The Philippine Fault is the greatest transcurrent fault in the Philippines. This is traceable from the Lingayen Gulf in north along the southern border of the Luzon Central Cordillera, across Southern Sierra Madre and through Leyte and Surigao into Southern Davao in Mindanao. Present movement of the fault is confirmed to be left-lateral, displacing Neocene rocks in Northern Leyte for at most 8 km. Activity in the fault appears to have been continunous since the Paleocene with apparently more intense activity in the past than at present.

The Dingalan-Lingayen segment of the Philippine Fault spilits into several splices in the vicinity of the Caraballo Mountains in Nueva Ecija, one of which is the Digdig Fault. Normal faults are commonly observed along the flanks of majar structural basins and actively rising mountains masses. Majar gravity faults in Luzon are the faults bounding the Laoag Plain in Ilocos Lowland, the faults in Cagayan Valley area, San Antonio Fracture zone in the southern part of the Zambales Range, and the west Marikina Fault.

Many thrust faults occur in the archipelago but most of them are minor. The more prominent ones are generally along the borders of the main Philippine Archipelago. The thrust faults in the Bicol Regions are located in the northeastern parts of Camarines Norte and Camarines Sur.

3.2.6 Seismicity

(1) General

The seismic activity of the Luzon Island is potentially high, because the Philippine Archipelago is located along the circumpacific Seismic Belt. Most of the epicenters in and around the Luzon Island are concentrated in the east offshore of the Luzon Island from 17°N to 15°N latitude and in the area of the Verde Island Passages at southwest of Batangas. And also earthquakes mostly occur at shallow depth (up to 70 km from surface). The distribution of earthquake epicenters are shown in Fig. 3.6.

In 1981 BMG compiled the seismic zones in the Philipine Archipelago. Fig. 3.7. shows the seismic zones, and interpretation of each zone by BMG is as follows:

Zone I	- Related to the Manila Trench Subduction dippiing east.
Zone II	- Related to subduction along the East Luzon Trench, dipping west.
Zone III	- Related to subdiction along the Sulu Sea Trench and Antique Trough, dipping east.
Zone IV	- Related to the Philippine Trench subduction zone, dipping west.
Zone V	- Related to the Cotabato Trench subduction zone, dipping east.
Zone VI	- Related to activities along the Philippine Fault.
Zone VII	- Possibly related to a west-dipping subduction zone surfacing at the Agusan-Pano Trough and traceable southward into the Mollucas Sea.

The intense seismic activity of the Luzon Island is mainly related to Zones I, II and VI. Most of the intermediate depth earthquakes (focal depth from 79 km to 299 km) run approximately along the west side of the Philippine Trench. Some of them locate west part of northern Luzon Island. Deep focus earthquakes (focal depth from 300 km to 699 km) are mostly concentrated between the Mindanao-Sulamedi Region.

(2) Seismic record

The seismic record of the Philippines are available. These are four kinds of earthquakes data file as shown in Table 3.5. The most datailed and latest catalogue is number four in Table 3.5.

Historical huge earhquakes of magnitude more than 7, listed from NOAA data file (1897-1976), are as shown in Table 3.6 and Fig. 3.8. The destructive earthquakes in the Philippines (1589-1983) listed by SEASEE Series in seismology (Volume IV, Philippines) are as shown in Table 3.7 and Fig. 3.9.

In order to assess the seismic hazard to each damsite in the Luzon Island, the whole of the available earthquake data file should be considered. Some feasibility sutdies on acceration for the earthquake-resistant design of the dam construction as follows.

Scheme	Dam Type	Maximum Credible Acceleration/ Return Period	Design Basic Acceleration
Binongan	Rockfill	0.5g/1000yrs	0.2g
Chico 4	Rockfill	0.65-0.85g/2500yrs	-
Diduyon	Concrete gravity	0.128g/500yrs	0.12g
Marikina	Arch		0.13g

In Japan, the maximum ground seismic coefficient of concrete gravity dam is established by Japanese National Committee on Large Dams. Accordin to the Design Standards of Dam, maximum ground seismic coefficient in Japan is 0.2 which corresponds to the maximum ground accelation of 1,000 gal (for return period of 200 years).

3.3 Hydrology

3.3.1 Rainfall and climatological data

(1) Rainfall data

In the Luzon Island, there exist more than 300 rain gauges managed by NPC, PAGASA and NIA. Monthly and annual rainfall data have been collected from the data books prepared by the authorities concerned, the existing reports on water resources projects, original data not compiles yet, and others. Out of monthly rainfall data collected, those of 177 rain gauges with data more than 5 years were stored in the computer VAX/750 owned by NPC. These data were reviewed and used for the estimation of rainfall-runoff relationship and for the preparation of an isohyetal map on an annual rainfall base.

(2) Climatological data

The climatological data such as temperature, evaporation rate, and relative humidity have also been collected from the existing data books and reports.

Among them, pan-evaporation rates at 38 sites in the Luzon Island were analysed to estimate the evaporation rate from the reservoir surface at each scheme. Data used are summarized in Table 4.3.

3.3.2 Hydrological data

(1) Monthly streamflow data

Monthly streamflow data were collected from more than 300 gauging stations managed by NPC, NWRC, NIA and BPW. Monthly streamflow data are one of the most important data to determine the development scale of the hydropower schemes, so that the collection of data was intensively made.

Out of monthly streamflow data collected, those of 152 gauging stations with data more than 10 years were stored in computer as well as monthly rainfall data.

(2) Flood data

The observed maximum floods of around 300 streamflow stations were collected from the data book titled "SURFACE WATER SUPPLY BULLETIN" (No.2 - No. 12, BPW), and the existing reports concerned. Moreover, the floods with various probabilities were also collected at 162 gauging stations, referring to the reports titled "FRAME WORK PLAN" (Region I-V, 16 vols.) issued by NWRC.

These flood data were analysed to estimate the design floods for river diversion work and spillway of the hydropower schemes to be studied this time.

(3) Sediment data

In this study, a reservoir sedimentation is estimated by the denudation rate in the catchment, the catchment area, and the life time of the scheme. Denudation rates actually applied to several existing projects and named projects were collected and are shown in Table 4.4.

3.4 Socio-Economy

Following data were collected for socio-economic study during the study period. These are mainly categorized into three groups as shown below:

(1) General Backgroud

Position, industrial structure of the country, Economic recession in early 1980s, and Updated Philippine Development Plan 1984-1987

(2) Study Area

Administration and regional characteristics of the Study Area in the country with demographic data (upto 2030) and GDP/GRDP (historical and NEDA projection upto 1987)

(3) Energy

Organization and electric power expansion record, and Analysis on its correlation with socio-economic indices

Since thise informations have been originated in 1985, the reference is updated and summarized as per Table 3.8.

IV. HYDROLOGICAL ANALYSIS

4.1 Introduction

Meteo-hydrological studies are intended to provide the basic information necessary for determining the development scale of hydropower schemes. The contents of the studies are mainly composed of the high and low flow analyses and the estimates of evaporation and sediment yield according to the objectives of studies. Furthermore, the determination of hydrological regions and the preparation of isohyetal map are also included as a part of the studies.

The meteo-hydrological studies consist of four parts as a flow of studies; data collection on meteorology and hydrology, data filing in the computer, scrutinization of meteo-hydrological data, and hydrological analyses.

As a large number of schemes for the hydropower development are raised up in this study, the hydrological analyses are extensively made and practical assumptions are given, especially in the high flow analysis. Furthermore, the electronic computer has been fully utilized for the execution of numerous computation. Several computer programs have been prepared for the hydrological data processing and analyses.

4.2 Background

4.2.1 Study area

The Luzon Island of 104,700 km^2 in area, the largest island of the Philippine Archipelago, lies between latitudes 12° and 19° north and longitudes 119° and 125° east. The study area covers the whole Luzon Island.

The northern part of the Luzon is ridged along the west coast by the Ilocos Mountains, the Cordillera Central Range further inland, and the Sierra Madre near the east coast. Main river basins in this part are the Laoag, Abra, Apayao-Abulog, and Cagayan with its principal tributaries; namely Chico, Ilagan, and Magat. The central Cagayan Valley constitutes a relatively flat plain of up to 100 m in elevation.

Central Luzon consists of a large plain drained by the Pampanga river system, which flows southward and discharges into the Manila Bay. Further west the Agno river flows south, then northwest to discharge into the Lingayen Gulf. Much of this area is a flat agricultural land bordered on the east and west by the central ranges of the Sierra Madre and Zambales Mountains. To the north, the Caraballo Mountains form the basin divide between the Cagayan and Pampanga river basins.

The area to the southeast of the Manila Bay has a mixed topography of plains and mountains. The major rivers flowing in this area are the Marikina, Agos, and Bicol. South of the Sierra Madre lies the volcanic region around Laguna de Bay, and Mayon Volcano with an elevation of 2,469 m, which has erupted periodically about once every 10 years, is located in the southernmost part of this area.

4.2.2 Climate and meteorology

The climate of the Luzon Island in the Tropics is controlled by the prevailing wind systems, principally the southwest monsoon and northeast monsoon. The former prevails from July to September and brings heavy rainfall to western-exposed locations. The latter prevails from November to February, giving heavy rainfall to the east coast and along the Sierra Madre Mountains. Several typhoons hit the Luzon Island every year, bringing torrential rains.

Rainfall characteristics in the Luzon Island are considerably orographic: the mountainous areas in the west and east intercept the southwest and northeast monsoon rains, respectively, leaving the central regions relatively dry. In contrast, some exposed locations have rainfall more evenly distributed throughout the year, being influenced by both monsoon periods. The mean annual rainfall in the Luzon Island ranges from 1,500 mm in the lower Cagayan Valley up to 6,000 mm in the north of Cordillera Central Mountains and the southeast of the island.

Annual pan-evaporation ranges from 1,100 mm to 2,300 mm, depending on geographic location, exposure, and elevation. The high values tend to occur in the irrigated lowlands with evaporation decreasing in the mountainous area.

Annual mean air temperature is 26.8°C with the range of between 25.7°C and 27.7°C, excluding highland areas such as Baguio of 1,482 m in altitude whose temperature is 18.2°C. The mean monthly temperature has a small variation throughout the year: in general, the highest values are observed in April and May, while the lowest ones are in January in the lowlands.

The absolute maximum temperature recorded in the Luzon Island was 42.2°C at Tuguegarao, located at the Cagayan Valley in Northern Luzon, on April 29, 1912. The absolute minimum of 3.0°C was recorded in Baguio in January, 1903. Table 4.1 shows the monthly and annual mean temperatures at 20 stations in the Luzon.

The monthly and annual mean relative humidities are also tabulated in Table 4.2 for these stations. Throughout the Luzon, the relative humidity is rather high. This condition is mainly a result of extensive evaporation from the seas surrounding the island, the rich vegetation, the moist air stream, and a large depth of rainfall.

The annual mean relative humidity is 80%, ranging from 76% at Cabanatuan to 87% at Casiguran. Most of the stations have high relative humidity from June to November and low one from December to May. Almost all the stations have monthly values of relative humidity greater than 70% and have more than 7 months of the year with relative humidity greater than 80%.

Since temperature differences in the Philippines are relatively slight and also rainfall differences are, on the contrary, important and decidedly variant due to the combined influence of topography and air stream direction, the classification of Philippine climate is based solely on rainfall characteristics, that is, the presence or absence of the dry season and maximum rain period. Four climate types chosen are:

Type I	:	Two pronounced seasons, dry from November to April and wet during the rest of the year.
Type II	:	No dry season with a so pronounced maximum rainfall from November to January.
Type III	:	Seasons not so pronounced, relatively dry from November to April and wet during the rest of the year.
Type IV	:	Rainfall more or less evenly distributed throughout the year.

In the Luzon Island, there exist all climate types abovementioned as shown in Fig. 4.1.

4.3 Data Collection on Meteorology and Hydrology

4.3.1 Rainfall and climatological data

(1) Rainfall data

In the Luzon Island, there exist more than 300 rain gauges managed by NPC, PAGASA, and NIA. Monthly and annual rainfall data and rainstorm data were collected for this study from the data books prepared by the authorities concerned, the existing reports on water resources projects, uncompiled original data, and others.

Out of monthly rainfall data collected, those of 177 rain gauges with more than 5 years recorded data were stored into computer VAX 11/750 owned by NPC. These data were reviewed and used for the estimation of rainfall-runoff relationship and for the preparation of an isohyetal map on an annual rainfall base.

As for rainstorm data, 1-day, 2-day, and 3-day annual maximum rainfall data at about 70 gauge sites, and hourly rainfall data in connection with the said annual maximum rainfalls at about 50 gauge sites were collected and filed in the computer. These rainstorm data were used for the estimation of design storm in the high flow analysis.

(2) Climatological data

The climatological data such as temperature, evaporation rate, and relative humidity have also been collected from the existing data books and reports.

Among them, pan-evaporation rates at 38 sites in the Luzon Island were analyzed to estimate the evaporation rate from the reservoir surface at each scheme. Data used are summarized in Table 4.3.

4.3.2 Hydrological data

(1) Monthly streamflow data

Monthly streamflow data of more than 300 gauging stations, distributed to major river basins in the Luzon Island, were collected. These gauging stations are managed by NPC, NWRC, and NIA. Monthly streamflow data are one of the most important data needed in order to determine the development scale of the hydropower schemes. Then the collection of data was intensively made.

Out of monthly streamflow data collected, those of 152 gauging stations with data more than 10 years were stored in the computer as well as rainfall data.

(2) Flood data

Flood data collected are those of observed maximum flood, probable floods of various return periods, and flood hydrograph.

The observed maximum floods of around 300 streamflow stations were collected from the data book titled "SURFACE WATER

SUPPLY BULLETIN" (No. 2 - No. 12 BPW), and the existing reports concerned. The floods with various probabilities were also collected at 162 gauging stations, referring to the reports titled "FRAME WORK PLAN" (Region I-V, 16 vols.) issued by NWRC. The annual maximum flood data at 131 gauge sites were also collected in order to update the said flood data.

These flood data were analyzed to estimate the design floods for river diversion works and spillway of the hydropower schemes.

(3) Sediment data

In this study, a reservoir sedimentation is estimated by the denudation rate in the catchment, the catchment area, and the life time of the scheme. Denudation rates actually applied to several existing projects and named project were collected and are shown in Table 4.4.

4.4 Mateorological Analysis

4.4.1 Isohyetal map

An isohyetal map for mean annual rainfall is prepared with monthly rainfall data of each rainfall station, as shown in Fig. 4.2. The modification and confirmation is made for the areas with isohyetal maps by previous studies, especially for the areas with more than 4,000 mm in annual rainfall.

The isohyetal map enables estimate of the long term mean value of annual rainfall on any point or in any area. For instance, if several isohyetal lines are included in an area, the mean annual rainfall in the area is calculated by the weighted average on the area.

In this way, the annual rainfall in the streamflow station and project catchments are calculated by planimetering the enclosed areas on the isohyetal map. The rainfalls at the project and streamflow catchments are used for the conversion of streamflow data from the station to the project site.

4.4.2 Evaporation

Evaporation from an open surface is estimated, since the evaporation is counted as losses in the reservoir simulation study. The evaporation rates applied to the simulation study are estimated using the pan-evaporation data collected from the existing reports on hydropower projects and meteorological stations as shown in Table 4.3.

It is said that the evaporation rate of an open surface is around 60% to 70% of the pan-evaporation rate. In this study, the pan coefficient is assumed to be 0.7 as shown in Fig. 4.3. The Figure shows the evaporation rate becomes smaller as the elevation becomes higher, the open surface evaporation rates are classified according to the elevation as tabulated below:

Elevation (m)	Evaporation Rate (mm/day)
less than 600	3.5
600 to 1,000	3.0
more than 1,000	2.5

The above values are applied to the reservoir simulation study throughout the year.

4.5 Scrutinization of Monthly Streamflow Data

The monthly streamflow data are scrutinized from various view points, and thereafter 18 streamflow key stations are selected as available stations for the power output calculation of each scheme.

4.5.1 Scrutinization of streamflow data

For evaluating the reliability of streamflow data, subsequent analysis is taken for all the streamflow stations filed in the computer;

(1) Detection of station site: The station sites are plotted on topographical maps of 1:250,000 scale using coordinates or location maps. The catchment at the site is planimetered on the maps.

(2) Calculation of annual rainfall depth: The mean annual rainfall depths are measured for the catchment at the stations using the isohyetal map prepared.

(3) Calculation of streamflow depth: The streamflow depth is calculated based on the mean discharge and the catchment.

(4) Annual runoff pattern: Annual runoff patterns are prepared as with the rainfall to check seasonal distribution of runoff. Generally, the runoff pattern closely follows the rainfall pattern, though the former is milder in variation due to the retention within the basin.

