REPORT
ON
HYDRO-POWER SURVEY PROJECT
IN
REPUBLIC OF INDONESIA

VOLUME II
DETAILED DESCRIPTION

March, 1971

OVERSEAS TECHNICAL COOPERATION AGENCY

JAPAN

REPORT

ON

HYDRO-POWER SURVEY PROJECT

IN

REPUBLIC OF INDONESIA

VOLUME II

DETAILED DESCRIPTION

March, 1971

OVERSEAS TECHNICAL COOPERATION AGENCY

JAPAN

CONTENTS

Volume II Detailed Description

1. Present situation of the survey work in Indonesia

1. Present situation of the survey work in Indonesia

1-1 Survey of the hydro-power potential

The history of the hydro-power potential survey in Indonesia may be divided to two periods, namely, before the second world war and after the war. Before the war some survey works were carried out by Dutch people concerning Djawa island and some parts of Sumatera, Sulawesi and Kalimantan. The results of these survey works became the basis of the hydro-power resources estimation*which was published in 1968 by the Power Research Institute, Ministry of Public Works. Some survey works were executed by Japanese people during the war.

Recently a report of the hydro-power survey in Sulawesi was found by us which was prepared by Japanese engineers during the World War II.

After the World War II, the systematic survey of hydro-power potential has made little progress, due to the war for the freedom after the proclamation of independence, and only some survey works have been carried out mainly by the aid of foreign countries about the promising site for power generation and irrigation or about the rivers which have some problems as flood control, debris and so on. Japan, USSR, France, Hungary and others have carried out survey works and have submitted the reports, and there is also a report on the hydro-power potential in West Irian which was prepared by the Dutch.

It is necessary to mention the body for survey and exploration was just established in 1962 in PLN.

According to the report on the hydro-power resources estimation, prepared by the Power Research Institute, the total hydro-power potential in Indonesia was estimated to be at least 28,000MW including West Irian. (Table 1-1-1)

Investigating the report in detail, it seems that the method of estimation is rather rough for outside of Djawa and it can hardly be said that this figure shows the total hydro-power potential in Indonesia properly. Because the estimation was carried out by using the ratio of non-surveyed area to the surveyed area and adopting bold assumptions. (see appendix 1-2)

Table 1-1-1 Estimated hydro-power potential in Indonesia

	1968	1951 #
Sumatera	6,000 MW	1,050 MW
Djawa	725	850
Kalimantan	6,000	520
Sulawesi	5,250	380 (Sulawesi, West Irian, Nusa Tenggara & Maluku combined)
West Irian	9,500	
Nusa Tenggara & Maluku	150	
Total	27,625 MW	2,800 MW

#; by the statistics of UN in 1957.

* Sebuah studi tentang sumber-sumber tenaga di Indonesia, 1968, Drs. C.S. Hutasoit

The territory of Indonesia covers broad area crossing the equator from Lat. 6° N to Lat. 11° S, and from Long. 95° E to Long. 141° E. Its area reaches to more than 1,900,000 km^2, which is five times as large as Japan. In the main island such as Djawa, Sumatera, Kalimantan, Sulawesi and West Irian, there are mountaineous area with the height of more than 2,000 m and some of the mountains have the height of 3,000 m to 5,000 m.

The annual precipitation in the most part of Indonesia exceeds 2,000 mm and at some parts it reaches to more than 5,000 mm.

Taking these factors into consideration, it can be said that the above-mentioned figure is rather underestimated.

But, outside of Djawa, the topographical maps of 1/50,000, which is to be used for the estimation of hydro-power potential, are available only for the limited region and the observation of rainfall and river discharge is quite difficult because of rather under-developed condition with scarce population. Considering these conditions, it may be said that the above-mentioned method of estimation has no alternative up to now.

1-2 Survey of the hydro-power project

As was mentioned before, the survey work of hydro-power potential has made little progress in Indonesia after the World War II and only some survey works for the development projects have been carried out at random mainly by the survey team from foreign countries and by some joint teams of Indonesian experts and experts from a foreign country.

The survey works have been executed up to now by Indonesia itself, Japan and other countries at several sites all over the country and the degree of the survey works varies from the preliminary survey to the feasibility study including detailed design. (see Appendix 1-3) Survey works for Djatiluhur (Tji Tarum), of which construction was already completed, and for Karang kates (Kali Brantas), Seloredjo (Kali Konto) and Riam Kanan which are now under construction, are among them.

It seems that most of the survey works for the above-mentioned development projects have been executed by the reparation or by the foreign aid. It means that most of them have been carried out not by Indonesian but by foreigners. This is because of the fact that the Indonesian technical personnel have faced the difficulties of the lack of fund, experience and engineers up to now. The lack of basic data causes also the difficulties for the survey work.

However, Indonesia is luckily favoured with abundant hydro-power resources, and they can be used circulatingly for good and contribute remarkably to the welfare of the people and the progress of the national economy. Therefore, it may fairly be said that the drawing out the exact hydro-power potential and the execution of sruvey works for the preparation of development are urgent matters.

After having explained these circumstances, the procedure how to survey the hydro-power resources will be given below.

2. Basic data

2. Basic data

2-1 Topographical data

(1) Authorities

The preparation and keeping of the topographical maps are the duties of the Directorate Topography Angkatan Darat (Army).

(2) Available maps

The list of available topographical maps can be seen on Table 2-1-1. Only the maps of 1/1,000,000 cover all over the territory of Indonesia and the maps of larger scale are available for some regions.

Most of them were made during the Dutch-time, before the World War II, and they were reproduced by US Army during the war. Since that time, little revision has been made, therefore, the name of some cities and others are still as they were in Dutch-time. The exact date of production of these maps are not known, but they were likely prepared at the beginning of the twentieth century.

(3) Triangulation and leveling points

Triangulation points and leveling points with their height are marked on the maps of 1/50,000 with the following symbols.

i) Triangulation points

P; Primary S; Secondary T; Tertiary Q; Quaternary

ii) Level points

◇ ; the height is marked on the maps in metre and is recorded in the master file in centi-metre

The master files of the triangulation and leveling are at the Directorate Topography Angkatan Darat and the coordinates of triangulation points and the height of leveling points can be obtained from the Directorate if necessary. They say that the triangulation points and leveling points are not maintained well.

(4) Plan of map preparation

It is known that the Authorities have the plan of revision and production of new maps and they have begun the works.

(5) Aerial survey

The organizations in Indonesia which are equipped with instruments of aerial survey are as follows.

i) Aerial survey state enterprise. (Air Force)

ii) Army

iii) a private enterprise (connected to KLM)

iv) Foreign enterprise

The Power Research Institute has the aerial photograph of 1/10,000~1/20,000 for Larona, Sekampung, Riam Kanan, Asahan, upstream of Tji Tarum.

(6) Map administration

Most of the topographical maps are under the administration of the Indonesian Army and the maps with the scale larger than 1/100,000 are kept confidential. These maps can be borrowed or bought from the Army upon request.

Table 2-1-1 List of topographical maps in Indonesia

No.	Scale	District ( ); numbers of sheets
1	1:1,000,000	whole territory of Indonesia (29)
2	1: 500,000	whole territory except West Irian (58)
3	1: 250,000	Djawa, Madura & Bali (20) Sumatera (68) South and East parts of Kalimantan (14)
4	1: 200,000	West Kalimantan (53) some parts of Sulawesi (43)
5	1: 125,000	South-west Sulawesi (19)
6	1: 100,000	some parts of North Sumatera (22) some parts of North Sumatera (9) some parts of West Sumatera (55) South Sumatera (102) South and East parts of Kalimantan (31) Minahassa and Middle Sulawesi (12)
7	1: 50,000	Djawa & Madura (450) North-East Sumatera (40) North-West Sumatera (25) East coast of Sumatera (54) some parts of Middle Sumatera (19) Simeulue (8) Nias (21) some parts of West Kalimantan (18) South and East parts of Kalimantan (57) South-west Sulawesi (70) Bali (27) Lombok (7)
8	1: 40,000	some parts of Central Sumatera (127)
9	1: 25,000	Djawa (622) Bangka (177), Lombok (7) some parts of South Sulawesi (27)
10	1: 20,000	some parts of Talund Islands (11) some parts of P. Morotai (19) some parts of Tjendrawasih-West Irian (23) Manokwari & Surroundings-West Irian (15) Mumi & Surroundings-West Irian (5) Sawan & Surroundings-West Irian (9) Kotabaru & Surroundings-West Irian (31) Mapia Eiln (2) Eilanden Surroundings (3) Numfoor & South Biak (19)

(7) Recommendations for the topographical maps

The present situation of map preparation has been described before and it can be summarized as follows;

1) Before the war, during the Dutch-time, topographical maps were prepared over fairly wide region but they did not cover all the territory of Indonesia.

2) After the Independence, these maps have been under the administration of the Indonesian Army. Though the revision has been made little by little, most of them are still as they were in Dutch-time.

3) Contour lines or some other marks on the maps are not so distinct, therefore, there are some difficulties to use them.

4) Maps of the scale larger than 1/100,000 are kept confidential and cannot be used freely.

It is needless to say that the maps are the most fundamental data for the national land development and if the better maps are available, the better development plan will be possible. In view of these circumstances following matters may be recommended.

1) To prepare the maps for the area where no maps is available now. For this purpose, it is desirable to use the aerial survey.

2) To revise the maps, which are available now, and to increase the accuracy of the maps.

3) To prepare the maps of the scale larger than 1/100,000 which can be used freely.

4) To increase the numbers of copy of each map to use them as the consumption article, for example, by using copy machines.

2-2 Geological data

The descriptions about the ordinary geological survey method are given in the section 4-2, (1), (b).

(1) Present situation

The general geological feature in Indonesia has been investigated to some extent and the geological maps, which are shown in the table below, are available at present.

Table 2-2-1 List of geological maps in Indonesia

District	Scale
All over the country	1/2,000,000 & 1/5,000,000
Djawa & Madura	1/500,000
Sumatera	1/500,000 & 1/1,000,000
Sulawesi	1/500,000

According to the report of Mr. Purbo-Hadiwidjojo, the geological survey works in Indonesia have been carried out actively complying with the requirements of the surveys of dam sites, the foundation of structures, ground water, landslide, geothermal resources and so on.

The geological survey of the river basin, which has close relation with the hydro-power development, has been carried out at many places with the expansion of the irrigation facilities by the Five Year Development Plan and, at present, the engineering geological data have been or being accumulated at the Tjimanuk river basin in West Djawa, the Tjisanggarung river basin and the Tjitanduj river basin between West and Central Djawa, the Seraju river basin and the composite river basin of the Djratunseluna in Central Djawa, Solo river basin partly in Central Djawa and partly in East Djawa, Brantas river basin in East Djawa, and Barito river basin in Central and South Kalimantan.

The geological surveys of the dam and the power plant have been executed at the sites of several projects such as Djatiluhur, Karangkates, Selordjo, Riam Kanan, Sempor, Asahan and others.

The requirements for the geological survey in Indonesia have been increased with the progress of several development projects, but the number of engineering geologist is quite limited and only one geologist is in the Directorate General for Power and Electricity. There are two other geologists in the Department of Public Works & Electric Power, one in the Directorate General of Water Resources and another in the Trans-Sumatera Highway Project. Therefore, most of the geological survey works depend, for the time being, on the foreign consultants.

The education of geologist in Indonesia is done at the Bandung Institute of Technology but the graduates from the Institute are only several persons a year and most of them get employment on the oil extracting enterprises and the mining enterprises for the sake of the working condition. In these circumstances, it is quite difficult to employ the geologist for the electric power sector.

(2) Recommendation

The requirements for the geological survey in the electric power sector will increase hereafter, therefore, it is necessary that the electric power sector keeps several engineering geologists of its own, in order to let them execute the geological survey works related to the development projects under direct control of the authorities, and administrate the geological survey works which are executed by the consultants or by the experts of technical aid.

2-3 Precipitation data

2-3-1 General

The river discharge, one of the elements of the hydro-power resources, is brought on by the precipitation. The precipitation can be measured relatively with ease and the precipitation data can be used for the estimation of the river run-off by estimating the proper run-off coefficient, where the river run-off has not been gauged. The precipitation data are used also for the checking of the existing run-off data. The record of the precipitation is used, moreover, for the operational control of the reservoirs and power plants by informing the rainfall condition in the upstream area to those concerned.

Therefore, the precipitation data are regarded as the basic data of importance for the planning and the utilization of hydro-power.

2-3-2 Observation of precipitation

The observation of the precipitation is generally carried out at the weather stations as a part of the general meteorological observations. In many cases, the rain-gauges are installed at specially fixed places for the specific purposes such as hydro-power, agriculture, forestry, flood control, sand arrestation and so on.

The items of observation are to be hourly rain-fall, daily rain-fall, the amount of each rain-fall and others, according to the observation purpose. The precipitation data are usually arranged, compiled and printed every year.

There are many facilities for the precipitation measurement such as relatively primitive rain-gauge of cylinder type, automatically recording rain-gauge of a long term, robot rain-gauge which is installed at a remote place and sends the rain-fall record by wireless or over wires, radar rain-gauge which calculates the expected rain-fall previously by observing the nimbi, and so on.

The multi-directions rain-gauge, with the cylinders of inclined and horizontal directions, has been used for the rain-fall observation in the mountaineous area and the rain-fall alarming equipment has been developed as the countermeasure for the disaster caused by the heavy rainfall.

2-3-3 Characteristics of precipitation

In many cases, the precipitation has the special characteristics in each region and season, in accordance with the topographical and meteorological conditions.

For example, the rainfall in Indonesia brought by the monsoon, the rainfall in Japan brought by the typhoon or the seasonal rainfront in early summer, the thunder-storm, the rainfall in the mountaineous area have their own characteristics respectively.

Generally speaking, the rainfall, brought by the seasonal wind such as monsoon, shows somewhat constant feature but the rainfall in the mountaineous area with the complicated topography is likely to have the characteristics of locality and it is fairly difficult to find the representative rainfall data over a whole region concerned from the data of a few observation stations there.

However, the water resources for the hydro-power are available mainly in the mountaineous area and it is necessary to grasp properly the characteristics of the rainfall which have the remarkable influence upon the river run-off condition in the mountaineous area.

2-3-4 Treatment of precipitation data

(1) Annual and monthly precipitation data

The seasonal rainfall feature at each place can be found by investigating the precipitation data for respective place or region. The annual and monthly precipitation data at several places in Indonesia are attached in the appendix 2-1 and 2-2.

(2) Isohyetal map (equi-precipitation map)

This is the map which is prepared by plotting, on the map, the points of the annual or monthly precipitation records and drawing the equi-precipitation countors. Seeing this map, we can easily find the general feature of the annual and monthly precipitation at each region.

The isohyetal map may be used for the estimation of the precipitation at the region where the observation station does not exist.

The annual isohyetal maps for Indonesia are attached in the appendix 2-3.

(3) The map showing the dry and rainy seasons

The duration time of the dry and rainy seasons varies in accordance with the region. In order to find this relationship, some map showing the dry and rainy seasons in Indonesia is attached in the appendix 2-4.

(4) The chart expressing the time distribution of the daily rainfall

In order to see the general feature of the time distribution of the daily rainfall in a year, it is convenient to arrange the daily rainfall time data at each observation station and get them into a chart.

Plotting these data on a map, the rainfall time distribution in respective regions can be seen conveniently. These maps for Indonesia are attached in the appendix 2-5.

(5) Calculation methods of total precipitation in a certain area

In order to estimate the total precipitation in a river basin, there are several methods for the calculation using the precipitation data at the places in this area. Some of them are briefly explained below.

(a) Simple mean value method

This is the method which takes the simple mean value of the precipitation data, at several observation stations in this area, for the mean precipitation to the unit area in the region concerned.

(b) Thiessen's method

This is the method which takes the weighted mean value of the precipitation data for the mean precipitation to the unit area in the region concerned. The weighted mean value can be obtained by giving the weight to the precipitation data at several observation stations in this area respectively, corresponding to the area where the data of each observation station can be regarded as to show the representative values.

The representative area can be measured graphically as the area of the polygon enclosed by the perpendicular bisectors to the sides of triangulation network connecting the observation stations.

(c) The method using the isohyetal map

This is the method to calculate the mean precipitation to the unit area in the region concerned, by using the isohyetal map.

The method (a) is the simplest one and gives same results whoever may use it. But, if the observation points are not distributed densely, the accuracy of the results may be unsatisfactory.

The method (b) is more rational one than the method (a) and it is widely used. This method gives relatively accurate results even in case where the numbers of observation points are a little.

The method (c) may be right theoretically but the isohyetal map may have some differences according to the person who draws it.

It can be said that each method has its own merit and demerit. Anyway, it is necessary to take due consideration the topographical and meteorological conditions of the area, when we try to estimate the total precipitation there.

(6) Unit-hydrograph method

The hydrograph is a diagram showing the variation of the water level or the river discharge with respect to the time. If we know the hydrograph for some place of a river with regard to the rainfall at a certain time, with a certain intensity and a certain duration time, and at a certain place at upstream, then we can get the hydrographs at the place for the rainfall of various natures.

The estimation method of the river discharge from the rainfall to the river basin concerned, by preparing the fundamental hydrographs at the place, namely the unit-hydrograph, is called the unit-hydrograph method.

This method has been used for the reservoir operation and others to take a measure to meet the situation properly and promptly by estimating the expected river discharge, using the informations about the rainfall condition in upstream region.

In some regions where the distinction of dry and rainy seasons are evident, it is necessary to prepare the unit-hydrographs for the respective seasons.

2-3-5 Present situation

(1) Meteorology and precipitation in Indonesia

The climate in Indonesia is of high temperature and high humidity with much rainfall, in general, and the islands of Indonesia are located in the region with the most plenty rainfall on earth. These islands are in the doldrums and there blows no strong wind such as hurricane or typhoon, but the southward parts from the equator of Sumatera and Djawa belong to a weak seasonal wind zone and they have much rainfall during the period of the west monsoon and little of it during the period of the east monsoon. The rainfall is relatively little in the south-east part of Indonesia.

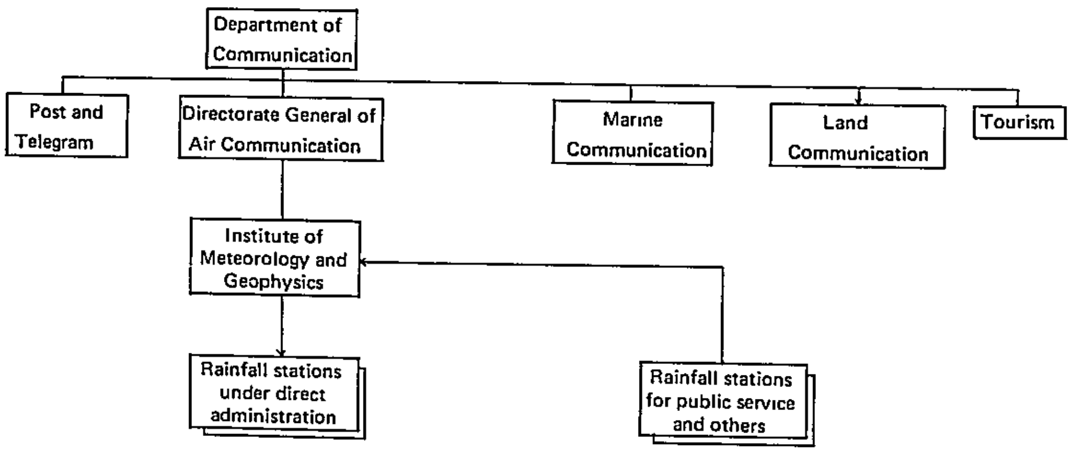
The annual precipitation in Indonesia varies from region to region as it can be seen on Appendix 2-1. On the windward slope in the mountaineous area, there is a plenty of rainfall and in the plain area the rainfall is less.

Seeing the daily rainfall time distribution, it seems that there are many regions where the rainfall occurs in a short time concentratedly in the afternoon. This feature may be reflected on the characteristics of the river run-off conditions. (refer to the appendix 2-5 and 2-11)

(2) Organization of precipitation observation

The Institute of Meteorology and Geophysics, Directorate General of Air Communication, Department of Communication, is now in charge of the observation of precipitation in Indonesia.

There are many precipitation observation stations at various places in Indonesia. The results of the observation at these stations are arranged and published every year.



(3) Observation stations

The observation stations in Indonesia have been established in a large number since a long time ago. The number of stations can be seen on Table 2-3-1 and their distribution is also shown in the appendix 2-6.

Table 2-3-1 Observation Stations in Indonesia

Province	(1) Area (Km^2)	(2) Number of Stations			(1) / (2)		
		1931	1960	1968	1931	1960	1968
(Sumatera)	473,605.9	503	224	126	941	2,114	3,759
1. Atjeh	53,840.0	64	30	16	841	1,795	3,365
2. North Sumatera 3. Riau	154,200.0	135	101	53	1,142	8,687	23,217
4. West Sumatera	43,760.0	108	21	15	405	2,084	2,917
5. Djambi	50,765.9	23	72	5	2,207	3,081	10,153
6. South Sumatera	171,040.0	173		37	989		4,623
(Djawa and Madura)	132,174.1	2,464	1,960	1,586	54	67	83
1. West Djawa	46,876.7	667	435	318	70	108	147
2. Central Djawa	34,206.3	860	785	657	40	44	52
3. East Djawa	47,922.3	915	675	550	52	71	87
4. Madura	3,168.8	22	65	61	144	49	52
(Kalimantan)	539,460.0	103	81	41	5,237	6,660	13,158
1. West Kalimantan	138,438.9	40	19	7	3,461	7,286	19,777
2. East Kalimantan 3. South Kalimantan	253,160.1	63	62	34	6,365	6,468	11,795
4. Central Kalimantan	147,861.0						
(Sulawesi)	189,034.9	195	62	40	969	3,049	4,726
(West Irian)	412,781.3	28	–	–	14,742	–	–
(Nusa Tenggara)	73,614.5	99	79	55	744	932	1,338
(Maluku)	83,675	33	21	10	2,536	3,985	8,367
Total	1,904,345.7	3,425	2,427	1,858	556	785	1,025

2-3-6 Recommendation

(1) The precipitation observation in Indonesia is under the administration of the Ministry of Communication, and the distribution of the observation stations is not always suitable for the purpose of the hydro-power planning. Therefore, it is necessary, as occasion demands, to review the distribution of the observation stations from the viewpoint of hydro-power planning and establish the new stations to provide the effective observation systems.

(2) The situation of keeping the precipitation data in the electric power sector seems to be insufficient under the present circumstances. Therefore, it is necessary

to collect and keep the data, as much as possible, not to bring hindrance to the planning of the hydro-power development.

(3) In planning the hydro-power development, the precipitation data are used mainly as the supplementary ones to the run-off data. Therefore, it is necessary to arrange the precipitation data with respect to the water systems and investigate beforehand the correlationship between the precipitation and the river run-off.

2-4 Run-off data

2-4-1 General

After the precipitation reaches to the land surface, some part of it evaporates from the land surface, transpirates from the leaves of plants and infiltrates into the ground. The remaining portion of the precipitation flows down and becomes the run-off of the river, together with the ground-water which comes out from springs.

The ratio of the run-off to the precipitation is called the run-off coefficient and this coefficient varies remarkably according to the conditions of topography, geology, land surface, plantation, climate and the preceded rain-fall. It may vary from time to time in a year and from place to place along a river course. The loss of precipitation due to the evaporation and others increases, in general, as the river goes to the down-stream region and there is a tendency that the run-off coefficient becomes smaller towards down-stream.

In Japan, the run-off coefficent is assumed to be 0.6 – 0.8 for the upper and middle part of rivers where the rivers have been utilized for power generation. But the coefficient may be considerably smaller for Indonesia, because the conditions are fairly different from those in Japan. An example of the run-off coefficient in Djawa will be seen in appendix 2-7.

Although the estimation of the run-off from the precipitation and the run-off coefficient is useful for rather rough estimation of hydro-power resources, the run-off data from gauging stations are indispensable to the planning of the hydro-power development. The planning should be started at first from the observation of the river run-off.

In order to grasp the duration of river run-off in a year, following run-off (water discharges) has been used in Japan as the indexes.

1) Droughty water discharge (355-days water discharge)
2) Low water discharge (275-days water discharge)
3) Ordinary water discharge (185-days water discharge)
4) Plenty water discharge (95-days water discharge)

This division means that the run-off of a river is not less than each above-mentioned discharge for 355, 275, 185 and 95 days respectively in a year.

The available discharge for a run-of-river type power plant can be easily estimated by these index discharges.

