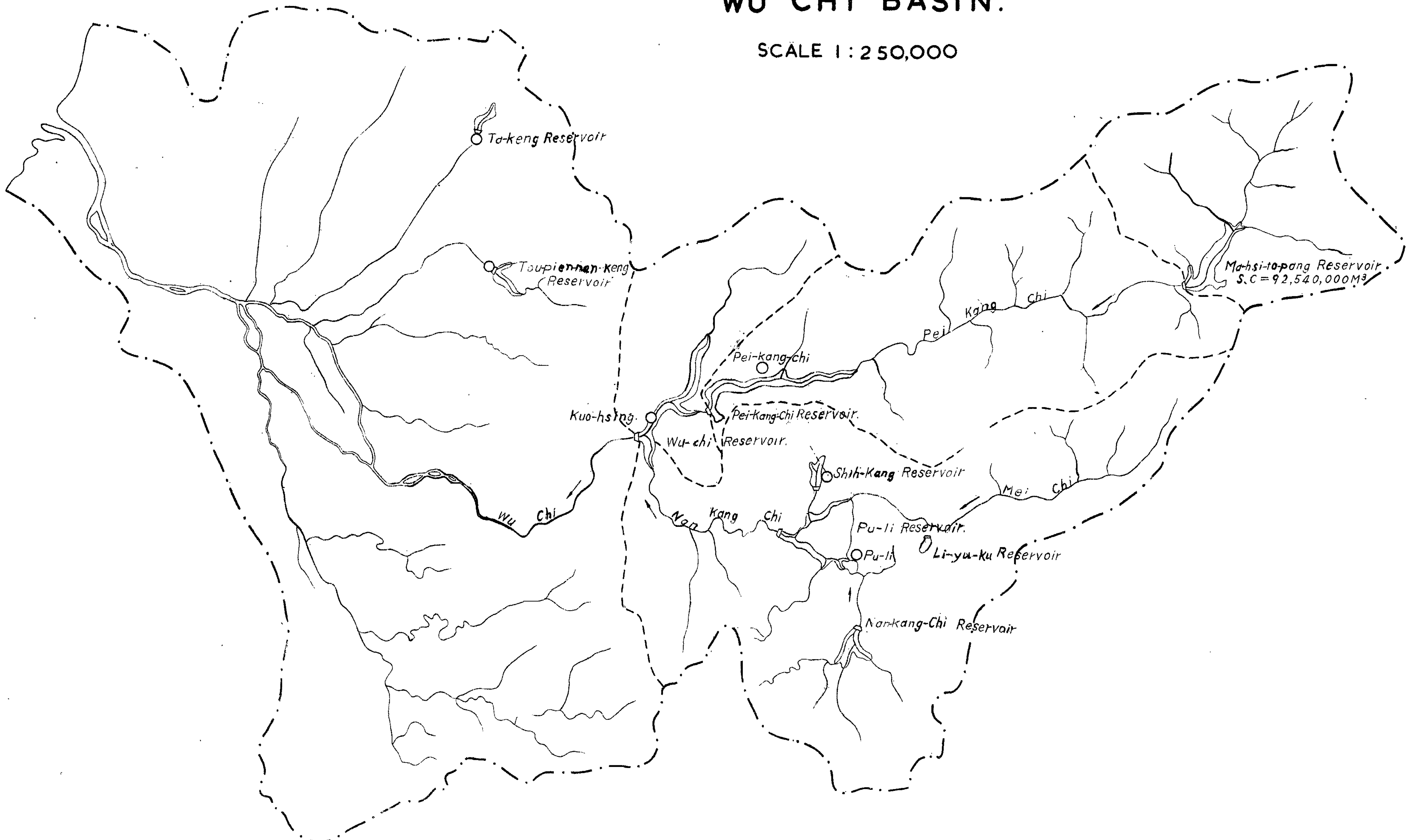
WU-CHI WATER POWER DEVELOPMENT

Item \ Power plant		①	②	③	④	⑤
		Tung feng	Kwantao	Shihkang	Puli-No 1	Puli-No.2
Location of Intake		Mahsitopang	Meiyuan	Meiyuan	Shuiwei	Tamaopu
〃 Powerhouse		Mei yuan	〃	Shihkang	Tamaopu	Tsukowkeng
Length of tunnel.		5,600 m	8,100 m	7,600 m	1,800 m	8,850 m
Q c.m.s	Max.	12	17	20	52.5	52.5
	Min.	–	–	8	33.8	33.8
H_{NET}	Max.	141 m	198 m	38 m	106 m	124 m
	Min.	–	–	18 m	–	–
P_{KW}	Max.	14,094	27,709	6,200	46,000	54,000
	Min.	–	–	2,500	29,670	34,830
Remark		Proposed	Proposed	Proposed	Proposed	Proposed

Fig 18

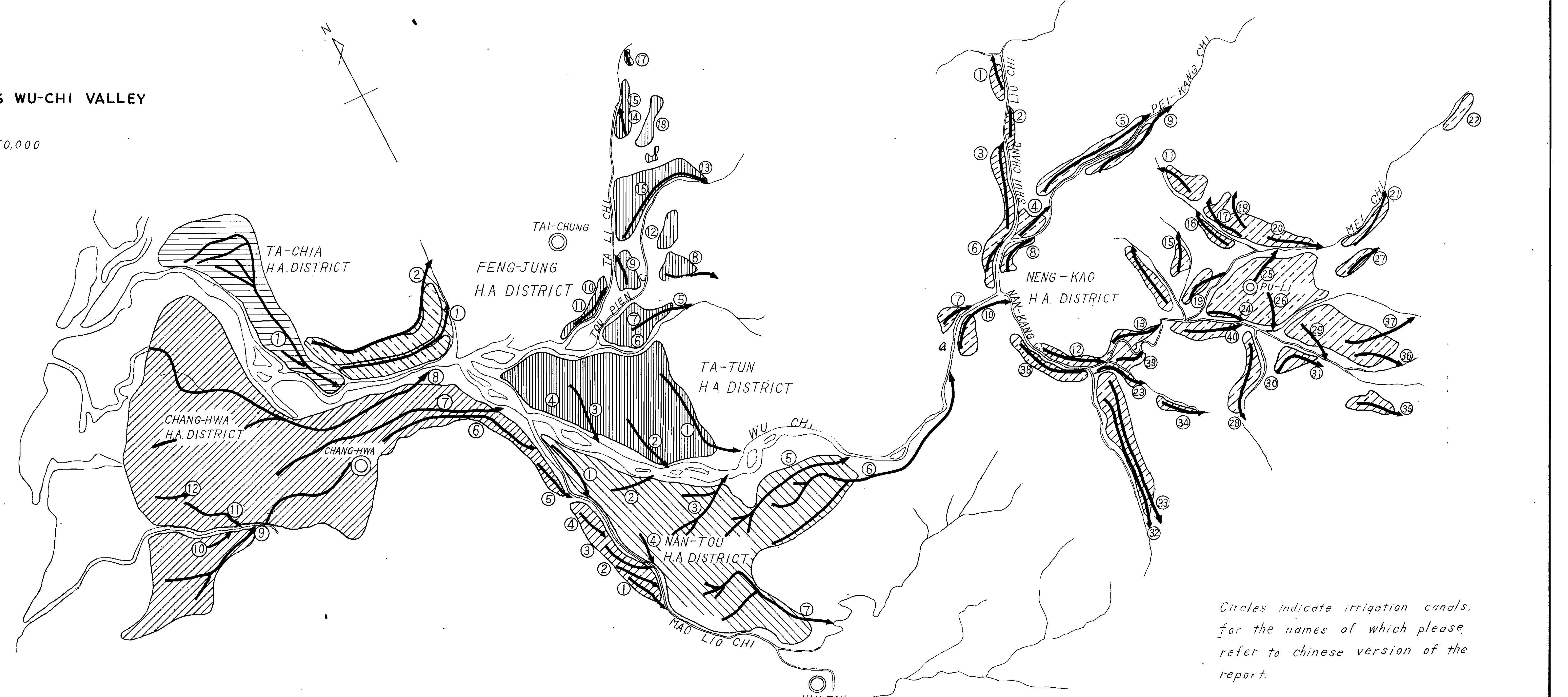
THE PROPOSED RESEVOIR SITES
WU CHI BASIN.

SCALE 1 : 250,000



IRRIGATION DISTRICTS WU-CHI VALLEY

SCALE 1:150,000

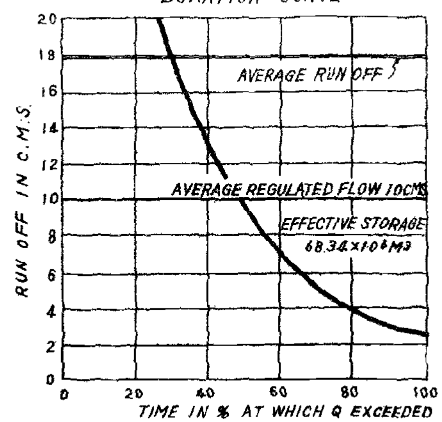


Circles indicate irrigation canals, for the names of which please refer to chinese version of the report.

Fig 20

MA-HSI-TO-PANG RESERVOIR PLAN

DURATION CURVE



RUN-OFF RECORD

Q_{max} 284 cms Q_{min} 1.74 cms

Q_{AVE} 17.9 cms

REGULATED FLOW

Q_{max} 10.6 Q_{min} 8.9 Q_{AVE} 10.0 cms.

DURING 1937–1941 MASS CURVE ANALYSIS.

WITH STORAGE 68,340,000 M³.

$\Delta Q = 10 - 1.74 = +8.26$ cms ---- DRY SEASON

AVERAGE PRIMARY POWER

AT DAM SITE ONLY D=6,650 KW

LEAD TO TUNG-FENG ΣP=17,000 KW WITH 5.6 KM. TUNNEL.

NOTE: HYDROLOGICAL DATA PROPORTIONED FROM RECORD AT CHUAN-CHUNG-TAO STATION. 1937–1941: 5 YEARS.

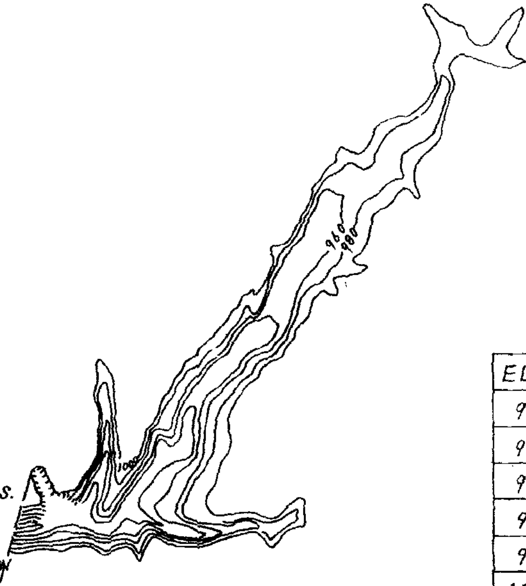
POWER DEVELOPMENT RESERVOIR

D.A. 157.5 Sq. KM.

AVERAGE PRECIPITATION

ANNUAL 3,240 mm.

MAX. ONE DAY 339 mm.



5 0 1 Km

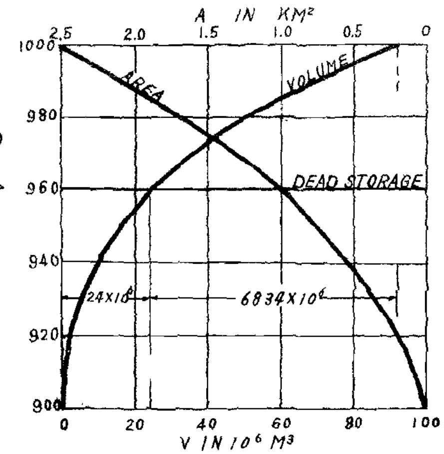
1:50,000

FLOOD ESTIMATION:

$Q = 0.2778 f r \left(\frac{24 \times 72 H^{0.6}}{L^{1.6}}\right)^{2/3} A$

$f = 0.83$, $r = 339/24$, $H = 1.656$, $L = 17.5$

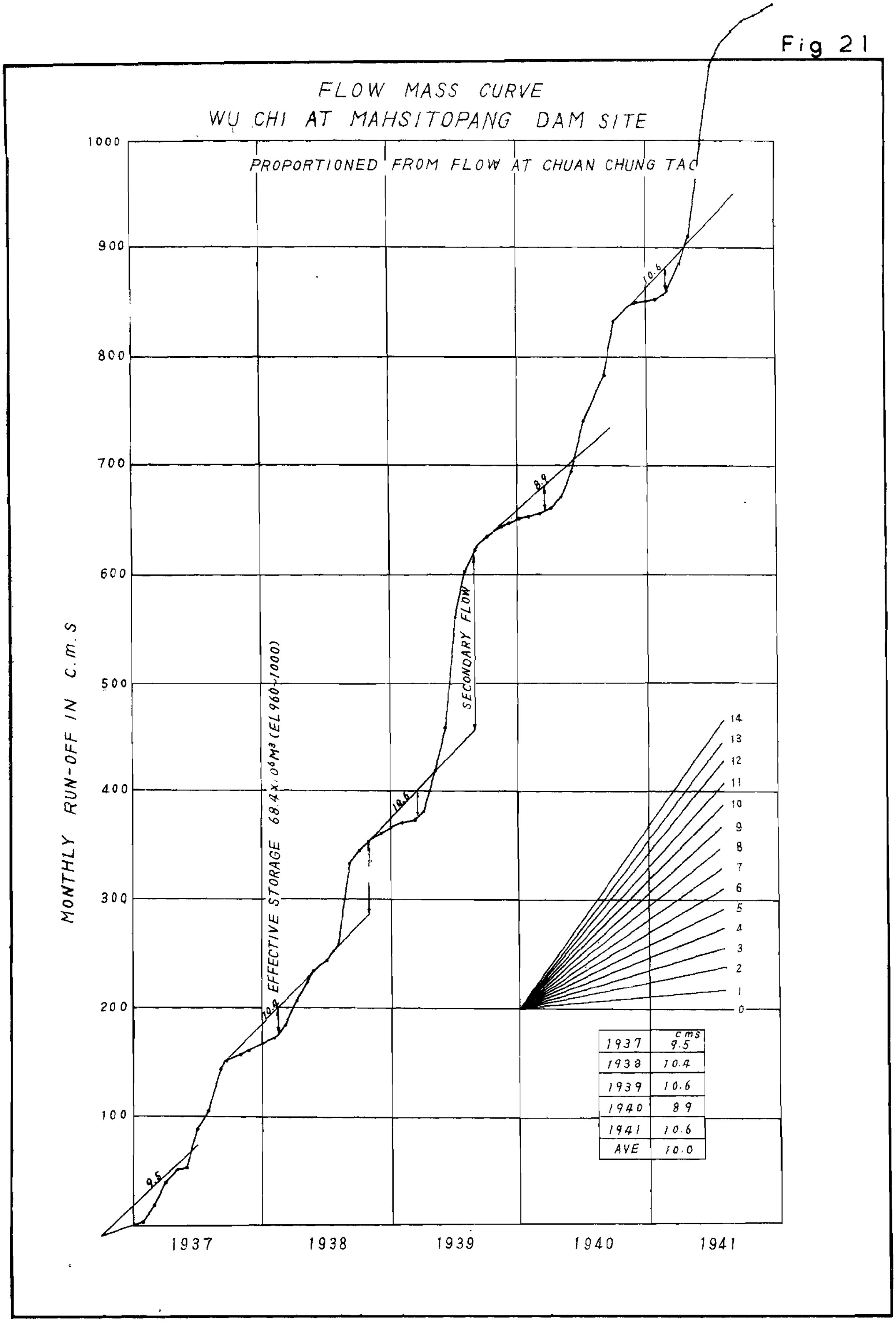
$A = 157.5$, GET $Q_{FLOOD} = 4330$ cms



ELEV.	AREA	VOLUME
900 M	0	0
920	180,000 M²	1,800,000 M³
940	540,000	9,000,000
960	980,000	24,200,000
980	1,674,000	50,740,000
1,000	2,506,000	92,540,000

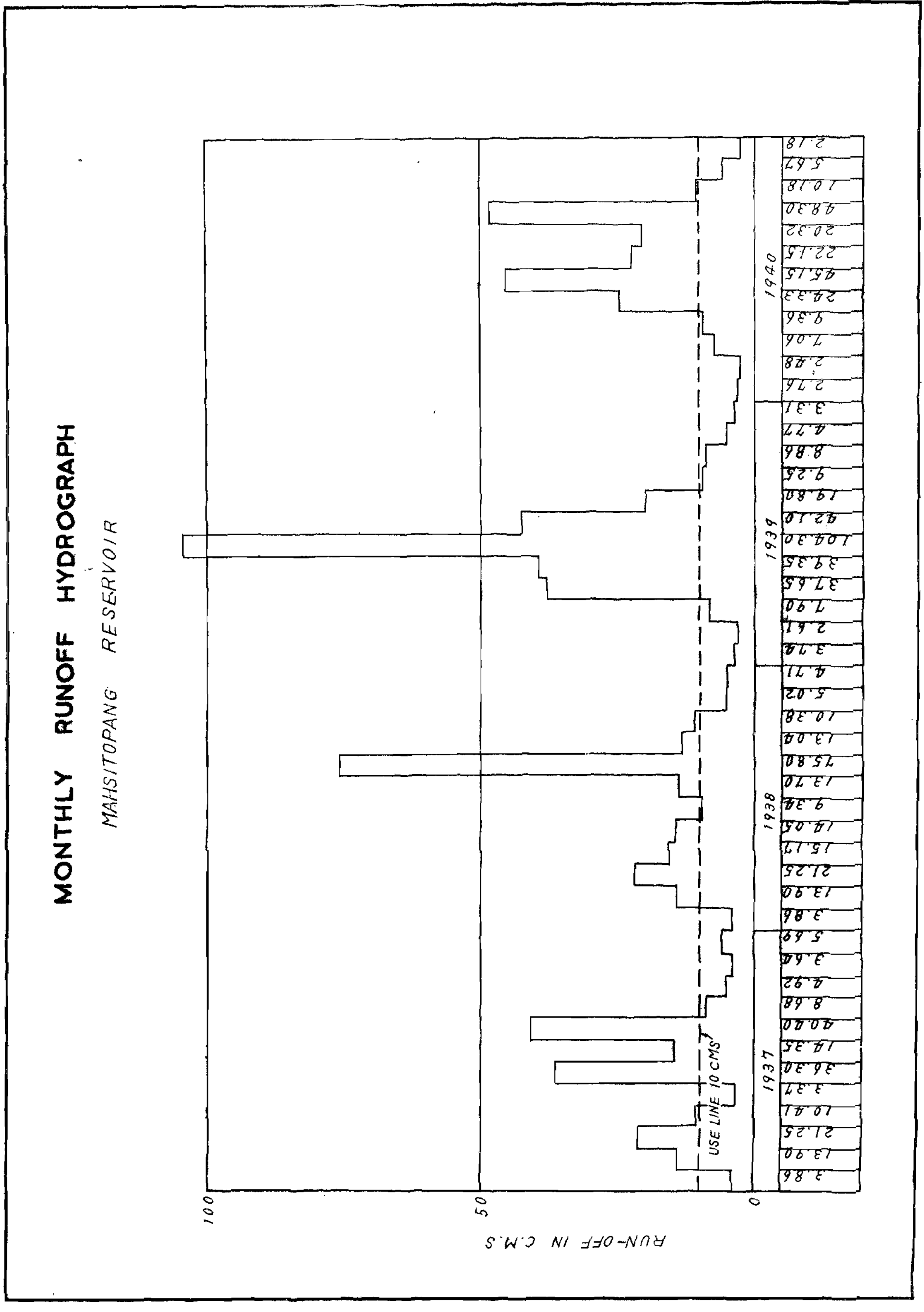
NOTE: RESERVOIR CHARACTERISTICS TAKEN FROM 1:50,000 MILITARY MAP.

Fig 21



	cms
1937	9.5
1938	10.4
1939	10.6
1940	8.9
1941	10.6
AVE	10.0

Fig 22



MONTHLY RUNOFF HYDROGRAPH
MAHSITOPANG RESERVOIR
RUN-OFF IN C.M.S
100
50
0
USE LINE 10 CMS
1937
1938
1939
1940
3.86
13.90
21.25
10.41
3.37
36.30
14.35
40.00
8.68
4.92
3.64
5.69
3.86
13.90
21.25
15.17
14.05
9.34
13.70
75.80
13.04
10.38
5.02
4.71
3.74
2.61
7.90
37.65
39.35
104.30
42.10
19.80
9.25
8.86
4.77
3.31
2.76
2.48
7.06
9.36
24.33
45.15
22.15
20.32
48.30
10.18
5.67
2.18

Fig 23

MONTHLY RUN-OFF HYDROGRAPH

MA-HSI-TO-PANG RESERVOIR

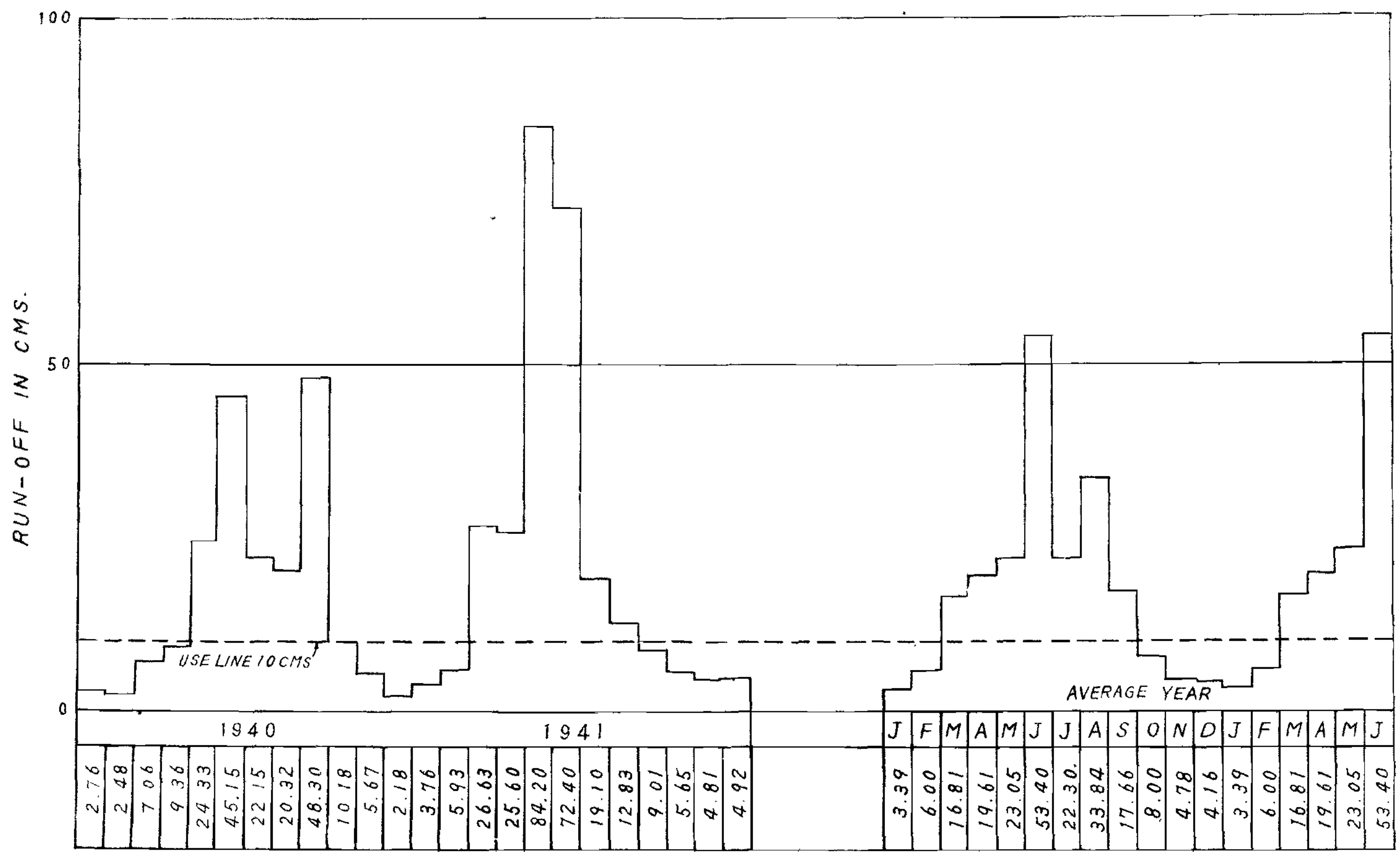
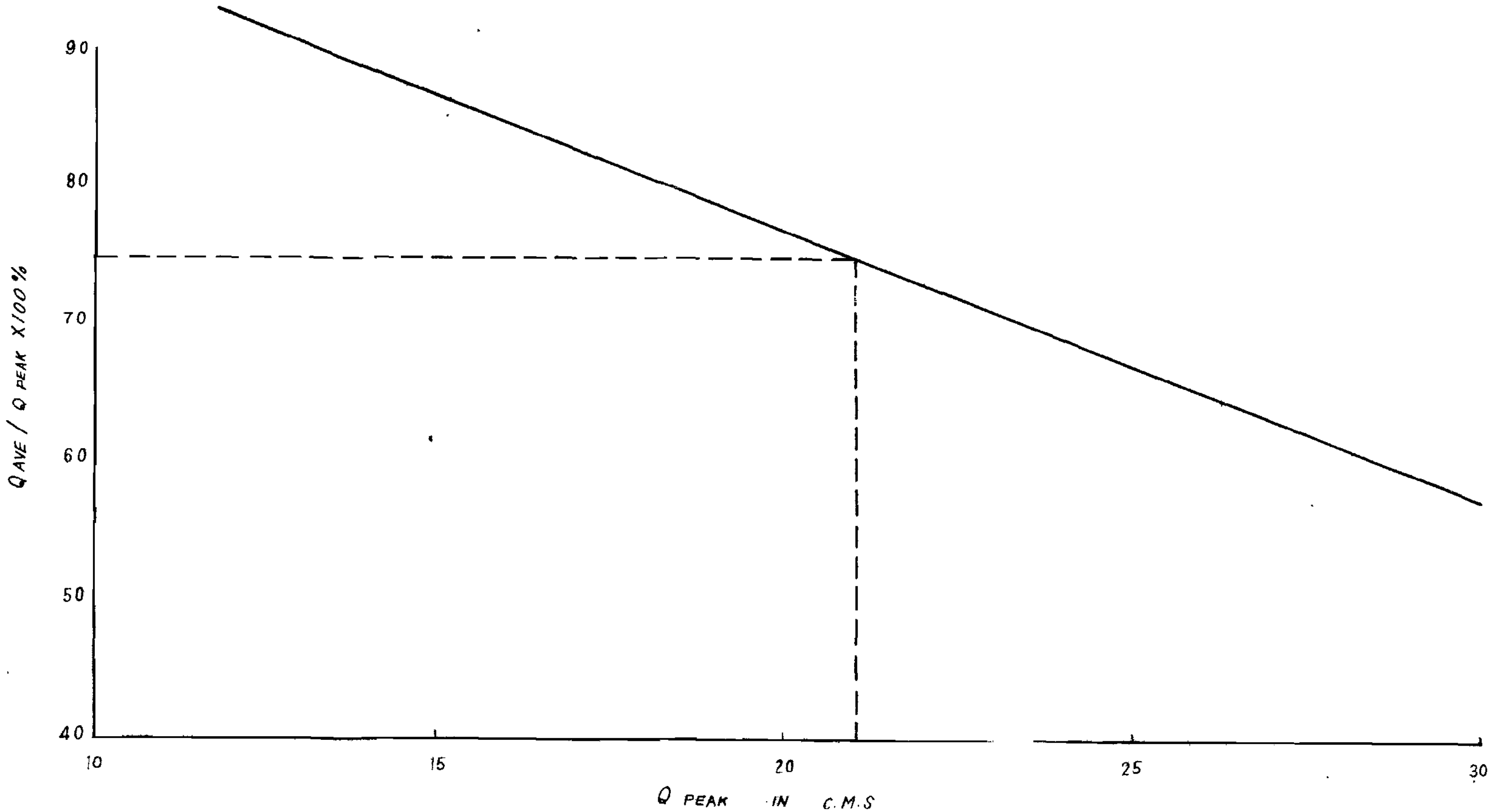


Fig 24

MA-HSI-TO-PANG RESERVOIR
AVAILABLE FLOW INVESTIGATION



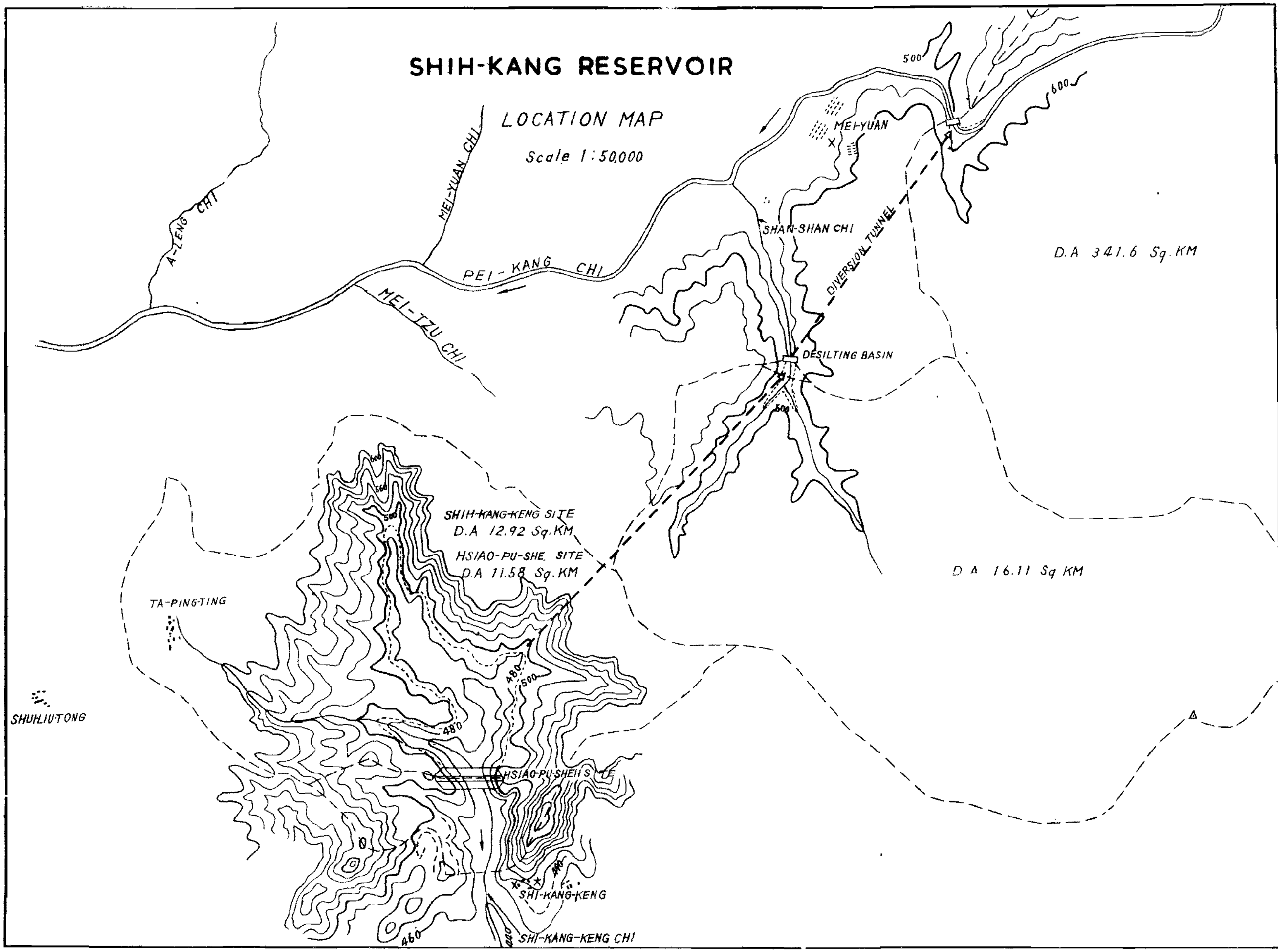
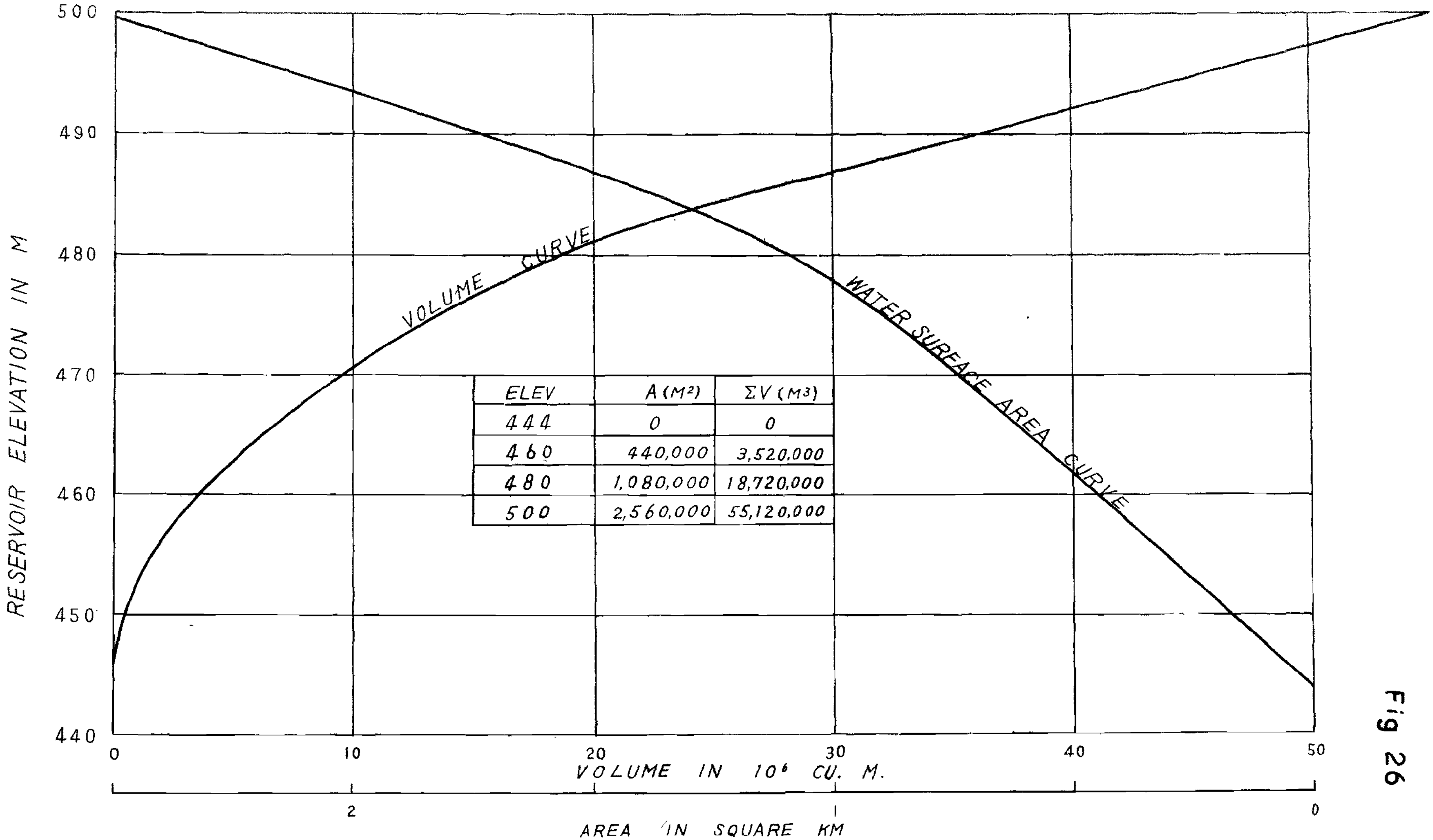

SHIH-KANG RESERVOIR
LOCATION MAP
Scale 1:50,000
A-LENG CHI
MEI-YUAN CHI
PEI-KANG CHI
MEI-TZU CHI
MEI-YUAN
SHAN-SHAN CHI
DIVERSION TUNNEL
DESILTING BASIN
D.A 341.6 Sq.KM
D.A 16.11 Sq KM
SHIH-KANG-KENG SITE
D.A 12.92 Sq.KM
HSIAO-PU-SHE SITE
D.A 11.58 Sq.KM
TA-PING-TING
SHUI-LIU-TONG
HSIAO-PU-SHEH SITE
SHI-KANG-KENG
SHI-KANG-KENG CHI
500
600
480
460

Fig 25

SHIH-KANG RESERVOIR VOLUME & AREA CURVES

SHIH-KANG-KENG SITE



ELEV	A (M^2)	ΣV (M^3)
444	0	0
460	440,000	3,520,000
480	1,080,000	18,720,000
500	2,560,000	55,120,000

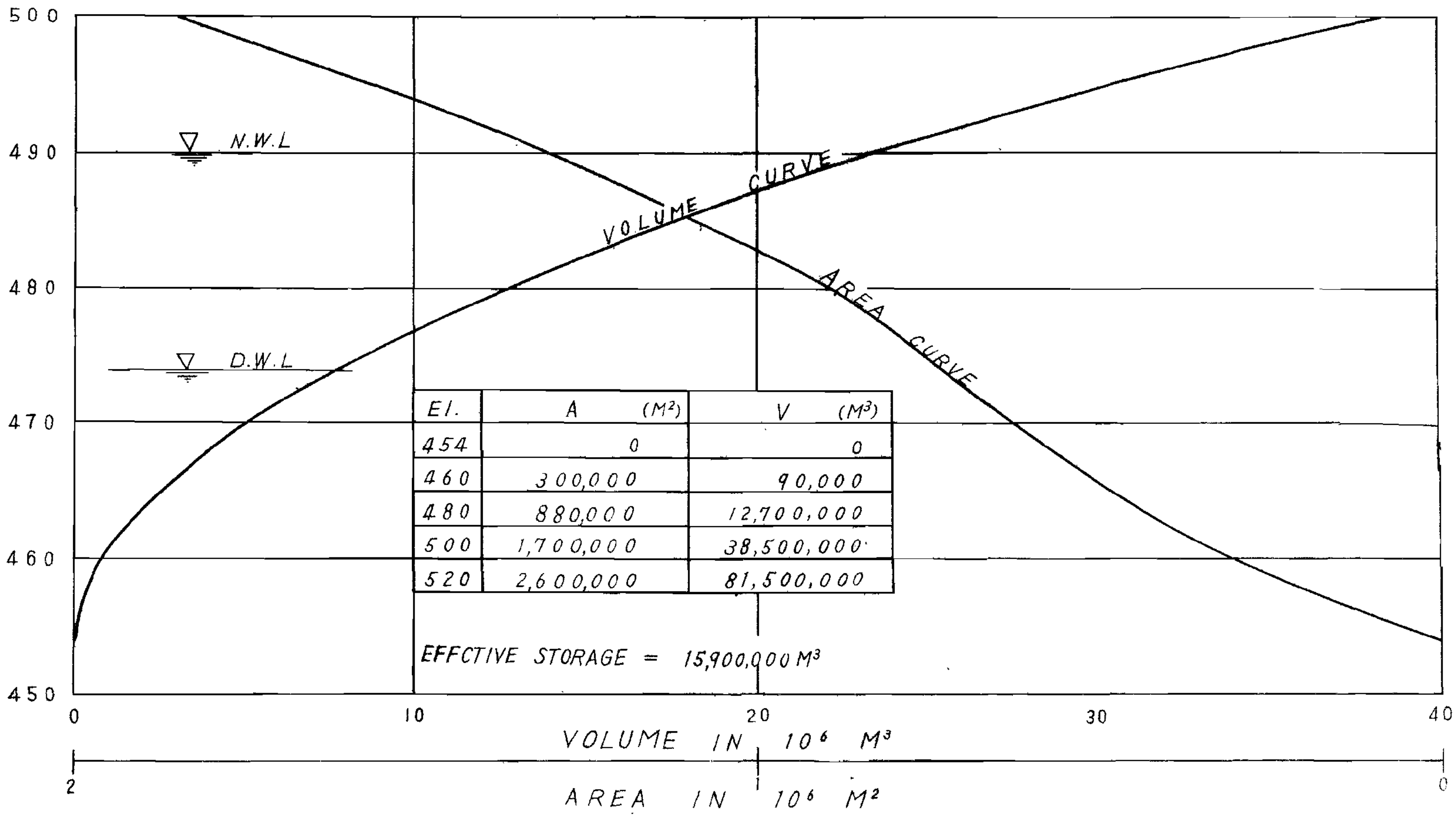
Fig 26

Fig 27

SHIHKANG RESERVOIR

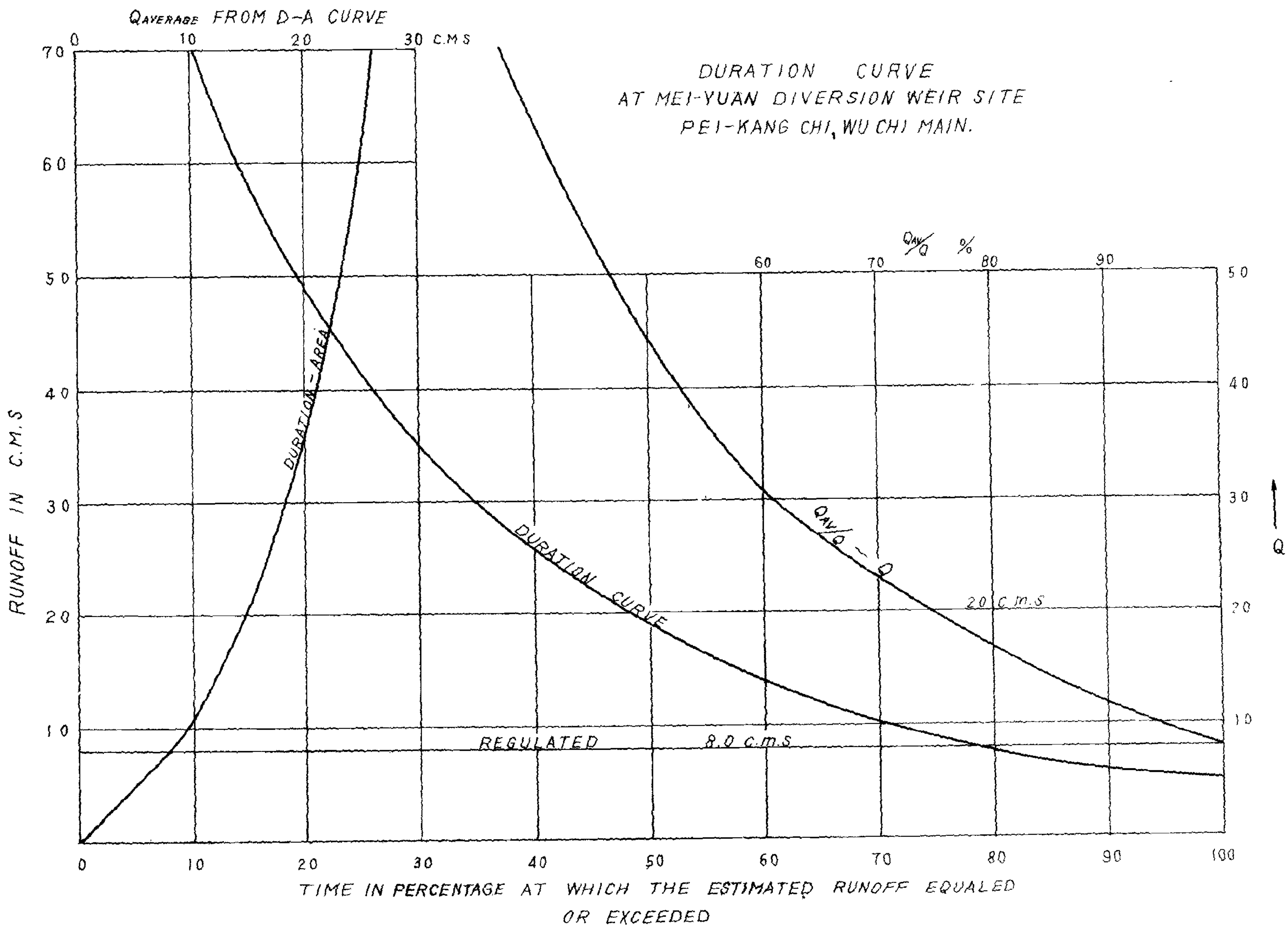
HSIAO-PU-SHE SITE

V-A CURVE



El.	A (M²)	V (M³)
454	0	0
460	300,000	90,000
480	880,000	12,700,000
500	1,700,000	38,500,000
520	2,600,000	81,500,000

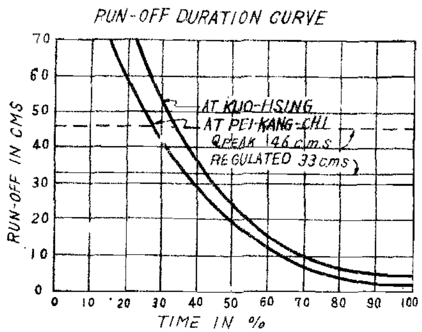
EFFCTIVE STORAGE = 15,900,000 M^3

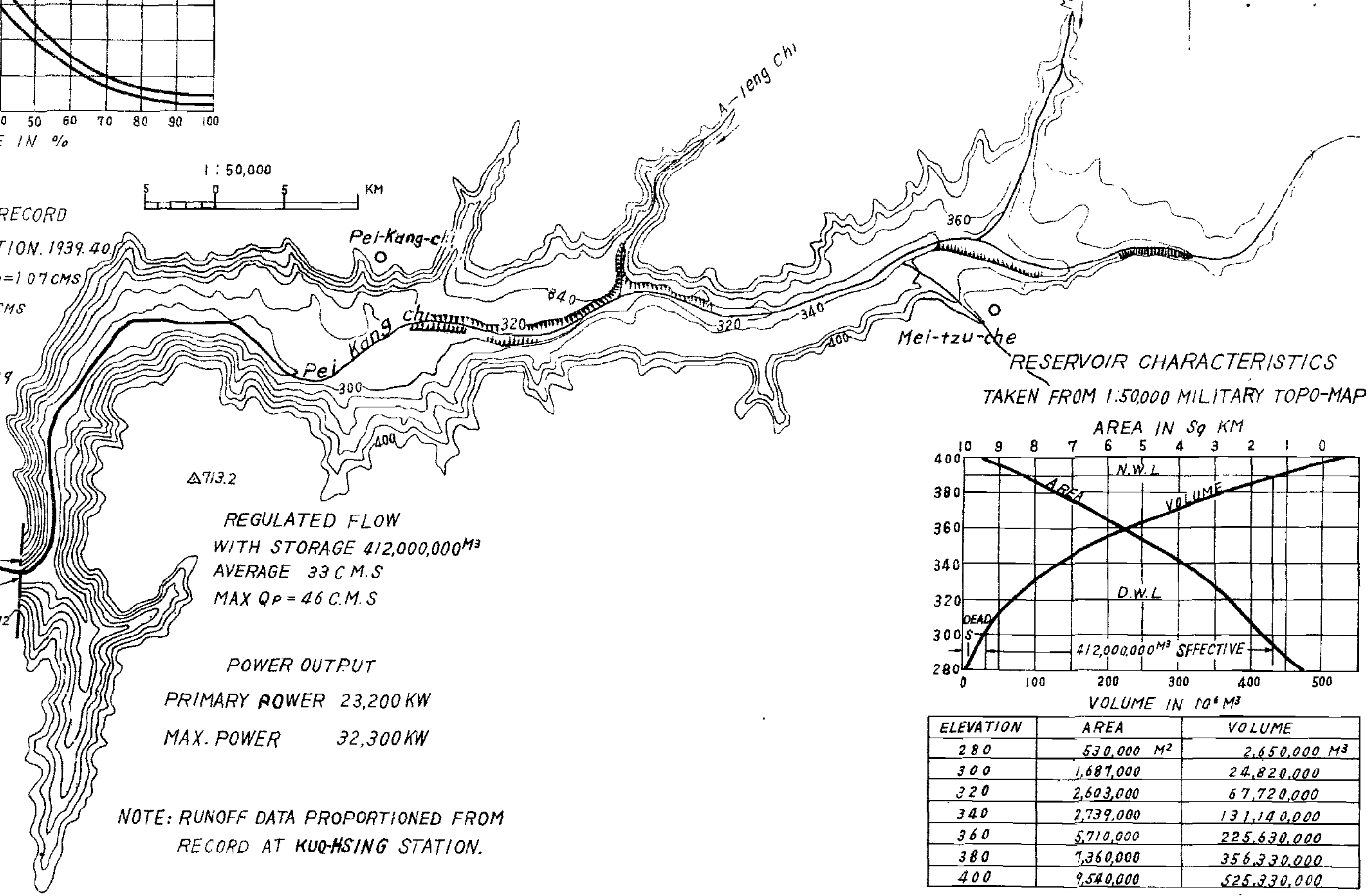


QAVERAGE FROM D-A CURVE
0
10
20
30 C.M.S
DURATION CURVE
AT MEI-YUAN DIVERSION WEIR SITE
PEI-KANG CHI, WU CHI MAIN.
QAV/Q %
60
70
80
90
DURATION - AREA
DURATION CURVE
QAV/Q ~ Q
20 C.m.S
REGULATED
8.0 C.m.S
RUNOFF IN C.M.S
70
60
50
40
30
20
10
Q
0
10
20
30
40
50
60
70
80
90
100
TIME IN PERCENTAGE AT WHICH THE ESTIMATED RUNOFF EQUALED OR EXCEEDED

Fig 28

PEI-KANG-CHI RESERVOIR.





RUN-OFF RECORD

AT KUO-HSING STATION. 1939.40

Q_{max} = 588 CMS Q_{min} = 1.07 CMS

$Q_{AVE. ANUAL}$ = 48.52 CMS

AT PEI-KANG-CHI

Q_{max} = 488 Q_{min} = 0.89

Q_{AVE} = 39.4

REGULATED FLOW
WITH STORAGE 412,000,000 M^3
AVERAGE 33 C.M.S
MAX Q_P = 46 C.M.S

POWER OUTPUT

PRIMARY POWER 23,200 KW

MAX. POWER 32,300 KW

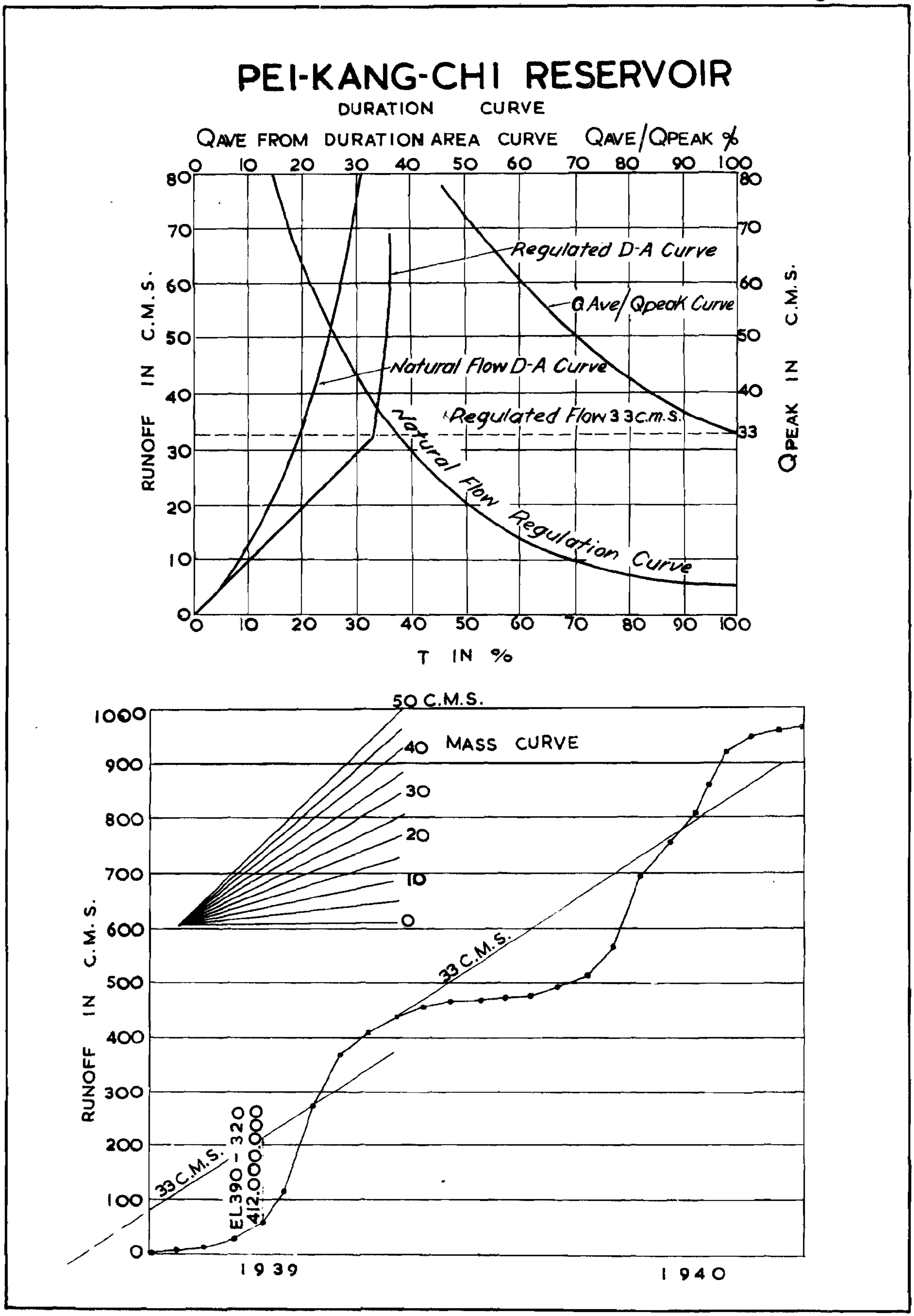
NOTE: RUNOFF DATA PROPORTIONED FROM RECORD AT KUO-HSING STATION.

RESERVOIR CHARACTERISTICS
TAKEN FROM 1:50,000 MILITARY TOPO-MAP

ELEVATION	AREA	VOLUME
280	530,000 M^2	2,650,000 M^3
300	1,687,000	24,820,000
320	2,603,000	67,720,000
340	2,739,000	131,140,000
360	5,710,000	225,630,000
380	7,360,000	356,330,000
400	9,540,000	525,330,000

Fig 29

Fig 30


PEI-KANG-CHI RESERVOIR
DURATION CURVE
QAVE FROM DURATION AREA CURVE
QAVE/QPEAK %
Regulated D-A Curve
Q Ave/Qpeak Curve
Natural Flow D-A Curve
Regulated Flow 33 c.m.s.
Natural Flow Regulation Curve
RUNOFF IN C.M.S.
QPEAK IN C.M.S.
T IN %
50 C.M.S.
MASS CURVE
33 C.M.S.
EL390 - 320
412,000,000
1939
1940

PEI-KANG-CHI RESERVOIR INFLOW & OUTFLOW CURVES.

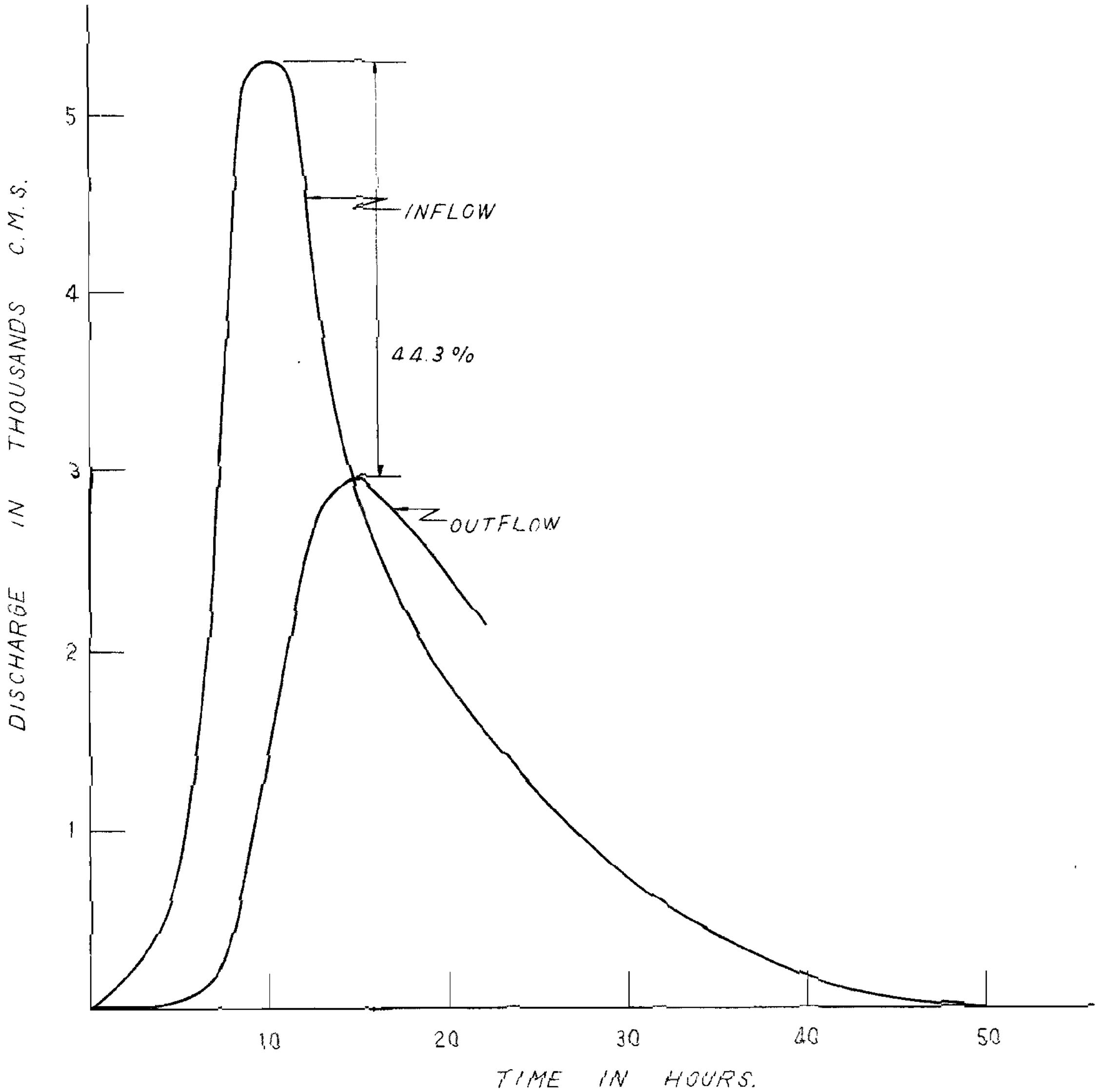
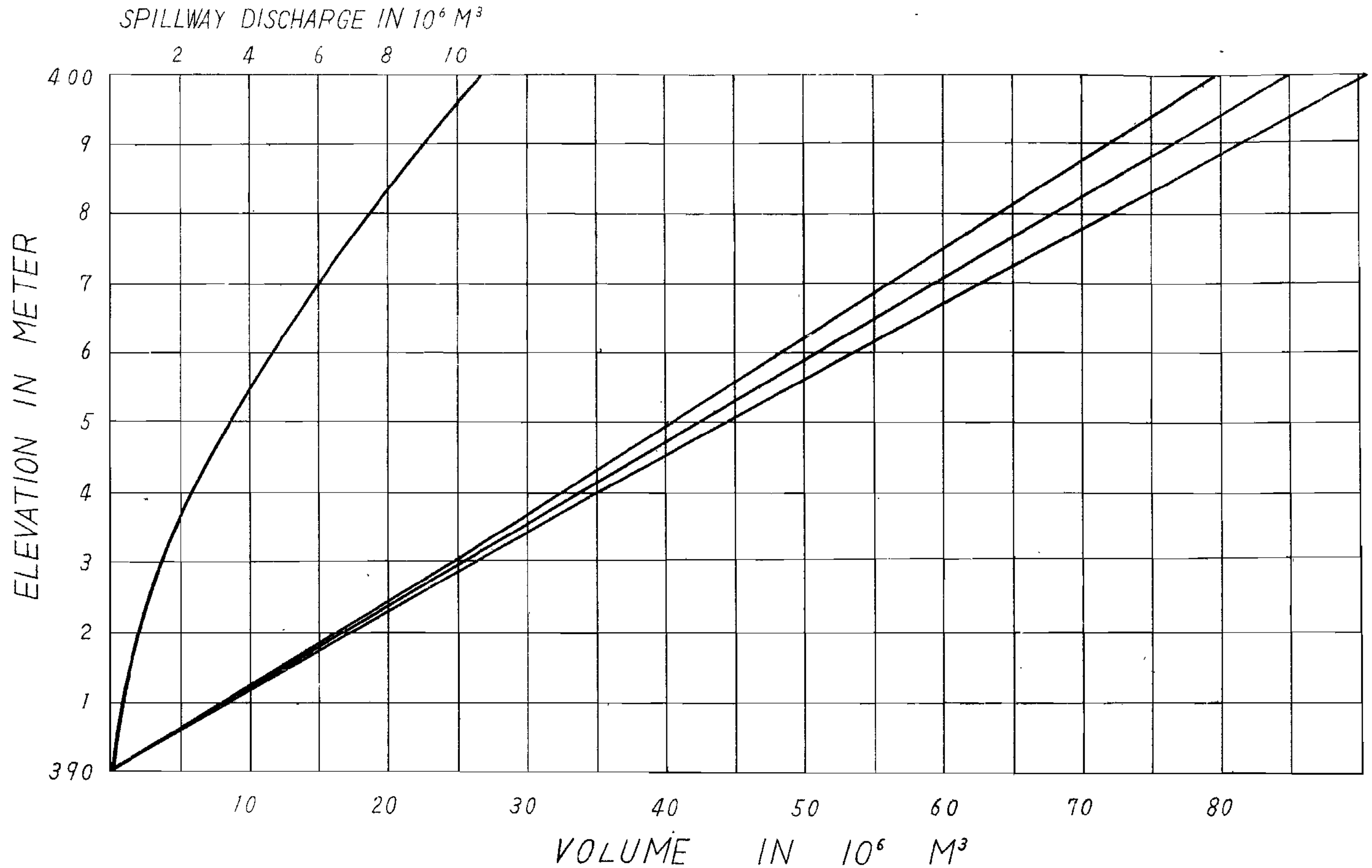


Fig 32

PEI-KANG-CHI RESERVOIR FLOOD ROUTING.



PEI-KANG-CHI RESERVOIR
FLOOD ROUTING.