4.5.2 Selection of streamflow stations

Several criteria described below are set up in order to select the streamflow key stations used for the power output calculation.

(1) Identification of stations

The identification of station site is an indispensable item as the background information. The streamflow data can be significant only if the station site in the river system is correctly detected and the water divide is properly bounded.

(2) Observation time period of data

The time period of streamflow data observation is an important factor to contribute to the dependability of the data. A short observation period only discloses a limited characteristics of runoff events, and has a chance to give bias views on the power output calculation. Thus, the station with the data less than 10 years are eliminated from the selection list.

(3) Rainfall-runoff relationship

It is presumed that an inappropriate process on translation from water stage records to discharge data causes defects in the resultant power outputs. To rule out such possibility, cross-checking of streamflow data with rainfall data is made on the basis of annual rainfall loss. Considering the observation years of rainfall data not necessarily coincide with those of streamflow data, the stations with the apparently unreasonable value resulting from the average annual rainfall and streamflow depths are discarded.

(4) Other points considered

- The streamflow data collected are natural runoff data which are not regulated by a natural lake or a reservoir in the upstream reach, or not.
- Runoff and rainfall patterns are highly correlated, or not.
- The key stations are evenly distributed within the study area, or not.

Table 4.5 tabulates the selected key stations picked up on the basis of the criteria mentioned above. The drainage areas and the long term average rainfalls in the areas used for the conversion process of the key station data to the scheme sites are also included in the Table. Moreover, Fig. 4.4 illustrates the key station sites and the annual runoff pattern diagrams.

4.6 Hydrological Analysis

4.6.1 Low flow analysis

(1) Hydrological region

Hydrological regions in this study denote the areas where similar hydrological characters are shared. The determination of hydrological regions is made in order to convert the available streamflow data to the arbitrary point where the hydrological characteristics resemble, and is best achieved by scanning the river flow characteristics. However, the scarcity of available discharge data is defective for this method. The rainfall data, on the other hand, are more extensive in distribution throughout the Luzon Island. Considering that the discharge at a site is closely related with the rainfall in its catchment, the hydrological regions are determined on the basis of the rainfall data collected.

The rainfall condition in one area is characterized by the annual rainfall and its seasonal distribution. To analyze the similarity among areas, the seasonal rainfall patterns are examined. Indices taken here are monthly mean rainfall non-dimensionalized with the annual rainfall.

For all the rainfall stations stored in the computer, the non-dimensional monthly rainfalls are calculated and presented in the rainfall pattern diagrams. Based on the above data, areas sharing similar rainfall distributions are put together to compose hydrological regions. Ten hydrological regions, HR-A to HR-J, are established in the Luzon Island as illustrated in Fig.4.5. Figs. 4.6 to 4.11 show the annual distribution of rainfall in each region.

The annual distribution of rainfall in the Luzon Island is characterized into 4 types under the climate classification system described in Paragraph 4.2.2. According to this system, HR-B, -D, and -E belong to Type I; HR-H and -J to Type II; HR-C and -G to Type III; and HR-A, -F, and -I to Type IV, respectively.

(2) Discharge data at scheme sites

The estimate of discharge data at a scheme site starts with the selection of the streamflow key station to be applied to the site. Criteria for this process are:

(i) For a scheme, it is checked in the first place if there is a key station at the scheme site, or not. If there is, it is used.

(ii) If the above data are not available, the key station in the same river basin is used. If there are several of such data, those in the nearest reach are used.

(iii) If the above data are not available, the key station within the same hydrological region is used. If there are several of such data, those in the nearest basin area are used.

(iv) If such data are not available, the key station in other region which shares hydrological similarity are used.

The hydrological regions except HR-J are presented with one or more key stations as illustrated in Fig. 4.5. Thus, the key station to be applied to each scheme site is decided by steps (i) to (iii) stated above. In the hydrological region HR-J with no key station, the station of ID. 45001NW501 in HR-H adjacent to HR-J is converted across the hydrological region.

(3) Flow duration and storage-draft curves

The preparation of flow duration and storage-draft curves on each streamflow key station are made using monthly streamflow data. The flow duration curve is used to determine the development scale of the run-of-river type scheme, while the storage-draft curve is for the reservoir type scheme.

The flow duration curve is a figure to express discharges against their excess rates by arranging the monthly streamflow data in the numerical descending order. Fig. 4.12 shows one of the typical flow duration curves. The flow duration curves prepared are expressed in the non-dimensional form; the ordinate is denominated by mean discharge. The flow duration curve at the scheme site is obtained by multiplying the mean discharge at the scheme site.

The storage-draft curve is a diagram to show the relationship between the draft discharge and the required active storage volume in the reservoir. Figure 4.12 also shows one of the typical storage-draft curves. The non-dimensionalization of the curve is made by annual inflow volume in ordinate and mean discharge in abscissa, respectively. The required active storage volume on the curve is the volume required for the drought year with the recurrence interval of 50 years.

4.6.2 High flow analysis -I: on 1st screening stage

The objective of the high flow analysis is to estimate the design floods for spillway and river diversion works for the scheme under the first screening work. For this purpose, 200-year flood multiply by 1.2 for spillway and 25-year flood for river diversion works are employed as the criteria for the design floods on condition that neither flood is subjected to the retardation effect due to the flood discharge impoundment at a damsite, in that a fill type dam is adopted on this screening stage.

Since more than 100 reservoir type schemes are raised up on this stage, a concept of zonal design flood curve is introduced and the study area was divided into 7 zones, as shown in Fig 4.13, from the standpoint of flood discharge so that processing of many schemes can be done at a time. The procedures and the results are discussed in the following sections.

(1) Zone division of study area

First, the observed maximum flood of about 300 stations within the whole Luzon Island were plotted against drainage area on the basis of specific discharge which means a peak flood discharge per unit area. Then, reviewing the distribution of the plotted discharge points and keeping the watersheds of major river systems in mind, the study area was divided into 7 zones for zonal analyses of design floods.

(2) Design flood curves for spillway

For estimation of the spillway design flood curves, 200-year floods at 118 streamflow stations were used excluding the stations located on the downstream river courses in the plain areas, for instance, the flat agricultural lands such as Central Cagayan Valley and Central Luzon Plain in the Pampanga and Agno river basins.

After plotting these floods against drainage area, the envelope curves of 200-year floods and the design flood curves with 20% allowance in discharge were drawn by zone as illustrated in Fig. 4.14. To supplement the scarcity of flood data, the design flood discharges adopted in the previous studies in the Luzon Island were also referred to on the Figure.

The envelope curve of maximum floods in Taiwan, Japan, Korea, Philippines, and Viet-Nam prepared by ECAFE is presented together for comparison.

(3) Design flood curves for diversion works

The regression lines are employed to represent the zonal 25-year floods corresponding to drainage area (Fig. 4.14). Table 4.6 tabulates the zonal design flood curves generated according to the procedures mentioned above.

4.6.3 High flow analysis - II: on 2nd screening stage

The objective of the high flow analysis on the second screening stage is to estimate the design flood hydrographs of spillway and river diversion works for 20 reservoir type schemes which passed the first screening. The scheme are shown in Table 4.7 and Fig. 4.15.

In the second stage analysis, the concept of P.M.P. (Probable Maximum Precipitation) and P.M.F. (Probable Maximum Flood) Methods were adopted.

Since, there is little information required for the said estimate, practical assumptions were made, especially in synthesization of design storm.

(1) Spillway design storms

(a) Storm data

Spillway design storms were estimated by maximizing and transposing to a scheme site a rainstorm on the basis of a maximum depth-duration curve, depicted in Fig. 4.16 which is obtained by enveloping the observed maximum point rainfall in the Philippines and controlled by rainfalls at Baguio.

The curve gives priority to the data with 10 hours or more in rainfall duration. In this study, the curve is adopted considering there is every possibility that shorter duration rainfalls at ungauged sites might be higher than the observed maximum.

(b) Storm maximization

For a storm maximization, a 10% increase above the envelope curve was assumed, that is, storm maximization factor of 1.10 which compares favorably with similar adjustments based on dew point for Gulf Coast hurricanes in the United States. A 10% increase was also assumed in a similar study for the Angat Project.

(c) Storm transposition

The maximized rainstorm at Baguio was transposed to each scheme watershed by multiplying it by the following adjustment factor.

Adjustment Factor =Rs/Ro

where, Rs : maximum point mean monthly rainfall during heavy rainfall period in scheme watershed

Ro : mean monthly rainfall during heavy rainfall period (at Baguio, Ro = 750 mm)

The adjustment factor for each watershed is tabulated in Table 4.8. Ro of 750 mm was obtained from 82-year monthly rainfall data obtained from 1902 to 1984. Rs is obtained based on the actual monthly data at the rain gauge located in or near the scheme watershed.

(d) Design storm

The transposed point rainstorms were reduced to average rainstorms over the individual watersheds by assuming reduction factors shown in Fig. 4.17. The factors give the conservative results to spillway design storms, since the Figure is prepared by using both the areal reduction factors for 100-year flood in Pampanga river basin and those in Magat river basin.

The most critical temporal pattern of spillway design storm would be for rainfall intensities to increase to a maximum near the end of the storm. Such an increasing pattern of intensities was followed in the rearrangement of rainfall increments of the design storm.

Fig. 4.18, illustrating hourly rainfall patterns of heavy storms in connection with annual maximum 1-day rain observed in the Luzon, indicates that annual maximum 1-day rains have been actually recorded at several sites on the third day during one storm duration. It is reported in "Spillway Design Flood" (BPW, 1964) that in the 100-year design storm for Pampanga river basin, the maximum rainfall (in average daily rainfall) also occurred in the third day and, furthermore that the data from hurricanes in the southeastern U.S. also indicate the maximum 24-hour rainfall will most likely occur not later than the third day of the storm.

Thus, assuming the storm duration of 108 hours (4.5 days), the design storm as re-arranged, increases up to afternoon of the third day from the beginning of storm and decreases gradually to the end of the storm as exemplified in Fig 4.19.

Since no actual record on the rainfall loss was available, the following minimum loss rates for the Central Luzon were used to compute the effective rainfalls, assuming conservatively that the antecedent soil condition is well saturated.

Initial loss : 25m mm
Retention loss : 1.5 mm/hr

Use of the said rates resulted in flood runoff coefficients of about 0.9.

(2) Spillway design floods

(a) Flood data

In the Luzon Island, runoff observation has been made at more than 300 gauging stations and annual maximum discharge data have been collected at 131 gauge sites for this study. However, little information concerning the actual flood hydrographs is available, which are indispensable as the basic data to develop the spillway design flood. Thus, the subsequent flood hydrographs were collected for this study, referring to the previous study reports.

River System	Station	Data
Abra	Tapayen	Dimensionless Hydrograph
Abulog	Sisiritan	July 24, 1977 Flood (Q=5,651 m^3/s)
Cagayan	Magat	Dimensionless Hydrograph
Agos	Banaoang	Nov. 20, 1966 Flood (Q=6,070 m^3/s)
		Sep. 29, 1968 Flood (Q=1,210 m^3/s)
		Oct. 14, 1970 Flood (Q=2,228 m^3/s)

(b) Unit graph

Applying a dimensionless hydrograph method for the estimate of the hydrographs at the above-mentioned stations and for transposition to the scheme sites in the same basin, the collected hydrographs are converted to the dimensionless hydrographs by river system, as shown in Table 4.9 and in Fig. 4.20.

Since no actual flood hydrograph is available in Marikina and Labo basins, the dimensionless hydrograph for the Agos basin was used for Wawa and Bosigon schemes which is nearest to both.

In the derivation of unit hydrograph at the scheme site, the method requires two factors on the scheme watershed, that is, lag time and drainage area.

The drainage area was planimetered, using topographic maps of 1:50,000 scale.

On the other hand, since no rainfall information corresponding to the flood hydrographs collected was available, the basin lag time was calculated by using the lag curve expressed by the following equation (modified Synder's lag equation):

$$Lag = C \times \{L \times Lca/(Sst)^{1/2}\}^{n}$$

where,

Lag : basin lag time (hrs)

L : mainstream length from outlet to watershed (km)

Lca : mainstream length from outlet to watershed centroid (km)

Sst : overall slope of mainstream

The constant of C=1.188, and n=0.2715 were obtained for this study on the basis of the lag curve for Central Luzon basin

(Ref. 43) and that of C=1.324, and n=0.259 for the Philippines (Ref. 39). The difference between the two is negligibly small.

Table 4.10 shows basin factors for each scheme and Fig. 4.21 exemplifies the unit hydrograph of 2 hours - 1 mm at Banaoang site.

(c) Synthetic flood hydrograph

To begin with, the flood hydrograph under the present watershed condition of without dam was developed by the summation of the following two component inflow hydrographs:

1) Direct flood runoff from the watershed
2) Inflow hydrograph of base flow

The direct flood runoffs for component 1) were derived by means of the unit hydrograph method using the foregoing spillway design storms and unit hydrograph. The base flows for component 2) were estimated scheme by scheme as the average rates of low flow at the site during the flood season, referring to daily discharge data at least 5 years of the nearest gauge (Ref: Table 4.10).

The resulting hydrographs, non-dimensionalized by the peak discharge, are shown in Fig. 4.22.

For the verification of the estimated results, the subsequent comparisons were made on a specific discharge base (Ref: Fig. 4.23).

i) It was found out that the flood magnitudes within the same river basin are more or less same and the greater magnitude occurs in the basin with the higher annual rainfall, from the view point of the Creager's coefficient of C, related to the maximum floods envelope curve in the Luzon (Ref.: Fig. 4.24).

ii) Compared with the envelope curve of maximum floods in Taiwan, Japan, Korea, Viet-nam, and the Philippines where typhoons strike most often (Ref. 42), the specific discharges are plotted around the curve with slight deviation.

iii) The C value of each scheme is within the same range (9 to 16) as that of most of the spillway design floods used in the existing and named projects in the Luzon Island.

Judging from the discussions mentioned above, it is considered that the estimated results and some assumption applied are satisfactorily acceptable.

(d) Spillway design floods

The previous flood hydrographs were developed under the present condition of the scheme watershed without dam. the concentration time of floods will, however, be more or less changed due to the impoundment of the reservoir. In this study, some reservoirs out of 19 schemes will occupy more than 10% of the surface area at the full supply level to the total drainage areas at the scheme site.

Therefore, the flood hydrograph into the reservoir for the design of spillway capacity was also synthesized, in view of the change in watershed condition due to impoundment, by the summation of the following three component inflow hydrographs:

1) Hydrograph of direct flood runoff from the watershed above reservoir head of net drainage area.

2) Hydrograph of inflow resulting from precipitation over the reservoir area.

3) Base flow hydrograph into the reservoir.

The synthetic hydrographs in the case of with dam are illustrated in Fig. 4.22 together with those in the case of without dam. As for 7 schemes; namely, Supo, Eteb, Sisiritan, Sadanga, Dabba, Daraitan, and Wawa, the flood hydrograph in case of with dam is the same as that in case of without dam since it is presumed that the change in watershed condition due to impoundment is negligible.

Table 4.11 tabulates the design floods of both cases. The floods in the case of with dam were used for the design of spillway.

In case that one or more dams exist in the upstream of the scheme site, the flood hydrograph at the site was developed adding the discharge spilled out from the upstream dam to the inflow hydrograph originative from the remaining basin of the scheme.

(3) Diversion works design flood

The criteria applied for the design flood for river diversion works are:

- Fill Type Dam	25-year flood
- Concrete Dam	2-year flood

For the estimation of the said flood, the annual maximum discharge data at the nearest stream gauge to each scheme site in the same river system were subjected to frequency analysis, assuming a Log-Pearson Type III distribution which has been recommended by the US Water Resource Council in Bulletin No. 37 (March, 1976) and has been applied to a lot of water resources projects in the Philippines.

The 25-year or 10-year flood at the gauge was transferred to the scheme site through the Creager's coefficient corresponding to the flood: the coefficient was derived on the basis of the Creager's Curve for the Luzon Island as shown in Fig. 6.21. The temporal pattern of the design flood is presumed to be the same as that of the PMF in case of without dam.

4.6.4 Sediment yield analysis

Sediment yield analysis was made for estimating sediments deposited in the reservoir for the physical life of a hydropower scheme. The sediment load into the reservoir is usually estimated by streamflow data and the sediment discharge rating curve established at the damsite. However, the sediment into the reservoir is estimated as products of the denudation rate, drainage area, and the physical life of a scheme, since it is scarce for the schemes raised up in this study that the sediment discharge rating curve is available.

The denudation rate were collected from the existing reports on hydropower project in the Luzon Island, as shown in Table 4.4. For estimation of the denudation rate for all of the reservoir type project site, the values of the Ambuklao, Binga, and San Roque were eliminated because of higher rate due to mine tailing in their catchments. The average denudation rate of 1.4 mm/year was employed in this study.