For the planning of the hydro-power development, it is necessary to prepare several data such as annual mean run-off, monthly mean run-off, maximum and minimum run-off in a month and flood discharge and its frequency, besides the daily run-off and above-mentioned index discharges.

Investigating these data, the annual energy of the power plant can be estimated and the firm output of the power plant can be decided. Still more, the storage capacity of the reservoir and the operation programme can be determined by these data, and the design of the spill-way and the flood control programme should be also based on these data.

The observation of the river discharge is, accordingly, the most fundamental and most important work for the planning of the hydro-power development.

In Japan, there are 3,151 gauging stations as of 1969 and among them 786 stations are for the survey of power generation. Others are for the irrigation, the flood control and so on. The data from the gauging stations for each purpose can be used supplementally with one another.

2-4-2 Run-off gauging

It is desirable to gauge the run-off at the place of the proposed intake or its neighbourhood to eliminate the inaccuracy or uncertainty of the data due to the loss of discharge which is taken away for the irrigation or other purposes.

The discharge is the amount of the run-off which passes through a cross section of a river course in the unit time and it can be expressed by the product of the cross-sectional area and the mean flow velocity at the section. The run-off gauging can be executed by measuring above-mentioned two factors. The correlation between the water level and the run-off has the characteristics of approximately quadratic and using this correlation, the run-off can be found from the water level.

The gauging should be carried out, to get the accurate data, at the place where the river course has the stable condition, the variation of the river bed is little and the irregular disturbance of the water surface does not occur.

The gauging station should be established accordingly at the most suitable place from the view point of the gauging purpose and the gauging principle.

The run-off gauging is to be executed by the river-stage measurement and the stream flow measurement. The river-stage measurement is to be carried out by measuring the water level by the staff-gauge at least once a day, or by the automatic water-stage-recorder which operates continuously.

The stream-flow measurement should be carried out three times a month, as the standard, to measure the discharge for several water level.

If the staff-gauge is to be used, the gauging time, when the daily mean run-off can be observed, must be fixed beforehand.

There are two types of automatic water-stage-recorder, i.e., the float type and the water pressure type. Recently the float type water-stage-recorder, which can oeprate over such a long period as three months, has been developed and this type has become to be used mainly. (For example, Suiken-62 type is widely used in Japan.)

In order to execute the stream flow measurement, it is necessary to measure the velocity of stream flow and, generally speaking, there are four kinds of measuring method, i.e., the current-meter method, float method, slope method and weir method. Some brief explanation will be given below to each method.

1) Current-meter method

The flow velocity is measured by the current-meter, such as Price type, at several part of a cross-sectional area and then the mean velocity is calculated. After that, the discharge can be obtained as the product of the mean flow velocity and the cross-sectional area. The actual measurement is executed by fording or by using a boat, a bridge or a suspended gondola.

The flow velocity shows, in general, the parabolic distribution along a vertical line at the place where the river flows stationarily. Then, it is usual to measure the flow velocity at four to six points along a vertical line.

2) Float method

This is a method which may come into use at the flood time when the use of current-meter is impossible. Two types of float are used in general, i.e., the surface-float and the rod-float.

The flow velocity can be estimated by observing the time when the float, which has been thrown in the river, flows through the definite distance along the river.

3) Slope method

This method comes into use at the flood time when neither the current-meter method nor the float method is to be used. The discharge can be estimated by Manning's formula (refer to 4-2-3) or by Kutter's formula taking into account the water surface slope, hydraulic mean depth and the assumed coefficient of roughness of the river bed.

4) Weir method

This method can be adopted if the river is small and the discharge is little. The discharge can be observed by providing a weir of V-notch or rectangular shape and measuring the over-flow depth.

In order to make an inventory of the run-off data, following charts and tables are to be prepared.

(i) Transversal cross section of the run-off gauging station
(ii) The table of the results of the stream flow measurement (arranged for every year)
(iii) Stage-discharge relation diagram
(iv) Stage-discharge relation table
(v) Daily stage and discharge table (arranged for every year)
(vi) Daily stage and discharge diagram (ditto)
(vii) Discharge duration table
(viii) Discharge duration diagram
(ix) The record of high-water discharge

In Japan, the run-off gauging has been executed under the provision of 'Standards of Run-Off Gauging' and this standards will be annexed for reference. (See appendix 2-8)

2-4-3 Present situation

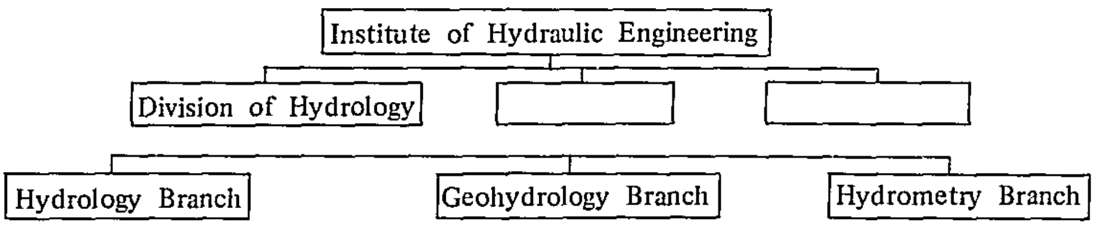
(1) The authorities in charge

'The Hydrology Division' of the Institute of Hydraulic Engineering, Directorate General of Water Resources, Department of Public Work and Electric Power, is now in charge of the run-off gauging in Indonesia. This Division administrates the guidance of the gauging technology, management of run-off gauging, data arrangement and publication.

The actual gauging is executed by respective organizations, such as irrigation, power generation and some others, and the results of the gauging are to be reported to this Division.

If a new gauging stations is to be established, it is necessary to get the guidance and advice of this Institute, and to report to the Institute afterwards.

The organization of this Institute, which is related to the run-off gauging, is as shown below;



There are about fourty technical personnel in the above-mentioned organization as of July 1970, and about ten of them are able to teach how to gauge the run-off.

The equipment for run-off gauging in this Division are 18 automatic water-stage-recorders, which are for the gauging stations under its direct control, including those which are not yet installed, and 7 current-meters.

This Division has a hydraulic laboratory in I.T.B. (Institut Technologi Bandung).

(2) Gauging activity

The run-off gauging in Indonesia has been executed since a long time ago in Dutch time, and it is known that there are the run-off data since 1909. After the war, gauging activities has been stagnant but it is getting better recently. The number of gauging stations for each year can be seen in Table 2-4-1.

(3) Gauging data

The results of the run-off gauging are compiled and published every year, as a rule, with the title of 'Publikasi Dinas Hidrologi' which is available upon request. Recently, every volume contains the data for two or three years.

There are 92 gauging stations all over the country as of 1967 and about a half of them are for the survey of the hydro-power. The list of gauging stations is given as appendix 2-9 and their distribution can be seen in appendix 2-10. The run-off gauging record of every gauging station, such as date of gauging, water level, run-off, cross-sectional area of the river course and the mean flow velocity, are annexed at the end of the above-mentioned data book.

The run-off data which were prepared in old days, in Dutch time, are almost the same as above-mentioned published data and some of the duration data are annexed at the end of the volume, but such data are not accompanied with the data books which are published at present time.

(4) Gauging facilities

Among 92 gauging stations all over the country, 23 stations are equipped with automatic water-stage-recorder and others are with staff-gauge for the regular time gauging.

The regular time gauging has a problem of accuracy which may be affected by the daily variation of the river run-off. Because the rain-fall intensity differs from time to time and from place to place. These characteristics of the rain-fall have a remarkable effect on the run-off, especially for the upstream part where the run-off is utilized for power generation. This effect is evident when we investigate the record of automatic water-stage-recorder and it is noticed that the daily variation of the run-off is remarkable. (see appendix 2-11)

Table 2-4-1 Number of Gauging Stations in Indonesia

(1909 1967)

District / Year	Djawa & Madura		Sumatera		Sulawesi		Others		Total		
	A	N	A	N	A	N	A	N	A	N	A + N
1909		1								1	1
10		1								1	1
11		1								1	1
12		1								1	1
13		2								2	2
14		4								4	4
15	7	4							7	4	11
16	7	4							7	4	11
17	10	4							10	4	14
18	14	18		2		2			14	22	36
19	14	20		11	2	3			16	34	50
1920	16	25		11	4	6			20	42	62
21	16	26	1	11	4	6			21	43	64
22	24	37	1	11	5	9			30	57	87
23	28	39	1	10	5	9			34	58	92
24	28	34	1	2	5	9			34	45	79
25	29	34	1	2	5	9			35	45	80
26	28	34	1	2	5	7			34	43	77
27	33	35	1	1	5	7			39	43	82
28	39	40	4	1	5	7			48	48	96
29	40	41	6	2	5	7			51	50	101
1930	39	40	6	2	5	7			50	49	99
31	39	40	6	2	5	8			50	50	100
32	39	37	6	2	1	8			46	48	94
33	36	24	3	1		4			39	29	68
34	31	19	3	1		4			34	24	58
35	25	19	4	1		3			29	23	52
36	27	19	3	1		3			30	23	53
37	25	18	5	8		17			30	42	72
38	29	18	7	18		18		2	36	56	92
39	32	18	8	17		18		3	40	56	96
1940	30	18	8	18	1	19		2	39	57	96
41											
42											
43											
44											
45											
46											
47											
48											
49											
1950	1								1		1
51	1								1		1
52	3			1					3	1	4
53	4			1					4	1	5
54	6	1	1	1					7	2	9
55	6	2	4	1					10	3	13
56	6	5	5						11	5	16
57	6	9	5						11	9	20
58	6	11	5						11	11	22
59	10	17	5						15	17	32
1960	10	20	5						15	20	35
61	10	32	5	1		2			15	35	50
62	11	48	5	4	1	3			17	55	72
63	11	47	5	4	1	3		6	17	54	71
64	12	55	5	4	1	3		6	18	62	80
65	15	51	5	4	1	3		6	21	64	85
66	15	51	5	4	1	3		6	21	64	85
67	15	51	7	9	1	3		6	23	69	92

(Notes) A: Automatic gauging station
N: Non-Automatic gauging station

Therefore, it is necessary to pay attention to the daily variation of the run-off to get the accurate daily mean run-off by the regular time gauging with the staff-gauge.

(5) Gauging method

There is a regulation that the transversal cross-section of a gauging station and the stream flow measurement should be carried out several times a year to revise the stage-discharge relation diagram and improve the accuracy of the data. But it seems that the frequency is rather few in Indonesia. (for example, three times a month in Japan)

If the frequency of stream flow measurement is less, it is impossible to grasp sufficiently the change of run-off which is caused by the change of cross-section of the river, therefore, there is a necessity to increase the frequency of stream-flow measurement.

(6) Some remarks on the treatment of the run-off data

(a) It is necessary to prepare the run-off data continuously at least for ten years as the fundamental data of the hydro-power development. This can be said especially for the planning of a project with dam and reservoir, for the run-off data are significant for the planning of the reservoir operation.

(b) It is necessary to check the run-off data before we use them if there are any errors or mistakes. The checking may be done by comparing the annual rain-fall with the annual total run-off, or by comparing the run-off at the upstream and downstream gauging stations along a river. By this way, we can decide if the data are adequate or not. In some cases, there are strange data that the run-off at the upstream gauging station is more than that of the downstream one. In these cases, it is necessary to investigate if there is any irrigation intake or any geological condition which causes infiltration, between two stations and, furthermore, to check the data of gauging themselves, if necessary.

(c) In order to find the daily mean run-off of a river, it is necessary to grasp its daily variation beforehand for the river with the significant daily run-off variation. In case of the regular time gauging, it is necessary to investigate the adequacy of the gauging time beforehand.

2-4-4 Recommendation

(1) The gauging stations in Indonesia are very small in number. Therefore, it is necessary to install more than one automatic water-stage-recorder for each river where the development is anticipated, according to the priority, and to install the staff-gauges at the river with less significance.

It is desirable to establish the gauging station at the neighbouring place where the development is anticipated.

There are many cases where the river will be developed multi-purposely and it is necessary to cooperate with other related fields about the run-off gauging.

(2) There may be some problems in connection with accuracy of the run-off data due to the less frequency of the cross-sectional survey and the stream flow measurement. Therefore, it seems to be necessary to increase the frequency of stream flow measurement, in order to check the variation of the river bed before and after a flood, and to carry out the measurement for the various water stages.

It is supposed that some changes may be made as to the river bed at the transitional period of dry and rainy season, then, it is necessary to choose the measuring time properly.

It is necessary to check the stage-discharge relation by executing the high water observation, because, in many cases the discharge for the higher water level is estimated by the extrapolation from the lower water level and there may be some problem of accuracy. The rule for this observation is to be fixed beforehand.

(3) The run-off data, which are now published, does not include the data of discharge duration and it is necessary to arrange the run-off data with the duration table, duration curve and some index discharges such as droughty, low, ordinary and plenty water discharge in order to grasp the duration condition of a river easily.

2-5 Others

2-5-1 Evaporation

Evaporation is the transfer of water from the liquid to the vapour state. Transpiration is the process by which plants remove moisture from the soil and release it to the air as vapour.

Some part of the precipitation which reaches the land surface is returned to the atmosphere by the evapotranspiration which is the combination of the above-mentioned two processes. The remainder of the precipitation returns finally to the ocean through surface or underground channel.

In arid region, or in the tropics, evaporation may consume some portion of the stored water in reservoir and it may not be neglected in planning of the reservoir.

The evaporation process is affected by many factors. The rate of evaporation from a water surface is proportional to the difference between the vapour pressure at the water surface and the vapour pressure in the overlying air, according to the Dalton's law. Turbulence caused by wind and thermal convection transports the vapour from the surface of the reservoir and permits evaporation to continue.

Evaporimeter or evaporation pan, has been widely used for agricultural purpose and others. In order to estimate the evaporation from the lake surface, a kind of evaporation pan, which has the diameter of 120 cm and the depth of 25 cm, has been used in several countries and the amount of the evaporation is to be measured by a point gauge every day.

Numerous devices have been made to get the same condition as on the lake surface, floating the pan on the lake or installing it along the lake shore. According to some investigation, the pan coefficient, E_r/E_p, is 0.66~0.90 where E_r is the annual lake evaporation and E_p is the annual pan evaporation.

The evaporation from the reservoir surface is one of the factors affecting the available discharge of the power plant. After the reservoir has been accomplished, the water surface area becomes larger than that of the original river and the discharge loss due to the evaporation increases. On the other hand, the precipitation to the reservoir can be used fully, while only a part of the precipitation becomes the river run-off, if the original river remains as it was.

Owing to the above-mentioned two factors, the available discharge in the wet region becomes larger, however, in dry region, it becomes less in general.

It is necessary to check the factors in case where the natural inflow to the reservoir is relatively little, the surface area of the reservoir is large and the reservoir is located in the dry region.

The amount of the evaporation which were measured by evaporimeter at several places in Indonesia and Japan are given on appendix 2-13. We can see rough correlations between the amount of the evaporation and the conditions around the measuring stations.

2-5-2 Sedimentation

(1) General

The river stream transports fine suspended sediment and more course bed load which moves down rolling on the river bed.

The specific gravity of the suspended sediment is heavier than that of the water and it is apt to settle but forced upwards by the turbulent flow. After the river flow with the suspended sediment has reached to the reservoir, the flow velocity decreases and the turbulence is reduced. Accordingly, the course particle of the suspended sediment and a large portion of the bed load settle at the upstream end of the reservoir forming a delta. The finer suspended particles continue the suspended state still longer and sometimes are transported to the deeper part of the reservoir by the density current and settle there or are discharged to the downstream of the dam.

It is not too much to say that the useful life of the reservoir may be determined mainly by the sedimentation. The reservoir will finally be filled up with the sediment and the useful life is determined by the relation between the amount of the inflowing sediment and the capacity of the reservoir. There are some cases where the dams which were inadequately planned have been filled up with the sediment in a few years. In planning the reservoir, it is necessary to estimate the amount of sediment inflow at the early stage of the planning.

The production and the transportation of the sediment are affected by following factors.

1) catchment area

2) geological conditions, characteristics of the surface soil and the state of slope surface rupture

3) topographical conditions (undulation, altitude, inclination of slope and the configuration of river basin).

4) meteorological condition (precipitation and its intensity, duration time and distribution of rain-fall)

5) hydraulic characteristics of mountain torrent and river

6) the extent of covering vegetation and artificial working (land development, afforestation, sand arrestation and others)

(2) Estimation methods of sedimentation

The useful life of the reservoir is an important factor for the determination of the depreciation years of the hydro-power plant and the useful life is to be greatly influenced by the amount of sedimentation. Therefore, the sedimentation has the definite influence upon the economy of the hydro-power plant and the careful investigation of the sedimentation is necessary in planning the reservoir.

There are several kinds of estimation method for sedimentation and two of them are as follows.

1) the method using the sediment rating curve and trap efficiency

2) the method using the correlation between the topographical condition of the catchment area and the sedimentation in the reservoir

(3) Measurement of sedimentation

The amount of the suspended sediments in the river stream is measured by taking out the sample of river water with a sampler, filtrating it, drying the residue and weighing it. The amount of the sediments is, in general, expressed with the unit of ppm (parts per million).

The amount of the bed load transport is estimated by taking the grading of the river bed material and the river discharge into account.

The result of the sedimentation in each reservoir has been measured every year and has been provided as the statistic data in several countries. These records have been used as the important data for the planning of a new reservoir.

(4) The formation of sedimentation in reservoir

It is necessary to estimate previously the possible formation of the sedimentation in the reservoir for the investigation of the following matters.

1) the location and the elevation of the intake structures of the outlet and penstock which are to be located around the dam
2) the progress of the reduction of effective storage
3) the effect of the river bed rising and the flood water level rising on the several facilities at upstream

The factors which have the influence on the formation of the sedimentation are as follows.

1) the shape and the dimension of the reservoir
2) characteristics of sediment
3) operational regulation of the reservoir
4) the ratio of the amount of the sediment to the capacity of the reservoir
5) the relation between the river discharge and the capacity of the reservoir

There are several estimation methods of the sedimentation formation progress in successive years. The general formation of the sedimentation and the related terms are shown on Fig. 2-5-1. The formation may be variable according to the conditions. There are many cases where the formation of the top-set beds does not exist or where the fore-set beds are not notable, although the top-set beds are formed. Generally speaking, the top-set beds grow notably when the rate of the course particles in the sediment inflow is large.

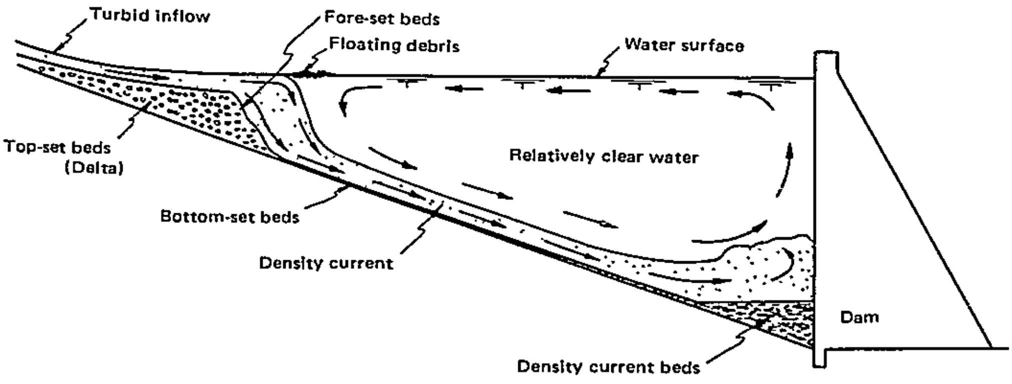


Fig. 2-5-1 Sedimentation in a typical reservoir

Fig. 2-5-1

The distinctions of top-set beds, fore-set beds, bottom-set beds and density current beds are relatively clear when the water level of the reservoir is kept constant. When the annual variation of the water level is remarkable, the top-set beds, which are once formed at the upstream part, may be eroded during the low water period and may be transported again to the neighbourhood of the dam. Consequently, the distribution of the sedimentation becomes uniform over the whole area of the reservoir and the notable top-set beds do not grow.

(5) The treatment of sedimentation in the reservoir

In determining the site of the proposed reservoir, following investigations are necessary.

1) the investigation of sedimentation condition in the reservoirs in the neighbourhood

2) the investigation of the suspended sediment and bed load of the river concerned

3) the investigation of the errosion condition in the river basin

In order to control the sediment inflow, following measures are applied.

1) the sand arresting works in the upstream region

2) the plantation and afforestation in the upstream region

There are mechanical methods or hydraulic methods to remove the sediment in the reservoir but they are practically uneconomical. In some cases where the big demand of the aggregate for the construction materials is not far from the reservoir, the sediments can be taken away economically.

(6) Present situation

In Indonesia, there are many rivers which transport much sediment. The Institute of Hydraulic Engineering has executed some measurement of the suspended sediment for a few rivers. (refer to Appendix 2-14)

The systematic investigation on the sedimentation results in the existing reservoirs is not seemed to have been carried out.

(7) Recommendations

1) In planning the hydro-power development at the river where the sediment discharge is considerable, it is necessary to execute the systematic investigation on the suspended sediment and bed load.

2) It is necessary to measure the sedimentation results in the existing reservoirs and also the suspended sediment and bed load in the rivers which flow into the reservoirs, in order to provide the basic data for the future reservoir planning.

3) There are some area where the overcutting of mountain forests has made the land surface bald and has promoted the erosion progress. In these area, it is necessary to execute the systematic afforestation and to provide the sand arresting facilities for the flood control, the stabilization of the mountain slope and the control of the sediment transportation.

3. Survey of the hydro-power potential

3. Survey of the hydro-power potential

3-1 Hydro-power potential

The hydro-power is the potential energy of the running river water and the amount of the energy is to be determined by the river-discharge due to the rain-fall and the available head which is determined by the topographical conditions.

Generally speaking, the hydro-power potential may be classified into two categories, namely, the theoretical potential and the technically developable potential. Some of the technically developable potential are called as the economically developable potential. Therefore the categories of hydro-power potential may be shown as below;

Potential
- Theoretical
- Technically developable (Some of them are economically developable)

(1) Theoretical potential

The theoretical potential is the electric energy which the whole river discharge is converted to and has the meaning of statistics to recognize the general feature of the hydro-energy resources in the concerned area. It cannot be used directly for the planning of hydro-power development but may be used for the preliminary understanding of the hydro-power resources in some under-developed area.

The theoretical potential is to be estimated generally by following formula;

$$p = \int_{O}^{H} g\ q\ dh$$

where,

- p : mean potential (KW)
- g : acceleration of gravity (m/sec^2)
- h : elevation above sea level (m)
- q : river discahrge (m^3/sec)
- H : maximum elevation in the area to be estimated (m)

If the precipitation is to be used in this formula then 'q' is calculated by following formula;

$$q = p\ s\ a$$

where,

p : precipitation (m/sec)

s : catchment area of the concerned elevation (m^2)

a : coefficient of run-off

(2) Technically developable potential

The technically developable potential is a part of the above-mentioned theoretical potential which is able to be developed technically. It is expressed by the capacity (KW) of the respective site taking off the losses of discharge and head.

Among the technically developable potential, there is the potential which is called as economically developable one. This is the potential which can be developed economically and may become the object of the development plan at this stage.

The following losses must be taken off when the technically developable potential is to be estimated;

1) loss of head

variation of the available depth of the reservoir, head losses along the water way

2) loss of discharge

evaporation, transpiration and infiltration

3) others

losses due to the efficiency of turbine and generator, loss due to the over-flow of the run-off which exceeds the maximum discharge of the power plant, loss due to the unavailability of the discharge which comes from the area where the water way passes through. (in case of run-of-river type power plant)

These losses may be determined inevitably when the development method has been decided. Taking off the losses, the technically developable potential will become fairly less than the theoretical one.

3-2 Estimation method of the hydro-power potential

(1) Theoretical potential

There are following two methods for estimating the theoretical potential.

1) Contour line method

At first, the maps with contour lines for whole concerned area are to be prepared, then the areas between adjoining contour lines are to be measured. These areas are to be plotted on a graph having the abscissa of the area and the ordinate of the elevation, and the curve line of elevation-area is to be drawn.

On the other hand, the total discharge from the areas between adjoining contour lines are to be estimated using the annual mean specific discharge ($l/sec/km^2$) of the average year.

Multiplying the total discharge from each area by the difference between adjoining contour lines, the theoretical potential for each area can be obtained. Summing up these potentials, the theoretical potential for whole area can be estimated. An example is shown about Kali Bogowonto in the appendix 3-1.

2) Discharge data method

Supposing the longitudinal cross section of a river between two places A and B, the elevation of A and B are expressed as Z_A (m) and Z_B (m), and the discharges are expressed as Q_A (m^3/sec) and Q_B (m^3/sec) respectively.