STEP	(1) T	(2) I C.M.S	(3) I_1+I_2 C.M.S	(4) $(I_1+I_2) \times 3600/2$ M^3	(5) ELEVATION M	(6) DISCHARGE C.M.S.
1	1	80	80	144,000	390.03	2.8
2	2	180	260	467,000	390.06	8.3
3	3	300	480	864,000	390.14	13.9
4	4	480	780	1,405,000	390.29	27.8
5	5	840	1,320	2,380,000	390.50	55.6
6	6	1,500	2,340	4,210,000	390.91	86.2
7	7	2,640	4,140	7,450,000	391.70	194.4
8	8	4,360	7,000	12,600,000	393.01	417.0
9	9	5,220	9,580	17,250,000	394.80	889.0
10	10	5,280	10,500	18,900,000	396.46	1,450.0
11	11	5,240	10,520	18,950,000	397.89	2,027.0
12	12	4,680	9,920	17,850,000	398.94	2,500.0
13	13	3,800	8,480	15,270,000	399.55	2,780.0
14	14	3,240	7,040	12,650,000	399.82	2,900.0
15	15	2,840	6,080	10,950,000	399.88	2,940.0
16	16	2,560	5,400	9,720,000	399.75	2,860.0
17	17	2,320	4,880	8,790,000	399.52	2,778.0
18	18	2,120	4,440	8,000,000	399.28	2,640.0
19	19	1,920	4,040	7,275,000	399.00	2,530.0
20	20	1,800	3,720	6,700,000	398.70	2,390.0
21	21	1,660	3,460	6,230,000	398.40	2,250.0
22	22	1,520	3,180	5,730,000	398.10	2,133.0

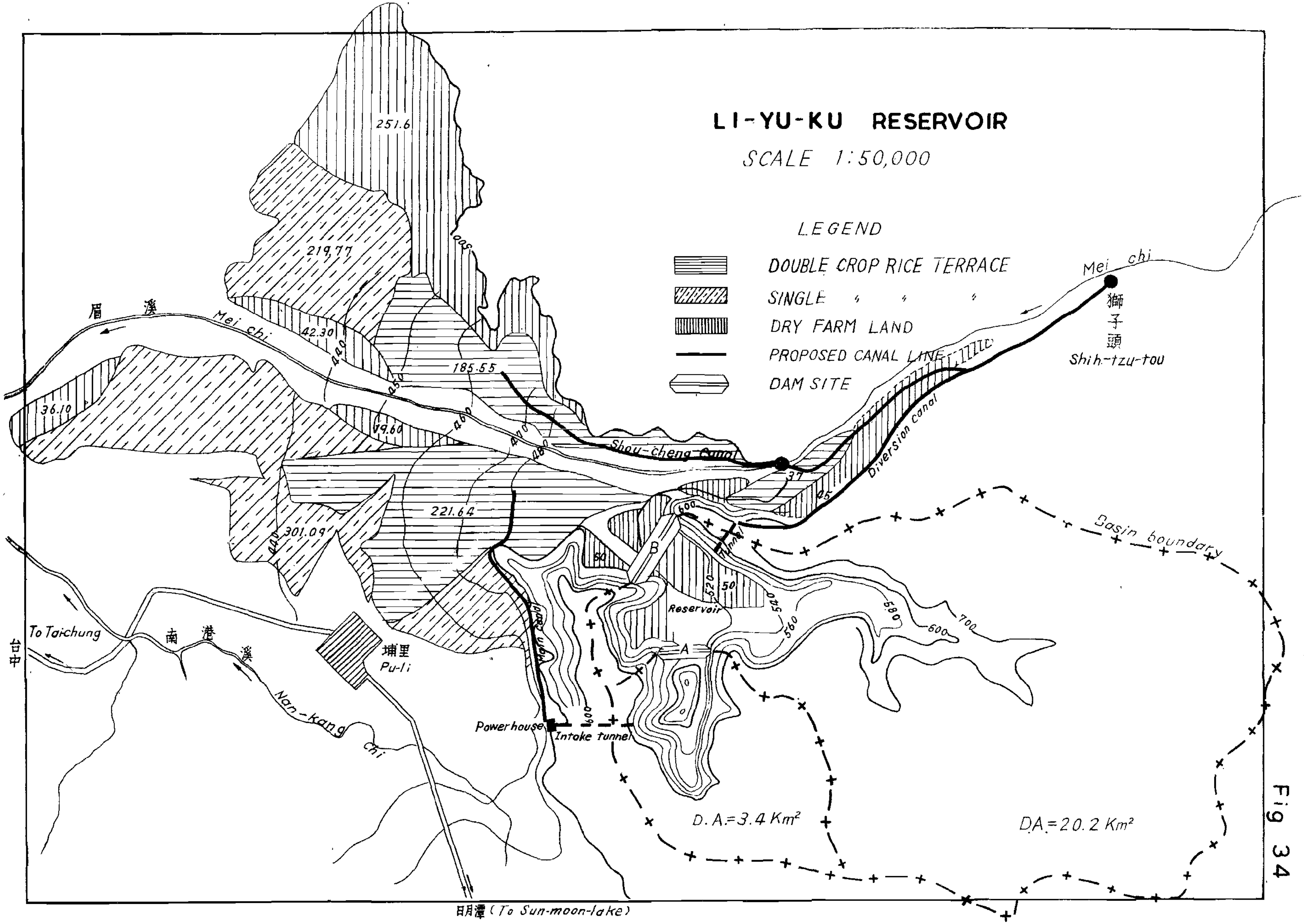
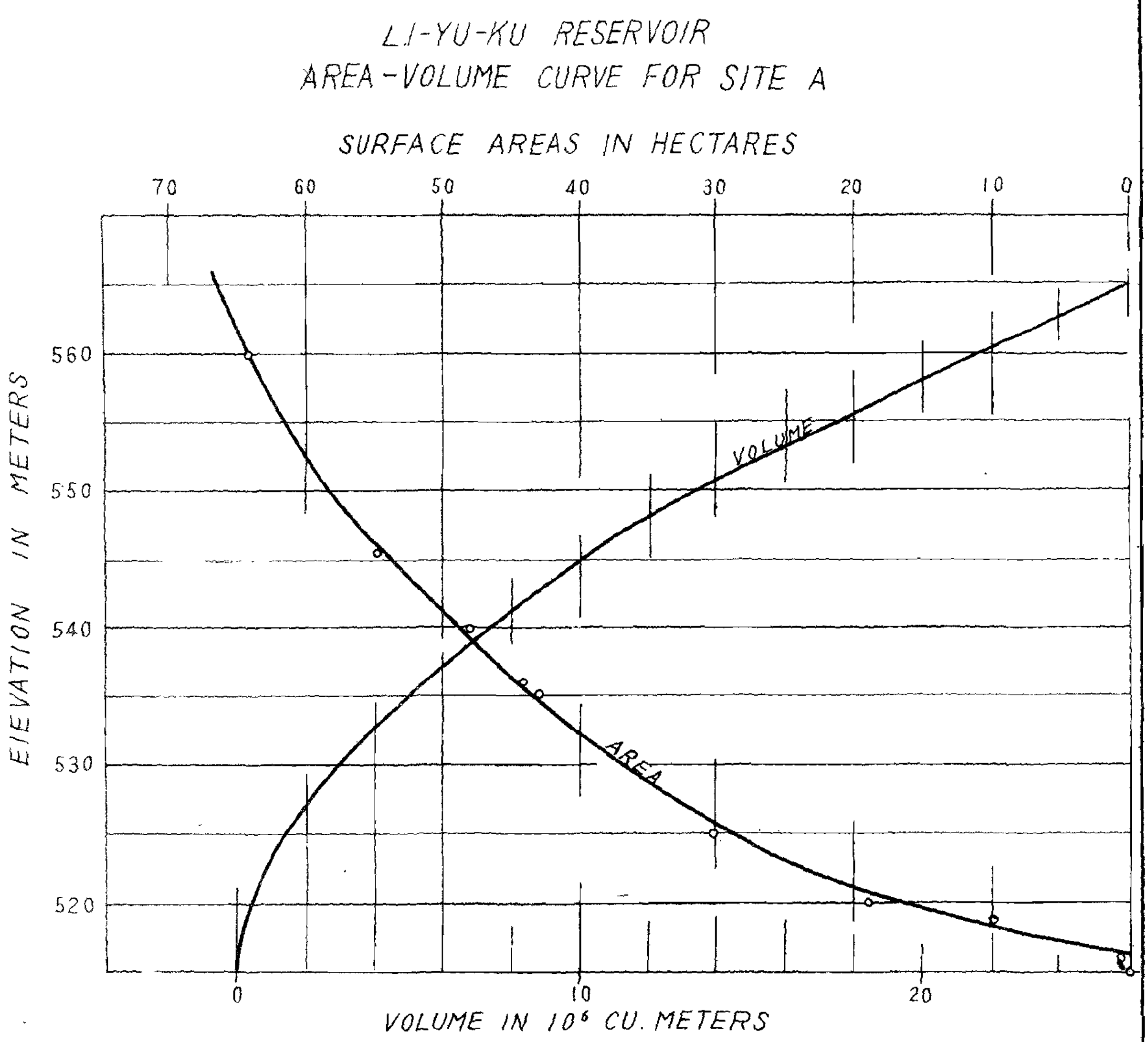

LI-YU-KU RESERVOIR
SCALE 1:50,000
LEGEND
DOUBLE CROP RICE TERRACE
SINGLE " " "
DRY FARM LAND
PROPOSED CANAL LINE
DAM SITE
Mei chi
獅子頭
Shih-tzu-tou
眉溪
Mei chi
Shou-cheng Canal
Diversion Canal
Basin boundary
Reservoir
Tunnel
Main canal
Powerhouse
Intake tunnel
D.A.=3.4 Km²
DA.=20.2 Km²
埔里
Pu-li
南港溪
Nan-kang chi
To Taichung
台中
明潭 (To Sun-moon-lake)
251.6
219.77
42.30
185.55
36.10
79.60
221.64
301.09
37
05
A
B
700
600
580
560
540
520
500
480
460
450
440

Fig 34

Fig 35


LI-YU-KU RESERVOIR
AREA-VOLUME CURVE FOR SITE A
SURFACE AREAS IN HECTARES
70
60
50
40
30
20
10
0
560
550
540
530
520
ELEVATION IN METERS
VOLUME
AREA
0
10
20
VOLUME IN 10^6 CU. METERS

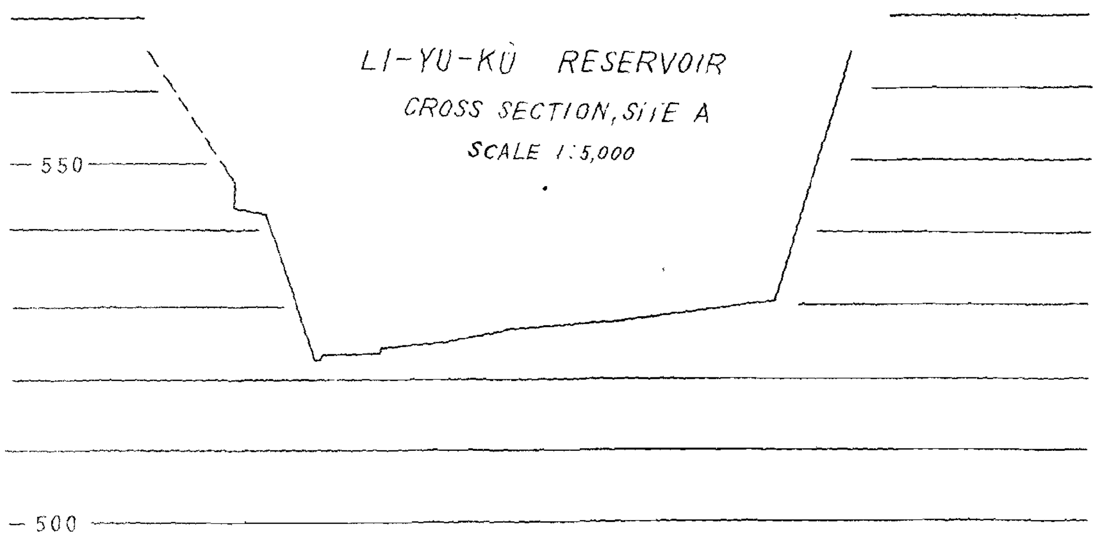
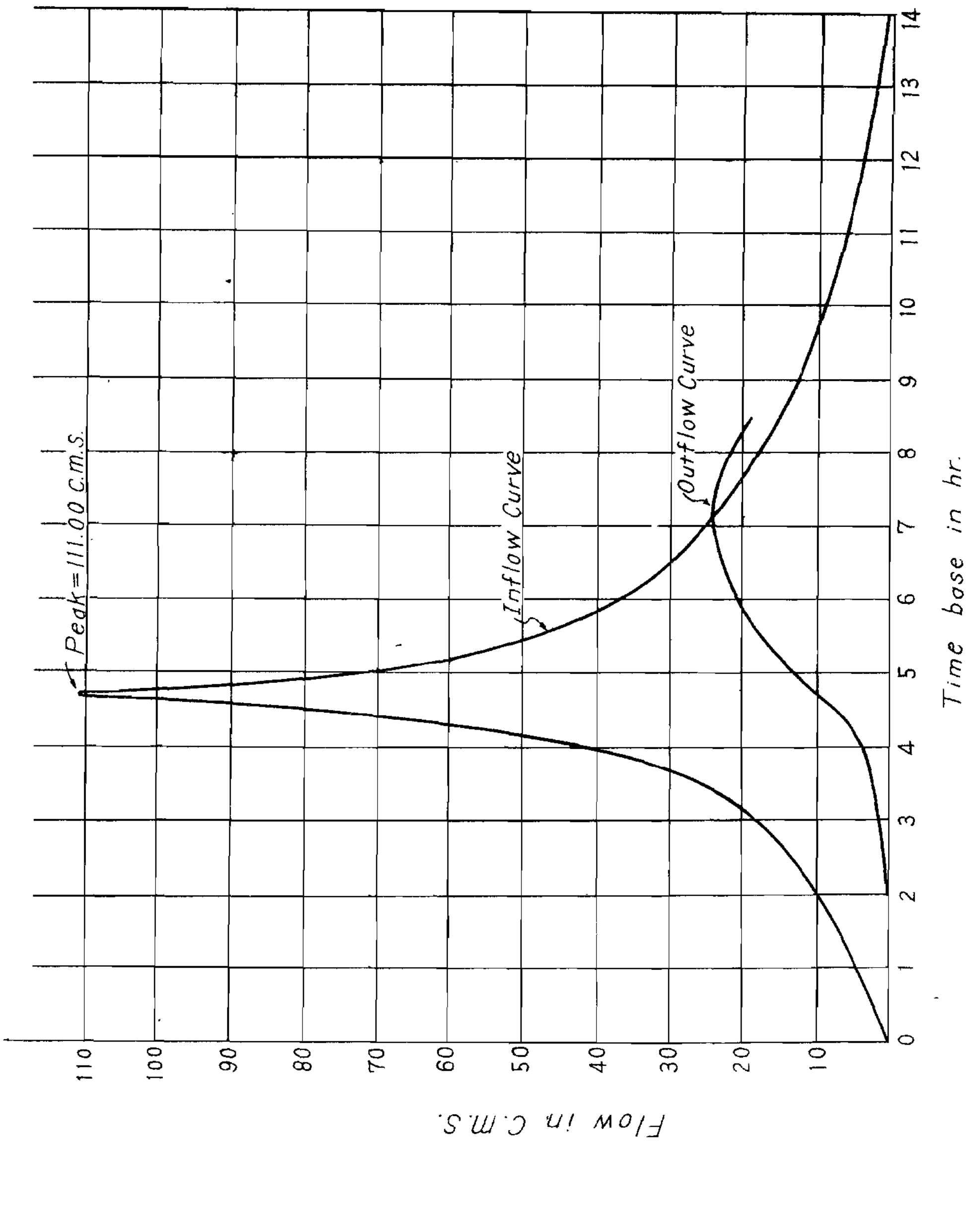
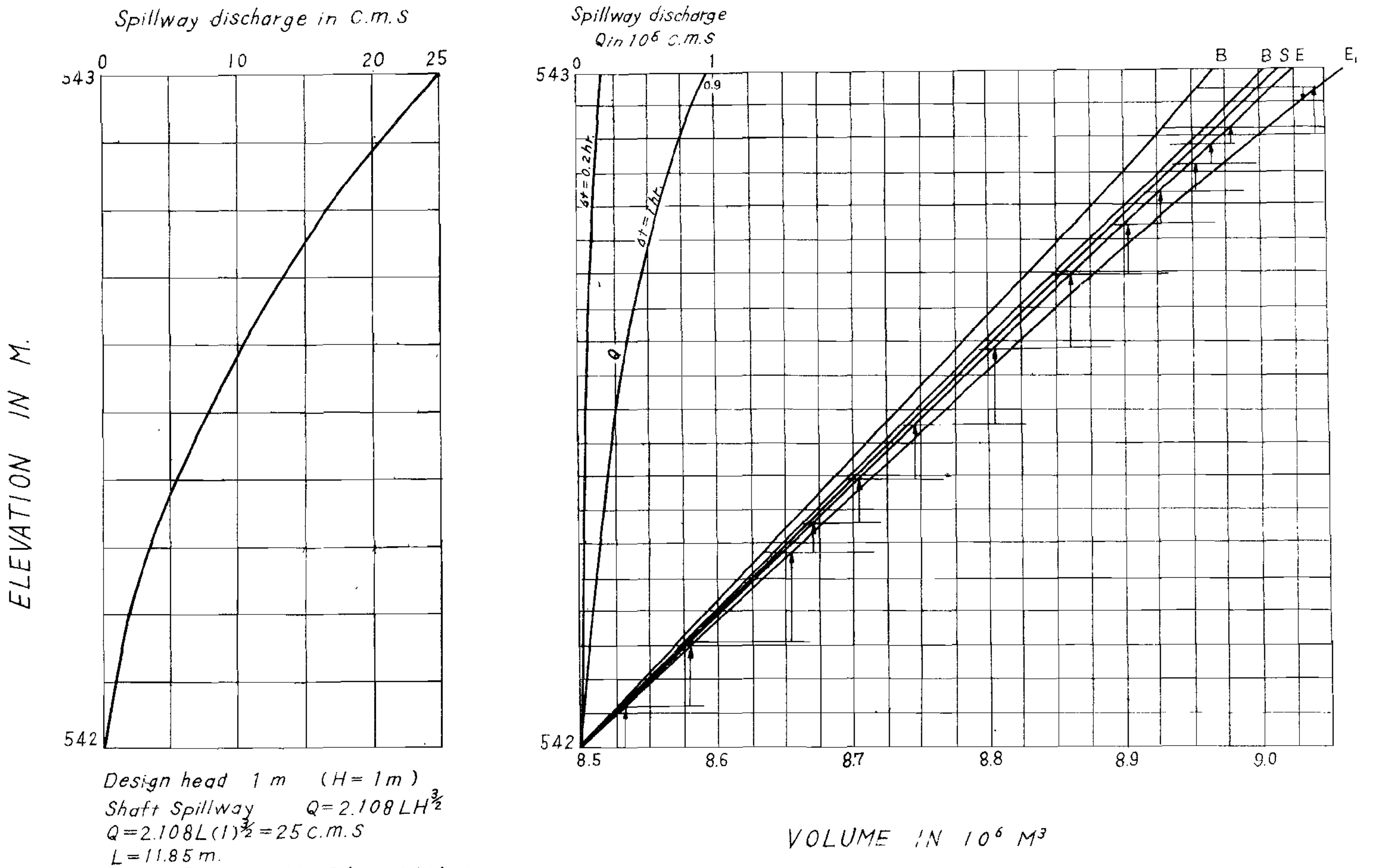

LI-YU-KU RESERVOIR
CROSS SECTION, SITE A
SCALE 1:5,000
550
500

Fig 36

INFLOW-OUTFLOW CURVE



SPILLWAY DESIGN & FLOOD ROUTING



Design head 1 m ($H = 1 m$)

Shaft Spillway $Q = 2.108 LH^{3/2}$

$Q = 2.108 L (1)^{3/2} = 25$ c.m.S

$L = 11.85$ m.

$L = 2\pi R$ $R = 11.85/2\pi = 1.89 \doteqdot 2$ m

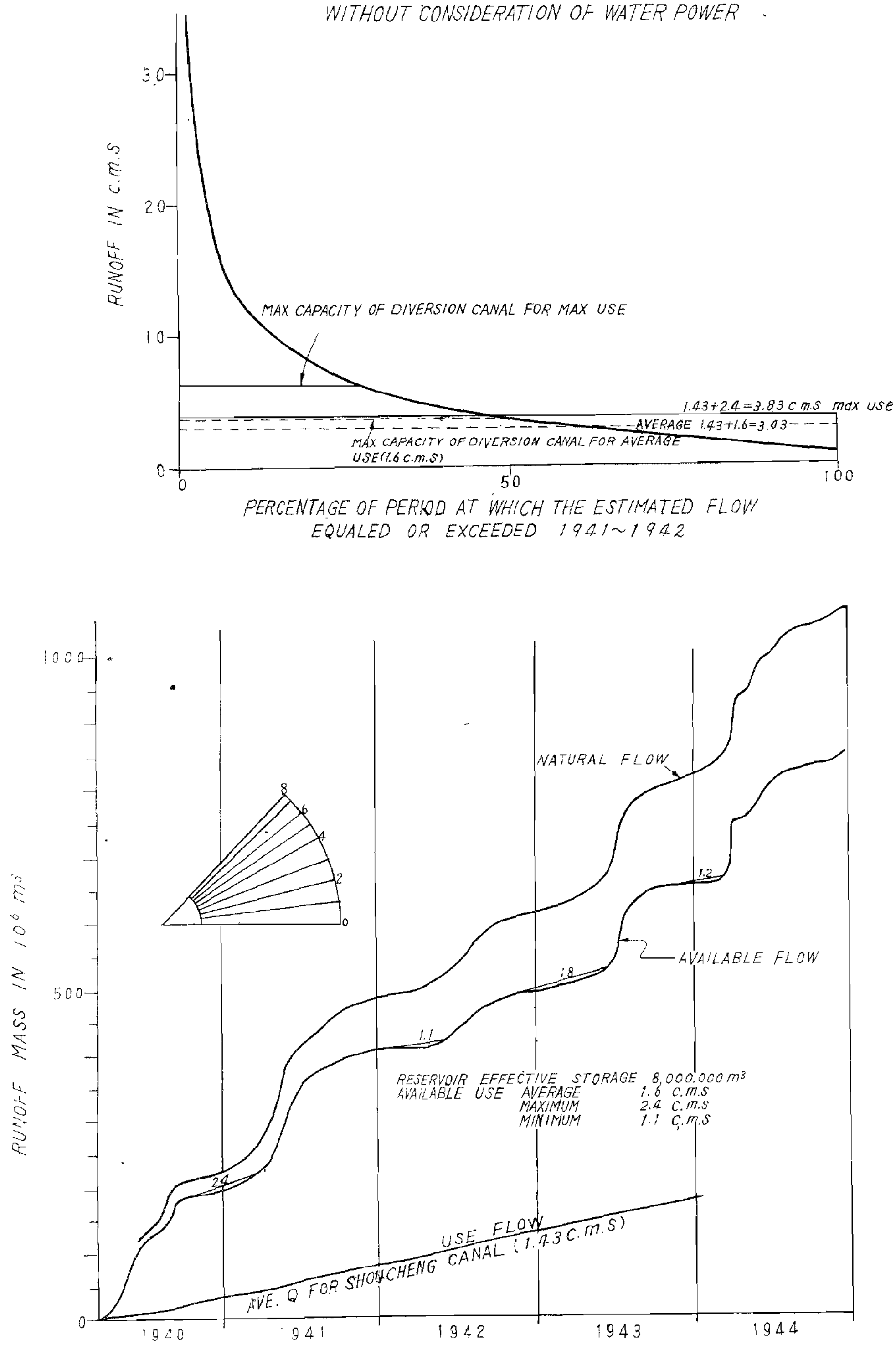
LI-YU-KU RESERVOIR
FLOOD-ROUTING COMPUTATION

STEP	(1) TIME FROM BEGINNING OF FLOOD IN HOURS	(2) INSTANTANEOUS RATE OF INFLOW INTO RESERVOIR (I) IN C.M.S.	(3) SUM OF DISCHARGE AT BEGINNING AND END OF INTERVAL $(I_1 + I_2)$	(4) VOLUME OF INFLOW INTO RESERVOIR DURING INTERVAL IN CU.M. $[(I_1+I_2)/2]$ 3600	(5) RESERVOIR ELEVATION AT END OF INTERVAL IN M.	(6) SPILLWAY DISCHARGE RATE AT END OF INTERVAL IN C.M.S.
1	1	3.50	3.50	6,300		
2	2	10.00	13.50	24,300	542.06	0.50
3	3	16.50	26.50	47,700	542.16	1.50
4	4	39.00	45.50	82,000	542.29	3.50
5	4.2	52.00	91.00	32,700	542.33	4.00
6	4.4	66.00	118.00	42,500	542.40	5.50
7	4.6	84.00	150.00	54,000	542.48	7.50
8	4.8	111.00	195.00	70,200	542.59	10.00
9	5	80.00	191.00	68,700	542.70	13.20
10	5.2	61.00	141.00	50,700	542.77	15.90
11	5.4	52.00	113.00	40,700	542.82	17.30
12	5.6	46.00	98.00	35,300	542.86	19.00
13	5.8	41.00	87.00	31,300	542.89	20.00
14	6	37.00	78.00	28,000	542.91	21.00
15	7	25.50	62.00	112,000	542.97	23.50
16	8	18.00	43.00	78,300		
17	9	12.80	30.80	55,400		
18	10	9.60	22.40	40,300		

LI-YU-KU RESERVOIR.

DURATION & MASS CURVES FOR SITE A

WITHOUT CONSIDERATION OF WATER POWER



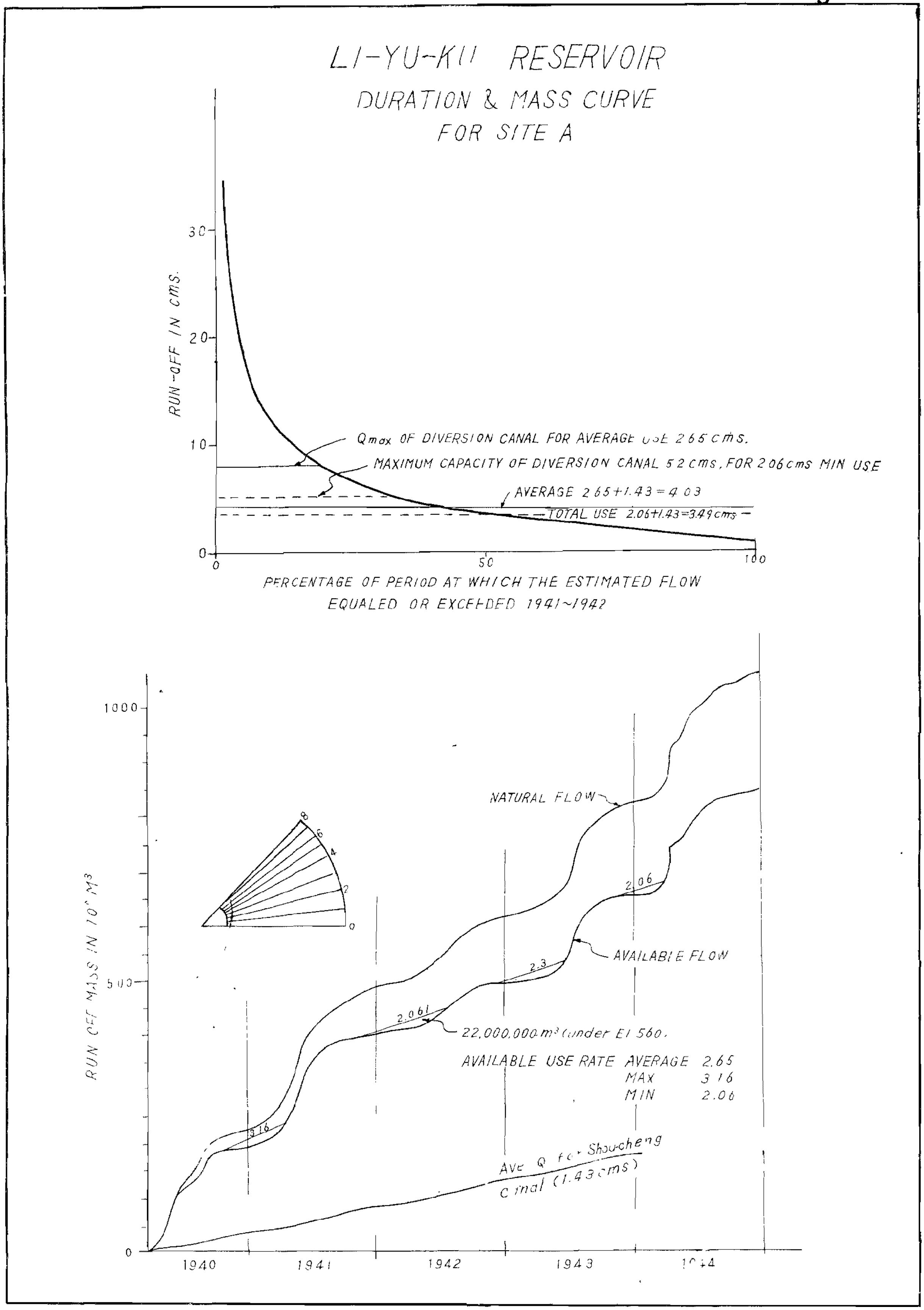
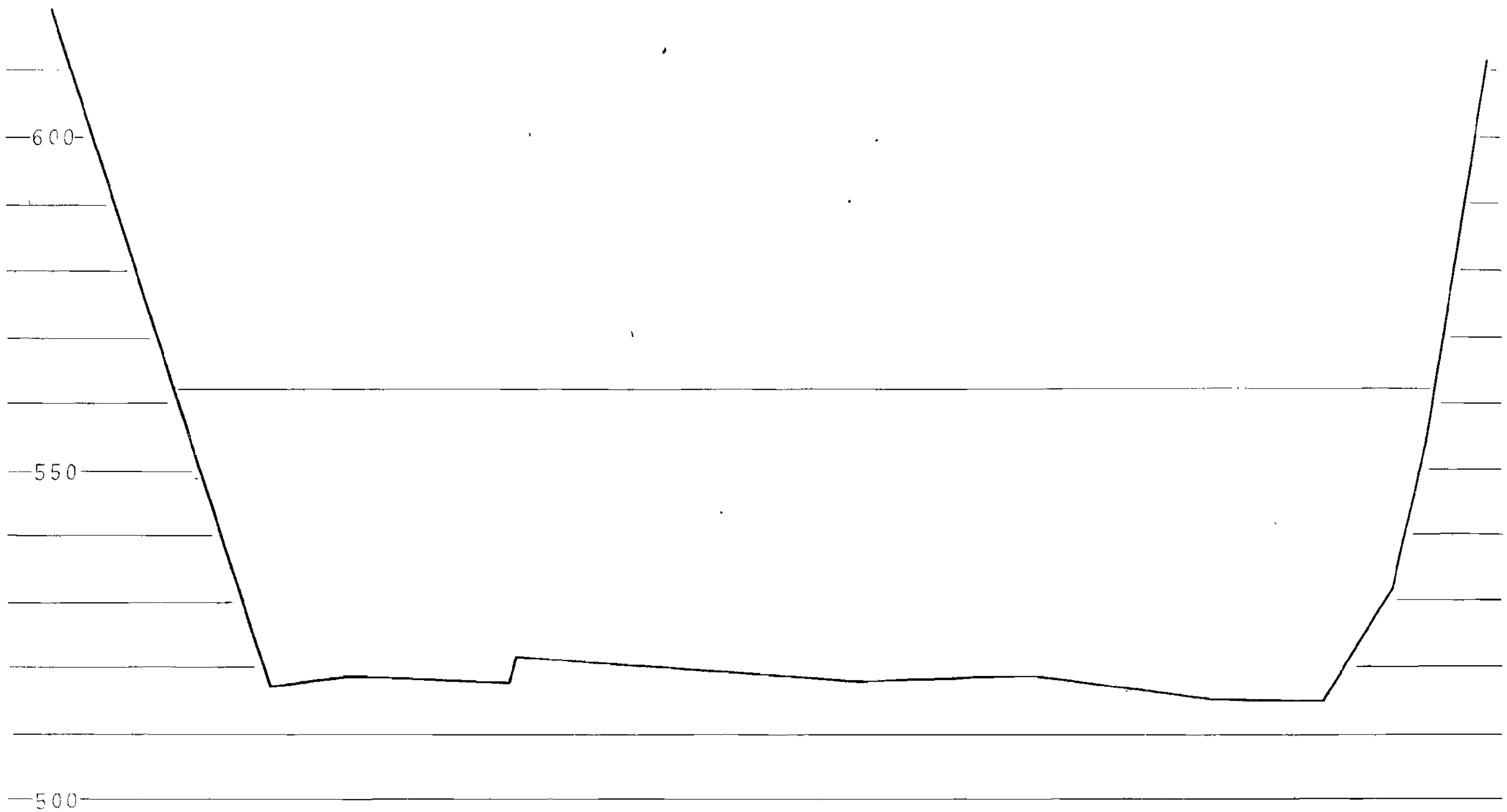

LI-YU-KU RESERVOIR
DURATION & MASS CURVE
FOR SITE A
RUN-OFF IN cms.
30
20
10
0
50
100
Qmax OF DIVERSION CANAL FOR AVERAGE USE 2.65 cms.
MAXIMUM CAPACITY OF DIVERSION CANAL 5.2 cms, FOR 2.06 cms MIN USE
AVERAGE 2.65+1.43=4.03
TOTAL USE 2.06+1.43=3.49 cms
PERCENTAGE OF PERIOD AT WHICH THE ESTIMATED FLOW
EQUALED OR EXCEEDED 1941~1942
RUN OFF MASS IN 10⁶ M³
1000
500
0
NATURAL FLOW
AVAILABLE FLOW
2.06
2.3
2.061
3.16
22,000,000 m³ (under El 560)
AVAILABLE USE RATE AVERAGE 2.65
MAX 3.16
MIN 2.06
Ave Q for Shou-cheng
Canal (1.43 cms)
1940
1941
1942
1943

Fig 41

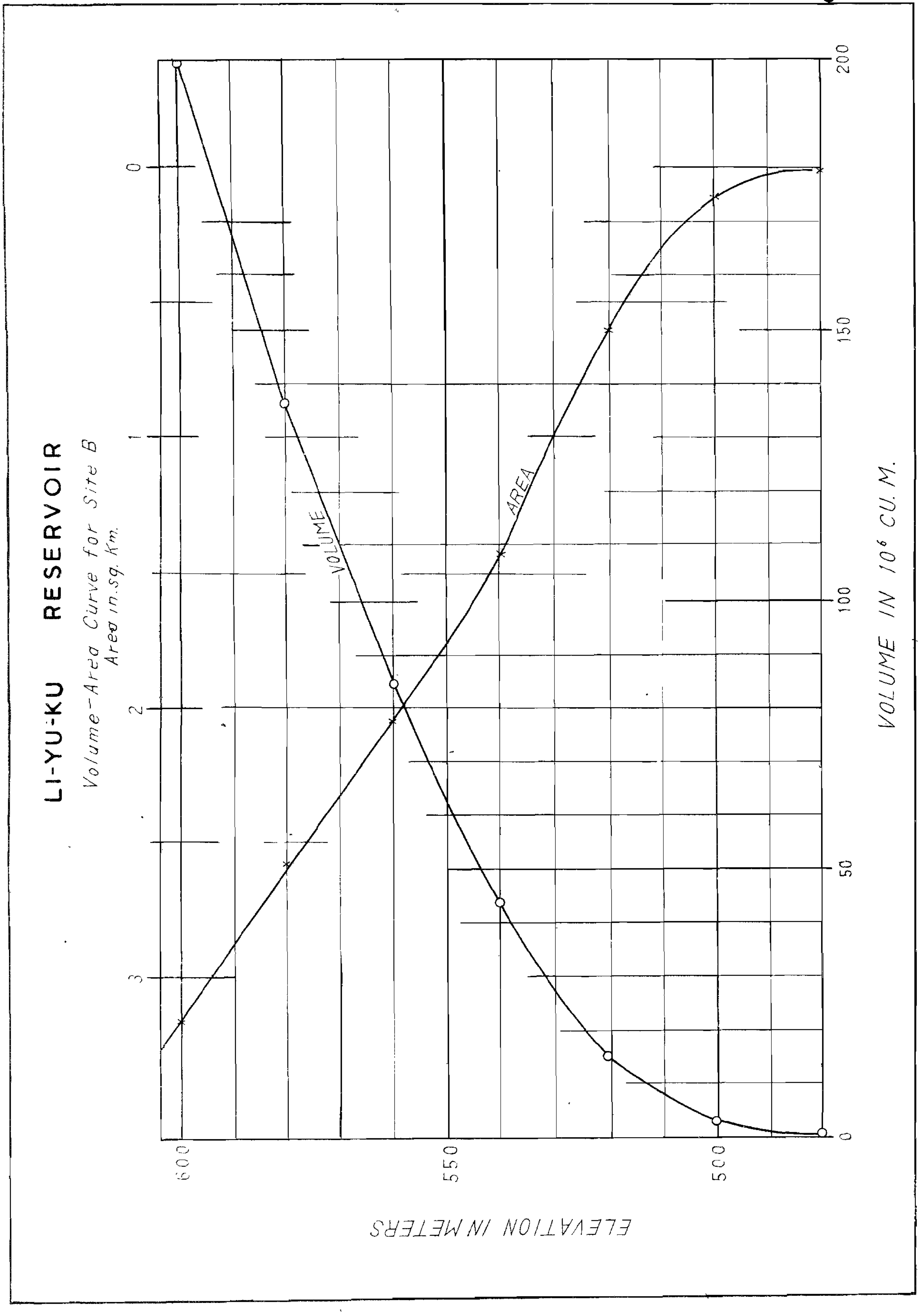
LI-YU-KU RESERVOIR

CROSS SECTION—SITE B



1 : 5,000

Fig 42



LI-YU-KU RESERVOIR
Volume-Area Curve for Site B
Area in.sq. Km.
VOLUME
AREA
0
1
2
3
0
50
100
150
200
VOLUME IN 10⁶ CU.M.
600
550
500
ELEVATION IN METERS

Fig 43

INFLOW-OUTFLOW CURVE

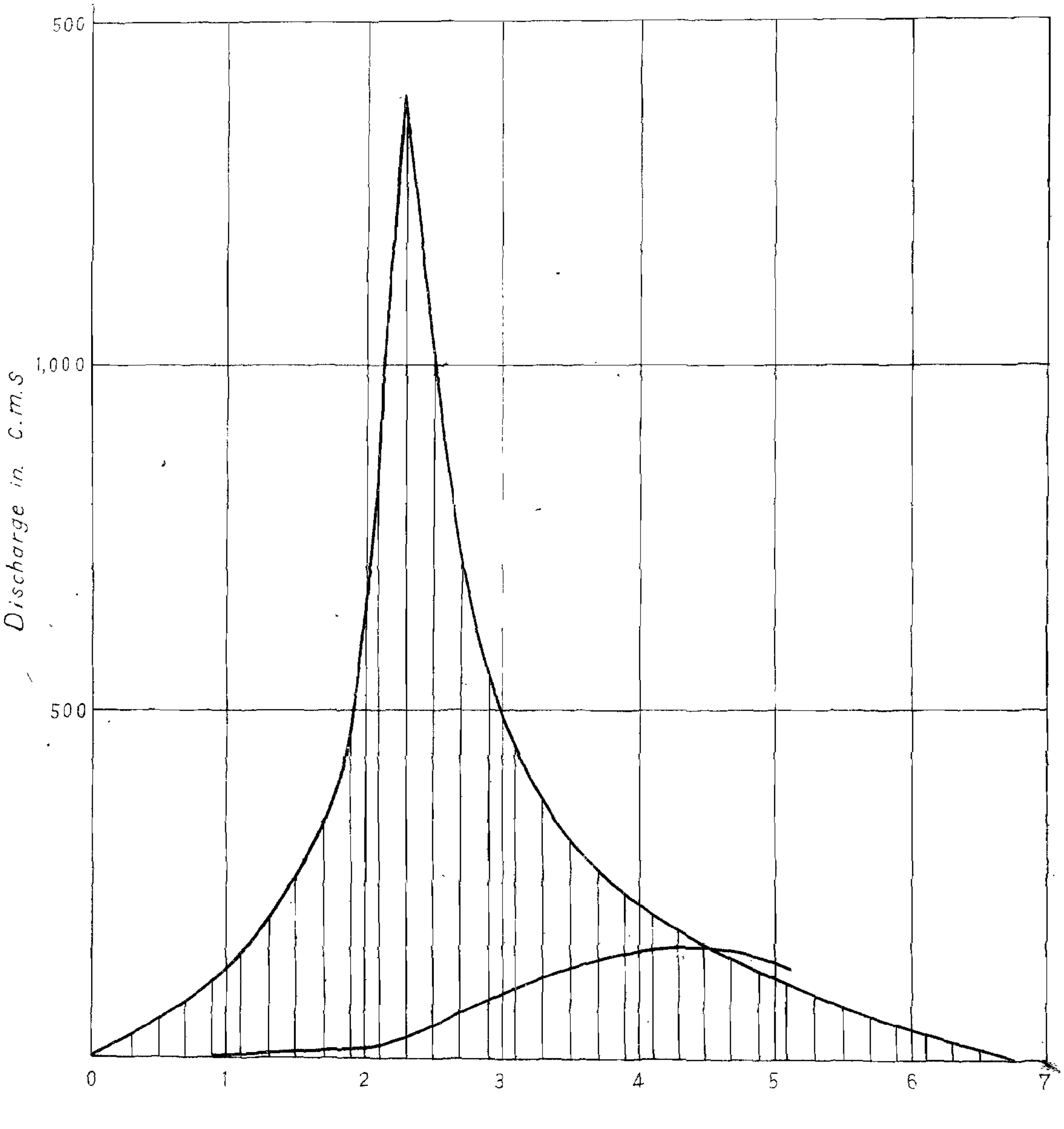


Fig 44

SPILLWAY DISCHARGE CURVE

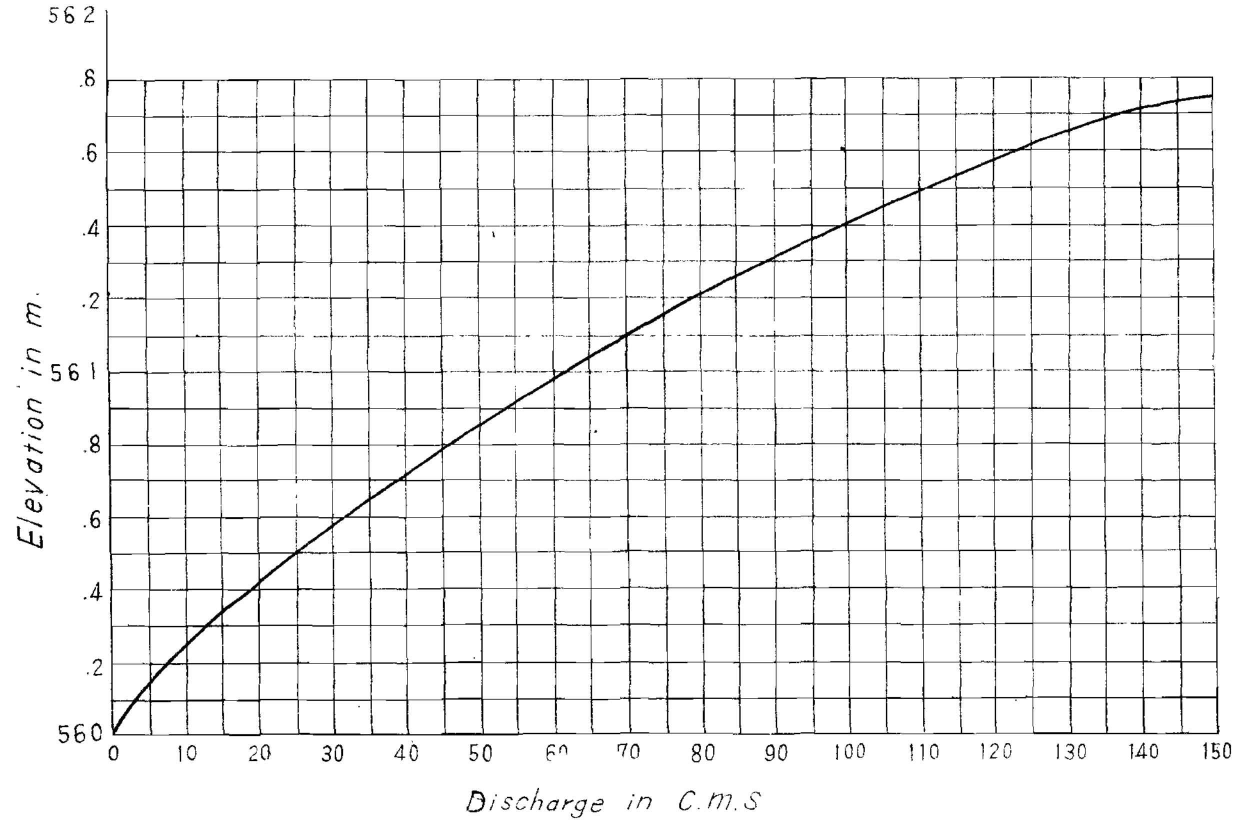
Shaft spillway — $Q = 2.108 L H^{3/2}$

Design head — $H = 1.74\ m$

$Q = 150$ c.m.s

$L = 31\ m$

$R = L/2\pi - 4.94 \approx 5\ m.$



FLOOD-ROUTING

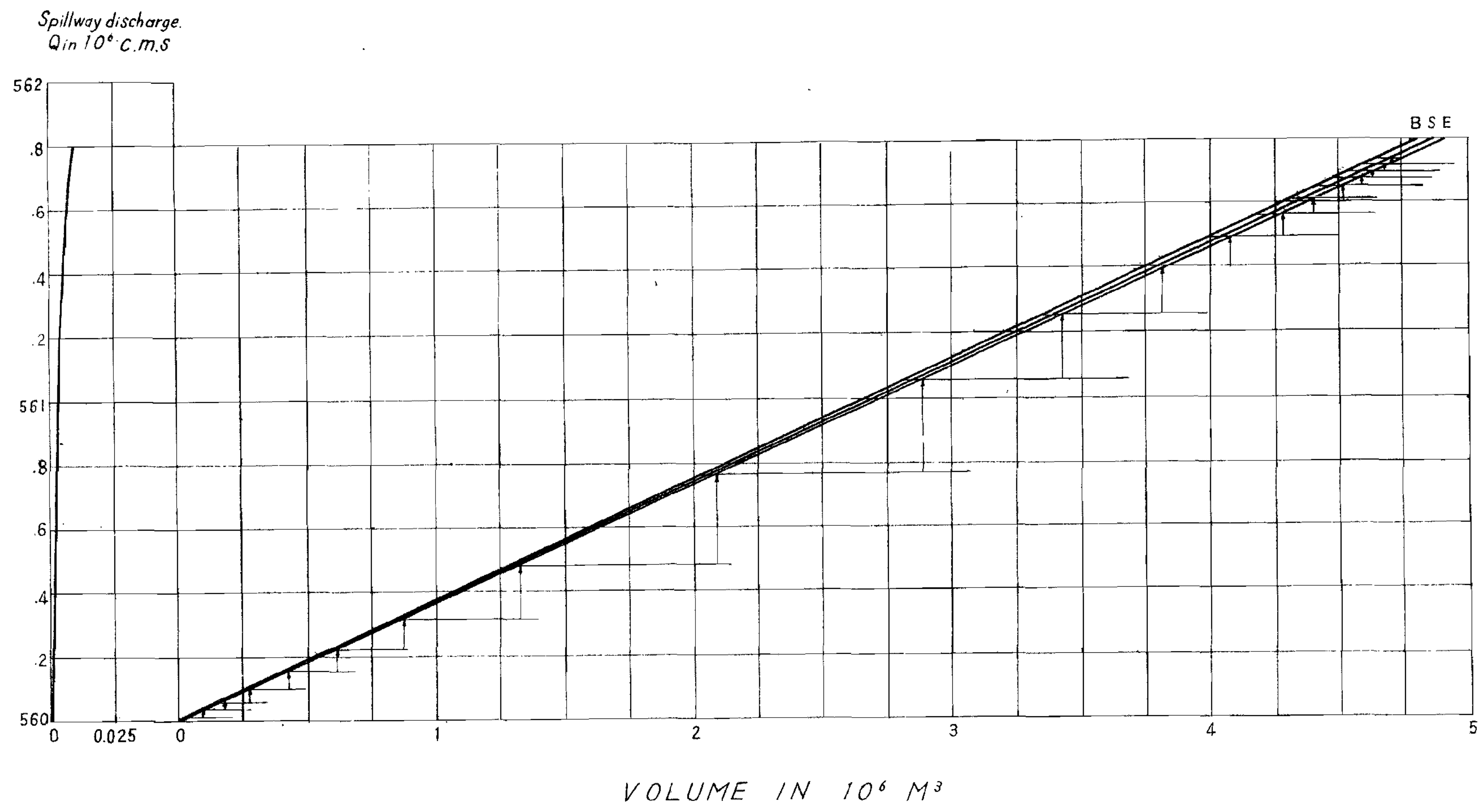
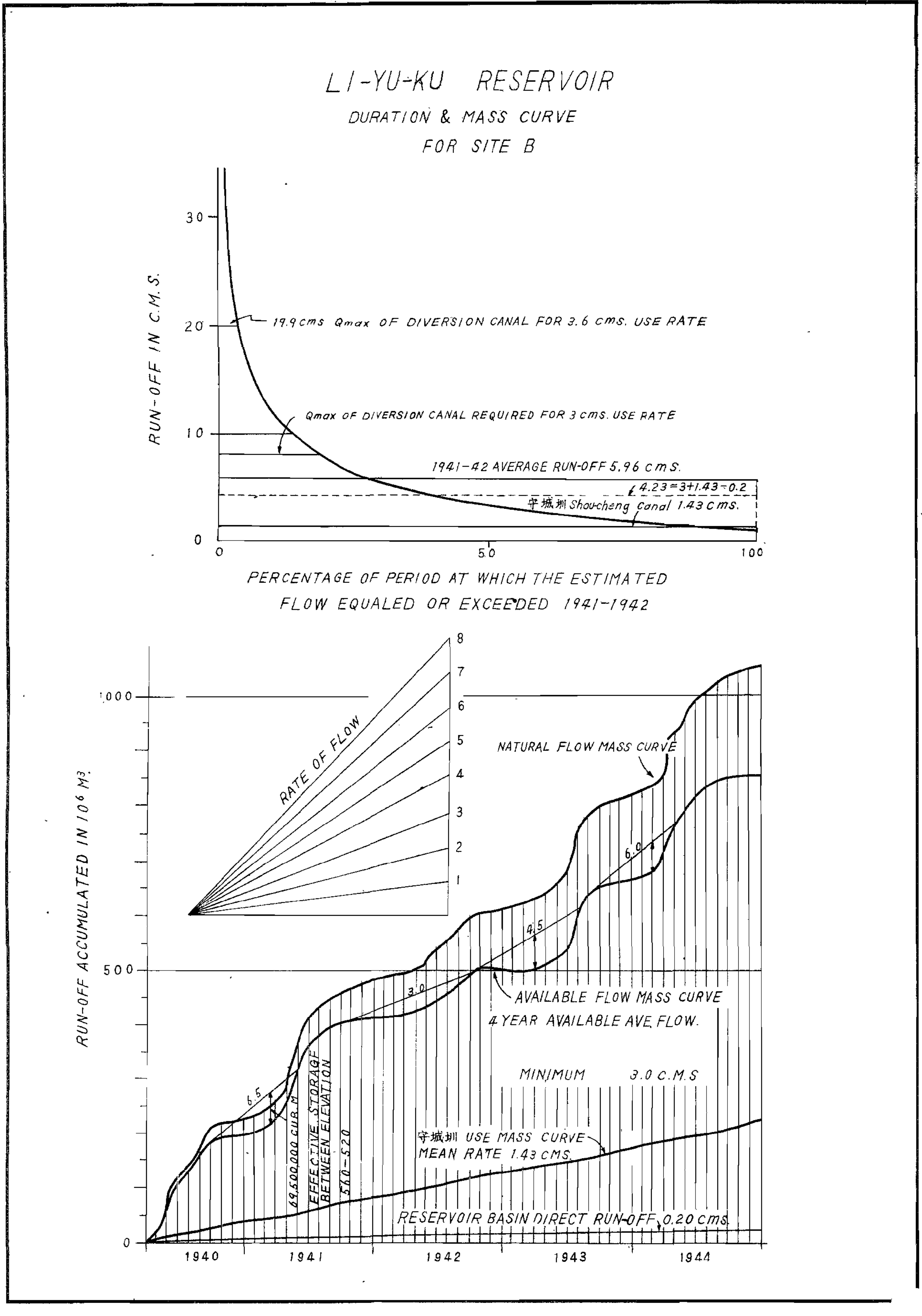


Fig 45

LI-YU-KU RESERVOIR
FLOOD-ROUING COMPUTATION

STEP	TIME FROM BEGINNING OF FLOOD	INSTANTANEOUS RATE OF INFLOW AT THE END OF TIME INTERVAL C.M.S.	MEAN RATE OF INFLOW DURING TIME INTERVAL C.M.S.	VOLUME OF INFLOW DURING THE TIME INTERVAL M^3	RESERVOIR ELEVATION AT THE END OF TIME INTERVAL	SPILLWAY DISCHARGE AT THE END OF TIME INTERVAL
1	0.1	5				
2	0.3	30	17.5	12,600		
3	0.5	55	42.5	30,600		
4	0.7	82	68.5	49,000		
5	0.9	110	96.0	69,200	560.01	
6	1.1	150	130.0	93,500	560.04	
7	1.3	200	185.0	136,200	560.06	
8	1.5	250	225.0	162,000	560.10	
9	1.7	330	290.0	208,800	560.15	
10	1.9	470	400.0	287,800	560.22	
11	2.1	900	685.0	493,200	560.30	
12	2.3	1390	1145.0	824,400	560.48	
13	2.5	1020	1205.0	867,500	560.76	
14	2.7	720	870.0	626,200	561.06	
15	2.9	550	635.0	457,000	561.26	
16	3.1	450	500.0	360,000	561.40	
17	3.3	370	410.0	295,000	561.50	
18	3.5	315	342.5	246,700	561.56	
19	3.7	270	292.5	211,000	561.61	
20	3.9	240	255.0	183,500	561.68	
21	4.1	210	225.0	162,000	561.72	
22	4.3	190	200.0	144,000	561.73	
23	4.5	170	180.0	130,000	561.74	

Fig 46


LI-YU-KU RESERVOIR
DURATION & MASS CURVE
FOR SITE B
RUN-OFF IN C.M.S.
19.9 cms Qmax OF DIVERSION CANAL FOR 3.6 cms. USE RATE
Qmax OF DIVERSION CANAL REQUIRED FOR 3 cms. USE RATE
1941-42 AVERAGE RUN-OFF 5.96 cms.
4.23=3+1.43-0.2
守城圳 Shou-cheng Canal 1.43 cms.
PERCENTAGE OF PERIOD AT WHICH THE ESTIMATED FLOW EQUALED OR EXCEEDED 1941-1942
RUN-OFF ACCUMULATED IN 10⁶ M³
RATE OF FLOW
NATURAL FLOW MASS CURVE
AVAILABLE FLOW MASS CURVE
4 YEAR AVAILABLE AVE. FLOW.
MINIMUM 3.0 C.M.S
69,500,000 CUB. M.
EFFECTIVE STORAGE BETWEEN ELEVATION 560-520
守城圳 USE MASS CURVE
MEAN RATE 1.43 cms.
RESERVOIR BASIN DIRECT RUN-OFF 0.20 cms.
1940
1941
1942
1943
1944

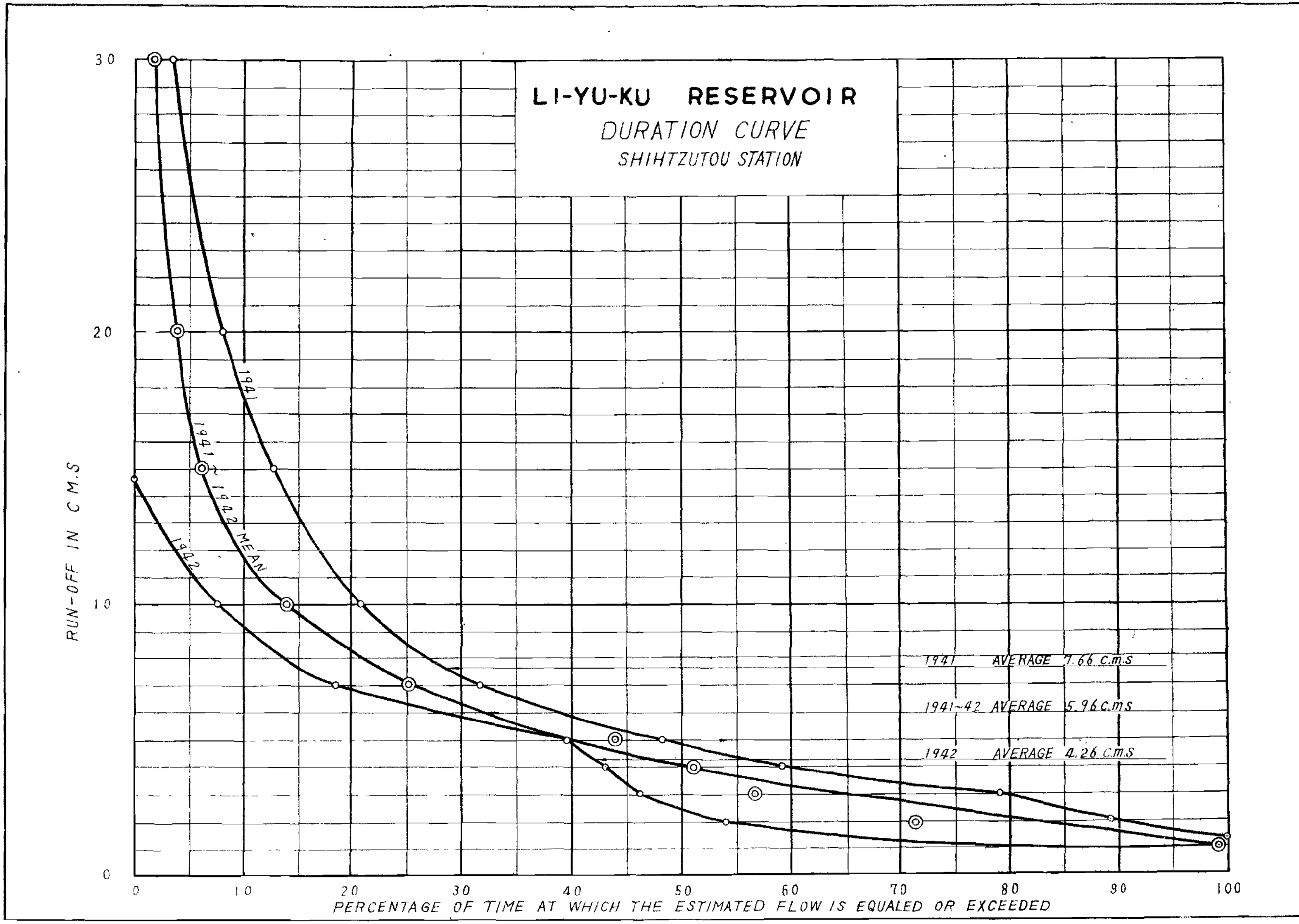
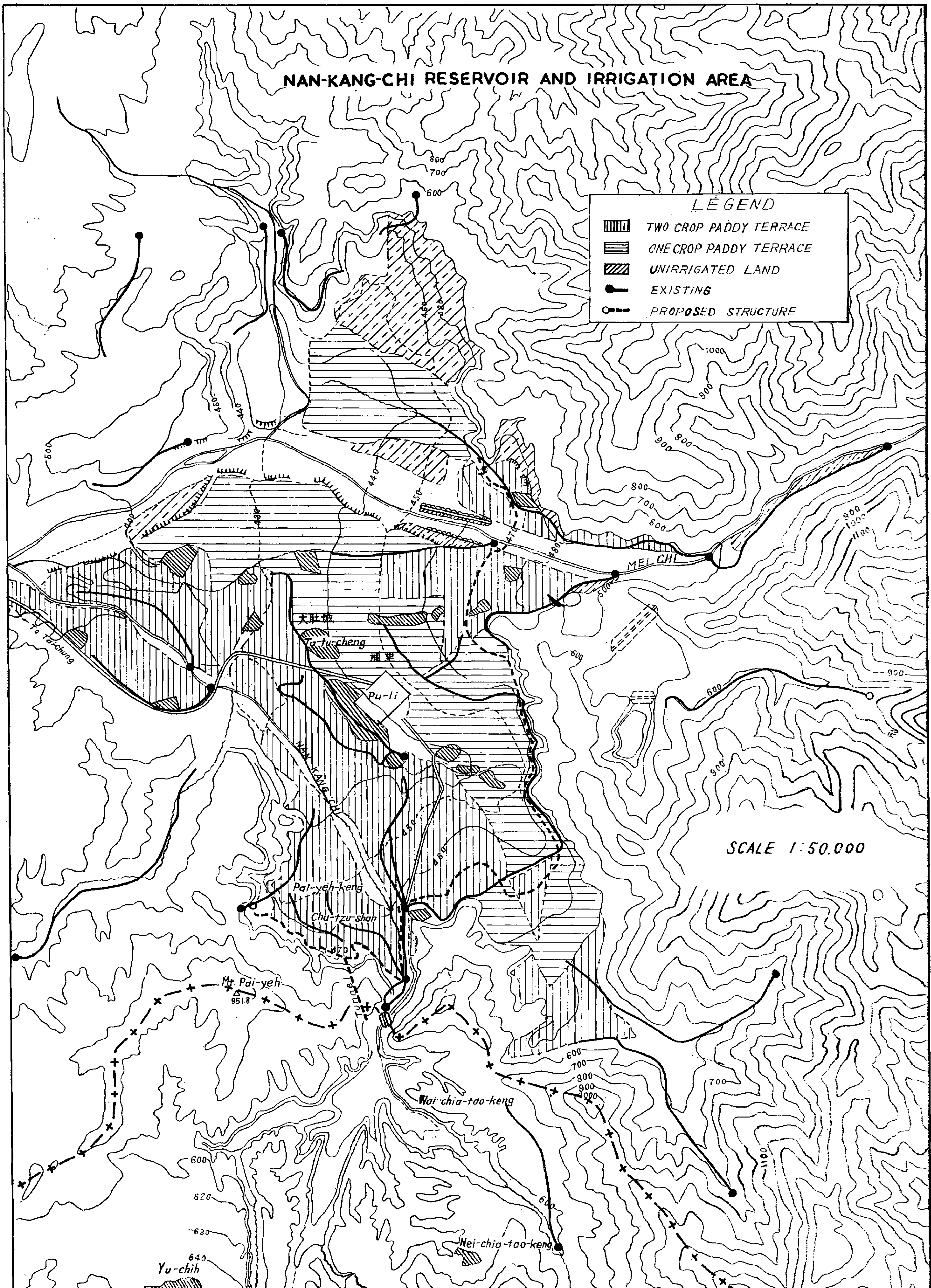

LI-YU-KU RESERVOIR
DURATION CURVE
SHIHTZUTOU STATION
1941 AVERAGE 7.66 c.m.s
1941~42 AVERAGE 5.96 c.m.s
1942 AVERAGE 4.26 c.m.s
1941
1941 ~ 1942 MEAN
1942
30
20
10
0
RUN-OFF IN C.M.S
0
10
20
30
40
50
60
70
80
90
100
PERCENTAGE OF TIME AT WHICH THE ESTIMATED FLOW IS EQUALED OR EXCEEDED

Fig 48



NAN-KANG-CHI RESERVOIR AND IRRIGATION AREA
LEGEND
TWO CROP PADDY TERRACE
ONE CROP PADDY TERRACE
UNIRRIGATED LAND
EXISTING
PROPOSED STRUCTURE
SCALE 1:50,000
MEI CHI
NAN KANG CHI
大肚城
Ta-tu-cheng
埔里
Pu-li
To Tai-chung
Pai-yeh-keng
Chu-tzu-shan
Tunnel
Mt. Pai-yeh
851.8
Wai-chia-tao-keng
Nei-chia-tao-keng
Yu-chih

Fig 49

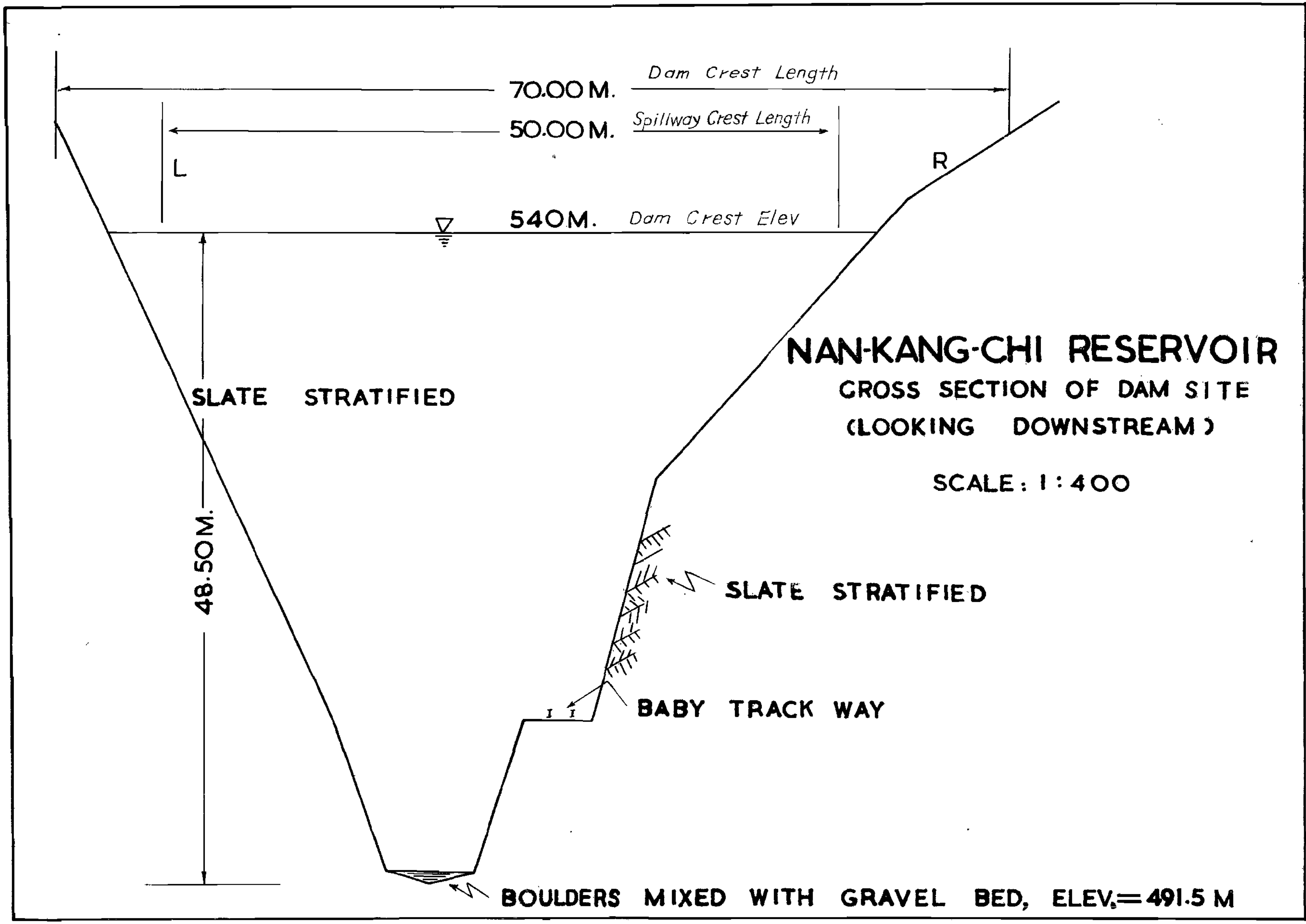

70.00 M.
Dam Crest Length
50.00 M.
Spillway Crest Length
L
R
540 M.
Dam Crest Elev
48.50 M.
SLATE STRATIFIED
NAN-KANG-CHI RESERVOIR
CROSS SECTION OF DAM SITE
(LOOKING DOWNSTREAM)
SCALE: 1:400
SLATE STRATIFIED
BABY TRACK WAY
BOULDERS MIXED WITH GRAVEL BED, ELEV.=491.5 M

Fig 50

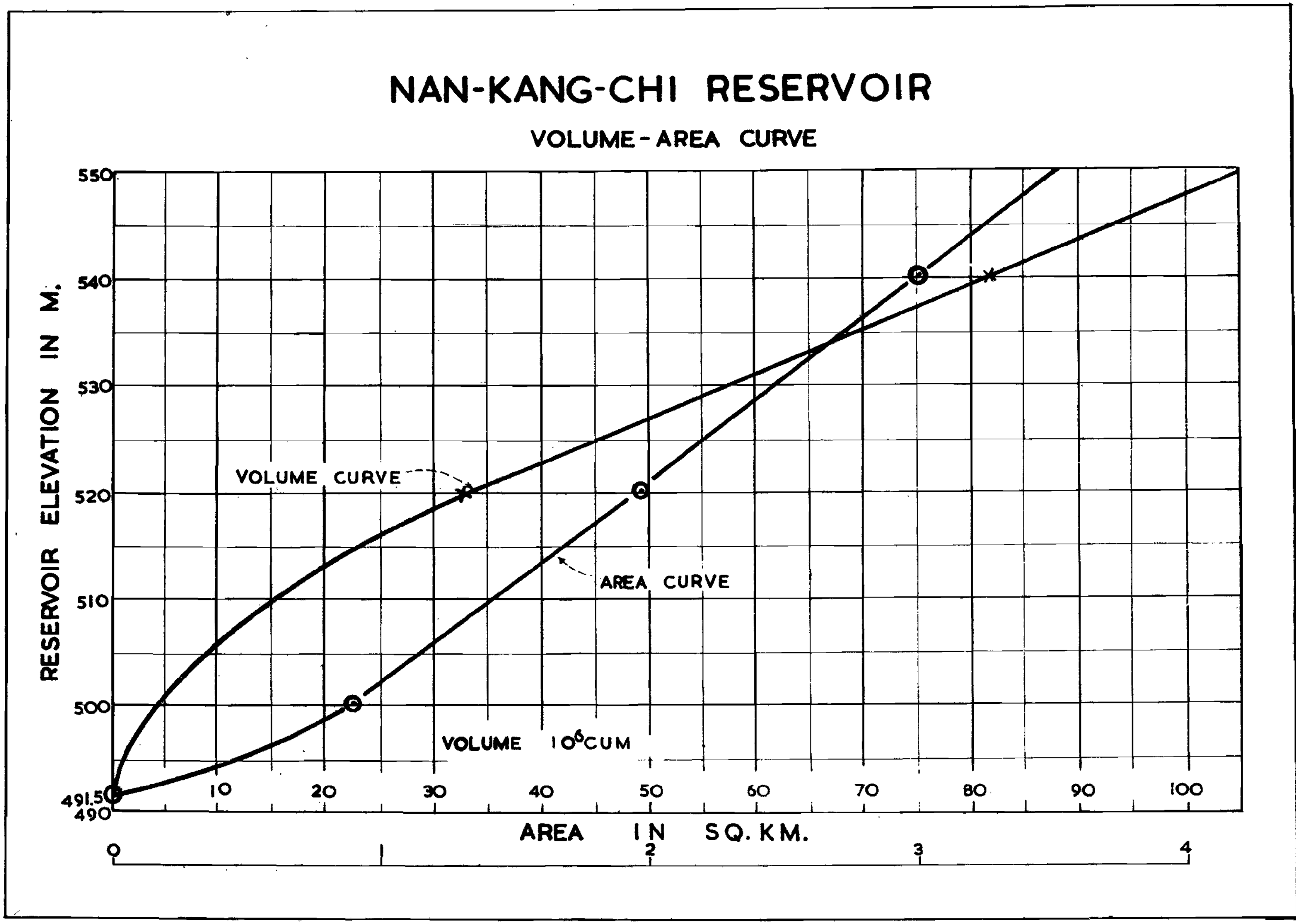

NAN-KANG-CHI RESERVOIR
VOLUME-AREA CURVE
RESERVOIR ELEVATION IN M.
550
540
530
520
510
500
491.50
490
VOLUME CURVE
AREA CURVE
VOLUME 10^6 CUM
0
10
20
30
40
50
60
70
80
90
100
AREA IN SQ.KM.
2
3
4

Fig 51

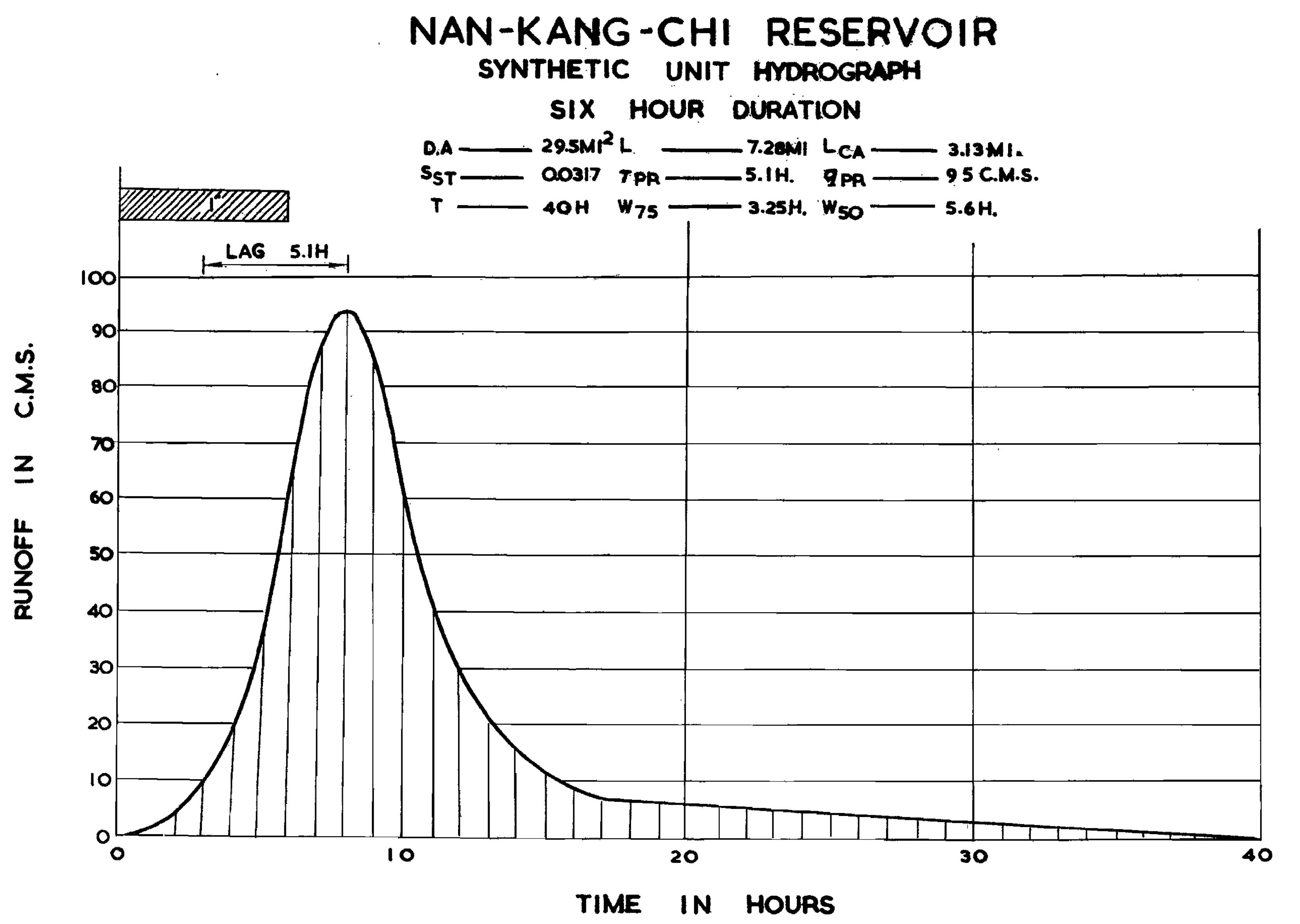

NAN-KANG-CHI RESERVOIR
SYNTHETIC UNIT HYDROGRAPH
SIX HOUR DURATION
D.A — 29.5MI^2 L — 7.28MI L_{CA} — 3.13MI.
S_{ST} — 0.0317 T_{PR} — 5.1H. q_{PR} — 95 C.M.S.
T — 40H W_{75} — 3.25H. W_{50} — 5.6H.
1"
LAG 5.1H
RUNOFF IN C.M.S.
0
10
20
30
40
50
60
70
80
90
100
TIME IN HOURS
0
10
20
30
40

Fig 52

NAN-KANG-CHI RESERVOIR

D.A. = 76.3 KM = 29.5 MI^2

L = 11.7 KM = 7.28 MI.