V. SOCIO-ECONOMY

5.1 General Background

The economic depressions which abruptly enveloped the Philippines in late 1983 through the inability to meet external debt repayment obligations and which led to the cessation of most forms of foreign credit, has involved a sharp change to the nation's standard of living as well as the pace and direction of their development. As in the case of other middle-income developing countries beset with external debt repayment problems, the Philippines' prospective course of development is intensely affected by the outcome of balance of competitive needs between foreign credit requirements for development and debt repayment obligations.

Out of the characteristic industrial structure of the country, the precipitate decline in the national economy is reflected in a negative real growth rate of Gross National Product (GNP) of 6.8% in 1984 and a further downdrift of 3.8% for 1985. Inflation, largely under the impetus of monetary policies and currency devaluations, registered a postwar record-breaking increase of 48.9% in 1984, which, however, was successfully reduced to a rise of 17.8% in 1985, mainly due to the pursuance of a much tighter monetary policy and a setback of oil price.

The advent of the new Government in early 1986 presents an opportunity for taking firm and effective measures to carry through the structural reform process. The Government has issued a number of policy statements indicating its attitude toward the management of the economy, while a more comprehensive new economic plan is under preparation.

The Government emphasizes to reduce the previous policy bias against agriculture sector not only in terms of the monopolies and privileges but also in terms of the cost of tariff protection adding to the input cost for the sector. And it is also contemplating to adopt a concept of nucleus estates to promote development into non-traditional crops. In the trade and industry sector, the major issue is the programs of diversification of manufacturing industry and import liberalization to reduce the cost of items to consumers and to promote higher domestic productivity through competitive markets. The Government has announced the phased removal of quantitative restrictions on imports and temporary tariffs in relate with the most prevailing domestic industries will be applied so as to progressively phase out over a five-years period.

Policy pronouncements have generally indicated a desire to see an economy strongly based upon free enterprise principles. Recovery prospects appear to lie in creating a reasonably neutral policy environment free from privileges and other distortions, which in turn will encourage higher domestic and foreign private investments in the country with a more equitable distribution of income. A comprehensive National Development Plan for 1987-1991 has not been released yet with exception of their development target in the form of Gross Domestic Product (GDP) and Gross Regional Domestic Product (GRDP) (Ref.:Table 5.3).

5.2 Economic Performance

Our study on economic indices of the national/regional breakdown at historical level are shown in Tables 5.1 and 5.2.

The Philippines' external debt recession in late 1983 signalled the end to the country's uninterrupted economic growth in the postwar era.

For the first and second halves of 1970s, it had marked significant economic development as 6.03% and 6.2% respectively in compound annual real growth rates of GDP. In sharp contrast, however, their extensive growth was downed to -0.49% for the next 5 years since 1980, under the influence of the worldwide stagnation that followed the second oil shock. The same but far more sensitive fluctuation with massive volumes had been appeared in Luzon area, particularly in National Capital Region (NCR).

Among sectoral breakdown, service sector shares a constant top of around 40% followed by industry and then agriculture. A steady growing and sudden drop in industry sector have been closely linked to the country's economic performance. Furthermore, because of majority on scale occupied by Luzon and NCR in this field, their deterioration has worse affected to the national sum. Proportionally some slow down trend in expansion of agriculture sector has been observed, however, still remained as a mainstay in the national economy with fulfillment of self-sufficiency of the food crops.

Under the succession of such economic tendencies, the recovery frame is released by the Government to target the economic growth for 1987-1991 as per Table 5-3. Thereupon, it aims at a high real GDP growth of 6.29% per annum throughout the period, centering around construction, public utilities (electricity, gas and water) and manufacturing as much higher annual growth of 9.21%, 7.44% and 6.80% respectively. Similar to the past, the growing pace of sectoral development is set forth high in industry, sustained in service and low in agriculture. In the meantime, the economic recovery in Luzon and NCR will be rather slow than the national average out of their serious damages in the past.

With diffusion of family plan, the population growth has been gradually paced down. Even though, the net personal income average will be expected to return to the empirical highest level until 1991.

5.3 Power Expansion Program

The power development program of National Power Corporation (NPC) aims for a broader distribution and greater availability of usable energy throughout the country, possibly for industrial recovery and rural development. The envisioned energy plan is also certainly expected to have a favorable impact on the employment situation and trade balance position of the country.

Even after releasing of the latest Power Development Program 1985-1995 on May 30, 1986, further studies and determinations in success of basic data collections have been made by NPC themselves. A stack of such conceivable reviewing of the power program are made from electricity consumption forecast based on the sales projections for each of the seven grids, namely Luzon, Cebu, Negros, Leyte, Panay, Bohol and Mindanao, with due reference and adjustment of assumptions on GRDPs and regional economic performances. As for the regional characteristics, NPC applies correlation and extrapolation techniques on classified incentive customers, historical and potential households energized.

Similar reference on GDP and GRDP have been also studied. Tracing the historical development, the projection are investigated along with a context of National Economic and Development Authority (NEDA) internal paper released. Whereas, introduced are reasonable comments in respect of average GDP performance in the case of middle income oil-importing developing country, set forth by The World Bank (Ref. 55) and United Nations (Ref. 52) as well as authoritative think tank.

The comparison of these power generation forecast and GDP/GRDP projection upto 2005 in the whole country and Luzon is listed on Tables 5.4 and 5.5, and of which final issue is hereby summarized as follow.

Compound Annual Growth Rates of
Power Generation and GDP, GRDDP-Luzon 1970-2005

	PHILIPPINES			LUZON (6 Regions)		
	Power Generation	GDP[1/]		Power Generation	GRDP[1/]	
Year/Scenario:	(1)	Low (2)	High (3)	(1)	Low (2)	High (3)
1970/75	7.2[2/]	6.0	6.0	7.0	6.5	6.5
1975/80	9.4	6.3	6.3	7.7	6.3	6.3
1980/85	4.5	-0.5	-0.5	2.0	-0.6	-0.6
1985/90	5.5	3.6	5.0	4.4	3.9	4.6
1990/95	5.6	5.0	5.9	5.4	5.0	6.0
1995/00	5.2	5.0	4.2	5.4	5.0	4.5
2000/05	5.1	5.0	3.9	5.4	5.0	4.2
1970/80	8.3	6.2	6.2	7.3	6.4	6.4
1980/90	5.0	1.5	2.2	3.2	1.6	2.0
1990/00	5.4	5.0	5.1	5.4	5.0	5.2

Notes : 1/ : at 1972 price level
2/ : growth rate per annum (%)
(1) : NPC projection, estimated in November 1986
(2) : NPC projection, estimated in June 1986
(3) : NEDA projection 1987-1991 with extension under extrapolation

Source : NPC, NEDA and NCSO

Both of the cases in Philippines and Luzon, the growing trend of power generation is marked between low and high growth of GDP/GRDP in 1985/1990 and 1990/1995, and more higher after 1995. As far as 10 years term, the prospective power expansion is succeedingly higher than the economic growth throughout the decades. Thus, from socio-economic view point, the said power expansion program is appropriately advancing than the national or regional development so as to enhance the industrial rationalization as a proper infrastructure.

VI. ELECTRIC POWER SUPPLY AND POWER DEMAND

6.1 Organization of Power Industries

The nationwide electric power supply is entrusted to the state-owned National Power Corporation (NPC) which provides power generation, transmission and distribution to the Utilities, Non-utilities such as public facilities, military bases, etc. and industries, and then entrusted to the Utilities which provide power distribution services to the end users. The Utilities consist of the electric cooperatives owned by the provincial membership and private utilities owned by the private firms.

NPC is also responsible to develop the power generating facilities more than 5 MW unit and to establish the transmission grids in the nation. For the development of hydropower projects, however, the responsibilities for the development of the resources has been tentatively agreed to be as follows in the Minutes of the Meeting of the Committees on Micro-Hydro Power Project held on Jan. 20, 1977:

Above	20	MW : by NPC
Below	5	MW : by NEA
Between	5-20	MW : by NPC or NEA depending upon the circumstances

Figs. 6.1 and 6.2 show the organization of the Philippine power industry and NPC, respectively.

The country is divided into 3 regions' Luzon, Visayas and Mindanao Power Grid, and the Luzon Power Grid is futher divided into 7 areas for the administration of the electric power supply. The boundary of the NPC administrative areas is shown on Fig. 6.3.

6.2 Existing Power Supply System

Most major load centers in the nation have been interconnected by the high voltage transmission lines above 69 kV and formed the Luzon Power Grid, Visayas Power Grid which consists of 5 sub-grids and Mindanao Power Grid. The existing transmission lines owned and operated by NPC are summarized in the following table.

(Unit: Circuit - Kilometer)

Line Voltage	Luzon	Visayas	Mindanao	Total
230kV	3,484	-	-	3,484
138kV	-	532	1,804	2,336
115kV	484	-	-	484
69kV	2,705	812	1,256	4,773
69kV below	528	104	100	732

In addition to the above-mentioned transmission line, the first extra high voltage (500kV) transmission lines of 327 km long have been constructing between the San Jose Substation near Metro Manila and the Naga Substaion which is located near the geothermal fields in Bicol, via the Kalayaan pumped storage power station.

The substaion capacities by voltage of the existing substations are summarized as follows:

(Unit: MVA)

Primary Voltage	Luzon	Visayas	Mindanao	Total
230kV	7,278	-	-	7,278
138kV	-	1,016	1,525	2,541
155kV	1,927	-	-	1,927
69kV	666	241	424	1,331
69kV below	200	22	8	230

Fig. 6.4 presents the existing power supply system of NPC on the Luzon mainland.

The installed capacity of the existing generating plants is summarized by type as follow and a detailed breakdown for the Luzon Power Grid is given in Table 6.1.

(Unit: MW)

Plant Type	Luzon	Visayas	Mindanao	Total
Hydropower	1,226 1/	2	181	1,409
Oil-fired thermal	1,925	256	-	2,181
Coal-fired thermal	300	50	-	350
Geothermal	660	234	-	894
Diesel	-	-	726	726
Total:	4,111	542	907	5,560

Remark: 1/: Including the Kalayaan pumped storage power plants (2 x 150 MW)

The above table shows that the power plants of 74% of the total is concentrated on Luzon which has 54% of the population and 47% of its total land area.

Annual energy production by the NPC's plants in 1985 is summarized in the following table.

(Unit: GWh)

Plant Type	Luzon	Visayas	Mindanao	Total
Hydropower	2,869	7	2,638	5,514
Oil-fired thermal	5,825	561	-	6,386
Coal-fired thermal	1,471	114	-	1,585
Geotheraml	4,284	661	-	4,945
Diesel	-	-	327	327
Total:	14,449	1,343	2,965	18,757

6.3 Power Market

6.3.1 Present power demand in Luzon

In 1985, the total energy generated in the Luzon Power Grid was recorded at 14,449 GWh, which had decreased by 1.4% against that in 1984, and 13,126 GWh was sold to the Utilities, Non-utilities such as public facilities, military bases, etc. and industries. The difference of the above both values, 1,323 GWh (9.1% of the generated energy) consists of station use and transmission line losses of the Grid.

The electric energy supplied to the Utilities was further sold through the distribution system of the each utility to the end users.

The breakdown of the sold energy is as follows:

(Unit: GWh)

Customers	Northern Area	Southern Area	Metro Manila	Total
Utilities	1,396	480	9,789	11,665
Non-utilities	412	33	-	445
Industries	918	98	-	1,016
Total:	2,726	611	9,789	13,126[1/]

Source: Monthly Operational Records from Dec. 26, 1984 to Dec. 25, 1985

Remark: 1/: Total sold energy in the Annual Report was amounted at 13,126 GWh.

Table 6.2 shows the historical record of NPC's energy production, sales and coincident peak at the generating ends.

The number of NPC customers in Luzon Power Grid as of Dec. 1985 is shown in the following table.

Customers	Northern Area	Southern Area	Metro Manila	Total
Utilities	49	19	1	69
Non-utilities	22	15	-	37
Industries	41	19	-	60
Total:	112	53	1	166

Source: Monthly Operational Records, December 1985

All customers including public facilities, industries, etc. in Metro Manila area are served through the Meralco's distribution system.

The electrification ratio (the ratio of the electrified households to the total households) in Luzon as of 1984 is amounted to be 71% on the basis of the actual connected households of 3,334,876. The breakdown by region is presented in Table 6.3.

6.3.2 Load curve

The typical load curves and load duration curves for one week from Apr. 6 to Apr. 12, 1986 of the Luzon Power Grid are shown on Fig. 6.5. It shows that the pattern of the load curves is going through the process of shifting its peak from night time to day time. The daily load with night time peak, usually, is shared with a considerable large residential demand and small industrial and commercial demands. In accompany with the industrial and commercial demands, the peak will shift to day time. The both peak demands in day and night time from Jan. to Dec., 1986 are shown in Table 6.4. It shows that the difference of the both peak demands is very small, i.e. only 5% in averaged peak, and the day time peaks of 54 days (15%) exceed the night time ones.

The annual load factor in 1985 of the Luzon Power Grid is calculated to be 71% at the generating ends on the basis of annual energy production of 14,449 GWh and a coincident maximum system peak of 2,311 MW. The annual energy generated by NPC's plants in 1985 was 14,449 GWh, including additional energy generation of 525 GWh for pumping-up water for the Kalayaan pumped storage power station. It means that the actual load factor of the Grid has been improved from 69% to 71% due to the operation of the Kalayaan power station.

6.3.3 Historical trends of power market in Luzon

In accompany with the increase of economical activities of the nation and of living level of peoples, the power market has also expanded with an annual increase rate higher than that of the GDP or GRDP. The detail of the historical trends of GDP and NPC's energy sales are shown in Tables 6.5 and 6.6, respectively.

Averaged annual increase rates of the both GDP and energy sales are summarized in the following table.

(Unit: % p.a)

	GDP/GRDP		Energy Sales in Luzon		
	Philippine	Luzon	Total	Meralco	Provincials
1970-75	6.03	7.41[1/]	7.26	5.13	15.76
1975-80	6.28	6.35	7.21	7.04	7.72
1980-85	1.11	0.70	1.55	1.47	1.78
1970-83	5.32	5.82[2/]	6.62	5.83	9.67
1983/84	-4.50	-6.88	-4.77	-6.52	0.61
1984/85	2.46	2.09	-0.82	-0.59	-0.88
1970-85	4.45	4.59[3/]	5.30(1.15)[4/]	4.52(0.98)	8.27(1.80)

Remarks: 1/: 1971 to 1975
2/: 1971 to 1983
3/: 1971 to 1985
4/: Elasticity against increase rate of GRDP in Luzon

The coefficients of correlation between the GRDP of Luzon and energy sales are as follows:

Total Luzon	0.991
Sales to Meralco	0.988
Sales to Provincials	0.985

6.3.4 Electric tariffs

The power rate or tariff schedule of Meralco is presented in Table 6.7. It is characterized by a lower rate for residential customers which constitute a large portion of the total customers and higher rate for industrial sector. The average tariff has been gradually increased as shown below:

Average Power Rate, Peso/kWh (Meralco)

Year	Paid to NPC	Charged to consumer
1978	0.2000	0.3094
1980	0.3599	0.5098
1982	0.4842	0.6789
1984	0.9686	1.3041
1985	1.2101	1.7915

6.4 Power Development Program

6.4.1 Power demand projection

Power demand projection is made and reviewed every year by NPC referring to the current NEDA's economic development plan and also a past trend of energy sales. The latest one, which was prepared on November 1986 by NPC, seems reasonable compared with various economic indices such as annual growth rates of population, GRDP per capita, etc. However, some modification of power demand projection may be necessary in the future, taking the change of economic situation of this country into consideration, and it is described more in detail in Chapter XIV. Latest power demand projection for Luzon Island is shown in Table 6.8.

6.4.2 Development program

In compliance with the above-mentioned power demand projection, NPC provided a Short-Medium Term Development Program up to 1995 in May 1986, on the basis of the basic planning criteria shown in Table 6.9. Detail of the power expansion program of Luzon Grid is presented on Table 6.10, and planned power and energy balance of the Luzon Grid for the planning horizon is presented in Table 6.11 and Fig. 6.6.

6.4.3 Retirement of plants

Retirement schedule of the existing oil-fired thermal plants are set as presented in Table 6.12, on the basis of its planned life time of 30 years.

All of above-mentioned retirement will be occurred after 1995, during study horizon of this Hydropower Potential Study. Those retirement of the oil-fired thermal plants are taken in the study as scheduled by NPC.

The first unit of the geothermal plant was put into operation in 1979 and coal-fired thermal plant in 1984. No retirement, therefore, is needed during the study horizon up to 2005.

VII. IDENTIFICATION OF HYDROPOWER POTENTIAL SITES

7.1 General

Previous studies so far conducted by NPC, NWRC, NIA and other agencies have identified approximately 220 schemes of varying study grades in the Luzon Island.