Then the theoretical potential between A and B can be obtained by the formula below.

$$p = \frac{Q_A + Q_B}{2}(Z_A - Z_B) \times 9.8$$

Therefore, as it can be seen on Fig. 3.2.1, the theoretical potential is shown by the area of the hatched part.

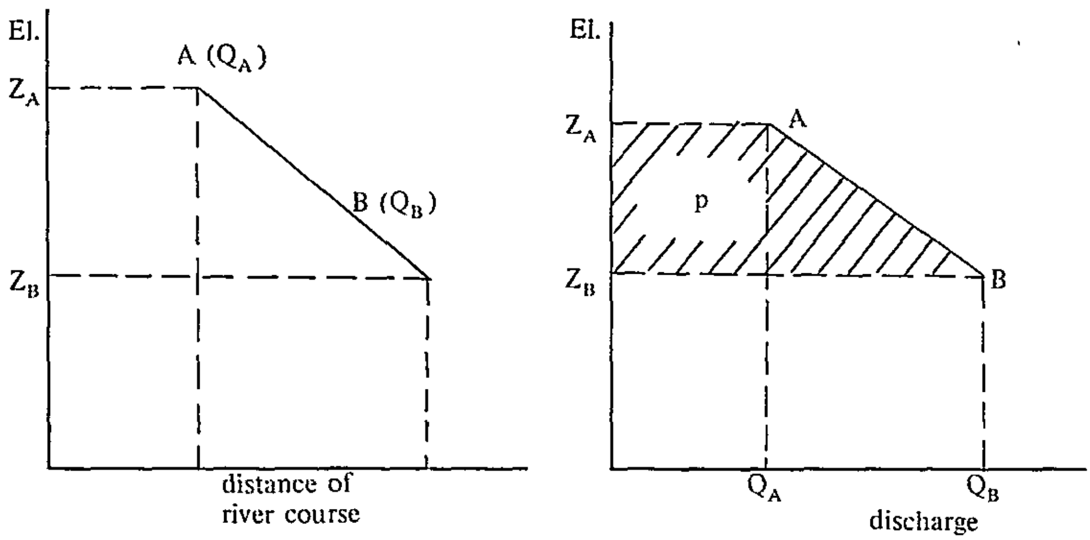


Fig. 3.2.1

(2). Technically developable potential

Following matters should be investigated to estimate the technically developable potential of a river for the present stage. After the electric power supply system have become big enough in future, some other considerations will be necessary.

1) To try to regulate and equalize the river discharge by constructing a dam, if it is possible. The higher the height of the dam is, the better to make a reservoir of enough capacity.
2) To decide the maximum discharge of the power plant and available discharge using the long range data of river discharge gauging.
3) To decide the outline of the development and to estimate the head loss, discharge loss and the efficiency of turbines and generators which are technically possible.
4) To calculate the capacity and energy of power plant using maximum discharge and available head.

It is needless to say that the development method may vary from river to river according to its characteristics but some criteria for the decision of the maximum discharge of the power plant are necessary, when we try to estimate the developable potential extensively, systematically and comprehensively. The criteria should be established according to the development types such as dam-type or run-of-river type.

Hydro-power resources can be used for good, and once a hydro-power plant is established, it will be able to be used for a long period over several decades. Consequently, the development of hydro-power should be based on the discreet economical investigation from the view point of a long range.

This investigation requires some complicated procedure for each site and may not be applied for the survey of the hydro-power potential. Therefore, the criteria are to be determined to estimate the hydro-power potential systematically.

Japanese criteria for the estimation of the hydro-power potential are shown below as an example. In Japan, the comprehensive surveys have been executed already four times. The criteria have been changed greatly according to the change of times and the progress of economy and technology, as can be seen below.

First Survey (1910 – 1913)

Most of the power plants were assumed to be of the run-of-river type and 355-days discharge (droughty water discharge) was adopted for the maximum discharge of the power plant.

Second Survey (1918 – 1922)

The maximum discharge was raised to 185-days discharge (ordinary water discharge) not to waste the water exceeding 355-days discharge. Most of the power plants were still assumed to be of run-of-river type.

Some thermal power plants were taken into consideration to be used together with the hydro-power plants to supply electric power in dry reason.

Third Survey (1937 – 1941)

The construction of the reservoir or regulating pondage became possible due to the progress of the technology and it was assumed that the river discharge was to be stored in wet season and at off-peak time, and the stored water might be used in dry season and at peak time. The thermal power plant might be used together with the hydro-power plant supplementally.

This survey was carried out under the principle of so-called 'Hydro-principal, Thermal-supplemental'. The hydro-power plants of dam-type were planned as much as possible and the maximum discharge of the run-of-river type plants was assumed to be 95-days discharge (plenty water discharge) as the standard, and other purposes such as flood control and irrigation were taken into consideration together with the power generation.

Fourth Survey (1956 – 1959)

After the world war II, the electric power demand increased very rapidly gearing to the restoration of the national economy. On the other hand, the ratio of hydro-power to thermal-power was expected to be changed remarkably according to the progress of the technology for the thermal power.

Consequently, the constitution of the electric power generation was turning from so-called 'Hydro-principal, Thermal-Supplemental' to 'Thermal-principal, Hydro-supplemental'. In these circumstances, considering the hydro-power as a part of the over-all energy problem in Japan, the new criteria for the economy of hydro-power were adopted.

This survey was carried out to draw up the integrated development programme of rivers and to aim the most effective utilization of rivers. The stress was put on the planning of large scale development including reservoir or regulating pondage and some preliminary surveys were executed at respective sites.

Since that time, the scarceness of remaining hydro-power potential in Japan have not been able to meet the rapidly increasing demand of electric power and the part of thermal power, including nuclear power, has become inevitably very large.

Now the base load of electric power is supplied by the large scale thermal power plants and the peak load is supplied mainly by the large scale pumped-storage power plants.

Comparing the above-mentioned circumstances with that of Indonesia, it seems to be difficult to determine the estimation method of developable potential in Indonesia. Because Indonesia is consisted of several regions which have the different conditions, from Djawa where the development has been proceeded rather well, to Kalimantan or West Irian where the rather under-developed condition remains.

It may be said that the method similar to above-mentioned First Survey can be adopted for Kalimantan and West Irian and the method similar to the Second or Third Survey can be adopted for Djawa and to a part of Sumatera.

But it is better to execute the potential survey with the common criteria, therefore, the method similar to the First Survey may be adopted for the time being, with additional remarks for the possibility of increasing capacity in future by grasping the variation of river discharge properly.

This procedure may be adequate for Indonesia where the systematic and comprehensive survey of hydro-power potential has not yet be executed up to the present time. Detailed procedure will be shown below.

1) To investigate the possibility of the dam construction to equalize the river discharge as much as possible, corresponding to the characteristics of the discharge. For this purpose, it is necessary to make the paper plan at first using the topographical maps with the scale of larger than 1/50,000, if available, and then to certify it by the reconnaissance survey.

2) To check the data of run-off, if the available data are insufficient from the viewpoint of accuracy and gauging period, the correlation between river discharge and rain-fall or among discharges of several gauging stations which are located different places from upstream to downstream along a river must be investigated in order to verify the applicability of the data.

3) To determine the maximum discharge of the power plant according to the criteria which should be established taking the present situation in Indonesia into consideration, where the development of the hydro-power is at its initial stage.

   350-days discharge has been generally used in Indonesia and it can be regarded as the droughty water discharge and is to be used as the maximum discharge of run-of-river type power plant.

   For the power plant with dam and water way, including regulating pondage, the above-mentioned criteria may be applied correspondingly. In this case, the maximum discharge may be raised according to the regulating capacity as shown on Fig. 3.2.2.

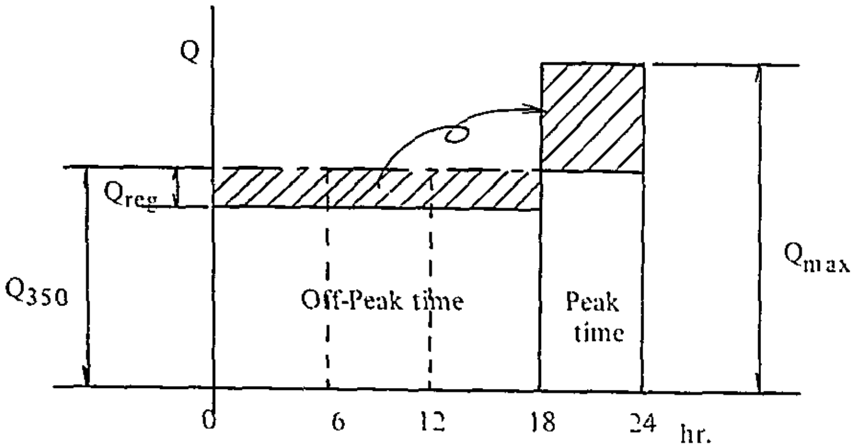


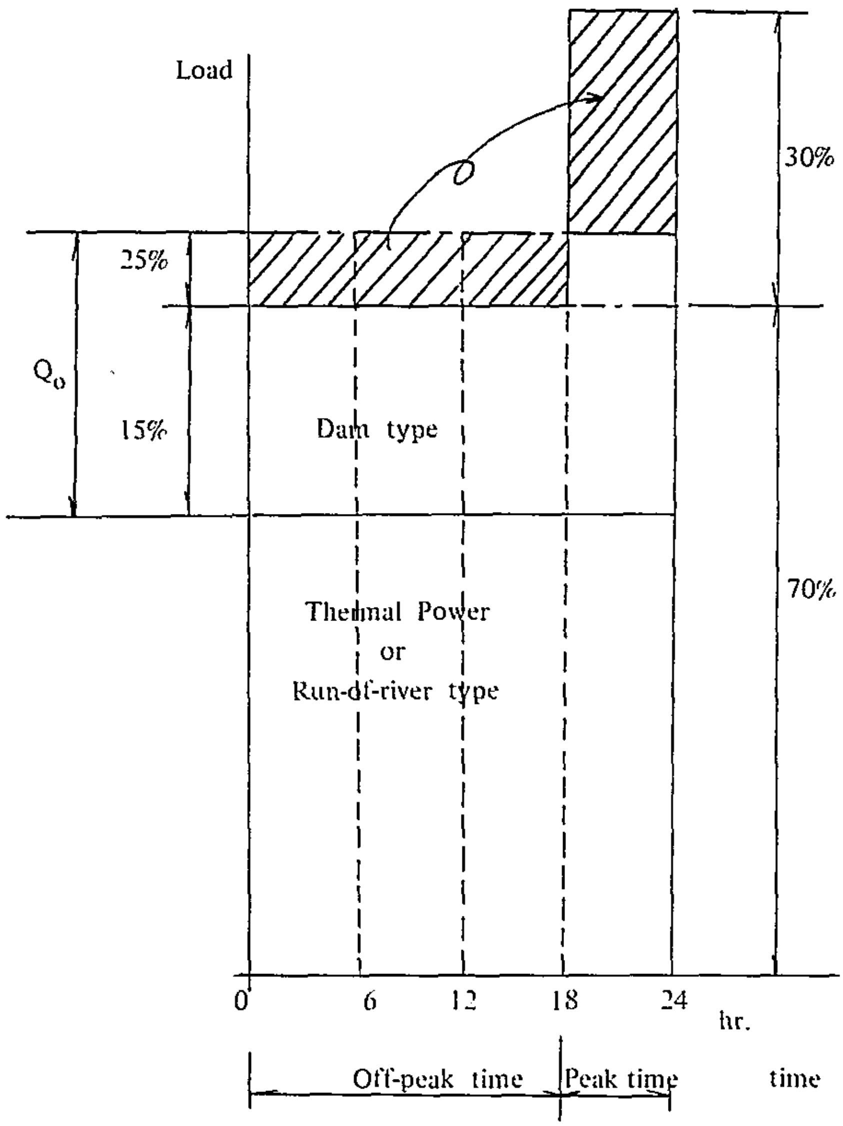
Fig. 3-2-2

For the power plant of dam type, the following consideration is necessary.

Investigating the present situation of load curve in Indonesia, it can be said that the part of peak load is comparatively small, that is, the base part of the load is about 70% and the peak part is about 30% and peak part can be regarded to be equivalent to 6 hours. Then we assume that the load curve is to be as shown on Fig. 3.2.3. Consequently, the maximum discharge (Q_{max}) can be expressed as;

$$Q_{max} = Q_o \times 75\% + Q_o \times 25\% \times 4 = Q_o \times 175\%$$

where Q_o is the minimum available discharge using the reservoir.



Fgi. 3-2-3

It is needless to say this assumption is based on the present situation of the load curve, taking the combination with the run-of-river type plants and thermal power plants into consideration, and there still remains the possibility of reinvestigation as the constitution of the load curve varies.

Although the supplemental use of the thermal power plant is seemed to be necessary in dry season, the detailed combination of hydro and thermal and its economic problem is not mentioned here but will be treated later.

Summarizing the above-mentioned maximum discharge for power plants of several types, we get;

(i) run-of-river type

$Q_{max} = Q_{350}$

(ii) dam and water way type (with regulating pondage)

$$Q_{max} = (Q_{350} - Q_{reg}) + Q_{reg} \times \frac{24}{6}$$

(iii) dam type (with reservoir)

$Q_{max} = Q_0 \times 75\% + Q_0 \times 25\% \times 4$

where,

$Q_{3\,)}$: 350-days discharge

Q_{reg} : possible regulating discharge

Q_0 : minimum available discharge using reservoir

If we adopt these criteria, then there still remains the problem of the excess discharge which means the discharge exceeding the maximum discharge of the power plant and may be used if other criteria might be adopted. Considering the availability of excess water, the droughty water discharge ratio, which is the ratio of droughty water discharge to the annual mean discharge, must be recorded to grasp the variation condition of river discharge and provide for the future purpose.

4) To determine the development method of the river and to choose the type of power plant as run-of-river type or dam type or combined type. In this case, the integrated development of the river and multipurpose utilization of river, such as irrigation, water supply and flood control, should be taken into consideration. After the development method has been determined, the effective head, discharge loss and the efficiency of available turbines and generators can be decided.

It is necessary to execute some reconnaissance survey at each site, based on the paper plan, to investigate if the topographical and geological condition may permit the development plan technically.

5) To calculate the capacity of power plant by using the maximum discharge and available head, and estimate the evergy, which will be generated by the power plant taking the available discharge into account.

By using above-mentioned criteria, the developable potential of each river can be estimated.

4. Survey of the hydro-power project

4. Survey of the hydro-power project

4-1 Preliminary investigations

4-1-1 Demand and supply of electric power

As the electric power cannot be stored, the production and the consumption should be taken place at the same time. Therefore, in drawing up the power development plan, the relation between the demand and the supply must be taken into consideration.

In Indonesia, the present situation of demand and supply varies remarkably with the districts. The load curves of each Exploitasi in Djawa are shown on the appendix 4-1, and the generating facilities in each district are mentioned in Section 4-1-2.

In general, the following regions are promising for the development of the hydro-power.

(i) The region where the big cities demand the plenty of electric power and the economical hydro-power resources are available in the vicinity.

(ii) The region where the establishments of big factories are expected and the promising hydro-power resources are available in the vicinity.

(iii) The region where the existing transmission lines can be used to transport the electric power from the economical hydro-power development sites to the consuming area.

(iv) The region where the hydro-power is to be developed as a part of the multi-purpose development of a river.

(v) The region where the local demand exists and the economical hydro-power is available in the vicinity.

As the hydro-power plants are durable over several decades, it is necessary to make a long term demand forecast taking into consideration of the role of the respective hydro-power plant in the power supply system. For this purpose, the feature of the load and the character of the hydro-power must be properly recognized. The brief explanations are given below.

(1) The feature of the load

1) Composite load

In general, electric power system supplies the electric power from the various sources to the different kinds of demand. The composite load is indicated as the integrated demand at a certain time.

2) The feature of the composite load

The composite load is consisted of various kinds of load and its character is the superposition of the respective character of each load. It varies with the time, weather, climate, season, social conditions and the situation of the industrial activities. The load curves of each Exploitasi in Djawa show fairly sharp peak load in the evening when the demand for the lighting is big.

3) Peak load and base load

The daily load can be divided into the peak part and the base part. In general, the peak load appears in the evening for the power supply system with the predominant demand for the lighting and it appears in the morning with big demand for industries.

The minimum load in the load curve is called the base load. The composite load is the superposition of the base load and the fluctuating load above it.

(2) Planning of the hydro-power development from the viewpoint of the power supply problem

1) Demand forecast

In planning the hydro-power development, it is necessary, at first, to analyze the composite load before-mentioned. Based on this analysis, the demand and load feature in future are estimated.

In estimating the demand, the rate of economic growth, the tendency of the industrial activities, the increase of the population, the tendency of the personal expenses and consumptions, and others are to be taken into account. Some descriptions about the load forecast will be given in Chapter 5.

2) Planning of the power supply by hydro-power

The power supply plan must be drawn up taking the possibility of the establishment of thermal, hydro, diesel and other power plants into consideration. Now, some description is given for the planning of the power supply by the hydro-power.

(a) Types of the hydro-power plant

Run-of-river type

This type is the hydro-power plant without regulating pondage. As its maximum discharge is taken, in general, to be about ordinary water discharge (185-days water discharge), the excess river discharge flows down in waste and the rate of the river discharge utilization is rather low.

Its output fluctuates with seasons, and it operates with full capacity in rainy season and less in dry season according to the river discharge.

Regulating pondage type

This type is the hydro-power plant with the regulating pondage which can regulate the river discharge corresponding to the daily or weekly variation of the demand.

Reservoir type

This type is the hydro-power plant with the reservoir which can regulate the seasonal variation of the river discharge, storing water in rainy season and discharging it in dry season.

The power plant of this type makes the utilization rate of river discharge high and can supply the electric power corresponding to the daily, weekly and annual variation of the demand. It can be used also to make the electric power system stable as the capacity in reserve for the system.

(b) Character of the hydro-power

(i) Ability to follow the demand fluctuation

The hydro-power facilities have relatively simple mechanism and, in general, they turn out full capacity within one minute from any stage of operation and the reverse is also possible. Therefore, they can easily follow the demand fluctuation, and we can use them for peak load including the frequency control.

(ii) Reliability

As the hydro-power facilities have relatively simple mechanism, the regular inspection does not take long time and the accident is quite rare. Therefore, the reliability of the hydro-power plant is fairly high.

4-1-2 Existing facilities for electric power

In planning the new project of power development, it is necessary to take the existing facilities into consideration in order to make the new power supply system most economical and effective. Some considerations are given below.

(1) Generating facilities

The existing facilities for power generation in Indonesia are as shown on the appendix 4-2, 4-3, and location of hydro-power plant can be seen on the appendix 4-4.

In planning the hydro-power development where some hydro-power plants already exist in the same water system, it is necessary to take the effect of the new power plant on the existing ones into consideration, so that the most effective operation as a whole can be brought about.

The natural river run-off may be controlled by the reservoirs or pondages of the existing power plants or of new ones and the resulting discharge may be different from the natural discharge according to the type, the discharge used and the operational regulations of the power plants. These factors must be taken into account as to make the waste of discharge minimum and make use of the river discharge most effectively.

The capacity of the reservoir or pondage, the maximum discharge, the number of untis and the operational plan of the proposed hydro-power plant must be decided basing on the above-mentioned consideration.

(2) Transmission facilities

The existing transmission facilities in Indonesia are as shown on the appendix 4-5. There are five transmission systems in Djawa but they are not interconnected at present. The maximum transmitting voltage is 150 KV for the lines connecting Djatiluhur hydro-power plant to Djakarta and Bandung. Besides these lines, there are also transmission lines with the voltage of 70 KV and 30 KV. However, the transmission line voltage which is shown in Table 4-1-1 will be adopted in Indonesia in the future.

Table 4-1-1 Transmission line voltage which shall be standardized in Indonesia

Nominal system voltages (between two phases) KV	Highest voltages for equipment KV
(30)*	(36)
66	72.5
110	123
(150)**	(170)
220	245
380	420
500	525

*) *Only allowed for service areas where 20 KV primary distribution voltage will not be used.*

**) *Not recommended, only allowed based on the results of special study.*

There is no transmission system outside Djawa but only the local distribution lines exist around each local power plant.

In future, it will be necessary to raise the transmitting voltage up to more than 200 KV with the increase of the demand and the progress of the power development and it may also be necessary to interconnect several transmission lines even between Sumatera and Djawa.

In drawing up the scheme of the new power plant, the plan of the transmission lines must be made up at the same time. If the existing transmission lines can be used to transmit the energy which is to be generated by new power plant, the overall cost of the development will decrease and the project becomes more economical.

In case where the transmission lines are interconnected or are possible to be interconnected, the hydro-power can be developed at the sites far from the consuming area, transmitting the energy by that transmission systems. Therefore, it becomes more economical than the case where the long transmission lines for the proposed power plant are to be constructed independently.

In investigating the possibility to use the existing transmission lines for the new power plants, following matters should be taken into account.

(i) allowable current of the transmitting wire

(ii) voltage drop and energy loss

(iii) allowable transmission capacity determined by the stability of the system

(iv) the possibility of adding new wires or of rewiring, and their method and cost

4-1-3 Related facilities

In many cases, the development of the hydro-power has the close connection with other purposes of river utilization, such as irrigation, water supply and navigation and also with the flood control.

Now, the main part of the irrigation and flood control facilities are under the administration of the Directorate General of Water Resources and this Directorate General has several plans related to the hydro-power, as shown on the appendix 4-6.

In case where the facilities for other purposes exist in the area related to the proposed hydro-power development, some coordination with them should be fixed up. If there is some right of river utilization for other purposes in the area related to the proposed hydro-power development, it is necessary to fix up some coordination likewise. This coordination is also necessary when the development plans for several purposes fall on in the same area.

If a dam is to be constructed for multi-purpose, sometimes the advantages and disadvantages of each purpose are contrary to each other. For example, the power generation desires to keep the water level high but the flood control requires to keep it low before the flood occurs and irrigation requires much water in rice planting season even drawing the water level down.

Therefore, if the hydro-power plant is to be established as a part of the multi-purpose development, it is necessary to fix up the proper coordination with other purposes and decide the maximum discharge, number of units and the operational plan of the proposed power plant taking these factors into account.

4-1-4 Others

(1) Compensation

For the construction of a power plant and a dam, a large area of the land is required and some problems of compensation will arise. The objects of the compensation are in general as follows.

houses and some other structures
forest and trees
farm field
public facilities (road, railway, bridge and so on)
right of river utilization
right of mining
others

In planning the hydro-power development, it is necessary to investigate the compensation problem beforehand.

(2) Cost allocation

When the river is to be developed multi-purposely, the cost for the common facilities is to be allocated to each purpose in a rational manner.

For this purpose, 'the modified alternative justifiable expenditure method' is widely used in Japan and is regarded as the most rational method. (refer to 3-4 and appendix 3-15 of the report of the Terada mission. The example of cost allocation for Djatiluhur project can be seen).

4-2 Survey method of the hydro-power project

4-2-1 Basic data

The basic data, which are necessary for the survey of the hydro-power development project, are as follows.

Topographical data
Geological data
Precipitation data
Run-off data
Others

The extent of the requirement and accuracy of these data may vary in accordance with the survey stages. Some explanations and survey methods are described here for each data.

(1) Topographical data

The topographical maps with the scale of 1/100,000~1/25,000, which can be obtained from the Directorate Topography Angkatan Darat, may be used for the paper plan at the early stage of the survey.

With the progress of the paper plan, the topographical maps with the scale of about 1/5,000, which may be provided by the aerial survey, are to be prepared for the estimation of the storage capacity in planning the reservoir project or for the route selection of the waterways and others.

The topographical maps with the larger scale, 1/1,000~1/100, are also to be prepared by direct surveying for the lay-out or the design of several structures. Recently, the ground photographic surveying is carried out to prepare the topographical maps at the area with steep topography where the direct survey is difficult to be executed. Table 4-2-1 shows the relation between the purposes and the scale of the maps.

Table 4-2-1

Purpose	Scale	Contour lines
General project planning	1/100,000 ~ 1/25,000	every 20 ~ 10 m
Reservoir planning, Water-way planning	1/10,000 ~ 1/5,000	10 ~ 5 m
Design of structures	1/1,000 ~ 1/100	5 ~ 1 m

The survey instruments have been fairly improved and several modern transit or theodolite with the minimum reading of 1 second, and the levels of automatic tilting type are available now for the general use. But it is necessary to choose the instruments in accordance with the survey purpose, for the expensive instruments are not always almighty.