L_{CA} = 4.05 KM = 3.13 MI.

S_{ST} = 0.0317

LL_{CA} = (7.28)(3.13) = 22.78

$M' = 0.212/(LL_{CA})^{0.36} = 0.212/(22.78)^{0.36}$

$= 0.212/3.08 = 0.0689$

$c' = 0.6/\sqrt{S_{ST}} = 0.6/\sqrt{0.0317} = 0.6/0.178 = 3.37$

Set t_R = 6 HR.

$t_{PR} = c'E^{M't_R} = 3.37E^{(0.0689)(6)}$

$= 3.37E^{0.4134} = (3.37)(1.512) = 5.10$ HR.

$\Delta M'' = 0.121 S_{ST}^{0.142} - 0.050$

$M'' = -M' + \Delta M''$

$= -0.0689 + 0.121(0.0317)^{0.142} - 0.050$

$= -0.1189 + 0.121\left(\frac{1}{31.60^{0.142}}\right) = -0.1189 + (0.121)\left(\frac{1}{1.63}\right)$

$= -0.1189 + (0.121)(0.614) = -0.1189 + 0.074 = -0.0459$

$c'' = 382(LL_{CA})^{-0.36} = 382(22.78)^{-0.36} = 382/3.08 = 124$

$q_{PR} = c''E^{M't_R} = 124E^{(-0.0459)(6)}$

$= 124E^{-0.75} = 124/1.32 = 94$ CFS/SQ. MI.

$T = 5(t_{PR} + t_R/2) = 5(5.10 + 6/2) = (5)(8.1) = 40.5$ HR

W_{50} = 4.75 (FROM PLATE 9. CORPS OF ENGINEERS 1948)

W_{75} = 2.75

q = (94)(29.5) = 2770 CFS/1"R = 110 CFS/1 MMR = 3.12 CMS/1 MMR

If R = 452 MM/6 HR

Q = (452)(3.12) = 1410 C.M.S.

DETERMINATION OF EQUIVALENT NAN-KANG CHI SLOPE

STATION	ELEVATION	△ ELEV.	L	S_i	$\sqrt{S_i}$	$\frac{1}{\sqrt{S_i}}$
DAM SITE	480					
	486	6	1,500	0.00400	0.0633	15.80
CHUNG-LIAO	519	33	1,500	0.02200	0.1483	6.75
TA-LIN	566	47	1,500	0.03130	0.1770	565
	625	59	1,500	0.03934	0.1975	507
	671	46	1,500	0.03070	0.1753	570
	860	189	1,500	0.12600	0.3550	282
	1300	440	1,500	0.29350	0.5420	184
TA-CHIEN-SHAN	1975	675	1,200	0.56250	0.7500	133

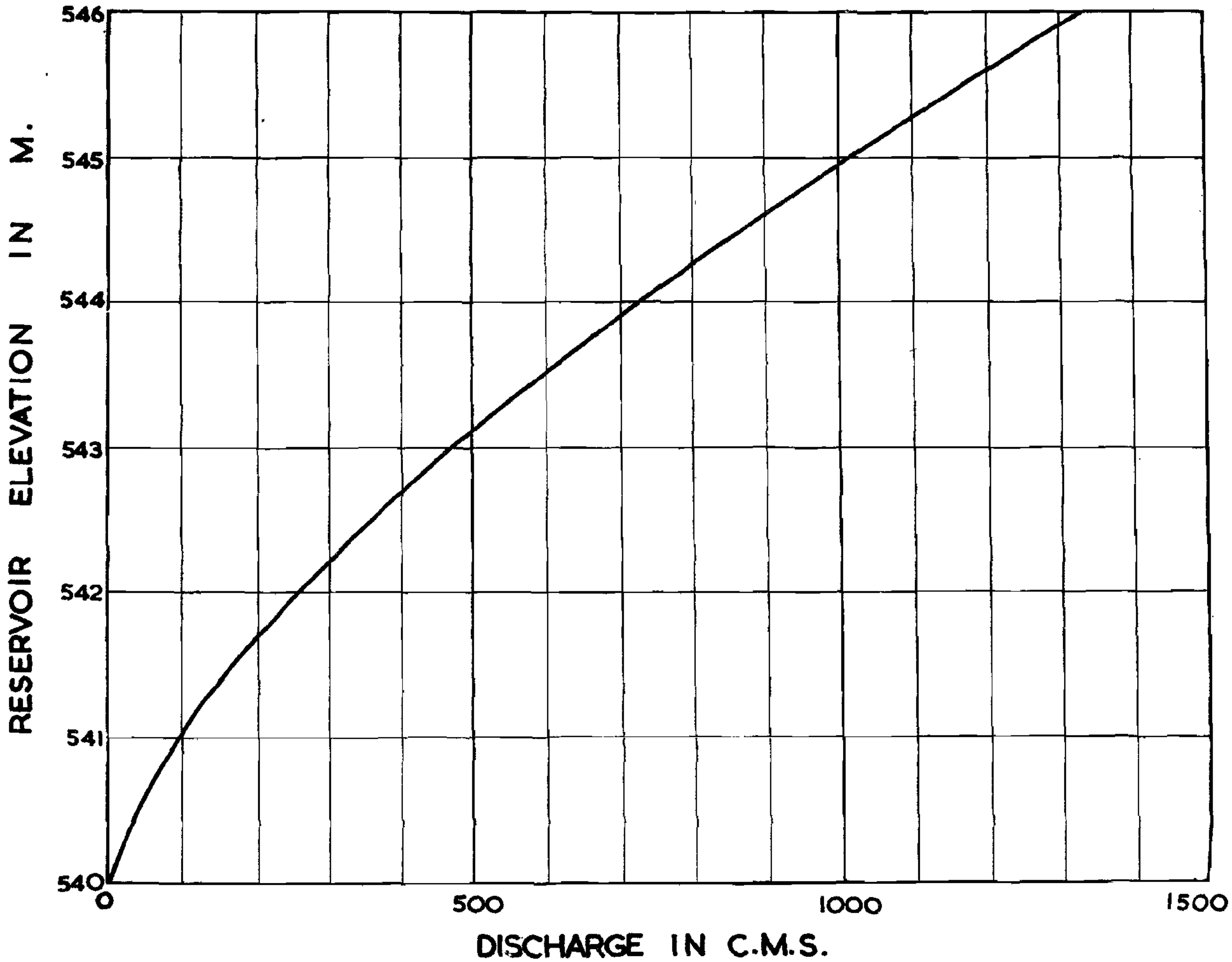
$N = 8 \quad \Sigma(1/\sqrt{S_i}) = 44.76$

$S_{ST} = (N/\Sigma(1/\sqrt{S_i}))^2 = (8/44.76)^2 = 0.0317$

Fig 55

NAN-KANG-CHI RESERVOIR

SPILLWAY CAPACITY CURVE



NAN-KANG-CHI RESERVOIR

INFLOW–OUTFLOW CURVE

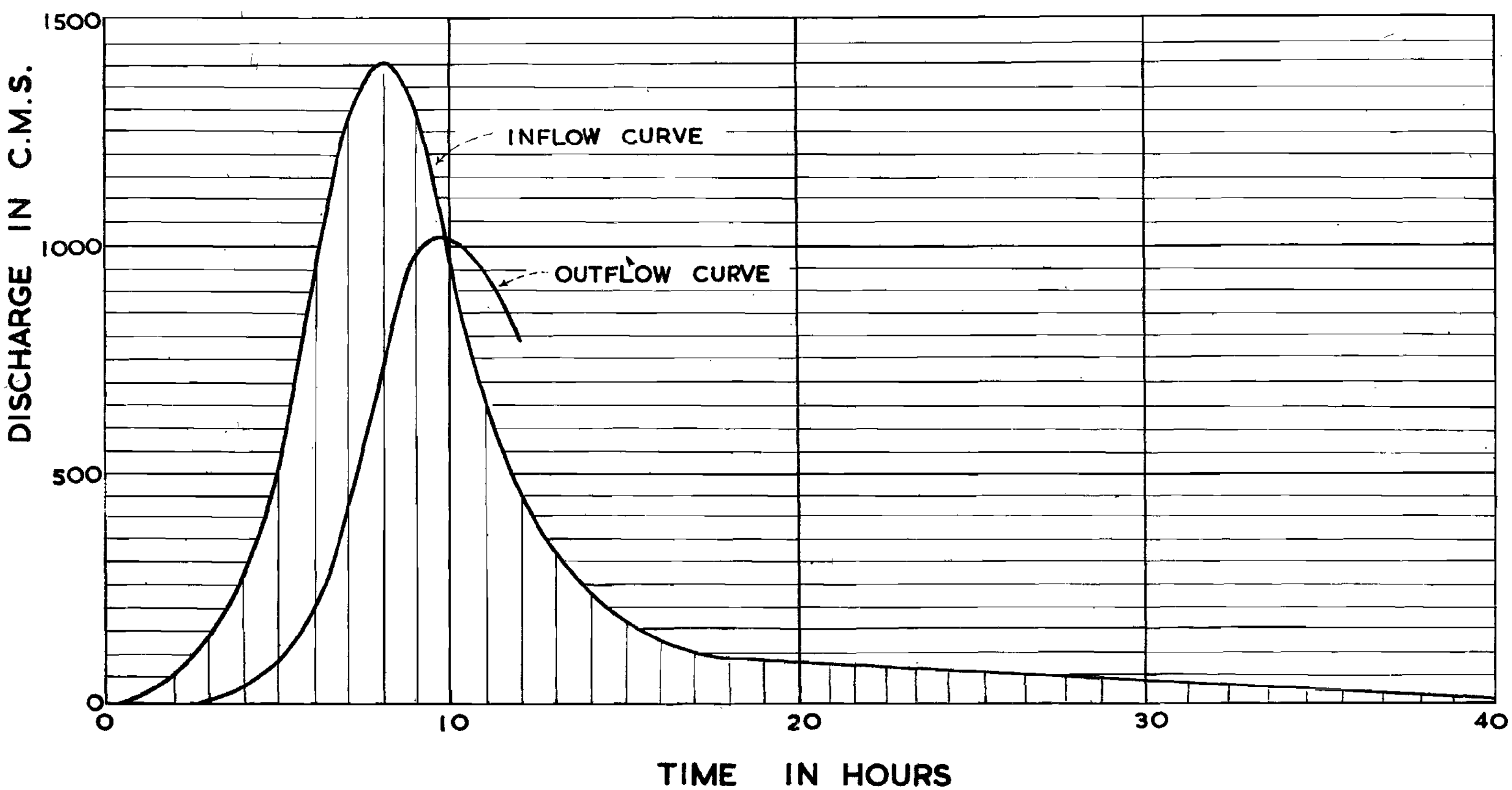
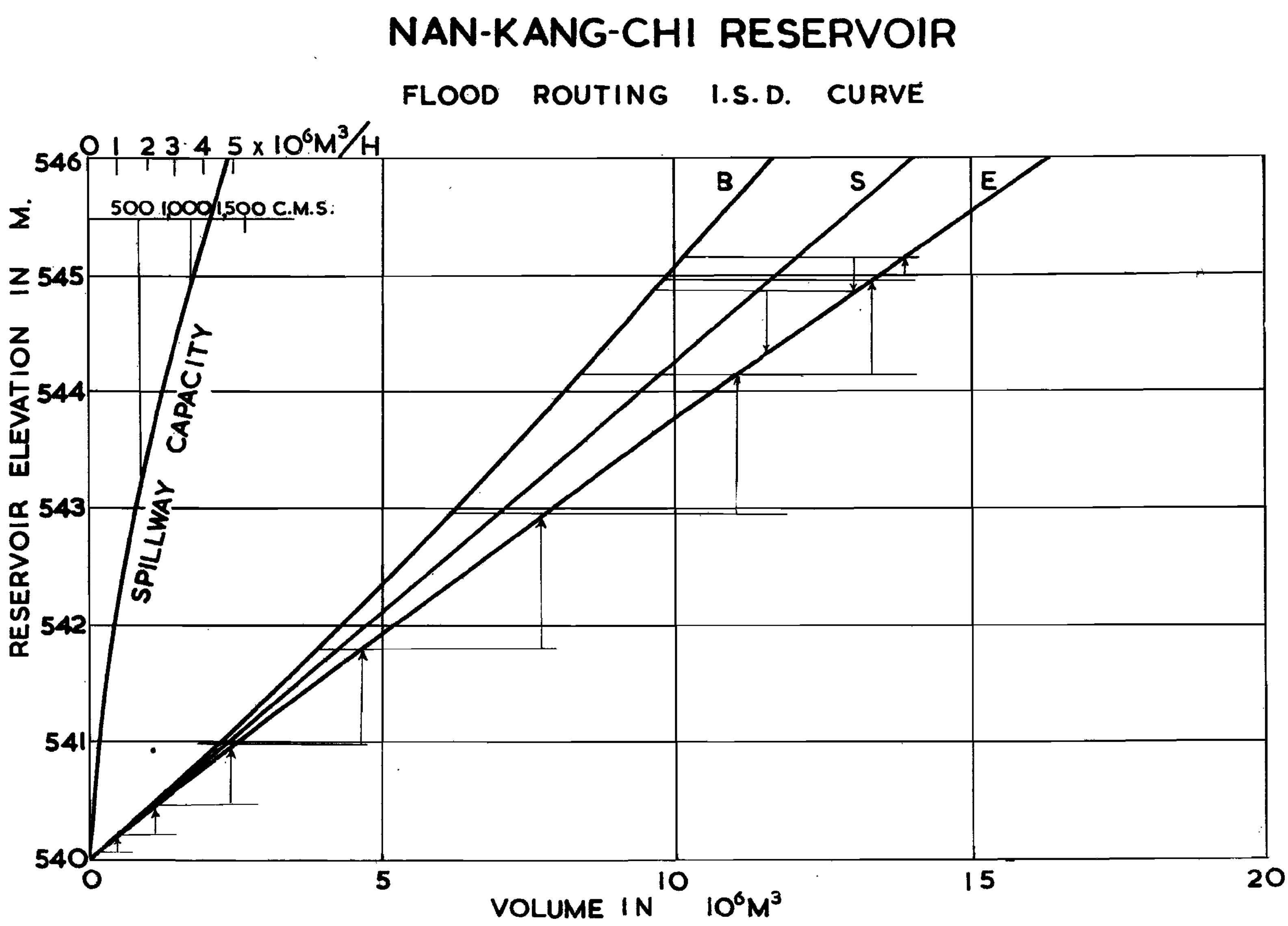


Fig 56


NAN-KANG-CHI RESERVOIR
FLOOD ROUTING I.S.D. CURVE
0 1 2 3 4 5 x 10⁶M³/H
500 1000 1500 C.M.S.
SPILLWAY CAPACITY
B
S
E
546
545
544
543
542
541
540
RESERVOIR ELEVATION IN M.
0
5
10
15
20
VOLUME IN 10⁶M³

NAN-KANG-CHI RESERVOIR

SAMPLE FLOOD ROUTING COMPUTATION

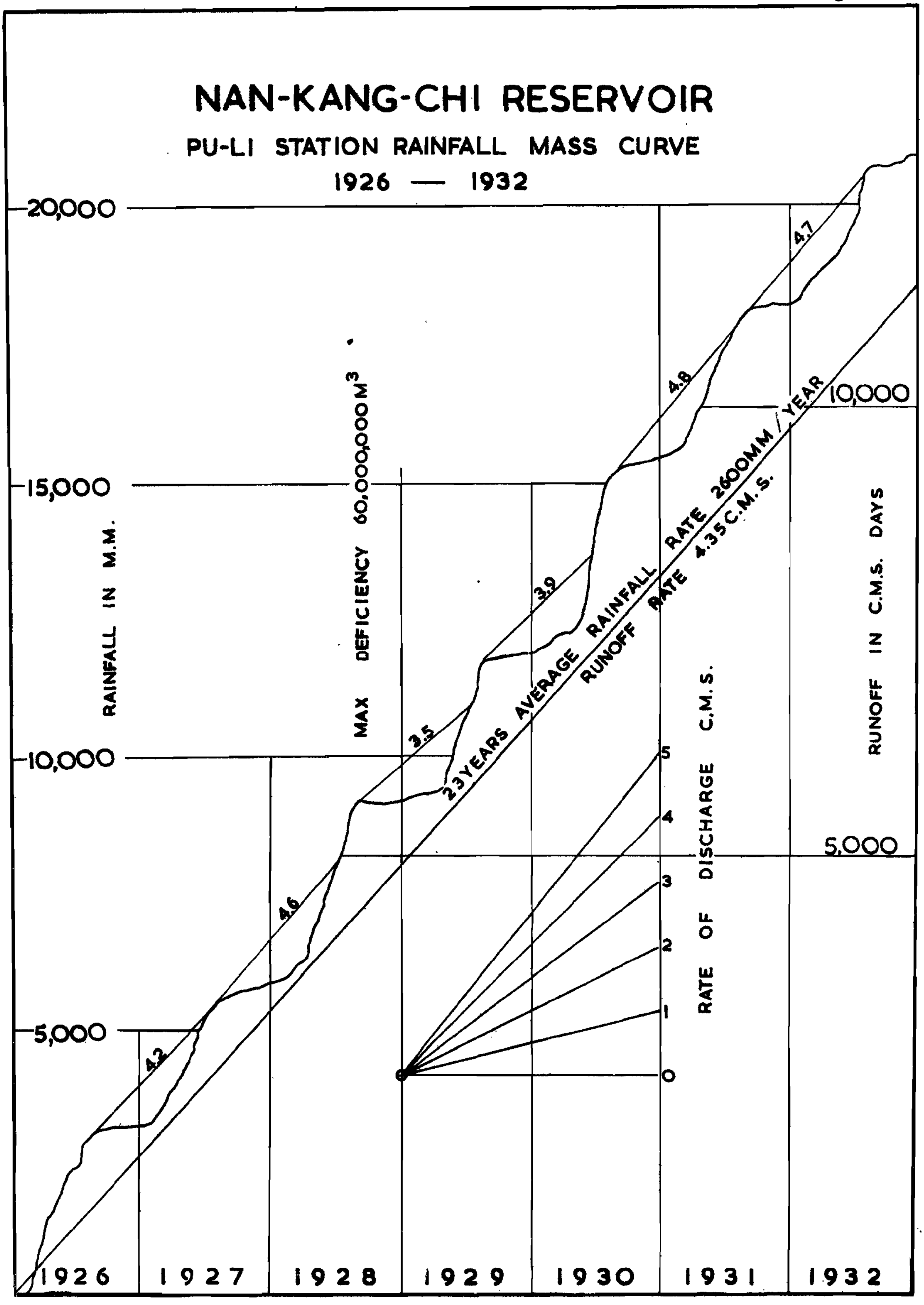
STEP	TIME HR	RATE OF INFLOW AT THE BEGINNING OF THE TIME C.M.S.	AVERAGE RATE OF INFLOW DURING THE TIME INTERVAL C.M.S.	TOTAL INFLOW DURING THE TIME INTERVAL M^3	ELEVATION OF RESERVOIR AT THE END OF THE TIME INTERVAL M	RATE OF OUTFLOW AT THE END OF THE INTERVAL C.M.S.	REMARKS
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	1	15	7.5	27000			ASSUME FREE OVER
2	2	50	32.5	117000	540.05		FLOW $Q=1.80LH^{3/2}$
3	3	130	90.0	324000	540.20	7.5	SPILLWAY WITH 50
4	4	290	210	756000	540.47	28.5	M CREST LENGTH.
5	5	500	395	1420000	540.98	90.0	
6	6	870	685	2465000	541.80	210.0	RESERVOIR STORAGE
7	7	1280	1075	3870000	542.95	445.0	EFFECT $\frac{1420}{1030}=1.38$
8	8	1420	1350	4860000	544.15	740.0	
9	9	1300	1360	4900000	544.95	975.0	
10	10	960	1130	4070000	545.15	1030.0	
11	11	620	790	2840000	544.85	945.0	
12	12	440	530	1908000	544.30	790.0	

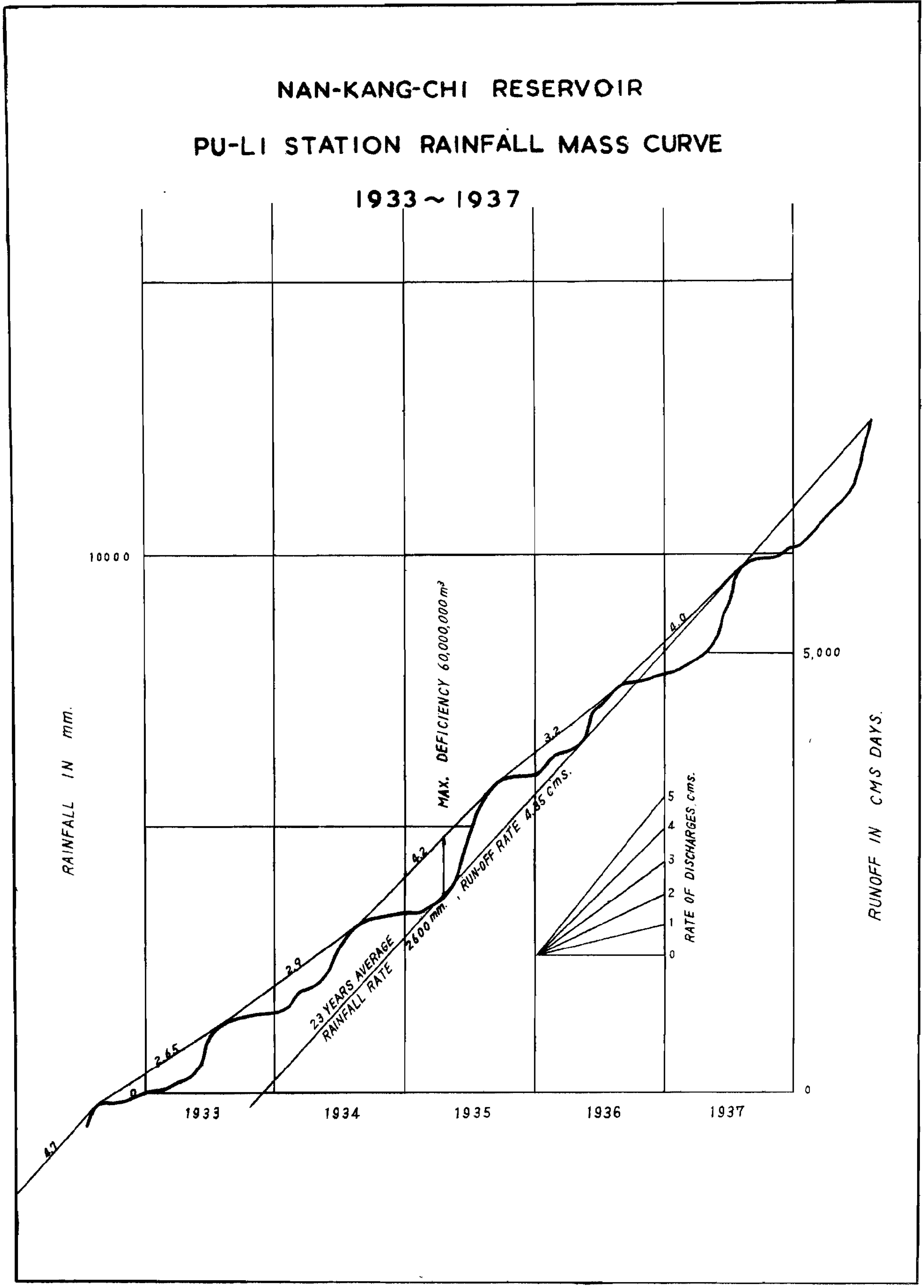
NAN-KANG-CHI RESERVOIR

PU-LI STATION ANNUAL RAINFALL

23 YEARS AVERAGE 2600 M.M.

YEAR	ANNUAL RAINFALL M.M.	ACCUMULATED RAINFALL M.M.	RUNOFF COEF-FICIENT	ANNUAL RUNOFF M^3
1926	3161.5	3161.5	0.67	156,500,000
1927	2599.9	5761.4	0.67	134,700,000
1928	3406.1	9167.5	0.67	179,200,000
1929	2519.2	11686.7	0.67	131,600,000
1930	3094.6	14781.3	0.67	163,000,000
1931	2837.1	17618.4	0.67	149,200,000
1932	2688.4	20306.8	0.67	141,600,000
1933	1496.7	21803.5	0.67	78,800,000
1934	1784.9	23588.4	0.67	94,000,000
1935	2701.3	26289.7	0.67	142,200,000
1936	1894.2	28183.9	0.67	99,700,000
1937	2449.6	30633.5	0.67	129,000,000
1938	3062.1	33695.6	0.67	161,300,000
1939	3022.9	36718.5	0.67	159,100,000
1940	2392.7	39111.2	0.67	126,000,000
1941	2770.7	41881.9	0.67	145,900,000
1942	2192.2	44074.1	0.67	115,400,000
1943	1941.6	46015.7	0.67	102,200,000
1944	3147.6	49163.3	0.67	165,700,000
1945	2790.1	51953.4	0.67	147,000,000
1946	1844.0	53797.4	0.67	97,100,000
1947	3642.4	57439.8	0.67	191,800,000
1948	2204.6	59644.4	0.67	115,100,000


NAN-KANG-CHI RESERVOIR
PU-LI STATION RAINFALL MASS CURVE
1926 — 1932
20,000
15,000
10,000
5,000
RAINFALL IN M.M.
MAX DEFICIENCY 60,000,000 M3
23 YEARS AVERAGE RAINFALL RATE 2600MM / YEAR
RUNOFF RATE 4.35 C.M.S.
RATE OF DISCHARGE C.M.S.
RUNOFF IN C.M.S. DAYS
10,000
5,000
4.2
4.6
3.5
3.9
4.8
4.7
0
1
2
3
4
5
1926
1927
1928
1929
1930
1931
1932


NAN-KANG-CHI RESERVOIR
PU-LI STATION RAINFALL MASS CURVE
1933 ~ 1937
10000
5,000
0
RAINFALL IN mm.
RUNOFF IN CMS DAYS.
MAX. DEFICIENCY 60,000,000 m³
23 YEARS AVERAGE RAINFALL RATE 2600 mm. , RUN-OFF RATE 4.85 cms.
RATE OF DISCHARGES. cms.
0
1
2
3
4
5
4.2
2.65
2.9
4.2
3.2
4.0
1933
1934
1935
1936
1937

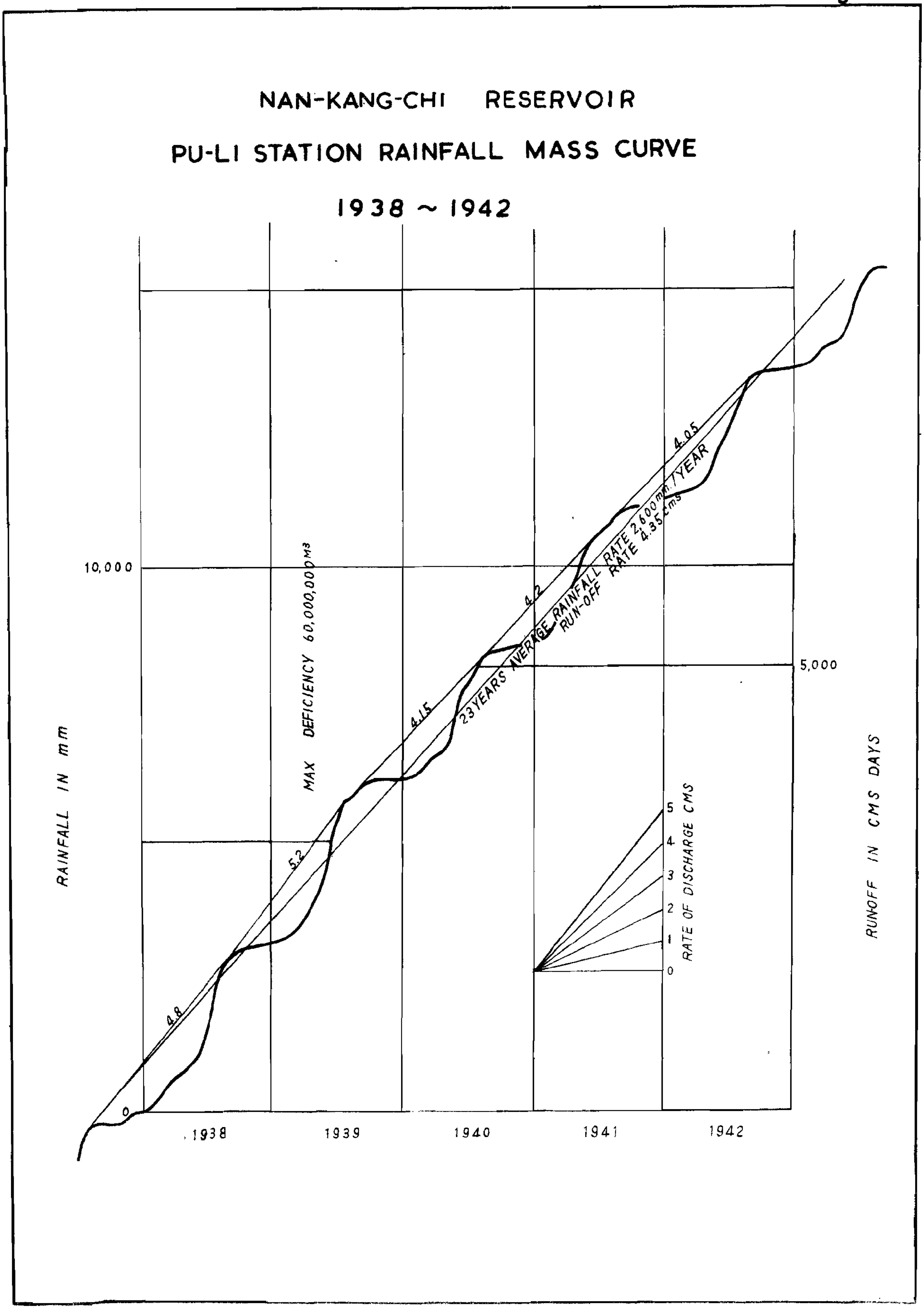
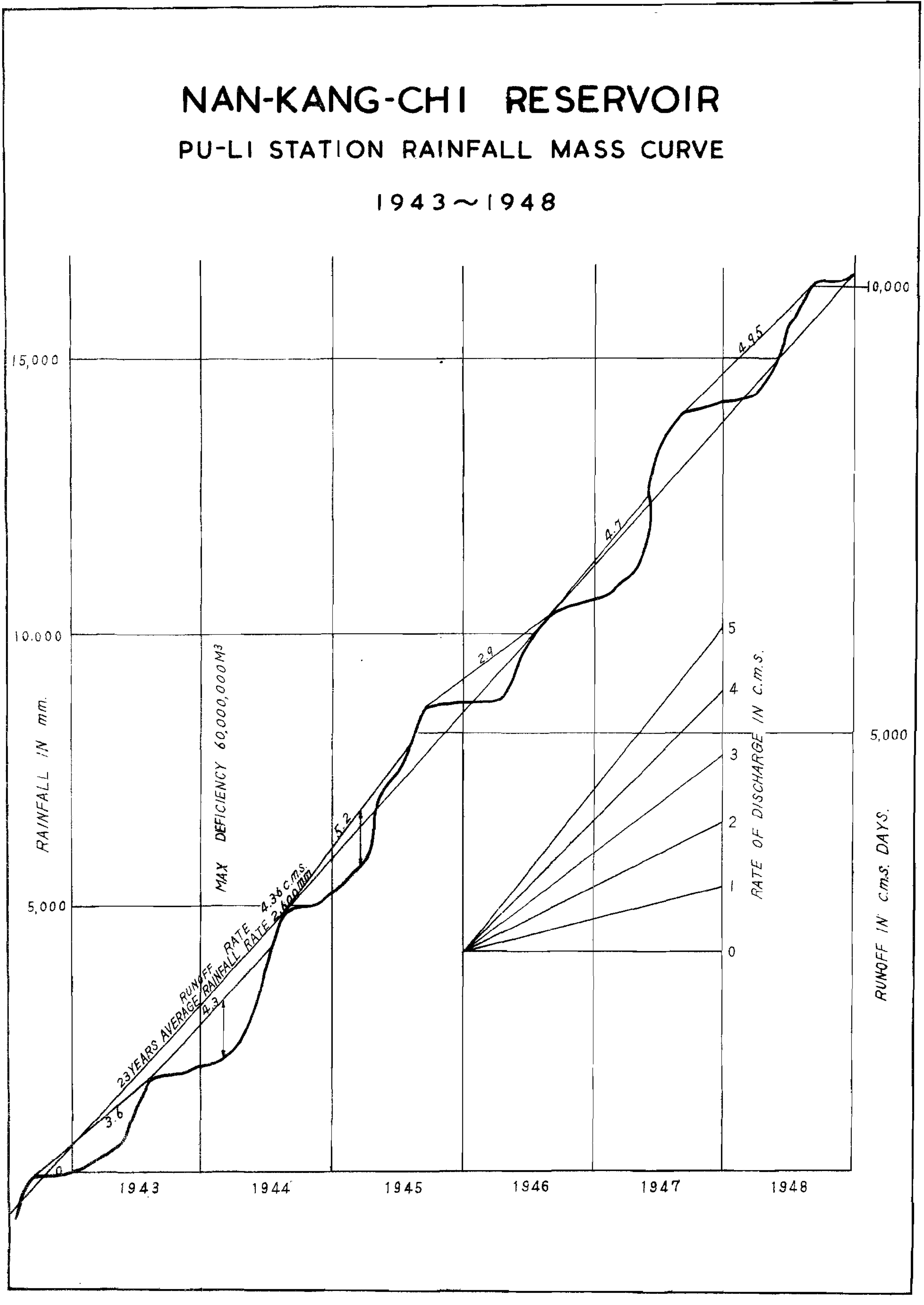

NAN-KANG-CHI RESERVOIR
PU-LI STATION RAINFALL MASS CURVE
1938 ~ 1942
10,000
5,000
RAINFALL IN mm
RUNOFF IN CMS DAYS
MAX DEFICIENCY 60,000,000M3
23 YEARS AVERAGE RAINFALL RATE 2600mm/YEAR
RUN-OFF RATE 4.35 cms
4.8
5.2
4.15
4.2
4.05
0
RATE OF DISCHARGE CMS
0
1
2
3
4
5
1938
1939
1940
1941
1942

Fig 63


NAN-KANG-CHI RESERVOIR
PU-LI STATION RAINFALL MASS CURVE
1943～1948
RAINFALL IN mm.
15,000
10,000
5,000
0
MAX DEFICIENCY 60,000,000M3
RUNOFF RATE 4.36 c.m.s
23 YEARS AVERAGE RAINFALL RATE 2,600 mm
3.6
4.3
5.2
2.9
4.7
4.95
RATE OF DISCHARGE IN C.m.S.
5
4
3
2
1
0
RUNOFF IN C.m.S. DAYS.
10,000
5,000
1943
1944
1945
1946
1947
1948

NAN-KANG-CHI RESERVOIR

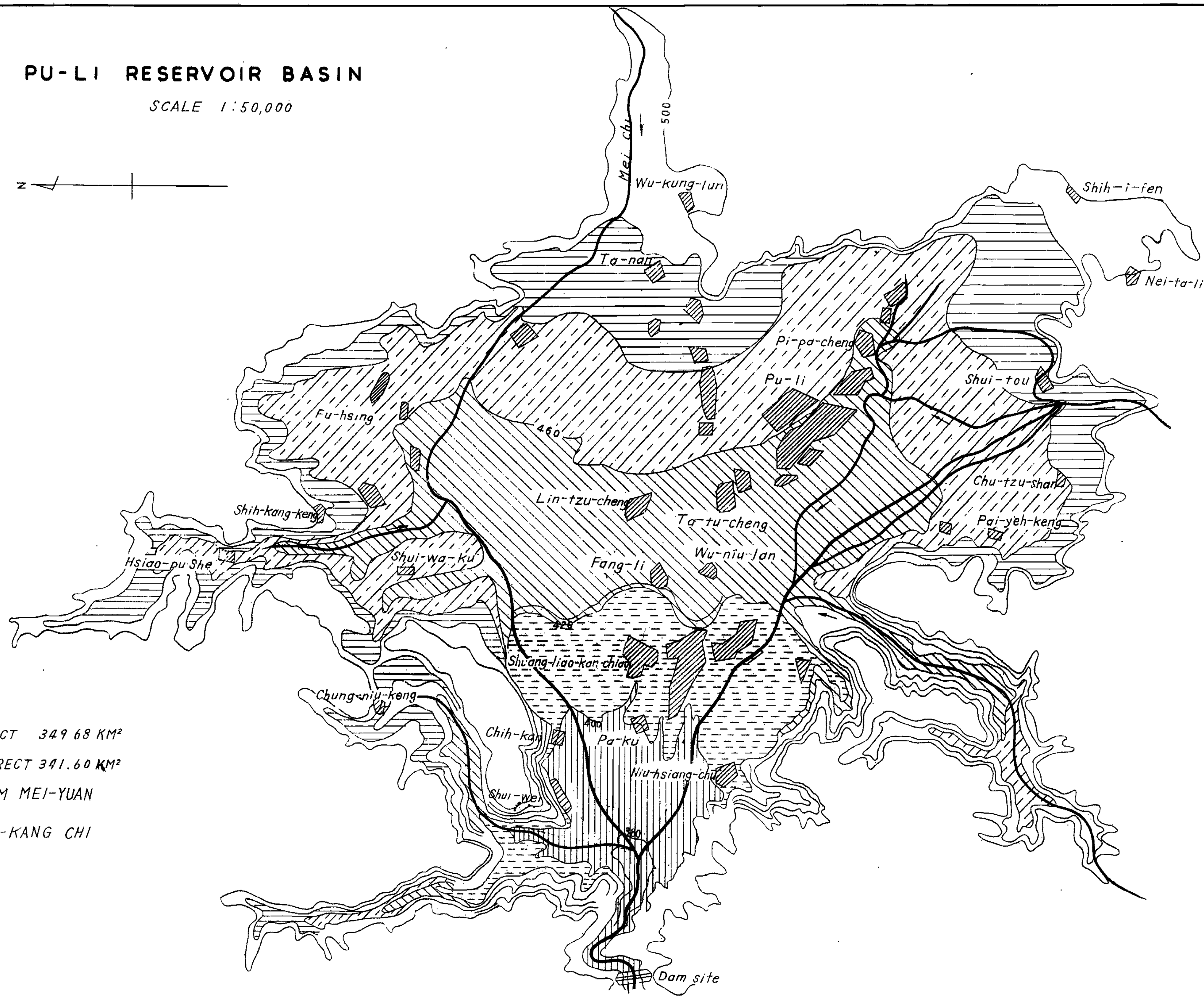
AVAILABLE RATE OF FLOW WITH MAXIMUM RESERVOIR STORAGE CAPACITY 6000000M^3

YEAR	AVAILABLE RATE C.M.S.	AVAILBLE RATE ARRANGED IN ORDER C.M.S.	ORDER NUMBER	
1926	4.95	5.2	1	
1927	4.7	5.2	2	
1928	2.9	4.95	3	
1929	5.2	4.8	4	
1930	4.3	4.8	5	
1931	3.6	4.7	6	
1932	4.05	4.7	7	
1933	4.2	4.6	8	
1934	4.15	4.3	9	
1935	5.2	4.2	10	
1936	4.8	4.2	11	
1937	4.0	4.2	12	
1938	3.2	4.15	13	
1939	4.2	4.05	14	
1940	2.9	4.0	15	
1941	2.65	3.9	16	
1942	4.7	3.6	17	
1943	4.8	3.5	18	
1944	3.9	3.2	19	
1945	3.5	2.9	20	
1946	4.6	2.9	21	
1947	4.2	2.65	22	

$\Sigma = 90.70$ AVERAGE RATE $= \frac{90.70}{22} = 4.1$ C.M.S.

PU-LI RESERVOIR BASIN

SCALE 1:50,000



D.A.

DIRECT 349.68 KM^2

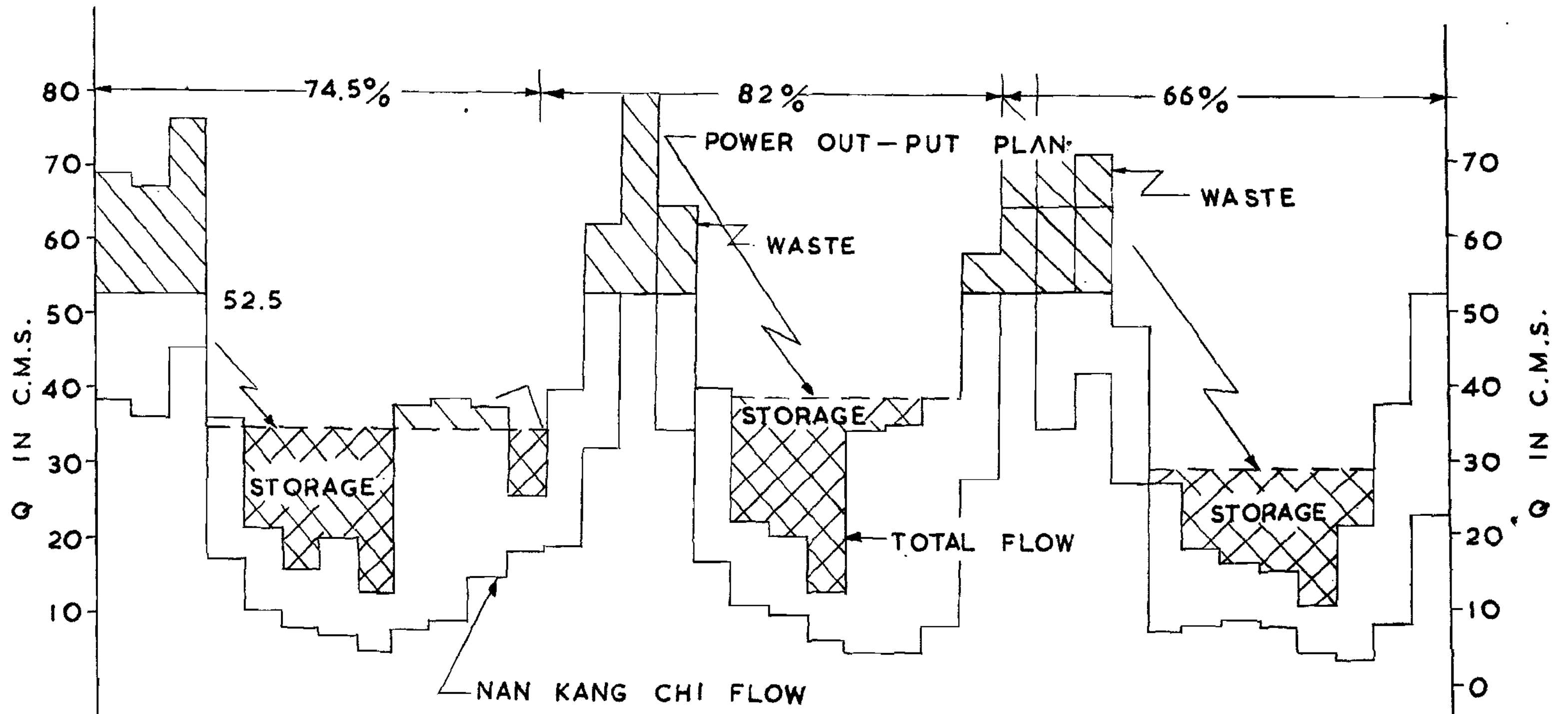
INDIRECT 341.60 KM^2

FROM MEI-YUAN

PEI-KANG CHI

Fig 66

PU-LI RESERVOIR



YEAR	1937						
MONTH	J	J	A	S	O	N	D
NAN KANG CHI FLOW C.M.S.	37.76	35.79	45.27	16.71	9.84	7.25	6.70
PEI KANG CHI INTAKE FLOW C.M.S.	30.00	30.00	30.00	19.00	11.00	8.20	12.30
USE FLOW C.M.S.	52.50	52.50	52.50	34.50	34.50	34.50	34.50
STOR-AGE C.M.S.	15.24	13.29	22.77	1.21	-13.61	-19.05	-15.00

YEAR	1938											
MONTH	J	F	M	A	M	J	J	A	S	O	N	D
NAN KANG CHI FLOW C.M.S.	4.71	7.64	8.43	13.94	17.66	18.04	31.48	118.46	34.25	16.32	10.27	8.87
PEI KANG CHI INTAKE FLOW C.M.S.	7.50	30.00	30.00	23.00	7.60	21.00	30.00	30.00	29.00	23.30	11.30	10.60
USE FLOW C.M.S.	34.50	34.50	34.50	34.50	34.50	39.04	52.50	52.50	52.50	39.62	38.00	38.00
STOR-AGE C.M.S.	-22.29	3.14	3.93	2.44	-9.24	0	8.98	95.96	10.75	0	-16.43	-18.53

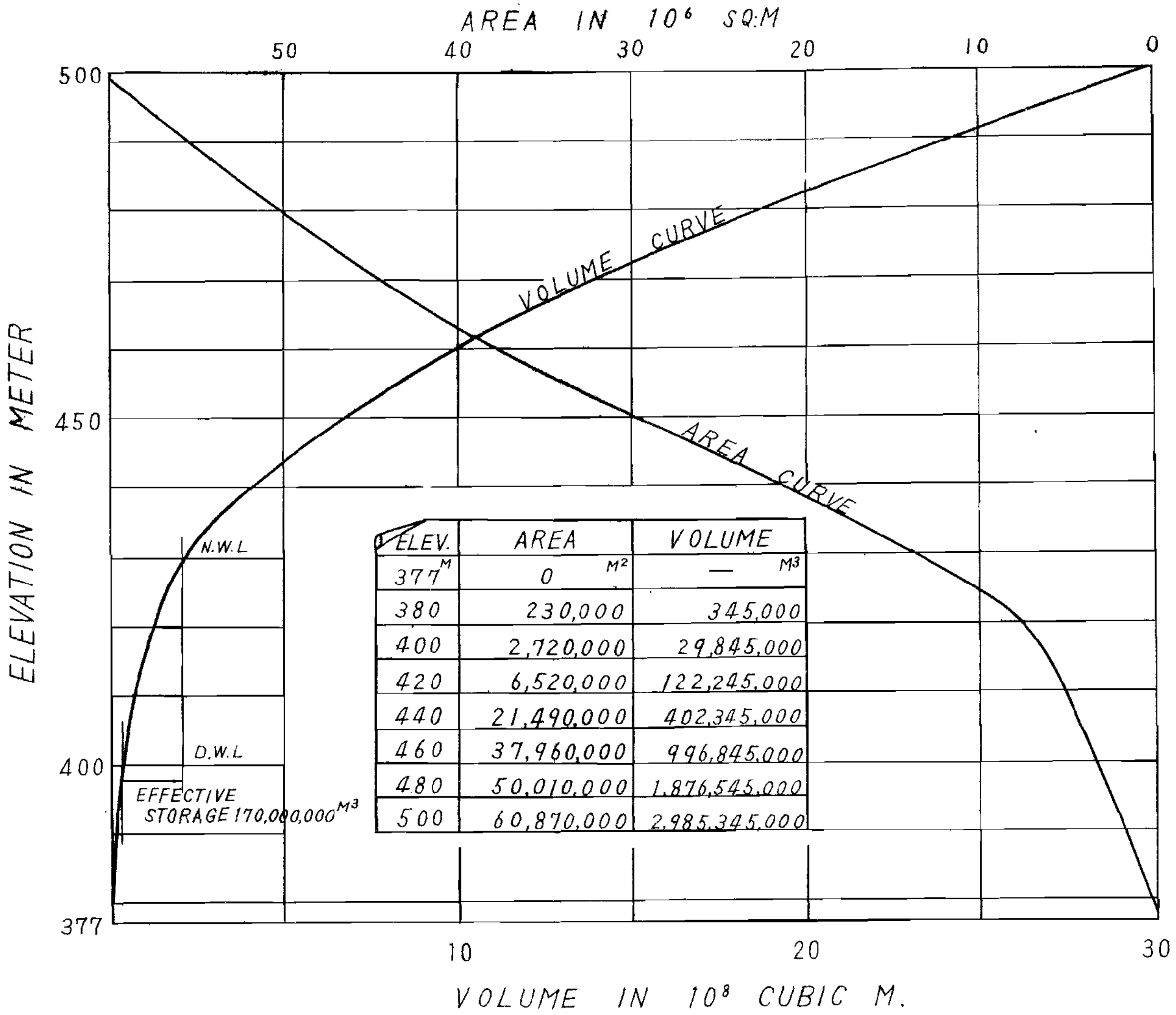
YEAR	1939											
MONTH	J	F	M	A	M	J	J	A	S	O	N	D
NAN KANG CHI FLOW C.M.S.	5.73	4.21	4.36	7.73	27.47	63.73	33.84	41.77	27.02	6.87	7.25	8.00
PEI KANG CHI INTAKE FLOW C.M.S.	7.50	30.00	30.00	30.00	30.00	30.00	30.00	30.00	20.80	19.90	10.40	7.40
USE FLOW C.M.S.	38.00	38.00	38.00	38.00	52.50	52.50	52.50	52.50	47.82	29.00	29.00	29.00
STOR-AGE C.M.S.	-24.77	-3.79	-3.64	-0.27	4.97	41.23	11.34	19.27	0	-2.23	-11.35	-13.60

YEAR	1940				
MONTH	J	F	M	A	M
NAN KANG CHI FLOW C.M.S.	6.82	4.12	3.42	7.50	22.68
PEI KANG CHI INTAKE FLOW C.M.S.	8.40	5.90	17.80	30.00	30.00
USE FLOW C.M.S.	29.00	29.00	29.00	37.50	52.50
STOR-AGE C.M.S.	-13.78	-18.98	-7.78	0	0.18

AVERAGE ANNUAL LOAD FACTOR 74 % PRIMARY FLOW 33.8 C.M.S. PMAX = 46,000KW.

USE FLOW PEAK 525 C.M.S. EFFECTIVE HEAD 106M. PPRIM = 29,700KW. PAVE = 34,000KW.

