(2) Distribution Map of Limestone Deposits

A distribution map of limestone deposits is shown below.

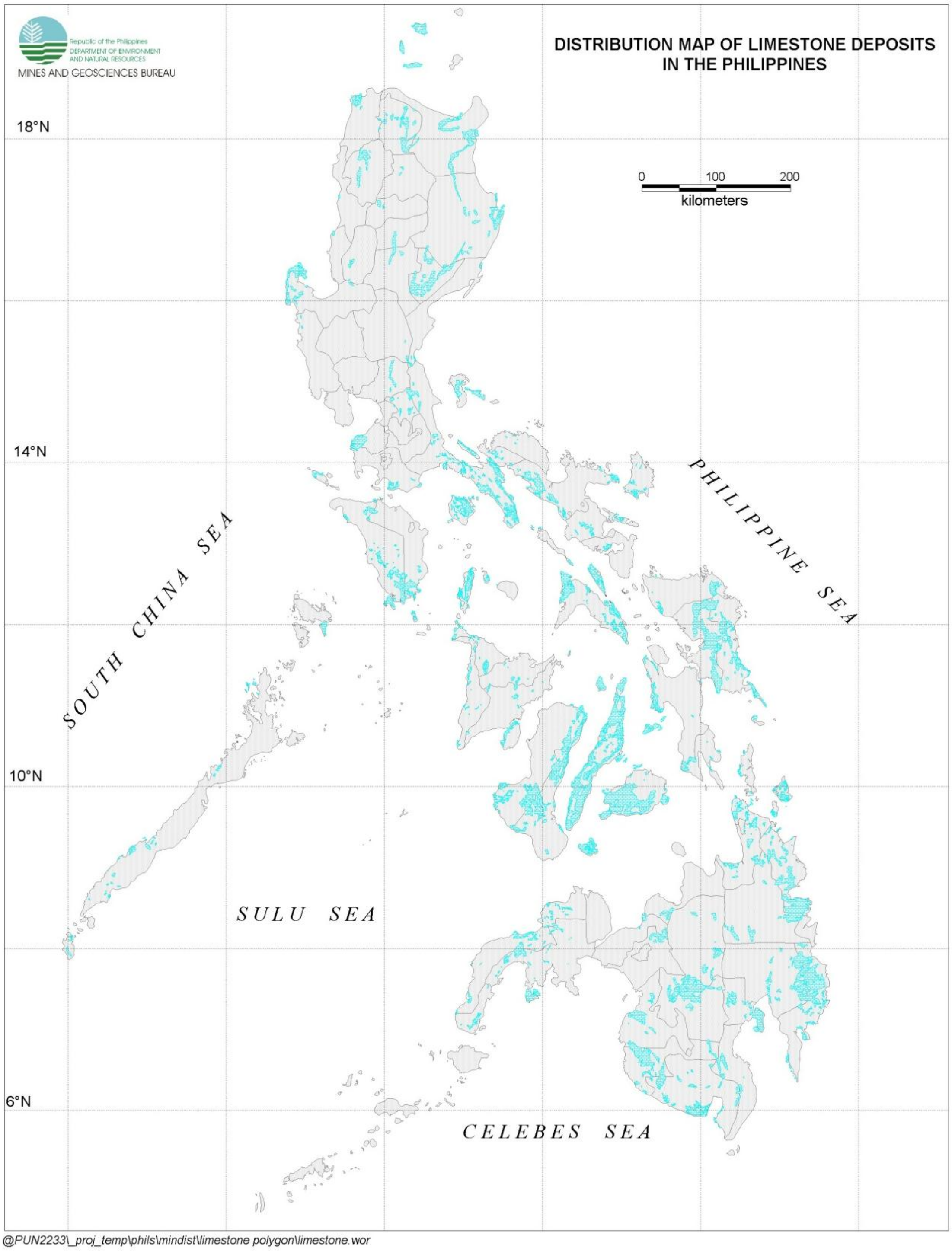


Fig. 4.8-2 Distribution Map of Limestone Deposits

Source: MGB

(3) Distribution of Active Faults

The active faults map used in this study is shown below.