In addition to these previously identified schemes, this study attempts to identify newly other hydropower potential sites especially in river basins where the previous studies are absent or scarce. The main objectives of this study are to assess the hydropower potential on individual scheme basis and secondly to sieve attractive schemes worth for future development among those identified schemes.

The identification of hydropower potential sites (herein called "map study") was carried out on contoured topographic maps of 1:50,000 scale. Topographic maps of 1:250,000 scale were also used for reference.

7.2 Type of Power Development

The type of power development assumed in this map study is broadly classified into two types, i.e. (1) Reservoir type development and (2) Run-of-river type development. Each type has several variations as listed below:

(1) Reservoir type development

- A1. Single dam scheme
- A2. Dam + waterway scheme
- A3. Reservoir scheme with saddle dam(s)
- A4. Reservoir scheme with inter-basin water transfer intake(s)
- A5. Reservoir scheme with both saddle dam(s) and inter-basin water transfer intake(s)

A6. Scheme with natural lake as a reservoir (lake outlet type)

(2) Run-of-river type development

B1. Run-of-river scheme with single intake

B2. Run-of-river scheme with inter-basin water transfer intake(s)

B3. Run-of-river scheme with regulating pondage

As a result of map study, development types identified are A1, A2, A4, and B3 among the above types.

7.3 Method and Criteria for Map Study

Map study was conducted by a group of civil engineers and a geologist including NPC working group. In order to attain a consistent map study by group members, an uniform criteria of the map study had been established. The followings are the criteria and guideline applied to the map study. As for named hydropower potential sites identified in "SURVEY/INVENTORY ON WATER IMPOUNDING RESERVOIRS" issued by NWRC, the same criteria and guideline were applied in this study, as technical informations obtained from that report were not enough.

7.3.1 Selection/Identification of site

The selection/identification of sites should consider various factors which were varying at each location and river stretch. Principal factors given are;

(1) Dam (Reservoir) scheme:

The site is selected at a location in narrow gorge or at a place of closed topography with steep sloped banks. The gradient of river profile upstream of the site is to be reasonably gentle, preferably with an open plane topography in upper area to have a larger reservoir pocket.

(2) Dam + waterway scheme:

This scheme can be proposed in river streches where both the run-of-river and reservoir type schemes are simultaneously conceived, in particular, in the folloing cases:

(a) topography of the proposed intake site is suitable for construction of a medium to high dam.

(b) steep river gradient in stretch downstream from the dam.

(3) Inter-basin(river) water transfer scheme:

Inter-basin(river) water transfer plan is considered basically in the following cases:

(a) catchment of the adjacent basin is comparatively large (say more than 25% of the main basin).

(b) length of connecting tunnel is comparatively short.

(4) Run-of river scheme:

The scheme consists of a diversion dam (weir) and a tunnel waterway to take water to a power station at a lower elevation. The scheme is conceived in the river stretches of steep gradient (basically steeper than 1/60) or in places where the equivalent head is made available.

7.3.2 Power scale

At the beginning of the study, the Study Team and NPC discussed and agreed that all conceivable schemes larger than 5 MW in capacity should be identified in whole Luzon Island.

7.3.3 Preliminary estimation of power output

During the map study, potential power output of the site under examination had estimated on an approximate basis, especially in relation to the criterion set out in Paragraph 7.3.2 above. For this purpose, catchment area, approximate available head, and annual rainfall at each site were checked and used. The exploitable discharge was approximately estimated as a parameter of annual rainfall.

7.3.4 General development plan

After the identification of hydropower potential sites which are estimated to have power output more than 5 MW, preliminary general plan was prepared for each scheme and plotted directly on the topographic maps of 1:50,000 scale. This work was made for all the schemes identified from the map study.

In many cases, a few alternative ideas were conceivable in formulating the development plan of a scheme (e.g. alternative dam axis, alternative power house locations, two low-head waterway schemes instead of one high head waterway scheme). At this phase of the study, only a selected plan most suitable to the river stretch under examination was chosen and listed for estimating the hydropower potential at each site.

General development plan plotted on the maps comprises;

- axis of dam/weir
- location of surge tank
- location of power station
- waterway route

In addition to the preparaion of power scheme plan above, the routes of access road and tansmission line were also examined.

Major items of the criteria applied to this general planning are described in Table 7.1.

7.4 Geological Assessment of Schemes

7.4.1 Method of geological assessment

Engineering geological assessment of the identified sites for dam, intake weir, power house, waterway, impounidng and regulating resorvoir have been carried out by means of field survey and geological map study. The field visits involoved only surface inspections and no exploratory borings have been carried out. Fig 7.1 shows the location of each identified scheme site.

Aerial photographs were also available for the four river basins, namely, Abulog, Abra, Agos prepared by NPC, and Casecnan basin prepared by NIA (Ref.: Fig 3.3).

7.4.2 Criteria for assessment

Geological assessment is mainly carried out on the following particulars:

- rock type formation, age and structure of the scheme site;
- rock quality, permeability and overburden of dam site;
- rock quality in relation to tunneling operations;
- rock quality and overburden of power house foundations;
- permeability, slope stability and sedimentation of reservoir; and
- characteristics and location of construction materials.

The description of each item is given as follows:

(1) Rock type, age and structure

Rock types which are used for this assessment, are given below.

Rock Classification	Rock Name
<u>Igneous Rocks</u>	
- Plutonic or Intrusive Rocks	Granite, Diorite, Granodiorite, Quartzdiorite, Gabbro, etc.
- Hypabyssal Rocks	Quartz porphyry, Porphyrite, Diabase etc.
- Volcanic or Extrusive Rocks	Rhyolite, Andesite, Basalt, Dacite etc.
<u>Sedimentary Rocks</u>	
- Clastic Rocks	Mudstone, Sandstone, Graywacke, Conglomerate, Shale etc.
- Pyroclastic Rocks	Tuff, Lapilli tuff, Tuff breccia Agglomerate etc.
- Chemical Sedimentary Rocks	Chert, Limestone, Gypsum, Dolomite etc
- Organic Sedimentary Rocks	Coral limestone, Chalk, Coal etc.
<u>Metamorphic Rocks</u>	
- Regional Metamorphic Rocks	Gneiss, Schists etc.
- Contact Metamorphic Rocks	Hornfels, Marble etc.
- Dynamic Metamorphic Rocks	Mylonite etc.

The geological age and structure is based on the geological time scale and stratigraphical column of BMG (1981) Geology and Mineral Resources of the Philippines, as shown in Table 3.4

(2) Rock quality

From the viewpoint of engineering geology, quality of rocks and ground are classified by four classes in regard to lithology of rock, freshness and hardness as follows:

Class	Description	Typical rocks and ground	Easimated value of shearing Strength
Very hard	Very sound, very high strength, well compacted and fresh	Igneous rock, Paleocene - Cretaceous metavolcanics and metasediments	20 kg/cm^2 or more
Hard	Sound, high strength, massive and compacted	Eocene - Early Miocene sedimentary and pyroclastic rocks, fresh limestone	10 to 20 kg/cm^2
Rather hard	Slightly sound, medium to low strength, less compacted, slightly weathered	Late Miocene - Pliocene sedimentary and pyroclastic rocks	5 to 10 kg/cm^2
Soft	Weak, low to very low strength slightly consolidated to loose, medium to highly weathered	Upper Pliocene - Quaternary pyroclastic rocks and semiconsolidated rocks or unconsolidated sediments	5 kg/cm^2 or less

(3) Permeability

All rocks and ground are classified by characteristics of permeability as follows:

Class	Description	Typical rocks and ground	Estimated Lugeon value	Estimaged permeability coefficient
Very high permeability	Open cavity sinkhole, cave, fissure wide fractured zone very high porosity	Limestone, porous lava flow porous pyroclastics and unconsolidated sand	Lu>100	$K>10^{-3}$cm/sec
High Permeability	Weathered, open cracks, fractured zone, high porosity, geologic contact, loose joint	Slightly porous sedimentary and pyroclastic rock, metaporphic and igneous rocks with open cracks	Lu=10-100	$K=10^{-4}\sim 1x10^{-3}$cm/sec
Low Permeability	Tight joints sound, slightly cemented,	Slightly cmemnted sedimentary and pyroclastic rock, metamorphic and igneous rocks without open cracks	Lu=1~10	$K= 1x10^{-5}$cm/sec $\sim 1x10^{-4}$
Watertight (Impermeable)	Massive, fresh well compacted and cemented	Well compacted sedimentary rocks, fresh igneous and metamorphic rocks, residual clay	Lu>1	$K< 1x10^{-5}$cm/sec

(4) Overburden

Overburden is composed of various kinds of unconsolidated sediments such as residual soil, river deposits, talus deposits and volcanic sediments (pyroclastics). The total thickness of overburden including consolidated formation is taken in considerations in the case of waterway tunnel assessment.

(5) Slope stability

Possibility of landslide and landslip in a revervoir area is examined by studying existing topographic and geological maps.

(6) Sedimentation

In proportion to ratio of totaled area occupied by volcanic piedmont, landslide area, volcanic products zone and non vegetation area to the catchment area, extent/possibility of sedimentation in a reservoir is estimated as follows by reconnaissance and/or map study.

(i) Much : 1/3
(ii) Common : 1/3 to 1/5
(iii) A little : 1/5 or less

(7) Topographic condition

Cross profile of dam sxis and slope inclination are observed by topographic map study. In present study cross profile of dam axis is calssified mainly into simple three types as follows.

(i) V-shaped valley (open or shallow)
(ii) U-shaped valley
(iii) Dish-shaped valley

(8) Construction materials

(i) "Rock material and aggregates"

These materials are assessed by availability of quarried fresh hard rocks and coarse grained river deposits such as gravel, cobble and boulder.

(ii) "Sand material"

Materials are assessed by availability of river deposits, terrace deposits, talus deposits and alluvial fan sediments.

(iii) "Earth material"

Earth material is assessed by availabiity of weathered rocks, residual soil, talus deposits, fine volcanic products and river terrace deposits.

7.4.3 Geological assessment

The standard of geological assessment is summarized in Table 7.2. The results of geological assessment of each scheme are shown in Table 7.3, and its data sheets are compiled in APPENDIX A.

Geological and geotechnical conditions at thirty seven scheme sites, which passed the first screening prosess, were studied referring to the results of field survey, existing geological maps, aerophotos and reports. Those schemes are listed below in the order of ID number for each region and geological study level of each site.

Region	ID No.	Scheme	Study Level				
			FT	OS	GM	GP	GR
I	1-3-0-2	Naguilian	0	-	0	-	-
	1-10-0-1	Luya	-	-	0	-	-
	1-10-0-2	Bakum	-	-	0	-	-
	1-10-1-4	Amburayan	0	-	0	-	-
	1-22-0-1	Banaoang	0	-	0	-	-
	1-22-0-5	Supo	-	-	0	0	0
	1-22-0-6	Eteb	-	-	0	0	0
	1-22-10-0	Abra	-	-	0	-	-
II	2-6-0-1	Sisiritan	-	-	0	0	0
	2-6-0-2	Bubulayan	-	-	0	0	0
	2-6-0-3	Bulu	-	-	0	0	0
	2-6-1-4	Nababarayan	-	-	0	0	0
	2-6-1-5	Dibagat	-	-	0	0	0
	2-6-1-6	Agbulu	-	-	0	0	0
	2-6-1-8	Apayao	-	-	0	-	0
	2-8-3-4	Chico-1R	-	-	0	-	-
	2-8-3-5	Sadanga	-	0	0	-	0
	2-8-3-6	Chico-2R	-	-	0	-	-
	2-8-3-7	Chico-3R	-	-	0	-	-
	2-8-3-9	Chico-4R	-	-	0	-	-
	2-8-5-15	Saltan	-	-	0	-	0
	2-8-6-22	Pasil	-	-	0	-	0
	2-8-6-23	Tanudan	-	-	0	-	0
	2-8-7-24	Bantay	-	-	0	-	0
	2-8-8-25	Dabba	-	0	0	-	0
	2-8-14-34	Maliano	-	0	0	-	0
	2-8-20-46	Ibulao	-	-	0	-	-
	2-8-28-52	Cabingatan	-	0	0	-	0
	2-8-29-58	Casecnan	-	-	0	0	-
	2-8-29-59	Upper Casecnan	-	-	0	-	-
	2-8-29-61	Upper Casecnan 3	-	-	0	-	-

Region	ID No.	Scheme	Study Level FT	OS	GM	GP	GR
III	3-77-0-6	Agno-2	0	0	0	-	-
	3-77-0-7	Agno-3	0	0	0	-	-
IV	4-7-0-1	Kanan	-	0	0	-	0
	4-7-0-2	Daraitan	-	0	0	0	0
	4-7-0-5	Upper Agos-2	-	0	0	-	0
	4-115-1-1	Wawa	0	0	0	-	0
	5-14-1-1	Bosigon	0	-	0	-	-

NOTES:
FT : Geological inspections by field trip.
OS : Overfight survey by helicopter.
GM : Interpretation of site geology by existing maps.
GP : Interpretation of site geology by aerial photos.
GR : Interpretation of site geology by existing geology literatures and project reports.

Detailed descriptions together with general geologic map for each scheme site are compiled in APPENDIX A.

7.5 Extraction of Scheme Data

The estimation of power output and cost for all the identified schemes was made by using a computer. The scheme data required for these calculations were extracted from the maps of 1:50,000 scale which were used for map study. The items of the extracted data are shown in Table 7.4.

Besides the scheme data, the catchment area and average annual basin rainfall at the scheme site were also measured for all the schemes. This work was made on 1:50,000 topographic map. Annual rainfall isohyetal map was once prepared on 1:250,000 scale map, and tansferred to 1:50,000 scale map.

7.6 Scheme Identified from Map Study

As a result of the map study over the whole Luzon Island, 145 hydropower potential sites have been identified in total, a breakdown of which is shown below.

	Reservoir type	Run-of-river type	Total
Newly identified:	16	32	48
Named:	97	-	97
Total:	113	32	145

Scheme newly identified from map study of this time are listed in Table 7.5. Locations of schemes both of newly identified and named are shown region by region in Figs. 7.2-7.6. 145 schemes in total include some schemes which are mutually exclusive with other proposed schemes, e.g. an inter-river diversion scheme at upper reach as an alternative to along-stream scheme in the lower reach. As for the optimum development plan of each river basin, and the total hydropower potentials of the Luzon Island, it is described in detail in the subsequent chapters.

VIII. POWER OUTPUT CALCULATION

8.1 General

For each hydropower site identified, power and energy outputs were computed as well as dimensions of structures. Through this computation, various alternatives as to development scales were examined to find out optimal development scales of each site in combination with the preliminary cost estimate made successively, and also for the estimation of exploitable potential at the site. Each of identified sites was assumed to be independent of the other schemes.

For the calculation of power output of each site, the scheme data such as topographical features and waterway length, extracted from the topographic maps and previous study reports, were given to the computer programs as well as the storage draft and flow duration curves described in the preceding chapter. Through the power output calculation and the preliminary cost estimate, none of the other water resources development as a competitive to the hydropower development was considered herein.

8.2 Development Scale Alternatives

8.2.1 Reservoir development

The development scale of reservoir type was examined for the variations of reservoir capacity and water levels.

(1) Reservoir capacity alternatives

Several reservoir development scales in terms of active storage capacity were examined by varying a reservoir development ratio expressed by the following:

$$\mathrm{RDR}(i) = \frac{\text{Reservoir active capacity (m}^3\text{)}}{\text{Annual inflow volume (m}^3\text{)}}$$

$$= \frac{\text{Reservoir active capacity}}{\text{Long-term average discharge (m}^3\text{/s)} \times (86400 \text{ sec} \times 365)}$$

where,

RDR(i) : Reservoir development ratio, which was optionally given to the computer program repeatedly in order to select an optimum development scale combined with the preliminary cost estimate.

Fig. 8.1 shows graphical indication of the dimensionless storage draft curve, on which the conception of RDR is also shown.

(2) Full supply level alternatives

For each reservoir capacity alternative, the following 5 cases were also examined by varying the reservoir full supply level (FSL) as another variable parameter:

Case	Full Supply Level (FSL)	Min. Operating Level (MOL)
Case-1	Maximum FSL1/	Drawdowned level at a given active storage below the predetermined FSL
Case-2	At 3/4 intermediate height between Case-1 and -5	Same as the above
Case-3	At 2/4 intermediate height between Case-1 and -5	Same as the above
Case-4	At 1/4 intermediate height between Case-1 and -5	Same as the above
Case-5	Lowest FSL at a given active storage above the predetermined MOL	Lowest permissible MOL above sediment level

Note: 1/ Maximum FSL is defined as the water level at which reservoir gross storage is equivalent to the annual runoff volume.