PU-LI RESERVOIR CHARACTERISTICS



ELEV.	AREA	VOLUME
377 M	0 M²	— M³
380	230,000	345,000
400	2,720,000	29,845,000
420	6,520,000	122,245,000
440	21,490,000	402,345,000
460	37,960,000	996,845,000
480	50,010,000	1,876,545,000
500	60,870,000	2,985,345,000

Fig 67

Fig 68

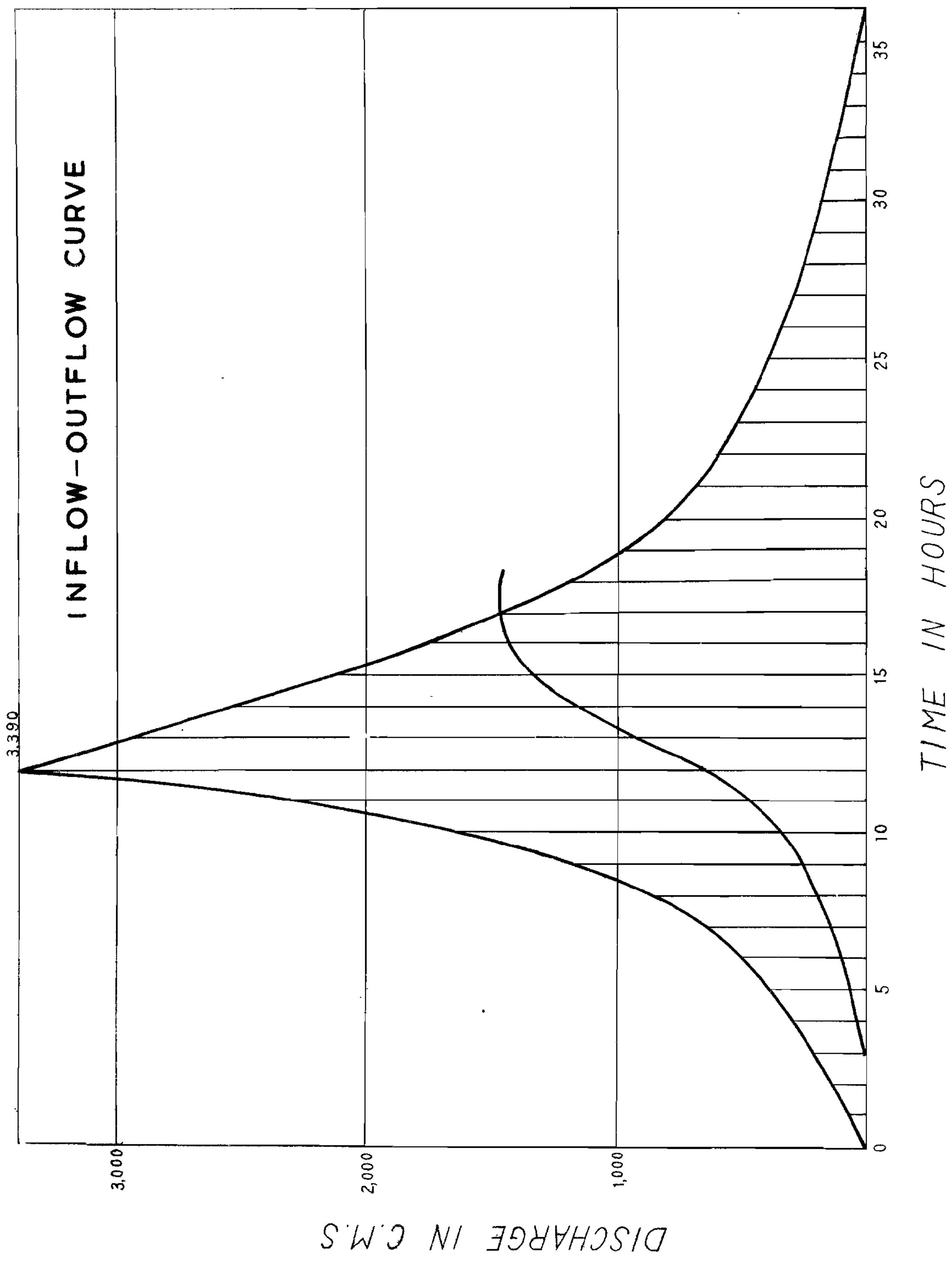

INFLOW-OUTFLOW CURVE
3,390
3,000
2,000
1,000
DISCHARGE IN C.M.S
0
5
10
15
20
25
30
35
TIME IN HOURS

Fig 69

I-S-D CURVE, PU-LI RESERVOIR

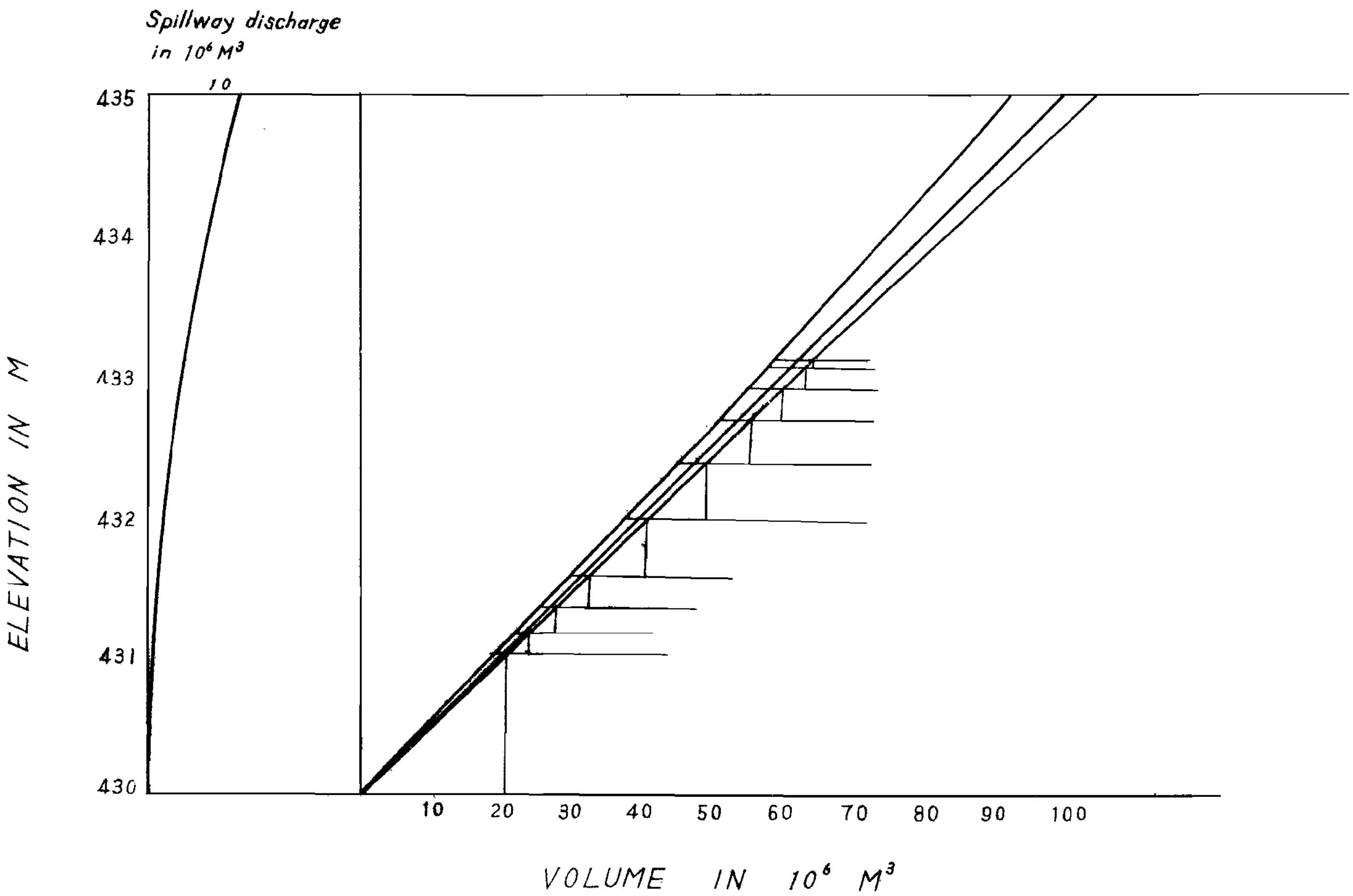
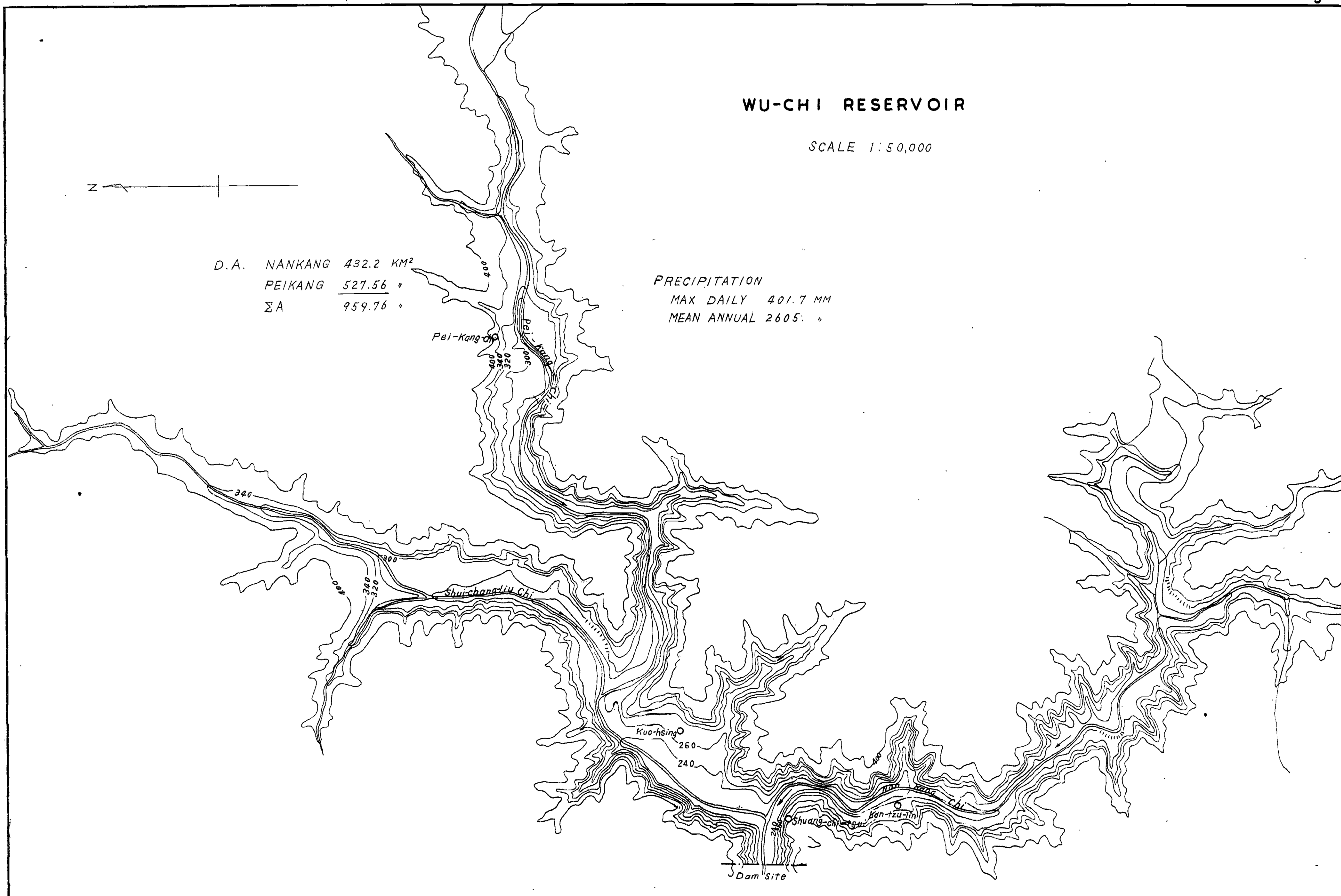


Fig 70

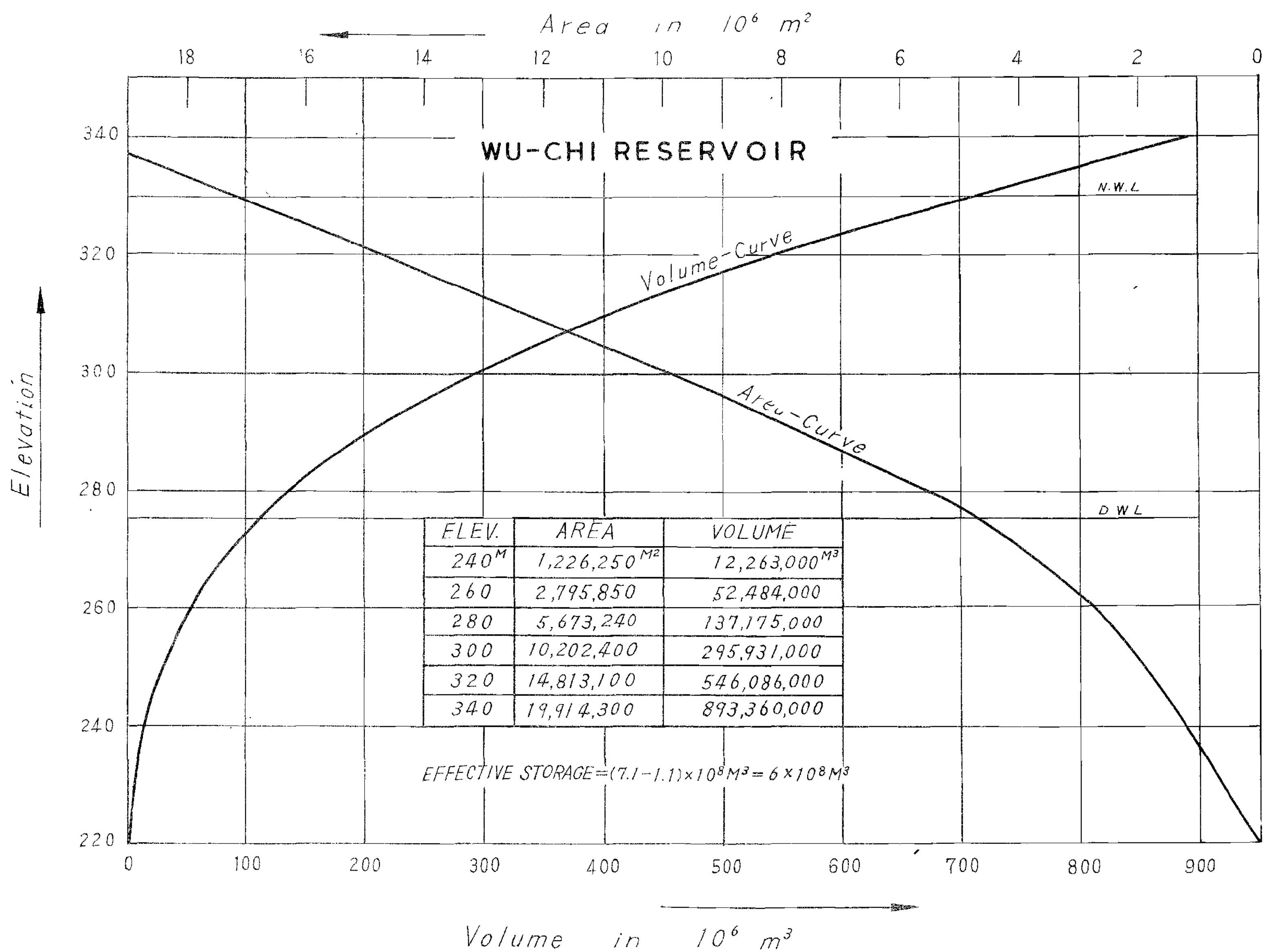
FLOOD-ROUTING COMPUTATION
PU-LI RESERVOIR

STEP	1 TIME OF BEGINNING OF FLOOD IN HOURS	2 INSTANTANEOUS RATE OF INFLOW INTO RESERVOIR. C.M.S.	3 MEAN DISCHARGE AT BEGINNING AND END OF INTERVAL	4 VOLUME OF INFLOW INTO RESERVOIR DURING INTERVAL	5 RESERVOIR ELEVATION AT END OF INTERVAL	6 SPILLWAY DISCHARGE RATE AT END OF INTERVAL
1	1	60	30	108,000		
2	2	148	104	374,000		
3	3	220	184	662,000		
4	4	290	255	918,000	431	189
5	5	368	329	1,184,000		
6	6	480	424	1,554,000		
7	7	610	545	1,960,000		
8	8	860	735	2,642,000		
9	9	1156	1008	3,610,000	431.15	229
10	10	1640	1398	5,000,000	431.35	312
11	11	2210	1925	6,930,000	431.51	438
12	12	3390	2800	10,080,000	432.00	625
13	13	3200	3295	11,850,000	432.35	905
14	14	2590	2895	10,420,000	432.70	1110
15	15	2200	2395	8,695,000	432.90	1360
16	16	1778	1989	7,150,000	433.05	1450
17	17	1430	1604	5,770,000	433.10	1480
18	18	1160	1295	4,660,000		

Fig 71



WU-CHI RESERVOIR
SCALE 1:50,000
N
D.A. NANKANG 432.2 KM²
PEIKANG 527.56 "
ΣA 959.76 "
PRECIPITATION
MAX DAILY 401.7 MM
MEAN ANNUAL 2605 "
Pei-Kang-Chi
Pei-kang Chi
Shui-chang-liu Chi
Kuo-hsing
Shuang-chi-tou
Kan-tzu-lin
Nan Kang Chi
Dam Site
400
340
320
300
260
240

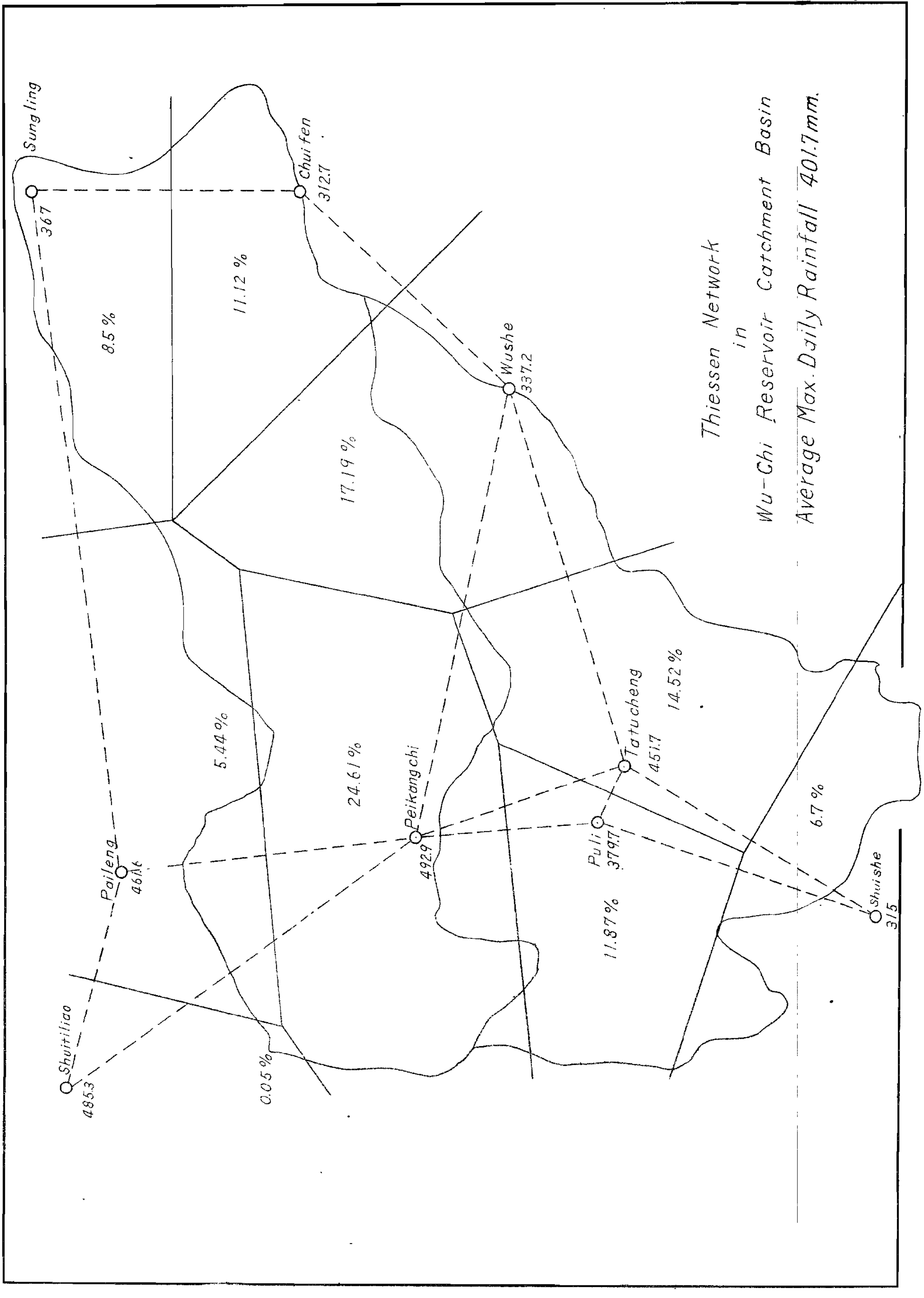


ELEV.	AREA	VOLUME
240^M	1,226,250^{M2}	12,263,000^{M3}
260	2,795,850	52,484,000
280	5,673,240	137,175,000
300	10,202,400	295,931,000
320	14,813,100	546,086,000
340	19,914,300	893,360,000

EFFECTIVE STORAGE $=(7.1-1.1)\times10^8 M^3 = 6\times10^8 M^3$

Fig 72

Fig 73


Thiessen Network
in
Wu-Chi Reservoir Catchment Basin
Average Max. Daily Rainfall 401.7mm.
Sungling
367
Chuifen
312.7
Wushe
337.2
Tatucheng
451.7
Puli
379.7
Peikangchi
492.9
Paileng
Shuitiliao
485.3
Shuishe
315
8.5 %
11.12 %
17.19 %
14.52 %
5.44 %
24.61 %
6.7 %
11.87 %
0.05 %

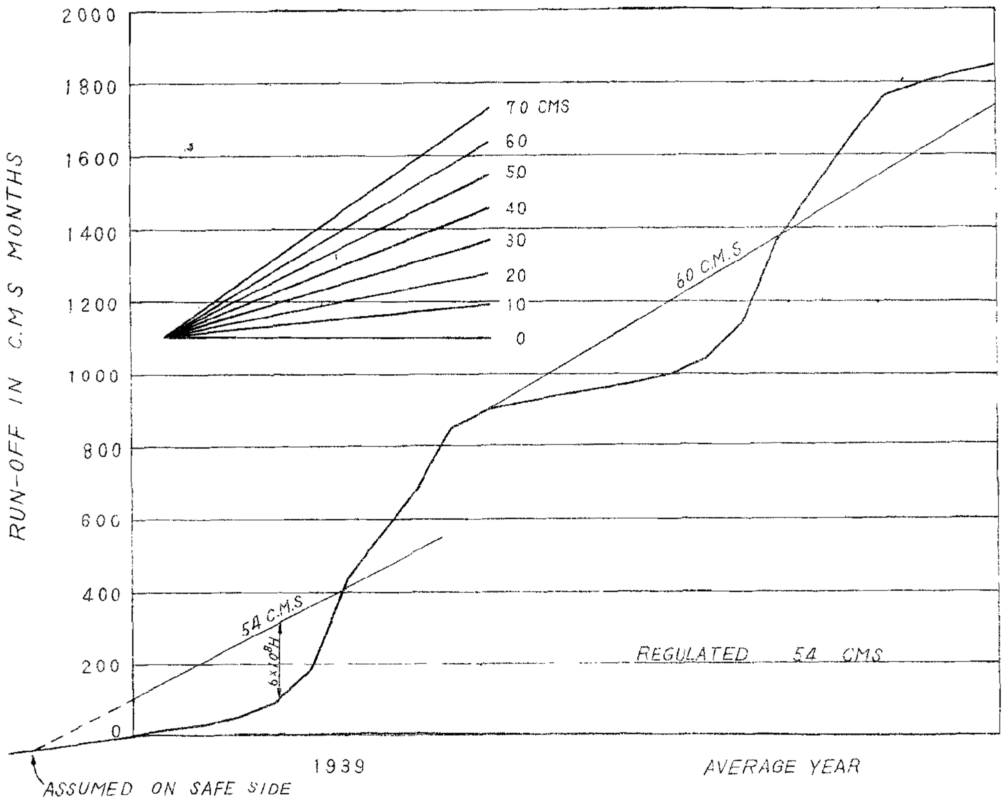
STATION & RECORD AVAILABLE

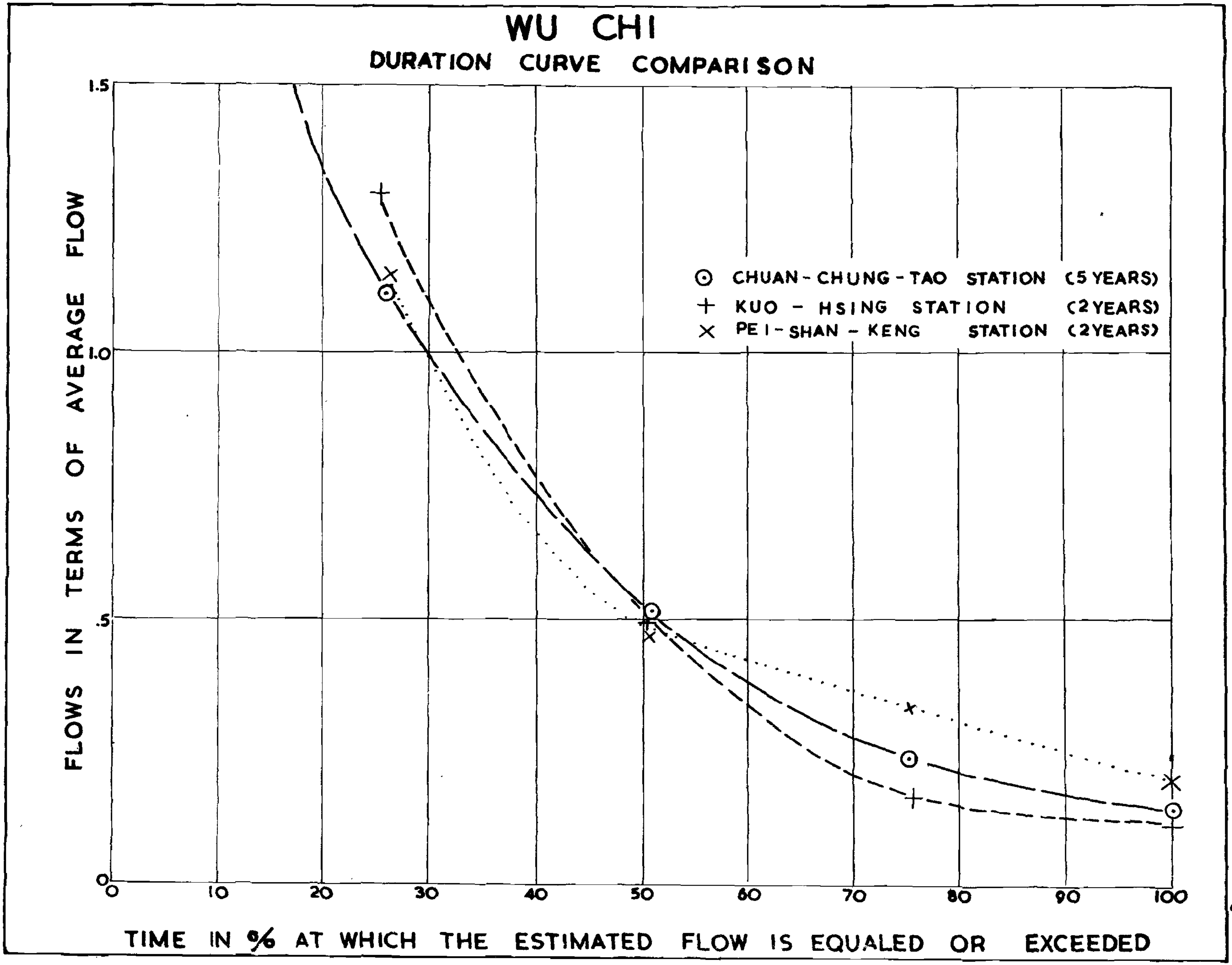
STATION	D A KM²	BRANCH	PERIOD OBS	REMARKS
CHUAN-CHUNG-TAO	382.9	PEI-KANG CHI	1937 — 41	TAIWAN POWER CO.
KUO-HSING	518.8	〃	1939 — 40	
PEI-SHAN-KENG	412.2	NAN-KANG CHI	1937 — 39	

WU-CHI RESERVOIR

MASS CURVE

ESTIMATED FROM RECORDS AT KUO-HSING & PEI-SHAN-KENG STA.





WU CHI
DURATION CURVE COMPARISON
CHUAN-CHUNG-TAO STATION (5 YEARS)
KUO - HSING STATION (2 YEARS)
PEI-SHAN-KENG STATION (2 YEARS)
FLOWS IN TERMS OF AVERAGE FLOW
TIME IN % AT WHICH THE ESTIMATED FLOW IS EQUALED OR EXCEEDED
1.5
1.0
.5
0
0
10
20
30
40
50
60
70
80
90
100

Fig 75

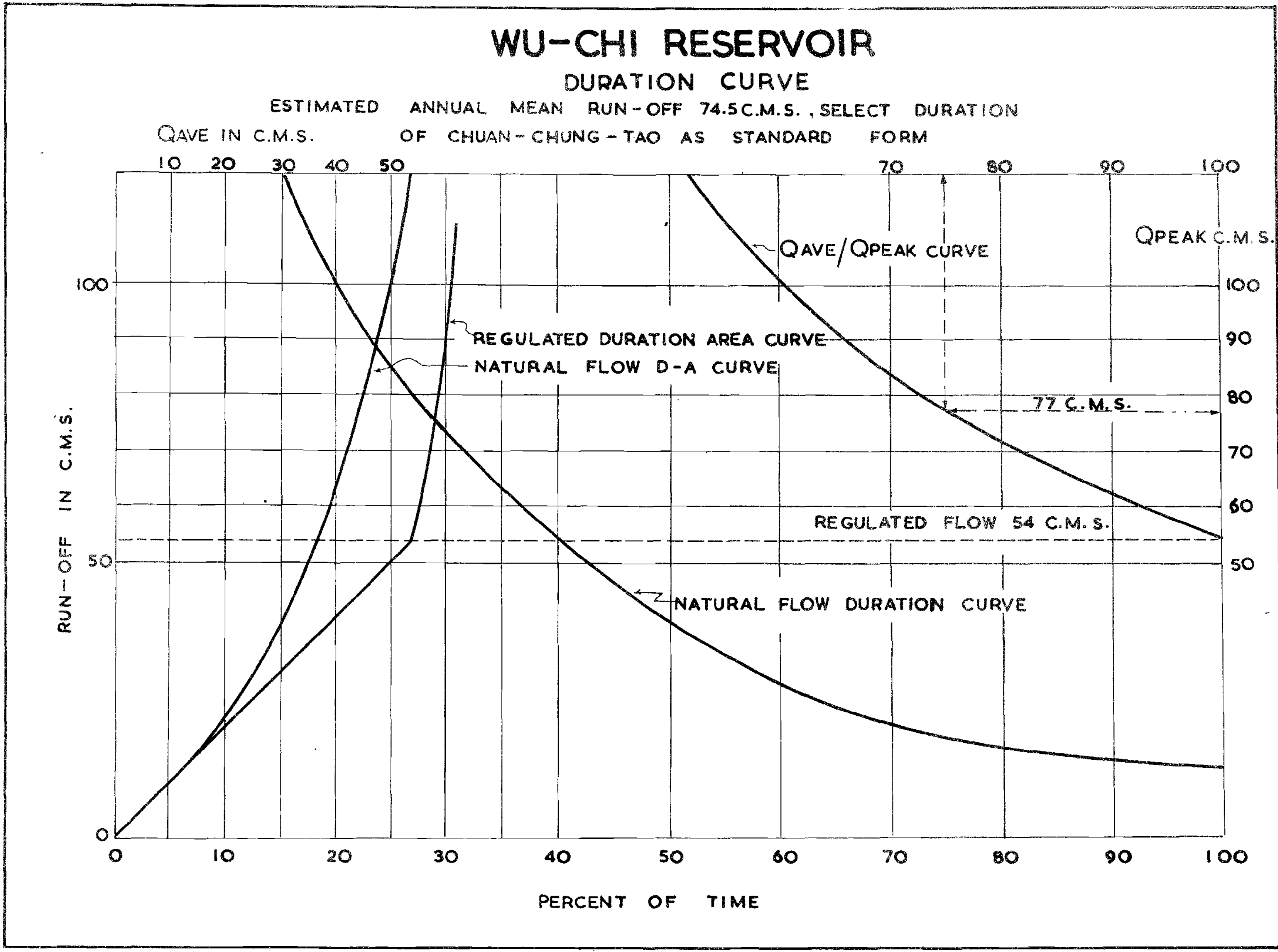
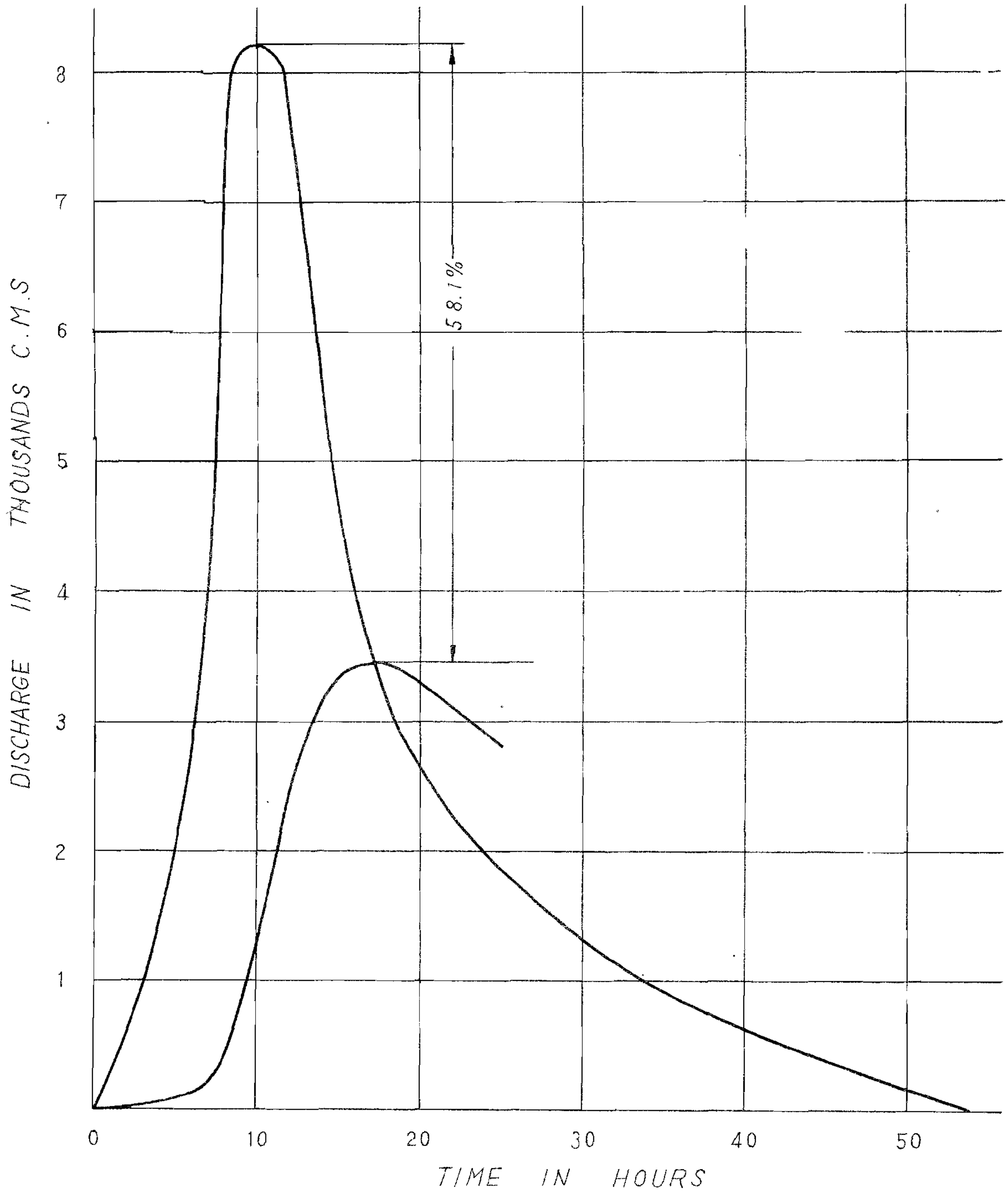

WU-CHI RESERVOIR
DURATION CURVE
ESTIMATED ANNUAL MEAN RUN-OFF 74.5 C.M.S., SELECT DURATION OF CHUAN-CHUNG-TAO AS STANDARD FORM
QAVE IN C.M.S.
QPEAK C.M.S.
QAVE/QPEAK CURVE
REGULATED DURATION AREA CURVE
NATURAL FLOW D-A CURVE
77 C.M.S.
REGULATED FLOW 54 C.M.S.
NATURAL FLOW DURATION CURVE
RUN-OFF IN C.M.S.
PERCENT OF TIME

Fig 76

WU-CHI RESERVOIR

INFLOW & OUTFLOW CURVE



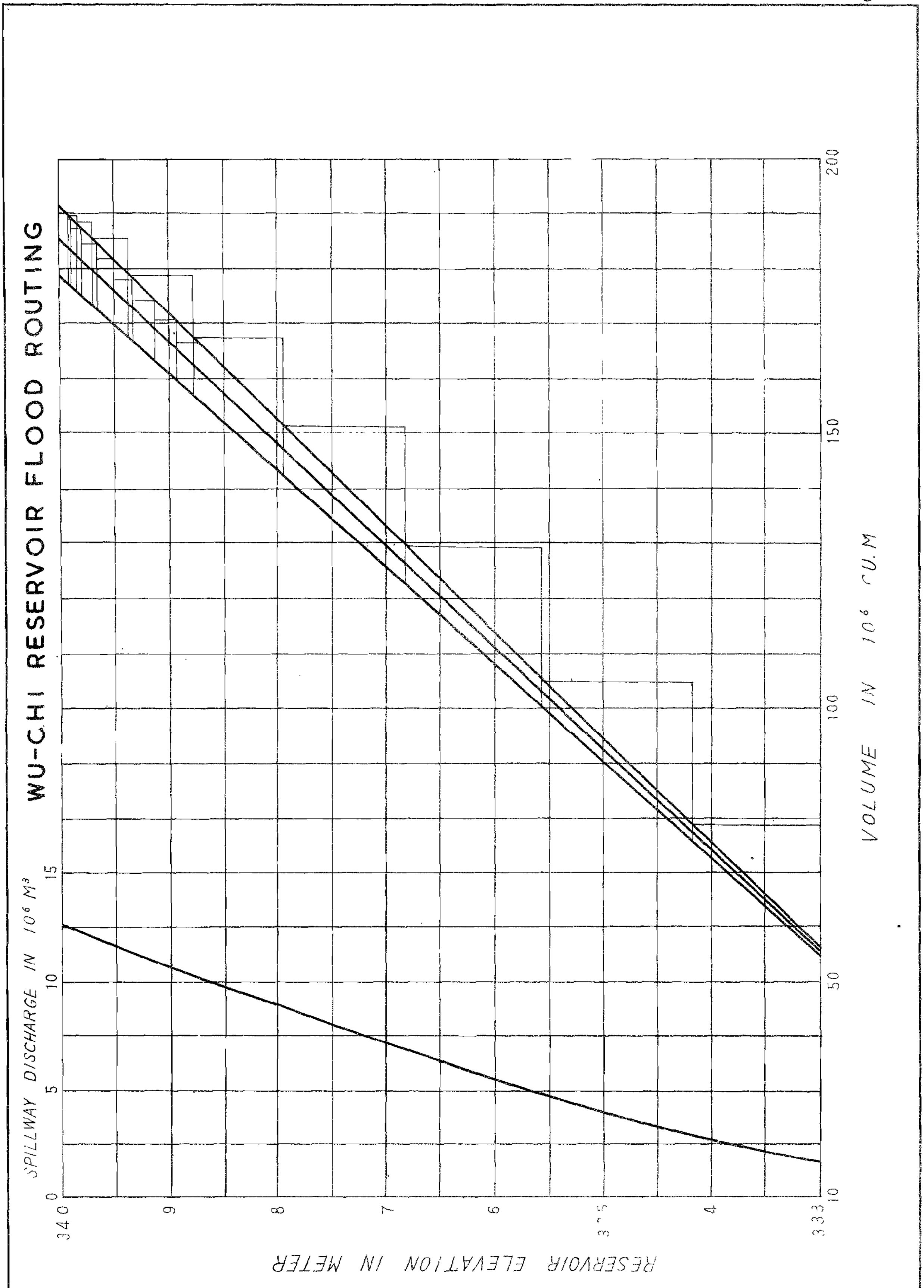

WU-CHI RESERVOIR FLOOD ROUTING
VOLUME IN 10⁶ CU.M
200
150
100
50
10
SPILLWAY DISCHARGE IN 10⁶ M³
0
5
10
15
RESERVOIR ELEVATION IN METER
340
9
8
7
6
4
333

Fig 78

WU-CHI RESERVOIR FLOOD - ROUTING

STEP	(1) T HR	(2) I C.M.S.	(3) $I_1 + I_2$ C.M.S.	(4) $(I_1+I_2)\times 3600/2$ M^3	(5) ELEVATION M	(6) DISCHARGE C.M.S.
1	1	300	300	540,000	330.04	5.6
2	2	620	920	1,656,000	330.12	13.9
3	3	1,000	1,620	2,920,000	330.26	27.8
4	4	1,400	2,400	4,320,000	330.50	55.6
5	5	2,000	3,400	6,120,000	330.80	97.3
6	6	2,850	4,850	8,730,000	331.20	125.0
7	7	4,150	7,000	12,600,000	331.80	208.0
8	8	7,100	11,250	20,250,000	332.82	417.0
9	9	8,170	15,270	27,500,000	334.18	798.0
10	10	8,230	16,400	29,570,000	335.55	1332.0
11	11	8,150	16,380	29,500,000	336.80	1890.0
12	12	7,630	15,780	28,400,000	337.94	2430.0
13	13	6,650	14,280	25,700,000	338.75	2850.0
14	14	5,570	12,220	22,000,000	339.35	3130.0
15	15	4,650	10,220	18,400,000	339.69	3340.0
16	16	4,000	8,650	15,580,000	339.84	3410.0
17	17	3,520	7,520	13,520,000	339.90	3440.0
18	18	3,120	6,640	11,940,000	339.87	3430.0
19	19	2,830	5,950	10,710,000	339.77	3370.0
20	20	2,630	5,460	9,830,000	339.63	3270.0
21	21	2,400	5,030	9,060,000	339.50	3220.0
22	22	2,240	4,640	8,350,000	339.31	3130.0
23	23	2,100	4,340	7,820,000	339.11	3000.0
24	24	1,960	4,060	7,310,000	338.92	2920.0
25	25	1,820	3,780	6,810,000	338.70	2810.0

Fig 80

PLAN OF CHELUNGPU IRRIGATION EXTENSION PROJECT

SCALE 1:50,000

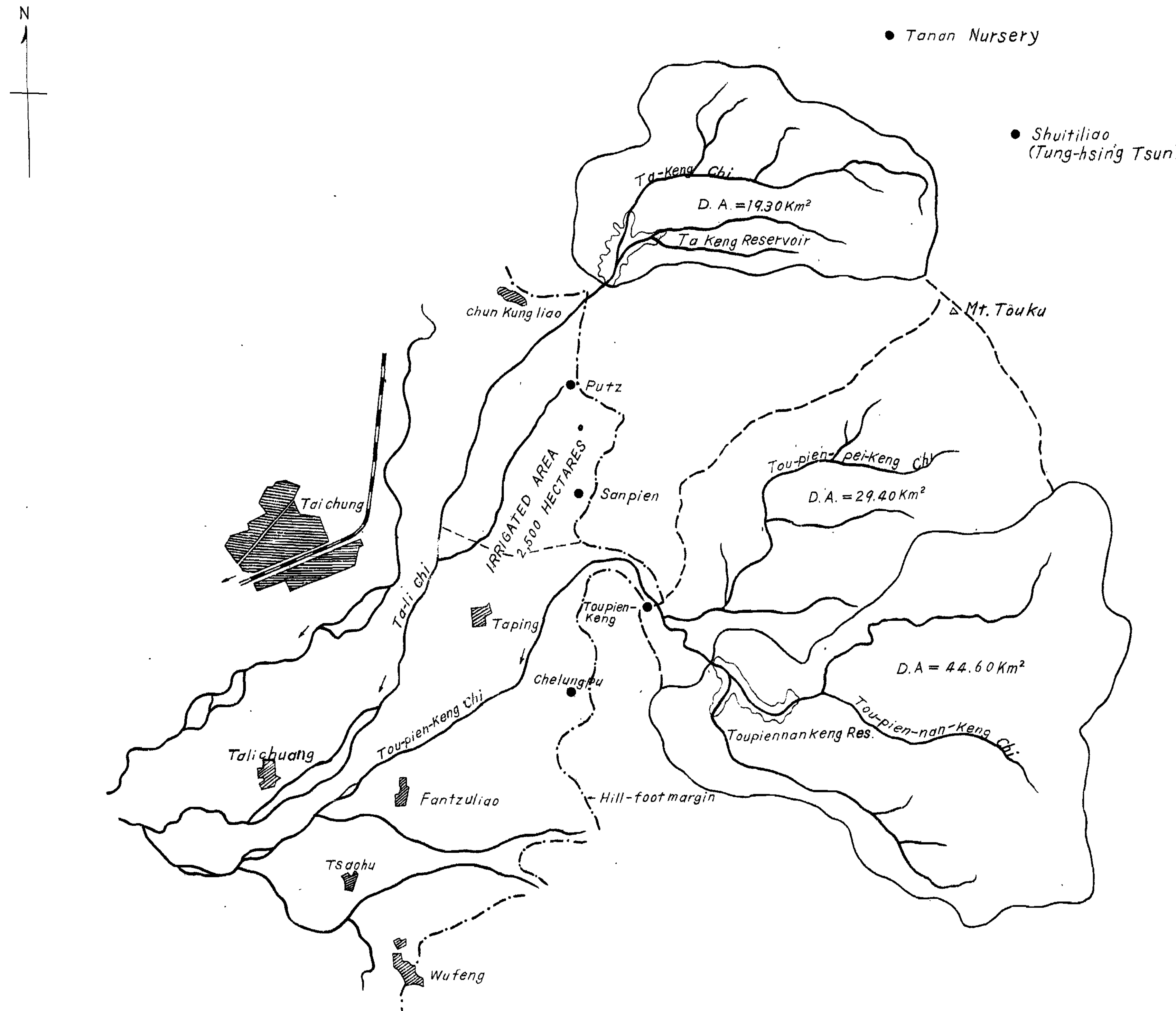
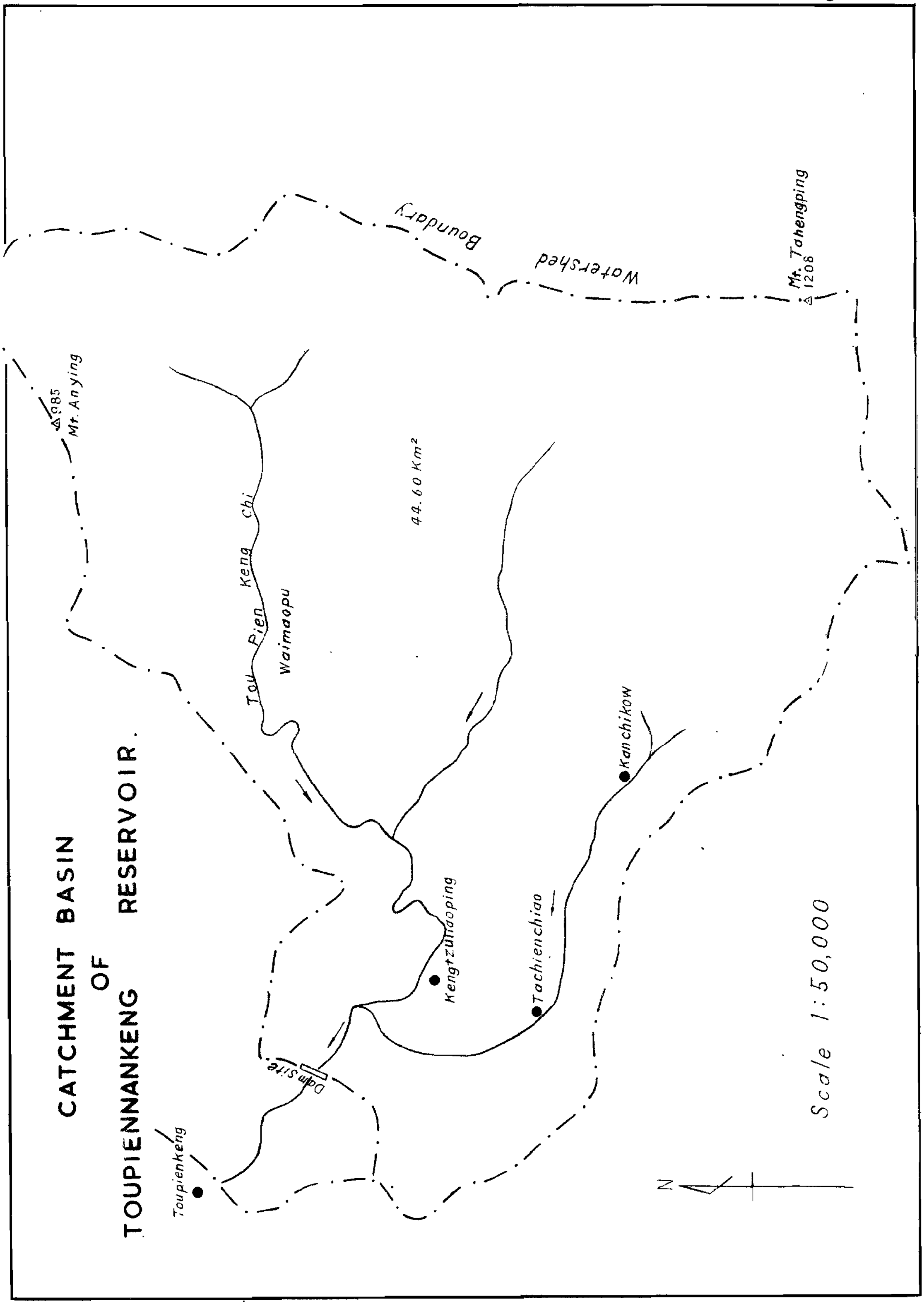


Fig 81



CATCHMENT BASIN
OF
TOUPIENNANKENG RESERVOIR.
Watershed Boundary
Mt. Tahengping
1208
985
Mt. Anying
44.60 Km²
Tou Pien Keng Chi
Waimaopu
Kanchikow
Kengtzuliaoping
Tachienchiao
Dam Site
Toupienkeng
Scale 1:50,000
N

Fig 82

TOU-PIEN-NAN-KENG RESERVOIR

SCALE 1:10,000

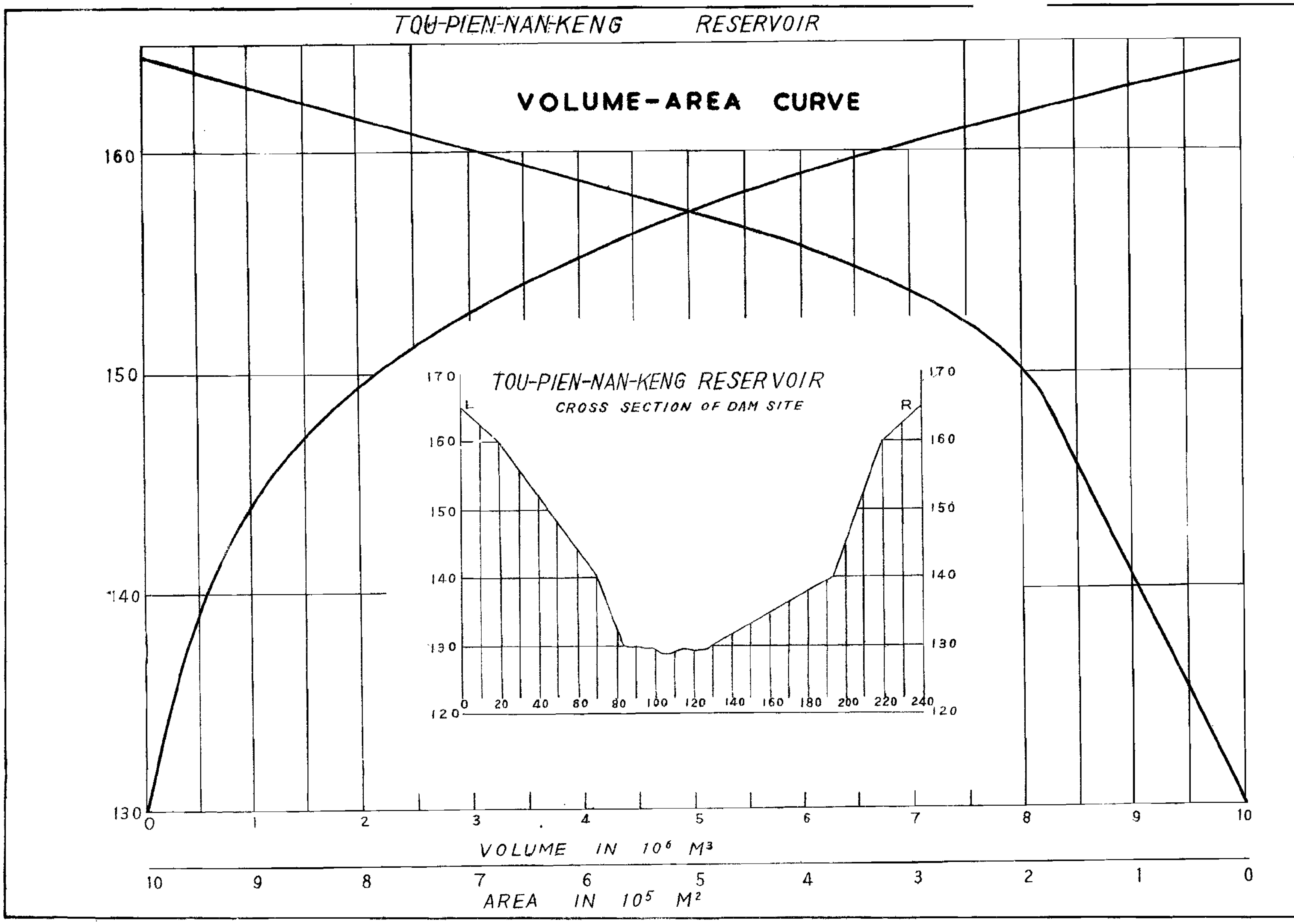

TOU-PIEN-NAN-KENG RESERVOIR
VOLUME-AREA CURVE
TOU-PIEN-NAN-KENG RESERVOIR
CROSS SECTION OF DAM SITE
L
R
VOLUME IN 10⁶ M³
AREA IN 10⁵ M²

Fig 83

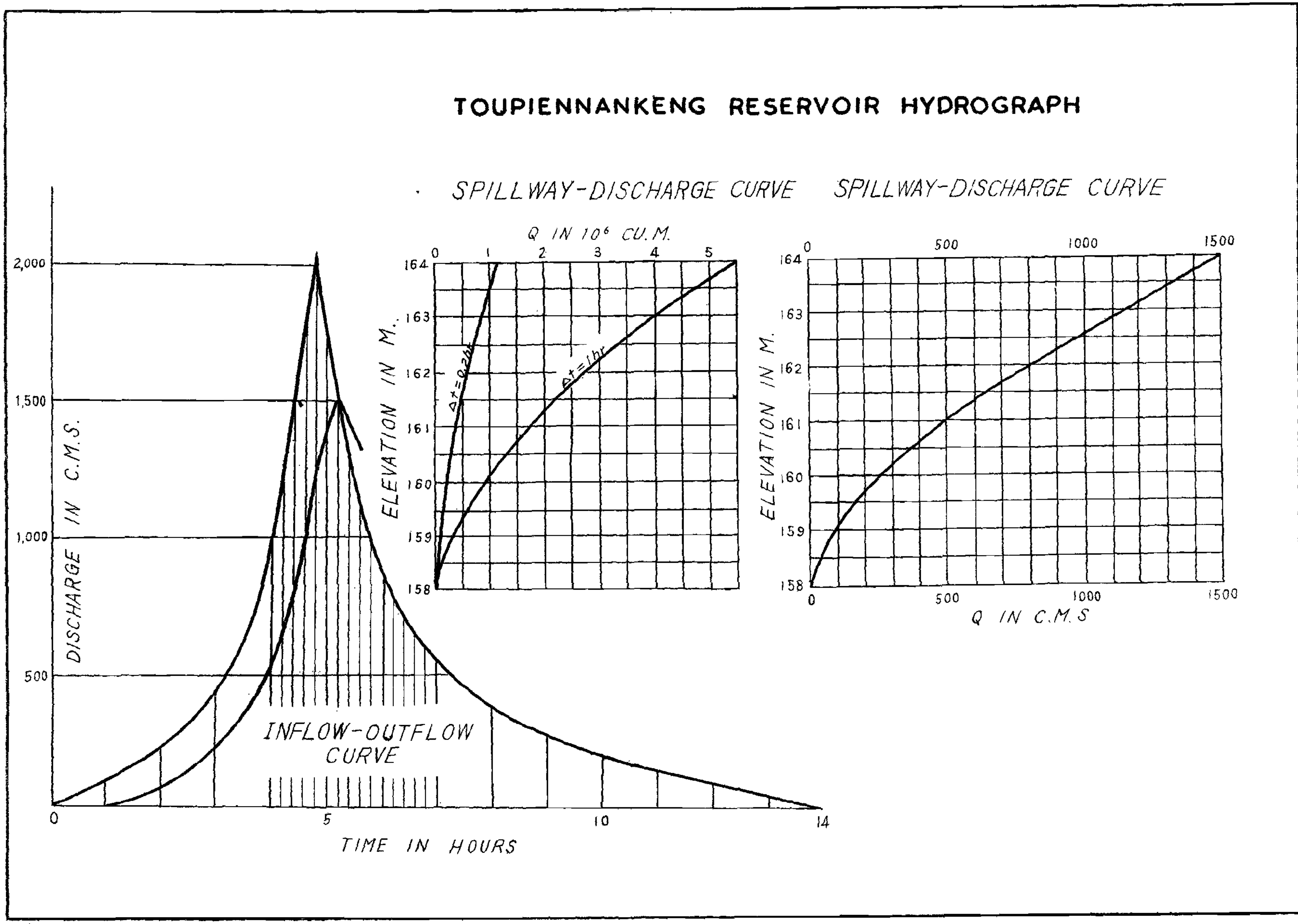

TOUPIENNANKENG RESERVOIR HYDROGRAPH
SPILLWAY-DISCHARGE CURVE
SPILLWAY-DISCHARGE CURVE
Q IN 10⁶ CU.M.
ELEVATION IN M.
Δt=0.2hr
Δt=1hr
ELEVATION IN M.
Q IN C.M.S
DISCHARGE IN C.M.S.
INFLOW-OUTFLOW CURVE
TIME IN HOURS

Fig 84

Fig 85

TOU-PIEN-NAN-KENG RESERVOIR
FLOOD ROUTING (I-S-D CURVE)

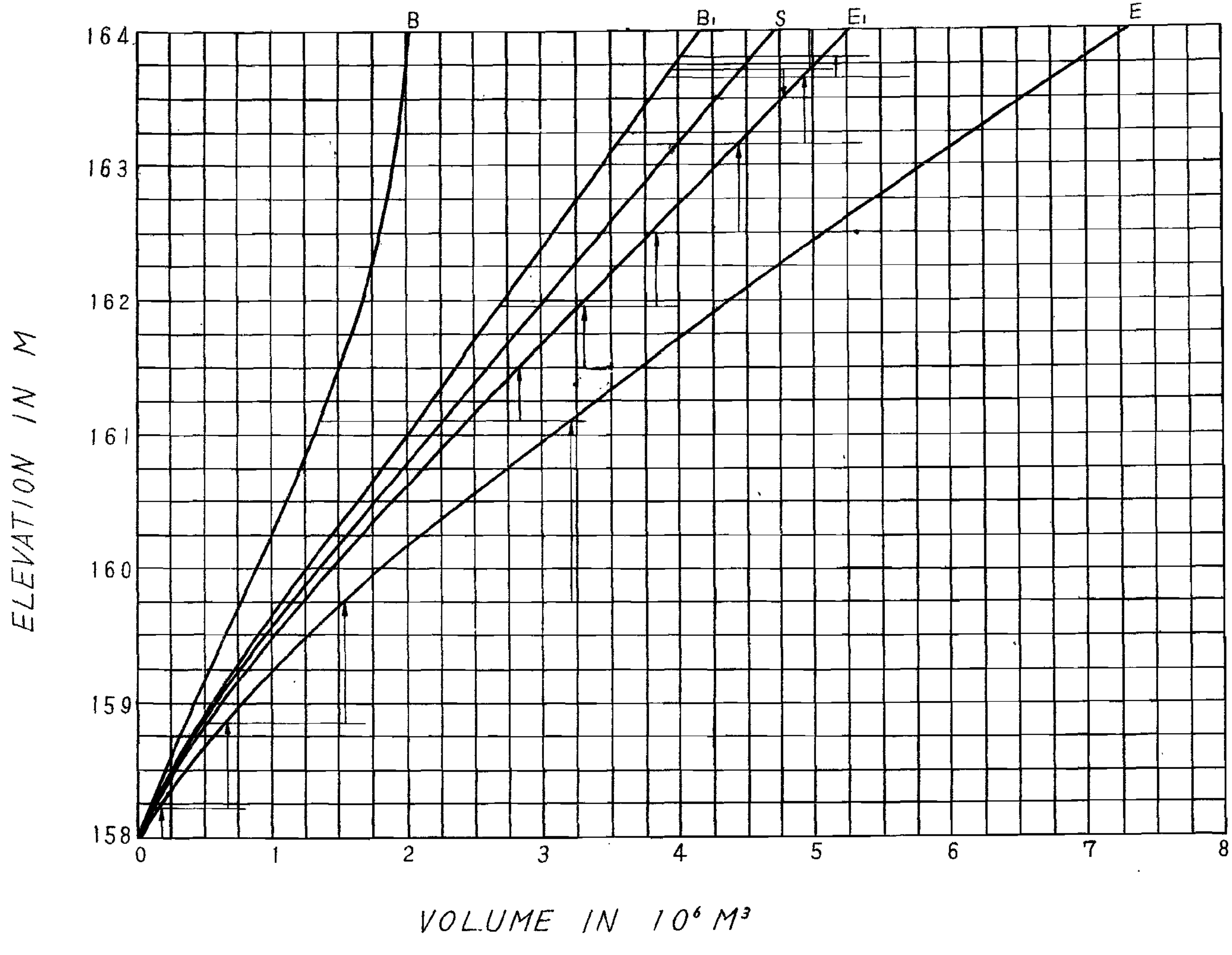


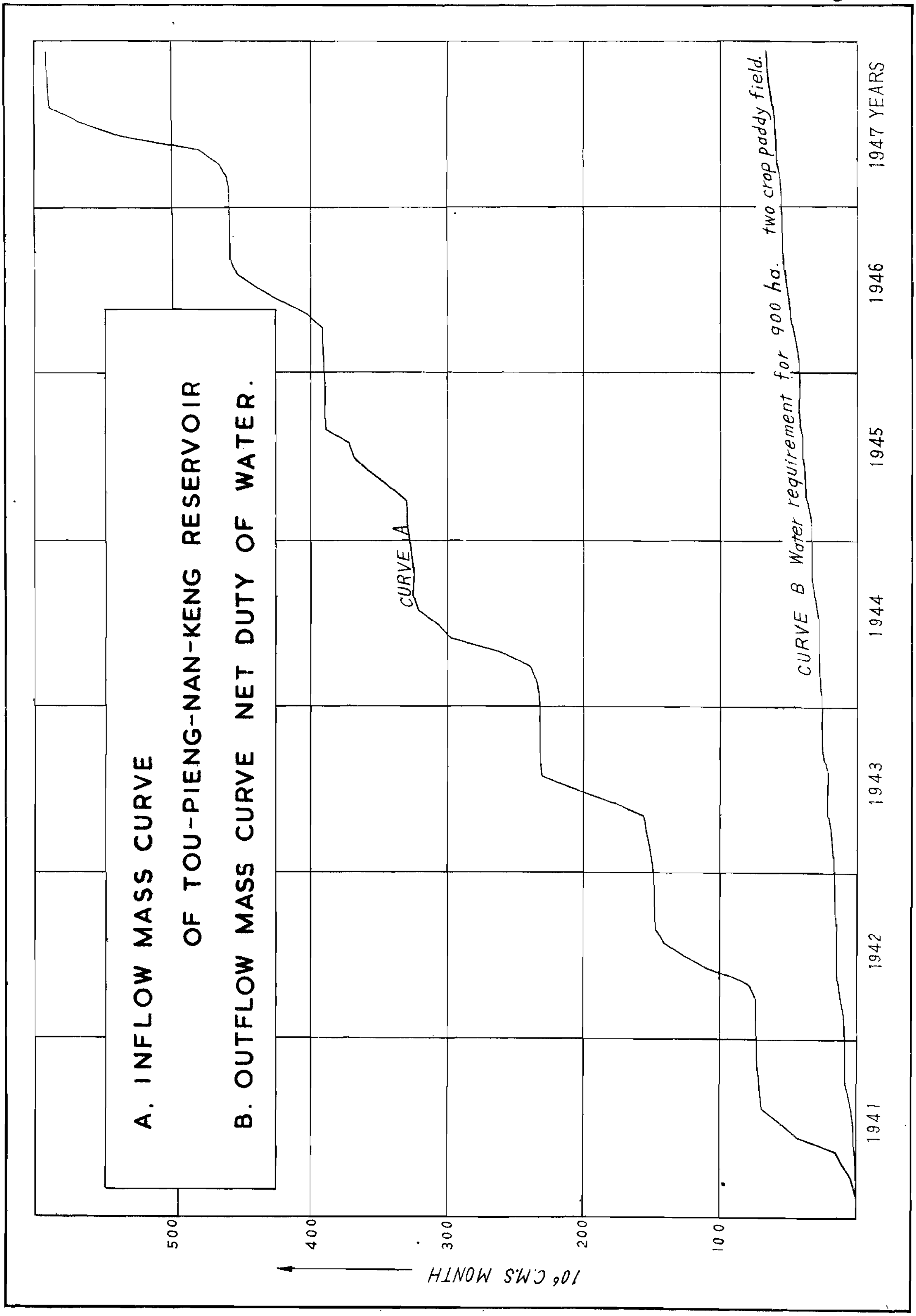
Fig 86

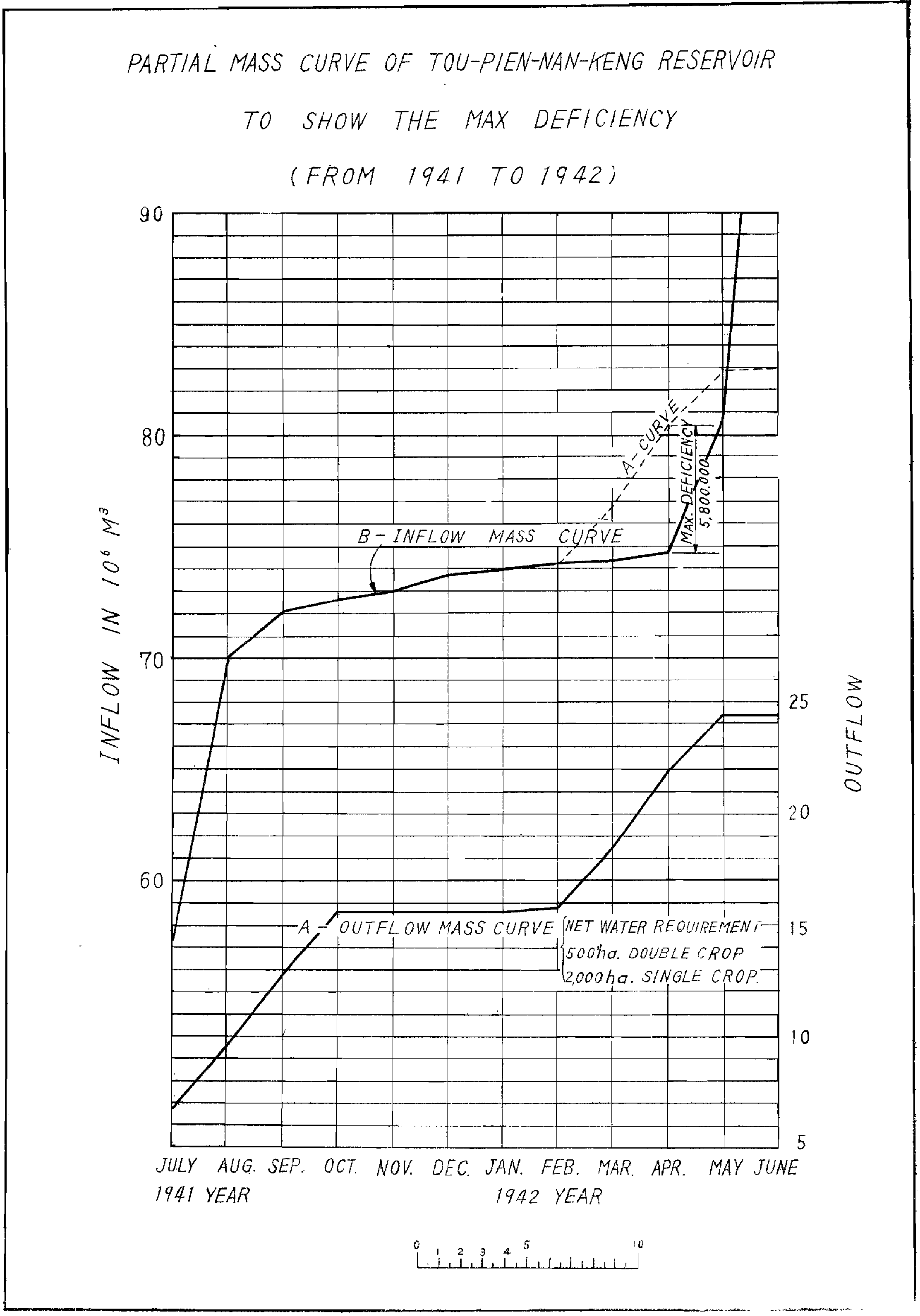
TOU-PIEN-NAN-KENG RESERVOIR

FLOOD-ROUTING COMPUTATION

STEP	(1) TIME FROM BEGINNING OF FLOOD IN HOURS	(2) INSTANTANEOUS RATE OF INFLOW INTO RESERVOIR (I) IN C.M.S.	(3) MEAN OF DISCHARGE AT BEGINNING AND END OF INTERVAL $\frac{1}{2}(I_1 + I_2)$	(4) VOLUME OF INFLOW INTO RESERVOIR DURING INTERVAL IN CU.M.	(5) RESERVOIR ELEVATION AT END OF INTERVAL IN M.	(6) SPILLWAY DISCHARGE RATE AT END OF INTERVAL IN C.M.S.
1	1	95	47.50	171,800	158.23	11
2	2	220	157.50	566,000	158.85	70
3	3	410	315	1,167,000	159.75	210
4	4	950	680	2,448,000	161.10	510
5	4.2	1140	1045	752,000	161.50	620
6	4.4	1440	1290	928,000	161.95	770
7	4.6	1750	1595	1,148,000	162.50	960
8	4.8	2040	1895	1,364,000	163.15	1200
9	5	1720	1880	1,355,000	163.65	1380
10	5.2	1430	1575	1,168,000	163.80	1500
11	5.4	1250	1340	965,000	163.70	1390
12	5.6	1080	1165	839,000	163.50	1320

Fig 87


A. INFLOW MASS CURVE
OF TOU-PIENG-NAN-KENG RESERVOIR
B. OUTFLOW MASS CURVE NET DUTY OF WATER.
CURVE A
CURVE B Water requirement for 900 ha. two crop paddy field.
500
400
300
200
100
10^6 C.M.S MONTH
1941
1942
1943
1944
1945
1946
1947 YEARS


PARTIAL MASS CURVE OF TOU-PIEN-NAN-KENG RESERVOIR
TO SHOW THE MAX DEFICIENCY
(FROM 1941 TO 1942)
90
80
70
60
INFLOW IN 10^6 M^3
OUTFLOW
25
20
15
10
5
A-CURVE
MAX. DEFICIENCY 5,800,000
B-INFLOW MASS CURVE
A-OUTFLOW MASS CURVE
NET WATER REQUIREMENT
500 ha. DOUBLE CROP
2,000 ha. SINGLE CROP
JULY AUG. SEP. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY JUNE
1941 YEAR
1942 YEAR
0 1 2 3 4 5 10

PLAN OF TA KENG RESERVOIR

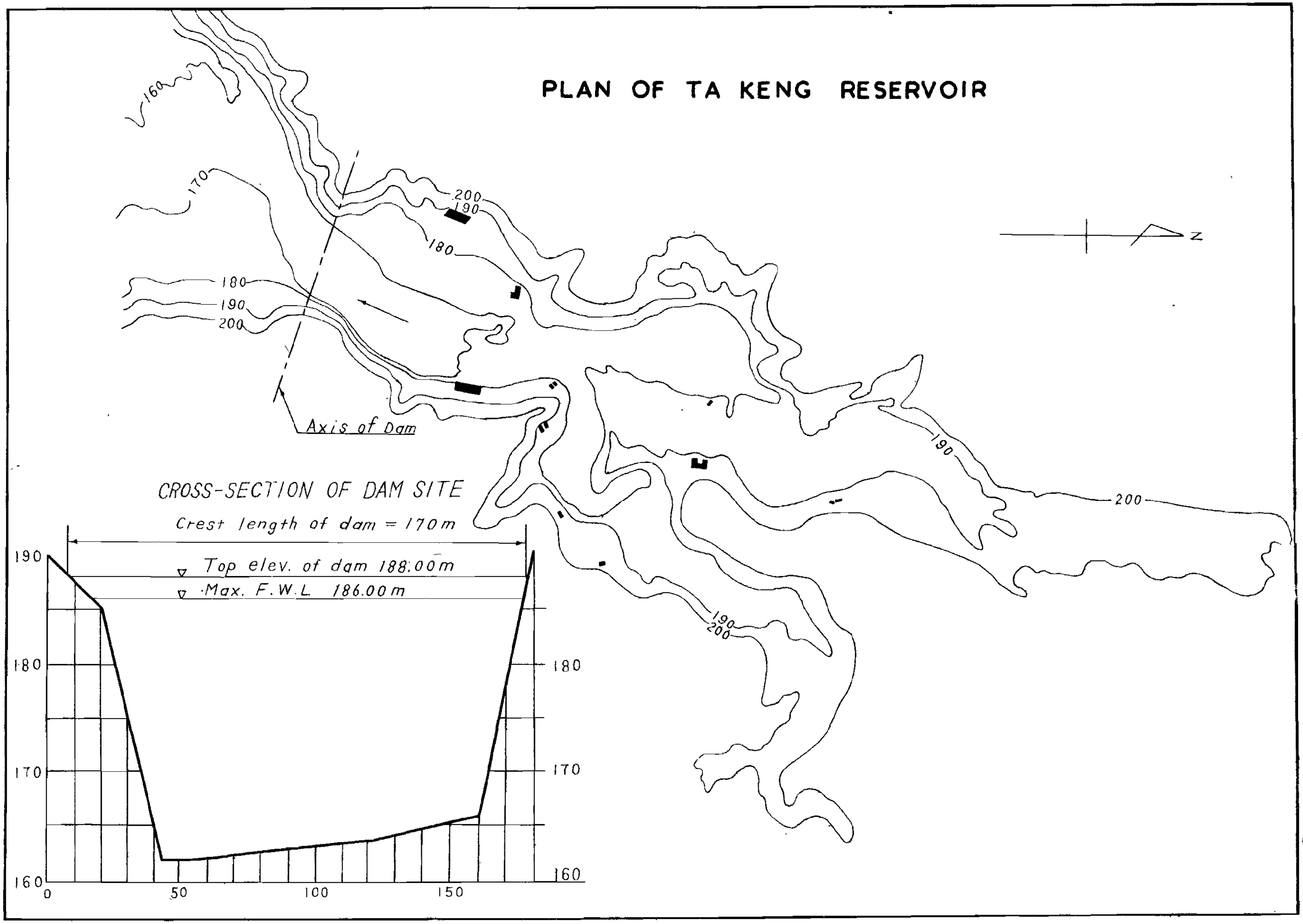


Fig 89

Fig 90

TA-KENG RESERVOIR

AREA - VOLUME CURVE

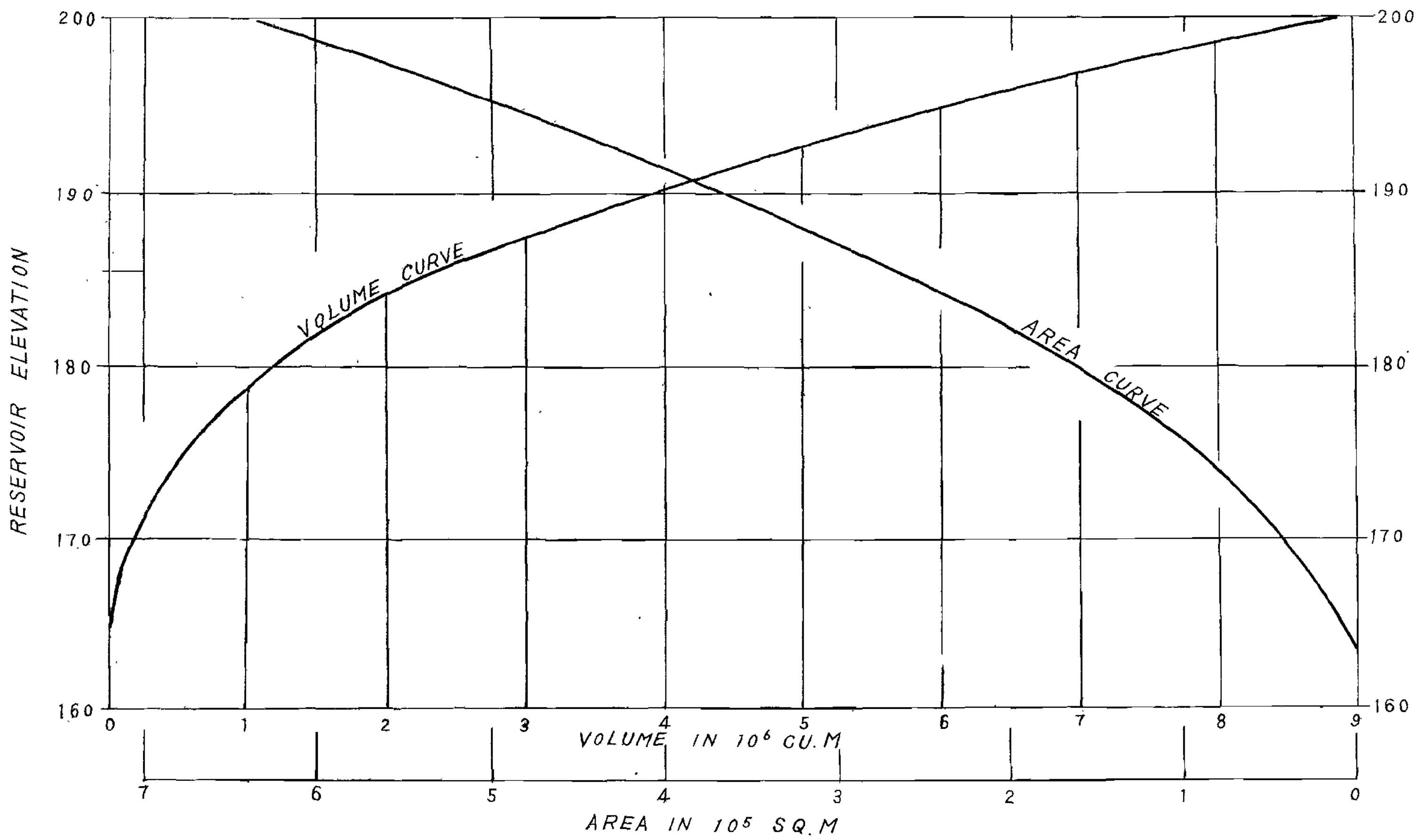


Fig 91

INFLOW & OUTFLOW HYDROGRAPH
FOR TA-KENG RESERVOIR.