The progress of the photographing technique of the aerial survey or the ground photographic survey, and the improvement of the mapping equipments have made the maps more accurate. Especially, the recent improvement of the mapping equipments is remarkable and the automatic mapping has been put into practice with the link to the computer.

Furthermore, the aerial photograph by the infrared film or the colour film is used nowadays for the special geological survey of the land slides and fractured zones.

The stereoscopic view of the aerial photos makes the investigation of the topography and the geological features possible, just as we have a look at the site actually.

(2) Geological data

The geological data are necessary to investigate the possibility of the construction of the structures. There are several stages of geological maps, from the one with a smaller scale showing the general feature of the geology, to the bigger one which is to be prepared by the elaborate geological survey at the local site of the proposed dam and other structures.

The geological maps of smaller scale are used to grasp the general geological conditions of the region concerned and to establish the plan of detailed survey work.

The geological maps of bigger scale are to be prepared basing on the results of the geological survey in the forms of geological plans and cross-sections, and they are used as the fundamental data for the design of structures.

In surveying the geological feature of the proposed site, the land surface survey and the underground survey are to be carried out. The investigations of the physical and chemical properties of the soil and rock are also carried out.

The land surface survey is a kind of the reconnaissance survey of geology. At this stage, we explore the topography and the aspect of the river at the proposed site and investigate the outcrops, talus and river terrace, and infer the formation process of the geological structures and the distribution of the strata. The cooperation of the geologists is quite useful for this purpose.

Based on the results of the above-mentioned reconnaissance survey, the schedule of the underground survey, by boring, exploration adit and others, is to be drawn up to investigate the detailed geological feature at the proposed site, keeping the pace with the progress of the survey.

The underground survey is carried out to make clear the kind of soil and rock, the distribution of strata, the conditions of faults, fractured zones and fissures, and others which are not to be made clear by the land surface survey. Following measures are usually used for the underground survey.

Boring
Exploration adit and shaft
Physical exploration

In some cases, these measures are used independently but, in most cases, they are used with the proper combinations supplementing each other to accomplish the expected purpose. Some explanations are given here to each measure.

1) Boring

Several types of boring method such as the auger type, the jet type, the percussion type and the rotary type are used corresponding to the survey purpose. The former two are for soil bed while the latter two are for the gravel stratum or the rock bed.

The survey boring can be executed easily with the direction and the depth of drilling as we like. Therefore, this measure is widely used for the foundation exploration of the dam, power plant and other structures in accordance with the requirements of the survey.

By this measure, the kind of soil and rock, the feature of strata, the conditions of fractured zones and fissures, and the stage of the ground water level are to be made clear.

By adopting the double-core-tube, the core sampling at the fractured zone is possible to some extent and the conditions of the fractured zone or fissure can be made clear by investigating the aspect and length of the core, core recovery ratio and others. The bored hole inspection scope may be used, if it is necessary to inspect the inside of bored hole. The permeability test (Lugeon Test) also may be carried out making use of the bored hole.

The results of the boring are arranged in the form of the log diagram, in which the name of soil, rock and stratum, colour of the core, conditions of fractured zone or fissure, core length, core recovery ratio, colour of slime, water leakage and ground water condition, and other remarks during the boring work are to be recorded. Further, the sampled core is to be kept in the box with the indication of the depth or put on record by colour photographs, if necessary.

In geological survey of the hydro-power plants, the rotary type boring is mainly used, for they are constructed on the rock foundation in most cases. This is the drilling method using the rod with the metal bit made of particular alloy or the diamond bit at its top. In drilling into the breakable strata such as gravel or talus, bentonite or cement milk is used to prevent the rupture of bored hole.

The diameter of boring bit has a wide range from 25 mm to 200 mm and we may choose it according to the survey purpose and the drilling depth. Usually, the bit with the diameter of 45~65 mm is widely used.

Recently, the diamond boring with the boring machine of high speed rotation is extensively used for the hard rock bed.

2) Exploration adit

The exploration adit and shaft are usually used for the inspection of the underground conditions. These measures can be said to be the most effective way of the geological survey, because we can see directly the underground geological feature in the adit or shaft. They are indispensable for the survey of large dams or other important structures but take long time.

The shaft has usually the square section of about 1.5 m x 1.5 m at its bottom and the adit has the shape of the rectangle with the breadth of 1.2~1.5 m and the height of 1.5~1.8 m.

By these measures, we can inspect directly the quality of soil and rock, the distribution of strata, the condition of the ground water, and the features of faults, joints and fissures including their strikes and dips. Moreover, we can make use of them for the execution of the foundation investigations as will be stated later.

For the site selection of adit and shaft, the convenience of grasping the general geological features there and the relation to the proposed structures should be taken into consideration.

After the geological exploration in the adit oı shaft has been finished, its development chart, which shows the aspect of its side walls or the ceiling, is to be prepared with the remakrs of the name and qualities of soil or rock, colour, the features of the fault, fissures and joints with their strikes and dips, the conditions of ground water, and so on. This chart becomes one of the fundamental data to prepare the geological maps at the site.

3) Physical exploration (Electrical and seismic exploration)

For the physical exploration, there are generally two kinds of method, namely the electrical exploration making use of the electric resistance, and the seismic (elastic wave) exploration making use of the seismic wave. The principle of the electrical exploration is as follows.

The electric resistance of the soil and rock bed varies in accordance with the water and electrolyte in the voids or fissures. If the bed of soil or rock is with less void, the electric resistance is relatively large, while at the bed with much void, it is relatively small. Making use of this tendency, we try to make clear the distribution of strata by measuring the electric resistance between two points under the given potential difference between both ends of measurement line.

As this method uses the weak electric current through the ground, it is impossible to apply it where some stray electric field exists, due to the electric rail-way or others.

The principle of the seismic exploration is as follows.

The propagation velocity of the elastic wave varies with the media and when the wave enters into another medium from some one, some part of the wave refracts and the other part reflects at the contact plane. Making use of this nature, we try to measure the depths of different kinds of strata by measuring the propagation time of the elastic wave of the artificial earthquake which is caused by the small blasting. The seismographs are used in this measurement.

These physical exploration methods are indirect ones to know the general features of strata and they can be carried out relatively cheap over fairly wide area. But if the physical properties of each stratum at the site are similar, the strata identification is very difficult. In this case, it is better to execute the direct survey together.

After the measurement, the results are to be analyzed and arranged in a form of the geological cross-section with the remarks of name of rock or soil strata, propagation time or the electric resistance and others, putting together the results of the exploration by boring or adit.

Laboratory and in-situ test

Several tests are carried out to investigate the properties of the foundation of structures. These tests are classified into the laboratory test and the in-situ test.

The laboratory tests are carried out to know the physical properties of rock such as the specific gravity, compressive strength, shearing strength, modulus of elasticity, Poisson's ratio, absorption and others using the test pieces made of rock pieces from outcrop, adit and shaft or made of boring core.

The laboratory tests are carried out also for the soil and, if necessary, for the fault materials. The test items are the grading analysis, specific gravity, water content, Atterberg's limit, consolidation, shearing strength, uniaxial compression, triaxial compression, permeability, compactibility and so on. The tests on the properties of the rock minerals are executed, if necessary.

The in-situ tests are carried out to know the physical properties of the foundation. It is necessary to keep in mind that the results of laboratory tests do not exactly express the properties of the foundation as it is at the site. These tests are indispensable in case where the properties of the foundation have considerable influence on the design of structures.

The test items are the modulus of elasticity, the modulus of deformability, shearing strength, compressive strength, permeability and so on.

The modulus of elasticity or the modulus of deformability is estimated by loading to the walls of the adit or shaft by oil jacks and measuring the relation between the load and the displacement. The modulus of elasticity, estimated by this method, is called the static modulus of elasticity.

The dynamic modulus of elasticity is estimated by measuring the propagation velocity of the elastic wave which is caused by the small blasting or some shock.

Generally speaking, the static modulus of elasticity is smaller than the dynamic one.

The shearing and compressive strength of the foundation are estimated from the results of the large scale in-situ rock tests.

The bearing capacity of the foundation is estimated by some bearing tests.

The permeability tests are executed making use of wells, ditches, and bored holes. Sometimes, electrical method also used to estimate the permeability of the foundation.

The results of the geological survey are to be arranged in the form of geological plan and cross section. In this case, it is desirable to classify the rocks into some categories, in order to prepare the fundamental data for the design of structures.

Schmit's net or Wulff's net is used conveniently to see the predominant directions of joints, fissures, and faults. Some geological models, made of coloured transparent plates, are used to see the general geological features at the site easily.

(3) Precipitation data

The precipitation data are used for checking the reliability of the run-off data or for the estimation of run-off in case where the run-off data are not available. The precipitation data are also used for the investigation of the climate conditions or the expected freshet during the construction period. Therefore, the precipitation data are to be of long term and the days of rainfall and the intensity of the precipitation (hourly rainfall) are also necessary, besides the daily precipitation data.

(4) Run-off data

As the run-off data are the fundamental ones for the planning of the hydropower development, it is necessary to check their reliability as stated in 2-4-3 (6).

The data of more than ten years are required for the planning, because the run-off, which is brought by the precipitation with the character of natural phenomena, varies from year to year and with the data of shorter term, it is difficult to estimate the expected average run-off or its variation properly. Especially in the planning of the reservoir, the data must cover the longer term.

After the run-off gauging stations, of which data are to be used for the proposed planning are determined, the run-off at the exact site of the development is estimated by the procedure as stated below.

(a) in the case of single gauging station

The ratio of the catchment area of the development site to that of the gauging station is generally used to estimate the run-off at the site.

But, in case where the catchment area of the site and that of the gauging station are remarkably different, there may arise some problems. If the catchment area of the site is considerably larger than that of the gauging station, namely, the station is located at the upstream part far from the site, the result of the above-mentioned method, using the ratio of the catchment area, may become excessive. Because there is the tendency that at the more upstream part, the more the run-off per unit area is. In this case, the checking of the data is necessary and it is also necessary to execute the run-off gauging at the site at least for one or two years to get the coefficient of modification from its results.

On the contrary, in case where the gauging station is located at downstream part of the site, there is a reverse tendency and the results of the estimation may be at the safety side. Therefore, if there is no remarkable difference between the catchment area of the site and that of the gauging station, the method using the catchment area ratio may be applied, but the proper modification is to be taken into account, if necessary.

(b) in the case of plural gauging stations in series

In this case, the tendency stated in section (a) can be seen clearly, if the accuracy and the reliability of the data can be assumed to be the same, and the run-off at the site is determined more effectively. In some cases, the accuracy of the data can be checked by comparing the data of respective stations.

It is needless to say that the discharge, which is taken away for the irrigation purpose, or some other effect on the run-off at the places concerned must be taken into account.

The determination of the run-off at the site is to be carried out as stated in section (a) of this paragraph.

(c) in case without gauging station

The run-off at the site is estimated, making use of the correlation between the precipitation and the run-off. Therefore, it is the precondition to have the precipitation observation stations located properly in the river basin concerned.

The correlationship maybe obtained by comparing the precipitation data to the run-off data in the river basin nearby and this correlationship is applied to the river basin concerned.

This method may be used at the early stage of the planning, out of necessity. Therefore, the run-off gauging stations must be established before the detailed planning starts.

The duration curve or mass curve at the site can be drawn using the run-off data which have been obtained as mentioned above. The former is effective for the planning of the run-of-river type power plant, while the latter is necessary for the planning of the reservoir type power plant. An example, how to draw the mass curve, will be given in the appendix 4-7.

Flood and flood discharge

The flood is a phenomena which the heavy rainfall in the rainy season or others causes the temporary increase of the river run-off, and the flood discharge and its frequency are the important factors to be taken into account in planning the hydro-power development.

These data are necessary for the determination of the spillway capacity and for the design of bank protection works at the power plant and others. Especially, the design of spillway is important to make safe the main structures such as dam and power plant during the flood time. These data are necessary also for the determination of the diversion capacity during the construction period.

For the flood control by the reservoir, the hydrograph of the flood is to be taken into consideration. This hydrograph has the shape as shown on Fig. 4-2-1 in general. There is a tendency that the discharge increases rapidly to the peak and, after that, it decreases gradually. This hydrograph may have the peaks more than one, according to the conditions of rainfall. It is known that the peak becomes flatter as river goes to downstream.

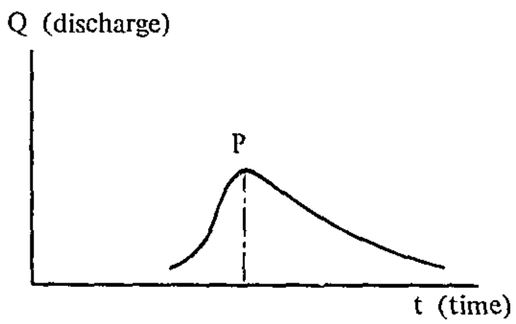


Fig. 4-2-1

There are several methods of flood discharge estimation as explained below.

(i) the method using the probability theory, taking the results of flood observation into account

(ii) the method based on the actual measurement or the specific discharge of the similar river

(iii) the method using the rational formula, taking into account the catchment area, hourly precipitation, time lag and run-off coefficient

(iv) unit-hydrograph method

The method (i) is used most widely. For this purpose, it is necessary to carry out the flood observation. In Japan, the design flood discharge for the concrete dam is taken as the discharge which may happen once a hundred years, and for the filltype dam, 20% extra discharge is taken into account.

These regulations differ with countries according to the accuracy of the run-off data and other conditions. In some countries, the design flood is taken as the discharge once a thousand years and more.

The method (ii) and (iii) are used when the sufficient data of the flood observation are not available. The method (ii) is a convenient one and is used in general but it is necessary to take due consideration the catchment area, topography, the character of the rainfall and flood, and so on. The confluence of tributaries and other effects, which have the influence upon the flood discharge, must be taken into account.

The method (iii) is used when the run-off data are insufficient and the precipitation data are available. In applying this method, there remains some uncertainty of the run-off coefficient or other factors. Therefore, this method may be used mainly for the flood estimation of the small area such as of tributaries.

The method (iv) is used for the planning of the flood control by the reservoir or the estimation of the flood hydrograph.

(5) Others

The data of sedimentation, evaporation and water quality are also the basic ones for the planning of the hydro-power development. The former two are necessary especially for the planning of the reservoir.

It is necessary to note that, if the water is acid, it has the bad influence upon the structures or equipments made of concrete or steel.

4-2-2 Determination of the maximum discharge of the power plant

The determination of the maximum discharge of the power plant is one of the most important matters of the planning of the hydro-power development.

The demand of the electric power shows, as previously stated in 4-1-1, the daily variation, peak time and off-peak time, and also shows the seasonal variation in a year. The power plant, therefore, is able to meet the demand with this characteristics.

The run-off of a river, which is the fundamental energy resources of the hydro-power plant, varies from time to time as it can be seen on the hydrograph or the duration curve and the mass-curve. Accordingly, if we try to supply electric power only by the run-of-river type power plant, the maximum discharge is to be the droughty water discharge in the dry year, and the excess water goes to waste at off-peak time or when there comes the run-off larger than the maximum discharge of the power plant as can be seen on Fig. 4-2-2.

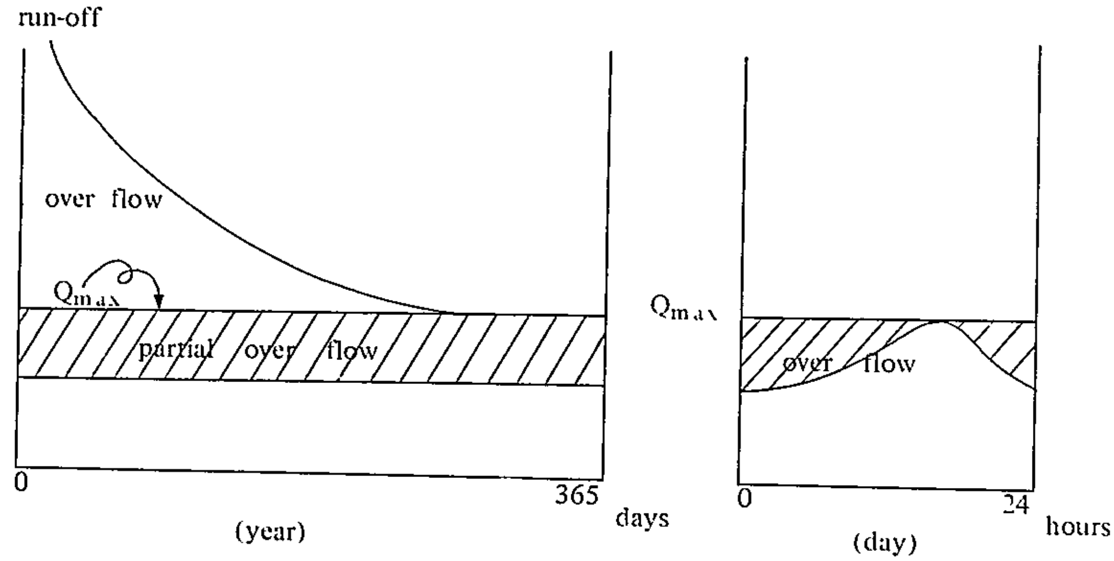


Fig. 4-2-2

In this case, the run-off cannot be used effectively and this is an uneconomical way from the viewpoint of the utilization of the energy resources. If the run-of-river type power plant is used together with the hydro-power plant with reservoir or the thermal-power plant, the above-mentioned way is apparently poor economy, so that it is desirable to increase the maximum discharge of the power plant as far as the economic consideration permits.

After the head of the power plant, namely, the location of the intake and outlet, has been given, the maximum discharge is to be determined by taking due consideration the demand of the electric power, the constitution of the power supply system, the tariff system at present and in future, the construction cost, relative difficulty of the fund raising and so on. By this way, the maximum discharge should be determined so that the output of the power plant will be as large as possible within the limit of economy.

Generally speaking, the thermal-power is the alternative of the hydro-power but we bypass the problem of the economic comparison of these two power resources for the time being. This problem will be treated later. (refer to the appendix 2-16 of the report of Terada Mission) Now, we assume that the proposed hydro-power is more economical than the alternative thermal-power and is worthy to be developed.

It may be the most economical to estimate the respective benefit (B) and cost (C) for several alternative maximum discharge of the power plant for the proposed project and determine the maximum discharge as to obtain the maximum surplus benefit, B-C. But the determination of the maximum discharge may be affected by the relative difficulty of the fund raising and the amount of the hydro-power resources.

When the fund raising is difficult, it may be the alternative way to determine the maximum discharge as to make the ratio B/C maximum. By this way, the fund recovery will be finished in the shortest period. The more detailed explanation will be given in the section 4-2-8.

(1) The calculating method

In order to determine the maximum discharge, several alternative plans are to be drawn up at first and by using the basic data, which were previously mentioned in section 4-2-1, the following values are to be estimated for each plan.

(i) Effective head (m)
to be determined from the topographical maps and the plan of reservoir operation

(ii) River run-off (m^3/s or m^3/day)
the droughty water discharge or the minimum available discharge, and the available total discharge (to be determined from the duration curve or the mass-curve).

(iii) Output of the power plant (KW)

the maximum output, P_{max}	(based on the maximum discharge and the maximum effective head)
the peak output, P_p	(the possible output of the power plant at the annual peak time)
the firm output, P_f	(derived from the above-mentioned droughty water discharge or the minimum available discharge and the available effective head)

(iv) Electric energy (KWH)
to be obtained from the above-mentioned available discharge for each month (the detailed estimation method will be mentioned in part (2) of this section.)

In determining the maximum discharge of the power plant, we should have more than three alternative plans for a proposed project and have to prepare the above-mentioned outputs and electric energy for the alternative maximum discharges respectively.

Now, we assume that we have four alternative plans and the outputs and electric energy of each plan are to be identified by suffix as follows.

	draft-1	draft-2	draft-3	draft-4
P_{max} (KW)	P_{max1}	P_{max2}	P_{max3}	P_{max4}
P_p (KW)	P_{p1}	P_{p2}	P_{p3}	P_{p4}
P_f (KW)	P_{f1}	P_{f2}	P_{f3}	P_{f4}
E (KWH)	E_1	E_2	E_3	E_4

Indicating the construction cost by K,

K (Rp)	K_1	K_2	K_3	K_4

The benefit (B) of the proposed power plant is calculated by taking the abovementioned outputs (P) and electric energy (E) into account and the cost (C) is calculated by taking the construction cost and other factors into account.

The cost may be calculated simply by multiplying the construction cost by the annual cost ratio but it may be calculated more exactly by accumulating following cost elements.

Capital cost (Depreciation, Interest)
Personnel expenses
Administrative expenses
Repairing expenses
Miscellaneous expenses

It may be convenient, for the time being, to calculate the cost by using the annual cost ratio.

In considering the cost, it is assumed to equalize the cost for each year all over the durable years of the power plant and the cost is to be calculated at the power plant side of the primary substation for the convenience of the comparison with the alternative thermal-power. In this case, it is necessary to take the primary transmission expenses into account but it may be neglected if it is small enough. (refer to the Report of the Terada-Mission, Appendix 2-6. According to the report, the annual expense ratio was assumed to be 7.13% in the case where the interest is 5%, durable years are 40 years, transmission expenses and tax are neglected.)

The benefit is generally represented by the cost of the alternative equivalent thermal-power plant, because it is necessary to supply the electric power by the thermal-power plant to fulfill the responsibility of the electric power supply, if we do not develop the hydro-power.

In considering the benefit of the hydro-power, it is necessary to divide it into two parts, namely KW-benefit and KWH-benefit. Accordingly, it is calculated by multiplying the unit benefit prices by the effective output (KW) and energy (KWH), respectively, at the power plant side of the primary substation.

The effective output of the hydro-power is the peak output in the month when the load of the thermal-power is maximum (in Djakarta area, July and August) and the run-off is droughty. In this case, the characteristics of the electric power demand should also be considered.

The effective electric energy (KWH) is the mean annual possible electric energy of the power plant, taking off the energy used at the power plant and others.

The unit benefit price of the output is calculated basing on the standard fixed cost of the alternative thermal-power. In this case, it is necessary to make the reliability condition of the hydro and thermal power plant equal. Therefore, the repairing time and the decrease of the output due to some accident should be taken into account for the thermal-power and some extra output should be added. (According to the report of the Terada Mission, the KW correction factor was assumed to be 1.1 and 10% of extra output (KW) was taken into account.)

The benefits of hydro and thermal power are compared each other at the power plant side of the primary substation and the transmission loss and the transmission cost must be taken into account, but if they are not so different each other, they may be neglected and the benefits may be compared at the power plant site.

The unit benefit price of the electric energy (KWH) is represented by the unit variable expenses (fuel expenses and operational expenses) of the alternative thermal-power plant, taking due consideration the utility factor that can be assumed for the electric power supply system. In this case, the out-of-operation time of the thermal-power plant due to the accident or the repairing must be taken into account.

Accordingly, the benefit (B) of the hydro-power plant is expressed as follows,

Benefit (B) = KW-benefit (B_{kw}) + KWH-benefit (B_{kwh})

$$B_{kw} = P_e \times \frac{C_f}{CP_i \times (1 - k_h)\ (1 - k_a)\ (1 - k_r)\ (1 - k_t)} + C_t$$

$$B_{kwh} = E_e \times \frac{C_v}{E_t \times (1 - r_h)\ (1 - r_t)}$$

where,

P_e ; effective output (KW) at the powr plant side of the primary substation

C_f ; fixed cost of the standard thermal-power

CP_i ; installed capacity of the standard thermal-power

k_h ; rate of the output consumption at the power plant

k_a ; rate of accident

k_r ; rate of repairing

k_t ; rate of transmission loss

C_t ; transmission cost per KW from the thermal-power plant to the primary substation

E_e ; effective electric energy (KWH) at the power plant side of the primary substation

C_v ; variable expenses of the standard thermal-power

E_t ; annual output of the electric energy of the standard thermal-power, taking the accident and repairing into consideration

r_h ; rate of the consumption at the power plant

r_t ; rate of mean transmission loss

Based on the data in the appendix of the report of Terada Mission, KW-benefit and KWH-benefit can be expressed as follows, provided that the transmission cost is the same for both of hydro and thermal power.

$$B_{kw} = P_e \text{ KW} \times \frac{100{,}000 \text{ Rp} \times 0.1234 \times 1.1}{(1 - 0.06)} = P_e \text{ KW} \times 14{,}440 \text{ Rp/KW}$$

$$B_{kwh} = E_e \text{ KWH} \times 5{,}000 \text{ Rp/kl} \div 9{,}900 \text{ kcal/kl} \times 860 \text{ kcal/KWH} \div 0.3 \times 1/(1 - 0.06) = E_e \text{ KWH} \times 1.54 \text{ Rp/KWH}$$

where,

0.1234 ; cost ratio for each year

1.1 ; kw correction factor

0.3 ; efficiency of the thermal-power plant

0.06 ; power ratio for station use

This is a simplified method of the calculation and the benefit and cost for each maximum discharge of the power plant of draft 1 to draft 4 can be obtained respectively by using the above-mentioned formula.