To determine an optimum reservoir development scale and dam height, it was assumed for every reservoir schemes that a ratio of firm discharge to peak discharge was 0.5.

8.2.2 Run-of-river development

In run-of-river development schemes, the location and altitude of both the head pondage and power house are prerequisitely determined in a sense to utilize the topographical favour of the site to its largest extent. Basically, no fundamental alteration is conceivable with regard to the topographical features of the scheme, because power head available in the river reach is almost fixed.

Alternative development plans considered herein were, therefore, the variation of maximum plant discharge. Several alternatives were examined by varying the development ratio:

$$\begin{aligned} DR(i) &= \frac{\text{Average turbinable flow } (m^3/s)}{\text{Maximum plant discharge } (m^3/s)} \\ &= \frac{\text{Area ABCEF}}{\text{Area ABCD}} \qquad \text{(see Fig. 8.2)} \\ &= 1.0,\ 0.9,\ 0.8 \ldots.,\ DR_{min} \end{aligned}$$

where,

$DR(i)$: discharge development ratio

DR_{min} : discharge development ratio when plant peak discharge is identical to the long-term average discharge at the site.

Generally, five to six cases were examined as discharge alternatives. Fig.8.2 shows graphical indication of the DR(i) illustrated on flow duration curve.

8.3 Power Calculation Criteria

To proceed with power output calculation for each individual scheme, plant discharges, operating level and head were determined by placing the criteria which are summarized in Table 8.1. These criteria were applied on an uniform basis to all the schemes.

Table 8.1 also shows the equations for calculating the firm power capacity, installed power capacity and annual energy production.

The flow duration curve which was based on monthly runoff record at each selected gauge seems to show more stable flow condition than the daily one. A coefficient 0.9 was introduced to adjust secondary energy estimated from the monthly flow duration curve. Adjusted secondary energy was regarded to be equivalent to that estimated from a daily flow duration curve.

The said coefficient was analyzed on the flow duration curve of Larion (ID No. 420 20NW 225, in Cagayan River basin) as depicted on Fig. 8.3. At the other two gauges, the comparison between daily and monthly duration curves was made for the confirmation of this coefficient.

8.4 Power Output Computation

Power output calculation was made repeatedly in combination with preliminary cost estimate for all the 145 schemes by applying the criteria set forth in Section 8.3, together with hydrological and scheme data. The computation by the computer program "RESEVAL" provides the following information:

(1) Reservoir development ratio,

(2) Reservoir water levels and plant discharge,

(3) Power capacity and energy production,

(4) Dam or weir scale, and

(5) Waterway dimension.

APPENDIX C demonstrates the computation outputs for all the 145 schemes with the optimized power output scale, which includes the case of optimum development scale of reservoir and dam.

8.5 Selection of Optimum and Maximum Development Scale

The optimum development scale was selected out of several alternatives examined for the reservoir and run-of-river type developments, respectively. The selection was based on the power output of each alternative as well as the evaluation index obtained by the preliminary cost estimate.

8.5.1 Evaluation index

The evaluation index in terms of construction cost per annual energy product was introducted. The index is expressed by the following:

$$\mathrm{CEDX} = \frac{\text{Construction cost (US\$)}}{E_{firm} + 0.3 \times E_{sec}\ \text{(kWh)}}$$

where,

CEDX : evaluation index (US$/kWh)

E_{firm} : Annual firm energy production (kWh)

E_{sec} : Annual secondary energy production (kWh).

The value of secondary energy was assumed to be 30% of firm energy value in this stage.

8.5.2 Optimum development scale

(1) Reservoir type development

To determine a development plan in each identified site, the optimum scale was selected in the following way out of all cases examined through iteration of the power output calculation and preliminary cost estimate.

(i) The optimum development scale of the reservoir and dam were determined among the alternatives which were composed of active reservoir capacity and water levels. An optimum scale was found such an alternative which produces the biggest power output with an evaluation index of less than 1.50. In case that no alternative has an evaluation index less than 1.50, a scale of the least evaluation index was chosen. This optimization was made under condition that a ratio of firm discharge to peak discharge was 0.5.

(ii) With the optimum scale of the reservoir selected by the above procedure, the optimization of power development was worked out in such manner as used variable ratio of firm discharge to peak dischage, 0.33, 0.25 and 0.17. Then the benefit of power generation; from kW value and kWh value was estimated by adopting conventional thermal as an alternative. An optimum power plan was selected through Benefit (B) - Cost (C) analysis. Among the cases given firm discharge ratio to peak discharge, a case which derived the maximum (B-C) at the highest discount rate was chosen as an optimum development plan. Computer output of estimation of the power benefit and cost is compiled in APPENDIX C.

(2) Run-of-river type development

The optimum development plan for a run-of-river type scheme was selected out of several alternative plans as to discharge development ratio described in Paragraph 8.2.2. The selection was followed the procedure (i) of (1) applied for reservoir type development.

8.5.3 Maximum development scale

The maximum development scale is that power output is the biggest of all alternatives examined regardless of the cost index value.

Generally speaking, the maximum development scale of reservoir type is that full supply level is at the maximum full supply level and that reservoir active storage is mostly identical to the annual inflow volume, while, as for run-of-river type development, the maximum scale has as same plant peak discharge as a long-term average inflow.

IX. BASIC DESIGN AND PRELIMINARY COST ESTIMATE

9.1 General

An attempt was made to prepare a preliminary cost estimate for equal base comparison for all the 145 schemes identified through the map study. For this, the basic dimensions of principal structures of the scheme were determined first, and then an approach to the preliminary cost estimate was performed. Namely, standard design criteria and cost estimate formulae were established as described hereunder.

9.2 Basic Design Criteria

9.2.1 Dam and waterway

(1) Storage dam

In the evaluation at this phase of the study, it was assumed that the dam would be of a rock-fill type for all reservoir schemes to attain an uniform comparison among the schemes. Other types of dam were examined for the selected schemes in the second screening evaluation stage.

Topographical features of the damsite was extracted by measuring the valley widths at elevation of contour lines appeared on topographic map, including the riverbed width at the bottom of valley. It was assumed that the valley profile is longitudinally uniform for a stretch where the dam was located. Average excavation depth was also assumed to take into consideration the increase of dam volume due to excavation.

The dam volume is calculated by the following equations, assuming a composite trapezoidal valley profile with varying slopes between the elevations at each contour line measured on map:

$$VD = VD1 + VD2$$

$$VD1 = \sum_{2}^{n} VD_i$$

$$\begin{aligned} VD_i = {} & 1/6 \times [3 \times \{a + (m + n) \times (EL_n - EL_i)\} \times (L_i + L_{i-1}) \\ & + 2.0 \times d \times (L_i - L_{i-1})/(EL_i - EL_{i-1}) \\ & + (m + n) \times \{L_i + 2.0 \times L_{i-1} + 3.0 \times d \times (L_i - L_{i-1}) \\ & /(EL_i - EL_{i-1})\} \times (EL_i - EL_{i-1})] \times (EL_i - EL_{i-1}) \end{aligned}$$

$$\begin{aligned} VD2 = {} & d \times \{L_1 + d \times (L_2 - L_1)/(EL_2 - EL_1)/2.0\} \\ & \times \{a + (m + n) \times (EL_n - EL_1)\} \end{aligned}$$

where,

VD : Approximate volume of dam (m^3)

$VD1$: Embankment volume above the original riverbed elevation (m^3)

$VD2$: Embankment volume below the original riverbed elevation (m^3)

i : Trapezoid segment slice no.;
$i = 1$ at riverbed, $i = n$ at dam crest

a : Dam crest width (m)

EL_n : Dam crest elevation, at H_f above full supply level (FSL), where H_f is freeboard

EL_i : Elevation at height i (EL. m)

L_n : Dam crest length (m)

L_i : Valley width at height i (m), where excavation depth is considered.

m : Upstream slope of embankment

n : Downstream slope of embankment

d : Excavation depth (m).

In this basic design, the following standard dam cross section is assumed:

- Upstream slope of embankment : $m = 1:2.5$

- Downstream slope of embankment : $n = 1:2.0$
- Crest width : $a = 10$ m
- Freeboard above FSL : $H_f = 6$ m
- Excavation depth : $d = 5$ m in average.

(2) Diversion dam/weir for run-of-river scheme

Various types of run-of-river diversion dam/weir are conceived. A typical design assumed herein was a concrete diversion dam having a fixed overflow weir.

The volume of dam concrete including all of associated structures is estimated by the following equation:

$$VDD = 1.15 \times HDD^2 \times L$$

where,

VDD : Volume of diversion dam (m^3)

HDD : Height of diversion dam, where the excavation depth below the riverbed was assumed to be 2.5 m

L : Width of river at diversion dam site, plus 10 m to include abutment structures (m).

This type of dam/weir was assumed normally to be less than 15 m in height including a freeboard of 3 m, just to suffice to keep a diurnal regulating pondage volume.

(3) Diversion tunnel

Pressure tunnel type was assumed for a diversion channel in this basic design stage. The inner diameter of tunnel is calculated by the following equation:

$$DIAD = 0.291 \times Q_{dt}^{0.5} \geq 2.5$$

where,

DIAD : Inner diameter of diversion tunnel (m)

Q_{dt} : Design flood discharge for river diversion (m^3/s).

The minimum diameter is fixed to be 2.5 m.

(4) Headrace tunnel

A headrace tunnel was assumed to be a pressure type tunnel for a reservoir scheme, while non-pressure type for a run-of-river scheme. In case of a run-of-river scheme, either horseshoe shape or semi circle/rectangular one was considered according to the discharge. The inner diameter or width of each tunnel is calculated by the following equations, respectively:

$$DHTP = 0.651 q_p^{0.5}$$

$$DHN = 1.084 q_p^{0.375}$$

$$B = 1.06 q_p^{0.375}$$

where,

DHTP : Diameter of pressure type tunnel (m)

DHN : Diamter of non-pressure type tunnel (m), it was applied for a scheme with the discharge of more than 8.6 m^3/s

B : Width of non-pressure type tunnel (m), it was for the discharge of less than 8.6 m^3/s

q_p : Maximum discharge per tunnel (m^3/s).

The minimum diameter or width was fixed to be 2.5 m, 2.0 m, 1.8 m, for DHTP, DHN, B respectively. While, two or more tunnels were considered if the discharge exceeds 100 m^3/s.

(5) Pressure shaft

Under ground inclined pressure shaft was considered as a typical layout of penstock line. The slope of the inclined shaft was assumed to be 50° from horizontal.

The inner diameter of steel-lined pressure shaft was selected for varying ranges of discharge and head. The diameter-discharge relationship can be approximated by the following equations:

$$\begin{aligned} DIAP &= 0.794 \times Q_p^{0.404}, \text{ at } H_o = \pm\ 50 \text{ m or smaller} \\ &= 0.785 \times Q_p^{0.400}, \text{ at } H_o = \pm\ 100 \text{ m} \\ &= 0.733 \times Q_p^{0.407}, \text{ at } H_o = \pm\ 200 \text{ m} \\ &= 0.733 \times Q_p^{0.396}, \text{ at } H_o = \pm\ 300 \text{ m or larger} \end{aligned}$$

where,

DIAP : Diameter of penstock (m)
Q_p : Installed capacity discharge (m^3/s)
H_o : Power head (m).

In case the discharge exceeds 100 m^3/s, two or more lines of penstock were considered. A condition to be given was that the number of penstock lines should be equal to that of headrace tunnels. The minimum diameter of the embedded penstock was fixed at 1.3 m.

9.2.2 Access road

A permanent access road led to the scheme site has to be built for use during the construction and after the completion. Assumptions made herein were:

- Access road is connected from the existing or planned all-season public road passing nearby the proposed hydropower site.
- The cost of new access road is borne by the hydropower scheme, while existing public road will be upgraded to an acceptable grade by another agency before the start of the construction.

The length of access road was basically measured on 1:50,000 scale topographic maps. However, most of such topographic maps had been printed in 1950s, and locations of roads on the maps are not always reliable. Then, a road maps of 1:1,000,000 scale and of 1:100,000 scale, which had been issued in 1985, were also used for reference. The route was selected as far as applicable along the river valley or the existing pathway route. The access road is of 6.0 m wide shoulder to shoulder, 4.0 m penetrated-asphalt paved.

9.2.3 Transmission line system

Four kinds of transmission voltage, i.e. 69 kV, 115 kV, 138 kV and 230 kV, are used in NPC's power supply system in the Philippines at present. Of those, 138 kV transmission line is, however, not used in the Luzon Grid. Furthermore, 500 kV line is under construction from the Southern Luzon to Metro Manila, and is planned to be extended to Northern and Central Luzon.

In this study, therefore, the transmission voltage, 69 kV, 115 kV, 230 kV and 500 kV were considered for the basic design of the transmission line system.

Each identified hydropower scheme was assumed to be connected to the nearest substation including planned one. Therefore, in this study, extension of switchgear of substation for incoming lines only was considered. Namely, construction of new substation for receiving electric power generated by hydropower plants was not considered.

(1) Carrying capacity of transmission line

Allowable carrying capacity means maximum load level to be transmitted without any trouble and/or fault under actual conditions which shall be judged from the technical and economical view points.

The maximum transmission capabilities per circuit of each voltage level are shown in Fig. 9.1. The curves were determined on the basis of the following criteria:

Short distance transmission line

Carrying capacity of transmission line is mainly determined by the maximum thermal loading of conductor. For calculation of maximum allowable carrying capacity, it was assumed that maximum allowable conductor temperature is 80°C in still air under the condition of ambient temperature of 40°C.

Middle and long transmission line

Carrying capacity of transmission line is mainly determined from the viewpoint of stability of the system and is usually expressed as:

$$P = k \cdot V^2 / l$$

where,

P : Transmitted load (MW)

V : Line-to-line voltage of transmission line (kV)

l : Transmission line length (km)

k : Carrying capacity factor which is experimentally determined from the ratio of resistance and reactance of transmission line ($\leq$ 1,200).

Taking account of the above criteria and the conductors used in the present transmission line system in the Luzon Grid, the following conductors were adopted for the basic design:

- ACSR 336.4 mm^2 for 69 kV and 115 kV systems
- ACSR 795 mm^2 for 230 kV and 500 kV systems.

(2) Constitution of transmission line

Most of the existing transmission lines with 69 kV and 115 kV are constituted of the single circuit and wooden pole excluding some lines. While, all of lines with 230 kV capacity are made up of single or double circuits, and steel towers.

Taking the present constitution into account, the following line configuration were considered in this basic design.

Voltage (kV)	Conductor	Circuit	Tower
69	ACSR 336.4 mm^2 x 1	Single	Wooden Pole
115	ACSR 336.4 mm^2 x 1	Single	Wooden Pole
230	ACSR 795 mm^2 x 1	Single	Steel Tower
	ACSR 795 mm^2 x 1	Double	Steel Tower
	ACSR 795 mm^2 x 3	Double	Steel Tower
	ACSR 795 mm^2 x 4	Double	Steel Tower
500	ACSR 795 mm^2 x 4	Single	Steel Tower
	ACSR 795 mm^2 x 4	Double	Steel Tower

(3) Number of circuit

Referring to Fig. 9.1, number of circuits of transmission line was determined based on the total installed capacity of the power station and transmission line length in accordance with the following criteria:

(a) Number of circuits is two (2), excluding 69 kV and 115 kV connecting to a hydropower plant of rather small installed capacity,

(b) A hydropower plant of the installed capacity less than 30 MW is provided only a single circuit not to bear high cost of transmission line on the total besides the consideration on the system characteristics of Luzon Grid, and

(c) 69 kV and 115 kV lines are designed to have only single circuit due to wooden pole provision.

(4) Transmission line route

The selection of planned line route connecting the hydropower station and the nearest substation was made individually. Namely, no interconnection between hydropower stations was taken into account.

Based on the above consideration, the length of transmission line was measured on a map of 1:500,000 scale.

9.3 Preliminary Cost Estimate

9.3.1 Basic approach

Preliminary cost estimate was made by establishing cost function formulae or unit prices for each segment of the works of hydropower project. The cost formulae and unit prices were derived from cost data obtained in various projects including the recent projects in Philippines as well as overseas projects. The estimated cost is expressed in US$ equivalent at the price level of end-1985.

The estimate was made for the following three (3) separate items:

(a) Power development; comprising of dam, waterway and power plant,

(b) Access road, and

(c) Transmission line system including a main receiving substaion.

The details of cost components evaluated in this estimate are described in Table 9.1.

Cost for land procurement/resettlement and other special items peculiar to the projects were not included in the estimate of this stage, leaving their assessments to the evaluation at the second screening process.