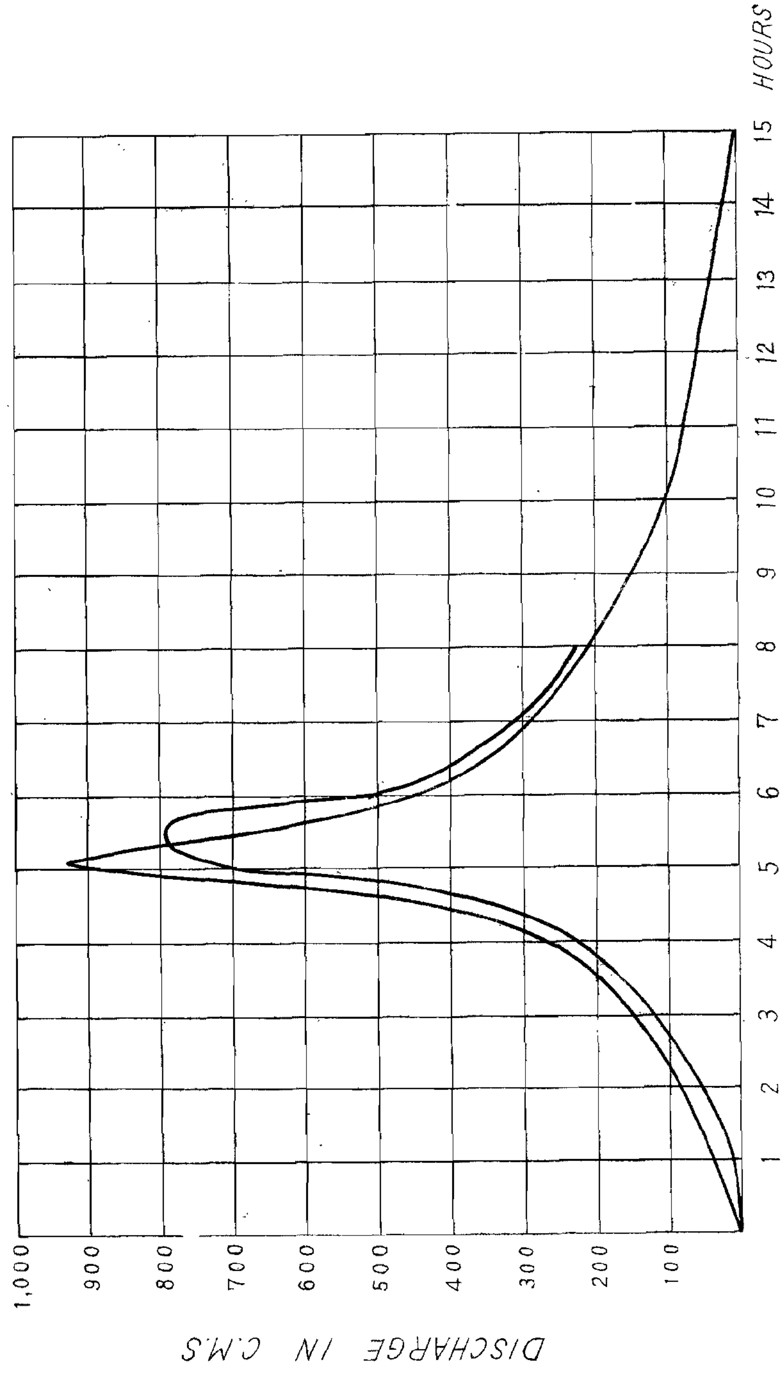
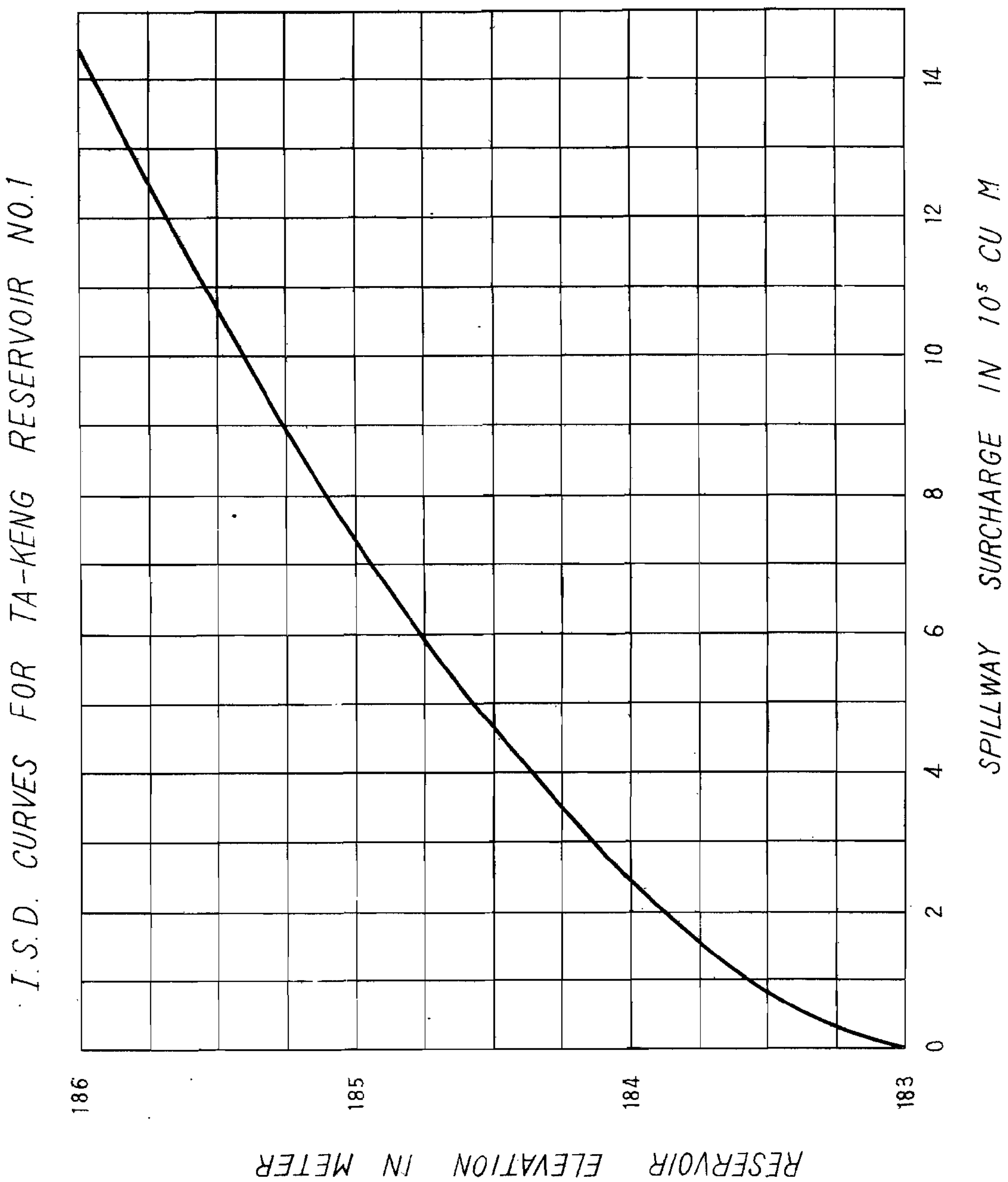


Fig 92



I.S.D. CURVES FOR TA-KENG RESERVOIR NO.1
SPILLWAY SURCHARGE IN 10^5 CU M
0
2
4
6
8
10
12
14
RESERVOIR ELEVATION IN METER
186
185
184
183

I.S.D CURVES FOR TA-KENG RESERVOIR NO.2

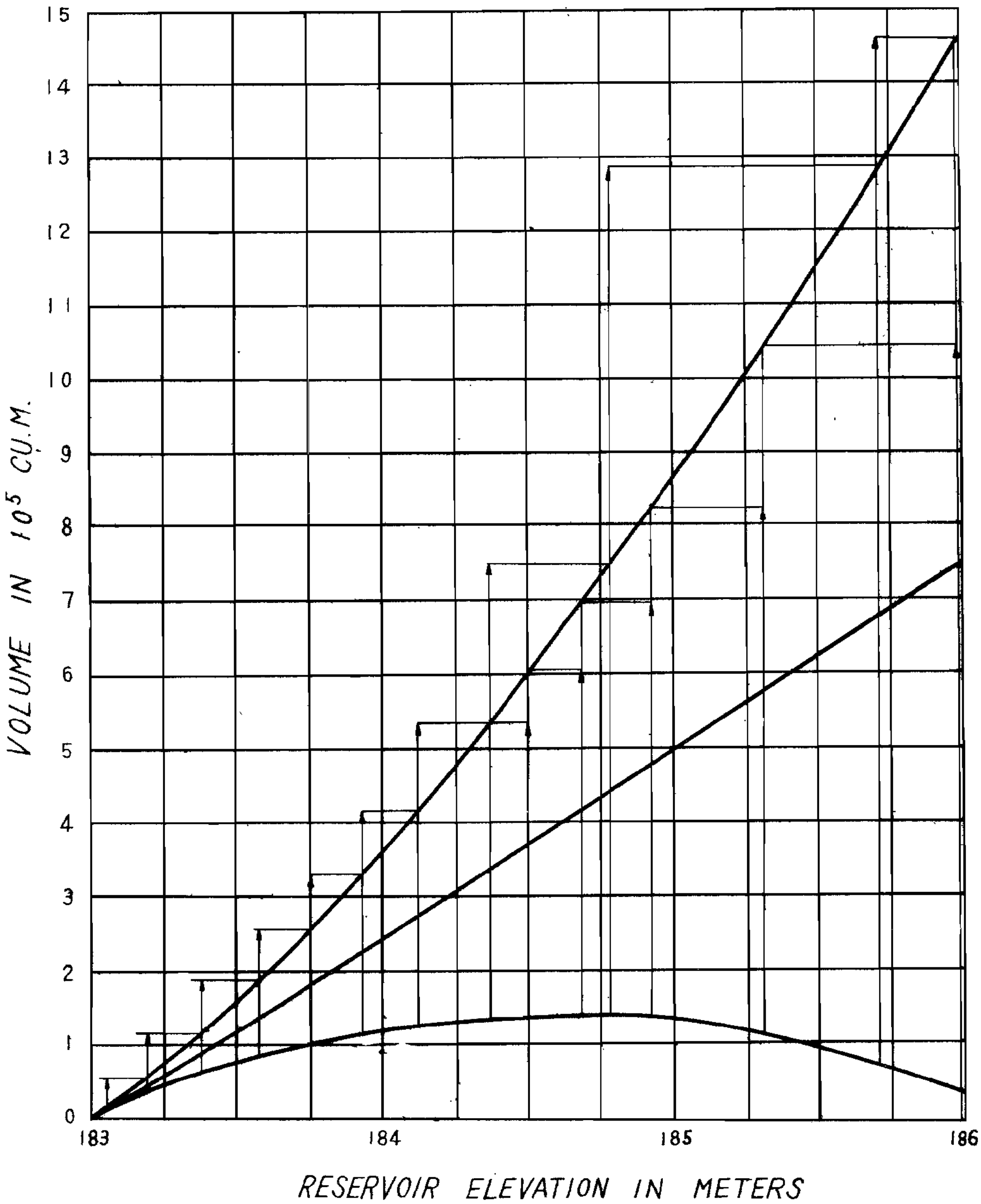
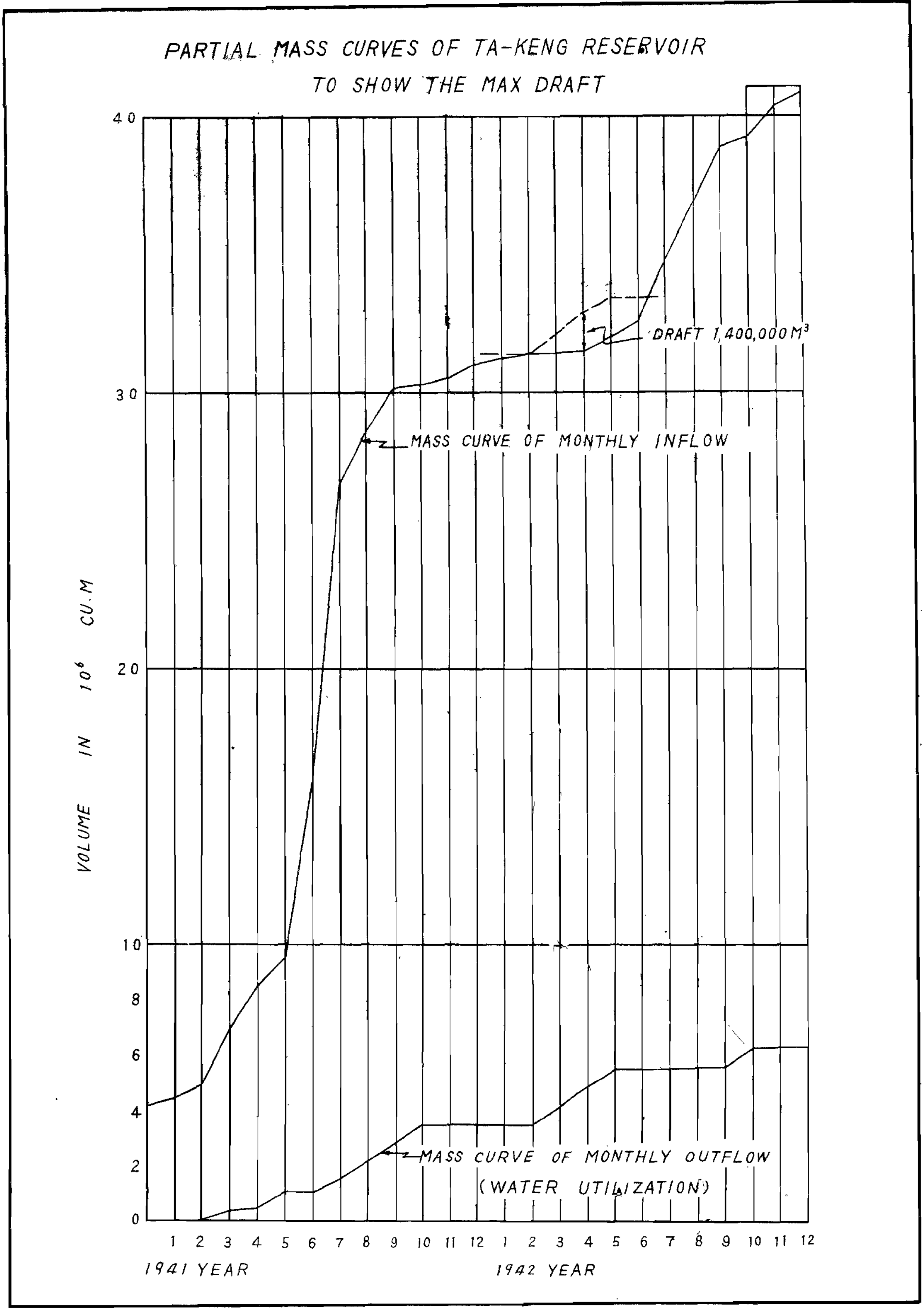


Fig 94

TA-KENG RESERVOIR
FLOOD-ROUTING COMPUTATION

STEP	TIME FROM BEGINNING OF FLOOD IN HR.	INSTANTANEOUS RATE OF INFLOW INTO RESERVOIR	SUM OF DISCHARGE AT BEGINNING AND END OF INTERVAL M^3	VOLUME OF INFLOW INTO RESERVOIR DURING INTERVAL, IN M^3	RESERVOIR ELEVATION AT END OF INTERVAL IN M.	SPILLWAY DISCHARGE RATE AT END OF INTERVAL IN C.M.S.
1	0.5	15	15	13,500	183.05	2.2
2	1.0	33	48	43,200	183.20	11.1
3	1.5	55	88	79,200	183.38	27.8
4	2.0	80	135	121,500	183.58	55.6
5	2.5	108	188	169,000	183.76	86.2
6	3.0	145	253	227,500	183.94	119.5
7	3.5	190	335	302,000	184.13	163.0
8	4.0	265	455	409,000	184.32	225.0
9	4.5	415	680	612,000	184.79	339.0
10	5.0	870	1285	1,155,000	185.71	675.0
11	5.5	680	1550	1,395,000	185.99	792.0
12	6.0	445	1125	1,012,000	185.30	516.0
13	6.5	345	790	712,000	184.93	383.0
14	7.0	280	625	563,000	184.70	310.0
15	7.5	238	518	466,000	184.50	258.0
16	8.0	203	441	396,500	184.38	225.0

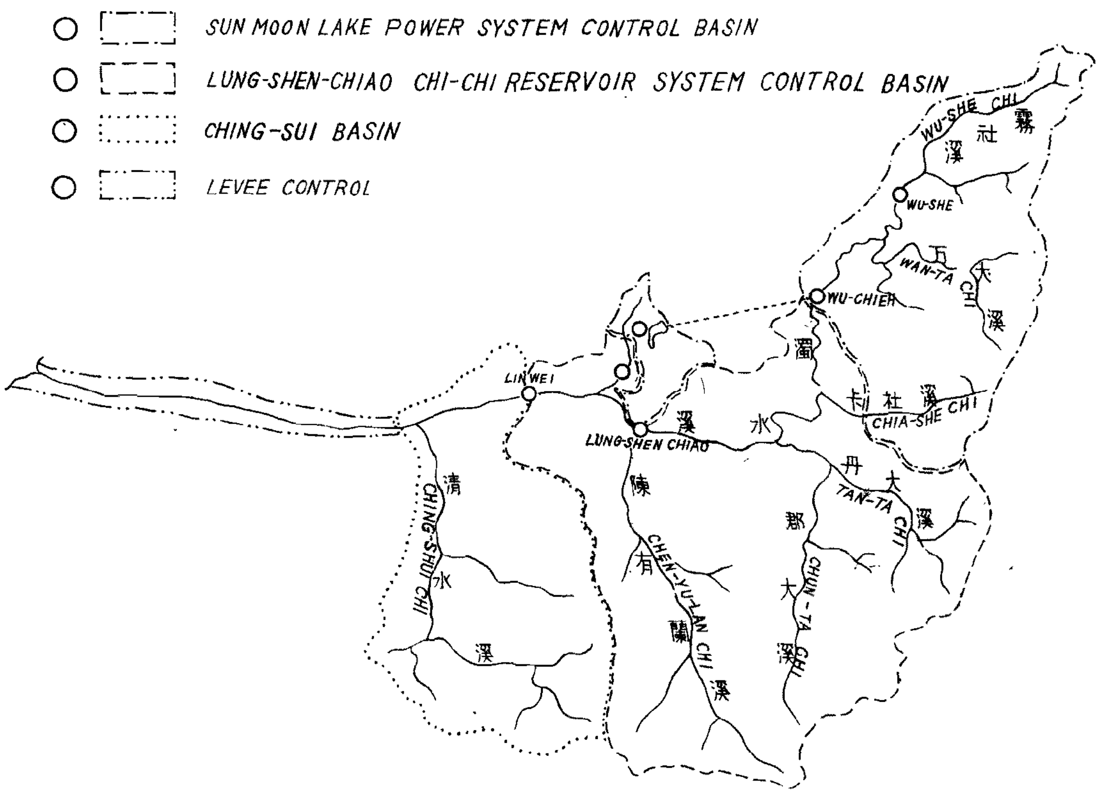
Fig 95



PARTIAL MASS CURVES OF TA-KENG RESERVOIR
TO SHOW THE MAX DRAFT
DRAFT 1,400,000 M³
MASS CURVE OF MONTHLY INFLOW
MASS CURVE OF MONTHLY OUTFLOW
(WATER UTILIZATION)
VOLUME IN 10⁶ CU.M
40
30
20
10
8
6
4
2
0
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
1941 YEAR
1942 YEAR

Fig 96

CHO-SHUI CHI BASIN.



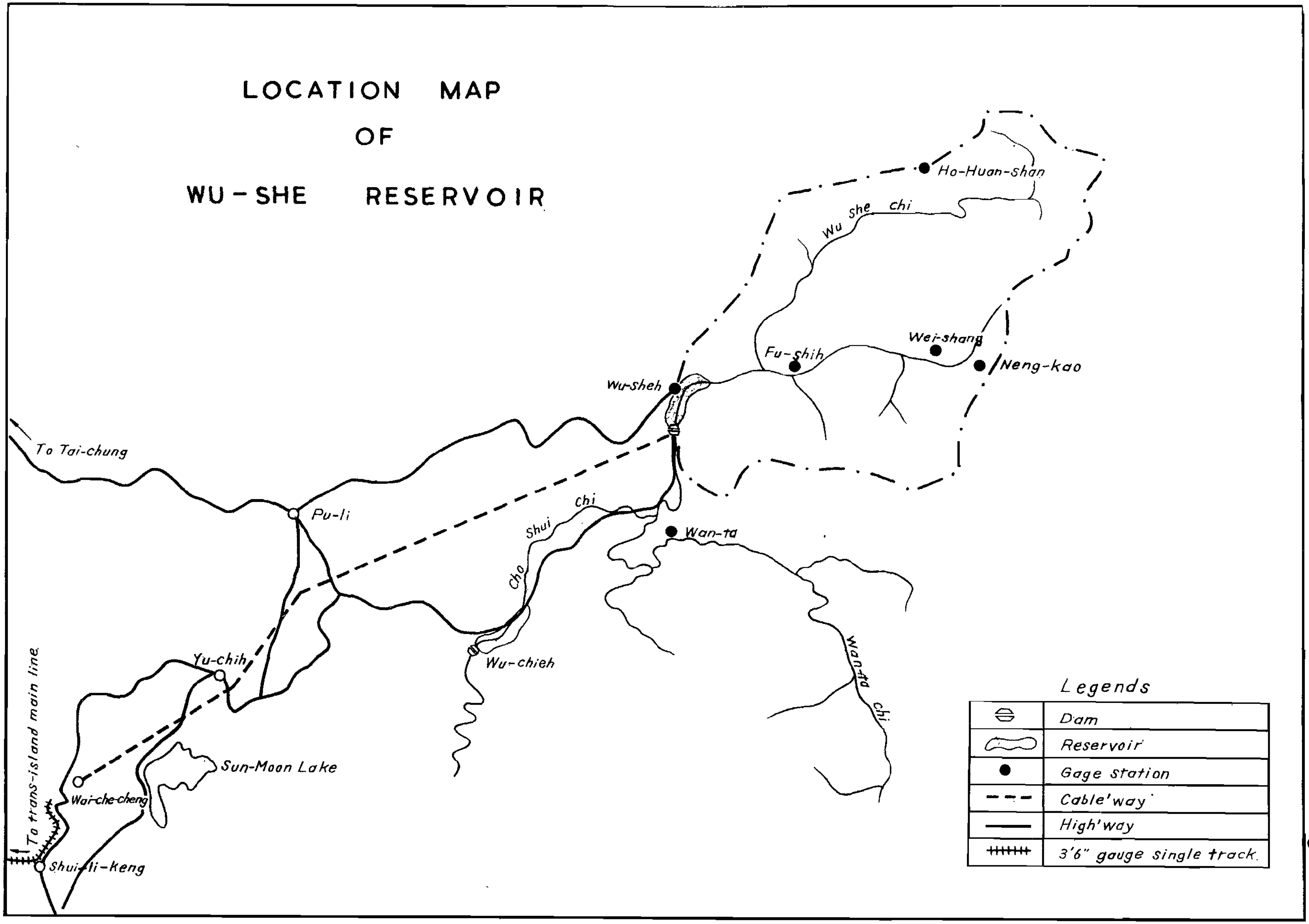
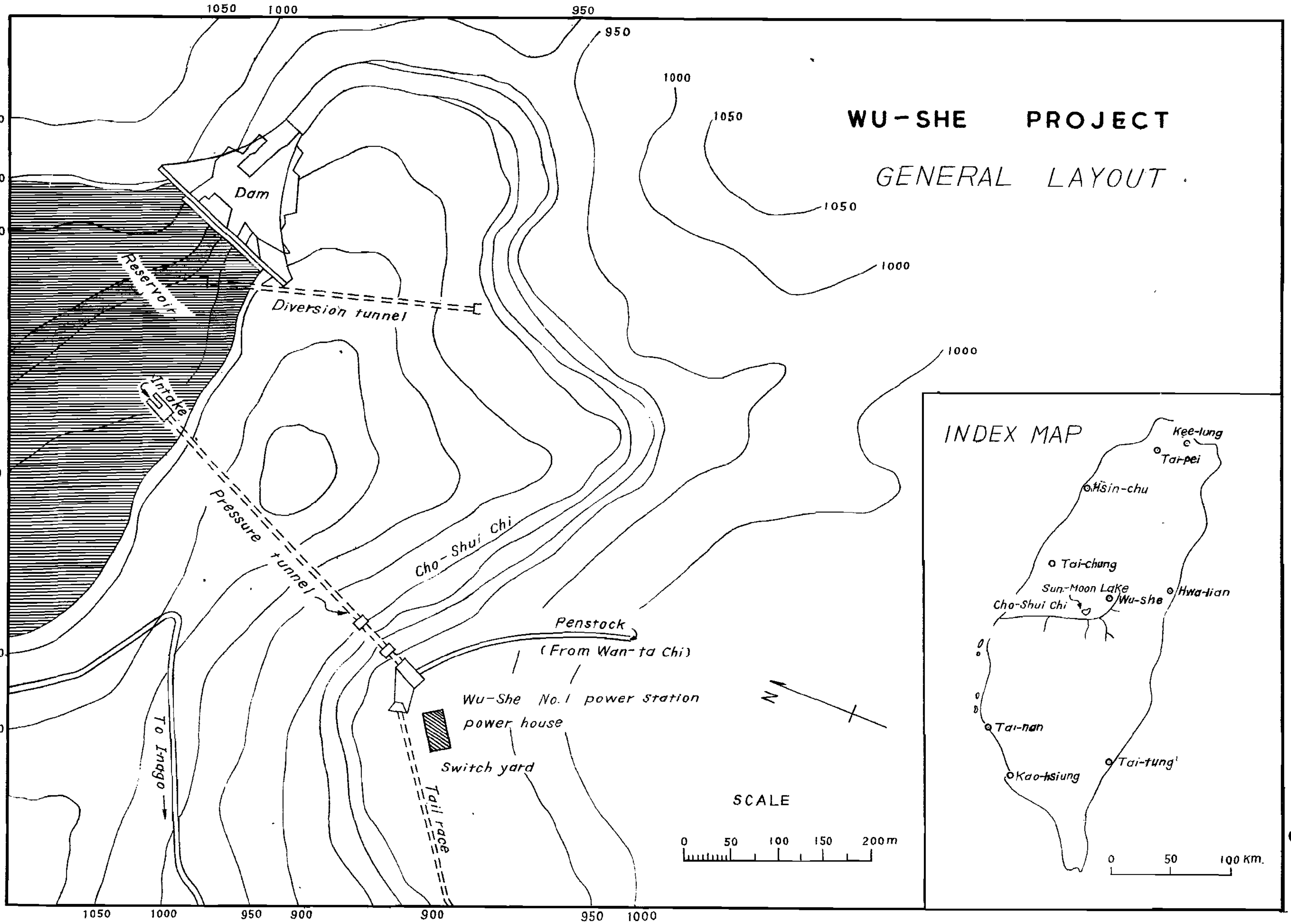

LOCATION MAP
OF
WU - SHE RESERVOIR
Ho-Huan-shan
Wu she chi
Wei-shang
Fu-shih
Neng-kao
Wu-sheh
To Tai-chung
Pu-li
Cho Shui chi
Wan-ta
Wu-chieh
Wan-ta chi
Yu-chih
Sun-Moon Lake
Wai-che-cheng
To trans-island main line
Shui-li-keng
Legends
Dam
Reservoir
Gage station
Cable'way
High'way
3'6" gauge single track

Fig 97



WU-SHE PROJECT
GENERAL LAYOUT
Dam
Reservoir
Diversion tunnel
Intake
Pressure tunnel
Cho-Shui Chi
Penstock
(From Wan-ta Chi)
Wu-She No. 1 power station
power house
Switch yard
Tail race
To I-nago
N
SCALE
0 50 100 150 200m
INDEX MAP
Kee-lung
Tai-pei
Hsin-chu
Tai-chung
Sun-Moon Lake
Wu-she
Hwa-lian
Cho-Shui Chi
Tai-nan
Kao-hsiung
Tai-tung
0 50 100 Km.

Fig 98

RESERVOIR AREA, VOLUME-ELEVATION CURVE

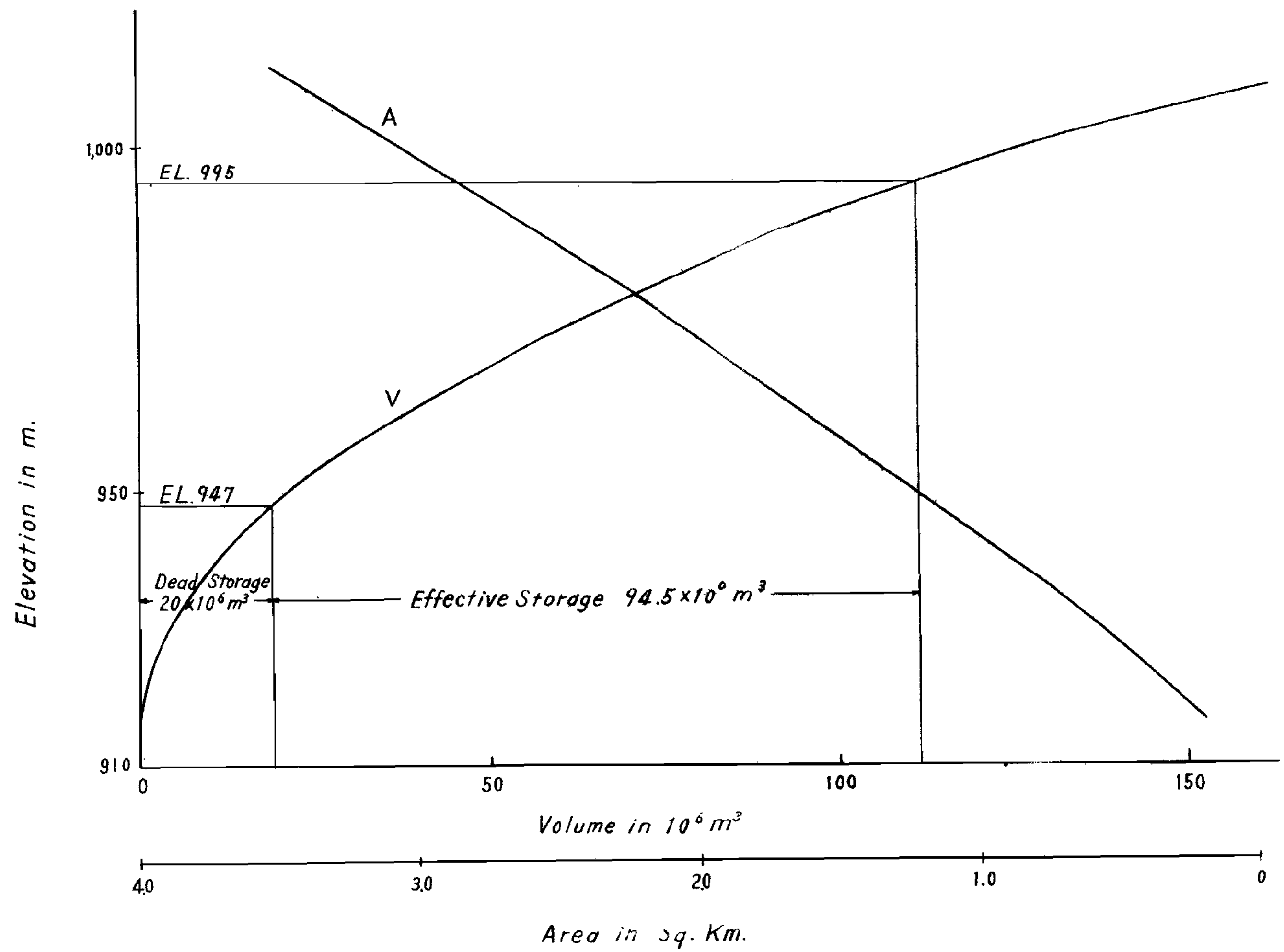
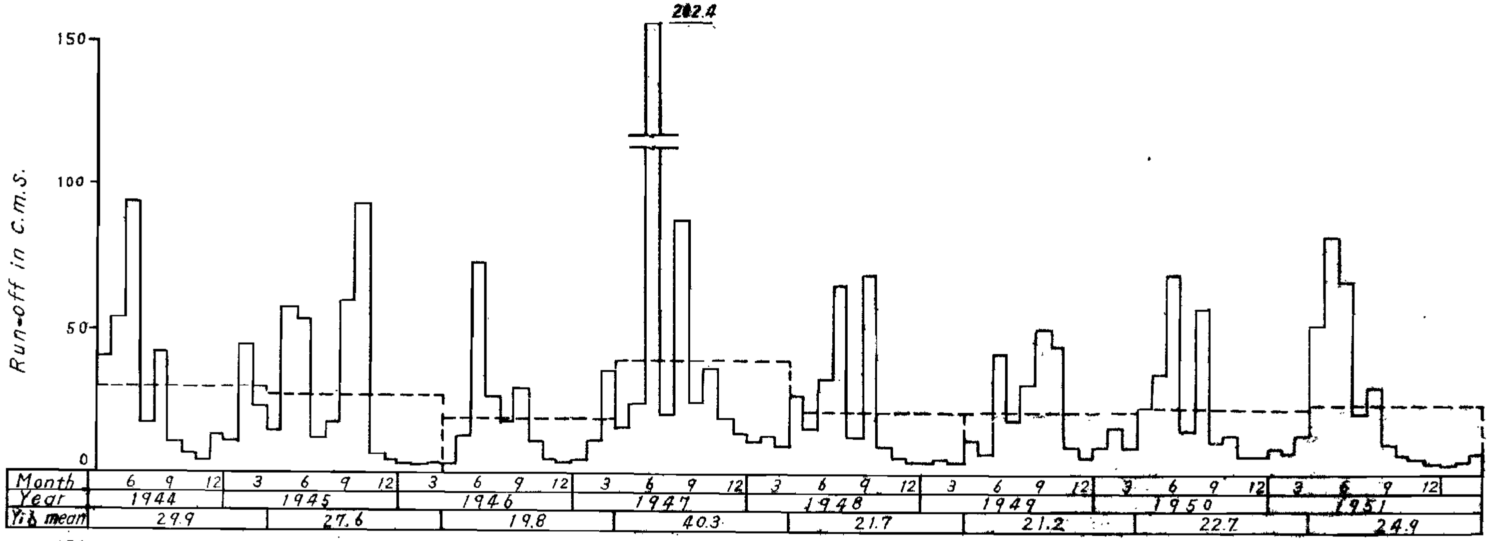


Fig 99

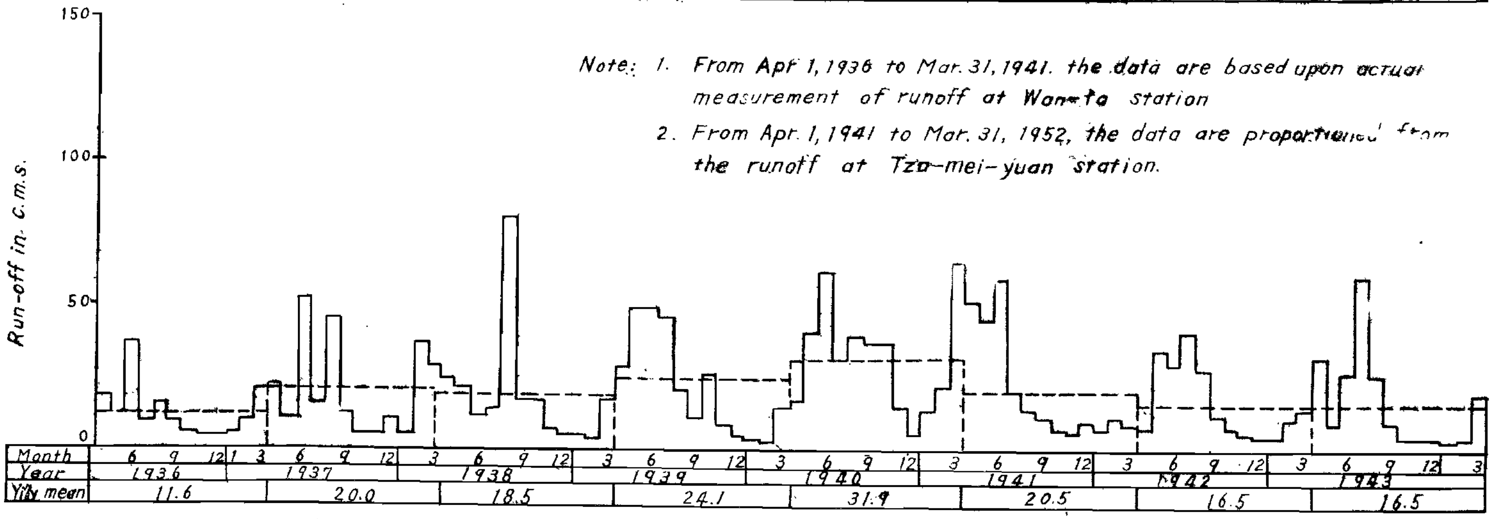
Fig 100

Hydrograph
Wu-she project (Wan-ta station)



Note: 1. From Apr 1, 1936 to Mar. 31, 1941. the data are based upon actual measurement of runoff at Wan-ta station

2. From Apr. 1, 1941 to Mar. 31, 1952, the data are proportioned from the runoff at Tza-mei-yuan station.



WU-SHE PROJECT DURATION CURVE

Wan-ta Station

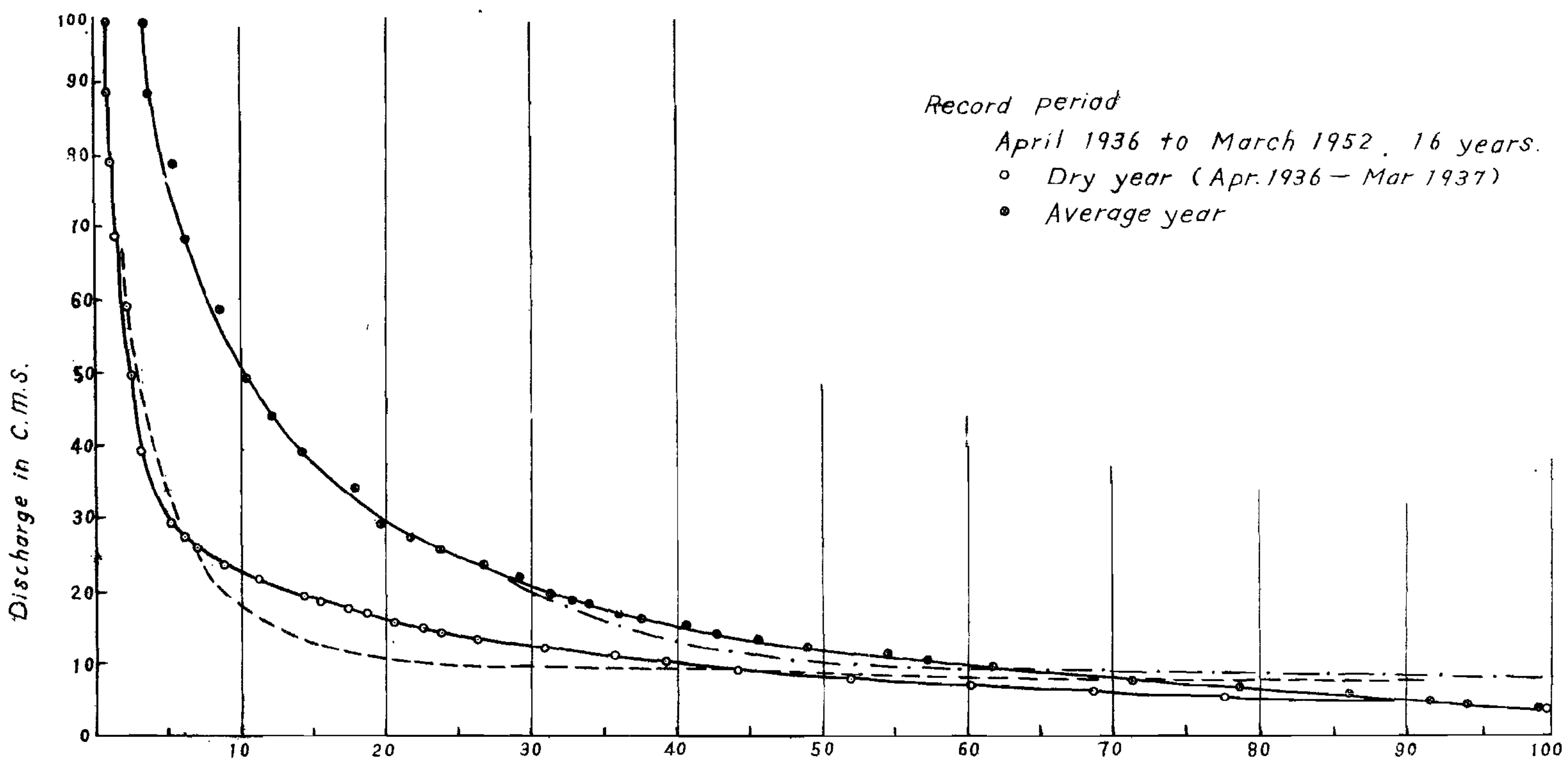


Fig 101

Fig 102

WU-SHE PROJECT FLOW MASS CURVE

Wan-ta Station

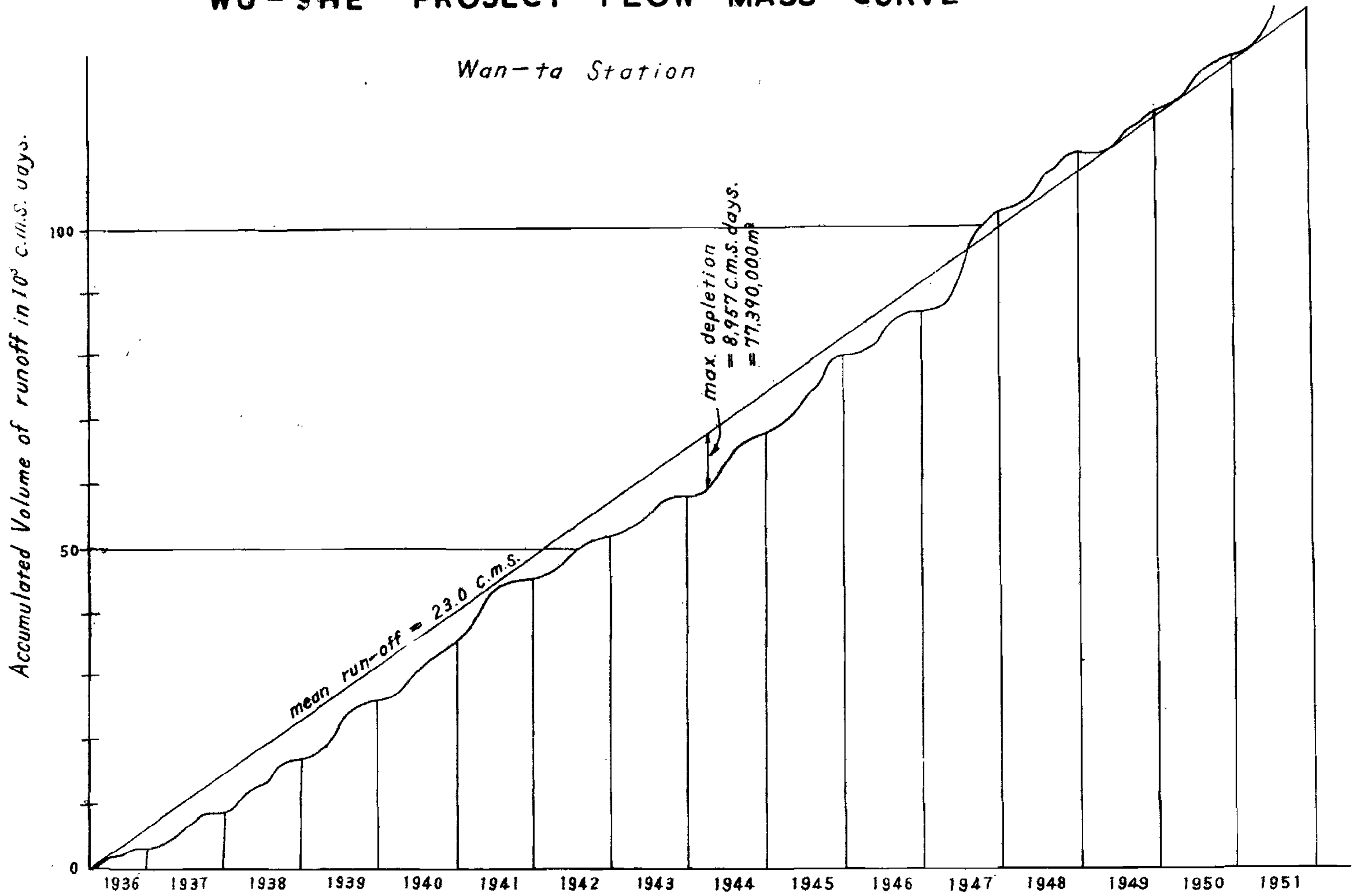
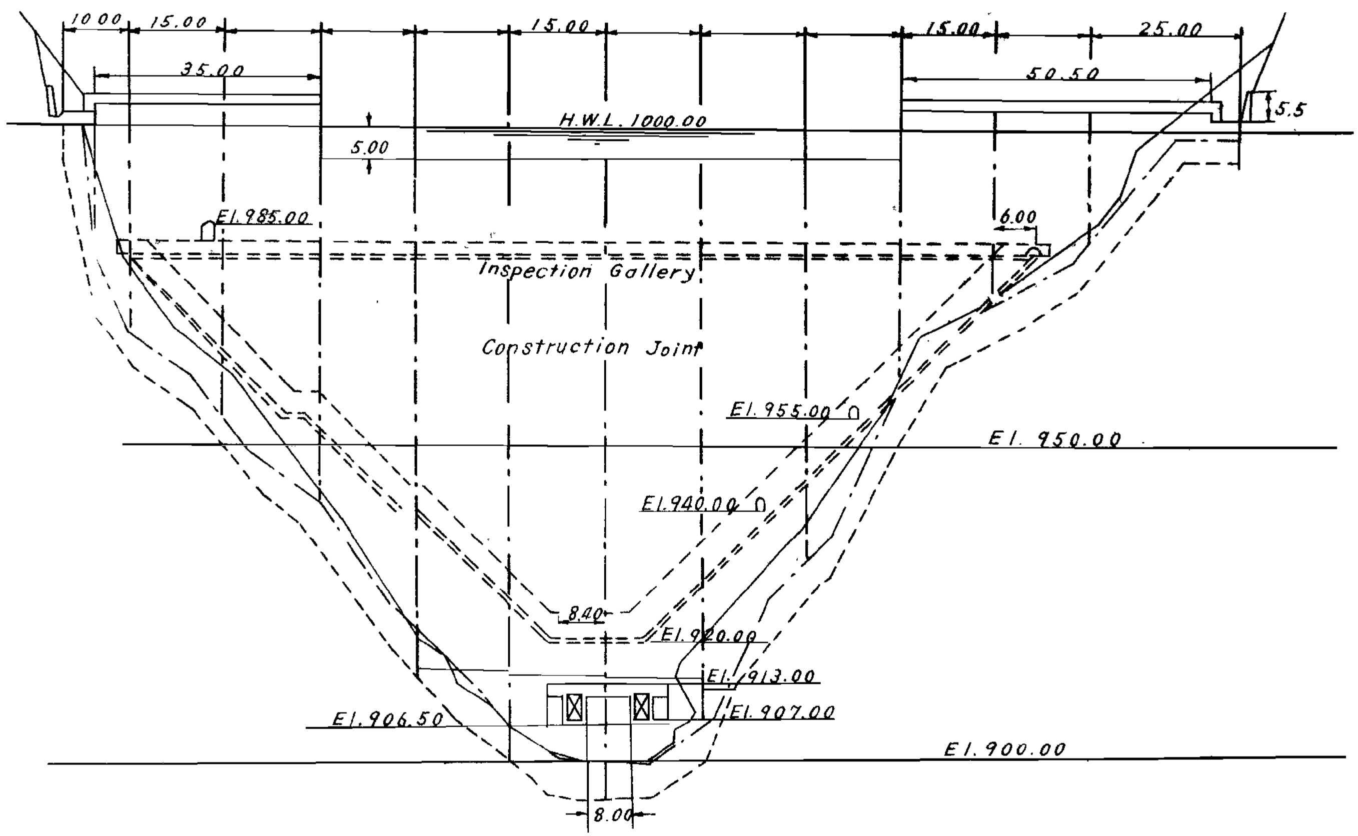


Fig 103



DAM LONGITUDINAL SECTION

DAM CROSS SECTION

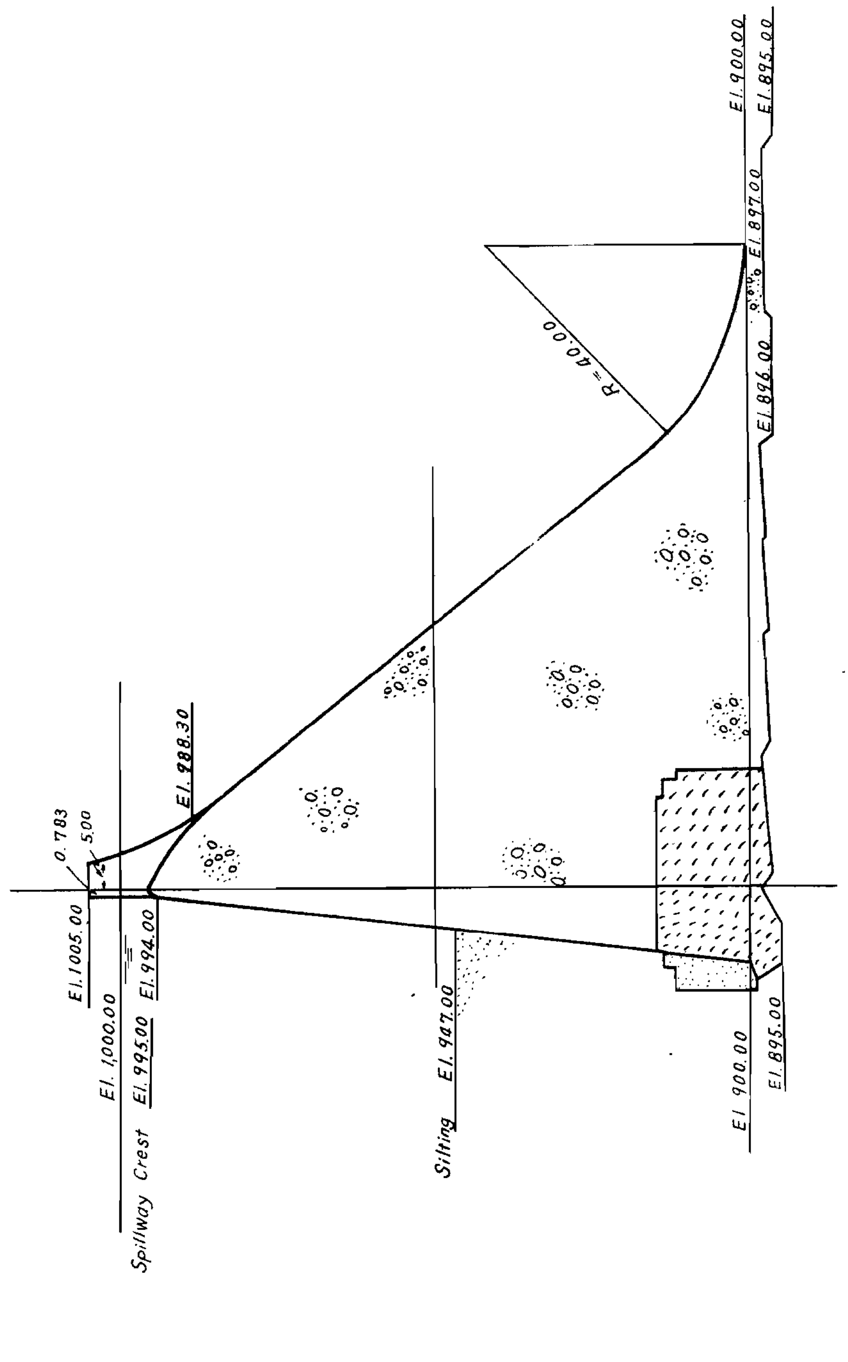
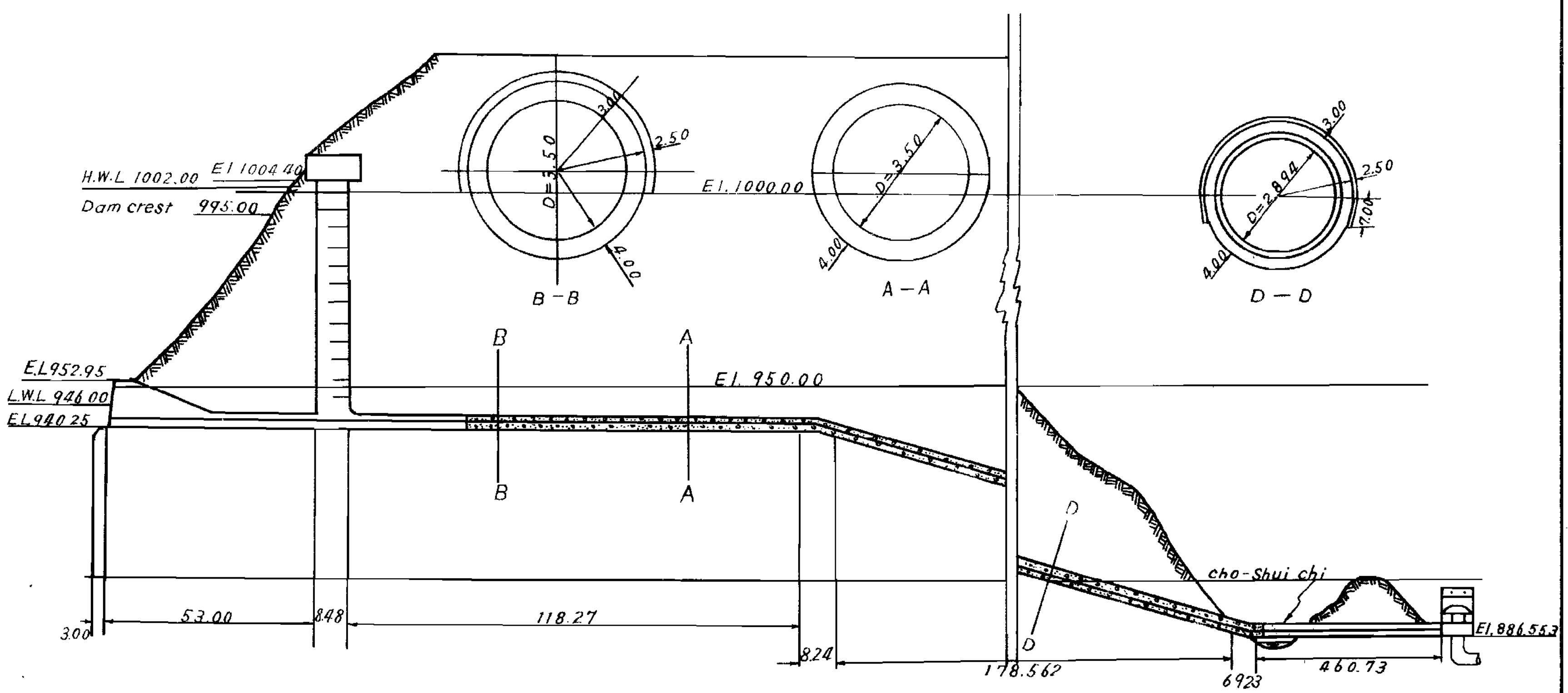
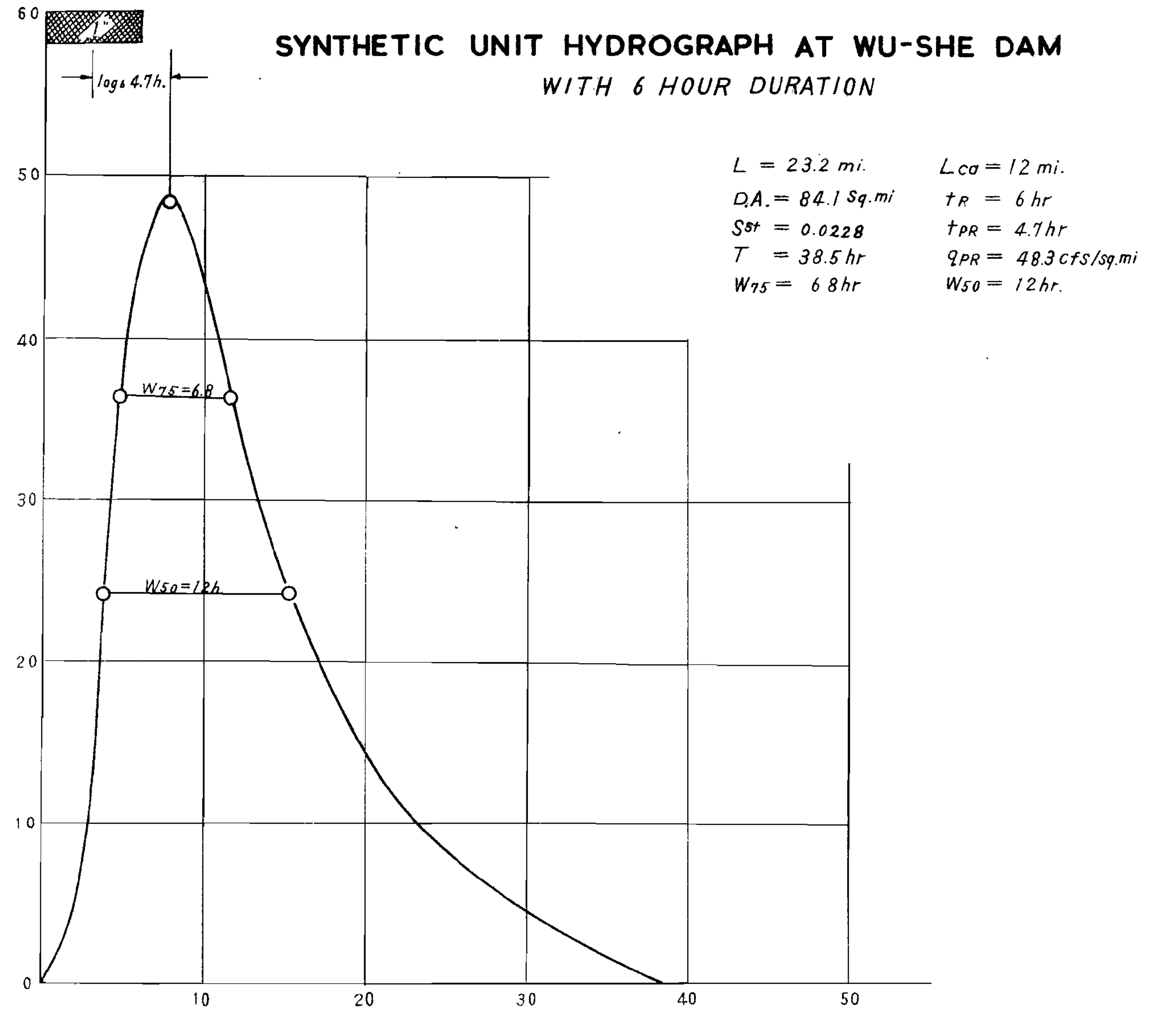


Fig 105



PROFILE OF INTAKE PRESSURE TUNNEL AND POWER HOUSE



SYNTHETIC UNIT HYDROGRAPH AT WU-SHE DAM
WITH 6 HOUR DURATION
L = 23.2 mi.
D.A. = 84.1 Sq.mi
Sst = 0.0228
T = 38.5 hr
W75 = 6 8hr
Lca = 12 mi.
tR = 6 hr
tPR = 4.7hr
qPR = 48.3 cfs/sq.mi
W50 = 12hr.
lag 4.7h.
W75=6.8
W50=12h
0
10
20
30
40
50
60

Fig 106

Fig 107

INFLOW–STORAGE DISCHARGE CURVE.