Then, the optimum maximum discharge of the power plant can be determined as stated in section 4-2-8.

(2) Estimation method of the annual energy output of the hydro-power plant

(i) Run-of-river type (including the type with the daily regulating pondage)

In planning the hydro-power development, it is necessary to estimate the annual output of the electric energy, after the run-off data has been prepared.

The run-off data are generally represented by the daily mean run-off and the total available discharge is calculated by accumulating the discharge less than the maximum discharge of the power plant. But this procedure is quite troublesome, if it is carried out by the manual work. Therefore, in order to estimate the annual available discharge, it is better to use the duration-curve and measure the corresponding area by the planimeter.

If the total monthly available discharge is required, the maximum monthly discharge (F_{max}), the mean monthly discharge (F_o), and the minimum monthly discharge (F_{min}) are able to be used for the preparation of the simplified monthly duration curve represented by two straight lines, F_{max}~b and b~F_{min}, which can be drawn by putting $\overline{ab}$ is equal to $\overline{cd}$, as shown on Fig. 4-2-3.

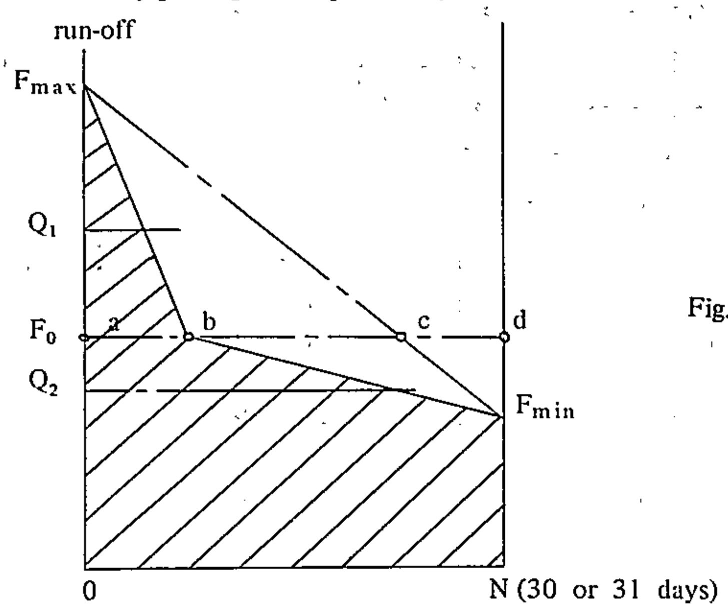


Fig. 4-2-3

The monthly available discharge can be calculated by the following formula, taking off the run-off larger than the maximum discharge of the power plant (Q_1 or Q_2) as shown on Fig. 4-2-3.

if $Q_{max} > F_o$ ($Q_{max} = Q_1$)

$$\Sigma\ q = NF_o - 0.5\,(F_{max} - Q_1)^2\ \frac{F_o - F_{min}}{F_{max} - F_o}$$

if $Q_{max} < F_o$ ($Q_{max} = Q_2$)

$$\Sigma\ q = NQ_2 - 0.5\,(Q_2 - F_{min})^2\ \frac{F_{max} - F_o}{F_o - F_{min}}$$

This relation can be demonstrated geometrically with ease. This method has been proved empirically to be sufficiently accurate within the error of only a few percent at the most and can be used practically as the simplified method.

Consequently, the total available discharge is estimated by one of the above-mentioned methods, which is to be chosen in accordance with the accuracy of the planning, and the electric energy can be calculated by multiplying the total available discharge by the discharge-energy ratio which is the electric energy generated by the unit (1 m^3/s) discharge.

(ii) Reservoir type (including the type with the weekly regulating pondage)

The hydro-power plants with the reservoir or the relatively large regulating pondage are classified in Japan into three classes, A, AB and B class, in compliance with the maximum discharge of the power plant (Q_{max}), the effective storage of the reservoir (V), the mean natural run-off (F_o) and the total annual run-off (Σ F). In this case, the following factors are introduced.

$f_1 = Q_{max}/F_o$ (%)

$f_2 = V/\Sigma F$ (%)

$f_3 = V/Q_{max}$ (days)

Using these factors, the hydro-power plants are classified with the following standards.

A class; run-of-river type with the daily regulating pondage

AB class; the type with weekly regulating pondage

$f_2 > 5\%$, $f_3 > 3$ days

B class; the type with the reservoir

$f_1 > 150\%$ $f_2 > 20\%$ $f_3 > 15$ days

This classification is conveninet as the index to see the faculty of a hydro-power plant.

The reservoir of the hydro-power plant aims to equalize the natural run-off. After the height of the dam has been determined, the draw-down of the reservoir becomes inevitably large, if the effective storage is to be made large. Sometimes, this fact may decrease the mean available head of the power plant and this may be the negative factor for the power plant itself, but the discharge from the reservoir may be supplied to the downstream power plants, if any, in dry season.

Consequently, the economy of the hydro-power is to be considered over the water system as a whole. It is desirable to establish the reservoir at the upstream part of the river, as far as possible, for the above-mentioned reason.

The effective storage of the reservoir is to be determined from two viewpoints, namely, from the technological viewpoint, and from the viewpoint of the power economy.

With regard to the aspect of technology, the height of the dam is restricted by topographical and geological condition of the site and the social restriction such as the compensation for the matters which will be submerged to the bottom of the reservoir. The draw-down of the reservoir may be affected by the sedimentation, which will be transported from the upstream part of the river, and may have the influence on the output of the power plant. These problems need careful investigation.

With regard to the aspect of power economy, the duties of the proposed hydro-power plant in the electric power supply system, including the effect on the downstream power plants, must be properly evaluated and carefully investigated.

Based on these consideration, the approximate capacity of the reservoir and the power plant is determined and, after that, the available electric energy is calculated.

The calculation of the available electric energy is started from the preparation of the mass-curve.

The ordinate of the mass-curve indicates the amount of inflow or the storage volume of the reservoir. It is convenient to incline the mass-curve so that the horizontal axis corresponds approximately with the mean run-off over the period of calculation. When the height of the dam was determined and the draw-down of the reservoir, namely the effective storage, was determined thereafter in practical way, the operational plan of the reservoir can be drawn up based on the effective storage.

The discharge of the power plant is to be estimated as follows. At first, the point B is plotted as shown on Fig. 4-2-4 and after that, an operational line is drawn as to pass the points, A, B and C. The inclination of the operational line indicates the discharge of the power plant.

The state of the water level of the reservoir is estimated by the difference on the ordinate of the run-off mass-curve and the operational line.

Consequently, the available electric energy can be calculated by multiplying the discharge of the power plant by the effective head which is calculated from the above-mentioned water level.

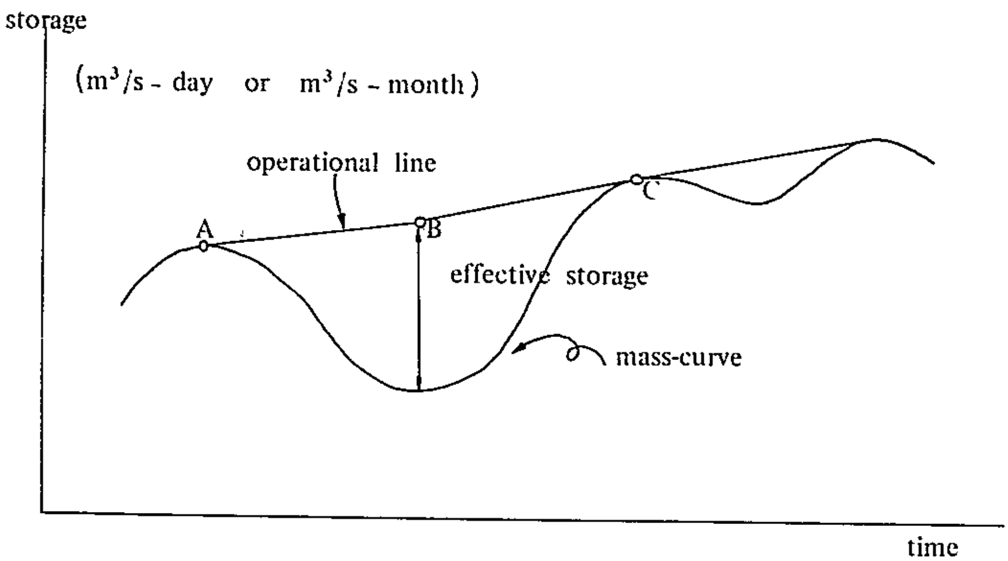


Fig. 4-2-4

(3) Determination of the maximum output of the power plant with reservoir

After the available depth of the reservoir and the maximum discharge of the power plant have been determined, the maximum output of the power plant is to be investigated. The matters of investigation for the determination of the maximum output are described here.

An example of the relation of output and discharge of the turbine to the effective head is shown on the Fig. 4-2-5. The abscissa denotes the effective head and the maximum and minimum effective head, H_{max} (m) and H_{min} (m) respectively, are to be given from the high water level, the available depth of the reservoir and the relative situation of the tail-race. The ordinate denotes the output P (KW) and the discharge Q (m^3/s). Following three cases should be taken into consideration for the determination of the maximum output.

case 1. The discharge and the output of the turbine increase in proportion as the effective head (H) increases, keeping the gate of the turbine opened fully. The maximum output P_1 and the maximum discharge Q_1 are given corresponding to the maximum effective head H_{max}.

case 2. If the gate opening of the turbine is controlled so as to keep the discharge constant (Q_2) for the part where the effective head higher than a certain height (H_b), the maximum output P_2 is given corresponding to the maximum effective head. In this case, the maximum discharge is Q_2.

case 3. If the gate opening of the turbine is controlled so as to keep the output constant (P_3) for the part where the effective head higher than H_b, the discharge corresponding to H_{max} becomes Q_3 and, in this case, the maximum output is P_3 and the maximum discharge is Q_2.

The merits and demerits of these cases are as follows.

case 1. ($P_{max} = P_1$)

(i) The biggest output can be obtained but its duration time is short.

(ii) As the time, when the turbine works with full load and with the maximum discharge, is short, the utilization rate of the electric equipments and waterway is low. Accordingly, the power plant is generally uneconomical.

(iii) The variation of the output due to the variation of the effective head between H_{max} and H_b is large.

case 2. ($P_{max} = P_2$)

(i) Relatively big output can be obtained but its duration time is relatively short.

(ii) As the time, when the turbine works with full load, is short, the utilization rate of the electric equipments is low but, as the Q_{max} is kept constant for the effective head higher than H_b, the utilization rate of waterway is high.

(iii) The variation of the output due to the variation of the effective head between H_{max} and H_b is relatively large.

case 3. ($P_{max} = P_3$)

(i) The maximum output is smaller than that of case 1 or case 2 but its duration time is long.

(ii) As the time, when the turbine works with full load, is long, the utilization rate of the electric equipments is high but, as the turbine works with the maximum discharge only around H_b, the utilization rate of the waterway is low.

(iii) The maximum output is kept constant, regardless of the variation of the effective head between H_{max} and H_b.

The maximum output and the height of H_b should be determined considering the above-mentioned merits and demerits and investigating the following matters, so that the power plant can fulfill the required functions effectively and economically.

a) Electric energy and peak demand, which should be supplied by the power plant concerned, and the peak duration time.

b) The annual variation of the water level of the reservoir corresponding to the operational plan.

c) The cost of construction and the working expenses of the power plant.

d) The cost of the equipment. (if H_b is lower, relatively big output can be obtained until lower level but the cost of turbine is high, vice versa).

e) The KW-benefit and KWH-benefit which are mentioned before.

In many cases, it is convenient to start the investigation setting H_b at around the center of gravity of the effective storage as an aim, and after that shift H_b higher and lower as the occasion demands.

(4) Utilization of the computer

The electronic digital computer is widely used nowadays for the planning of the reservoir operation in Japan.

In this case, the proposed operational plan is given to the computer in the form of the programme and the run-off data are also given as the input data. Then, we can simulate the actual operation in the computer and the required data are taken out as the output.

The merits of the drawing up the operational plan by the computer are the correctness and quickness of the computation. Consequently, it is possible to investigate the fairly complicated plan in a short time and to get the most economical plan by comparing many alternatives.

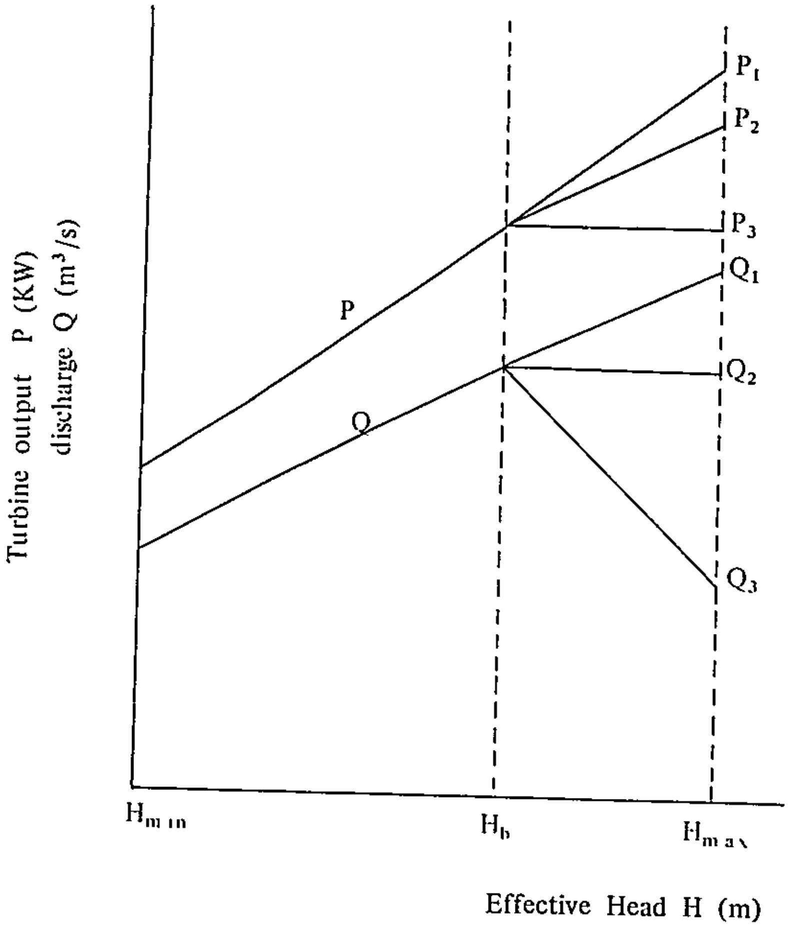


Fig. 4-2-5 Relationship between Effective Head and, Output and Discharge of Water Turbine

4-2-3 Layout of the structures

In planning the hydro-power plant, several matters should be investigated to determine the layout of the structures. The matters of investigation may vary with the ways how to get the head for the hydro-power generation. The head can be acquired by the following three ways.

(i) Run-of-river type

This type is one of the hydro-power generation methods which makes use of the gradient of the natural river. Therefore, it is desirable that the gradient of the natural river is steep to get the head easily and it is considered that the gradient is desirable to be steeper than 1/150.

For this type, the river discharge is taken from the intake and is conducted through the tunnel or open channel or culvert with the slow gradient.

There are two kinds of system. One is the simple run-of-river type and the other is the type with the pondage on route of the waterway. The layout of the structures of these types can be seen on Fig. 4-2-6 and its outline is as follows.

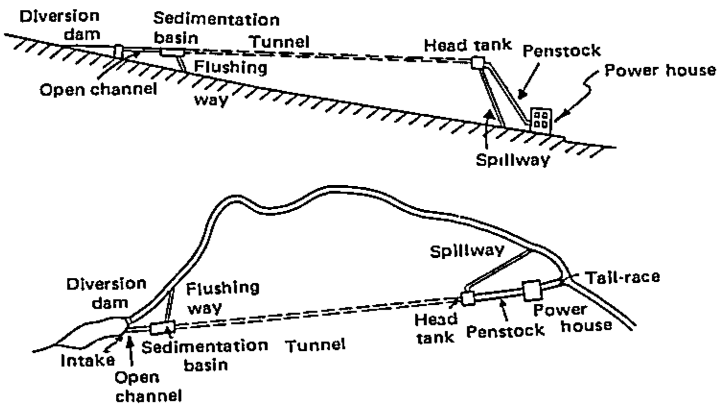


Fig. 4-2-6 (a) Run-of-river Type Generation

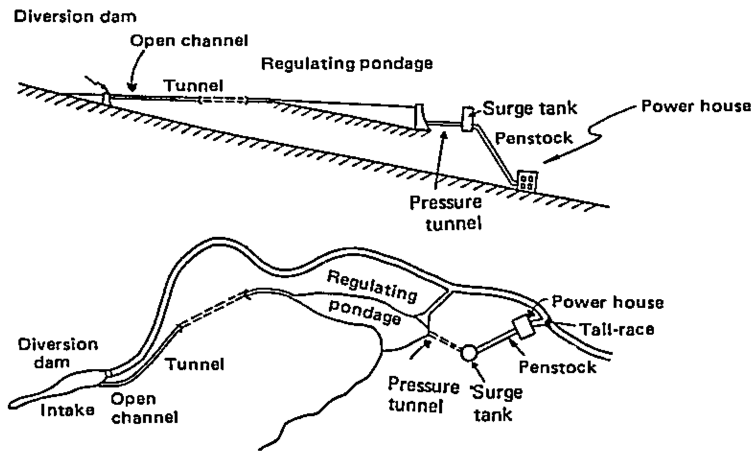


Fig. 4-2-6 (b) Run-of-river Type with Pondage

The diversion dam is constructed across the river and the discharge is taken from the intake. Then the discharge is conducted to the sedimentation basin to remove the suspended sediment. After that, the discharge is conveyed through the waterway to the head tank. The waterway can be the tunnel or the open channel or the culvert. At the head tank, the spillway is provided to make the discharge run out when the turbine is out of work. From the head tank, the water runs down to drive the turbine and generates the electric energy. After the generation, the water returns to the river through the draft tube and the tail-race.

In case with the regulating pondage, it is provided on route of the waterway and its capacity is for the daily regulation or so. The discharge is conducted from the pondage to the power plant through the head-race, surge tank and penstock or directly through the penstock. After the generation, the discharge returns to the river in the same way as the simple type.

(ii) Dam type

This is the type getting most of the head for power generation by constructing the high dam. The pondage of the dam is used also for the discharge regulation. In general, this type of the development is adopted at the downstream part of the river where the gradient is slow, and at the upstream part of the river, in case where the pondage of the dam can be used for the water supply to the existing power plants at the downstream part of the dam.

In many cases, the dam is used for multi-purposes, namely, for the irrigation, flood control, water supply and power generation. Therefore, the outlet facilities should be provided to make the discharge run out for the purposes other than power generation. The layout of the structures can be seen on Fig. 4-2-7.

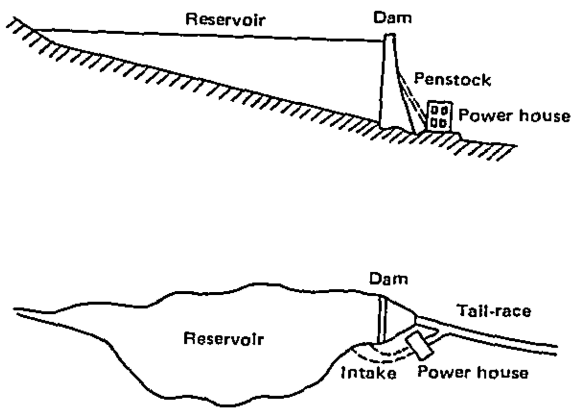


Fig. 4-2-7 Dam Type

(iii) Dam and waterway type (combined type)

This is the combined type of the run-of-river-type and the dam type. The head for the power generation is obtained by the dam and the waterway with slow gradient. There are two kinds of system, namely, the head type and tail type.

The head type has the under ground power plant at the downstream of the dam and the discharge from turbine is conducted to the river by the tail-race. In this case, the surge chamber is provided at downstream part of the power plant, if necessary.

The tail type has the head-race, which is in general the pressure tunnel, to get the additional head for power generation. The layout of the structures can be seen on Fig. 4-2-8.

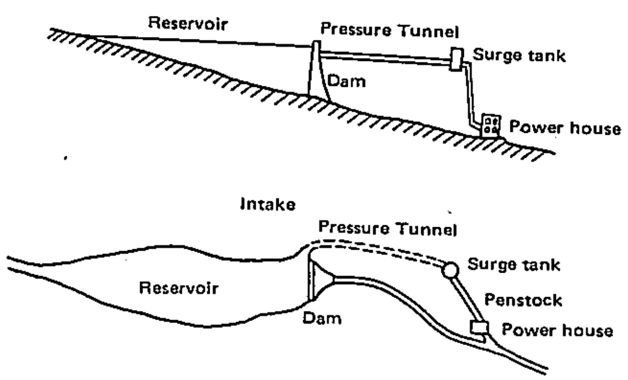


Fig. 4-2-8 Dam and Waterway Type

Some explanation of each structure is given here in relation to the survey planning of the development but the detailed descriptions are left to the respective technical books.

(1) Diversion dam

The diversion dam is the low dam which is used to divert the river discharge to the waterway of the run-of-river type power plant and this kind of dam is distinguished from the high dam for the water storage.

In general, it is usually the concrete dam or masonry. The dam site is to be chosen for the convenience to provide the intake structure and the sedimentation basin around the dam.

The foundation of the dam is desirable to be rock bed but it may be the gravel foundation if the bearing capacity is enough. The dam which is founded on the gravel stratum is called the floating dam and, in this case, it is necessary to make the creep length under the dam long enough so as not to cause the piping action.

It is desirable to provide the flushing gate near the intake structure to flush out the sediment and keep the forebay of the intake clear so as not to be filled up by the sediment.

The height of the dam should be high enough for the intake of the river discharge and should be determined in relation to the capacity of the intake facilities. The influence of setting up the dam, especially those at the flood time, should be investigated carefully. If the dam-up of the water level at the flood time has the bad influence to the upstream region, the gate type dam is to be investigated as an alternatives.

In some cases, it is necessary to provide the timber-pass, fish-pass or navigation-pass according to the habitual practice in the district concerned.

(2) High dam .

The high dam for the water storage is the very important structure therefore, it is necessary to make the thorough investigations in planning it.

Types of the dam is divided into the concrete dam and the fill-type dam by the construction materials.

The concrete dam has several varieties such as the gravity dam, the hollow gravity dam, the arch dam and the buttress dam according to the structural properties. The fill-type dam may be divided into the rockfill dam and the earth dam but it is difficult to draw a definite line between these two types.

The topographical and geological conditions of the dam site and the availability of the construction materials are the important factor for the choice of the dam type. There are many other factors to be investigated such as the purpose of the development, the scale of the project, the period of construction, available technical faculties, labour power and machinery, the meteorological conditions, hydrological conditions, seismological conditions, and availalbe transportation facilities and other facilities.

After carrying out these fundamental investigations, the type of the dam is to be determined on the basis of the considerations upon the structural safety and also upon the economic profitability.

The dam should be stable against the overturning, sliding and crushing due to the external and internal load. The foundation of the dam should have the enough bearing capacity and impermeability. In general, the concrete dam is adopted at the site where the geological conditions is favourable. It is classified as follows.

a) Gravity dam

The gravity dam supports the water pressure by the weight of the mass concrete. Usually, the slope of the upstream face is about 1:0.1 and that of the downstream face is about 1:0.8. In many cases, the spillway of center overflow type with gate is provided.

b) Hollow gravity dam

The function of the hollow gravity dam is almost the same to the gravity dam. This type of the dam has the following merits in comparison with the gravity dam.

(i) The concrete volume can be reduced

(ii) The uplift pressure at the base of the dam can be lessened

(iii) The foundation treatment is relatively easy

(iv) The maintenance and inspection is relatively easy, after the completion.

The demerit is that the dam structure becomes relatively complicated.

Recently, the slope of the upstream and downstream face is about 1:0.45 – 0.55, in case the slopes of both faces are made to be the same.

The spillway is similar to that of the gravity dam.

c) Arch dam

The arch dam transmits the water pressure to the rock foundation by the arch action and it can be regarded as the most reasonable type from the viewpoint of the structural function.