9.3.2 Power development cost

(1) Cost formulae

With a due reference to recent price levels of construction works, cost formulae were derived for respective components of the works. Major items of parameters used in this preliminary cost estimate are dam volume, tunnel diameter, tunnel lengths, power head, plant discharge and installed power capacity. The formulae derived are shown in Table 9.2.

(2) Calibration of cost formulae

The cost formulae derived in (1) above was then compared with the estimate of various projects in previous study reports. Furthermore, the coefficients related to an unit price was adjusted referring to the price escalation data obtained.

9.3.3 Access road

In this preliminary estimate, an average unit price of US$220,000/km was used for road through all terrains. The construction cost of access road was calculated by multiplying this unit price by road length.

9.3.4 Transmission line and substation

The preliminary cost estimate of the transmission line and the substation equipment was based on unit prices information provided by NPC that was derived from the several recent projects of transmission line construction. Unit prices obtained were represented as those of 1982 price level. Those data, therefore, were updated taking three years price escalation into account.

The unit prices of transmission line and substation equipment used for the estimation are summarized below:

TRANSMISSION LINE

Voltage (kV)	Conductor	Circuit	Unit Pirce (US$/line/km)
69	ACSR 336.4 mm^2 x 1	Single	23,000
115	ACSR 336.4 mm^2 x 1	Single	34,000
230	ACSR 795 mm^2 x 1	Double	110,000
230	ACSR 795 mm^2 x 2	Double	220,000
230	ACSR 795 mm^2 x 4	Double	459,000
500	ACSR 795 mm^2 x 4	Double	678,000

SUBSTATION

Voltage (kV)	Unit Price (US$/bay)
69	270,000
115	310,000
230	480,000
500	1,860,000

9.4 Cost Computation

Applying the cost estimate formulae and unit prices presented in Section 9.3 above, preliminary cost estimate was made for all the 145 schemes.

The cost estimated at this stage was based on the limited topographic data only extractable from topographic maps of 1:50,000 scale. The topographic parameters introduced in the estimate are basically as follows:

- Width of river and valley cross section at the proposed dam/weir site,
- Riverbed levels at dam/weir and power house sites,
- Length of waterway consisting of diversion tunnel, headrace tunnel and pressure shaft,
- Length of access road, and

- Length of transmission line.

Other related information required for estimate, such as selected dam height, dam volume, tunnel diameter, were calculated in the computation system based on the design criteria predetermined in Section 9.2 hereinbefore.

Hydrological and power information, such as average reservoir release, discharge, power and energy outputs, were also introduced into the computation system, being derived from the power output calculation.

APPENDIX C contains the outputs of cost computation for all the schemes examined.

X. FIELD INVESTIGATION

10.1 General

The field investigation is attempted to make site reconnaissance, aerial survey and collection of data concerned at each site or in region. The purposes of field investigation are to confirm and to find technical site conditions, socio-environmental problems at and around the sites, and other water use from the river concerned as follows:

(1) Technical observation of schemes (named and newly identified sites including surrounding areas), in viewpoints of river morphology, topography, geology, availability of construction materials, and accessibility.

(2) Other water use for irrigation and/or drinking and industry, and relation with flood control.

(3) Socio-environment concerned with land use, resettlement requirement and submergency of roads and others of a project area including dam and power station sites, a reservoir area etc.

The selection of schemes to be investigated is made considering the followings:

(1) Schemes which will be retained through the first and second screenings.

(2) Possible approach to a scheme by a car and/or a boat without any special route to be newly constructed.

(3) Schemes located at place within a few days trip distance from a nearest city or town.

The reconnaissance is scheduled before the first and second screenings because of the limited study period of about two years from July 1985. Moreover, only the dry season is available for the field reconnaissance of difficult approach sites. The schemes in Northern Luzon, especially upstream reaches of Abra, Chico, and Saltan river basins, are rather difficult to access. In such a case, aerial survey is tried as an alternative mean.

10.2 Field Reconnaissance

The site reconnaissance has been carried out on selected schemes in Water Resources Regions I, II, III, IV and V during the study period. These schemes were basically selected on the basis of results of the map study and power output calculation. However, the number of schemes visited were quite limited because of the poor accessibility and the security problem. In addition, the aerial survey was also made for the schemes, accessibility to which were rather difficult. The schemes investigated are summarized below:

Water Resources Region	Name of Scheme investigated
I	Banaoang, Naguilian, Amburayan
II	Cagayan 1, Huoab, Basao, Sadanga, Bontoc, Pinukpuk, Adaga, Dabba, Saltan-4, Dalaya, Tamauini-1, Sta. Cruz, Maliano, Pinaripad, Maddela, Alimit-1, Alimit-2, Cabingatan, Dakgan, Kagipsipan, Gaden
III	Agno-1, Agno-2, Agno-3, Tabu
IV	Kanan, Daraitan, Upper Agos-1M, Upper Agos-1S, Upper Agos 2, Wawa
V	Bosigon

The reconnaissance works were done by the survey team consisting of the following members:

- 2 or 3 NPC civil enginners
- 1 NPC geologist

- 1 or 2 JICA civil engineer(s)
- 1 JICA geologist

The reconnaissance works were done mainly by visual observation with hand level, distance meter, altimeter and geological survey tools such as a hummer and a clinometer.

Topographic maps of 1:50,000 scale were used for the reconnaissance. Most of such topographic maps were printed in 1950s, then the location of roads was not always correct. However, another informations on the maps such as topographic conditions, locations of structures, villages etc. were mostly correct.

10.3 Engineering Assessment

During field survey, engineering assessment on the schemes were made on the following standards. The survey results are compiled in Table 7.3 and in APPENDIXES A and C.

(1) Topographical assessment

Overall topographical assessment is made for a scheme site mainly for a dam(weir), power house and waterway as follows:

a) "Excellent"	: The best topographical site surely confirmed.
b) "Good"	: A suitable site in a topographical viewpoint confirmed on maps.
c) "Acceptable"	: A possible site in a topographical viewpoint, but some modification required.
d) "Not acceptable"	: An unsuitable site in a topographical viewpoint.

(2) Geological assessment

Overall geological assessment for a dam(weir), power house, waterway and reservoir area is made as follows:

a) "Excellent" : The best site in geological viewpoint, for which no foundation treatment will be required.

b) "Good" : A good site for which any special foundation treatment or countermeasure will not be required and common treatment can be applied.

c) "Acceptable" : A site for which some special foundation treatment or countermeasure will be required.

d) "Poor" : A site with poor geological conditions (not recommendable due to some geological defects).

(3) Accesibility

"Access" means mainly an access road(s) from a public road to a site which shall be newly constructed or much improved by widening and paving. Informations on other transportation facilities such as bridges, port and railway are also included in this item.

a) "Excellent" : Total length of a new access road is less than 5 km through hilly or plain area without any special and costly facilities.

b) "Good" : Total length of a new access is between 5 and 10 km without any special and costly facilities and earth works.

c) "Difficult" : Total length of a new access road is between 10 and 30 km with some special facilities and/or large earth works.

d) "Very difficult" : Total length of the new access road is over 30 km and many special and costly facilities and/or large works are necessary.

(4) Overall assessment

Overall assessment judged on not only technical points mentioned above but also socio-environmental viewpoints from survey results, is given for each scheme as follows:

a) "Excellent" : The most recommendable scheme without any difficulties in technical and socio-environmental viewpoints.

b) "Good" : The recommendable scheme even though it has minor difficulties.

c) "Acceptable" : The scheme having some difficulties in technical and/or socio-environmental points for which the plan and/or design shall be modified.

d) "Discarded" : The scheme having some fatal defect in technical and/or socio-environmental points for which the plan shall be given up or completely changed.

XI. HYDROPOWER PROJECT INVENTORY

11.1 General

In order to estimate the hydropower potential of the Luzon Island and to select promising schemes out of all identified hydropower potential sites to the further study stage, all the hydropower projects falling into the following three categories are taken into account:

Developed :	- existing hydroelectric plants
Developing :	- projects under construction or already committed for implementation
	- projects of the feasibility study level
Undeveloped :	- schemes of the pre-feasibility study level
	- schemes identified in the previous studies
	- schemes newly identified in this study.

Although there are many differences among the above three categories in their level of study depth and data accuracies, it was attempted to estimate the hydropower potential of each category under the following conditions and assumptions:

(1) The hydropower potential is indicated in terms of Power (Installed Capacity, MW) and Energy (GWh)

(2) Regarding the Developed and Developing hydropower potentials, power and energy are obtained based on the installed capacities of the existing plants and ones recommended in the previous studies

(3) Installed capacitiy and energy outputs for the identified Undeveloped schemes are the optimum development scale at each site (Ref. Section 8.5)

(4) Total hydropower potential in Luzon Island was estimated by accumulating output of developed and developing projects as well as the identified schemes that were judged to be

technically possible to develop taking account of power output and economic index in terms of minimum discount rate at which (benefit-cost) becomes positive valve.

11.2 Inventory of Hydropower Projects

The inventory of hydropower projects was compiled by three categories of development level described hereinbefore.

The inventory of Developed hydroelectric plant, 11 existing plants in Luzon Island, is compiled in APPENDIX C, which information were collected and confirmed as much extent as possible in the study period.

The inventory information of Developing projects, which consist of two committed projects and 9 projects of feasibility or higher study level, is compiled in APPENDIX C as a form of Catalogue.

For the identified 145 schemes, information derived from the map study on each scheme have been preserved in the permanent data file of the computer VAX11-750 owned by NPC, as well as project feature which was evaluated as an optimum development scale by the power output and preliminary cost calculations. This permanent data file is called the Inventory of Hydropower Site.

The computer output of the Inventory for identified schemes is represented in Table 11.1, as example, besides the full set of inventory output compiled in APPENDIX C.

The inventory contains the following information;

(i) Scheme identification information
  - Water resources region No., name of province
  - Names of river basin and stream
  - Scheme No., name of scheme, location (on Greenwich grid)
  - Study grade

(ii) Hydrological and topographical information
- Average annual rainfall
- Average runoff
- Stream gauging station correlated
- Catchment area of the gauge
- Average runoff at the gauge
- Denudation rate applied
- Evaporation rate applied
- Catchment area
- Tailwater level at powerhouse/outlet site

(iii) Scheme information
- Type of development
- Optimum development scale in terms of development ratio expressed by the following:
  - ·Reservoir scheme : Reservoir active capacity / annual runoff volume
  - ·Run-of-river : Average turbinable flow / max. plant discharge
- Reservoir/pondage capacity
- Dam/weir height, volume, and crest length and elevation
- Waterway length, diameter and number
- Length of transmission line to a main grid substation
- Length of access road from nearest existing road

(iv) Power information
- Firm and peaking discharges
- Operating levels and head
- Installed, dependable peak and firm powers
- Firm and secondary energy

(v) Preliminary cost information
- Construction cost by item of power development, power transmission and access road
- Construction cost per kW installation
- Construction cost per kWh production (firm energy + 0.3 x secondary energy)

Following information are inventoried as required for the promising projects.

(vi) Technical comment

(vii) Others
- Land use in reservoir area
- Resettlement requirement
- Submerged road class
- Map(s) used.

11.3 Installed Capacity of Existing Hydroelectric Plants

In Luzon Island, there are 11 existing hydroelectric plants, which had been developed from year 1945 to 1983 including one pumped storage plant. The installed capacity and energy production of those, as of end-1986, are shown in Table 11.2.

Total installation accounts for 1,226 MW, which is composed of 1,163 MW (95%) by six big plants (larger than 50 MW) and the others. As presented in Table 11.2, the big scale plants are concentrated in the water resources region III, although one each big plant exists in the regions II and IV, respectively.

11.4 Hydropower Potential of Developing Projects

Developing hydropower potential in the study area consists of two projects committed for implementation and 10 projects comfirmed to be feasible. Name of those pojects and potential are shown in Table 11.3.

Total hydropower potential of the developing projects is accumulated to be 2,569 MW in terms of installed capacity including 291 MW of the committed projects. Most of developing project are found in the water resources regions I, II and III, while only one project in the Region IV. Of those, the Region II is noticed as a high potential area, at where it is expected to be developed for 1,760 MW, which is about 70% of the total of developing projects.

The hydropower potential developed and developing reaches approximately 3,795 MW in terms of installed capacity and 11,500 GWh in annual energy production.

11.5 Hydropower Potential of Identified Schemes

11.5.1 Total potential of identified schemes

The hydropower potentials, in terms of installed capacity (power) and energy, of each identified scheme were estimated through the power output calcualtion and benefit/cost analysis. The summation was made in the following ways:

(1) Total potential of all the identified schemes including;

- overlapped potential of schemes which is mutually exclusive with the other scheme or project completed its feasibility study
- minor potential of schemes of which power output is less than 5 MW

(2) Technically possible potential of the schemes excluding;

- overlapped potential,
- minor potential, and
- schemes which (benefit-cost) value does not reach to positive at a discount rate of 5%.

In this estimation, a discharge regulation merit due to storge effect of upstream schemes and/or projects including existing reservoir was not considered.

The total potential of all identified schemes and of technically possible development are summarized in Table 11.4 by each river system and water resources region. Total power potential in whole Luzon of which development seems technically possible is accumulated to be 4,701 MW.

11.5.2 Big potential scheme

Big potential schemes of reservoir type development which has an optimum power output of over 200 MW are summarized in Table 11.5, which over 20 MW for run-of-river type schemes. The power output of big potential schemes is based on variant plant factor.

11.6 Total Hydropower Potential in Luzon Island

It is estimated to be 8,500 MW and 24,000 GWh in power and energy respectively that contain existing hydroelectric plants, projects of every study levels and identified schemes of technically possible development . The total potential in power by river system and water resources region is summarized in Table 11.4.

The table below presents the power and energy potentials of each development stage:

Development	Power (MW)	Energy (GWh)
Developed	1,226	2,956[1/]
Developing	2,569	8,482[2/]
Undeveloped[3/]	4,701	12,408[2/]
Total	8,496	23,846

Remarks : 1/ Actual energy product in 1986

2/ Firm and secondary energy

3/ Total of technically possible development.

XII. PREPARATION OF GENERAL LAYOUT PLAN AND SECOND CONSTRUCTION COST ESTIMATE

12.1 Preparation of General Layout Plan

12.1.1 General

After the first screening study, 37 schemes in total were evaluated as potentially feasible schemes, of which 20 schemes are reservoir type and 17 schemes are run-of-river type.

For all of those schemes, a general layout plan was drawn on the topographic map of 1:10,000 scale. The most large scale map which covers Luzon Island is that of 1:50,000 scale, however no larger scale one was available. Then, enlarged maps of 1:10,000 scale were prepared from the existing 1:50,000 scale maps.

12.1.2 Preliminary review and study on alternative plans

Prior to the preparation of general layout plan, preliminary review was made for all the schemes which had passed the first screening, from the viewpoints of technical aspects, such as site geology, accessibility, socio-environment, etc. As a result, six schemes, Banaoang, Buburayan, Dabba, Cabingatan, Upper Casecnan-3, and Daraitan were discarded due to some disadvantages (Ref.: Paragraph 13.4.2).

In the preparation of layout drawing, some alternatives of construction type such as dam types of rockfill, earthfill and concrete, waterway, power house, etc. were considered.

12.1.3 Schemes to be studied

Besides 6 discarded schemes mentioned above, two schemes, Basao and Tabu were revived for the examination of upstream storage effect, and also some schemes were studied in combination with neighboured schemes as is described in Chapter XIII. Finally 22 reservoir type schemes (14 independent schemes and 8 combined schemes), and 19 run-of-river type schemes (18 independent schemes and 1 combined scheme) were studied hereunder.

12.1.4 Basic design

In order to estimate construction cost of those schemes, basic design was made on major dimensions of important structure. Design criteria, method and calculation formulae are compiled in APPENDIX A, where type of structure, its function, design of dimensions, and so forth are discussed in detail. Items for the basic design and the second cost estimate are as follows:

Power Development

(1) Storage dam
(2) River diversion
(3) Spillway
(4) River intake weir
(5) Intake structure
(6) Headrace
(7) Surge tank
(8) Head tank
(9) Penstock
(10) Power House
(11) Tailrace
(12) Water transfer facilities
(13) Miscellaneous civil works
(14) Power equipment

Access Road

(15) Access road

Transmission Line

(16) Transmission line

(17) Substation

Land Acquisition

(18) Land acquisition

After designing major dimensions of such individual structure, general layout drawings were arranged. They are compiled in APPENDIX B. Main features of both reservoir type and run-of-river type schemes are tabulated in Tables 12.1 and 12.2.

12.1.5 Work quantity calculation

Construction work quantity was calculated on all of work items listed above based on the layout plan drawings. Construction work items are mainly divided into civil works, mechanical works and electrical works as shown below.