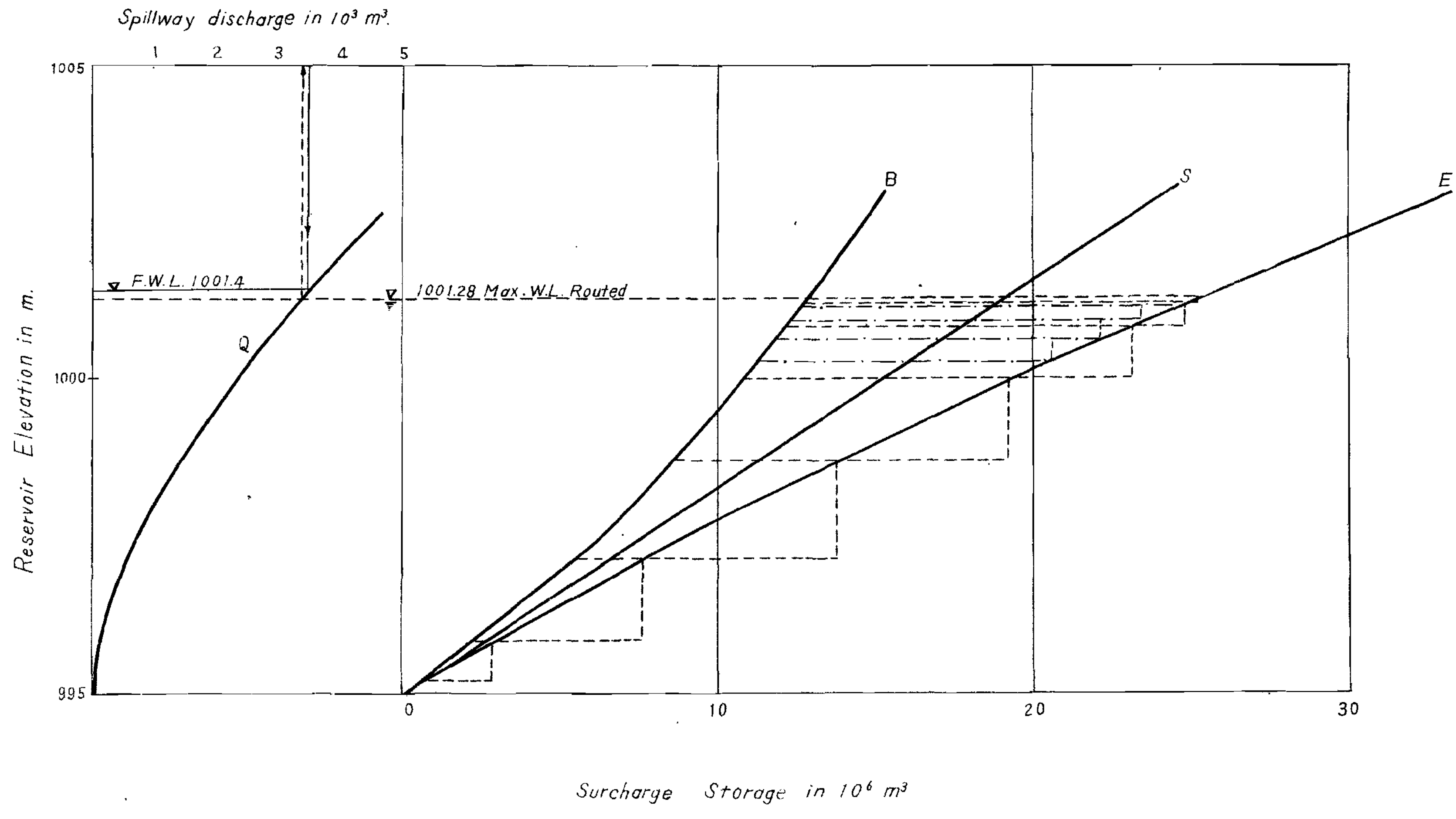
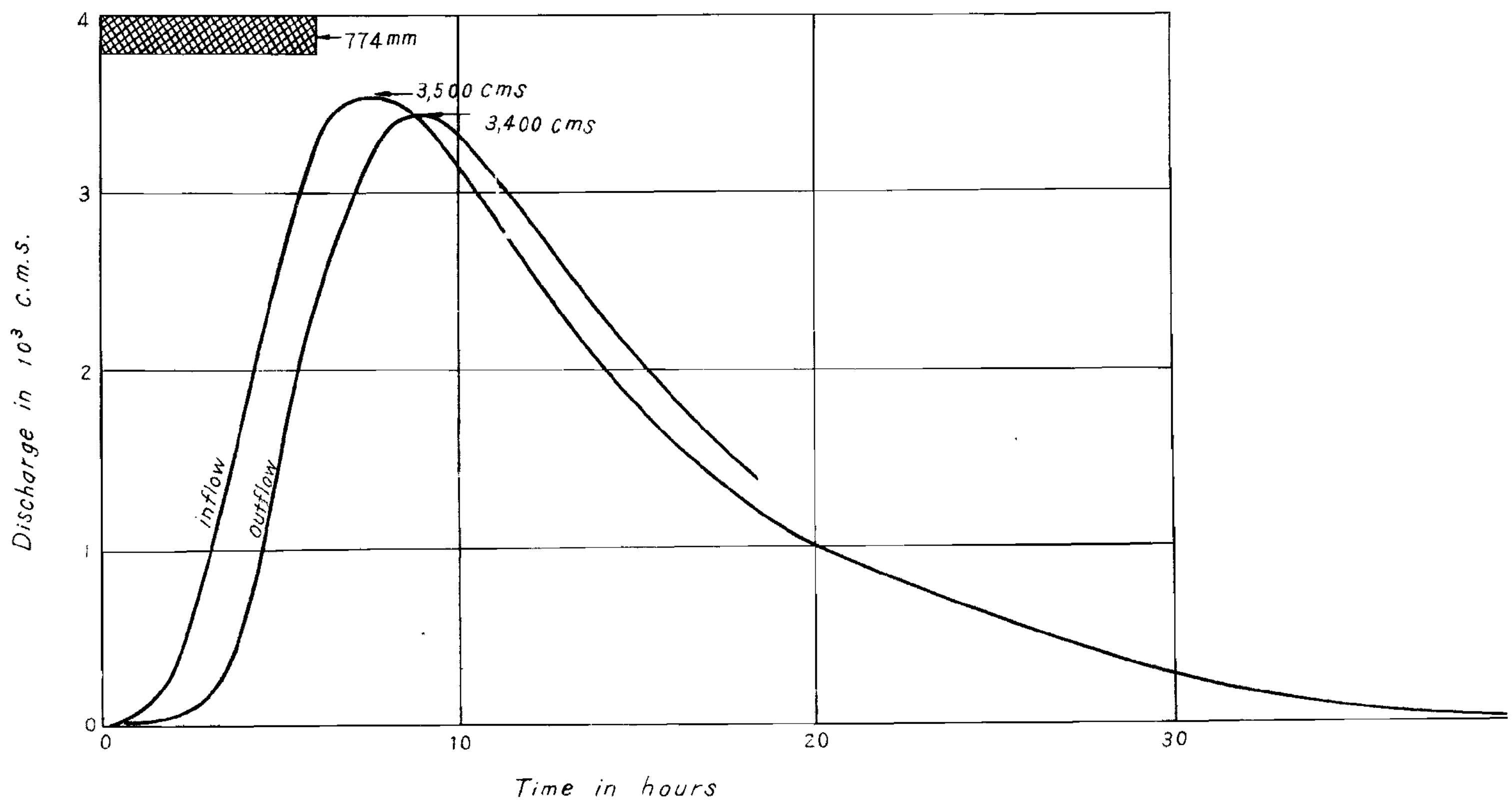


Fig 108

INFLOW-OUTFLOW CURVE

(Disregarding Intake Discharges)



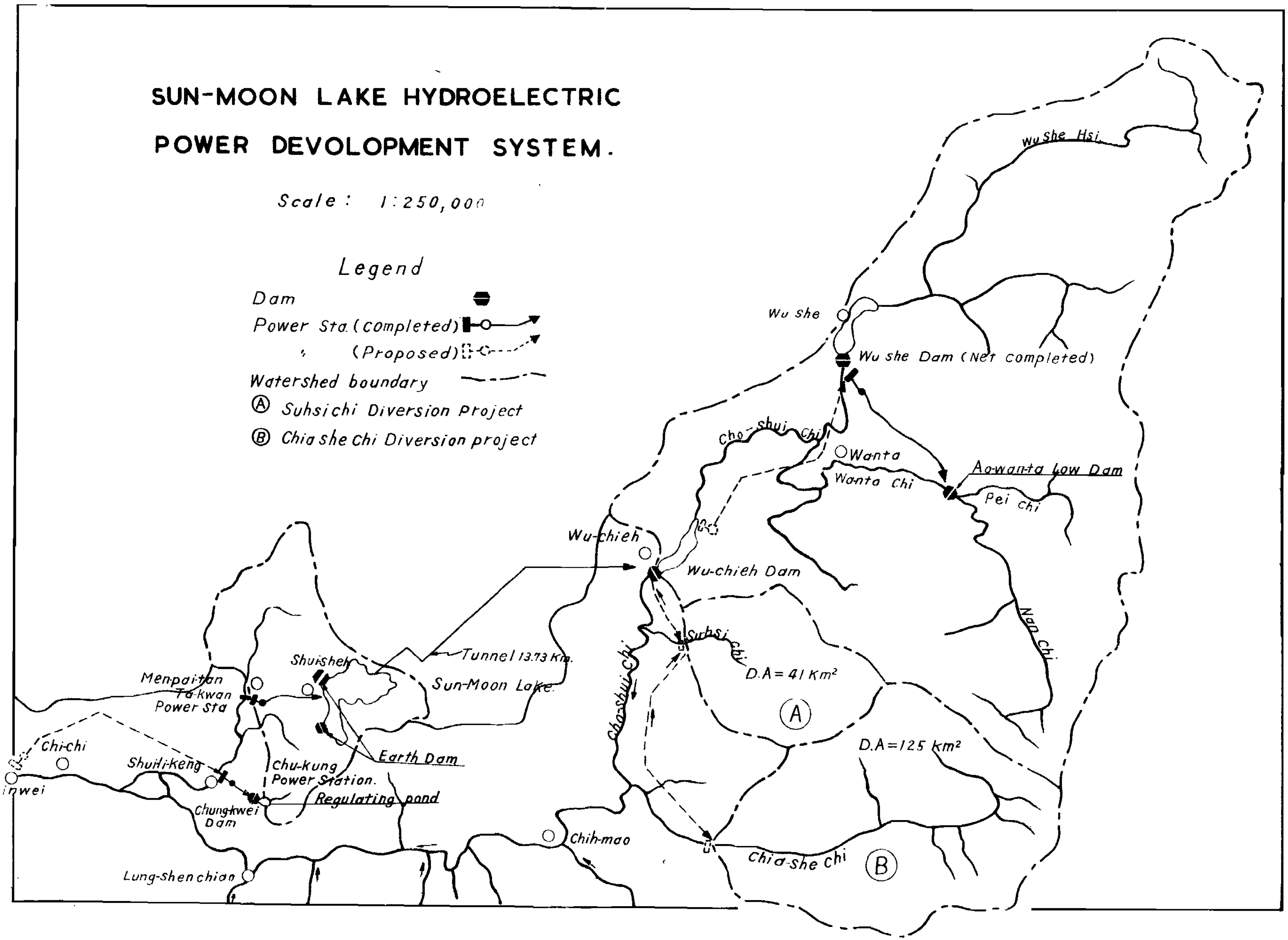
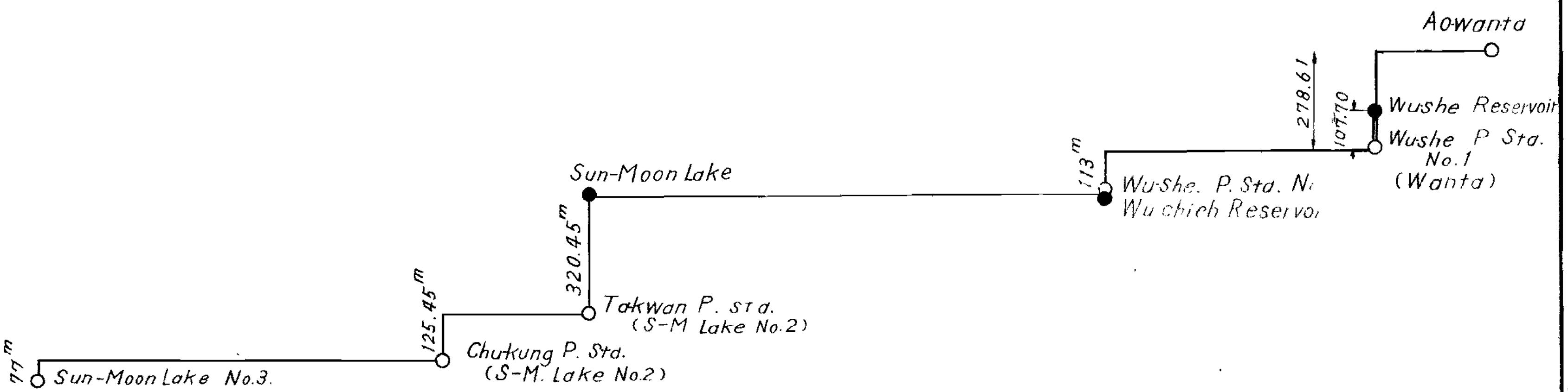

SUN-MOON LAKE HYDROELECTRIC
POWER DEVOLOPMENT SYSTEM.
Scale : 1:250,000
Legend
Dam
Power Sta.(completed)
" (Proposed)
Watershed boundary
Ⓐ Suhsichi Diversion Project
Ⓑ Chia she chi Diversion project
Wu she Hsi
Wu she
Wu she Dam (Not completed)
Cho-shui Chi
Wanta
Wanta Chi
Ao-wanta Low Dam
Pei chi
Wu-chieh
Wu-chieh Dam
Nan Chi
Suhsi chi
D.A = 41 Km²
Ⓐ
D.A = 125 Km²
Ⓑ
Chia-she chi
Cho-shui chi
Tunnel 13.73 Km.
Sun-Moon Lake.
Shui-sheh
Menpai-tan
Ta-kwan
Power Sta
Earth Dam
Chu-Kung
Power Station.
Regulating pond
Chi-chi
Shuili-keng
Linwei
Chung-kwei
Dam
Chih-mao
Lung-shen chian

Fig 110

List of Sun-Moon Lake power development system.

Item	Power No. / Sta.	1 Wanta	2 Wushe No. 1	3 Wushe No. 2	4 Takwan S-M Lake No. 1	5 Chukung S-M Lake No. 2	6 Sun-Moon Lake No. 3	Total
Total length of Tunnel. Open channel. etc.		6.40 Km	0.37 Km	8.05 Km	15.12 Km	4.15 Km	12.00 Km	
Q	Max	6.60 cms	22.60 cms	29.20 cms	41.53 cms	41.60 cms	41.60 cms	
	Min	2.40 "	11.30 "	13.70 "	23.18 "	23.18 "	23.18 "	
Hnet	Max	278.61 m	107.70 m	113.00 m	320.45 m	125.45 m	77.00 m	
	Min	276.13 m	61.70 m	—	304.85 m	125.04 m	—	
P	Max	15,200 KW	20,000 KW	27,000 KW	100,000 Km	43,500 KW	26,500 KW	232,200 KW
	Primary	4,600 KW	5,700 KW	12,700 KW	58,800 KW	24,640 KW	15,000 KW	121,440 KW
Remark		completed	Underconstruction.	Proposed	completed	completed	proposed	



GENERAL LAYOUT OF CHECK DAM PROJECT.

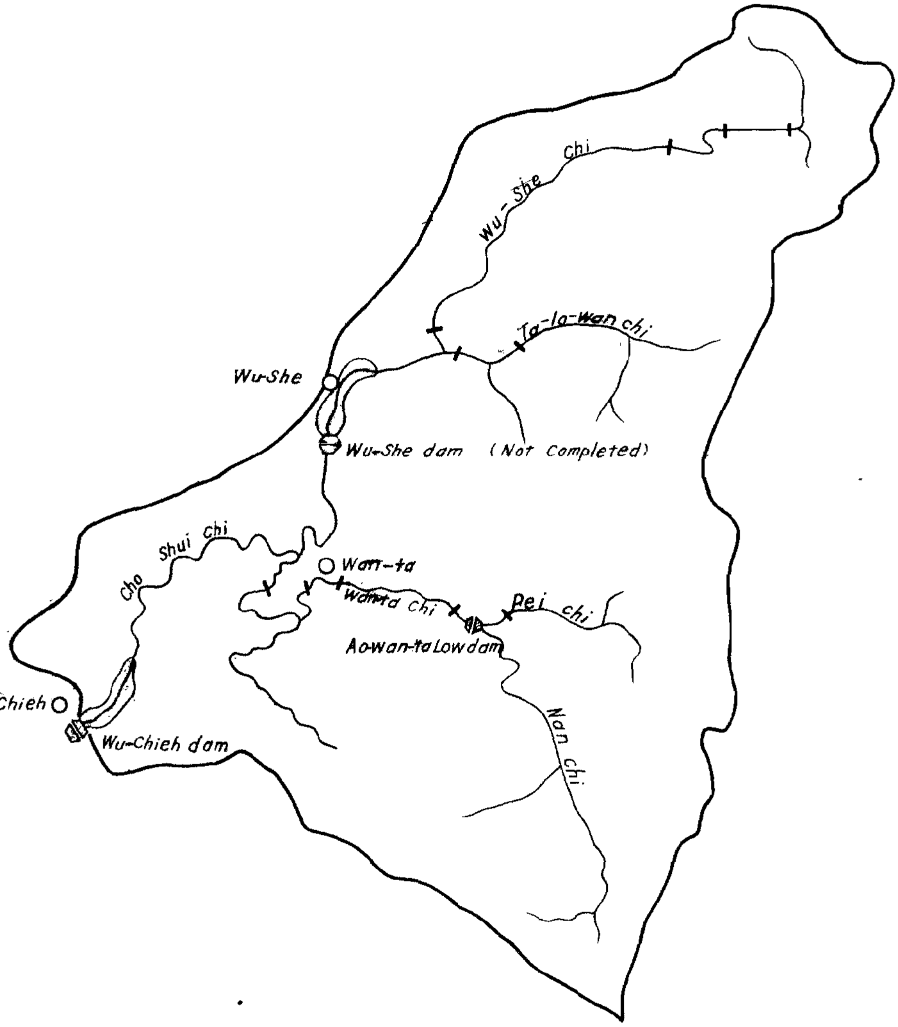


Fig 112

GEOLOGICAL MAP OF LUNG-SHEN-CHIAO DAM SITE

Scale 1:50,000

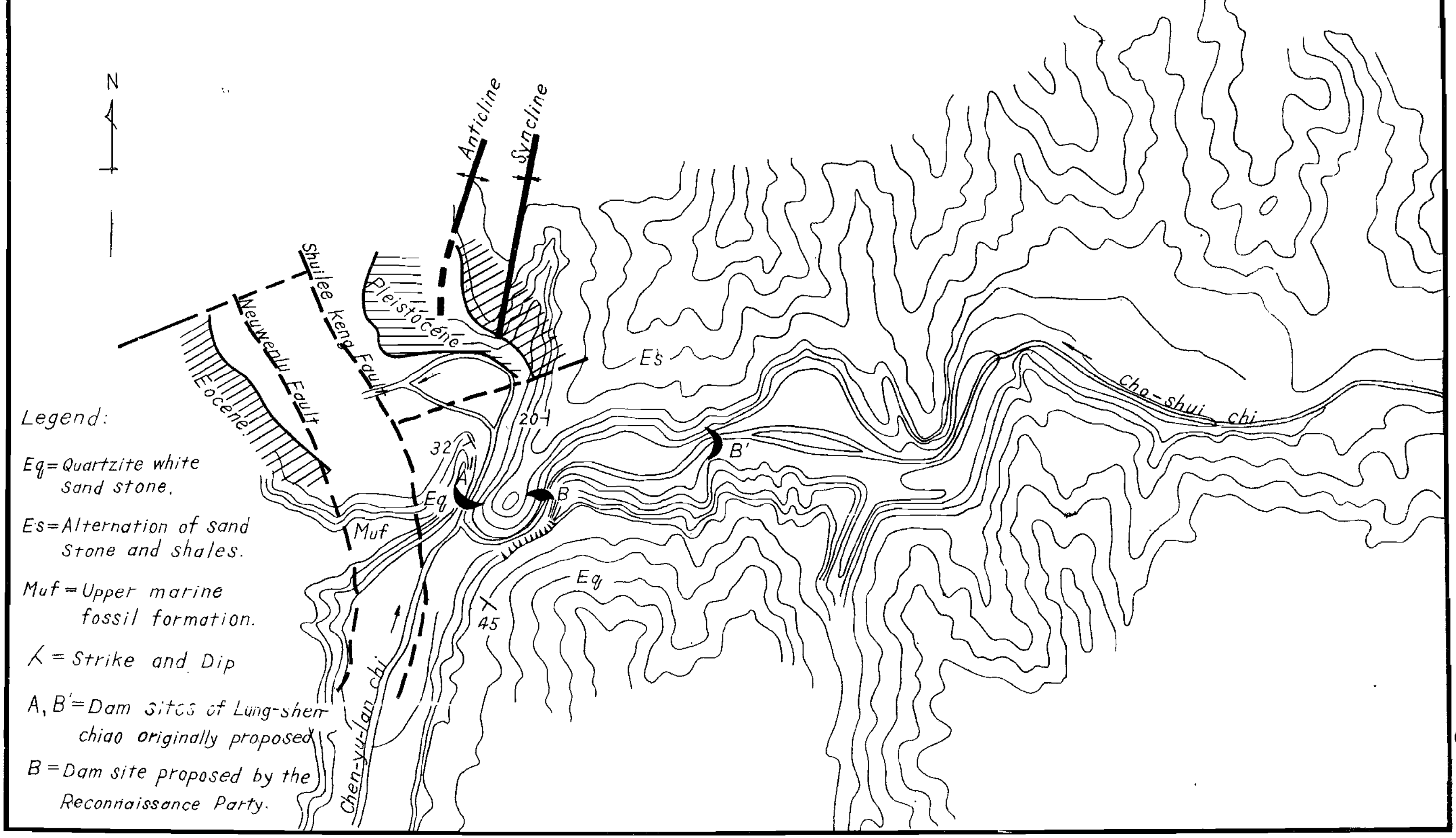


Fig 113

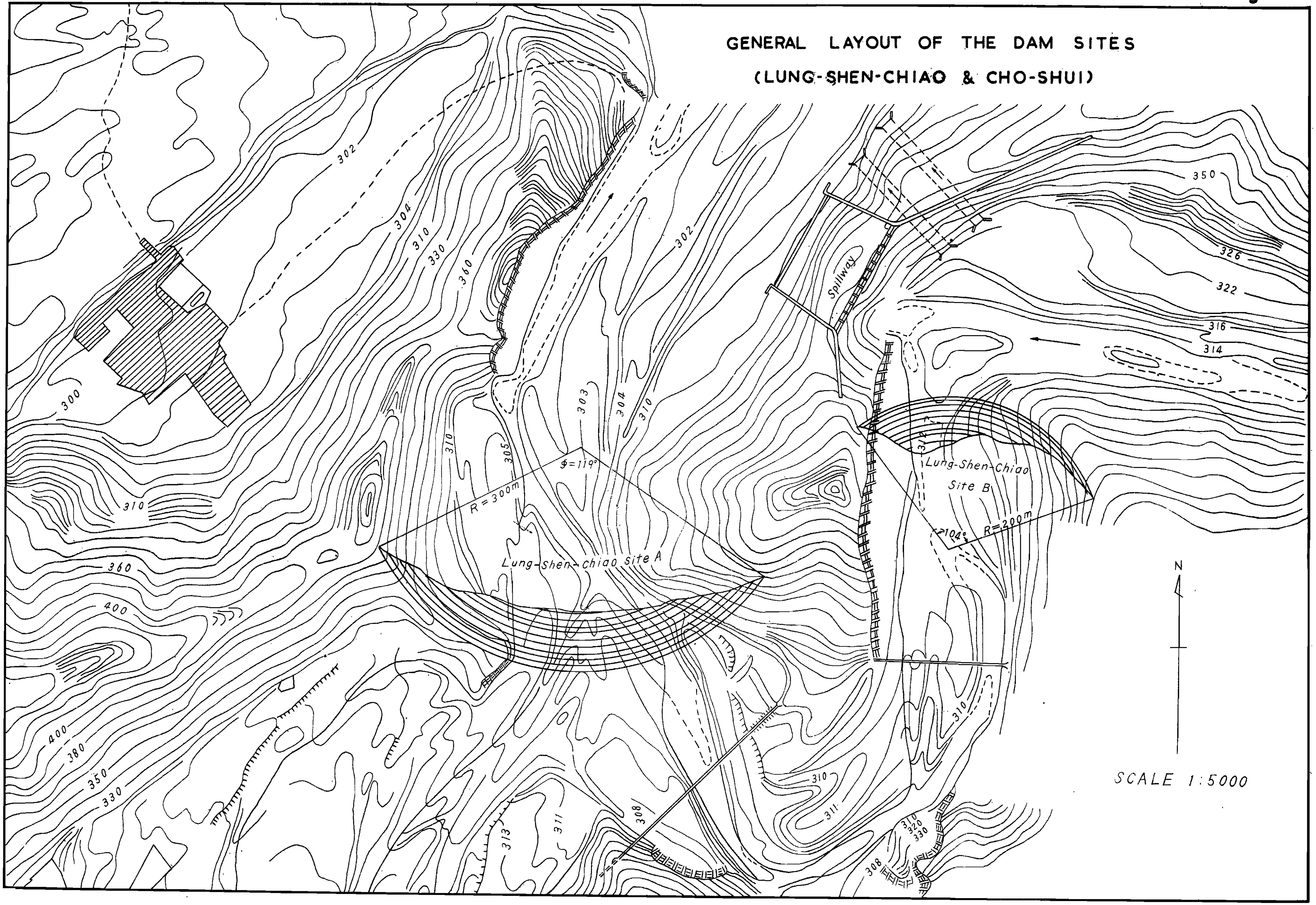

GENERAL LAYOUT OF THE DAM SITES
(LUNG-SHEN-CHIAO & CHO-SHUI)
Spillway
Lung-Shen-Chiao
Site B
R=200m
Lung-Shen-chiao site A
R=300m
N
SCALE 1:5000

Fig 114

LUNG-SHEN-CHIAO

AREA VOLUME CURVE

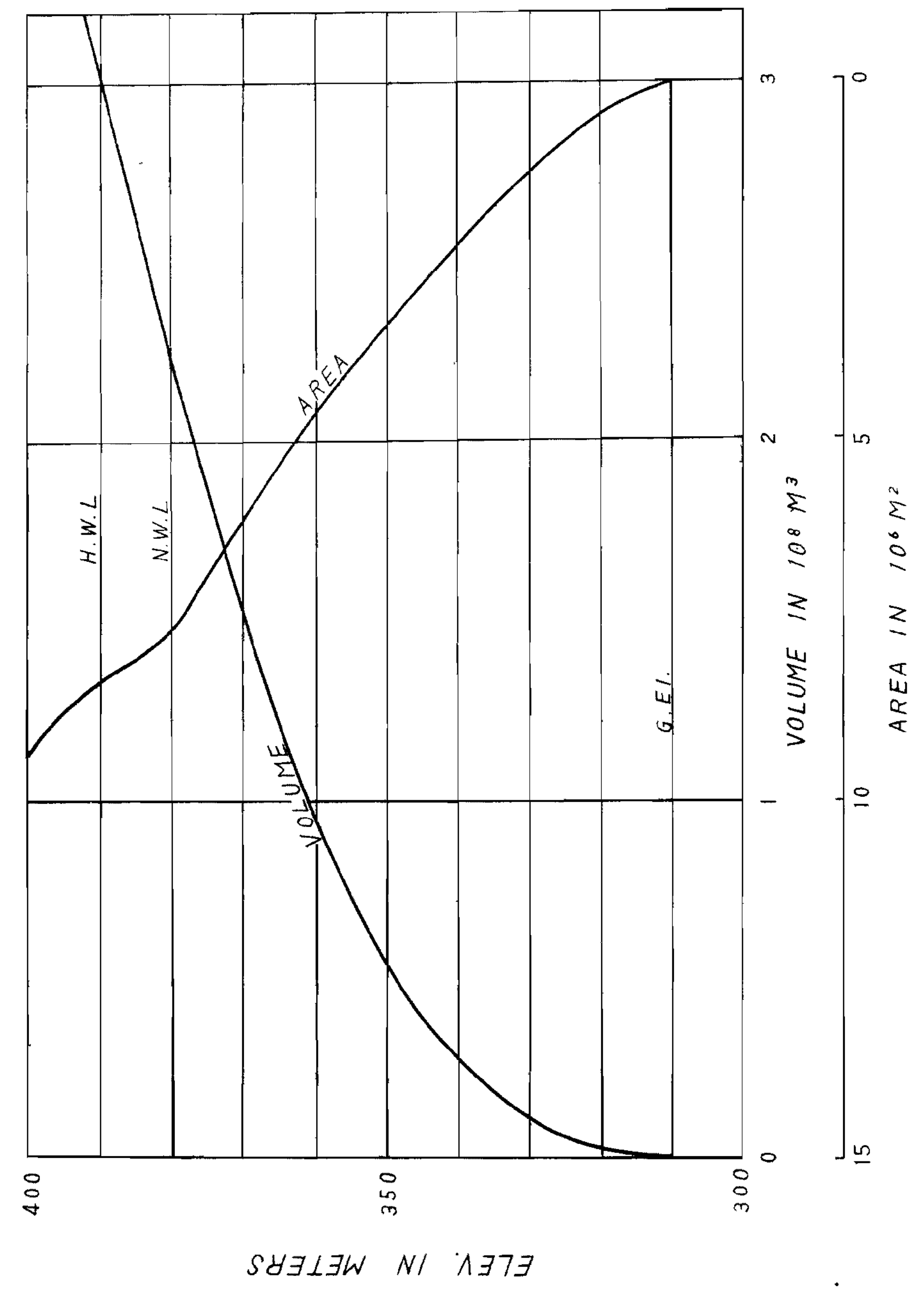


Fig 115

SYNTHETIC UNIT HYDROGRAPH
AT
LUNG-SHEN-CHIAO RESERVOIR (SITE B)

With 12 hour duration

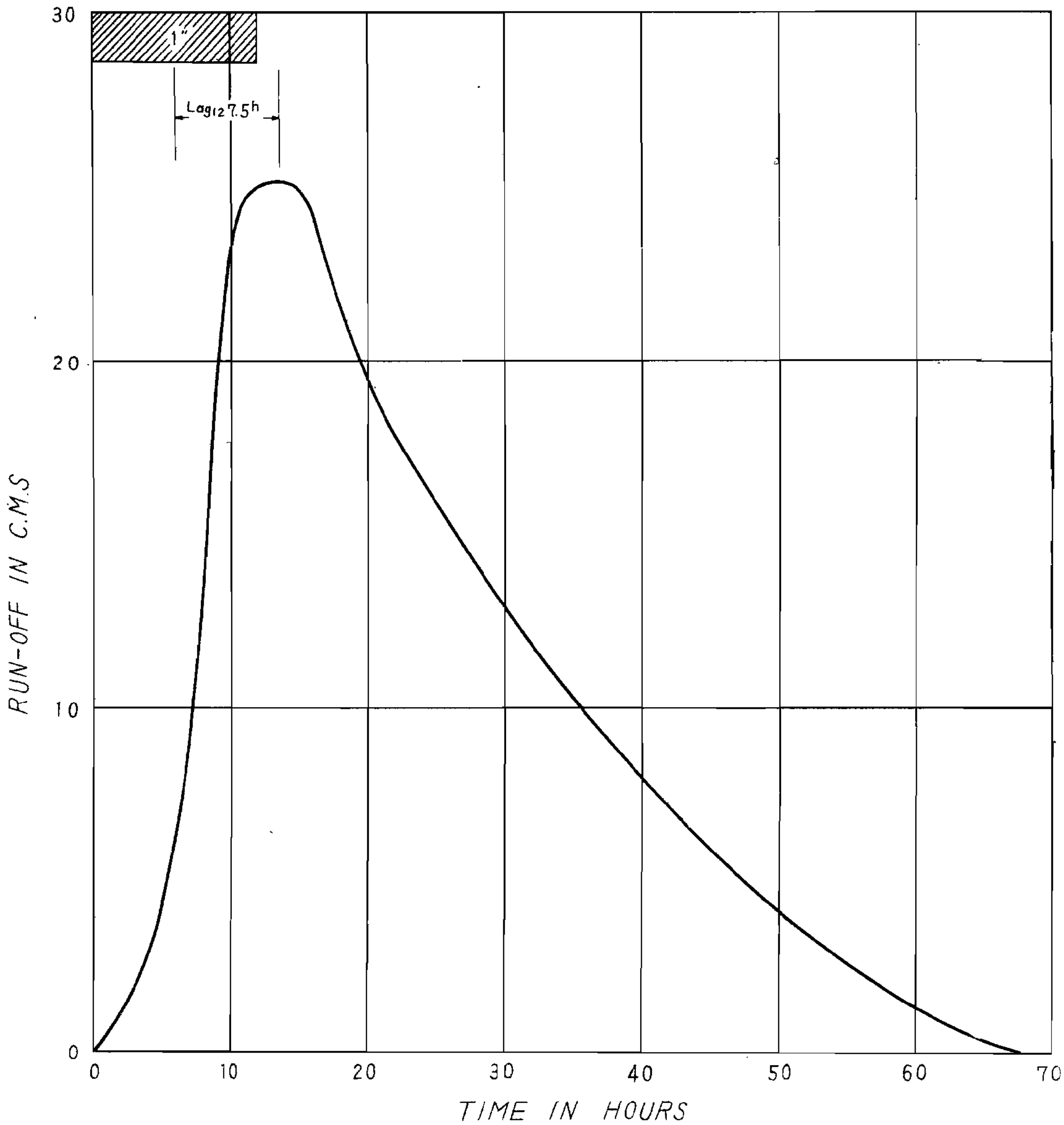
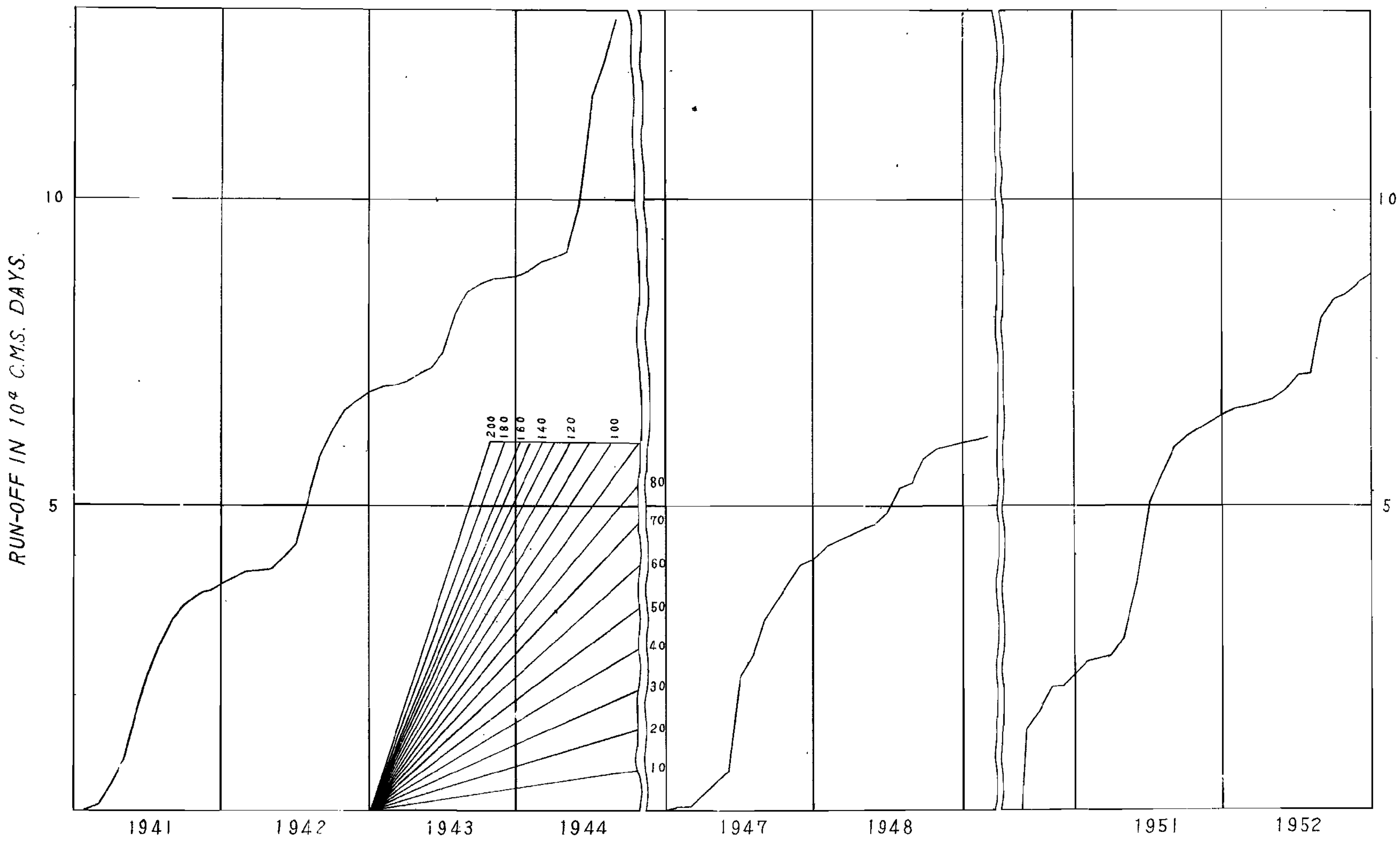


Fig 116

LUNG-SHEN-CHIAO RESERVOIR (SITE B)

RUN OFF MASS CURVE



PROPORTIONED FROM RUN-OFF OBSERVATION AT LIN-WEI STATION

LUNG-SHEN-CHIAO RESERVOIR (SITE B)

STORAGE CAPACITY & REGULATION EFFECT

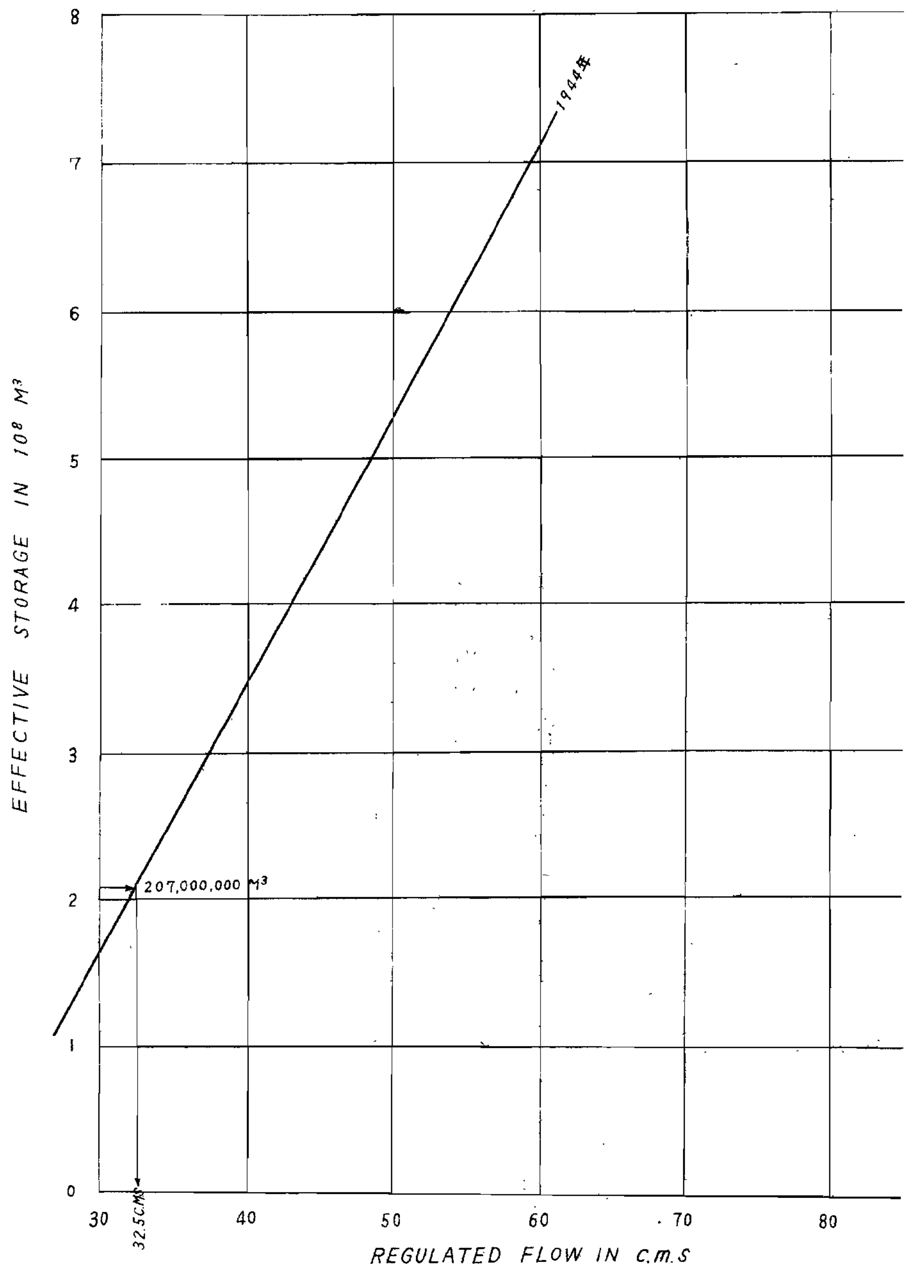
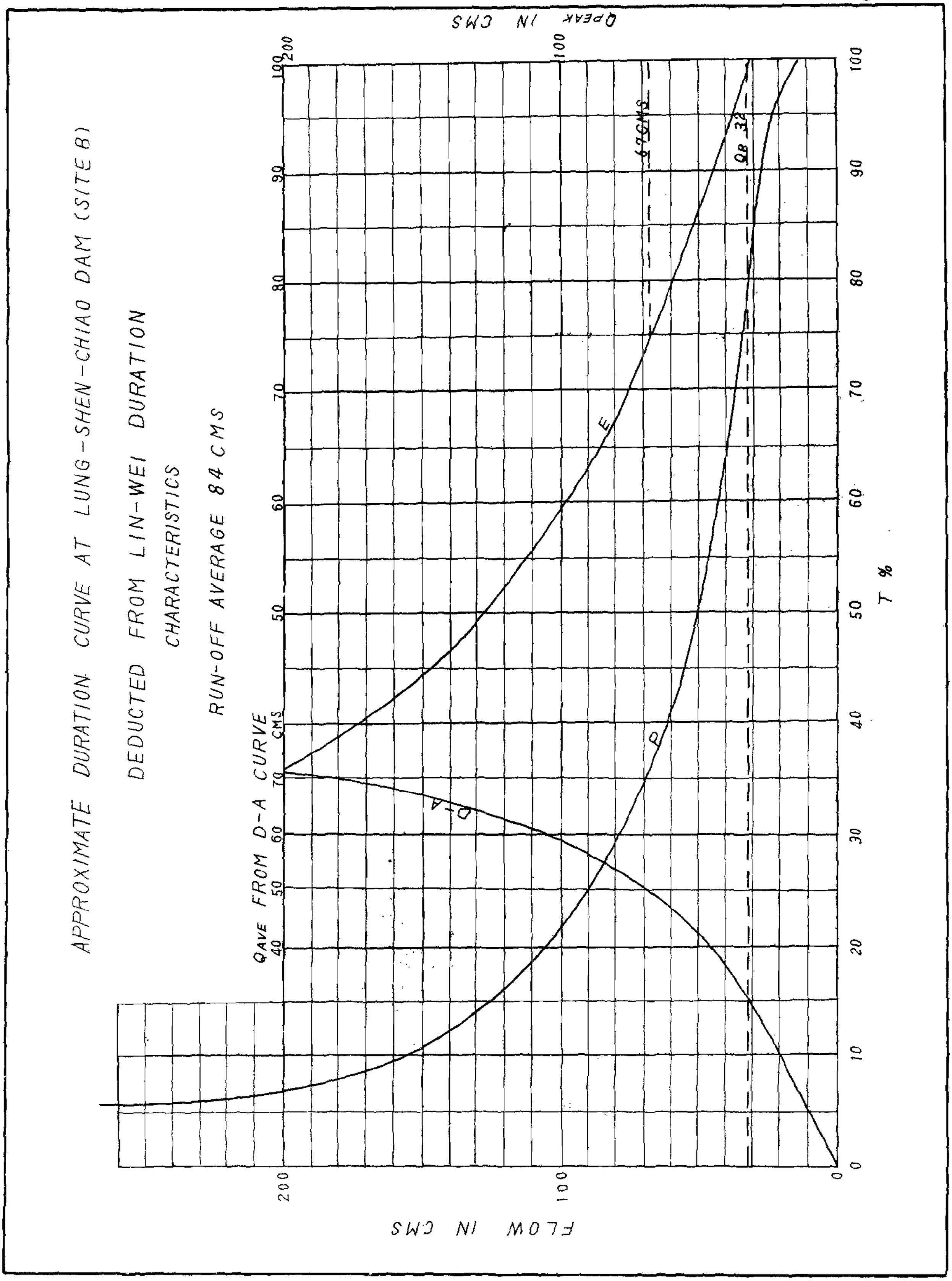
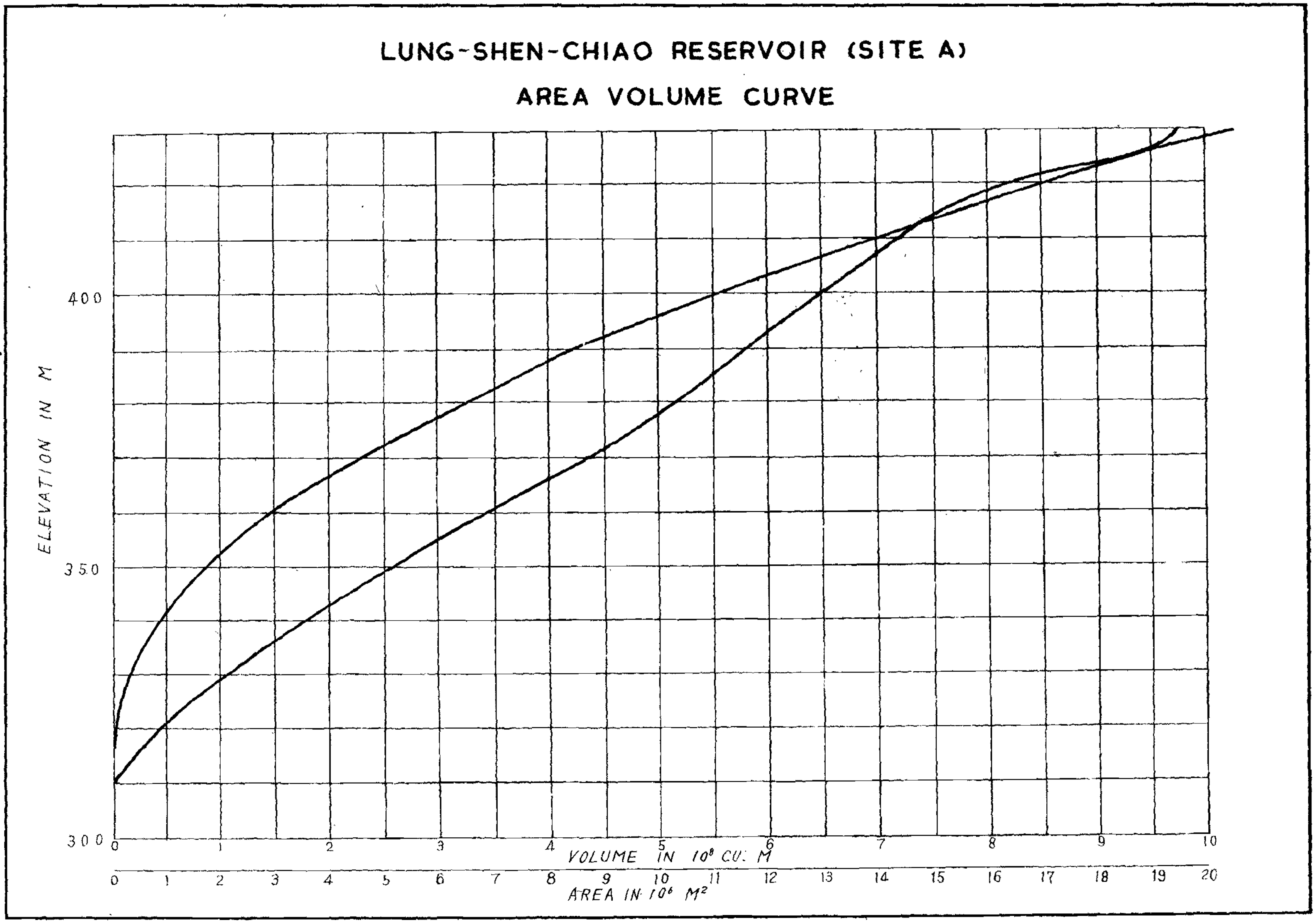


Fig 118



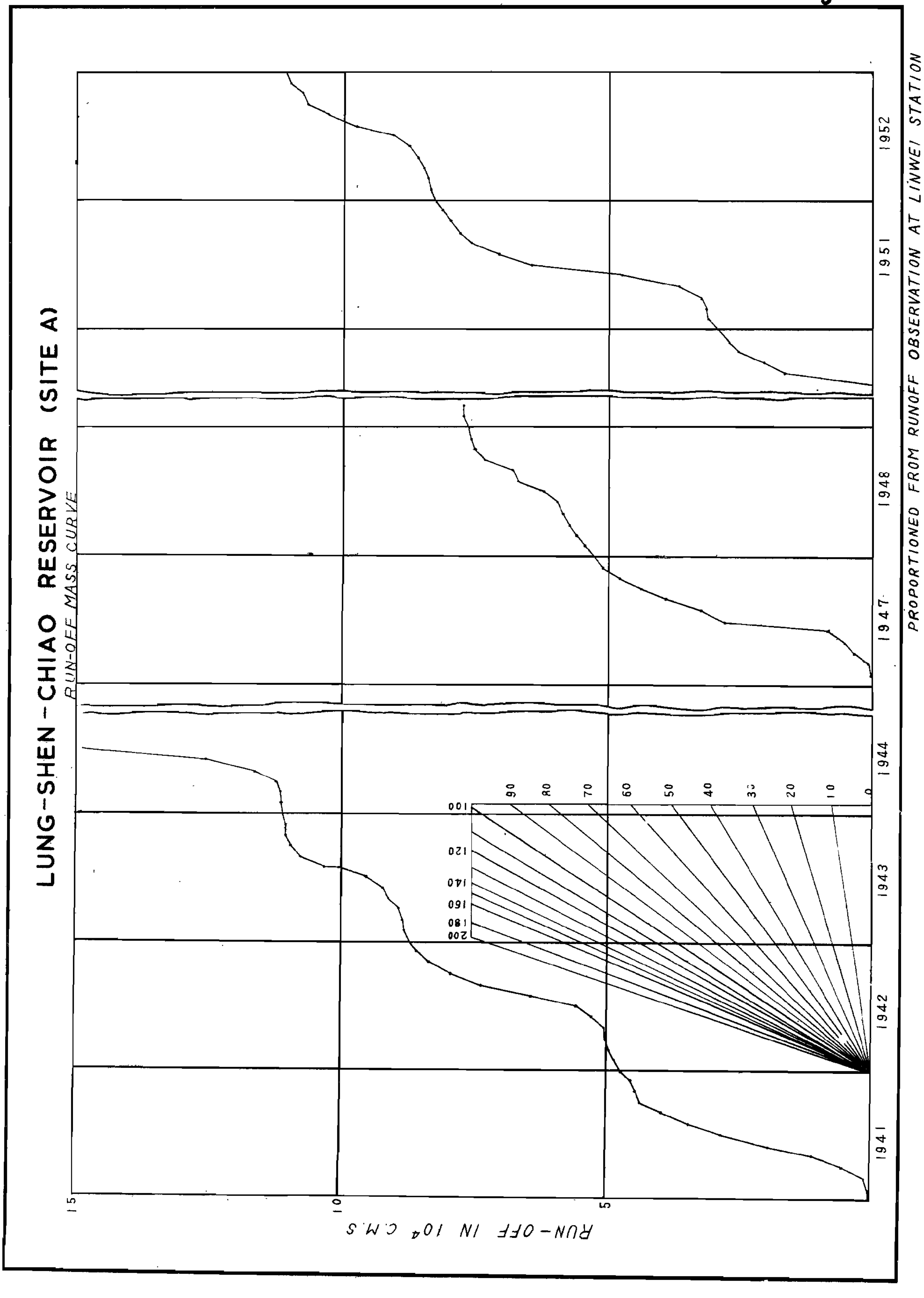
APPROXIMATE DURATION CURVE AT LUNG-SHEN-CHIAO DAM (SITE B)
DEDUCTED FROM LIN-WEI DURATION
CHARACTERISTICS
RUN-OFF AVERAGE 84 CMS
QAVE FROM D-A CURVE
CMS
40
50
60
70
QPEAK IN CMS
200
100
100
90
80
70
60
50
E
P
D-A
67CMS
QB 32
T %
0
10
20
30
40
50
60
70
80
90
100
FLOW IN CMS
200
100
0

Fig 119



FROM" DATA IN LUNG-SHEN-CHIAO RESERVOIR" P.W.C.B

Fig 120



LUNG-SHEN-CHIAO RESERVOIR (SITE A)
RUN-OFF MASS CURVE
RUN-OFF IN 10⁴ C.M.S
15
10
5
1941
1942
1943
1944
1947
1948
1951
1952
100
120
140
160
180
200
90
80
70
60
50
40
30
20
10
0
PROPORTIONED FROM RUNOFF OBSERVATION AT LINWEI STATION

SYNTHETIC UNIT HYDROGRAPH AT LUNG-SHEN-CHIAO RESERVOIR (SITE A)

With 12 hour duration

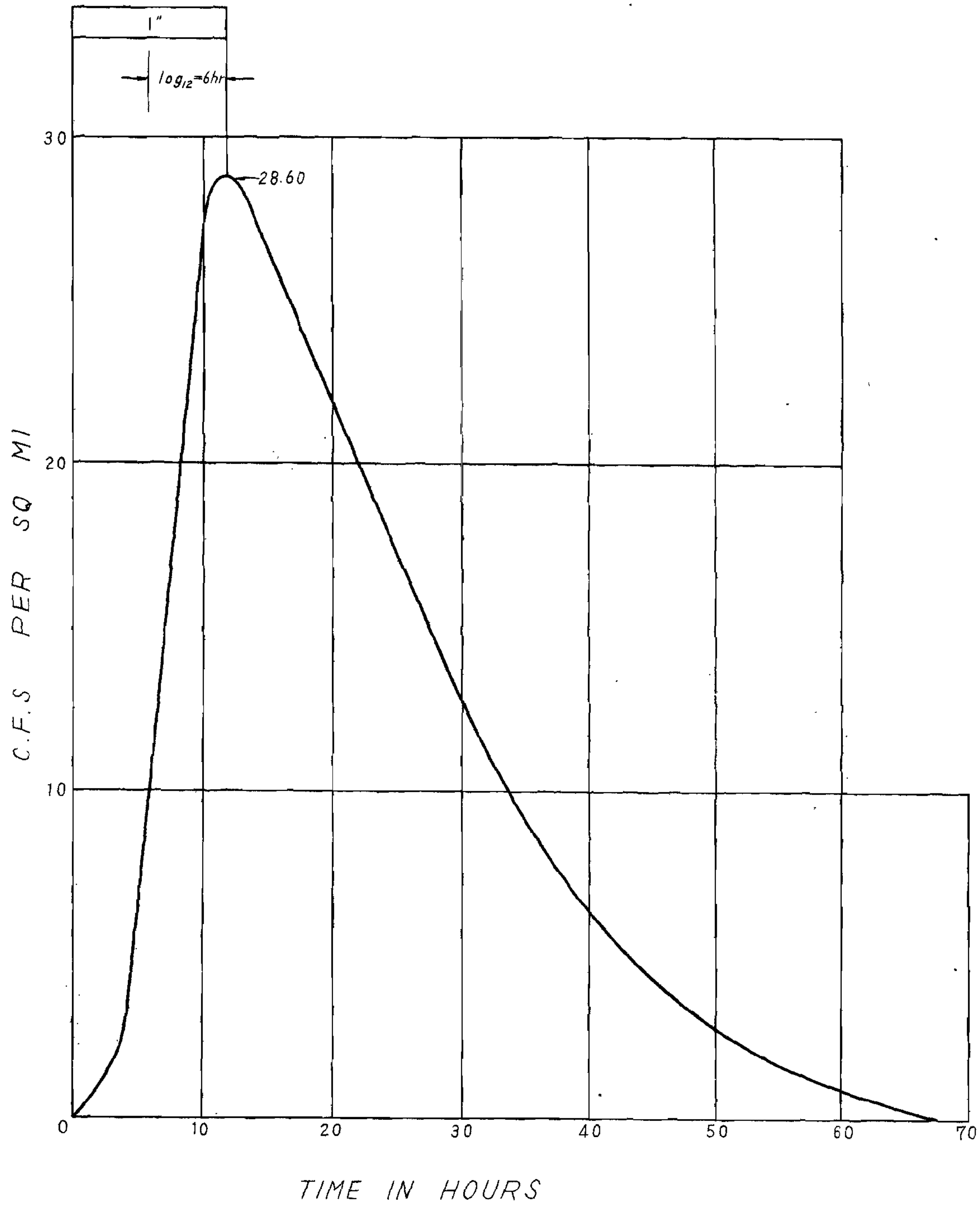
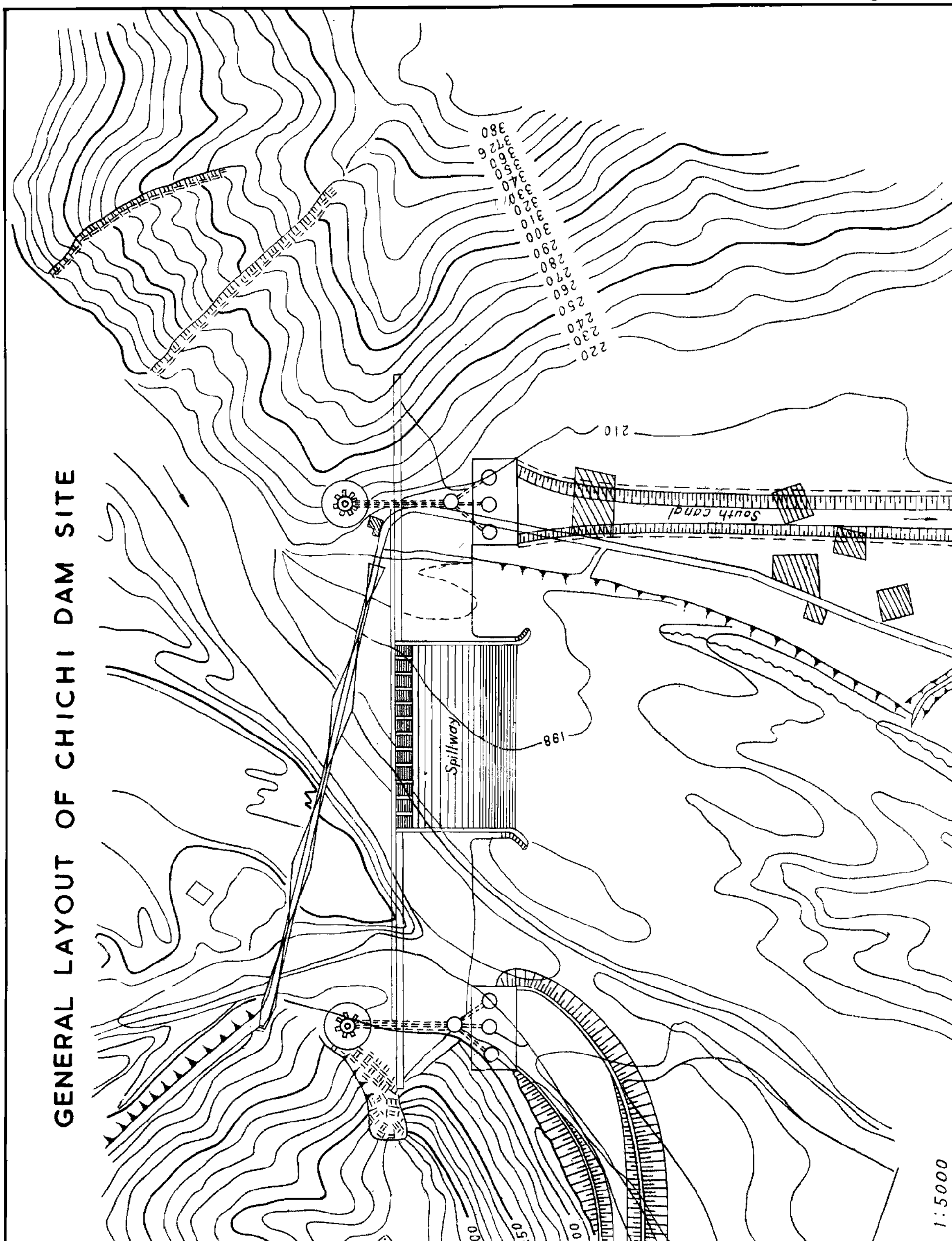


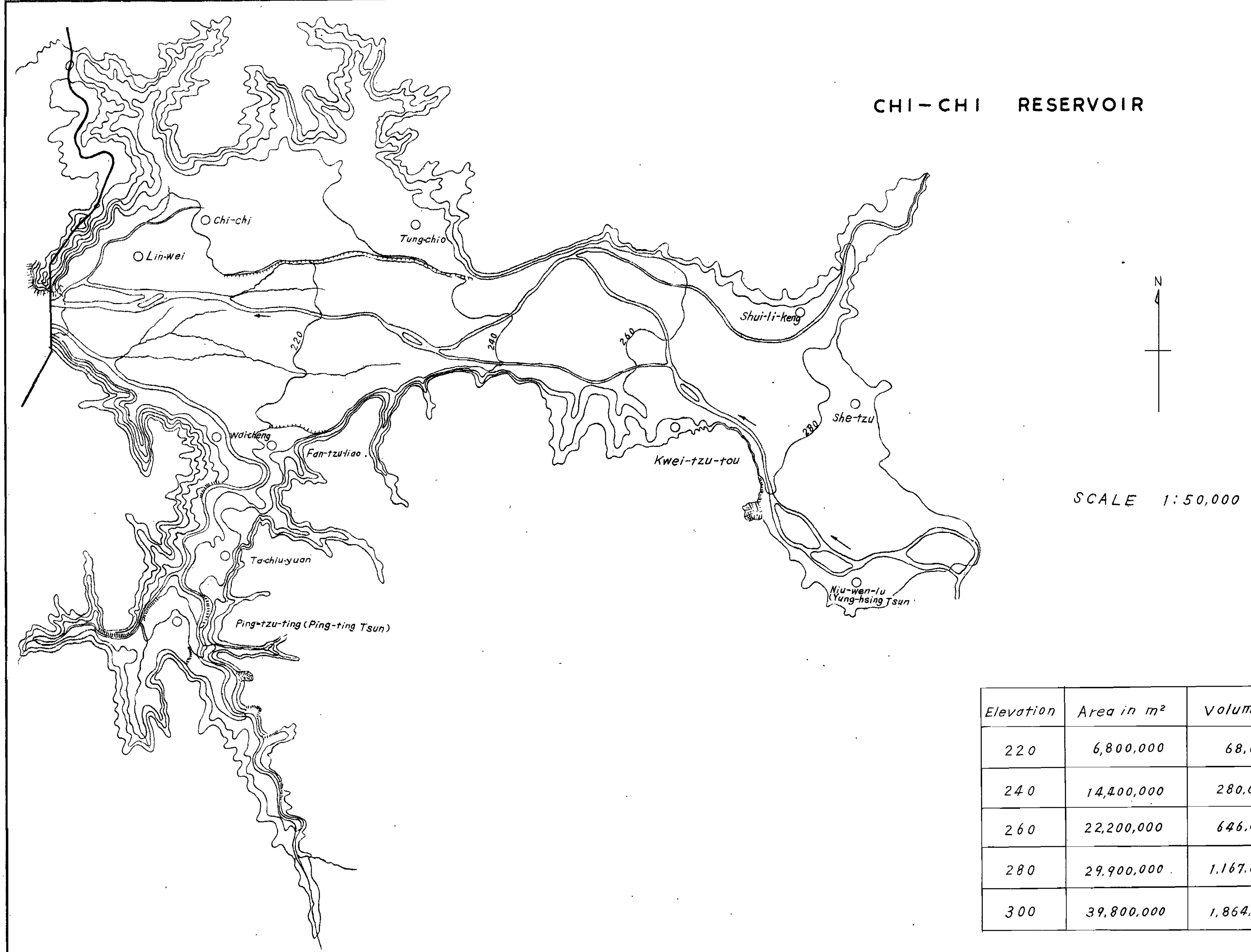
Fig 122



GENERAL LAYOUT OF CHICHI DAM SITE

Fig 123

CHI-CHI RESERVOIR



SCALE 1:50,000

Elevation	Area in m²	Volume in m³
220	6,800,000	68,000,000
240	14,400,000	280,000,000
260	22,200,000	646,000,000
280	29,900,000	1,167,000,000
300	39,800,000	1,864,000,000

Fig 124

CROSS SECTION OF CHI-CHI DAM SITE STRAIGHT GRAVITY TYPE.