In planning the arch dam, the topographical and geological conditions should be investigated thoroughly. The shape of the arch dam has the varieties from the thin dome type to the massive arch gravity type. The spillway may be the center overflow type or the chute type or the tunnel type. It is to be determined according to the topographical condition and the layout of the downstream structures.

d) Buttress dam

The buttress dam supports the water pressure by the flat face slab and then transmits the pressure to the foundation by the buttress and bracing struts. It is usually made of reinforced concrete. The dam of this type has rather complicated structure and cannot be adopted for relatively high dam.

The fill type dam is classified as rock-fill dam and earth dam.

a) rock fill dam

The rock fill dam resists the water pressure by the weight of the heaped up rock fill and secures the impermeability by the facing membrane, which is made of reinforced concrete or bitumen or the steel plate, or by the impervious core. The bearing capacity of the foundation may be less than that for the concrete dam, so long as the permeability of the foundation is little.

The approximate slope of the upstream and downstream face is as follows according to the type.

upstream face,	facing membrane type	1 : 0.8 – 1.8
	center core type	1 : 2.0 – 2.5
	inclined core type	1 : 2.5 – 3.0
downstream face,		1 : 1.4 – 1.7

where the figure at the right side corresponds to the dam with the height of more than 50 m.

In principle, the spillway is to be located separately from the dam body and its capacity must be large enough so as not to make the flood water overflow the dam. The appurtenant works, such as intake and outlet, are also to be located separately from the dam body, as a rule.

b) earth dam

The earth dam resists the water pressure by the weight fo the heaped up earth fill and it is to be designed so as not to let the upper limit of the seepage line appear at the downstream face in order to secure the stability of the downstream slope. The foundation should have little permeability and enough bearing capacity. It is said that this type of dam can be constructed at the site where the geological condition is worse than that of the other types of dam.

The earth dam has the varieties such as teh homogeneous type, the zone type, and center core type corresponding to the quality and quantity of the available materials. According to the recent instances, the approximate slopes of the upstream and downstream face are as follows.

upstream face,	1 : 2.5 – 4.5	(average; 1 : 3.3)
downstream face,	1 : 2.0 – 3.3	(average; 1 : 2.9) with berms

The spillway and other appurtenant works are to be provided in the same way as those for the rockfill dam.

(3) Intake works

The intake works are the facilities to take in the discharge to the waterway. Following conditions should be considered in planning the intake works.

(i) The intake works are to be able to take in the design discharge and control the quantity of the water intake, as occasion demands.

(ii) The shape of the intake works is to make the loss head as little as possible and not to let in the sediment to the waterway. For this purpose, it is desirable that the flow velocity at the screen is less than 0.5 m/s.

(iii) The intake works are to be located where they will not be suffered from the flood or from the landslide.

The intake works are connected with the non-pressure waterway or directly with the pressure tunnel including the penstock. In the former case, the sill of the intake works should be situated higher than thqt of the flushing gate in order to prevent the sediment from flowing into the waterway, and in the latter case, the intake is situated lower than the low water level of the reservoir or the regulating pondage by at least the diameter of the connected waterway, with the bell-mouthed inlet to make the loss head little and to prevent the obstruction of taking in due to the getting of the air mixed.

The appurtenant works such as the stop gate, the screens and the screen rake are provided according to the demand of the occasion but the former two are indispensable.

(4) Sedimentation basin

In case where the discharge is taken into the naturally flowing down waterway, the sedimentation basin is provided to removed the sediment which might have the bad influence upon the turbine and others.

The sedimentation basin is designed so that the cross-sectional area is widen gradually in order to get the uniform flow with low velocity. In Japan, the design velocity is considered to be lower than about 0.3 m/s and the length of the basin is considered to be two or three times of the required length to settle the suspended sediment within the basin. The minimum required length is given by the following formula.

$$L=h\,v_1/v_2$$

where:

L	;	minimum required length of the basin (m)
h	;	depth of the basin (m)
v_1	;	flow velocity in the basin
v_2	;	design velocityof the sediment settling

The shape and the structure of the sedimentation basin is to be convenient for removing the sediment. In case the sediment is turned out by the flushing water, the stop gate and the flushing gate should be provided at the suitable places.

(5) Head-race

1) General

The part of the waterway from the intake to the head tank is called the head-race. In some cases, the sedimentation basin, the regulating pondage and other appurtenant works are provided along the head-race. It is structurally consisted of the opne channel, culvert, tunnel, aqueduct bridge or the inverted siphon.

It is classified from the viewpoint of the hydraulics, into the non-pressure waterway and the pressure waterway. The former is used for the simple run-of-river type waterway while the latter is used to conduct the water from the reservoir or regulating pondage to the power plant.

The determination of the route of the waterway requires the prudent investigation, because, in case of the run-of-river type or the combined type, the cost of the waterway takes the considerable part of the total construction cost and teh construction period of the waterway has a great influence on that of the total works. As a rule, it is desirable to connect the power plant with the intake by the waterway of the minimum distance in order to make the construction cost and the loss head minimum, but the route should be determined from the viewpoint of the overall economy according to the topographical and geological conditions.

2) Cross-section

The cross-section of the head-race is to be determined corresponding to the maximum discharge and the hydraulic gradient. The hydraulic gradient has the direct relation to the flow velocity and, if the velocity is high, the cross-sectional area becomes small but the loss head becomes large, and vice versa. If the cross-sectional area becomes small, the construction cost becomes small correspondingly. Therefore, the route and the shape of the head-race is to be determined on the basis of the economical consideration as a whole, taking the construction cost and the loss energy due to the loss head into account.

In Japan, the gradient of the non-pressure waterway is chosen to be 1/1,000 – 1/2,000 and the shape of the pressure tunnel is designed to make the flow velocity of the maximum discharge to be 2.5 – 3.5 m/s.

3) Discharge

In general, the discharge can be calculated by Manning's formula, that is

$$v = C\sqrt{RI} \qquad C = \frac{1}{n} R^{\frac{1}{6}}$$

$$\text{or } v = \frac{1}{n} R^{\frac{2}{3}} I^{\frac{1}{2}}$$

where

v	;	flow velocity
R	;	the hydraulic mean depth of the waterway
I	;	the gradient of the waterway
n	;	coefficient of roughness, the approximate value of 'n' is as follows,

steel pipe	0.011 – 0.014
concrete	0.013 – 0.015
tunnel without lining	0.030 – 0.045
natural river course	0.030 – 0.060

4) Thickness of tunnel lining

The thickness of tunnel lining is to be determined taking into consideration the breadth of the tunnel, the geological condition, the pressure of the ground water, the internal pressure, the grouting pressure, the material of the lining, the reinforcement, and the construction method. In general, the predominant factor is the geological condition around the tunnel.

In case of the non-pressure tunnel, the thickness is taken to be about 10% of the tunnel diameter and it is increased or decreased according to the geological condition. The minimum thickness is to be 15 – 20 cm.

In case of the pressure tunnel, the standard of the depth is about 10% of the tunnel diameter but it is to be changed corresponding above mentioned conditions.

The tunnel excavation is accompanied in general with the over-broken part and the excess rock inside the designed cross-section. Therefore, the design line and the pay line are usually fixed beforehand. It is to be noticed that the volume of the excavation increases by 20% – 30% or, in some cases, by 50% according to the geological conditions, in comparison with the volume of corresponding design section.

5) Others

In case where the open channel or culvert is adopted, they should be designed considering the convenience of the maintenance and the influence of the land-slide.

The aqueduct bridge and the inverted siphon, made of concrete or steel, are to be designed, if the circumstances require.

(6) Water tank

1) General

The water tank is used for the regulation of the discharge fluctuation due to the load fluctuation of the turbine and is provided at the junction of the head-race and the penstock. At the same time, the water tank is used for removing the sediment or the floating materials finally which have flown into the waterway.

In case where the water tank is connected with the pressure water-way, it is used to absorb the water hammer and the surging in the water-way, due to the load variation of the turbine.

In general, the water tank is situated on the halfway of the hill slope. As it stores the large amount of water, it is necessary to choose the site where the stable foundation can be prepared.

If the water tank is connected with the non-pressure waterway, it is called the head-tank and if it is connected with the pressure waterway, it is called the surge-tank.

2) Capacity

For the head-tank, the capacity is taken to be the amount corresponding to the maximum discharge of the power plant for one or two minutes and it is desirable to be for more than two minutes, because, if the capacity is large, the regulation of the discharge can be carried out smoothly and it is favorable to the operation of the power plant. The surge-tank is classified by its hydraulic structure as follows.

Simple surge-tank
Chamber surge-tank
Differential surge-tank
Restricted oriffice surge-tank

The type of the surge-tank is to be determined corresponding to the several factors such as the usable depth of the reservoir, topographical and geological conditions, the operational plan of the power plant and others. Generally speaking, in case where the surge-tank is situated underground, it is made of concrete and in case where the tank is on the ground, it is made of steel.

For either type of the surge-tank, it is necessary to have the sufficient capacity for the smooth regulation of the discharge fluctuation due to the load fluctuation and it is also necessary to have the sufficient water surface area which is required not to cause the U-tube oscillation between the surge-tank and the reservoir or the pondage.

The design condition for the surge-tank is to be determined taking into consideration the maximum discharge, the regular operational plan of the power plant and the operation of the turbine in case of emergency.

3) Appurtenant works

In case of the head-tank, the spillway, which can spill out the maximum discharge of the power plant, should be provided. The flushing gate and the screen are also to be provided. The stop gate is to be set up at the inlet of the penstock.

In case of the surge-tank, the stop valve or gate is provided between the tank and the penstock for the convenience of the inspection and maintenance of the penstock and the turbine. The spill-way and the flushing gate are to be provided, if the occasion demands.

(7) Penstock

1) General

The penstock is the pressure pipe line connecting the turbine of the power plant with the water tank. In case where the number of the turbine is more than one, the penstock is provided separately for each turbine, or otherwise one penstock is used for more than one turbine and it is branched near the power plant.

The penstock is to be situated along the minimum distance between the water-tank and the turbine according to the topographical conditions, so long as the geological condition is good and there is no possibility of the landslip or landslide. It is also necessary to determine the route of the penstock not to make it situated above the hydraulic grade line.

If the penstock is to be provided underground, the vertical or inclined shaft is taken according to the geological condition and the construction method to be adopted. In many cases, the cross-section of the penstock is determined so as to make the flow velocity to be 2.5 – 4.0 m/s.

Generally speaking, the penstock consists of the steel pipe and the supporting structures which are made up of the anchor blocks and the supporting concrete blocks or the supporting steel shoes.

In case where the pressure pipe line is to be situated underground and the head relatively low, there are some instances using the reinforced concrete pipe as the penstock.

The recent progress of the welding technique has made it possible to fabricate almost all the steel structure of the penstock by welding, except some special parts.

2) Steel pipe

The steel pipe, should have the enough thickness to withstand the internal pressure. It should be reinforced by the stiffener so as not to cause the crushing due to the external pressure and the air pipe or air valve should be provided to prevent the negative pressure.

The thickness of the pipe, which is required to withstand the internal pressure, can be determined by the following formula.

$$t = \frac{p\,r}{\sigma\,\eta} + t_1$$

where,

- t ; thickness of the pipe
- r ; radius of the pipe
- p ; design head (hydrostatic pressure + water hammer pressure)
- σ ; allowable stress of the steel (in general, about a half of the yielding stress)
- η ; welding efficiency of the longitudinal joint (75 – 100% corresponding to the inspection method)
- t_1 ; allowance for the corrosion (equal or more than 1.5 mm)

The thickness of the pipe should be equal or more than 6 mm for the convenience of manufacturing, processing, transporting and erecting.

The water hammer pressure is to be considered together with the design of turbine, because ig has the close relation with the closing time of the guide vanes of the turbine. It is to be noticed that the water hammer pressure reaches, in some cases, to the 20 – 30% of the hydrostatic pressure, according to the design of turbine.

3) Others

The anchor blocks are to be provided to fix the steel pipe at the bent part where the centrifugal force of the running water, the weight of the water, the weight of the water and the pipe itself, the force due to the temperature variation and other forces might displace the steel pipe. Between anchor blocks, supporting steel shoes are to be provided in order to support the penstock on the stable condition.

In case where the penstock is situated in the rock or is embedded in the concrete dam, there are some instances to design the penstock with the condition that the rock or the dam concrete around the penstock is able to bear some part of the internal pressure. In this case, it is necessary to consider a countermeasure not to cause the crushing due to the external pressure. For this purpose, the pipe is to be reinforced by the stiffeners and is to be anchored tightly to the surrounding rock or concrete. As occasion demands, the rock around the penstock is to be consolidated by grouting and provided with some drainage facilities in order to lessen the external pressure and secure the stability of the structure.

(8) Power plant

1) Choice of water turbine and generator

a) Types of turbine

The water turbines are grouped as shown below according to their hydraulic action and the mechanism.

- Impulse turbine (Pelton type)
- Reaction turbine
  - Francis turbine
  - Diagonal-flow turbine – Adjustable blade (Deriaz type)
  - Propeller turbine
    - Fixed blade
    - Adjustable blade (Kaplan type)

Fig. 4-2-10 shows the standard for the choice of turbine type with respect to the effective head and the output. Some brief descriptions of each type are given here.

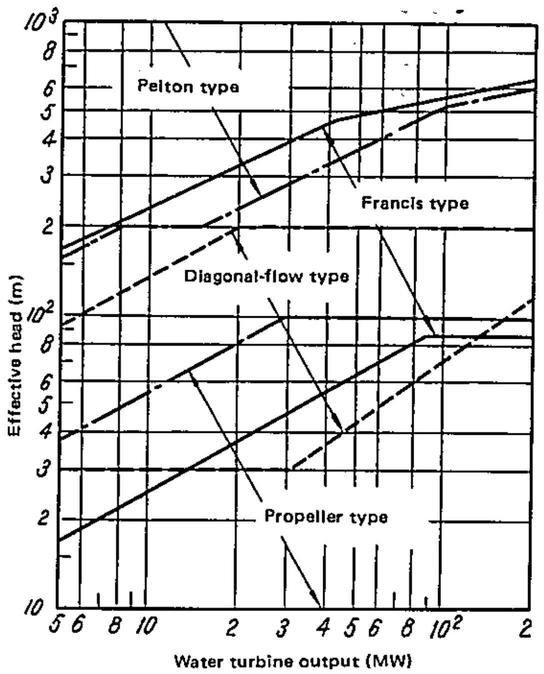


Fig. 4-2-9 Choice of Water Turbine Type

Impulse turbine (Pelton type) ;

In an impulse turbine, the effective head is converted into the velocity head of the water jets from the nozzles which strike against the bowl-shaped buckets and rotate the runner. The turbines of this type are adopted for the power plant with relatively high head and their characteristics are as follows.

(i) As the efficiency for the partial load is high, the turbines of this type are suitable for the power plant at which the variation of the discharge is remarkable.

(ii) As the replacement of the abraded parts is easy, the turbines of this type are convenient for the maintenance.

(iii) As the turbine is assembled with small parts, it is convenient for the transportation.

(iv) As the water jets from the nozzles can be turned away from the turbine at the time of load rejection, the extreme pressure rise is avoidable.

Reaction turbine ;

In a reaction turbine, the flow with the pressure head acts on the runner and rotates it. In the Francis turbine, the flow passes inwardly in the radial direction through the guide vanes. The turbines of this type are adopted for the power plant with medium head and their characteristics are as follows;

(i) As the specific speed can be higher than that of the Pelton type, and the revolving speed can be made higher, the size of the main machinery be made smaller and its cost can be reduced.

(ii) As the mechanism of the turbine is simpler than that of propeller type or diagonal-flow type, the turbines of this type are convenient for handling and maintenance.

(iii) As the efficiency for the partial load is not high, the turbines of this type are not suitable for the power plant at which the variation of discharge is remarkable.

In the turbine of the diagonal-flow type, the flow passes in the runner in the diagonal direction to the axis. The turbines of this type are adopted for the power plant with the medium head and their characteristics are as follows.

(i) As the specific speed can be higher than that for the Francis type, and the revolving speed can be made higher, the size and weight of the main machinery can be reduced. But, in comparison with the Francis type, the turbine of this type requires lower draft head and consequently the construction cost of the power plant is higher.

(ii) As the efficiency for the partial load is high, the turbines of this type are suitable for the power plant at which the variation of head and discharge is remarkable.

(iii) As the mechanism of this type is fairly complicated, the maintenance is not so easy as that for the Francis type.

In a propeller turbine (Kaplan), the flow passes in the direction of the axis. The turbines of this type are adopted for the power plant with low head and their characteristics are as follows.

(i) In comparison with the diagonal-flow type, the specific speed can be higher and consequently, the revolving speed can be made higher and the size and weight of the main machinery can be reduced.

(ii) As the efficiency for the partial load is high, the turbines of this type are suitable for the power plant at which the variation of head and discharge is remarkable.

(iii) The mechanism of the turbine of this type is as complicated as the diagonal-flow type.

The type of the turbine should be chosen taking into consideration the above-mentioned characteristics of each type, so that the power plant will be able to be operated most effectively and economically.

Direction of the turbine shaft ;

Most of the Pelton type turbine have the horizontal shaft but multi-jet turbines of big capacity with the vertical shaft have been developed.

As for the Francis type turbines, those with horizontal shaft are favorable and convenient for the maintenance, and are used for the small unit. But, for the large unit, those with the vertical shaft have several merits with respect to the mechanism. If the flood water level is high around the power plant, the turbines with vertical shaft are used even for small-unit.

As for the propeller type, the vertical shaft type is used generally, because the static draft head is relatively low. In some cases, the tubular type is also used for the small unit of the propeller.

b) Types of generator

Direction of shaft ;

The direction of the generator shaft is to be determined taking into the consideration the capacity and the revolving speed, the type of turbine, construction cost of the power house, the convenience of maintenance and other factors. Generally speaking, the horizontal shaft type is used for the generator of small capacity with high revolving speed, and the vertical shaft type is used for that of large capacity with low revolving speed.

Cooling method ;

The cooling methods for generators may be grouped into (i) the totally-enclosed, duct ventilated type, (ii) the torally-enclosed, water-air-cooled type and (iii) the open type. In the generator with the cooling method of the second type, the air duct is enclosed and the water-air-cooler is provided inside of it. Consequently, the generator can be kept clean and its noise is fairly low.

Generally speaking, the cooling method of this type is used for the generators of large capacity and the other two types are used for those of small capacity.

2) Determination of the number of units

After the maximum discharge and the effective head of the power plant have been determined, the number of units is to be determined considering the following matters.

(i) As mentioned earlier, the most suitable type of the turbine is determined with regard to the output and the effective head. Therefore, the determination of the number of units has close relation with the choice of turbine type.

(ii) The smaller the number of units is, then the larger the unit capacity is, the higher the efficiency of the unit at rating operation is, the lower the total cost of machinery is, the smaller the required power house is, the lower the construction cost of the power house is, and the smaller the working expenses is; vice versa.

(iii) In case of the power plant with remarkable variation of discharge, if the number of units is small, the power plant should be operated partially for a certain period of time and the efficiency of generation becomes low. In this case, if the number of units is large, some of units can be stopped and the rest can operate with full capacity and consequently, the efficiency becomes high.

(iv) From (ii) and (iii), it can be said that, for the peak load power plant with reservoir or regulating pondage, it is profitable to make the number of units smaller, while for the run-of-river type power plant with remarkable variation of discharge, it is profitable to make the number of units larger.

(v) For the important power plant in the electric power supply system concerned, the number of units should be two or more taking into account the halt due to the accidents or for the maintenance.

(vi) It is desirable that the transmission line is charged with certainty by single unit. Therefore, for the power plant, which is connected to the long transmission line and should carry out the line charge, the number of units should be determined taking into account the capacity required for this purpose.

In Indonesia, most of the hydro-power plants have a stand-by unit respectively at present. This practice will bring about the excessive stand-by units in the electric power supply system concerned, with the increase of the capacity of the system. As this tendency is unfavorable from the viewpoint of investment, it is necessary to investigate the system operation properly and to change the practice to have the common stand-by units for the system concerned as a whole.

3) Selection of the site for the power plant

The site for the power plant should be selected so that the power plant can be constructed and operated most reliably, effectively and economically, taking the following matters into consideration.

(i) The foundation should be stable and have sufficient bearing capacity.

(ii) There should be no possibility of land-slip or land-slide around the power plant, if it is to be situated on the ground.

(iii) It is necessary that the substation and switching yard can be provided near the power plant.

(iv) The transportation facilities should be available or can be prepared in order to convey the materials equipments and heavy parts of machinery to the to the power plant.

(v) There should be no danger to be damaged by flood, or it should be possible to protect the power plant from flood.

(vi) There should be the site for the lodging facilities for the workers of the power plant. (In case of the remote controlled power plant, this item needs no consideration.)

4) Types of power plant

After the types, the numbers and the fundamental specifications of main machinery have been determined, the design of the power house should be proceeded. The actual results of the area and volume of the Japanese hydro-power plants can be seen on Fig. 4-2-11.

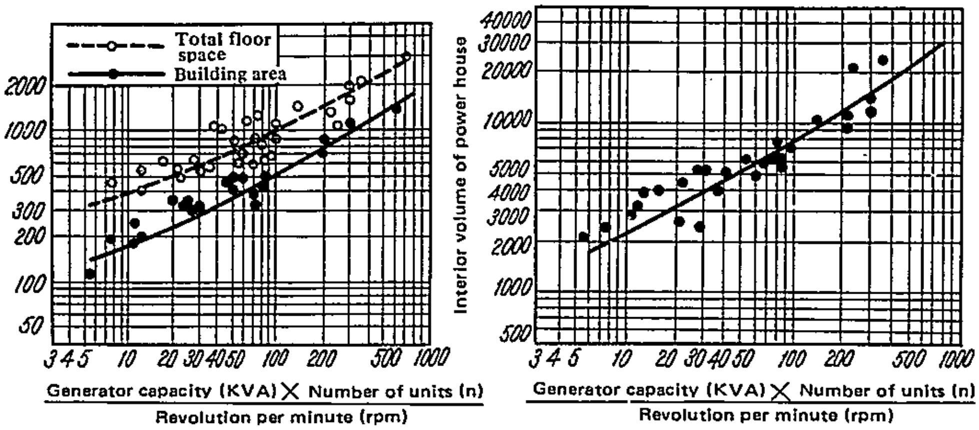


Fig. 4-2-10 Area and Volume of Power House (Actual results in Japan)

The power houses may be grouped into the indoor type, the outdoor type and the underground type. Brief descriptions about each type are given here.

(a) Indoor type

The indoor type power plants are most ordinary ones and the generators and turbines are installed indoors. This type may be subdivided into single floor type and multi-floor type. In a power plant of the former type, the turbine and the generator are installed on the same floor. In that of the latter type, the turbine and the generator are installed on their own floor respectively.

The number of the floors is to be determined taking into consideration the capacity of unit, relative situation of the turbine to the level of surrounding ground, the flood water level of the tail-race and other factors.

In many cases, the single floor type with barrel is adopted for the unit of large capacity, because it is difficult for the multi-floor type to support the water thrust and the weight of the rotary part of the unit of large capacity.

(b) Outdoor type

At the power plant of this type, no house is constructed above the ground level and the assembly and overhaul of machinery are to be executed outdoors, using the gantry crane. The generator must have the steel plate cover.

By adopting this type, the construction cost of the power house can be saved but the assembly and overhaul cannot be executed on rainy days.

(c) Underground type

At the power plant of this type, most of all the machinery are installed underground. This type is adopted in the following cases.

(i) The topography is too steep to establish the power plant on the ground.

(ii) It is unfavorable to establish the power plant on the ground for the reason of amenity.

(iii) The construction cost can be reduced, making use of the merit of underground type that the waterway and machines can be arranged ideally as far as the geological condition permits

(9) Tail-race

1) General

The tail-race is the waterway to discharge the water from the turbine to the river and, in general, it consists of the after-bay, the tail-race and the outlet. In case where the tail-race is the pressure waterway, the surge chamber is to be provided, as occasion demands.

2) After-bay

The after-bay is provided to conduct the water from the draft-tube to the tail-race smoothly. In case where the reaction turbines are used at the power plant, the after-bay is to be designed so as to secure the required draft-head for the turbine. In this case, the stop gate is usually provided around the end of the draft-tube for the inspection of the turbine.

3) Tail-race

The tail-race consists of the open channel, the culvert or the tunnel in the same way as the head-race. In case where the tail-race is relatively short, the culvert of flat cross-section or the wide open channel is used so as to make the effective head for the generation higher by making the water level of the tail-race lower.