Civil Works

- i) Earth work
  - Open excavation
  - Tunnel excavation
  - Embankment (Rockfill, Earthfill)
- ii) Concrete work
  - Open concrete placement
  - Tunnel concrete placement
  - Reinforcement bar installation
- iii) Grout work
  - Curtain grout
  - Blanket/Consolidation grout
  - Fill grout
- iv) Non listed civil work

Mechanical Works i) Steel conduit installation
ii) Gate installation

Electrical Works i) Power equipment
ii) Transmission line
iii) Switchyard and substation

12.2 Second Construction Cost Estimate

12.2.1 General

Based on the layout plan prepared as described in Section 12.1 above, the second cost estimate was performed for all the selected schemes. General approach to this second cost estimate is more or less similar to that applied in the first screening stage (Ref.: Chapter IX). Differences are shown in comparison form as follows:

Preliminary Cost Estimate	Second Cost Estimate
- Structure dimensions is extracted from the general develpment plant on the map of 1:50,000 scale	- Preliminary layout plan on the enlarged map of 1;10,000 scale.
- Basic cost component is each major structure.	- Basic component is a work item of each major structure.
- Cost formulae are applied to the major structures, therefore work quantities are not specified.	- Cost for each structure is summed up every costs of major work items, each of which is a product of the unit price and work quantity obtained from a formula/ layout plan.
- Land procurement/resettlement cost is not taken into account.	- Considered.

12.2.2 Unit price

Basically, standard unit price was estimated referring to that of similar projects in ASEAN countries. Some adjustment was made on it after reviewing unit price applied for the existing hydropower projects as well as F/S completed projects in Philippines.

Unit price is variable to some construction work items, to which it is not suitable to apply the constant unit price. For instance, work items having a large quantity such as dam or tunnel work are to have variable unit price depending on work quantity or structure dimension. Standard unit price applied is complied in APPENDIX C.

Unit price was also adjusted depending upon site condition of each scheme, such as accessibility, geological conditions and so forth. An appropriate coefficient was adopted to adjust such unit price. The co-efficients applied are listed in APPENDIX A.

12.2.3 Construction cost estimate

The second construction cost estimate was made on 41 schemes consisting of 22 reservoir type schemes and 19 run-of-river schemes. The cost was computed by summing up every construction work items, which were obtained by multiplying work quantity by unit price. In the estimation, engineering and administration costs, and physical contingency were also considered. Estimated construction cost for those 41 schemes are summarized in Tables 12.3 and 12.4.

As for F/S completed projects, updating of project cost was tried referring to price conversion factor and wholesale price index tabulated in Tables 12.5 and 12.6, respectively. Construction cost updated to the price level at end-1985 are shown in Table 12.7. As is seen in Table 12.7, components of local and foreign currencies of project cost vary project by project. However, no adjustment was made respecting the assumptions introduced in their study stage.

12.3 Preparation of General Development Plan

In the course of first screening evaluation, identified 145 schemes in total are classified into four categories judging from the evaluation index in terms of discount rate which makes (Benefit - Cost) positive. Those are;

- Category 1 : discount rate is more than 10%

- Category 2 : discount rate is between 8% and 10%

- Category 3 : discount rate is between 5% and 8%

- Category 4 : discount rate is less than 5%

Among them, schemes in Category 1 were evaluated as potentially feasible ones as explained in Paragraph 12.1.1 and general layout plan was prepared. Schemes in Category 2 which follows Category 1, may have some possibility to be developed in the future. Then, the general development plan for those schemes were arranged for reference in APPENDIX B.

XIII. SCREENING OF IDENTIFIED SCHEMES

13.1 General Flow of First and Second Screening

Through map study and review of identified sites compiled in "SURVEY/INVENTORY ON WATER IMPOUNDING RESERVOIRS" by NWRC, approximately 270 schemes have been revealed, whose relative attractiveness is still unknown. Through the two-staged screening processes, these 270 schemes are evaluated their relative attractiveness at each screening process which has different depth. Schemes finally sieved from these screening evaluations are registered in a hydropower project catalogue as final candidates for a priority ranking study.

The general flow of the screening of scheme is illustrated in Fig. 13.1 and outlined below.

1st screening: Elimination of too small schemes and expensive schemes

- Rough estimate of power output by manual calculation at each scheme has been made, and the schemes with a maximum output less than 5 MW were discarded.

- Preliminary cost estimate of the schemes including the cost of transmission line and access road was made for 145 schemes passed the first step described above. Power output calculation by using a computer was also made. The schemes with a maximum output less than 5 MW, and expensive schemes were discarded.

2nd screening : Selection of promising project

- General layout plan drawing were prepared for the selected schemes passed through the first screening process, and the second cost estimate was attempted on the basis of topographical/structural information obtained from the general layout drawings.

- The schemes which have some socio-environmental problems and/or geological problems were ruled out.

13.2 First Screening Elimination

13.2.1 Too small schemes

Referring to the Letter of Instruction No. 889 of july 23, 1979, the minimum power scale to be identified in this study is limited to 5 MW. As the map study to identify hydropower potential sites was based in principle on topographic maps of 1:50,000 scale with aid of topographic maps of 1:250,000 scale, the scale of 5 MW is deemed to be probable limit of accuracy in the map study.

Firstly the power output at each scheme has been estimated by manual calculation using the topographical/hydrological data obtained. As a result, 145 schemes have been remained out of 270 schemes.

Secondly the power output for the remained 145 schemes has been calculated by a computer on the basis of topographical/hydrological informations such as:

- draft storage curve,
- flow duration curve,
- average annual rainfall,
- denudation rate,
- riverbed elevation,
- maximum dam height, and
- tail water level.

As a result, 11 schemes were discarded due to power output smaller than 5 MW.

13.2.2 Costly schemes

(1) Comparison parameters

Basic parameter to assess the relative attractiveness of hydropower schemes is an internal rate of return (IRR) compared with alternative thermal schemes. This first screening adopts a certain discount rate used for (B-C) analysis referring to the construction cost per kWh of energy.

(2) Screening criteria

The basic criterion is to select competitive hydropower schemes with alternative thermal power plant. Since benefit of hydropower schemes was calculated from the alternative thermal plant at a discount rate of 12%, the hydropower schemes of which discount rate for positive (B-C) is less than 12% are not competitive. However, the first screening has been made by a linient criterion at 10% discount rate for positive (B-C), to remain a room to re-examine the schemes in more detail in the second screening study. The calculation result of (B-C) analysis for each scheme is summarized in Table 13.1.

13.3 Schemes Passed First Screening Evaluation

Schemes passed through the above processes are 37 schemes in total, consisting of 20 reservoir type schemes and 17 run-of-river type schemes. As for selected reservoir type schemes, the maximum output ranges from 39.8 MW to 576.4 MW, and run-of-river type schemes from 9.5 MW to 64.0 MW as shown in Table 13.2.

13.4 Second Screening of Schemes

For those 37 schemes passed through the first evaluation and other several schemes which may have some probabilities, the following examination were tried.

13.4.1 Evaluation of merits due to upstream storage effect

At the first screening evaluation stage, each of the identified scheme was examined on those optimum scale assuming that each scheme is planned independently with the other schemes being planned on the same river stretch.

If another reservoir type scheme is proposed on upstream reaches of a scheme, it will reduce sediment yield to the downstream schemes and also improve the runoff characteristics of downstream one due to its flow regulation effect. Therefore, the downstream schemes might be re-evaluated with more merits of these reduced sediment yield (only reservoir type scheme) and regulated flow condition.

The above examination was made for the following schemes locating on the Abra, Abulog, Chico, Agno, and Agos rivers.

River Name	Scheme Name Examined
1. Abra	Eteb, Supo
2. Abulog	Agbulu, Bulu, Gened, Buburayan, Sisiritan
3. Chico	Sadanga, Chico-1R, Basao
4. Agno	Binga, Tabu
5. Agos	Upper Agos 2, Kanan

Their location map and river profile are illustrated in Drwgs. 00-02 to 00-08 in APPENDIX B. Other river basins were not studied because planned schemes can stand independently along the river.

The cost and power output of these schemes were re-examined adding the following assumptions:

- Optimization of each scheme is made from upstream to downstream direction.
- Sediment from the upstream catchment area is trapped by the upstream reservoir, that is, sediment from the remaining drainage area is only taken into account for the downstream.

- Inflow to the studied scheme is calculated by adding the regulated discharge from the upstream scheme and river flow discharge from remaining drainage area.

- Maximum full supply level (FSL) of the studied scheme is lower by 10 m than tail water level (TWL) of upstream scheme.

- When upstream scheme is the existing one or its F/S is completed, the firm discharge from them is used without changing.

(1) Abra River Basin

It is planned that irrigation water of 9 m3/s will be diverted to adjacent river basin at the upstream of Supo dam (Ilocos Sur Transbasin Project, NIA). Therefore, the said discharge is deducted from the inflow used for the study of Supo scheme.

Results are summarized in the following table. FSL of Supo (Alt.1) and Supo (Alt.2) are adjusted to follow the assumption mentioned above. For this comparison, TWL of Supo (Alt.1) is same with that of the independently planned Supo scheme. However TWL of Supo (Alt.2) is lowered by means of waterway tunnel.

SCHEME	FSL (El-m)	TWL (El-m)	POWER (MW)	ENERGY (GWh)	COST (Mil.$)	C/P ($/kW)	C/E ($/kWh)
Eteb	371.0	273.0	107.1	296	239	2,236	0.946
Supo	320.0	204.0	142.1	438	250	1,759	0.715
Supo (Alt.1)	263.0	204.0	68.2	230	151	2,266	0.867
Supo (Alt.2)	263.0	178.0	99.7	330	176	1,762	0.698

As is seen in the above table, Supo (Alt. 1) scheme becomes less favourable than the original Supo scheme due to lowered head of about 57 meters, even though the flow duration is improved by the upstream Eteb scheme. Then Supo (Alt. 2) scheme was considered to recover this demerit by lowering the tail water level with extended waterway. Those two alternatives are mutually inclusive. Then Supo (Alt. 2) scheme which has more favorable figures than Supo (Alt. 1) scheme is proceeded to further study.

(2) Abulog River Basin

There are six proposed dam sites along the Abulog river basin. Impractical combinations, such as the combination of Agbulu and Dibagat which are closely located each other, were discarded by engineering judgement. Moreover, preliminary study was made to squeeze out competitive combinations and the following combinations are selected as attractive ones. The results of comparison are tabulated below.

SCHEME	FSL (El-m)	TWL (El-m)	POWER (MW)	ENERGY (GWh)	COST (Mil.$)	C/P ($/kW)	C/E ($/kWh)
Agbulu	346.0	185.0	216.4	713	316	1,458	0.481
Bulu	218.0	78.3	408.0	1,365	518	1,269	0.416
Gened	180.0	50.7	207.7	1,132	410	1,972	0.419
Sisiritan	100.0	10.0	418.3	1,082	537	1,283	0.714
Sisiritan (+Agbulu)	100.0	10.0	389.8	1,067	522	1,338	0.569
Gened (+Agbulu)	180.0	50.7	392.1	1,309	520	1,327	0,436
Bulu (+Agbulu)	175.0	78.3	356.5	963	432	1,212	0.517
Sisiritan (+Agbulu +Bulu)	68.3	10.0	199.8	696	324	1,620	0.525

The planned features in the first screening study for Agbulu was not changed because the scheme is located at the most upstream. The features for other schemes were changed depending upon the neighbored upstream scheme. As a result, two alternatives for Sisiritan scheme and one alternative for Bulu scheme become competitive with the original ones. In this comparative study, Gened scheme is considered as a dummy. Then the planned features of Gened scheme is not always coincide with those of Feasibility Study.

(3) Chico River Basin

Basao scheme was discarded by the first screening. However, the scheme combined with Sadanga scheme was studied, because Sadanga scheme improves river flow character and power output of Basao scheme. Along the Chico river, the following combinations were examined and results of comparison are tabulated below. TWL of Sadanga (Alt.1) is lowered by means of waterway tunnel.

SCHEME	FSL (El-m)	TWL (El-m)	POWER (MW)	ENERGY (GWh)	COST (Mil.$)	C/P ($/kW)	C/E ($/kWh)
Sadanga	890.0	676.0	238.2	611	463	1,943	0.844
Sadanga (Alt.1)	890.0	625.0	301.4	762	493	1,637	0.714
Chico-1R	624.2	555.0	26.6	140	36	1,353	0.581
Basao	768.0	510.0	522.4	895	910	1,741	1.134
Chico-1R (+Sadanga)	623.0	555.0	26.4	196	34	1,280	0.184
Chico-1R (+Sadanga(Alt.1))	643.0	555.0	26.4	198	34	1,280	0.181
Basao (Alt.1) (+Sadanga)	666.0	510.0	163.0	558	353	2,164	0.705

As a result, both of Sadanga (Alt.1) and Basao (Alt.1) become more favorable than the original ones, and also alternatives of Chico-1R is much improved because of augmented firm energy.

(4) Agno River Basin

Tabu scheme locating between the existing Binga dam/reservoir and F/S completed San Roque Project, was studied to check whether power is boosted up by the available flow regulated by the Binga reservoir. Two alternatives are considered changing the elevation of full supply level. As a result, both alternatives show almost same cost index. However, alternative 1 is preferable to Alternative 2 from the viewpoint of power output.

ROUTE	FSL (El-m)	TWL (El-m)	POWER (MW)	ENERGY (GWh)	COST (Mil.$)	C/P ($/kW)	C/E ($/kWh)
Tabu	414.0	290.0	67.4	460	162	2,402	0.782
Tabu (Alt.1) +Binga	404.0	290.0	135.8	439	215	1,580	0.792
Tabu (Alt.2) +Binga	348.5	290.0	20.4	164	81	3,980	0.726

(5) Agos River Basin

On the Agos river, Kanan and Upper Agos-2 schemes are planned on the upstream reach of the F/S completed Agos Project. As they are mutually inclusive, most favorable series development plan is studied. Maximum power output is obtained by a combination of Agos and Upper Agos-2. A combination of Kanan(Alt.1) and Upper Agos-2 follows. Kanan scheme can produce the maximum power output among the independent three schemes, however, it will sacrifice Agos and Upper Agos-2 schemes. Accordingly, Kanan(Alt.1) scheme is proceeded to further study.

SCHEME	FSL (El-m)	TWL (El-m)	POWER (MW)	ENERGY (GWh)	COST (Mil.$)	C/P ($/kW)	C/E ($/kWh)
Upper Agos 2	316.0	166.0	135.2	439	261	1,933	0.641
Kanan	294.0	100.0	213.9	691	476	2,225	0.738
Kanan (Alt.1) +Upper Agos 2	156.0	100.0	77.1	207	148	1,915	0.819

13.4.2 Technical review of schemes

Technical review was made for each selected scheme to judge the appropriateness of the scheme to define any constraint foreseen in actual implementation. The major items of the technical review are:

- Technical aspects, particularly geology,
- Constraints to construction works, particularly access facilities and other pre-construction work requirements,
- Conflicts with other water uses,
- Any noteworthy sociological and environmental problem, and
- Any other constraints to the implementation.

As a result, the following six schemes are discarded because of reasons described below.

(1) Banaoang (Abra river)

Banaoang site is located at 22 km upstream from the Abra river estuary. Studied optimum full supply level (FSL) is El. 78.0 m, which forms very large reservoir area of about 260 km2. Resettlement of so many residents and compensation of paddy fields/uplands would far exceed the cost of the construction of scheme itself. Therefore, it is judged that this scheme is not realistic.

(2) Buburayan (Abulog river)

Geology at Buburayan site is mainly composed of limestone, which seems to be not suitable as foundation for the planned high dam.

(3) Dabba (Pin. Tuguegarao river)

Damsite is composed of limestone from riverbed upto top of both abutments. Big amount of leakage is expected at the site.

Therefore the damsite is not recommendable for the planned high dam.

(4) Cabingatan (Conwap river)

Geology at Cabingatan site is also composed of limestone. It is judged the dam construction at site requires considerable high cost.

(5) Upper Casecnan 3 (Casignan river)

This scheme is planned as a transbasin scheme which diverts river water of Casignan river to another river basin. It results the negative effects to the committed Casecnan Transbasin Project which is located downstream of this scheme. Then this scheme is ruled out.

(6) Daraitan (Kaliwa river)

Catchment area at this site is estimated to be 325 km2. Out of this, Laiban dam harnessed276 km2, which is committed by Manila Water Supply III Project, and divert the water to Pasig basins. Then, this scheme becomes not promising.

13.5 Hydropower Project Catalogue

13.5.1 Hydropower project catalogue of promising schemes

The promising schemes which passed through the first screening mentioned above were registered in the Hydropower Project Catalogue in the computer VAX11/750 owned by NPC. The Catalogue contains information of 41 promising schemes which consist of 31 individual development schemes and 10 alternatives of series development in some river basins as described in Paragraph 13.4.1. For those 41 schemes, the layout plan drawings were prepared, then the second construction cost estimate was made. The catalogue, therefore, includes information on development scale, structure dimension, construction cost, updated evaluation indices and annual energy cost obtained from the drawings.