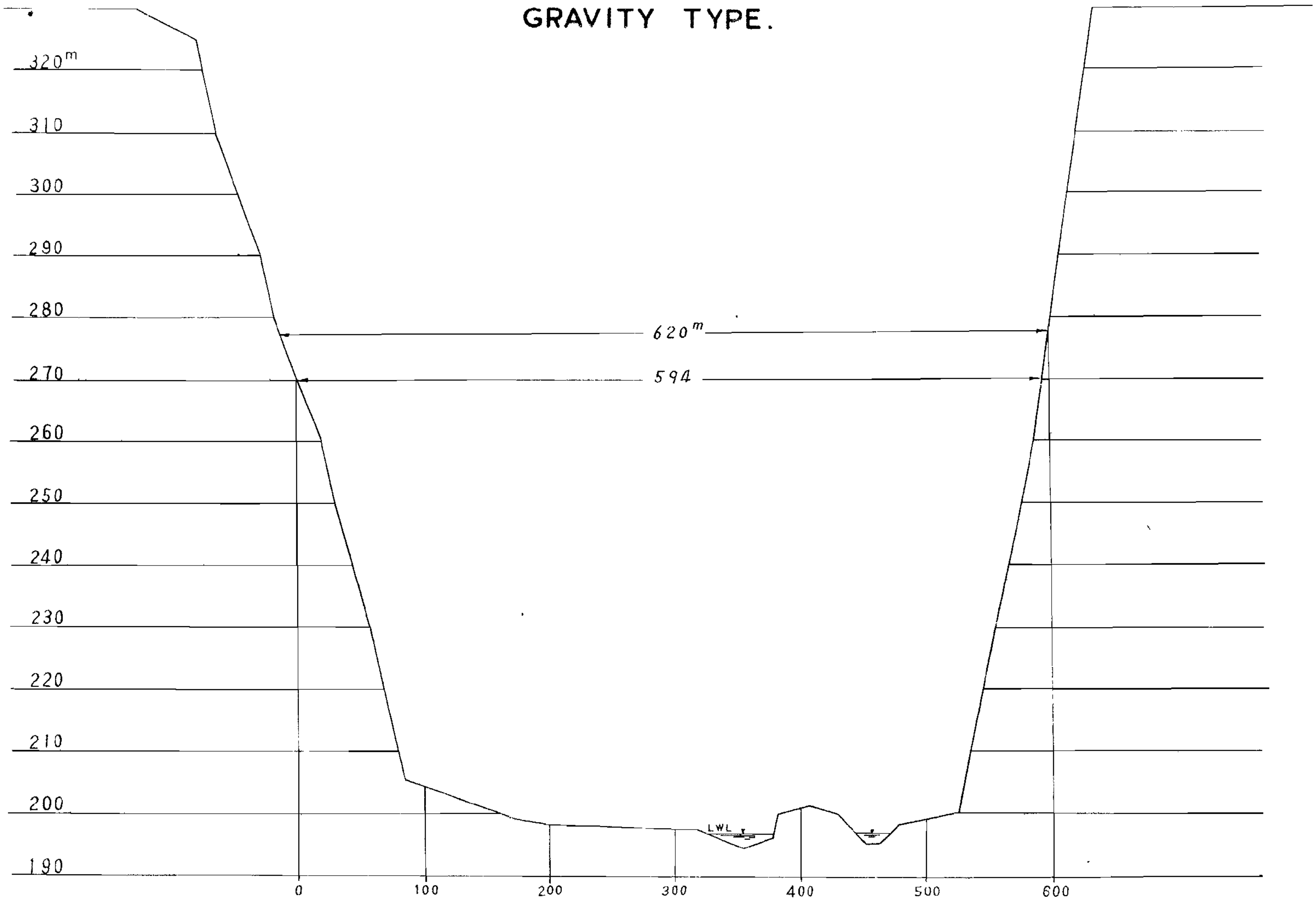


Fig 125

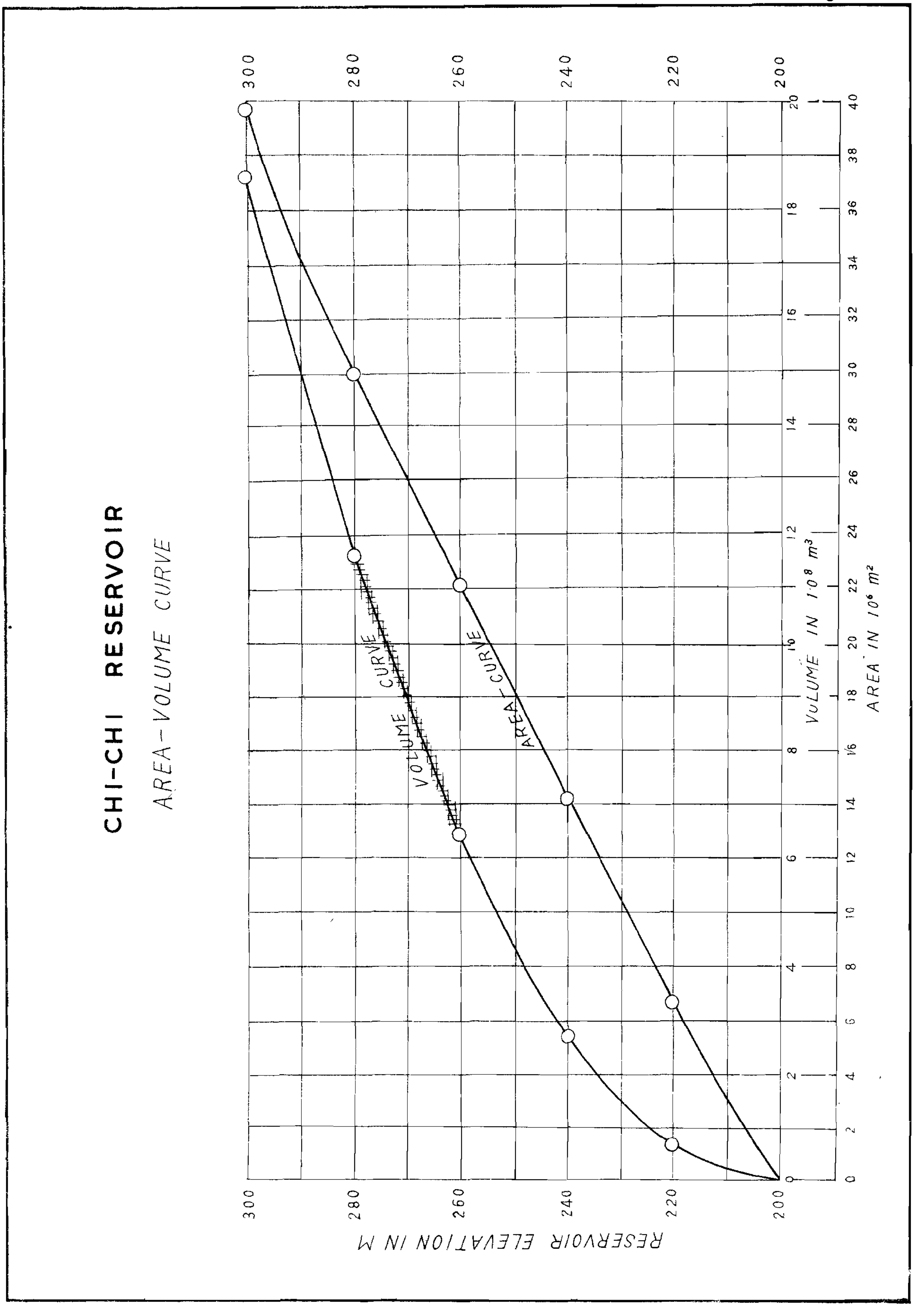
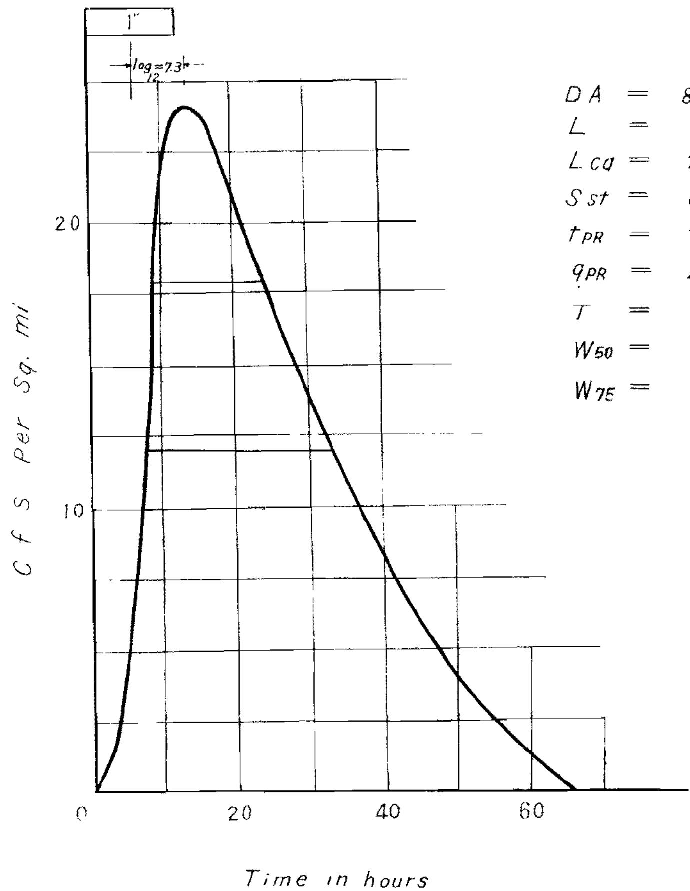

CHI-CHI RESERVOIR
AREA-VOLUME CURVE
VOLUME CURVE
AREA-CURVE
VOLUME IN $1\cdot0^8$ m^3
AREA IN 10^6 m^2
RESERVOIR ELEVATION IN M
300
280
260
240
220
200
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40

Fig 126

SYNTHETIC UNIT HYDROGRAPH AT CHI-CHI RESERVOIR.

With 12 hour duration.



$DA = 889.2\ mi^2$

$L = 72\ mi.$

$L_{ca} = 28.5\ mi$

$S_{st} = 0.00935$

$t_{PR} = 7.30\ hr$

$q_{PR} = 24.\ C.S.m.$

$T = 66.5\ hr$

$W_{50} = 25\ hr$

$W_{75} = 14.5\ hr$

$t_R = 12\ hr$

Fig 127

SYNTHETIC UNIT HYDROGRAPH

CHI-CHI AT RESERVOIR.

With 24 hour duration

$D.A. = 889.2\ mi^2$

$L_{ca} = 28.5\ mi$

$S_{st} = 0.00935$

$q_{PR} = 23.70$ cfs/sq.mi

$T = 103$ hr.

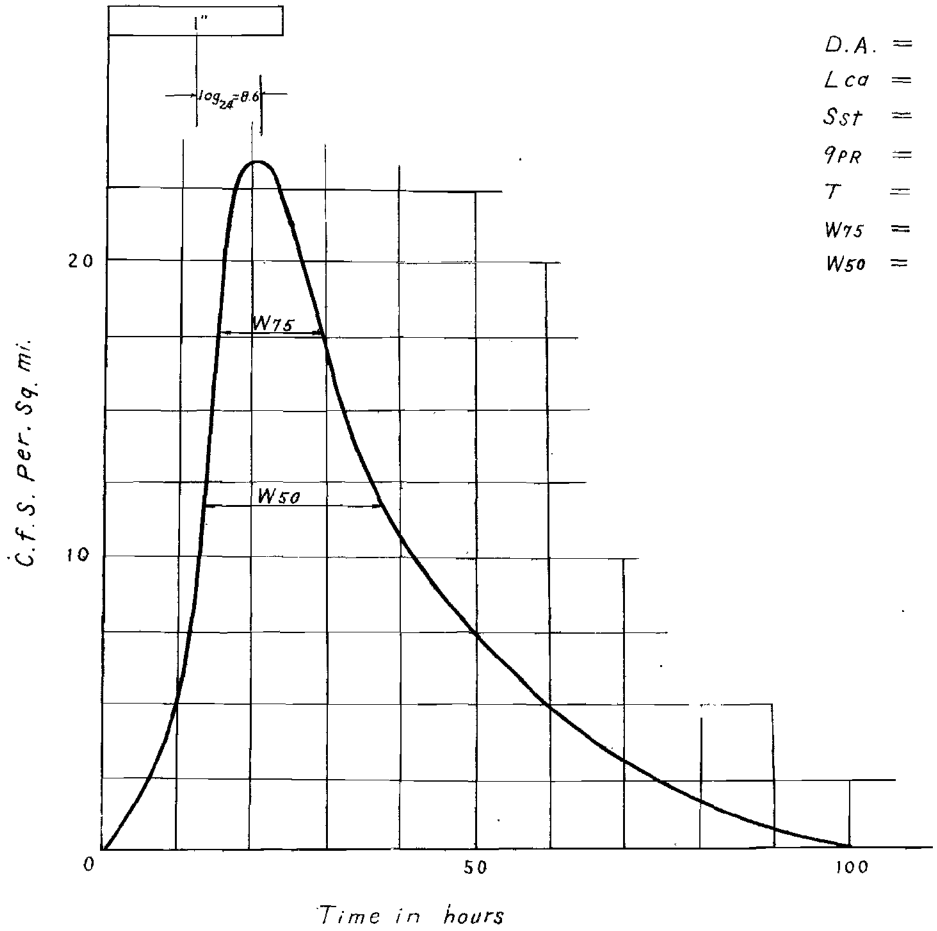
$W_{75} = 14$ hr

$W_{50} = 24$ hr

$L = 72$ mi

$t_R = 24$ hr

$t_{PR} = 8.6$ hr



DETERMINATION OF EQUIVALENT CHO-SHUI CHI SLOPE AT CHI-CHI DAM SITE

STATION	ELEVATION	Δ ELEVATION	L	SI	$\sqrt{SI}$	$1/\sqrt{SI}$
CHI-CHI RESERVOIR DAM SITE	200		L500 ↓			
	214	14		0.00934	0.0965	10.37
	226	12		0.00800	0.0895	11.17
	240	14		0.00934	0.0965	10.37
	260	20		0.01333	0.1154	8.67
	260					
	260					
	270	10		0.00667	0.0816	12.25
	280	10		0.00667	0.0816	12.25
	295	15		0.01000	0.1000	10.00
LUNG-SHEN-CHIAO	297	2		0.00133	0.0364	27.50
	300	3		0.00200	0.0447	22.38
	312	12		0.00800	0.0895	11.17
	329	17		0.01132	0.1064	9.40
	352	23		0.01533	0.1237	8.07
	362	10		0.00670	0.0820	12.20
	371	9		0.00600	0.0775	12.90
	395	24		0.01600	0.1265	7.92
	429	34		0.02262	0.1507	6.64
	443	14		0.00934	0.0965	10.37
	461	18		0.01200	0.1096	9.13
	478	17		0.01132	0.1064	9.40
	492	14		0.00934	0.0965	10.37
	508	16		0.01067	0.1062	9.42
	510	2		0.00133	0.0364	27.50
	521	11		0.00734	0.0856	11.68
	535	14		0.00934	0.0965	10.37
	546	11		0.00734	0.0856	11.68
	549	3		0.00200	0.0447	22.38
	553	4		0.00266	0.0516	19.34
	554	1		0.00067	0.0259	38.60
	557	3		0.00200	0.0447	22.38
	567	12		0.00800	0.0895	11.17
	580	11		0.00734	0.0856	11.68
	597	17		0.01132	0.1064	9.40
	622	25		0.01662	0.1285	7.78
	631	9		0.00600	0.0775	12.90
	640	9		0.00600	0.0775	12.90
	647	7		0.00466	0.0683	14.64
	652	3		0.00200	0.0447	22.38
	668	16		0.01066	0.1062	9.42
	674	6		0.00400	0.0633	15.80
WU-CHIEH DAM	714	40		0.02665	0.1662	6.02
	727	13		0.01250	0.1119	8.94
	740	13		0.01250	0.1119	8.94
TZU-MEI-YUAN	753	13		0.00867	0.0931	10.73
	781	28		0.01870	0.1368	7.32
	797	16		0.01068	0.1033	9.67
I-NA-KO	832	35		0.02333	0.1528	6.55
	847	15		0.01000	0.1000	10.00
	865	18		0.01200	0.1096	9.12
	882	17		0.01131	0.1064	9.40
	897	15		0.01000	0.1000	10.00
	906	9		0.00600	0.0775	12.90
	914	8		0.00534	0.0731	13.66
	933	19		0.01267	0.1125	8.89
	959	26		0.01731	0.1316	7.60
	1000	41		0.02730	0.1650	6.05
	1010	10		0.00667	0.0817	12.24
	1022	12		0.00800	0.0895	11.17
	1040	18		0.01200	0.1096	9.12
	1080	40		0.02666	0.1633	6.12
	1150	70		0.04670	0.2160	4.63
	1185	35		0.02333	0.1528	6.55
	1220	35		0.02333	0.1528	6.55
	1260	40		0.02666	0.1633	6.12
	1304	44		0.02939	0.1713	5.84
TO-LO-KU	1335	31		0.02065	0.1437	6.96
	1375	40		0.02666	0.1633	6.12
	1424	49		0.03263	0.1807	5.53
	1462	38		0.02534	0.1591	6.28
	1600	38		0.02534	0.1591	6.28
	1740	140		0.09330	0.3058	3.27
	1900	160		0.10680	0.3264	3.06
	2100	200		0.13333	0.3650	2.74
	2330	230		0.15333	0.3917	2.56
	2520	190		0.12670	0.3560	2.81
	2760	240		0.16000	0.4000	2.50

$N = 77$ $\Sigma(1/\sqrt{SI}) = 796.19$,

$S_{ST} = [N/\Sigma(1/\sqrt{SI})]^2 = [77/796.19]^2 = 0.00935$

D.A. = 3,303.30 KM^2 = 889.2 SQ.MI.
L = 115.5 KM = 72 MI.
L_{CA} = 45.8 KM = 28.5 MI.
S_{ST} = 0.00935
$LL_{CA} = (72)(28.5) = 2052$

$M' = 0.212(LL_{CA})^{0.36} = 0.212/2052^{0.36}$
$= 0.212/15.8 = 0.0134$
$C' = 0.6/\sqrt{S_{ST}} = 0.6/\sqrt{0.00935}$
$= 0.6/0.0968 = 6.21$
$t_{PR} = C'E^{M't_R} = (6.21)E^{(0.0314)(6)}$
$= (6.21)E^{0.0804} = (6.21)(1.084)$
$= 6.74$ HR ≑ 6.8 HR.
SET t_R = 6 HR

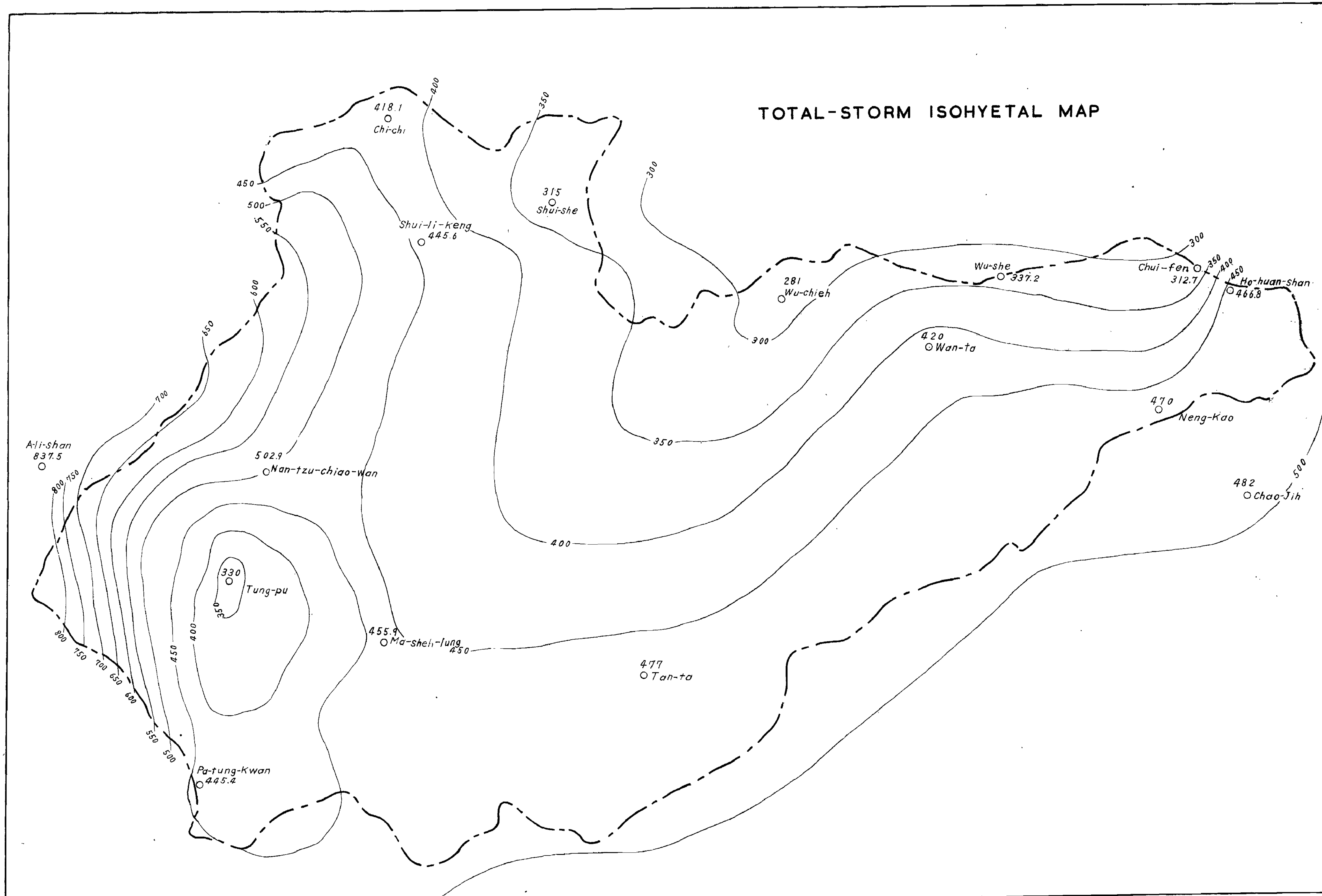
$M'' = -M' + \Delta M''$
$\Delta M'' = 0.121 S_{ST}^{0.142} - 0.050$
$M'' = 0.121 S_{ST}^{0.142} - 0.050 - 0.0134$
$= 0.121 S_{ST}^{0.142} - 0.0634$
$= 0.121(0.00935)^{0.142} - 0.0634$
$= (0.121)\frac{1}{(107)^{0.142}} - 0.0634$
$= (0.121)\frac{1}{1.94} - 0.0634$
$= (0.121)(0.515) - 0.0634$
$= 0.0623 - 0.0634 = -0.0011$
$C'' = 382(LL_{CA})^{-0.36} = 382/15.8 = 24.3$
$q_{PR} = C''E^{M''t_R} = (24.3)E^{(0.0011)(6)}$
$= (24.3)E^{-0.0066} = 24.3/1.009$
$= 24.2$ CFS/SQ.MI.
$T = 5(t_{PR} + t_R/2) = 5(6.8+3) = 49$
W_{50} = 25 HR. W_{75} = 14.5 HR.

$t_{PR} = C'E^{M't_R} = (6.21)E^{(0.0134)(24)}$
$= (6.21)E^{0.322} = (6.21)(1.379)$
$= 8.57 ≑ 8.6$ HOURS.
SET t_R = 24 HR.
$q_{PR} = C''E^{M''t_R} = (24.3)E^{(-0.0011)(24)}$
$= (24.3)E^{-0.0264} = (24.3)/(1.027)$
$= 23.70$ CFS/SQ.MI.
$T = 5(t_{PR} + t_R/2) = 5(8.6+12) = 103$ HR.
W_{50} = 24 HR.
W_{75} = 14 HR.

$t_{PR} = C'E^{M''t_R} = (6.21)E^{(0.0134)(12)}$
$= (6.21)E^{0.16} = (6.21)(1.174)$
$= 7.3$ HR.
SET t_R = 12 HR.
$q_{PR} = C''E^{M''t_R} = (24.3)E^{(-0.0011)(12)}$
$= 24.3E^{-0.0132}$
$= 24.3/1.0136 = 24$ CFS/MI^2
$T = 5(t_{PR} + t_R/2) = 5(7.3+6) = 66.5$ HR.
W_{50} = 25 HR.
W_{75} = 14.5 HR.

Fig 128

Fig 129



TOTAL-STORM ISOHYETAL MAP
418.1 Chi-chi
315 Shui-she
Shui-li-keng 445.6
281 Wu-chieh
Wu-she 337.2
Chui-fen 312.7
Ho-huan-shan 466.8
420 Wan-ta
470 Neng-Kao
482 Chao-Jih
A-li-shan 837.5
502.9 Nan-tzu-chiao-wan
330 Tung-pu
455.9 Ma-sheh-lung
477 Tan-ta
Pa-tung-Kwan 445.4
300
350
400
450
500
550
600
650
700
750
800

Fig 130

COMPUTATION OF DEPTH - AREA FROM ISOHYETAL MAP

LINE NO.	RAINFALL CENTER OR ZONE	ISOHYET M.M.	AREA ENCLOSED		NET AREA IN SQ.KM.	AVERAGE DEPTH OF RAINFALL IN M.M.	VOLUME OF RAINFALL IN M.M. SQ.KM.		AVERAG DEPTH OF RAINFALL IN M.M. (COl.9 ÷ COl.5)
			PLANIMETER READING	AREA IN SQ.KM.			INCREMENT (COl.6×COl.7)	ACCUMULATIVE	
1	2	3	4	5	6	7	8	9	10
1	A	800	17	8	8	800	6.400	6.400	800
2	B	750	16	7	7	750	5.250	11.650	
3	C	725	20	9	9	725	6.520	18.170	
4	D	675	25	12	12	675	8.100	26.270	
5	E	625	90	44	44	625	27.500	53.770	
6	F	575	108	53	53	575	30.500	84.270	
7	G	525	183	90	90	525	47.300	131.570	
8	H	475	1580	780	780	475	370.000	501.570	
9	I	425	1048	517	517	425	220.000	721.570	
10	J	375	706	348	348	375	130.400	851.970	
11	K_1	325	85	42	42	325	13.630		
12	K_2		237	117	117		38.200		
13	K_3		78	38	38		12.350		
14									
15	K	325	400	197	197		64.180	916.150	
16									
17	L_1	300	34	16	16	300	4.800		
18	L_2		11	5	5		1.500		
19									
20	L	300	45	21	21	300	6.300	922.450	
21									
22	M	330	—	STATION	—	—	—	—	330
23		350	12	5	5	340	1.700	1.700	341
24		400	150	74	74	375	25.900	27.600	374
25		450	441	217	217	425	60.700	88.300	407
26				2.303				1.010.750	

AVERAGE DEPTH OF RAINFALL $= \frac{1.010.750}{2.303} = 440$ M.M.

MONTHLY RUN-OFF RECORD

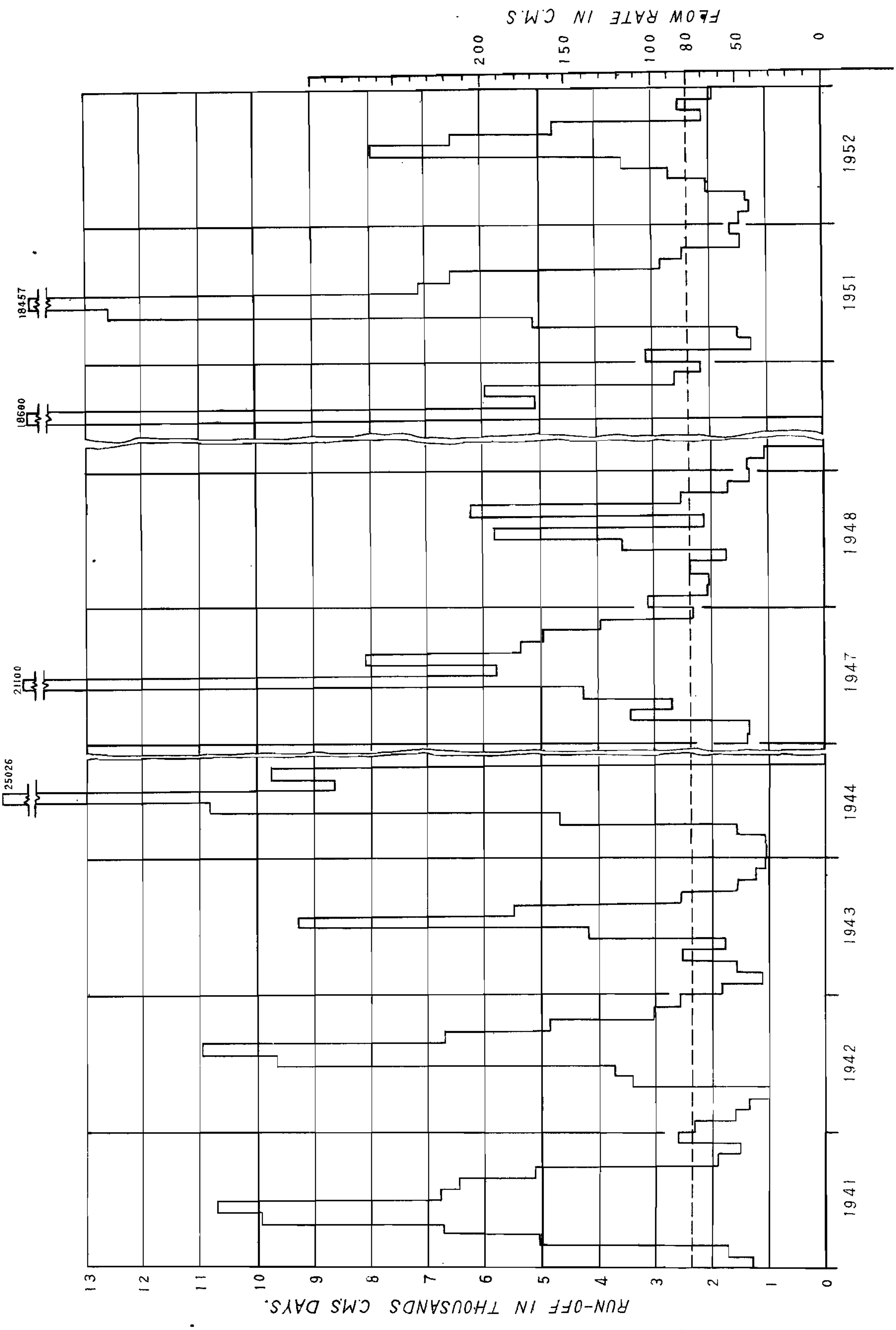
CHO-SUI CHI, AT LIN-WEI STATION

UNIT : C.M.S. DAYS

MO. \ YE.	1941	1942	1943	1944	1947	1948	1949	1950	1951	1952
1	1311.483	2337.102	1861.535	1053.541	1409.917	3140.00	1397.50		3138.088	1502.347
2	1764.015	1600.250	1124.022	1087.978	1358.002	2057.00	1034.00		1289.022	1315.438
3	5081.714	1351.285	1586.437	1594.243	3446.608	2014.00			1517.050	1384.882
4	6783.617	1001.471	2553.428	4691.139	2700.555	2399.00			5110.809	2047.747
5	9942.018	3425..041	1797.770	10836.040	4248.649	1747.79			12582.202	2736.283
6	10072.424	3748.407	4193.772	25026.713	21103.923	3598.50			18457.924	3556.368
7	6817.584	9693.914	9266.949	8625.526	5800.903	5825.05			7117.087	7996.007
8	6483.673	11057.250	5491.854	9787.784	8105.329	2118.84		18680.295	6575.817	6548.402
9	5131.726	6715.747	2566.396		5370.075	6226.00		5027.500	2897.057	4752.052
10	1924.105	4881.871	1577.634		4968.264	2532.00		5997.500	2472.469	2139.082
11	1517.923	3009.440	1244.795		3979.773	1709.71		2662.500	2471.950	2535.178
12	2653.232	2585.371	1068.384		2356.214	1315.00		2153.282	2686.934	1930.843

Fig 132

MONTHLY RUN-OFF HYDROGRAPH AT LIN-WEI STATION



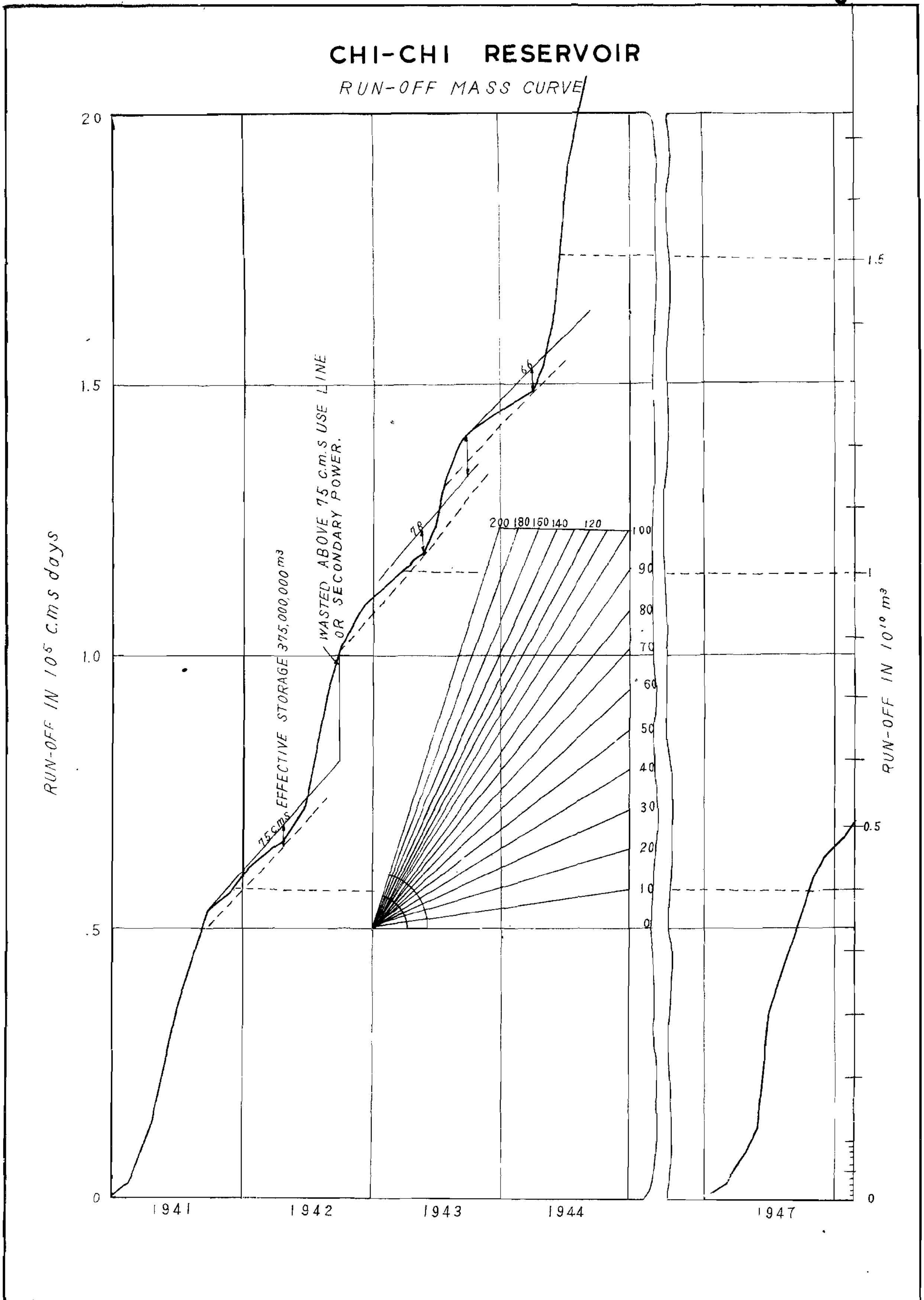
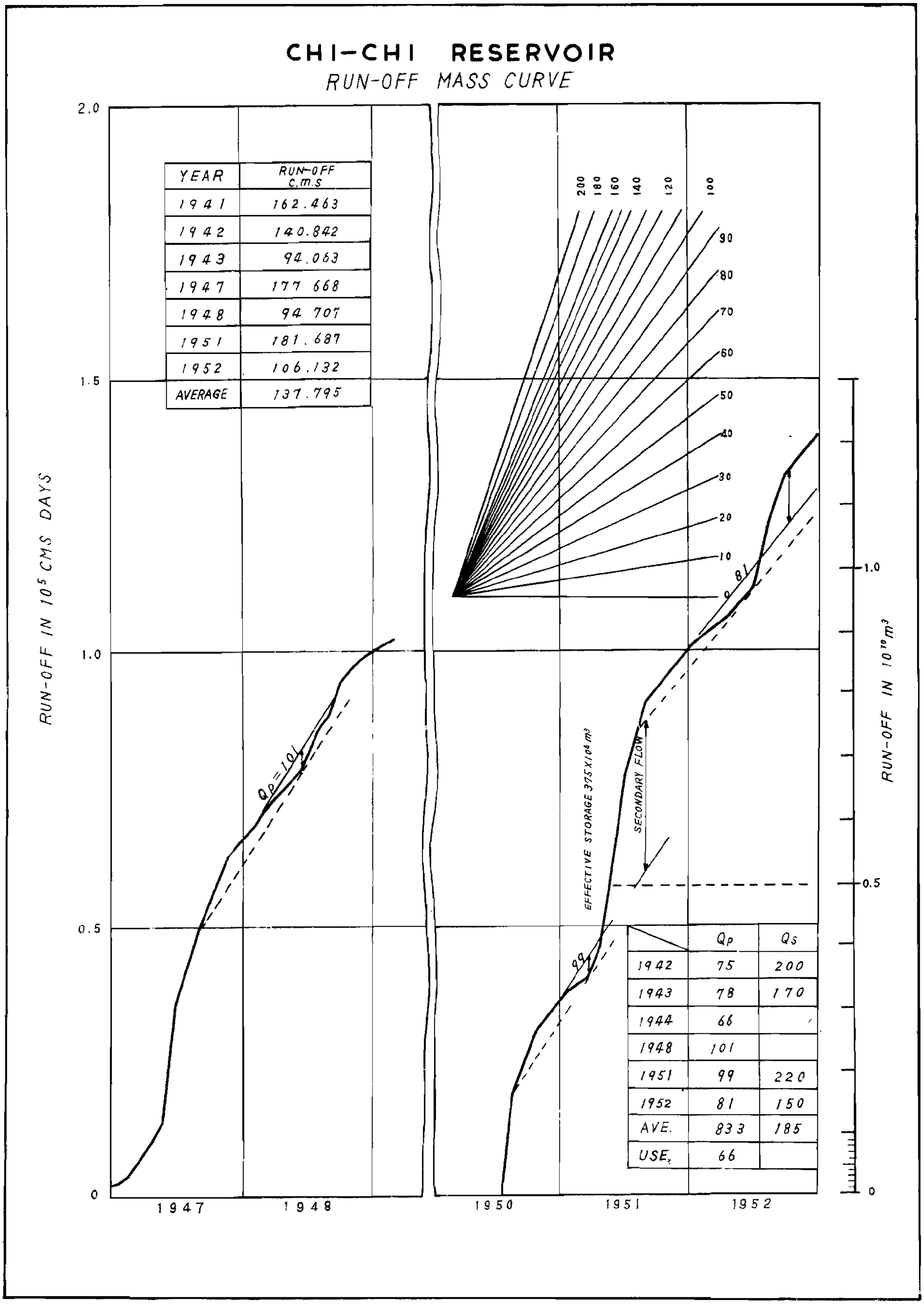

CHI-CHI RESERVOIR
RUN-OFF MASS CURVE
RUN-OFF IN 10⁵ C.m.s days
RUN-OFF IN 10¹⁰ m³
EFFECTIVE STORAGE 375,000,000 m³
WASTED ABOVE 75 C.m.s USE LINE
OR SECONDARY POWER.
75 c.m.s
78
66
200 180 160 140 120
100
90
80
70
60
50
40
30
20
10
0
2.0
1.5
1.0
.5
0
1.5
1
0.5
0
1941
1942
1943
1944
1947

Fig 134



YEAR	RUN-OFF C.m.s
1941	162.463
1942	140.842
1943	94.063
1947	177 668
1948	94 707
1951	181.687
1952	106.132
AVERAGE	137.795

	Q_P	Q_S
1942	75	200
1943	78	170
1944	66	
1948	101	
1951	99	220
1952	81	150
AVE.	83 3	185
USE.	66	

Fig 135

MAXIMUM DAILY DISCHARGE AT LIN-WEI STATION

ORDER	1	2	3	4	5	6	7
1941	1547 JUNE 16	1186 APR 26	1870 MAY 27	669 AUG 18	575 AUG 26	494 JUN 1	464 JUL 24
1942	697 AUG 9	612 JUL 8	603 AUG 12	499 JUL 21	480 SEP 12	464 JUL 25	
1943	1902 JUL 18	1470 JUL 8	327 JUL 21	310 JUL 13	291 JUN 23	245 AUG 18	238 AUG 8
1944	1408 AUG 14	1320 JUN 25	1235 JUN 17	1076 JUN 12	1063 JUN 9	1062 JUN 14	705 JUL 2
1947	3152 JUN 16	2582 AGU 29	1262 JUL 14	969 JUN 7	711 OCT 7	697 JUN 10	690 JUN 22
1948	1920 JUL 6	1781 SEP 6	350 SEP 17	267 SEP 12	225 JUL 10		
1950	1146 AUG 1	1108 AUG 16	854 JUL 27	746 AUG 3	583 AUG 12	535 SEP 4	461 AUG 26
1951	1307 APR 11	1289 JUN 16	1154 MAY 19	1021 JUN 19	980 MAY 21	779 JUN 9	765 AUG 14
1952	1273 JUL 30	864 JUL 19	573 NOV 14	421 SEP 2	272 AUG 6	258 JUL 26	232 AUG 9
REMARKS							

Fig 136

SEASONAL DISTRIBUTION OF FLOOD FLOW

DATA AT LIN-WEI STA.

Q. \ MO.	J	F	M	A	M	J	J	A	S	O	N	D	Σ	NOTE
500								2	1		1		4	OCCURRENCE OF Q > 500 C.M.S.
600						2		3					5	
700						2		2		1			5	
800					1	1	1						3	
900					1	1							2	
1000						4							4	
1100				1	1			2					4	
1200						3	1						4	
1300				1		1							2	
1400							1	1					2	
1500						1			1				2	
1900							2						2	
2500								1					1	
3100						1							1	
Σ	0	0	0	2	3	16	5	11	2	1	1	0	41	
%	0	0	0	4.88	7.31	39	12.2	37.3	4.88	2.44	2.44	0	100	

EVAPORATION RECORD

AT LIN-WEI STATION

UNIT: M.M.

YE. / MO.	1948	1951	1952
1		22.9	50.9
2		69.2	49.1
3		25.8	68.5
4		40.9	70.5
5		84.1	86.2
6	75.7	85.6	90.2
7	92.2	113.5	71.5
8	92.3	93.3	93.4
9	68.6	76.8	95.4
10	81.0	69.4	101.7
11	42.6	60.1	77.9
12	32.2	56.4	37.6
Σ	484.4	798.0	892.9

SUN-MOON-LAKE SYSTEM FLOW REGULATION

ORIGINAL PLAN

UNIT: C.M.S.

Q / MO.	CHO-SUI CHI DISCHARGE AT WU-CHIEH	INTAKE DISCHARGE WU CHIEH	MEAN USE OF SUN-MOON-LAKE W.P. SYSTEM
1	9.34	8.34	25.04
2	9.71	8.62	25.04
3	21.70	19.47	25.04
4	26.29	23.65	25.04
5	34.00	29.49	25.04
6	54.31	41.13	25.04
7	64.19	43.76	25.04
8	64.75	43.96	25.04
9	53.92	38.12	25.04
10	30.69	26.43	25.04
11	27.73	20.59	25.04
12	14.66	13.35	25.04
13	33.92	27.54	25.04

CHI-CHI RESERVOIR SILT CONCENTRATION AT LIN-WEI ST. (1948)

Q = FLOW IN C.M.S.
P = SILT CONCENTRATION IN PERCENT BY WEIGHT.
PQ = TOTAL SILT DISCHARGE IN TON PER SECOND DAYS.

ΣPQ = 238.1793 TONS DAYS.
ΣQ = 34682.89 C.M.S. DAYS.

$\frac{\Sigma PQ}{\Sigma Q} = 0.6875\ \%$ = P ANNUAL

$\frac{\Sigma P}{n} = \frac{3.82276}{12} = 0.3186\ \%$

DATE \ MO.	1 Q C.M.S.	1 ΣQ (period)	1 P %	1 PQ (Ton/s)day	2 Q	2 ΣQ (period)	2 P	2 PQ	3 Q	3 ΣQ (period)	3 P	3 PQ
1	200.00				86.00				66.00			
2	200.00				102.00	340	0.133	0.452	67.00	273	0.055	0.150
3	150.00				80.00				70.00			
4	155.00				72.00				70.00			
5	145.00				70.00				66.00			
6	135.00				69.00	267	0.28	0.748	67.00	261	0.051	0.133
7	120.00				72.00				66.00			
8	110.00				56.00				62.00			
9	105.00	2185.00			70.00				64.00			
10	100.00				72.00	214	0.084	0.180	66.00	196	0.044	0.0862
11	105.00				72.00				66.00			
12	105.00				69.00	200	0.074	0.148	66.00	194	0.034	0.066
13	100.00				66.00				66.00			
14	100.00				65.00				62.00			
15	90.00				65.00				64.00			
16	90.00		0.175	3.06	64.00	267	0.118	0.304	63.00	256	0.048	0.123
17	90.00				69.00				65.00			
18	85.00				69.00				64.00			
19	75.00	145			69.00				64.00			
20	70.00		0.155	0.24	69.00	207	0.094	0.1945	64.00	191	0.05	0.0955
21	69.00	225	0.165	0.371	69.00				63.00			
22	78.00				66.00	207	0.095	0.1967	65.00	195	0.048	0.0935
23	78.00				69.00				64.00			
24	74.00				72.00				66.00			
25	68.00				80.00				64.00			
26	70.00	370	0.15	0.555	72.00	221	0.052	0.115	64.00	256	0.045	0.115
27	78.00				69.00				64.00			
28	80.00				66.00				64.00			
29	75.00				66.00	132	0.049	0.0647	64.00			
30	70.00	215	0.13	0.279					64.00	192	0.046	0.0883
31	70.00								64.00			
Σ	3140.00		0.775	4.505	2057.00		0.984	2.4029	2014.00		0.421	0.8911
Arithmetic AVE.	101.29		0.135		70.93		0.1093		64.76		0.0468	
True PQ/ΣQ			0.144				0.117				0.0443	

DATE \ MO.	4 Q	4 ΣQ (period)	4 P	4 PQ	5 Q	5 ΣQ (period)	5 P	5 PQ	6 Q	6 ΣQ (period)	6 P	6 PQ
1	62.00				94.72				60.55			
2	62.00	186	0.03	0.0558	83.29	257.96	0.13	0.335	67.71	273.31	0.12	0.328
3	62.00				79.95				68.20			
4	61.00				64.35				76.85			
5	62.00				60.54	252.42	0.12	0.333	76.90			
6	63.00	313	0.03	0.0939	65.47				71.62	383.02	0.10	0.383
7	64.00				62.06				108.29			
8	63.00				73.76				126.21			
9	63.00				59.62	133.38	0.06	0.08	113.64			
10	63.00	187	0.04	0.0748	53.88		0.06	0.1165	108.57	354.78	0.34	1.206
11	61.00				48.45	193.89			132.75			
12	67.00		0.04	0.0796	46.16				117.83	340.11	0.345	1.173
13	66.00	199			45.40				113.10			
14	66.00				43.94				109.18			
15	64.00				47.15				107.97			
16	64.00	273	0.18	0.492	41.67	218.92	0.05	0.094	91.31	429.68	0.33	1.416
17	69.00				42.17				80.89			
18	76.00				43.99				149.51			
19	70.00				43.31				174.55			
20	70.00	210	0.05	0.105	47.31	140.1	0.05	0.07005	189.63	553.40	0.15	0.83
21	70.00				49.48				189.22			
22	102.00		0.05	0.1505	48.07	147.53	0.04	0.059	192.36	521.46	0.45	2347
23	95.00	299			46.71				187.07			
24	102.00				52.75				142.03			
25	134.00				53.74				136.40			
26	86.00	496	0.79	3.92	48.50	225.57	0.10	0.0226	131.67	530.55	0.35	1.860
27	158.00				61.84				134.01			
28	118.00				61.49				128.47			
29	118.00	236	1.00	2.36	55.74				124.42	223.2		
30	118.00				60.13	177.72	0.11	0.1956	98.78		0.32	0.715
31					61.85							
Σ	2399.00		2.21	7.3319	1747.79		0.72	1.2491	3598.50		2.505	10.258
Arithmetic AVE.	79.93		8.2454		56.38		0.08		119.95		0.2777	
True PQ/ΣQ			0.306				0.0715				0.286	

DATE \ MO.	7 Q	7 ΣQ (period)	7 P	7 PQ	8 Q	8 ΣQ (period)	8 P	8 PQ	9 Q	9 ΣQ (period)	9 P	9 PQ
1	87.42				71.50				53.00	107		0.182
2	85.04	244.37	0.33	0.807	71.37	214.36	0.22	0.472	54.00			
3	71.91				71.49				55.00			
4	72.26				67.51				52.00			
5	98.05				67.50				52.00			
6	1920.00	2970.31	3.19	95.00	69.51	345.53	0.19	0.656	(1781.94) 1245.00	2880.94	3.19	53.80
7	670.00				71.50				330.00			
8	210.00				69.51				320.00			
9	220.00				67.79				290.00			
10	225.00	643.08	1.33	8.55	67.69	210.26	0.22	0.468	275.00			
11	198.08				74.78				255.00			
12	161.31	398.43	0.63	2.510	65.95	208.45	0.18	0.375	(267.43) 258.00	1220.43	0.96	11.70
13	124.33				67.75				215.00			
14	112.79				74.75				208.00			
15	119.83				71.56				210.00			
16	127.98	462.29	0.42	1.94	76.50	280.35	0.16	0.449	(213.54) 208.00	873.54	0.78	6.81
17	104.09				71.49				350.00			
18	110.39				60.80				310.00			
19	180.00				65.95				220.00			
20	165.00	422.14	0.31	1.31	67.79	201.53	0.65	1.31	158.00			
21	77.14				67.79				(147.41) 136.00	791.41	0.59	4.61
22	75.12	215.88	0.30	0.647	71.49	230.54	0.19	0.438	128.00			
23	70.53				98.04				138.00			
24	70.23				61.01				127.00			
25	66.98				59.21				127.00			
26	60.83	245.86	0.36	0.885	64.41	269.74	0.23	0.62	(133.63) 118.00	643.63	0.64	4.12
27	57.53				74.57				93.00			
28	60.52				71.55				82.00			
29	90.18				57.45				81.00			
30	72.53	222.69	0.25	0.5565	52.79	996.5	0.17	0.169	78.00			0.218
31	59.98				46.86							
Σ	5825.65		7.12	112.206	2118.84		2.21	4.957	6226.00		6.16	81.44
Arithmetic AVE.	187.90		0.791		68.35		0.24556		207.53		1.232	
True PQ/ΣQ			1.93				0.234				1.310	

DATE \ MO.	10 Q	10 ΣQ (period)	10 P	10	11 Q	11 ΣQ (period)	11 P	11	12 Q	12 ΣQ (period)	12 P	12
1	112.00				60.39				54.00			
2	108.00	428	0.28	1.20	60.39	238.28	0.12	0.286	(51.23) 48.00	199.23	0.11	0.219
3	108.00				58.75				47.00			
4	100.00				58.75				47.00			
5	96.00				57.92				46.00			
6	94.00	372	0.27	1.004	57.09*	229.52	0.11	0.2525	48.00	181.00	0.37	0.670
7	92.00				59.08				47.00			
8	90.00				55.43				40.00			
9	90.00				64.54				39.00			
10	88.00				95.25				42.00			
11	88.00	439	0.24	1.078	92.25	384.48	0.82	3.15	43.00	203.00	0.10	0.203
12	86.00				72.05				39.00			
13	87.00				60.39				40.00			
14	88.00				57.92				46.00			
15	84.00				57.92				42.00			
16	(79.90) 75.00	325.9	0.19	0.62	64.20	292.96	0.37	1.086	46.00	229.00	0.07	
17	74.00				56.56				47.00			
18	72.00				56.36				48.00			
19	68.00				52.94				40.00			
20	69.00				52.11				42.00			
21	69.00	343	0.13	0.446	47.95	248.07	0.25	0.62	(50.82) 42.00	214.82	0.07	0.527
22	68.00				47.12				41.00			
23	69.00				47.95				41.00			
24	68.00				47.12				40.00			
25	67.00				46.29				36.00			
26	(49.11) 72.00	447	0.16	0.715	45.49	272.89	0.23	0.628	(41.19) 33.00	308.19	0.07	
27	69.00				46.33				37.00			
28	72.00				43.83				40.00			
29	72.00				43.83				37.00			
30	69.00				43.01			0.0473	36.00			
31	68.00	137		0.1645					41.00			
Σ	2532.00		1.27	5.227	1709.71		1.90	6.0923	1315.00		0.79	1.619
Arithmetic AVE.	81.67		0.2116		56.99		0.3167		42.42		0.13167	
True PQ/ΣQ			0.207				0.358				0.1233	

Fig 138

CHI-CHI RESERVOIR SILT CONCENTRATION AT LIN-WEI ST. (1951)

$\Sigma PQ = 374.1046$

$\Sigma Q = 66316.409$

$P = \frac{\Sigma PQ}{\Sigma Q} = 0.564\ \%$

$\frac{\Sigma P}{n} = \frac{3.522}{11} = 0.32\ \%$

	1				2				3			
	Q		P		Q		P		Q		P	
1	60.000				46.128				46.565			
2	74.000		0.066	0.244	50.014				46.128			
3	81.000	369.5			46.344				45.131			
4	79.500				47.381				40.522			
5	75.000				44.921				45.917			
	72.500				46.344				46.128			
7	69.500				43.756				46.344			
8	69.500				39.531				47.602			
9	72.500				43.756				46.565			
10	74.000				44.921				44.921			
11	75.000				38.762				38.762			
12	75.000	1285.525			45.131				47.381			
13	69.500				47.602				48.676			
14	77.500				50.014				48.676			
15	126.074		0.015	0.193	48.676				47.381			
16	132.985				50.482				47.602			
17	123.547				54.289				47.381			
18	124.372				46.344				42.835			
19	123.547				47.602				48.676			
20	123.547				44.912				48.903			
21	122.810				47.602				47.602			
22	122.579				43.962				47.381			
23	123.583				43.962				40.158			
24	128.109	987.723	0.015	0.148	47.829				40.522			
25	124.609				39.716				36.654			
26	121.354				46.344				40.522			
27	121.132				46.344				40.522			
28	123.079				46.344				41.556			
29	125.085								45.347			
30	125.322								116.653		0.32	0.324
31	121.854		0.000	0.00					98.036		0.10	0.098
Σ	3138.088		0.030	0.585	1289.022				1517.050		0.42	0.422
AVE	101.229		0.010		46.036				48.944		0.21	
P			0.01865								0.0278	

	4				5				6			
	Q		P		Q		P		Q		P	
1	63.157				68.535			0.151	553.373			
2	58.743	214.65		0.214	71.136				520.792	1567.043		6.19
3	47.623				65.973	261.563			492.878			
4	45.127				62.222		0.06	0.157	538.766			
5	53.352				62.222				483.260			
	60.081				62.222				463.285			
7	154.909				62.222		0.05	0.248	463.513			
8	152.644	550.581	0.19	1.045	75.133				466.709			
9	129.595				99.936	496.534			779.166	6616.954		
10	624.599				71.146				742.229			
11	1307.565	257.375	1.833	4.72	65.973				621.365			
12	375.150				59.762				550.999		0.367	24.25
13	266.436				56.167				619.959			
14	229.565				67.248				887.683			
15	170.112		0.35	3.77	384.201	2783.646			1095.071	2385.006		
16	148.440				751.477				1289.702		0.15	3.580
17	130.019	1077.409			582.396				866.863			
18	114.483				942.077		1.97	54.9	723.617		2.403	96.12
19	104.675				1154.127		2.11		1021.510			
20	92.281				821.549	379.405			945.753	4000.766		
21	87.834				280.822			80.0	699.145			
22	80.667				835.035				610.741			
23	80.667				717.612				536.684			
24	80.667				700.972				438.274			
25	73.805	694.419			624.599				423.418			
26	73.805				538.040		0.395	20.45	371.670	3021.545		
27	68.535				474.799	5780.421			339.664		0.52	15.71
28	65.973		0.22	1.53	438.098				299.188			
29	93.787				431.583				339.546			
30	76.513				582.396				273.101			
31					672.322							
Σ	2794.434		2.593	11.279	12582.202		4.585	155.906	18457.924		3.44	145.84
AVE	170.363		0.6483		405.877		0.917		615.624		0.86	
P			0.404				1.14				0.792	

	7				8				9			
	Q		P		Q		P		Q		P	
1	313.443				108.528				125.836			
2	380.337			9.36	117.951				129.716	373.628		0.8925
3	417.975	1800.594			99.996	583.566		0.385	118.076			
4	379.950				136.456				112.752			
5	308.889				120.635				132.764			
	336.985				111.384				113.725			
7	358.085				111.524				110.259			
8	338.187				189.829				108.620			
9	336.110				256.206	1722.531			104.102			
10	336.913				191.142				99.873	1218.547	0.074	0.902
11	340.702				159.428		0.134	2.31	91.712			
12	309.355	3491.755			128.271				90.657			
13	259.825				574.747				87.803			
14	187.458		0.199	6.95	769.211				84.364			
15	173.826				494.579	1968.044	1.075	21.15	81.916			
16	166.054				385.088				83.706			
17	177.143				319.166				81.473			
18	171.112				267.228		0.526	7.075	82.038			
19	171.624				255.363				81.473			
20	193.022				248.534	1346.108			81.517	752.032	0.051	0.3835
21	165.852				286.650				92.438			
22	129.300				288.333				86.892			
23	125.174	1362.898	0.088	1.20	260.673				79.991			
24	147.774				212.021				82.504			
25	161.827				199.933				83.782			
26	138.383				217.829				90.552			
27	129.942				243.878	1955.058	0.239	4.675	107.064	559.150		
28	124.518				242.970				94.047			
29	121.870				220.772				90.136			
30	107.535	461.86			193.097				87.569		0.133	0.736
31	107.946		0.066	0.305	163.885							
Σ	7117.087		0.353	17.815	6575.817		1.974	35.595	2897.057		0.258	2.914
AVE	229.584		0.1177		212.107		0.4035		96.568		0.086	
P			0.2505				0.542				0.1007	

	10				11				12			
	Q		P		Q		P		Q		P	
1	86.810				94.688				97.516	194.632		0.1168
2	84.273	254.229		0.338	91.970	280.587		0.55	97.116			
3	83.146				93.929				96.691			
4	83.636				91.970				91.597			
5	87.829				88.872				94.551			
	83.299				87.262				93.251			
7	79.143				86.317	606.665	0.072	0.479	91.186			
8	80.773	722.199	0.118	0.852	84.507				92.951	916.649	0.024	0.220
9	79.374				81.420				92.011			
10	77.092				86.317				88.123			
11	75.748				83.620				88.821			
12	75.305				80.126				87.327			
13	75.973				89.509				87.715			
14	75.973				80.339	574.194	0.046	0.264	86.497			
15	75.088				80.339				84.387			
16	74.207	520.421	0.067	0.3465	80.990				87.684	607.071	0.023	0.1395
17	72.697				79.271				87.715			
18	74.207				79.271				86.157			
19	72.276				76.551				86.916			
20	73.774				74.515	381.4	0.041	0.1563	83.644			
21	70.175				74.926				85.138			
22	71.452	397.661	0.030	0.119	76.137				85.388	569.806		
23	89.841				71.553				87.684		0.016	0.0815
24	92.421				73.308				82.110			
25	92.956				73.337				72.019			
26	93.497				83.858	629.696	0.060	0.378	79.823			
27	92.188				83.182				82.110			
28	89.614	640.603	0.196	1.254	82.748				85.388			
29	89.614				84.981				81.710	399.576		
30	89.614				76.729				74.634			
31	93.120								75.734		0.018	0.072
Σ	2472.469		0.411	2.9115	2471.950		0.226	1.8273	2686.934		0.018	0.6298
AVE	79.757		0.1028		82.395		0.0565		86.675		0.0203	
P			0.118				0.074				0.02375	

CHI-CHI RESERVOIR SILT CONCENTRATION AT LIN-WEI ST (1952)

	1			2			3			4			5			6			7			8			9			10			11			12		
	Q(CMSD)	P%	PQ(CMSD)	Q	P		Q	P		Q	P		Q	P		Q	P		Q	P		Q	P		Q	P		Q	P		Q	P		Q	P	
1	44.597			42.152			43.481			33.479			59.729			107.513		0.148	123.234			557.257			350.819	3.92	13.76	92.261		0.0738	61.280 (128.143)		0.0207	72.232		
2	48.485			44.461			44.097			31.834			61.763			120.181 (227694)			81.393 (275.007)		0.1046	419.086 (2176.129)		63.1	439.493	4.305	75.6	83.812			66.913			70.235 (214.699)		1.16
3	49.765			42.871			45.832			37.653			62.703			118.389			70.380			299.786			247.986			83.812			61.280			72.232		
4	50.561			42.512			45.835			40.113			62.230 (580.602)		0.319	119.532			65.727			269.842			188.020			80.995			58.464			76.278		
5	53.175			40.346			44.461			28.233			63.609			112.725	0.035	0.264	64.008			262.340			193.653 (1756.435)			78.179			61.280 (409.226)	0.011	0.045	74.247		
6	49.123			42.871			44.461			50.561			64.778			106.752 (755.766)			61.145			272.882			193.653			72.546 (689.527)			58.464			66.294		
7	50.164			43.845			46.457			68.150			65.478			102.118			59.985			238.011 (1853.634)	0.429	79.4	168.305			75.362	0.082	0.565	58.464			60.511 (513.730)		
8	49.123			42.510			46.457			166.688 (1035.352)	1.09	11.28	71.015			96.418			58.829			211.510			179.571			72.546			55.647			56.743	0.164	0.8425
9	48.099			43.845			38.816			111.416			69.297			99.841			60.641			232.928			145.774			72.546			55.647			62.421		
10	49.123			41.905			44.830			88.238			72.242			109.712			66.400 (902.57)			188.569			188.021			69.729			66.913			58.618		
11	50.412			42.871			48.485			88.238			93.141			107.362			65.601			177.552			171.122			72.546			64.097 (290.264)			58.618		
12	51.462			45.449			46.457			69.965			74.216			106.887			91.843	0.288	2.60	186.658			179.571			72.546			61.280			56.743		
13	44.214			48.099			44.830			72.366			98.768			134.910 (697.06)	0.040	0.2287	109.573			182.927			179.571			78.178	0.075	0.350	97.874	0.015	0.0436	56.743		
14	50.412			51.462			45.080			72.366			81.902			122.653			78.677			175.819			154.223			69.729 (499.37)			573.874	3.779	21.7	47.624		
15	48.737			49.765			46.074			76.052			79.292			115.536			61.043			172.441 (1225.331)	0.275	33.7	134.508 (1853.995)			66.913			163.627 (288984)	1.136	3.284	54.884 (411.242)	0.110	0.452
16	50.412			51.659			39.998			69.220			81.140			111.846			59.098			182.927			120.426			69.729			125.357			53.043		
17	48.099			46.334			39.752			68.479			80.596			108.841			59.020			161.546			123.242	0.272	50.5	69.729			113.467			51.220		
18	48.737			49.379			41.304			63.097			79.292			110.099	0.025	0.167	425.967 (484.987)	0.661	3.20	163.013			137.324			69.729			97.547	0.442	2.83	90.985		
19	47.974			56.543			42.971			66.127			73.480			118.858 (669.216)			1004.934	0.642	6.55	163.013			120.426			61.280			93.155			72.232		
20	42.512			51.062			43.738			60.136			74.957 (1753.286)			109.473			453.830 (886.358)	0.506	4.48	163.013			113.976			61.280	0.034	0.1705	86.697 (640.469)			66.294		
21	51.462			40.596			66.384	0.05		66.562			92.384			110.099			240.600			177.552	0.267	38.5	117.609			64.097			86.967			54.884		
22	51.063			39.998			70.304			63.815			91.529			129.290			191.928			230.431			113.976			64.097 (501.507)			84.578			62.421 (427.969)	0.078	0.334
23	51.859			47.086			52.026			65.400 (1003.385)			83.269			135.838			209.071			190.505 (1442.310)			114.793			61.280			78.328			56.743		
24	51.462			41.304			44.461			65.237	0.055	0.552	88.788			132.551 (592.336)			231.321 (947.781)	0.447	4.19	186.658			86.628			64.097			76.278			60.511		
25	53.175			47.086			42.512			65.400			113.538			194.657	0.042	0.249	249.195			172.441			106.343			55.647			74.247			54.884		
26	54.241			44.461			39.753			86.102			136.997	1.09	19.1	162.323	0.038	0.234	258.194			158.697			113.976			58.464			95.342 (604.248)			54.884		
27	48.019			44.461			40.706			61.551			128.554			125.004			238.376			153.353			103.527 (790.784)	0.08	0.633	55.647			106.540			62.421		
28	46.212			46.457			37.547			69.965			129.201			119.418 (614.297)			180.646 (1198.104)			152.090			86.628			58.464 (356.416)			90.985			58.618	0.066	0.2395
29	36.392			43.845			36.392			68.479			126.516			105.225			779.082	4.171	49.9	150.857 (750.998)			92.261			58.464			84.578	0.541	3.267	60.511 (363.204)		
30	36.309						34.036			63.815			152.695 (403.457)			102.327			1441.090 (2296.271)	2.897	66.5	148.479		29.4	86.628			64.097	0.016	0.057	76.278			62.421		
31	46.967						37.547						124.246	0.065	0.262				855.181			146.219						61.280						64.349		
Σ	1502.347			1315.438			1384.882	0.05	0.692	2047.747	1.145	11.832	2736.283	1.155	19.681	3556.368	0.180	1.2907	7996.007	9.612	137.5246	6548.402	0.971	244.1	4752.052	8.505	140.493	2139.082	0.207	2.163	2935.178	5.924	31.1903	1930.843	0.418	3.028
AVE	48.643			45.360			44.674		0.0223	68.258	0.5725		88.261	0.5775		118.546	0.036		257.936	1.2174		211.239	0.3237		158.402	2.1235		69.003	0.05175		97.839	0.98733		62.285	0.1045	
P											0.578			0.72			0.0364			1.720			0.3735			2.96			0.057			1.064			0.157	