In general, the tail-race is the non-pressure waterway but it may be the pressure tunnel, under certain circumstances. If it is the pressure tunnel, it is necessary, as occasion demands, to provide the surge chamber.

The function of the surge chamber is the same as the surge tank of the head-race and this chamber should have the required capacity and the area of the water surface.

4) Outlet

The outlet is to be located at the place where the outlet structure will not suffer from damage at the flood time and its function will not be damaged by the sedimentation. The direction of the outlet is to be decided so as to let the discharge from the tail-race join with the natural river flow smoothly.

In many cases, the stop gate is provided at the outlet for the inspection of the tail-race.

(10) Gates, valves and others

Several kinds of gate and valve are used to stop the water or control the quantity of the water intaken or outlet, at the dam, intake, sedimentation basin, head-race, water-tank, penstock, tail-race and others. The use and the type of the gate and valve are, in general, as follows.

(i) Spillway gates

The spillway gate is used to discharge the excess water from the reservoir or the pondage at the flood time or at other occasions.

The fixed roller gate, the stoney gate, the tainter gate, the sector gate, the rolling gate and the flushboard are used for this purpose.

(ii) Intake gates

The intake gate is used to control the quantity of the water intaken and to stop the water for the inspection of the waterway.

The sliding gate, the fixed roller gate, the caterpillar gate and the other types of gate are used for this purpose.

(iii) Outlet gates or valves at the dam

The outlet gate or valve at the dam is used to stop and control the discharge from the reservoir of the high dam and, in general, it is located in the dam body on the route of the outlet waterway or at the terminal of the outlet pipe.

The fixed roller gate, the tainter gate, the high pressure slide gate, the ring seal gate, the Howell-Bunger valve, the hollow-jet valve and others are used for this purpose.

(iv) Water-tank gates or valves

The water-tank gate or valve is used at the time of inspection and repair of the penstock, the turbine and the generator.

The fixed roller gate, the butterfly valve and others are used for this purpose.

(v) Outlet gates

The outlet gate is used at the time of the inspection of the turbine, the draft-tube and the tail-race, and is also used to protect the power plant from the rise of water level at the flood time which might have bad influence on the power plant. It is located at the after-bay or the outlet of the tail-race.

The sliding gate, the fixed roller gate and other types of gates are used for this purpose.

(vi) Flushing gates

The flushing gate is used for the flushing out the settled sediment from the dam, the sedimentation basin, the water-tank and other part of the waterway.

The sliding gate, the fixed roller gate and other types of gate are used for this purpose.

(vii) Stop logs for the inspection

In general, the stop logs are used for inspection and repair of the gate.

The stop logs are made of timber or steel according to the required strength and, if the stop logs are of large size, a certain handling equipment is to be provided.

4-2-4 Construction materials

(1) General

Keeping pace with the progress of the design of structures, the investigation of construction materials should be set forward. At this time, all the materials for the structures and the construction facilities should be listed up and their qualities, quantities, time and place of procurement, price and other factors are to be investigated carefully.

The construction materials are divided, in general, into the materials which are produced at factories and those which are procured around the construction site.

The materials which are produced at factories are as follows.

For the concrete works; cement, admixtures (pozzolan and others), additives (air entraining agent, dispersing agent and others), waterstops (metal or plastics), reinforcement (round bar or deformed bar), and others

For the steel structures; steel plate, round steel bar, section steel, steel pipe, and others

Other materials; precast concrete (pole, pile, plate and others), plastics (pipe, sheet, and others), sheet pile, ropes, paints and others

The materials which are procured around the site are as follows.

aggregates for concrete works, stones for masonry works, timbers, materials for fill-type dam (from rock fragment to fine core materials) and others

(2) Materials which are produced at factories

It is desirable to use the materials which conform to the industrial standards such as JIS (Japan), ASTM (USA), and DIN (Germany). If there is no standard, it is necessary to test the materials beforehand to confirm their qualities.

The use of these materials in Indonesia will increase hereafter and it is desirable to establish the industrial standards of her own.

(3) Material which are procured around the site

The quality and quantity of the materials which are to be procured around the site should be investigated carefully not to bring about the disqualification and shortage in the midst of the construction. Some brief explanations about the quality of materials are given here.

1) Aggregates for concrete works

Generally speaking, the aggregates are extracted from the natural deposit at the river bed or from the quarry as the crushed aggregates.

If both kinds of aggregates are available, it is necessary to compare their quality, quantity, relative difficulties of extraction and transportation, and the economy as a whole, in order to choose better one.

In case where the natural aggregates are to be used, the grading analysis should be carried out about the samples from the test pits which are dug at the proposed sand and gravel deposits. The physical and chemical suitability of the aggregate itself and of the concrete made with the aggregate is also to be investigated by testing several properties.

In case where the crushed aggregates from the quarry are used, the geological exploration by making use of the boring, test pits and test adits should be carried out to investigate the quality and available quantity of the aggregate. The suitability of the crushed aggregate should be investigated in the same way as the natural aggregate.

2) Materials for the fill-type dam

The suitability of the materials should be investigated beforehand by several tests. The required qualities are mentioned below.

The rock materials should be hard and durable against weathering, and should have few joint not to be broken by dumping. It is desirable for the stability of the dam that the rock materials are of big size. In some instances, the rock blocks with the weight of more than 20 tons were used as the materials for the fill-type dam.

Following items are to be tested to investigate the quality of the rock materials.

(i) specific gravity, (ii) absorption, (iii) compressive strength, (iv) durability against the weathering, (v) toughness against breakage due to dumping

The choice of the rock materials must be based on the results of the above-mentioned tests and also on the investigations of the extraction and transportation of the materials.

The earth materials should have the suitability regarding the stability, impermeability and easiness of works as follows.

(i) The earth materials should have the proper grading so as to get the high density by the suitable compaction. Their shearing strength should be high, and they must not be softened when they are saturated by water.

(ii) The materials should have the proper impermeability corresponding to the cross-sectional shape of the dam and the relative easiness of the works.

(iii) The materials should have little shrinkage ratio not to bring about the swelling and shrinking by the consolidation due to the self weight of the dam or by the rise up and draw down of the reservoir water level. The proper plasticity is also necessary to make effective the compaction by the construction machines.

(iv) The materials must not contain the organic matters or the water soluble minerals not to cause the piping action.

3) Other materials

The stones for masonry works, timbers, lime and other materials may be available around the construction site. In case where these materials are available, it is necessary to investigate their quality and quantity before adopting them in order to confirm if they fulfill the requirements of the design or not.

4-2-5 Construction facilities

In drawing up the hydro-power development scheme, the planning of the construction facilities is one of the most important matters. The facilities can be divided into the plant, machinery and others. The list of the main facilities are given below.

Plant

water supply plant (pumps, tanks, pipes)
compressed air supply plant (compressors, receivers, pipes)
electrical equipment (transmission lines, substations, distribution lines)
lighting equipment
communication equipment
cooling plant
transporting equipment (cable-ways, rail-ways, inclines, winches, hoists, cranes, belt conveyors)
aggregate plant (crushing, screening, washing plant)
concrete plant (batching and mixing plant)
concrete placing equipment (concrete pumps, concrete placers, chutes, pipes)
grout plant (mixing plant, pumps, pipes)
drainage plant (pumps, pipes)
asphalt plant
testing equipment (concrete, soil, others)

Machinery

- excavating (shovels, loaders)
- transporting (tractors, bulldozers, scrapers, trucks, dumptrucks, trailers, locomotives, trolleys, transfer-cars, mobile cranes)
- boring and drilling (boring machines, rock drills)
- compacting (road rollers, tired rollers, tamping rollers, vibrating rollers, rummers, tampers)
- concrete placing (track mixers, concrete vibrators)

Others

- buildings and houses (offices, lodgings, workmen's quarters, clinics, store-houses, workshops, car sheds, others)
- road (access roads, relocated roads)

4-2-6 Construction methods

The hydro-power project contains, in general, the constructions of several kinds of structure, but the brief descriptions about the construction methods of only the main structures such as the dam, waterway tunnel, power plant and others are given in this section.

(1) Dam

The dams may be divided into the concrete dam and fill-type dam.

1) Diversion

During the construction, the river discharge should be diverted to keep dry the foundation of the dam and other structures. The diversion method of river discharge depends on the types of the structures to be constructed and on the characteristics of the run-off, especially of the flood. Therefore, it is necessary to investigate beforehand the expected flood discharge and the frequency of the flood occurrence.

The common practice for the diversion is to provide the tunnel through the abutment, or the culvert through the dam, or the temporary channels through the construction site.

2) Excavation

In general, the ground surface is covered by weak materials such as silt, clay, sand, organic matters, weathered rock. Therefore, it is necessary to remove these weak materials before the construction of the dam, in order to expose the sound, hard and durable foundation. The extent of the excavation depends on the types of the dam and, usually, the concrete dam has the most severe requirements for the foundation.

The excavation works are carried out by machinery, humanpower, water jet and others. If there are hard zones to be excavated, they are to be loosened by blasting. The method of blasting varies with the condition of the site and the requirements for the foundation. The removed materials are to be brought to the spoil area.

In excavating the foundation, several machines are used such as rock drills, shovels, trucks, dumptrucks, bulldozers and others.

In many cases, the foundation is improved by the grouting and other measures.

3) Concrete works

The composition of the concrete is to be determined so as to fulfill the requirements regarding to the durability, strength, watertightness and so on. The concrete is produced at the batching and mixing plant, which can be controlled by one man in many cases, and is transported to the spot of placement by cranes or by other facilities. The type of the crane depends on the topographical condition of the dam site and the scale of the dam. If the span of the cable crane is to be within several hundreds meters, the crane of this type is used most frequently. If the topographical condition does not permit the use of cable crane, the jib crane and other types of crane are used to transport the concrete.

As the concrete for dam has the stiff consistency, it is to be poured to the spot of placing, in general, directly from the bukcets and should be consolidated by heavy vibrators.

The concrete dam is divided into many blocks by the construction joints and contraction joints, and the size of the block is to be determined considering the influence of the hardening heat of concrete, the capacity of the construction facilities, the time for completion of the structure and other factors.

The surface of the block is to be properly finished and several things which are to be embedded in the dam concrete should be prepared and fixed before the concrete placing.

The forms for the concrete placing are made of timber plate or steel plate, and it is desirable to use the sliding forms with big size in order to make the concrete works efficient.

After being placed, the concrete is to be cured carefully not to cause the cracks due to dry up or abrupt temperature variation. If the occasion demands, the artificial cooling is to be executed for the temperature control.

A laboratory is usually established near the construction site for the quality control of the concrete.

4) Embankment

Owing to the progress of the construction machinery, most of all the works of the embankment, from the extraction of materials to the compaction of the earthfill, can be carried out by several machines very efficiently. For the extraction of materials, several kinds of rock drills, shovels, bulldozers, scrapers and others are used at the quarry and borrow pit. For the transportation, scrapers, dumptrucks, belt conveyors, trolleys and others are used according to the circumstances. For the compaction, several kinds of rollers, rummers, tampers and others are used according to the properties of the materials to be compacted.

Each kind of materials, from coarse rock fragments to fine core materials, should be placed to the part of the dam in accordance with the indication of the design.

The materials for earthfill should be dumped and spread in continuous and almost horizontal layers. The thickness of the layer has the remarkable influence on the efficiency of the compaction and it should not be more than 15 cm after being rolled. The moisture control of the earthfill materials is very important to get the practically best degree of compaction and stability of the earthfill. It should be kept in mind that it is quite difficult to place the core part of the dam in a rainy season, as the moisture of the material must be kept to be about the optimum water content.

The rock materials are to be dumped and roughly leveled. and to the practical extent, the rocks of larger size are to be placed at the outer part of the dam and those of smaller size are to be placed at the inner part. In some cases, where the fine particles in the rock materials are limited, jet water is used to remove fine particles from the surface of the lift so as to make the settlement little after the completion.

A laboratory is usually established near the construction site for the control of the construction works, especially of the compaction.

(2) Waterway tunnel

The relative difficulties of the tunnel works depend largely on the geological conditions around the route. Generally speaking, if the tunnel is to be driven in rock, the full-face method is used with the steel support for the tunnel with the diameter up to about five meters. If the size of the tunnel is larger, the head-and-bench method is used. By this method, the cross-section of the tunnel is divided into two parts, namely the top heading and the bench. This method is favorable also for the safety of the construction works. If the ground is bad, the top-heading method is used.

The cycle of the tunnel driving consists of the drilling, shooting, ventilating, mucking, erecting support, trimming, cleaning invert.

The drilling is done, in general, by heavy drifter drills or light leg hammers which are mounted on the drill carriage named 'Jambo'. The pattern of the drill holes is to be determined in accordance with the size of tunnel and the type of the rock. The length of one cycle of blasting is usually 1.5 – 3.0m. After the firing, the smoke and dust should be blown out by proper ventialtion facilities.

Mucking is the work which requries the longest time in one cycle of the tunnel driving and it can be done effectively by the rocker shovels and trolleys, shuttle-car and other mucking machines and it has become possible to drive more than ten meters in a day.

Recently, the tunnel driving machines have been developed and, if the conditions permit, the tunnel can be driven fully automatically.

The most difficult problem of tunnel driving is the gushing out of ground water, and it is necessary to make the preparation to cope with such difficulties.

If the support is required, it should be errected immediately after the mucking. Recently, in many cases, the steel support is not removed but embedded in the concrete lining.

The concrete for lining is usually conveyed by the agitator car and placed by concrete-pump, placer and press-crete. The first one pushes out the concrete by the piston of oil pressure, while the latter two places concrete by the thrust of the compressed air. All of these equipments make it possible to place easily the concrete more than 10 m^3 in an hour.

(3) Power plant

As mentioned before, the power plant may be on the ground or underground in accordance with the topographical and geological conditions of the power plant site and the location of the turbine. It can be considered that the construction of the underground power plant is a kind of the tunnel works.

In either case, the works consist mainly of the excavation works and the concrete works, and thereafter the turbine and generator are to be installed.

It should be noted that, for the construction of the power plant, the civil engineering works, architectural works, electrical works, and mechanical works are to be carried out at the same time and at the same place, except during the first stage of the excavation. Therefore, it is necessary to adjust the schedule of these works not to interfere with each other. This adjustment is quite important to complete the construction works safely within the fixed time of completion.

(4) Others

The construction of intake, sedimentation basin, water tank, outlet and others is in general the works which are to be carried out on the ground. As they are usually constructed on the hillside, some considerations should be given to the muck treatment in excavation works and also to the transportation of the concrete. The most suitable and reasonable construction method, machines and equipments, from the viewpoint of technics and economy, should be adopted.

4-2-7 Cost estimation

(1) General

The construction cost of the hydro-power plant is, in general, consisted of the following items.

cost for the construction works
cost for the equipments
cost for the general affairs

In estimating these costs, the design reports, drawings, specifications and others of the project should be carefully investigated, and all the structures, equipments and others should be listed up without omission and thereafter the costs of them should be estimated.

(2) Cost for the construction works

The cost for the construction works is the accumulation of the costs of each individual structure related to the project, such as dam, spillway, intake, sedimentation basin, head-race, water tank, penstock, power house, tail-race, outlet, diversion works and so on.

The cost of the individual structures are to be estimated as the accumulation of the costs for the part of works, which are involved in the construction of the structure, such as excavation works, concrete works, grouting works and so on.

The cost of the part of the works is to be broken down to the elements such as labour cost, material cost, machinery rental and others.

The cost for the construction works can be divided into two kinds, namely, the direct cost which can be broken down to individual works and elements, and the common cost, which is to be used in common with several works of the construction, such as the costs for the construction machines and equipments.

The expenses for the safety of the construction works and the overhead expenses, such as head office expenses and field office expenses, should be also taken into account. Summing up, the cost for the construction works can be expressed as follows.

- Cost for the construction works
  - Direct cost
    - Materials
    - Labour
    - Machinery rental
    - Others
  - Common cost
  - Safety cost
  - Overhead cost
    - Field office expenses
    - Head office expenses

(3) Cost for the equipments

The cost for the equipments is the expenses which are required to purchase the equipments related to the project, such as several kinds of gates, valves, steel pipes of penstock, turbines, generators, transformers, switching equipments, and others.

The cost consists of the expenses for the production, transportation and installation.

(4) Cost for the general affairs

The cost for the general affairs involves the expenses to purchase the land of the construction site and the right of way, the interest during the construction time, the contingencies and others.

(5) Preliminary estimation

It is desirable to estimate the cost as above-mentioned, but for the preliminary estimation, the actual results of the project in the past can be used. For example, the statistical cost of power house per unit area or volume, or that of turbine and generator per KW or KVA can be used for the rough estimation. For this purpose, it is necessary to prepare the unit cost for several kinds of construction works and equipments beforehand, with respect to the districts.

4-2-8 Economic consideration

The determination method of the optimum scale for the hydro-power development has been stated in section 4-2-2 of this paragraph and some explanations on the meaning of Fig. 4-2-13 are given below.

The B~C curve is drawn by plotting the respective cost (C) and benefit (B) of draft-1 to draft-4, that have been stated in section 4-2-2. The points a, b, c and d are on and above the bisector of the B~C plane which is at 45 degree to the both axes, and this means that the segment of B~C curve from a to d is in the region where the surplus benefit may be expected.

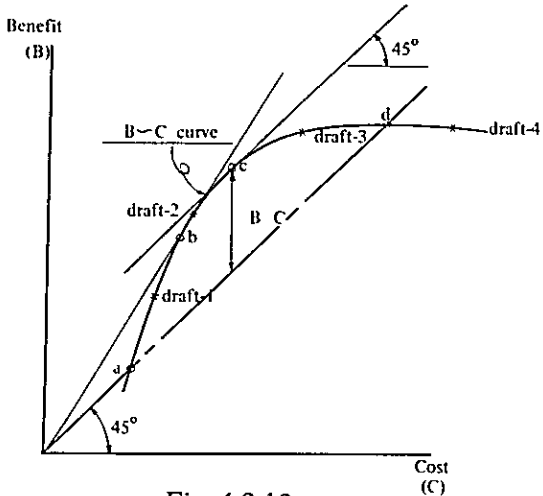


Fig. 4-2-13

The points a and d are on the bisector, where the benefit is equal to the cost, and denote the lower and upper limits of the economical maximum discharge of the power plant. If the maximum discharge is less than what corresponds to the point a or larger than what corresponds to the point d, the benefit will be smaller than the cost and the project will be poor economy.

The attention is to be given to the points b and c. The point b is the tangent point where the tangent line from the origin comes in touch with the B~C curve. The point c is the tangent point where the tangent line, which is at 45 degree to the horizontal axis, comes in touch with B~C curve. The meaning of these two points is as follows.

The point b indicates that the project is expected to be of good economy and the efficiency of the investment, B/C, becomes the largest. This point is to be adopted in case where the hydro-energy resources are plenty, the fund raising has some limitation and the stress is put on the efficiency of the investment.

The point c corresponds to the larger scale than the point b and the increment of the benefit is equal to that of the cost here, and the maximum surplus benefit, B-C, is expected, in other words, the profit of the project becomes the largest. This point is to be adopted in case where the hydro-energy resources are not so plenty and the maximum profit is required. This is the most economical point and is to be adopted if the fund raising is relatively easy.

Furthermore, the point d corresponds to the possible maximum scale and the region from point c to d is to be adopted in case where the energy resources are scarce but the demand of the electric power is large, and the larger scale development is required to fulfill the supply responsibility. This region is still better economy than the installation of the alternative thermal-power.

In considering the determination of the optimum scale of the hydro-power development in Indonesia, from the above-mentioned viewpoints, there are plenty of hydro-energy resources but the fund raising is relatively difficult, therefore, it is better to determine the scale of the development as to corresponds to the point b where the efficiency of the investment is the largest. The scale corresponding to the part of the curve from the point c to d may be considered in the future.

5. Planning of the hydro-power survey

5. Planning of the hydro-power survey

5-1 General descriptions

(1) Introduction

Planning of the hydro-power survey is classified in general as follows.

- Planning of hydro-power survey
  - survey planning of the basic data
  - survey planning of the hydro-power potential
  - survey planning of the development project
    - general planning
    - individual planning

About these subjects, their fundamental considerations, the present situation in Indonesia, and the recommendations have been described in each paragraph. Now, some explanations are given here from the viewpoint of survey planning.

(2) Survey planning of the basic data

For the basic data of the hydro-power survey, there are several matters as topographical data, geological data, precipitation data, run-off data and so on. Besides these ones, the informations about the consultants, the contractors, the manufacturer of equipments and instruments, construction materials, and others which are available in Indonesia are also the important data for the survey planning. Furthermore, the data of demand forecast in each district are inevitable for planning of the power development project.

(a) Topographical data

The topographical data are the most fundamental not only for the hydro-power development but also for general planning of the land development all over the country. Therefore, it is necessary to provide the topographical data as soon as possible.

For this purpose, the aerial survey is the most suitable one. The unit price of the aerial survey is the sum of the price of photographing and that of the mapping. Now, the unti price of the aerial survey to prepare the topographical maps with the scale of 1/25,000 - 1/50,000 are as follows.

The unit price of photographing ; 8 U.S. dollars/km^2

The unit price of mapping ; 50 U.S. dollars/km^2

Indonesian territory has the area of 1,904,000 km^2 and the abovementioned topographical maps have been prepared for Djawa. Therefore, it is necessary to prepare these maps for the islands outside of Djawa. In this case, the area below the elevation of 100 m above sea level is not likely to be developed for the purpose of the hydro-power and there remains about 50% of the total area as the mountaineous region. Therefore, about 950,000 km^2 is the object of the aerial survey.

If we try to prepare the topographical maps only along the river course (400,000 km^2), the total expenses will be

$$a \times 950{,}000\ km^2 + b \times 400{,}000\ km^2$$

where, a is the unit price of photographing and b is that of mapping.

Total expenses for the aerial survey is accordingly;

$$8 \times 950{,}000 + 50 \times 400{,}000 = 27{,}600{,}000 \text{ U.S. dollars}$$

The unit price of the direct (ground) survey to prepare the topographical maps with the scale of 1/200 - 1/500 at the site of the individual development project is 25,000 Rp/ha or 2,500,000 Rp/km^2. Using these data, we can estimate the total expenses of the survey at the individual project site.

The constitution of the party for the direct survey and the unit work for preparing the topographical maps with the scale of 1/500 are as follows.

personnel

chief engineer	1
technician	4
laborer	10 - 15

items of survey work

setting up the skelton (triangulation or traverse survey)
leveling
stadia survey or plane table survey
calculation
mapping

working days

(required for surveying 1 km^2 in mountaineous area)

field work	20 days
desk work	20 days
total	40 days

(b) Geological data

The general geological features in Indonesia have been known to some extent by the technical cooperation of Indonesia and the United States and, hereafter, the geological survey will be mainly executed corresponding to the individual development project.

For this purpose, it is necessary to keep several geological engineers in the electric power sector. The duties of the geological engineers are to execute the geological survey at the project site, which is under the direct control of the electric power sector, and to administrate the geological survey works which are executed by the consultants or by the experts of technical aids.

(c) Precipitation data

The precipitation conditions in all over the Indonesia have been fairly well known and, hereafter, the collection of the precipitation data will be carried out corresponding to the survey for the individual development projects or the survey of the hydro-power potential.

In planning the hydro-power survey, the precipitation data are mainly used as the supplement to the run-off data and it is necessary to take the relationship to the run-off data into consideration. Therefore, it is desirable to establish at least two or three precipitation observation stations for each run-off gauging station.

For this purpose, the cooperation with the Institute of Meteorology and Geophysics is required. The electric power sector must cover the deficiency by itself, when the occasion demands.

The expenses required for the establishment of a new precipitation observation station are 1,200 U.S. dollars.

The approximate number of the precipitation observation stations, which are to be newly established, is as follows.

Table 5.1.1 numbers of the precipitation observation stations to be newly established

Djawa	0
Sumatera	40
Kalimantan	8
Sulawesi	20
West Irian	10
Bali	0
Others	0
total	78

Working expenses of a observation station are 200 U.S. dollars a year.

(d) Run-off data

Run-off data in Indonesia are not sufficiently prepared at present time and it is necessary to establish new gauging stations extensively.

At the rivers which are regarded as the important or representative ones in Indonesia, at least one automatic water-stage recorder should be installed. The stream flow measurement should be carried out regularly, besides the daily river stage measurement.

For other rivers, it is necessary to install the staff gauge successively. The approximate numbers of the automatic water stage recorders and the staffgauges to be newly installed are shown on Table 5.1.2.