The Catalogue for 41 schemes printed out by the retrieval program "CATALOG" is compiled in APPENDIX C.

13.5.2 Hydropower project catalogue of F/S completed project

For the projects of which feasibility study have been completed, the Hydropower Project Catalogue have been also prepared as compiled in APPENDIX C. The projects contained in the Catalogue are nine of feasibility study level and two of committed.

These compiled in the Catalogue were proceeded to the second screening evaluation except two committed porojects for implementation since those implementation schedule have been already fixed.

13.6 Second Screening Selection of Promising Schemes

The second screening of selected schemes is made by the assessment of kWh cost (energy cost) to find appropriate number of promising hydropower schemes among those of named and newly identified, and also F/S completed projects. Total number of schemes and projects to be studied at this stage is 51 in total, breakdown of which is as follows:

- Reservoir type (Named & newly identified) : 22 schemes
- Run-of-river type (Newly identified) : 19 "
- Reservoir type (F/S completed) : 10 "

Total : 51 schemes

13.6.1 Assessment of kWh cost

The kWh cost is derived from the construction cost (second estimation) taking the following parameters into consideration.

- Discount rate: 12%
- Project service life: 50 years
- Operation and maintenance cost: 1.5% of construction cost

- Construction period is 4 or 5 years depending upon construction cost as follows:

Less tahn 100 x 10^6 US$: 4 years
More than 100 x 10^6 US$: 5 years

- Cost disbursement is assumed as follows:

Const. period	Disbursement ratio (%)				
	1st yr.	2nd yr.	3rd yr.	4th yr.	5th yr.
4 yrs.	20	30	30	20	-
5 yrs.	15	25	30	20	10

- Effective energy: Firm energy + 0.7 x Secondary energy

The kWh cost thus obtained is assessed comparing with that of competitive thermal plant according to the proposed scale of each hydropower scheme. Evaluation index for these schemes are summarized in Table 13.3.

13.6.2 Schemes passed second screening

As was discussed hereinbefore, selection of promising scheme is made based on the kWh cost. Construction costs of F/S completed projects were updated to the price level of end-1985 so as to enable equal comparison with schemes studied this time. As a result, kWh cost of Palsiguan Project is estimated to be 0.169 $/kWh. Taking this value as the highest limit, 45 schemes in total were finally selected as a promising scheme/project, and 6 schemes were discarded. Schemes passed second screening are summarized in Table 13.4.

XIV. PRORITY RANKING STUDY OF HYDROPOWER PROJECT

14.1 Approach

To recommend the master action program of hydropower development for a time span up to the year 2005, further scrutinization of hydropower schemes and projects which passed the second screening evaluation was made through the priority ranking study of hydropower project incorporating the development of other types of power plants such as geothermal and coal-fired thermal plants. Priority and adequate timing of installation of suitable types and sizes of power generation projects were searched by a simulation model applying the dynamic programming to meet the power and energy requirements. This simulation aimed to find the least cost development sequence up to the year 2005 taking account of appropriate share of each power generation source.

In the priority ranking study, the latest power and energy demand forecast was applied as well as three alternatives on power demand growth. The existing power plants were incorporated to the study considering those retirement schedule as well as several committed development projects for implementation which commissioning schedule have been fixed. The candidates of this study were geothermal and coal-fired thermal plants besides a hydropower. New installation of oil-fired thermal and nuclear power plants were not considered in the study in accordance with the power development policy of the Government of Philippines.

14.2 Power Demand Forecast

14.2.1 Power and energy demand up to the year 2005

Power and energy demand in Luzon Island was basically forecasted on the basis of the past trend of energy sales, growth rate of economic indices such as GRDP per caita and population which were forecasted by NEDA. In the medium-term power development program which is renewed every year by NPC, power and energy demand projection is reviewed as well as power generation projects. However, it only covers the span of 10 years starting from each study year. On the other hand, a target year of this study is 2005, spanning 20 years from 1986. Then, power and energy projection was extended up to this target year, referring to the latest information presented by NEDA and NPC. Power and energy at generation base were obtained from energy sales figures as was discussed in the preceding Paragraph 6.4.1. As a result, projected power and energy at the year 2005 is 6,429 MW and 39,422 GWh, respectively, and the average annual growth rate is 5.3% as shown in Table 6.8. This projection is deemed to be high side one.

14.2.2 Power demand alternatives

Power and energy projection discussed hereinbefore is judged to be reasonable at present. However, some power demand alternatives were studied here changing the growth rate of energy sales. Growth of power and energy demand is closely related to the economic development of the country. It can be said it is rather difficult to project it precisely, as the country might have some difficulties to attain the planned economic development program as scheduled because of instable economic situation easily being affected by neighboring countries. Then, the following three kinds of power demand alternatives were considered to meet the change of economic development:

Case	Annual Growth Rate of Power & Energy (%)	
	(1986-1995)	(1996-2005)
A) Original	5.3	5.3
B) Alternative 1	5.3	4.0
C) Alternative 2	4.0	5.0
D) Alternative 3	4.0	4.0

Power and energy of each case are summarized below:

Case	Power (MW) at: 1995	2005	Energy (GWh) at: 1995	2005
A. Original	3,813	6,429	23,382	39,422
B. Alternative 1	3,813	5,644	23,382	34,612
C. Alternative 2	3,415	5,563	20,943	34,133
D. Alternative 3	3,415	5,055	20,943	31,002

As is seen in the above, the differences between the two cases, Original and Alternative 3, are 1,374 MW and 8,420 GWh at the year 2005, respectively. Those figures are quite significant in the preparation of power expansion program on the basis of priority ranking study which is discussed in Section 14.5.

14.3 Existing and Planned Power Supply

14.3.1 Existing power plants

Existing power plants in Luzon Island owned by NPC are 11 hydropower, 10 oil-fired thermal, 2 geothermal and one coal-fired thermal as listed in Table 6.1. Installed capacity and actual energy production by power source are summarized as follows:

Source	Power (MW)	Energy (GWh)[1/]
Hydropower	1,226	2,869
Oil-fired	1,925	5,825
Geothermal	660	4,284
Coal-fired	300	1,471
Luzon Total	4,111	14,449

Remarks: 1/ Generation base (1985)

14.3.2 Committed power projects for implementation

According to the Power Development Program (30 May, 1986) by NPC, several power plants are going to be installed in Luzon Grid during ten years up to the year 1995, which includes two hydropower plants, three coal-fired, and one geothermal plant as shown in Tables 6.10 and 6.11. Planned power and energy increment expected by these plants are presented as below:

Source	Power (MW)	Energy (GWh)
Hydropower	291	1,533
Geo-thermal	110	751
Coal-fired	600	3,664
Total	1,001	5,948

14.3.3 Retirement of power plant

Several existing oil-fired thermal plants are scheduled to be retired after 1995 as shown in Table 6.12. As for hydroelectric plant, Caliraya and Botocan are assumed to be retired in 1995 and 1998, respectively, considering assumed project life of 50 years in the priority ranking study, although its retirement is not considered in the Power Development Program by NPC. Accordingly, installed capacity and energy production of plants assumed to be retired in the study are summarized by year as follows:

Year	Power (MW)	Energy (GWh)
1995	132.0	484.1
1996	100.0	411.7
1997	-	-
1998	167.0	656.1
1999	-	-
2000	200.0	823.4
2001	200.0	823.4
2002	375.0	1,544.0
2003	-	-
2004	300.0	1,235.2
2005	-	-
Total	1,474.0	5,977.9

Remarks: (1) Retirement schedule was slightly modified based on assumed project life

(2) Energy production was estimated based on the assumed plant factor described in succeeding section

(3) No retirement was considered until the year 1994.

14.4 Candidates for Priority Ranking Study

As candidates for the priority ranking study, four kinds of power generation sources were considered. These are, hydropower, geothermal, coal-fired thermal and oil-fired thermal plants. Nuclear power plant was not taken into consideration in line with the policy of the Government of Philippines.

14.4.1 Hydropower sources

Promising hydropower schemes which passed the second screening evaluation are 45 schemes in total including F/S completed projects, as was discussed in Chapter XIII. All of them are candidates for future installation to be evaluated in the priority ranking study. It is not known yet what candidates will be incorporated in the future power expansion program, however, it is presumed the schemes with rather small installed capacity may not have a chance to be incorporated judging from the big scale requirement of new installation for the latter ten years starting 1995.

14.4.2 Alternative power sources

The alternative power plants considered for the priority ranking study are:

(1) Coal-fired thermal plant

(2) Oil-fired thermal plant, and

(3) Geothermal plant.

Oil-fired thermal plant is still being considered as it is, however, new installation was not considered in line with the energy policy of the Government. As to the geothermal plant and coal-fired thermal plant, the candidates are not known yet at where those plants will be constructed. Then the size of candidates was only chosen in consideration of total installed capacity to be added newly during the study horizon.

The capital and running cost of alternative power plants were estimated at price level of end-1985, based on the data presented by NPC. Construction period considered is 5 years for both the alternative power sources judging from the size to be added.

Considering the above, the following alternative power sources were chosen as candidates for the priority ranking study:

Candidate	Installed Capacity (MW)	Const. Cost ($/kW)	O&M Cost ($/kWh)	Const. Period(yrs)
Coal-thermal	300 (300 x 1)	1,200	24	5
	600 (300 x 2)	1,200	24	5
Geothermal	330 (55 x 6)	1,500	30	5

14.5 Priority Ranking Study

14.5.1 Study methodology

The present worth method was applied for the economic analysis to find the optimum power expansion program. The capital, and operation and maintenance costs for constructing power plants for a time period were counted as the cost. The costs required for construction do not vary since it is independent of the benefits and power revenue, provided that the power and energy demand are given. The cost is only one parameter to be considered in the economic evaluation of power expansion program. The most economically feasible combination of power units added to the system in a series is defined to minimize the present worth of total capital, operation and maintenance costs of power plants to be newly installed under conditions and constraints given.

The objective mentioned above can be mathematically expressed as follows:

$$\mathrm{MIN}\ [\ \sum_{x=1}^{3} \sum_{j=1}^{T} f_{xj}(s_{xj}) + \sum_{k=1}^{k=T*} \sum_{j=0}^{j=k} \sum_{x=1}^{3} g_{xjk}(t_{xjk})\ ] \qquad (14.1)$$

where,

s_{xj} : power scale of type-x added to the system on j year

s_{x0} : (j=0) means the total installed capacity of existing plants

t_{xjk} : annual energy outputs from type-x on j year

f_{xj} : present worth of capital cost

g_{xjk} : present worth of operation and maintenance costs
j : time, $j = 1, 2, 3, \ldots\ldots, T$
k : time, $k = 1, 2, 3, \ldots\ldots, T^*$
x : type of power plant (3 different types were considered)
T : investment horizon
T^* : planning horizon

(1) Type of powr plants

(i) Coal-fired

(ii) Geothermal

(iii) Hydropower

(2) Constraints for objective function

The objective function is subject to the constraints on power and energy requirements as follows:

$$\sum_{x=1}^{x=x} \{ \sum_{j=0}^{j=j} s_{xj} \} \geq X_j \tag{14.2}$$

$$\sum_{x=1}^{x=x} \{ \sum_{j=0}^{j=j} t_{xjk} \} \geq Y_j \tag{14.3}$$

where, X_j and Y_j is the peaking power and annual energy requirements on j year, respectively.

14.5.2 Conditions of study

(1) Existing plants and committed projects

The power and energy supply capacity of the existing each plant was assumed to be same as it is throughout the study period. Supply capacities by power source described in Paragraph 14.3.1 were applied taking account of the retirement of plant discussed in Paragraph 14.3.3.

The project under construction and committed were added to the power supply system in the commissioning year as scheduled. Commission year and supply capacity to be added are presented in Tables 6.10 and 6.11, as well as in Paragraph 14.3.2.

(2) New installation of power plant

Power and energy demand discussed in Section 14.2 was assumed to be that at the beginning of each year. To meet power and energy requirement on a year, it was assumed that installation and commissioning have to be made by the end of the preceding year. Basically, a newly installed project has to meet the increments of power and energy requirements for one or several considering the reality of construction and financial budget problems.

(3) Construction period and lead time

The necessary construction period and estimated cost disbursement schedule applied in the study are shown as below:

Plant Type	Construction Period (years)	Disbursement (%)
Hydropower		
Construction cost < US$1.0 x 10^9	4	20/30/30/20
Construction cost ≥ US$1.0 x 10^9	5	15/25/30/20/10
Coal-fired	5	5/25/40/20/10
Geothermal	5	5/25/40/20/10

The typical lead time required for pre-construction stage was determined according to the present study level of each project. The necessary period for each study was assumed as follows:

Feasibility study	: 2 years
Detailed design	: 1 or 2 years
Finance	: 1 year
Tender/Contract	: 1 year

The time period of detailed design was assumed to be two years for the most of projects, however the detailed design for coal-fired thermal plant was assumed to require for a year in case of plant capacity of 300 MW or less.

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(4) Plant factor

Plant factor of existing plants and candidates was assumed to be same by plant type throughout the planning horizon, excluding hydropower plants. The assumption was based on the actual generating record and the Power Development Program by NPC, as follows:

- Coal fired	0.70
- Geothermal	0.73
- Oil fired	0.47

As for hydropower plant, same plant factor of 0.26 was assumed for the existing plants, while different plant factors were applied for the other committed projects and the candidates. For the candidates, an estimated plant factor was based on the assumption that the annual energy production by a plant counted 70% of secondary energy in addition to the firm energy.

(5) Economic evaluation

Economic evaluation parameters applied in the priority ranking study were:

Base year	1985
Investment horizon	1986 thru 2005
Planning horizon	1986 thru 2035
Discount rate	12%
Cost escalation	0%

14.5.3 Optimizing procedure of development sequence

Free competition of several kinds of power source for orderly development by the present worth of total costs related may result in unbalanced share of power generation sources in case that some of the alternatives are not competitive with others from point of view of energy cost.

The study aimed to find the appropriate and optimum sequence through several procedure including the mathematical simulation.

(1) Share of hydropower plant

Appropriate ratio of hydropower plants to the total installed capacity at the year 2005 was assumed for the range between 30% and 40% taking well balanced power generation into account.

(2) Share of geothermal plant

Geothermal power generation have been regarded as the alternative power source of oil-fired thermal plants which will be retired by the target year 2005. Total capacity of retired oil-thermal plant will be 1,425 MW during investment horizon.

As was discussed in Paragraph 14.4.2, installed capacity of a geothermal candidate to be considered is 330 MW (55 MW x 6). To meet the assumed requirement for geothermal plant, three or four plants, 990 MW to 1,320 MW in total, were assumed to be constructed by the target year 2005.

(3) Installation until the year 1995

Several power plants are scheduled to be installed during ten years from 1986 until 1995 according to the Power Development Program by NPC. After establishment of this program, NPC has updated power and energy demand forecast in Nov. 1986 which exceeds scheduled supply capacity in the said program.

Priority ranking study was actually made for eleven years from the year 1995 to 2005, without any modification of development program by NPC up to the year 1994. As for the year 1995, new installation besides the commissioning of the Casecnan Trans-basin Development was tried to meet the requirement of the year 1996.

(4) Combination of various type of power sources

The updated power demand forecast by NPC and three alternatives were considered as was discussed in Paragraph 14.2.2.

For each alternative case, various combination of power plants composed of the coal-fired and geothermal with some plant size were considered as alternatives among which optimum combination would be selected through the priority ranking study of hydropower development. The combinations were determined as presented in Table 14.1, taking account of power generation balance at the year 2005. The combination was selected incorporating the consideration that installation of same type of thermal plant will be made intermittently as far as possible, say, one or two years interval.

(5) Typical installation series

For each alternative of combination of thermal plants set forth in Table 14.1, a typical installation timing was conceived for the coal-fired and geothermal plants. Those installation series were programmed taking account of following conditions:

(i) not to produce excessive energy which was critical requirement in the study,

(ii) to be appropriate arrangement in technical and financial view points,

(iii) to be covered by thermal plant for much increment of energy requirement during investment horizon, and

(iv) to give a higher priority on installation timing to the geothermal plant than coal-fired considering cheaper energy cost of geothermal plant.

(6) Least cost development sequence

Among the alternatives described in the preceding paragraphs, the optimum development sequence of hydropower development was examined using the simulation model described in paragraph 14.5.2. The evaluation parameters obtained by the simulation are summarized in Table 14.2. The total present worth of capital, operation and maintenance cost was estimated at the year 1985 which is a base year of this study.

Furthermore, the optimum least cost development sequence by each alternative case was confirmed by means of comparison between some other arrangement of thermal plant installation timing.