$\Sigma PQ = 591.047$

$\Sigma Q = 38844.629$

$\frac{\Sigma PQ}{\Sigma Q} = 1.523\% = P$

$\frac{\Sigma P}{n} = 0.604\%$

Fig 141

RATE OF SEDIMENTATION AT WU-CHIEH RESERVOIR

	TOTAL RUN-OFF (1)	TOTAL INTAKE (2)	VOLUME OF SILT DEPOSITION (3)	(3)/(1) (4)	(2)/(1) (5)	REMARKS; (6)
	10^6M^3	10^6M^3	10^6M^3	%	%	OCCURRENCE OF 300<Q<1000 C.M.S.
1935	1218.522	427.647	3.429	0.28	35.1	5
1936	819.338	491.023	1.284	0.16	59.9	1
1937	901.063	565.958	0.881	0.10	62.8	
1938	1085.311	508.669	1.768	0.16	46.9	2
Σ	4024.234	1993.297	7.362			
AVE	1006.059	498.324	1.841	0.18	49.5	RESERVOIR COMPLETELY SILT UP 1934~1939. 6 YEARS

SILT CONCENTRATION AT LIN-WEI STATION

	TOTAL RUN OFF C.M.S. DAY	TOTAL SILT TON SECOND DAY	ANNUAL CONCENT %	REMARKS
1948	34,682	238	0.6875	REFER TO SHEET 12.1~3. 300<Q<1000 C.M.S. 3 TIMES
1951	66,316	374	0.564	7 TIMES
1952	38,844	591	1.523	4 TIMES
Σ	129,842	1203	0.927	

Fig 142

CHI-CHI RESERVOIR

SPILLWAY CAPACITY

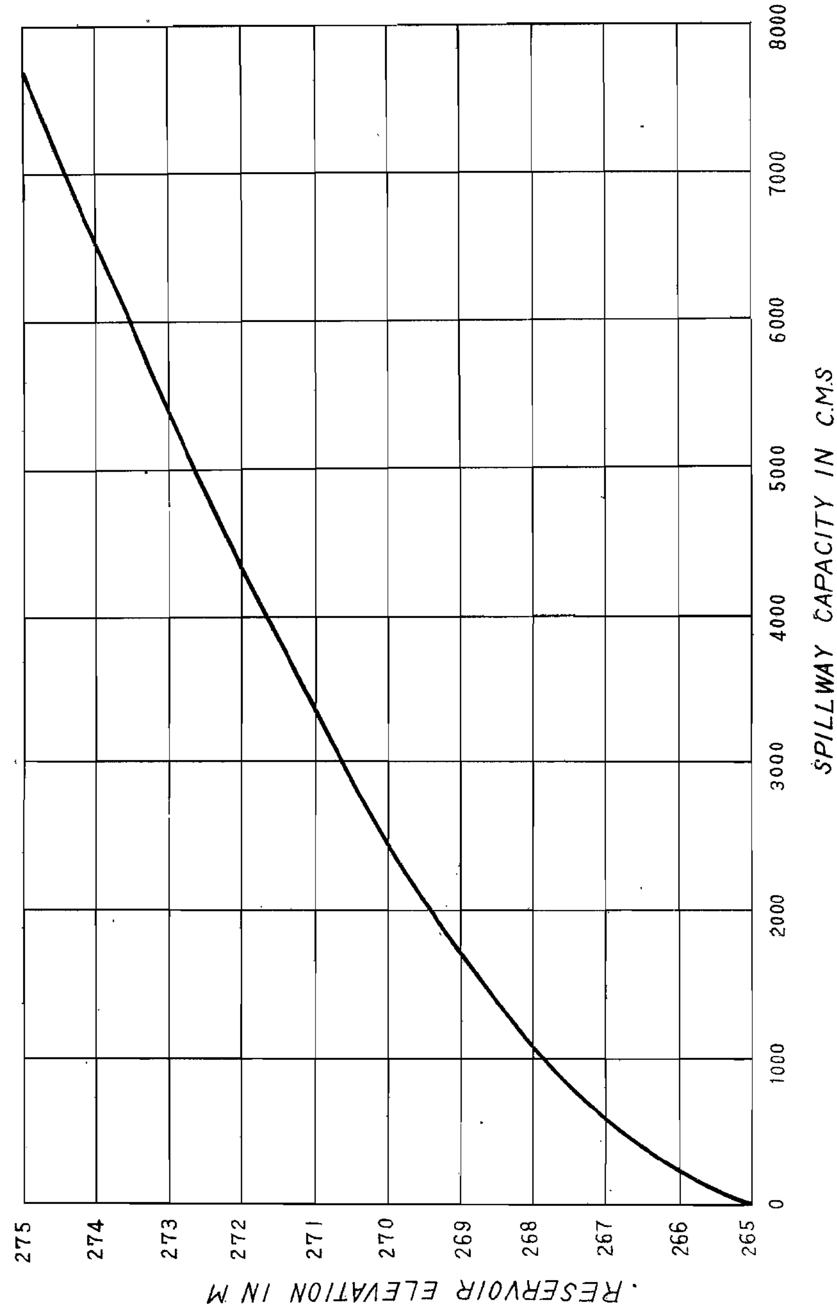
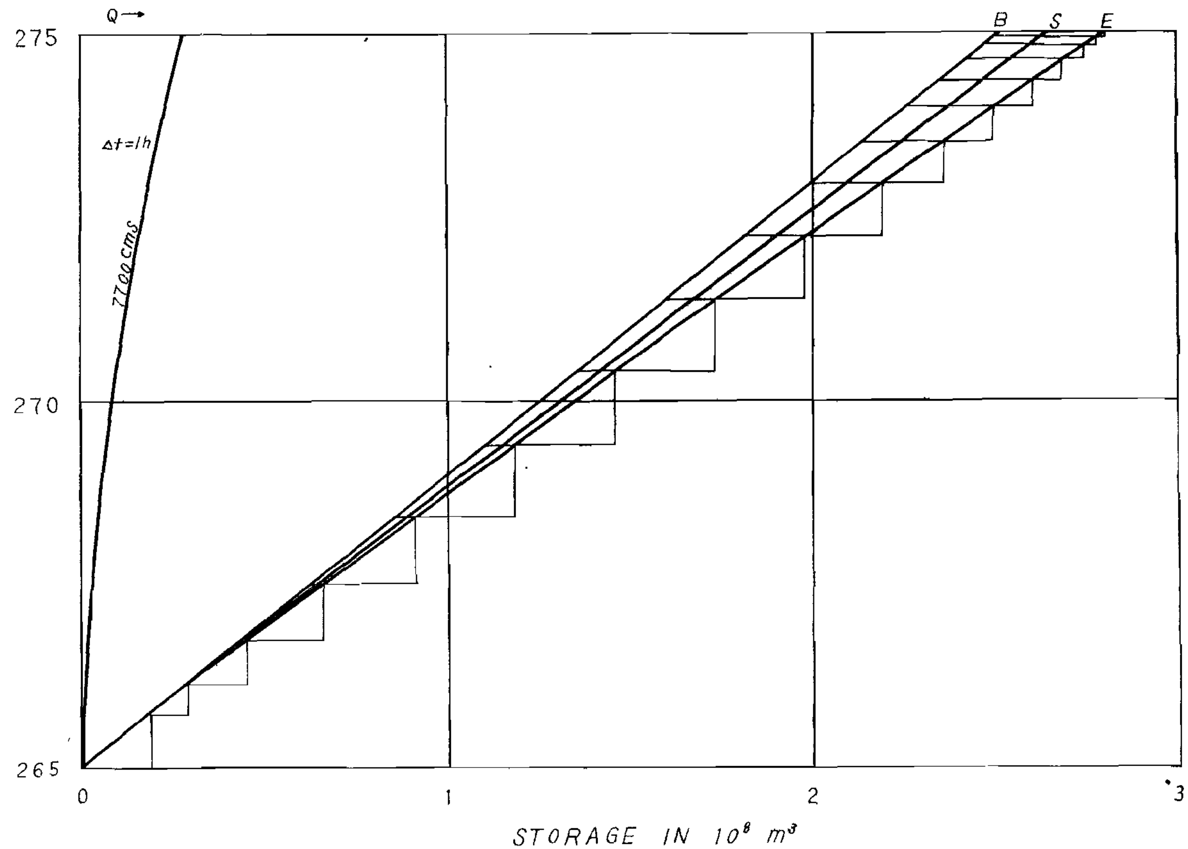


Fig 143

CHI-CHI RESERVOIR
FLOOD ROUTING

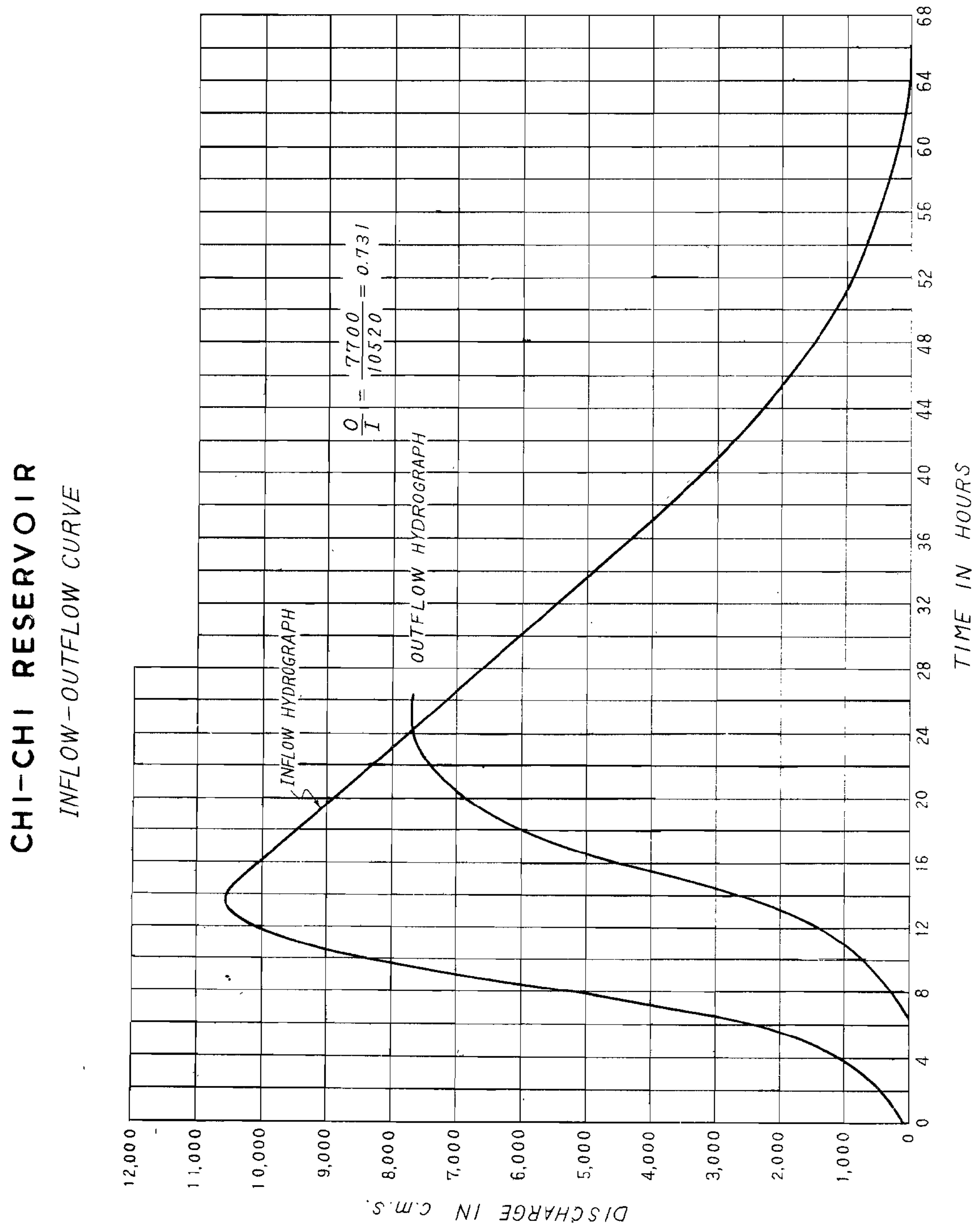


CHI-CHI RESERVOIR

FLOOD ROUTING

STEP (1)	T (2)	Δ T (3)	I C. M. S. (4)	I MEAN C. M. S. (5)	IMEAN Δ T $10^6 M^3$ (6)	EL. AT T (7)	Q C.M.S. (8)
1	1	1	200	100	0.36		
2	2	1	400	300	1.08		
3	3	1	710	555	2.00		
4	4	1	1050	880	3.17		
5	5	1	1650	1350	4.86		
6	6	1	2360	2005	7.22		
7	7	1	3740	3050	10.97	265.70	125
8	8	1	5200	4470	16.08	266.15	230
9	9	1	6900	6050	21.79	266.74	480
10	10	1	8340	7620	27.41	267.50	800
11	11	1	9400	8870	31.90	268.42	1300
12	12	1	10050	9725	35.00	268.90	1625
13	13	1	10500	10275	37.00	269.40	1980
14	14	1	10520	10510	37.93	270.40	2775
15	15	1	10250	10385	37.36	271.37	3600
16	16	1	10020	10185	36.69	272.23	4550
17	17	1	9730	9875	35.52	272.95	5320
18	18	1	9450	9590	34.52	273.50	5930
19	19	1	9160	9305	33.48	274.00	6500
20	20	1	8880	9020	32.44	274.34	6880
21	21	1	8590	8735	31.14	274.62	7200
22	22	1	8300	8445	30.20	274.80	7420
23	23	1	8020	8160	29.35	274.93	7525
24	24	1	7730	7875	28.32	275.00	7700
25	25	1	7450	7590	27.32	275.00	7700
26	26	1	7160	7305	26.28	275.00	7650
27	27	1	6870	7015	25.23		
28	28	1	6590	6730	24.21		
29	29	1	6300	6445	23.18		
30	30	1	6020	6160	22.16		
31	31	1	5730	5875	21.12		
32	32	1	5440	5585	20.10		
33	33	1	5160	5300	19.07		
34	34	1	4870	5015	19.05		
35	35	1	4590	4730	17.00		
36	36	1	4300	4495	16.16		
37	37	1	4010	4155	14.95		
38	38	1	3740	3875	13.94		

Fig 145



CHI-CHI RESERVOIR
INFLOW-OUTFLOW CURVE
INFLOW HYDROGRAPH
OUTFLOW HYDROGRAPH
O/I = 7700/10520 = 0.731
TIME IN HOURS
DISCHARGE IN C.M.S.
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
68
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
11,000
12,000

CHI-CHI RESERVOIR

SURCHARGE VERSUS SPILLWAY LENGTH

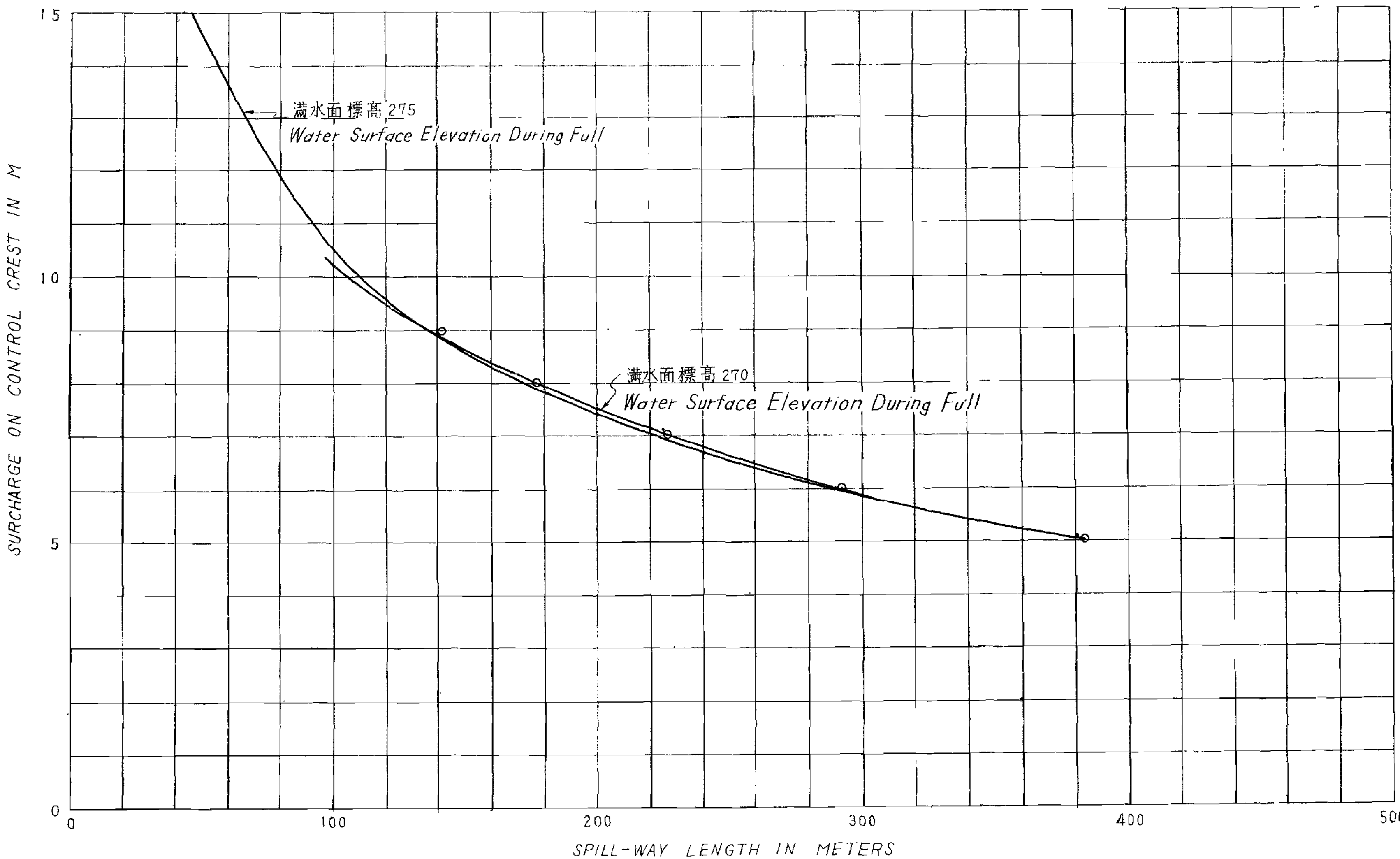


Fig 146

CHI-CHI RESERVOIR

FLOOD PEAK REDUCTION VERSUS SPILLWAY LENGTH

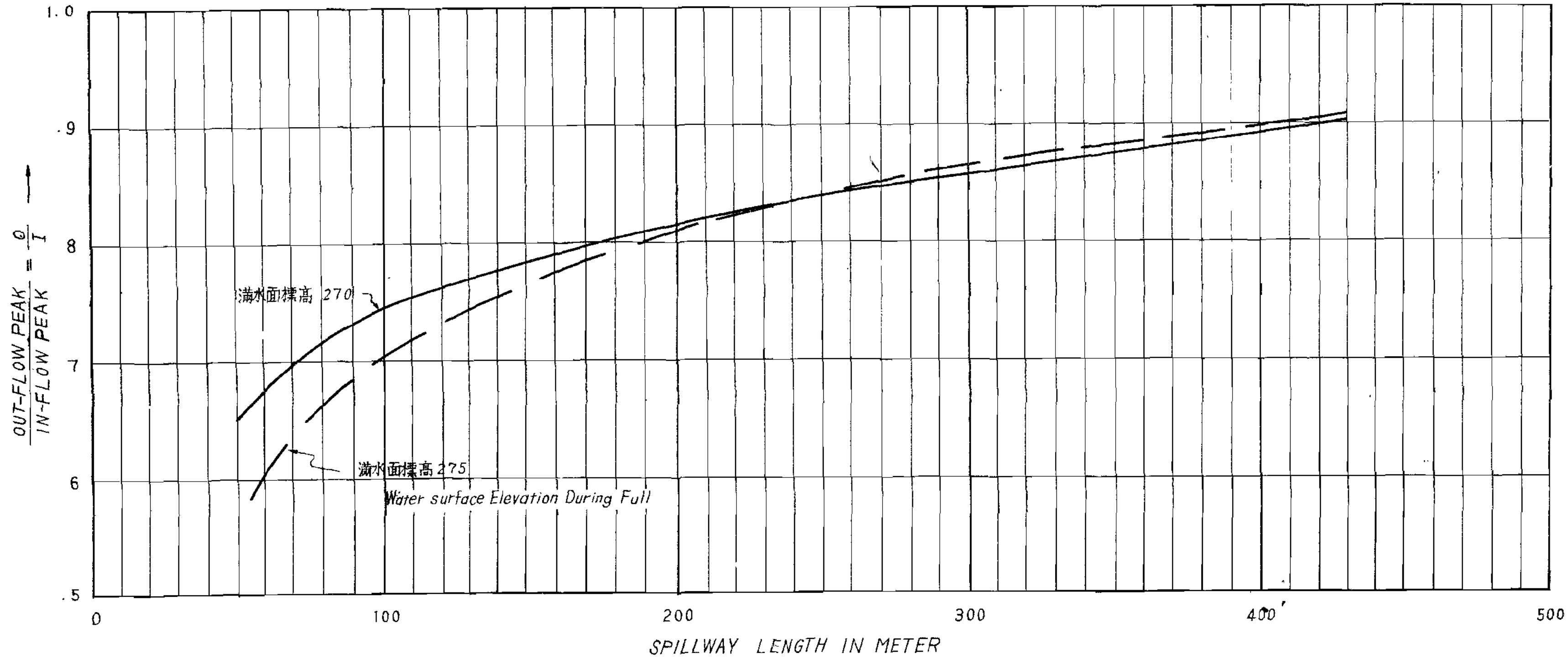
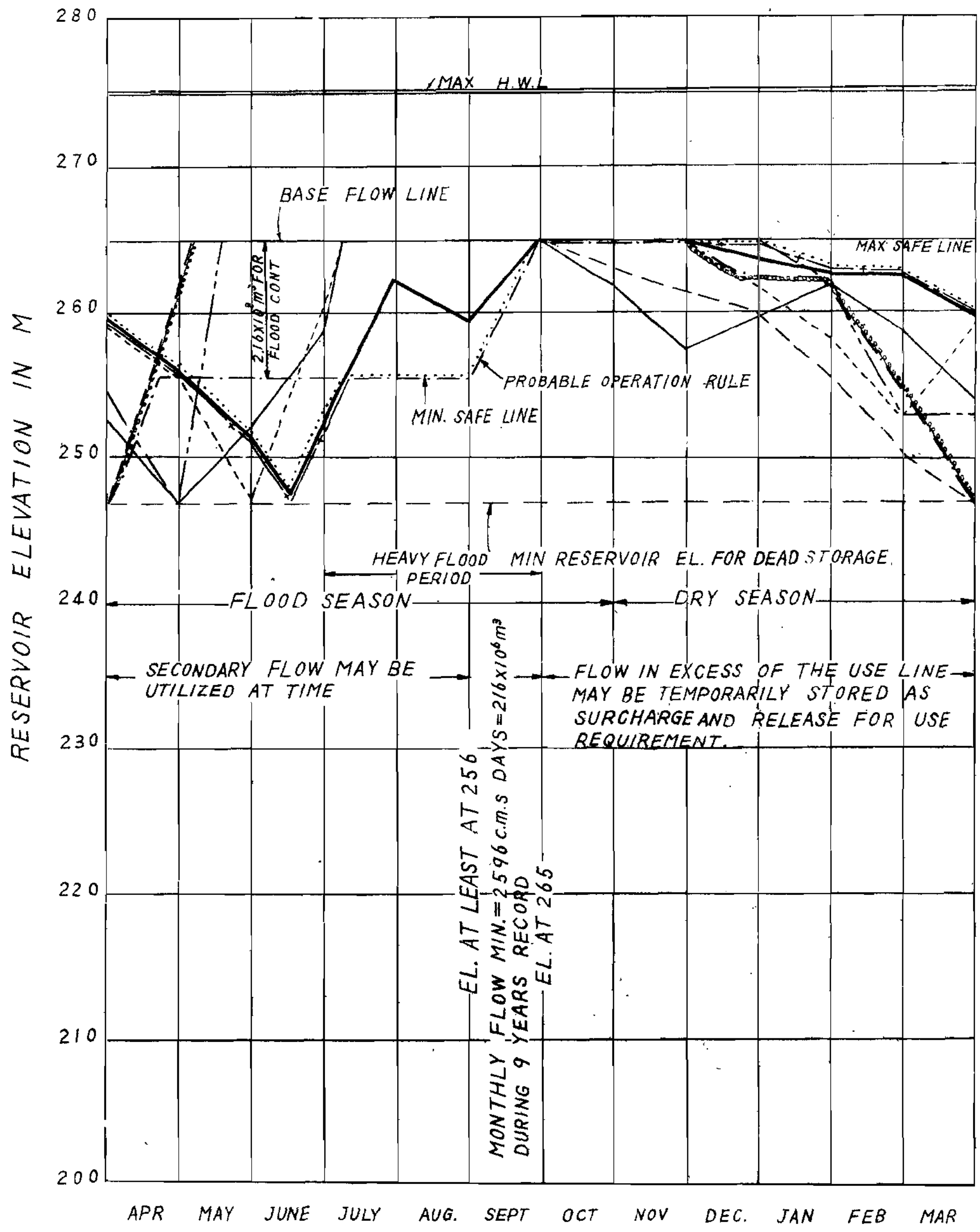


Fig 147

OPERATION RULE FOR CHI-CHI



CHI-CHI RESERVOIR

STORAGE CAPACITY-REGULATION EFFECT

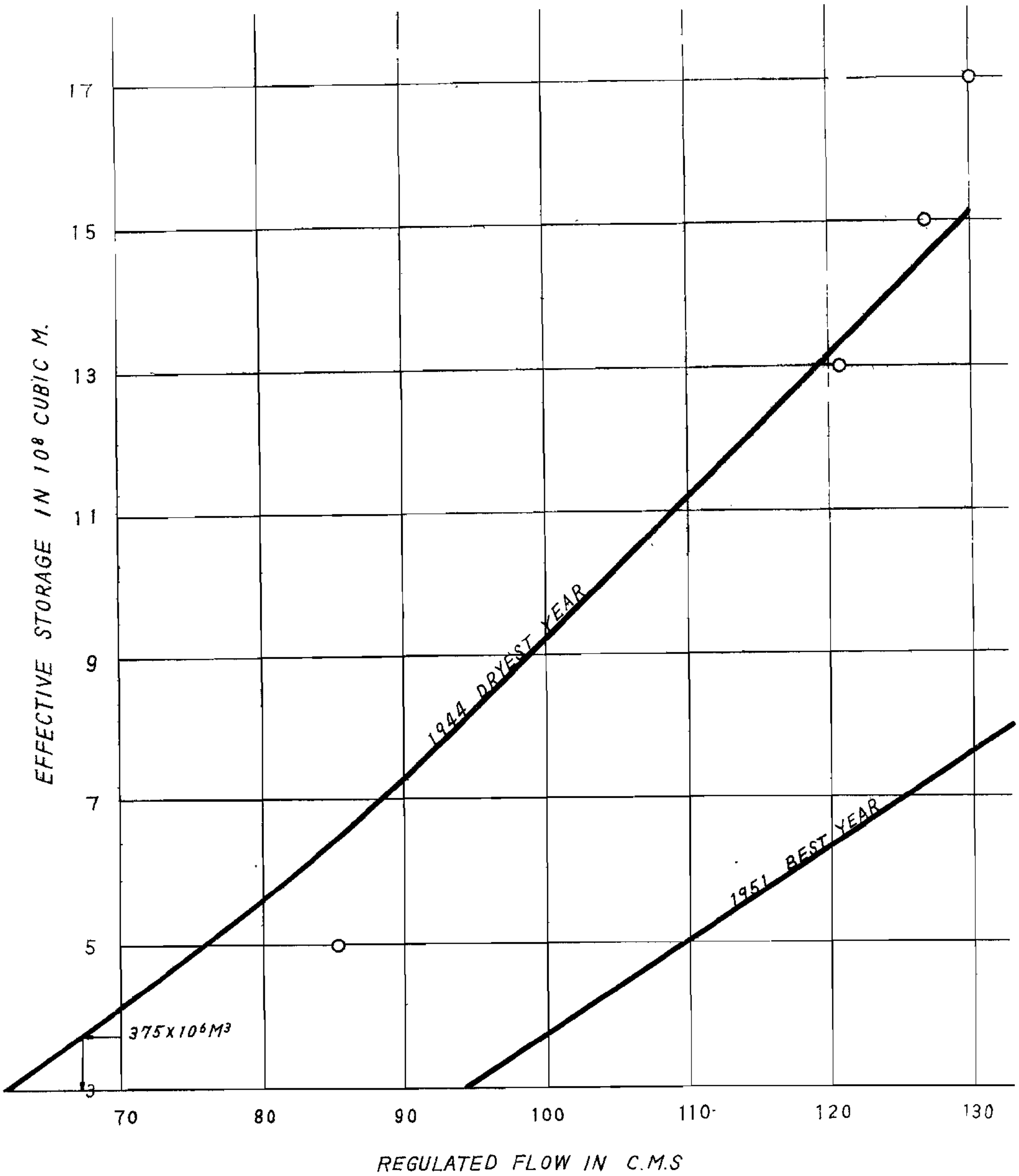


Fig 150

CHI-CHI RESERVOIR BACKWATER

BACKWATER FOR Q = 10520 C.M.S. $\frac{29 \times 0.035^2}{1.486^2} = 0.0357$ $\therefore S_F = 0.0357 H_V / R^{1/3}$
MANNING FORMULA WITH N = 0.035

1	2	3	4	5	6	7	8	9	10	11	12	13
STATION	W. S. El.	A	H_V	E. G. El.	R	$R^{4/3}$	S_F	AVE. S_F	ΔL	H_F	H_E	E. G. El.
0	275.0000	38.560	0.0038	275.0038	56.6	281	0.000624					275.0038
0.5	275.0040	100.420	0.0006	275.0046	61.4	296	0.000068	0.000346	500	0.000173	0.000648	275.0046
1.0	275.0044	150.160	0.0003	275.0047	58.8	229	0.000039	0.000053	500	0.000027	0.000089	275.0047
1.5	275.0045	153.600	0.0002	275.0047	57.1	220	0.000039	0.000039	500	0.000020	0.000002	275.0047
2.0	275.0046	185.660	0.0002	275.0048	55.9	213	0.000027	0.000033	500	0.000017	0.000015	275.0047
2.5	275.0046	182.200	0.0002	275.0048	48.1	174	0.000035	0.000031	500	0.000016	0.000000	275.0047
3.0	275.0046	167.100	0.0002	275.0048	44.7	159	0.000045	0.000040	500	0.000020	0.000011	275.0047
3.5	275.0046	145.380	0.0003	275.0049	41.8	145	0.000066	0.000056	500	0.000033	0.000070	275.0048
4.0	275.0046	102.130	0.0006	275.0052	36.7	121	0.000162	0.000114	500	0.000057	0.000300	275.0052
4.5	275.0047	75.290	0.0010	275.0057	32.6	104	0.000342	0.000252	500	0.000126	0.000400	275.0057
4.75	275.0049	46.280	0.0029	275.0078	27.6	88.3	0.00124	0.000791	250	0.000198	0.001900	275.0078
5.0	275.0052	40.150	0.0035	275.0087	30.2	94	0.00133	0.001275	250	0.000319	0.0006	275.0087
5.5	275.0059	39.323	0.0037	275.0096	31.7	100	0.00135	0.001338	500	0.000669	0.0002	275.0096
6.0	275.0080	45.643	0.0027	275.0107	29.2	90	0.00107	0.001208	500	0.000604	0.0005	275.0107
6.5	275.0085	43.730	0.0030	275.0115	21.2	58.5	0.00181	0.001440	500	0.000720	0.0006	275.0115
7.0	275.0100	31.206	0.0058	275.0158	17.6	45.8	0.00452	0.003165	500	0.001583	0.0028	275.0158
7.25	275.0115	22.775	0.0109	275.0224	15.4	38.1	0.0102	0.006005	250	0.001500	0.0051	275.0224
7.50	275.0149	18.460	0.0165	275.0314	14.6	35.5	0.0166	0.0134	250	0.003350	0.0056	275.0314
7.75	275.0217	14.449	0.0270	275.0487	11.4	25.8	0.0374	0.0270	250	0.00675	0.0105	275.0487
8.00	275.0403	11.045	0.0463	275.0866	7.6	14.9	0.1110	0.07420	250	0.01855	0.0193	275.0866
8.25	275.0720	10.320	0.0531	275.1251	6.8	12.9	0.1466	0.12695	250	0.03174	0.00675	275.1251
8.50	275.1640	6.350	0.1400	275.3040	4.98	8.5	0.589	0.3678	250	0.09195	0.0869	275.3040
8.75	276.2000	2.550	0.8680	277.0680	2.7	3.76	8.25	4.4195	250	1.10488	0.728	277.1369

Fig 151

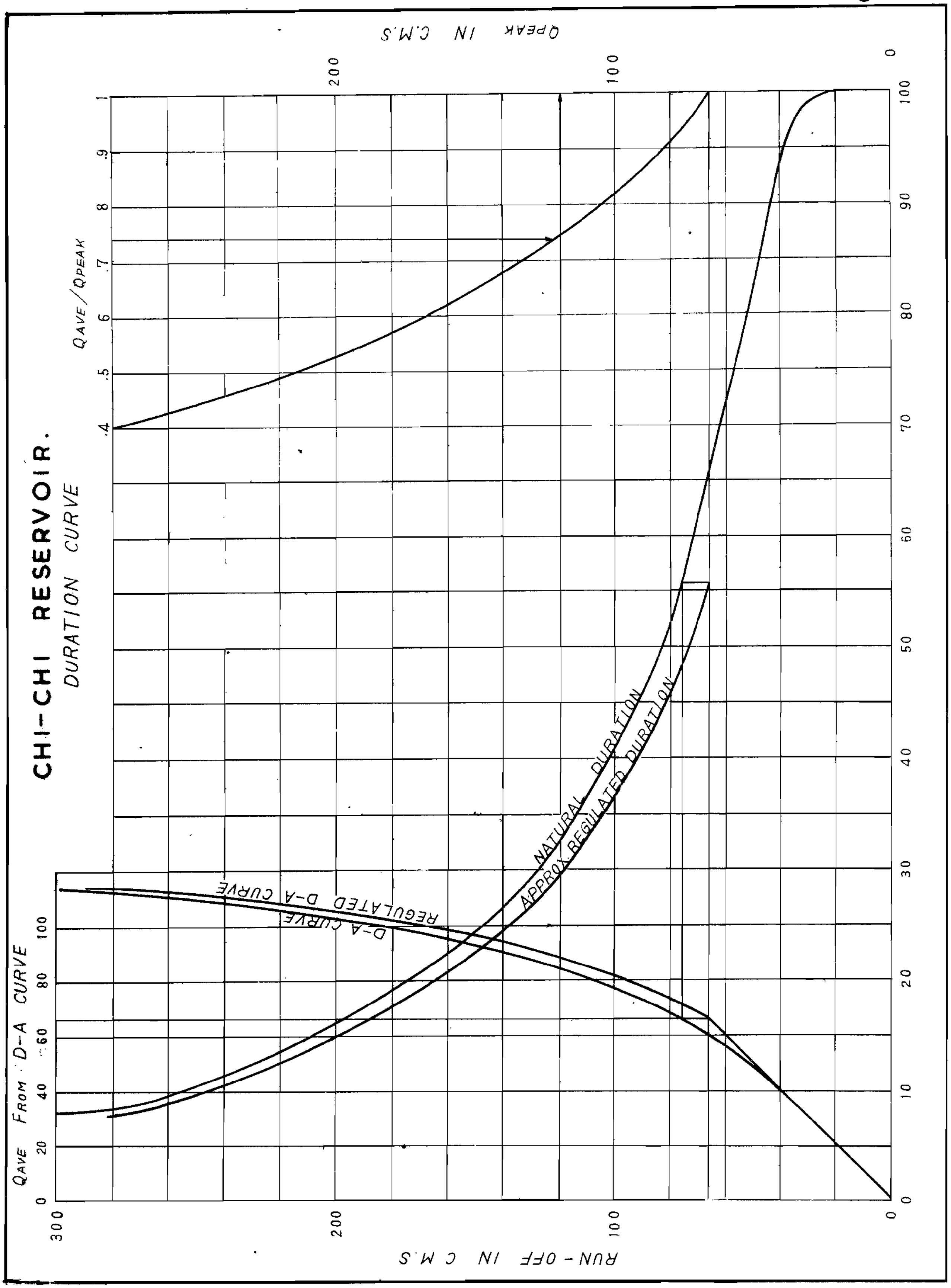
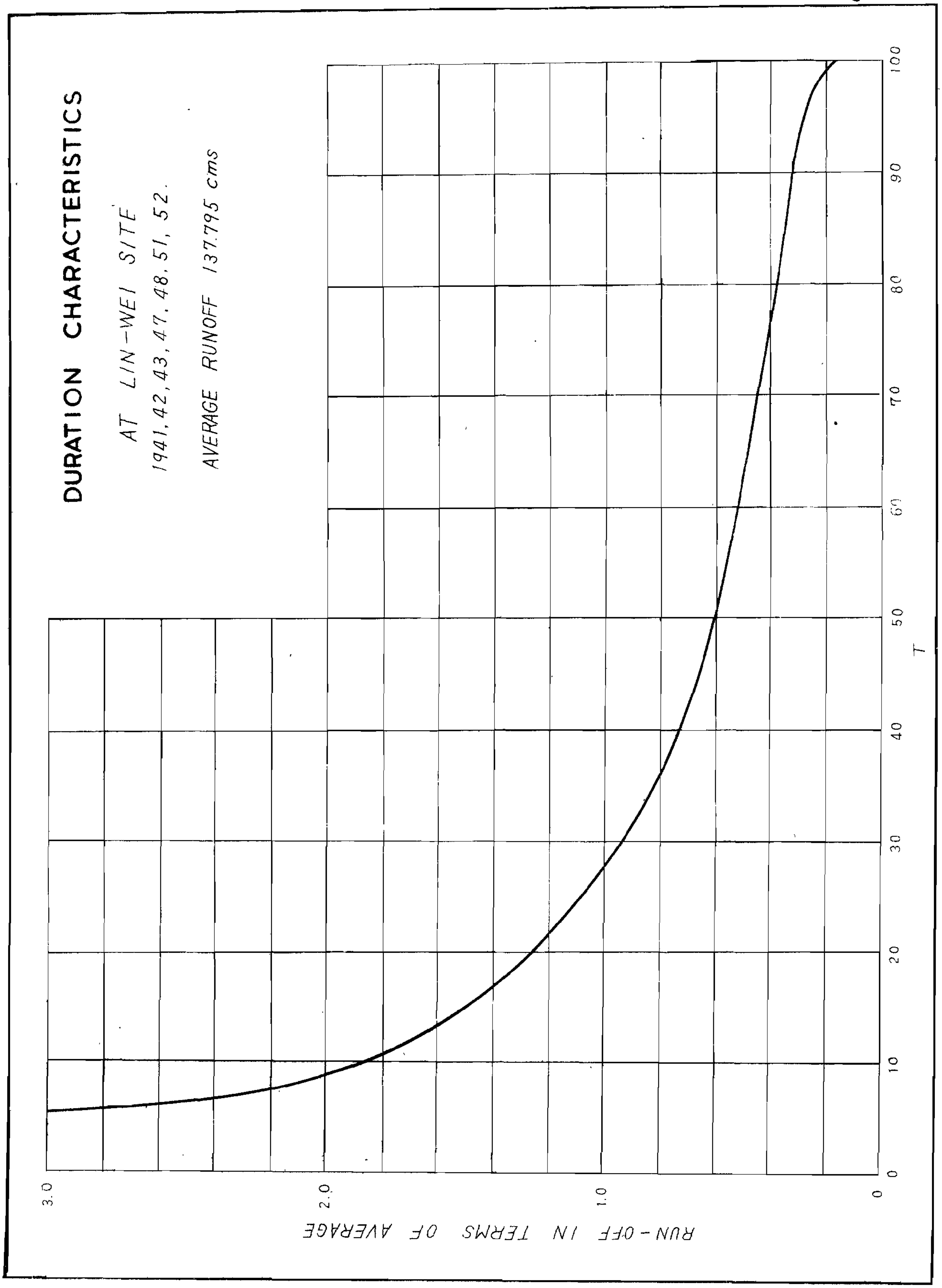

CHI-CHI RESERVOIR.
DURATION CURVE
QPEAK IN C.M.S
QAVE/QPEAK
QAVE FROM D-A CURVE
RUN-OFF IN C.M.S
NATURAL DURATION
APPROX. REGULATED DURATION
REGULATED D-A CURVE
D-A CURVE
0
100
200
300
.4
.5
.6
.7
.8
.9
1
20
40
60
80
10
30
50
70
90

Fig 152



DURATION CHARACTERISTICS
AT LIN-WEI SITE
1941, 42, 43, 47, 48, 51, 52.
AVERAGE RUNOFF 137.795 cms
0
10
20
30
40
50
60
70
80
90
100
T
0
1.0
2.0
3.0
RUN-OFF IN TERMS OF AVERAGE

Fig 153

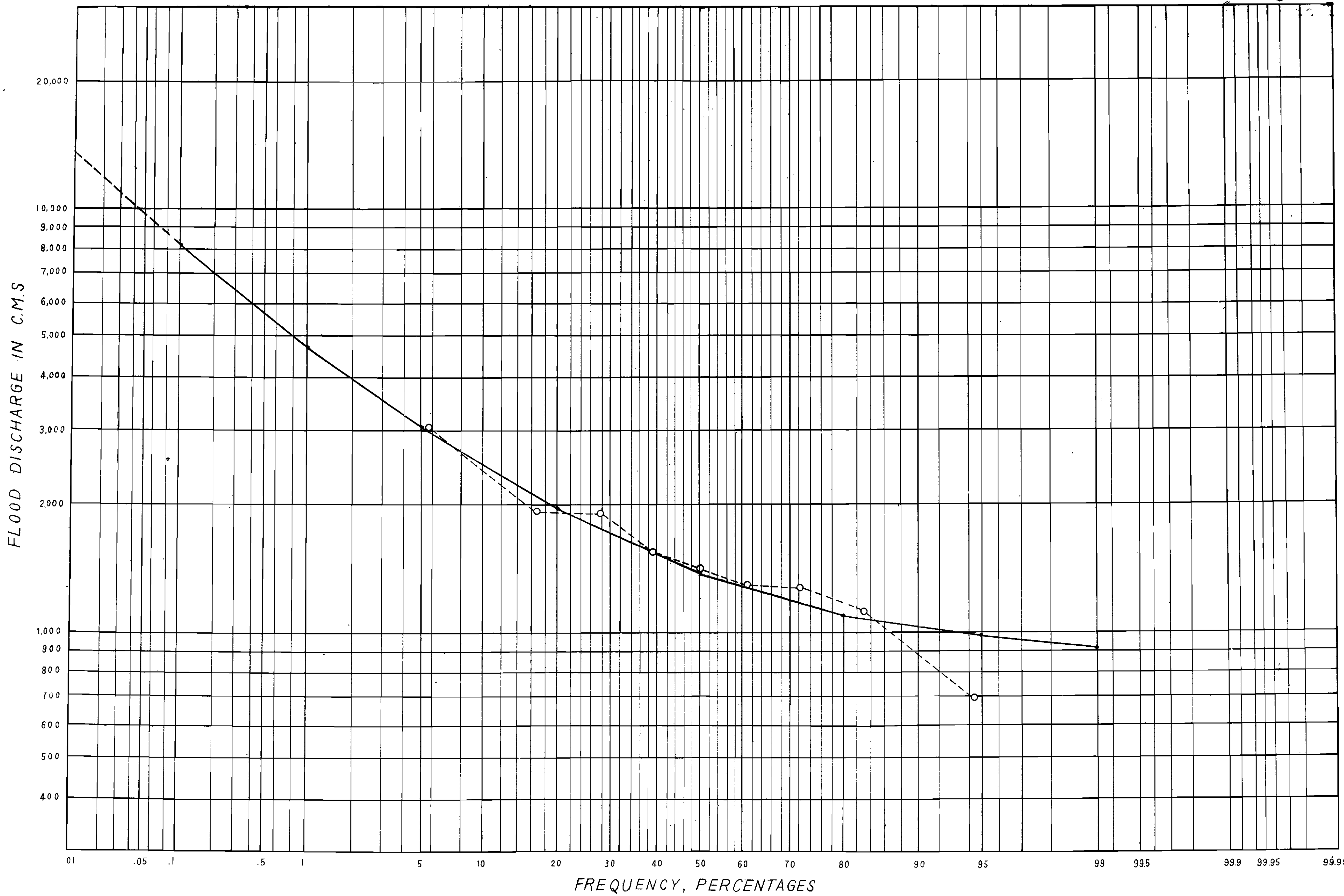
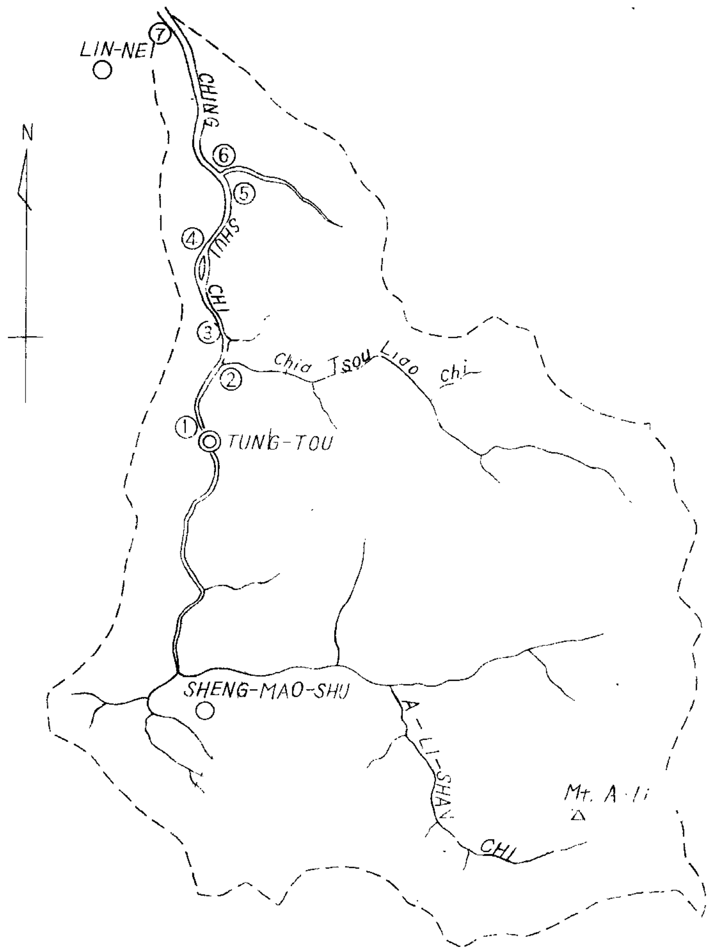

20,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
900
800
700
600
500
400
FLOOD DISCHARGE IN C.M.S
01
.05
.1
.5
1
5
10
20
30
40
50
60
70
80
90
95
99
99.5
99.9
99.95
99.99
FREQUENCY, PERCENTAGES

Fig 154

IRRIGATED AREA
ALONG CHING-SHUI CHI



NO.	CANAL	IRRIGATED AREA	
		2CROP	1CROP
1	LUNG-AN C.	HA 29.83	HA .
2	LAO-SHUI-KENG C.	12.58	
3	SHAN-PIEN C	26.69	.
4	SZU-CHUEH-TAN C.	8 10	8.07
5	KO-TZU-KENG C.	22 93	
6	HO-CHI-TSO C.	94.12	3 13
7	TOU-LIU C.		2,383.00

SCALE 1 : 250,000

CHING - SHUI - CHI RESERVOIR

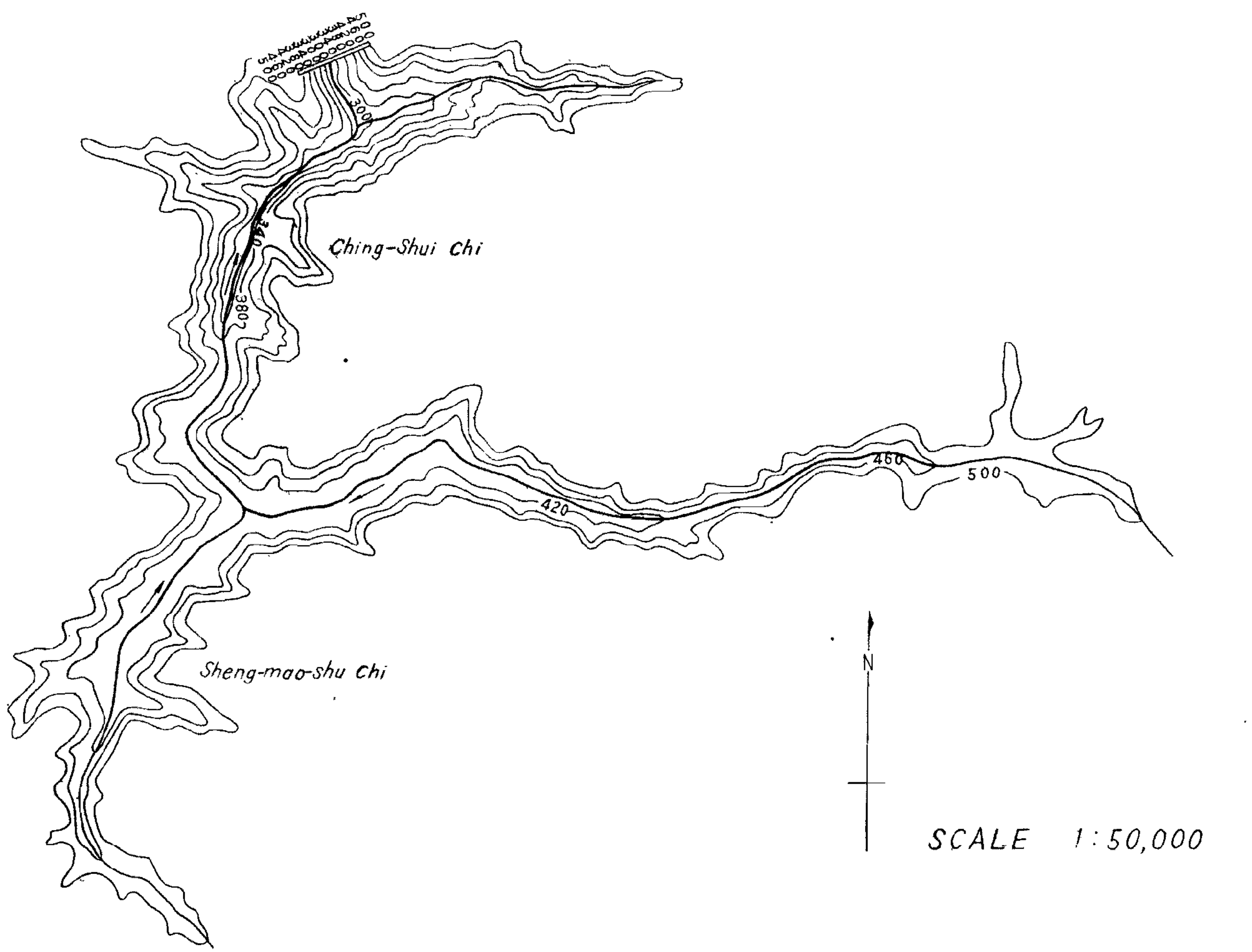


Fig 155

Fig 156

CHING-SHUI-CHI RESERVOIR
AREA VOLUME ELEVATION CURVE

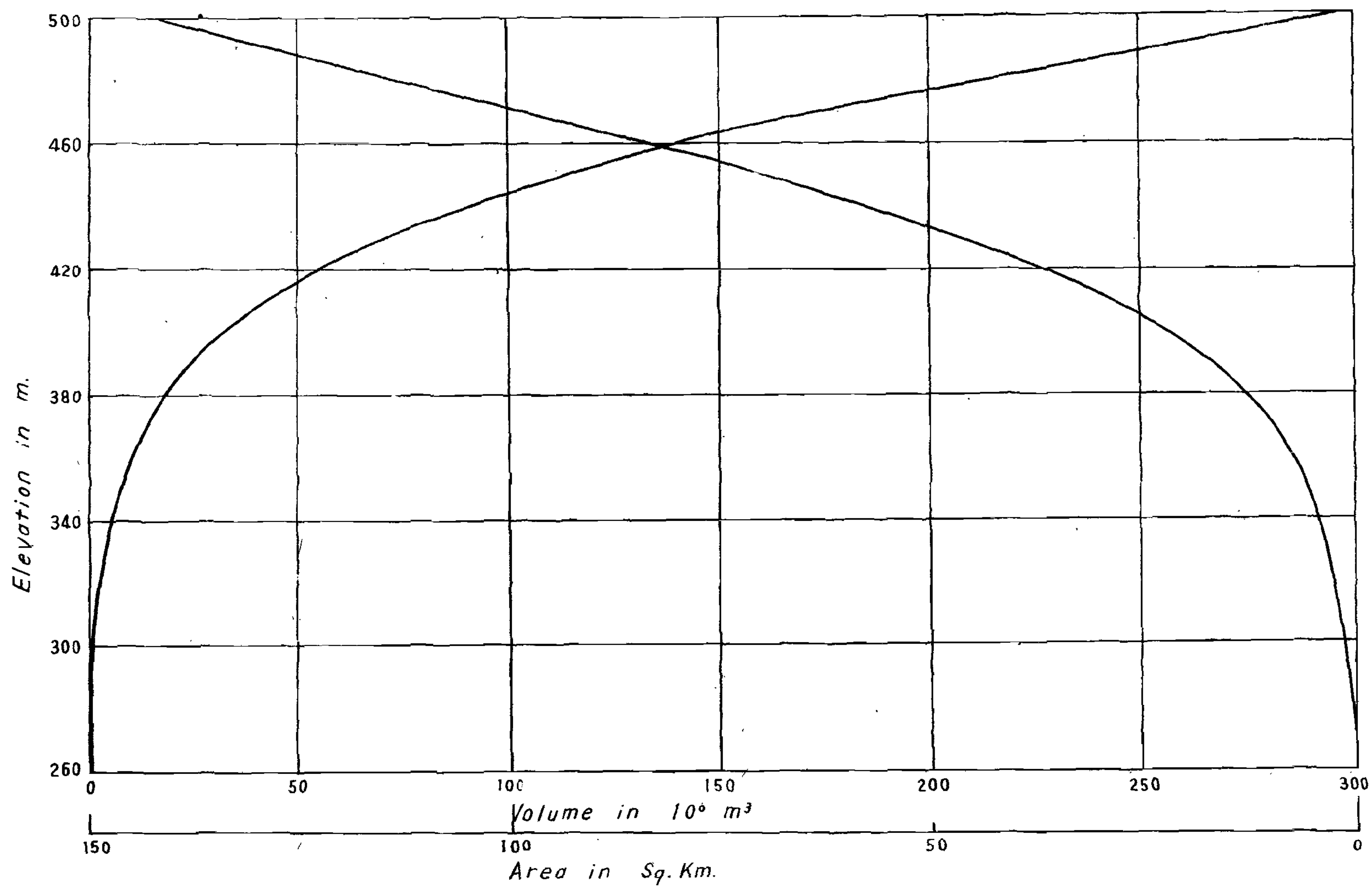


Fig 157

SYNTHETIC UNIT HYDROGRAPH AT CHING-SHUI-CHI RESERVOIR

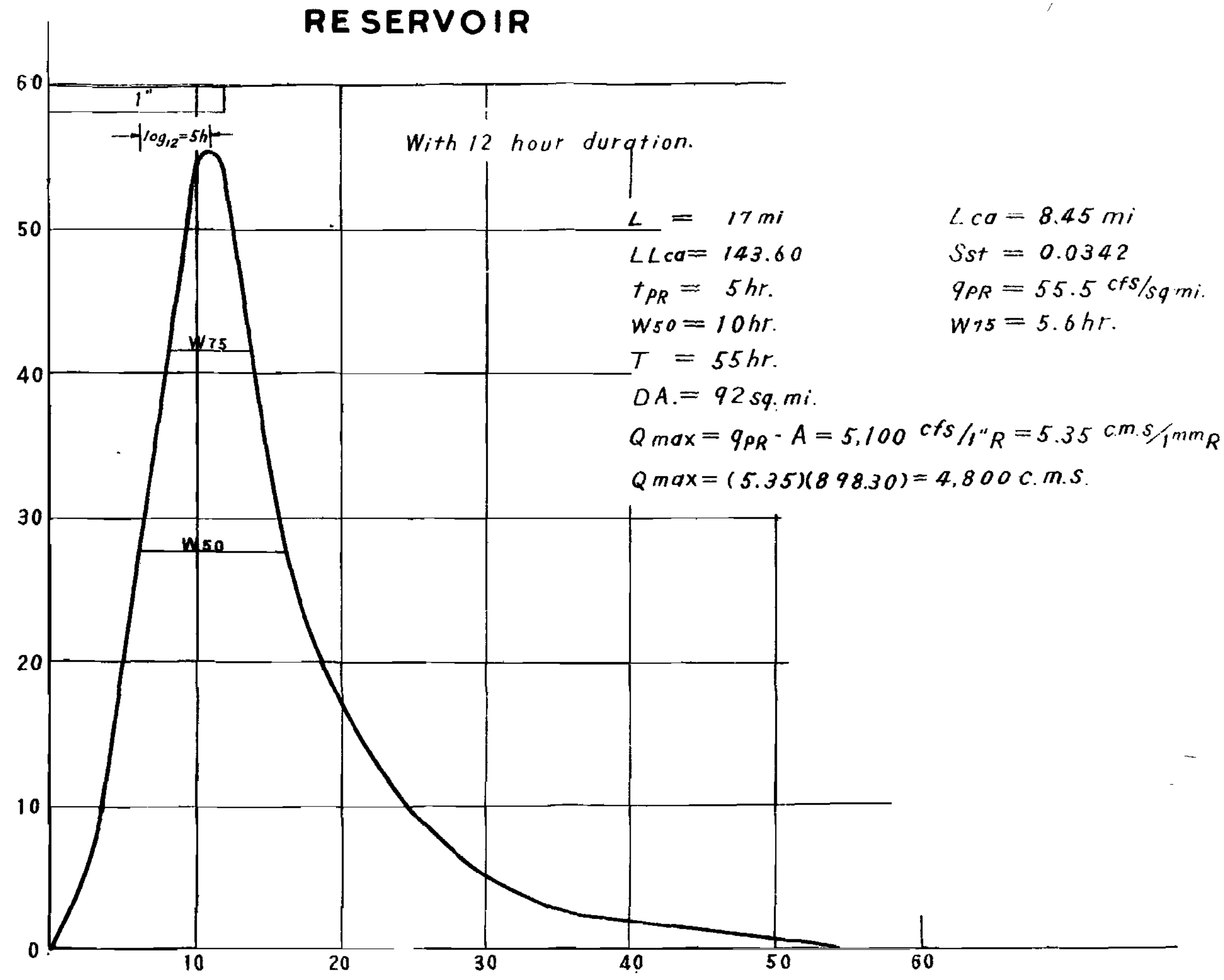
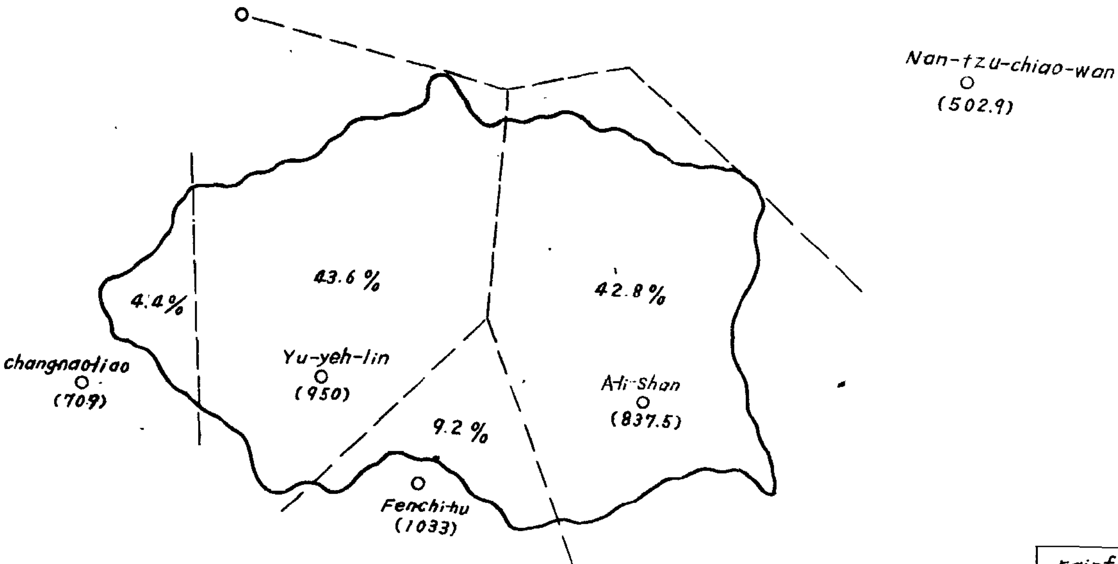


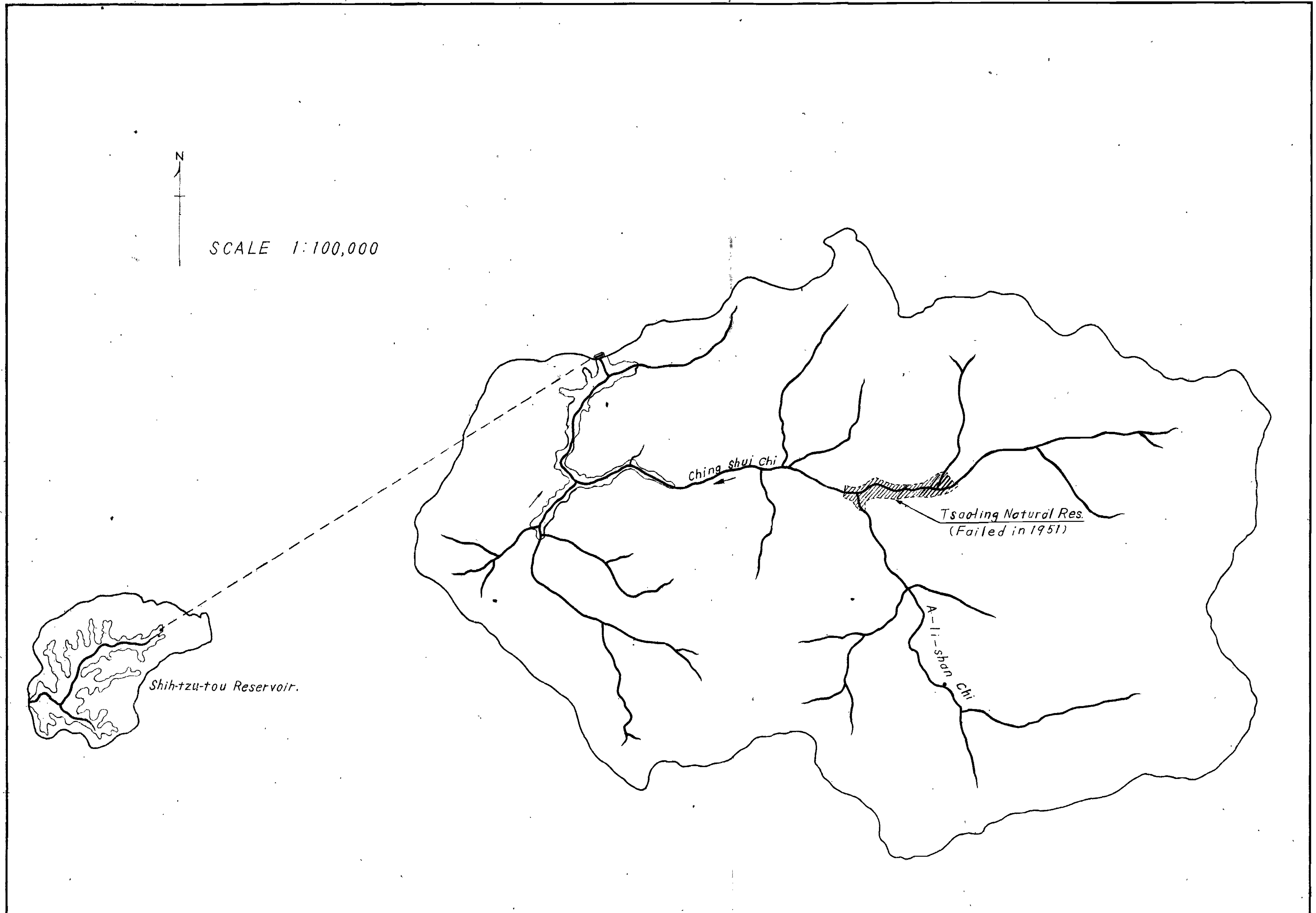
Fig 158

THIESSEN NETWORK AT CHING-SHUI-CHI RESERVOIR CATCHMENT BASIN



rainfall	percent.	
709	4.4	31.20
950	43.6	414.00
1033	9.2	95.10
837.5	42.8	358.00
average max. rainfall = 898.30		

Fig 159


N
SCALE 1:100,000
Ching shui Chi
Tsaoling Natural Res.
(Failed in 1951)
A-li-shan Chi
Shih-tzu-tou Reservoir.