Table 5.1.2 numbers of the automatic water stage recorders and staff-gauges to be newly installed

district	water stage recorder	staff-gauge	total
Djawa	13	9	22
Sumatera	17	17	34
Kalimantan	4	3	7
Sulawasi	8	7	15
West Irian	4	4	8
Bali	1	1	2
others	0	0	0
total	47	41	88

(The first priority must be put on the installation of the water stage recorders and it should be accomplished in five years. Staff-gauges must be installed keeping pace with the installation of the water stage recorders, or in next five years.)

For this purpose, the cooperation with the Institute of the Hydraulic Engineering is necessary. The electric power sector must cover the defficiency by itself, when the occasion demands.

The expenses required for installing a new automatic water-stage recorder are 3,300 U.S. dollars in Djawa and 8,700 U.S. dollars outside Djawa, and the expenses for installing a new staff-gauge are 135 U.S. dollars in Djawa and 280 U.S. dollars outside Djawa.

The annual working expenses of a run-off gauging station are 850 U.S. dollars in Djawa and 2,530 U.S. dollars outside Djawa.

(e) Sedimentation, Evaporation and others

For the sedimentation data, it is necessary to measure regularly the sediments transported by the river and the sedimentation results in the existing reservoirs.

For this purpose, the cooperation with the Directorate General for Water Resources and its Institute of Hydraulic Engineering is necessary, for the time being. The electric power sector must execute the survey works by itself, when the occasion demands.

For the evaporation data and others, it is appropriate, for the time being, to cooperate with the Institute of Meteorology and Geophysics and with other related organizations.

(f) The informations of the river utilization

The rivers are utilized for several purposes such as irrigation, water supply, navigation, flood control and others, besides the power generation and the river discharge is much influenced by the land utilization such as the agriculture and the forestry.

In planning the hydro-power development, it must be taken into consideration that, in some cases, the advantages and disadvantages of the river utilization for the purpose of power generation are opposed to those of other purposes.

As the river must be developed comprehensively as the national endowment, it is necessary to set up some liaison committee with related organizations to exchange the informations each other and adjust the development plan.

It is also necessary to prepare the data of the conventional rights of the utilization of land or river in each district, in connection with the hydro-power development.

(g) The informations of the consultants and others

The informations of the consultants, the contractors, the manufacturer of equipments and instruments and others are necessary as the basic data for survey planning. The information must cover such items as the results of business, the capability, the reliability, the recent record of business, and so on.

The consultants and contractors, which are available in Indonesia for the hydro-power survey are P.N. Indah Karja and P.N. Virama Karja.

In many cases, the foreign organizations take part in the survey and the construction of the hydro-power projects in Indonesia, and the information of these organizations are also important.

(h) The information of the construction materials

It is necessary to provide the data of the construction materials in connection with the hydro-power survey and construction, not to bring hindrance to the cost estimation of the survey woιks or the construction works. These information must cover the means of procurement, unit prices and their variations and others.

(i) Demand forecast data

The hydro-power is to be developed corresponding to the electric power demand. Therefore, the demand forecast data is one of the most important ones for planning the power development.

Now, there are much latent demand of waiting consumers in Indonesia and the electrification of the isolated under-developed regions is the big problem here. Therefore, the countermeasures to these problems are the important matters for planning the power development.

For the demand forecast around the big cities, the Terada Mission has presented some estimation. This estimation is quoted here with its basis.

Load estimation by the Terada Mission

Table 5.1.3 Estimated loads in West Djawa

Units: MW & %

Exploitasi	1968 (Actual)	1969 (Estimate)	1970 (")	1973 (")	1975 (")	1968-1973 (")	1973-1975 (")
X11	84.0	(10.5) 92.7	(10.5) 102.5	(13.0) 145.9	(14.2) 189.7	(11.7)	(14.0)
XI	53.3	(8.5) 57.8	(8.5) 62.7	(11.9) 85.8	(13.2) 109.6	(10.0)	(13.0)
Total	137.3	(9.7) 150.5	(9.7) 165.2	(12.6) 231.7	(13.8) 299.3	(11.0)	(13.6)

Note: Figures in parentheses indicate the percentage of increase over the previous year.

Table 5.1.4 Load estimation (Average annual increase) in Djakarta

Unit: %

	1-2 Years	3-5 Years
Load increase by population increase	3.5 (2.5)	3.0 (2.5)
Load increase by increase per capita income	1.5 (1.5)	3.0 (3.0)
Load increase by voltage improvement	2.6 (2.6)	2.6 (2.6)
Load increase by electrification	3.0 (2.0)	4.0 (3.0)
Total	10.6 (8.6)	12.6 (11.1)

Note: Up to 1973
: Figures in parentheses indicate the percentage of increase in all Djawa excepting Djakarta.

Table 5.1.5 Load estimation (Average annual increase) for 1974-1975

Unit: %

	Djakarta	The rest of Djawa
Load increase by population increase	3.0	2.5
Load increase by increase per capita income	3.0	3.0
Load increase caused by the voltage improvement	1.5	1.5
Load increase caused by the increase in the rate of electrification	4.0	4.0
Load increase caused by the increased electric power use by a consumer	2.5	2.0
Total	14.0	13.0

Note: The increase in the rate of electrification includes the waiting consumers.

Table 5.1.6 Estimated load increase (Djawa total)

Unit: %

	1969	1970	1971	1972	1973	1968 - 1975
Final estimation	8.0	8.4	10.1	10.9	15.4	10.5

As an example, the present situations of the waiting consumers in East Djawa is shown in the appendix 5-1.

(3) Survey of the hydro-power potential

It is said that the extent of the economic progress of a country is almost proportional to its energy consumption, and the hydro-power takes a important part in the national energy supply problem. Therefore, it is inevitable to carry out the survey of the hydro-power potential in order to grasp the energy endowment of a country and to establish the energy supply plan.

For the hydro-power potential in Indonesia, some investigations have been carried out and the potential is estimated to be approximately 28,000 MW, but more exact survey is required.

The estimated amount of the hydro-power potential varies with the assumed maximum discahrge of the power plants and the methods to give the almost minimum amount of the potential have already described in the section 3-2.

The hydro-power potential is to be estimated for each water system of the river. The number of main water systems in each district in Indonesia is shown on Table 5.1.7.

Table 5.1.7 number of the water systems in Indonesia

District	number of the water systems
Djawa	111
Sumatera	214
Kalimantan	50
Sulawesi	128
West Irian	34
others	—
total	537

In order to estimate the theoretical potential of a water system, the required working days are as follows, if we have the working team consisted of the members as shown below.

required working time for a water system

(i)	arrangement of the run-off data		5 man-days
(ii)	arrangement of the precipitation data		5
(iii)	estimation of the run-off coefficient		1
(iv)	preparation of precipitation distribution chart		3
(v)	calculation of the run-off from each division of elevation		3
(vi)	calculation of the potential		1
(vii)	final arrangement		2
		total	20 man-days

party

chief engineer	1
assistant	4

With this party, the estimation of the theoretical hydro-power potential of a water system can be accomplished in four days. Therefore, the potentials for 150 water systems can be estimated in two years. These water systems may cover the important ones in Indonesia.

For the estimation of the economically developable potential, much more engineers and working days are necessary than the estimation of the theoretical one. For example, the outline of the economically developable potential survey in Japan (the fourth survey) is as follows.

Survey of the economically developable potential in Japan

(the fourth survey)

Table 5.1.8 Expenses (excluding the personnel expenses)

year	topographical, geological survey	hydrological survey	total
	x 10^6 yen	x 10^6 yen	x 10^6 yen
1956	115	14	129
1957	155	20	175
1958	147	19	166
1959	2	3	5
total	419	56	475

outline of the survey work

number of the surveyed water systems;	198
number of the surveyed sites;	1,395
aggregate number of the staff personnel;	1,220
survey period (in years);	4
longitudinal cross section of the rivers which is newly surveyed;	11,150 km
number of the sites which are newly surveyed;	1,143
geological survey;	
land surface survey	197 sites
boring	5,550 m
exploration adits or shafts	2,539 m
physical exploration	30,927 m
aerial survey; (134 cases)	4,162 km^2
newly established run-off gauging stations;	109
newly established precipitation observation stations;	96

Table 5.1.9 The results

	site	maximum capacity	firm capacity	energy
already developed	1,211#	9,650 MW	3,140 MW	44,340 10^6KWH
under construction	84	3,340	600	11,440
to be developed	1,077	22,380	4,260	74,310
total	2,372	35,370	8,000	130,090

#; 1,541 sites have been already developed and 330 of them are to be redeveloped.

For the estimation of the hydro-power potential, it is the precondition that the enough basic data are provided. But, in Indonesia, the situations of data preparation differ remarkably with the districts. Therefore, it is appropriate, for the time being, to put the main effort on the estimation of the theoretical potential. In estimating the potential, it is necessary to use the run-off data, where they are available, or to use the estimated run-off data from the precipitation data, where the direct run-off data are not available, together with the available topographical data.

The survey of the economically developable potential in Indonesia may be executed in the form of the survey of the individual development projects, for the time being, and after the basic data will have properly prepared, it must be executed uniformly all over the country.

(4) Survey of the development project

For the general plan of the power development in Indonesia, we have the First and the Second Five Year Plans for the electric power sector. These outlines are as shown on Table 5.1.10.

Table 5.1.10 The Five Year Plan for the Electric Power Sector

district	installed capacity in 1968	1st Five Year		2nd Five Year	Total
		additional capacity	total	additional capacity	
	KW	KW	KW	KW	KW
Sumatera	97,879	84,450	182,329	670,000	852,329
Djawa	506,459	260,406	766,865	815,000	1,581,865
Kalimantan	15,679	30,100	45,779	35,000	80,779
Sulawesi	22,421	37,679	60,100	110,000	180,100
Others	19,133	10,434	29,567	14,000	43,567
Total	661,571	423,069	1,084,640	1,644,000	2,728,640
annual increase ratio		10.6 %		20.1 %	
			15.3 %		

At present, the electric power supply system in Indonesia is not well interconnected and the electric power is supplied separately to each district. For the power development, the projects in each district has just got under way. Therefore, after these projects will have acquired the definite outlook (it is said that this stage will come about two years hence), the general plan will have to be reviewed from a national standpoint and the new general plan of the power development will have to be drawn up.

For this purpose, it is necessary to accomplish the estimation of the theoretical hydro-power potential at the region where the hydro-power development is anticipated.

The matters, which should be taken into consideration in drawing up the general plan of the power development, are briefly explained here.

Generally speaking, the motives of the power development are as follows.

The motive corresponding to the demand increase
The motive corresponding to the special demand
The motive corresponding to the local development

In many cases, these motives are interconnected as the matter of course. Some explanations are given below to each motive.

(i) The motive corresponding to the demand increase

This motive of the power development is to correspond to the demand increase of the existing consumers in the supply area, to the new supply to the waiting consumers, and also to the electrification of the environs of the present supply area.

(ii) The motive corresponding to the special demand

This motive is to correspond to the big demand of some special project such as the refining or the smelting of ore and others. The typical case can be seen at Asahan Project. The circumferential area may naturally share in the benefit of this development.

(iii) The motive corresponding to the local development

This is the motive to correspond to the power development based on the new local comprehensive development plan, and to the electrification of the local isolated region.

The Riam Kanan Project is an example of the former case and the installation of the diesel power plant or the micro-hydro power plant in the isolated region is an example of the latter case.

In drawing up the general development plan, the respective amount of these demands must be duely taken into account.

The electric power supply system, which meets these demand, must satisfy the following three principles.

(i) Abundance
(ii) Good quality
(iii) Reasonable price

The abundance means to provide enough generating capacity to meet the demand. The good quality means to supply the stable electric power with little fluctuation of the voltage or the frequency and with little power failure. The reasonable price means the price to supply the economical electric power to the consumers and, on the other hand, the price which the enterprise can be properly operated with. These principles are also to be taken into consideration, in drawing up the general plan.

From the economic viewpoint, the electric power supply system must be of the minimum cost as a whole. For this purpose, the following two matters must be taken into consideration.

(i) the constitution of the generating system
(ii) the interconnection of the electric power supply system

The sources of the electric power supply comprise three varieties as follows.

(i) hydro-power
(ii) thermal-power (coal, heavy oil, natural gas, geothermal and nuclear)
(iii) diesel and gas turbine

The hydro-power requires much initial investment and relatively long time of construction but its running cost is relatively small and is able to make fit to the fluctuation of the demand with the easy start and halt of operation.

The thermal-power requires less initial investment and shorter time of construction compared with the hydro-power. But its running cost is relatively high and the quick start and halt of operation is rather difficult.

The diesel or gas turbine requires the shortest construction time and is able to make fit to the fluctuation of the demand with ease but its running cost is the highest.

From the viewpoint of survey planning, the thermal power and diesel or gas turbine can be installed at required place, at required time, and with required capacity. While, for the hydro-power, it is necessary to execute the detailed survey and investigations before the installation. Therefore, in drawing up the general power development plan, the constitution of the generating system must be decided keeping in mind the above-mentioned matters.

The next problem is the interconnection of the electric power supply system. In order to make the electric power supply stable, it is necessary to interconnect the main power plants with the transmission lines and substations. By interconnecting the supply system, it becomes possible to interchange the electric power between one district and another and to meet the fluctuation of the demand in each district with ease.

Moreover, if the supply system is interconnected, the power plants can be installed at the most economical site, even if it is far from the place of consumption.

We have described about the motives of the power development, three principles of the power supply system, and their economic aspects. In drawing up the general plan of the hydro-power survey, it is necessary to determine, at first, the optimum amount of the hydro-power to be developed, taking the above-mentioned matters into consideration, and then to investigate how to proceed the survey works.

It requires further investigations to fix exactly the optimum amount of the hydro-power to be developed, but it may be estimated roughly from the data which are available now.

In considering the hydro-power development planning, we have the Five Year Plan for the electric power sector in Indonesia and the demand forecast by the Terada Mission, as the basis. The demand increase ratio of about 10 % is assumed by the Five Year Plan and also by the Terada Mission. Therefore, planning of the hydro-power survey should be conformable to this figure, for the time being.

Djawa is the most important district from the view point of the electric power consumption, and the development plan for Djawa by the Five Year Plan is as shown on Table 5.1.11 and Table 5.1.12.

Table 5.1.11 Increase of the installed capacity

year	1968	1973	1978
total capacity	506 MW	767 MW	1,582 MW
annual increase rate	8.7 % (1968–1973), 15.6 % (1973–1978), 12 % (1968–1978)		

Table 5.1.12 Increase of the capacity of each source and in each district

		1968 - 1973	1973 - 1978
Diesel	East Central West	5,000 KW 19,750 –	– – –
	total	24,750	–
Thermal	East Central West	– 60,000 KW 100,000	100,000 KW 120,000 300,000
	total	160,000	520,000
Hydro	East Central West	74,500 KW – –	35,000 KW 10,000 250,000
	Total	74,500	295,000

In the above tables, it can be seen that the rates of the demand increase in the first five years and the second five years are fairly different, but, as a whole, the development plan was drawn up with the increase rate of about 12 % and with the ratio of thermal-power to the hydro-power of two to one.

It seems that, in planning the Five Year Development Plan, the balance of the demand and supply was attained by supplementing the defficiency of the hydro-power with the thermal-power.

As Indonesia has the fairly plenty of the hydro-power resources, it is necessary to execute the survey of the hydro-power to the extent making the economic comparison possible, and build up the most economical combination of the hydro and thermal power to meet the demand properly. In this case, the hydro-power may be used corresponding to the peak load and also to the base load.

The rate of demand increase will not fluctuate remarkably, if the special big demand will not arise or the economic upheaval will not occur.

On the other hand, the ratio of the thermal-power to the hydro-power may vary with the conditions such as the fund supply, the construction period of the power stations, the endowment of the hydro-power resources, the extent of the survey, the interconnection of the transmission system, and so on.

Taking these factors into consideration, it is necessary to execute the survey to keep the feasible sites corresponding to 50 - 100 % of the demand increase in successive years. As the construction of the hydro-power plant takes two to five years, it is necessary to make the construction go ahead of the demand increase.

Based on the above-mentioned considerations, the total capacity of the hydro-power to be surveyed in successive years is as shown on Table 5.1.13. In this case, we have assumed that the survey should be started three years before the construction.

Table 5.1.13 The total capacity of hydro-power to be surveyed

Year	Djawa		Outside Djawa		Total	
	minimum	ideal	minimum	ideal	minimum	ideal
1971	21 MW	42 MW	4.5 MW	9 MW	25.5 MW	51 MW
1972	22.5	45	5	10	27.5	55
1973	25.5	51	5.5	11	31	62
1974	29	58	6	12	35	70
1975	33	66	7	14	40	80
1976	36	72	8	16	44	88
1977	40	80	9	18	49	98
1978	45.5	91	10	20	55.5	111
1979	50.5	101	11	22	61.5	123
1980	58	116	12	24	70	140

Corresponding total demand is as follows. (with the increase rate of 12 %)

Table 5.1.14 The estimated total demand

year	Djawa	Outside Djawa	Total
1970	270 MW	60 MW	330 MW
1971	302	67	369
1972	338	75	413
1973	380	84	464
1974	425	94	519
1975	476	105	581
1976	534	117	651
1977	600	132	732
1978	672	148	820
1979	752	166	918
1980	843	186	1,029

We assume that the expenses for the survey works are to be $10 per unit capacity (KW), based on the results of the survey works which were already executed in Indonesia. The required expenses for the survey in successive years are as shown on Table 5.1.15.

Table 5.1.15 Expenses for survey unit; a thousand U.S. dollar

year	minimum	ideal
1971	255	510
1972	275	550
1973	310	620
1974	350	700
1975	400	800
1976	440	880
1977	.490	980
1978	555	1,110
1979	615	1,230
1980	700	1,400

5-2 Cost of the Survey

The summary of the cost estimation is as follows, and the required expenses in successive years are given in the Table 5.2.1.

(1) Topographical map (Aerial survey)

the area of photographing; 950,000 km^2
the area of mapping; 400,000 km^2
the unit price of photographing; $8/$km^2$
the unit price of mapping; $50/$km^2$
total expenses; 8 x 950,000 + 50 x 400,000 = 27,600,000 U.S. dollars

(2) Precipitation observation

the number of the precipitation observation stations to be newly established; 78
the cost of the establishment; $1,200/station
total expenses; 78 x 1,200 = 93,600 U.S. dollars
the working expenses; $200/station/year
total working expenses; 78 x 200 = 15,600 U.S. dollars/year

(3) Run-off gauging

the number of the automatic run-off gauging stations to be newly established
In Djawa: 13 Outside Djawa: 34

the cost of the establishment;
In Djawa: $3,300, Outside Djawa: $8,700 including the water stage recorder

total expenses;

13 x 3,300 + 34 x 8,700 = 340,000 U.S. dollars

the number of the staff-gauges to be newly installed;

In Djawa: 9, Outside Djawa: 32

the cost of installation;

In Djawa: $135, Outside Djawa: $280

total expenses;

9 x 135 + 32 x 280 = 9,800 U.S. dollars

the working expenses;

In Djawa: $850/year, Outside Djawa: $2,530/year

total expenses;

(13 + 9) x 850 + (34 + 32) x 2,530 = 186,000 U.S. dollars

purchase of current meters

number of the current meters to be purchased; 30
unit price; $1,870
total expenses; 30 x 1,870 = 56,000 U.S. dollars

Table 5.2.1 Expenses for the hydro-power survey

unit; one thousand U.S. dollars

Items	Total	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	Remarks
Precipitation observation	–	3.2	6.3	9.4	12.5	15.6	15.6	15.6	15.6	15.6	15.6	to be continued
Installation of new precipitation observation stations	93.6	18.7	18.7	18.7	18.7	18.8	–	–	–	–	–	
Purchase of current meters	56	56	–	–	–	–	–	–	–	–	–	
Stream flow measurement	–	26	46	66	86	106	126	146	166	186	186	to be continued
Installation of new *run-off* gauging stations (automatic)	340	70	70	70	70	60	–	–	–	–	–	
Ditto (staff-gauge)	9.8	–	–	–	–	2	2	2	2	1.8	–	
Project survey	–	510	550	620	700	800	880	980	1,110	1,230	1,400	to be continued
Sub total	–	683.9	691.0	784.1	887.2	1,002.4	1,023.6	1,143.6	1,293.6	1,433.4	1,601.6	
Aerial survey	27,600	1,380	1,380	1,380	1,380	1,380	1,380	1,380	1,380	1,380	1,380	to be continued
Total	–	2,063.9	2.071	2,164.1	2,267.2	2,382.4	2,403.6	2,523.6	2,673.6	2,813.4	2,981.6	

Excluding personal salary, expenses for administration, working expenses of the offices, and working expenses of *the observation and gauging* at the existing stations.

5-3 Organization related to the survey

Now, the electric power sector of Indonesia is in the course of the reorganization.

In the connection with the hydro-power survey, following duties should be assigned to the appropriate sections in the central office.

(i) Fundamental Research

Demand forecast.
Standardization of the facilities and equipments.
Standardization of the design.
Research of the new technology.
Administration of informations.
Statistics.

(ii) Facilities Planning

General and fundamental planning of the new establishment or extension of the electric power supply system including generation, transmission, transformation and distribution.
Funds supply and demand programme.

(iii) Planning and Survey

Collection and administration of the basic data.
Planning and survey of the proposed sites of the power development.
Planning and survey of the transmission, transformation and distribution facilities.
Administration of the survey works which are executed by local branch offices.

(iv) Design

Design work and its administration of the electric, civil and architectural facilities and structures related to the new establishment or extension of generation, transmission, transformation and distribution facilities.

(v) Training

Cultivation of the technical skill.
Technical education and training of the technicians.

(vi) Research and Investigation

Technical research, investigation and experiment related to the electric power.

No description is given here for the administration including financing, organization and management, logistics, and others, for they are the common divisions for the entire organization.

In each branch office of the electric power sector (Exploitasi), a group of civil engineers is to be kept. Its duties are to carry out the precipitation observation and run-off gauging which are under the direct control of the electric power sector, to execute some survey works such as simple topographical survey and others, and to administrate several survey works which are executed in the district concerned. In future, the preliminary planning of the hydro-power development may be drawn up by the branch offices.

For this purpose, it is necessary to train and educate the staff personnel in the branch offices.

The head office must collect and arrange the results of the survey works which are executed by the branch offices and put them to the practical use in the hydro-power development planning.

At the proposed project sites under surveying, the survey offices are set up when the occasions demand. The organization of the office is as follows.

Management.

- General affairs section.
  - accounting, logistics and others.
- Technical section.
  - execution and administration of survey works.

The number of engineers in the electric power sector in Indonesia is relatively limited and it is inadvisable to scatter them. Therefore, the duties of the survey office should be confined, in principle, to the execution of in-situ survey or the field works and their administration, and the fundamental planning and design should be carried out at the head office.

The right men should be put to each organization, according their kind of work, ability and experience. The number of the personnel in each organization may vary remarkably with how to proceed the work, especially with how to use the consultants.

It may be expedient, for the time being, to keep the standing advisers related to the planning and survey of the hydro-power development and make them cooperate with the technical personnel in the electric power sector.

5-4 Consultants

The fairly large part of the survey works in Indonesia are carried out by the consultants in the present circumstances.

In getting the consultants to execute the survey works, it is necessary to make their duties clear and distinct at the time of making contract. For this purpose, the specifications must be comprehensive without ommission or negligence.

In general, the items which are to be described in the specifications are as follows.

(i) the purpose of the survey

(ii) the outline and the circumstances of the survey

(iii) the extent of the survey works

(iv) the period of the survey

(v) the laws, the regulations and criteria to go by

(vi) the required applications and their procedures

(vii) the available data

(viii) the explanation of the conditions at the site (available facilities of transportation, communication, accommodation, medical treatment and so on)

(ix) the demarcation of the responsibility

(x) the demarcation of the expenses bearing

(xi) the special mentions for the survey method (including the kind and method of testing)

(xii) the special mentions for the equipments and materials for the survey works

(xiii) the special mentions for the countermeasures for the safety

(xiv) the procedure and the form of reporting

(xv) the gist of the report preparation and the number of copies to be submitted

(xvi) others

Before the survey works are started, the authorities of the electric power sector must get the consultant to submit the schedule of the survey works, the description of the survey method and the list of the equipments and materials for the survey works, to investigate their adequacy.

It is advisable to leave the method or equipments and materials for the survey works to the idea of the consultant, in order to make the survey economical.

After the survey works have been started, the authorities must get the consultant to submit the reports regularly to check the progress of the survey works and look after so as not to delay the works.

The staff personnel of the authorities must take part in the survey works, when the occasion demands, to solve the problems discussing each other.

After the survey works have been accomplished, the authorities must investigate the results and put them to the practical use in the power development planning.