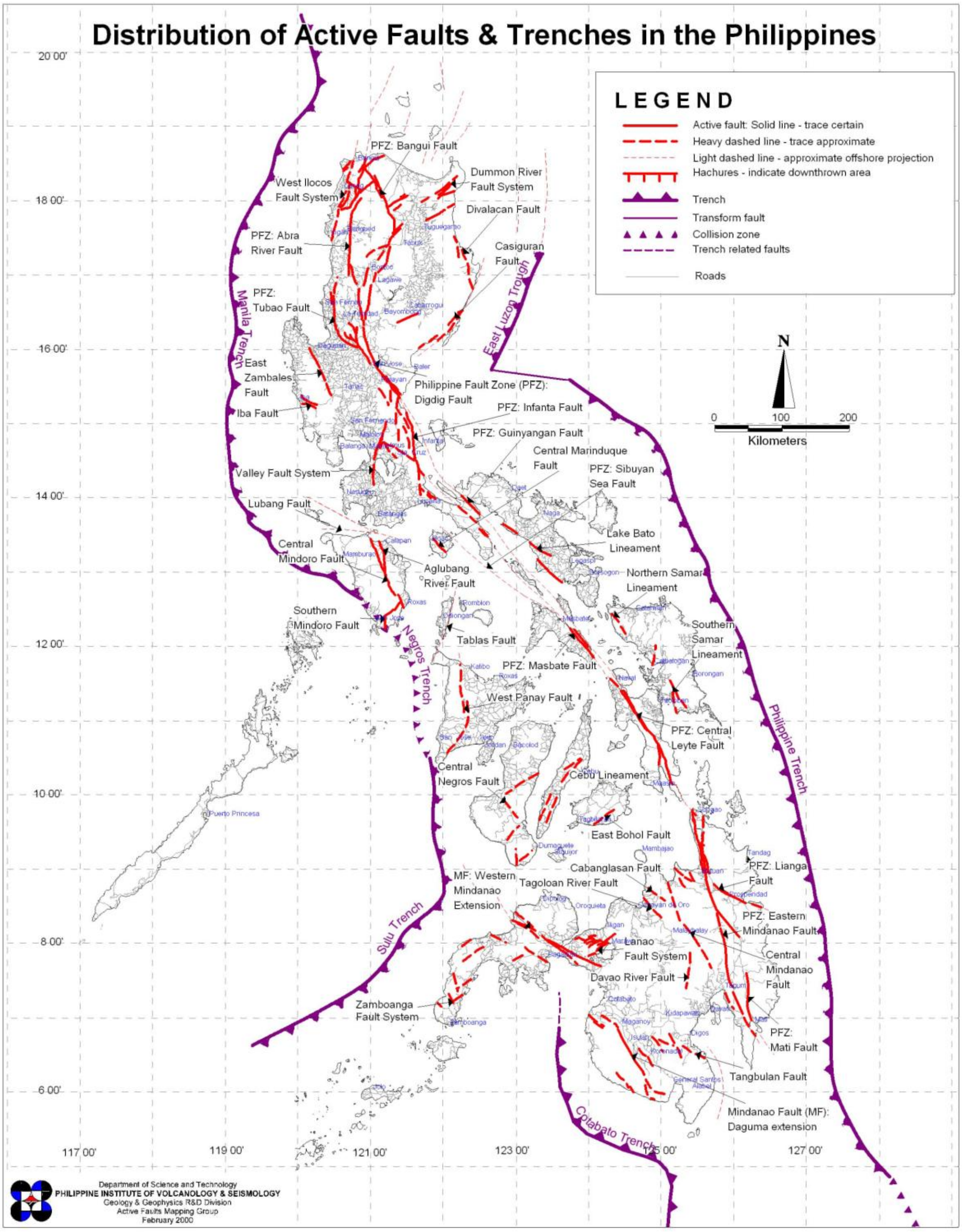


Fig. 4.8-3 Distribution of Active Faults

Source: PHIVOLCS (Philippine Institute of Volcanology and Seismology)

(4) Distribution of Volcanoes

The volcano map and list of active volcanoes used in this study are shown below.

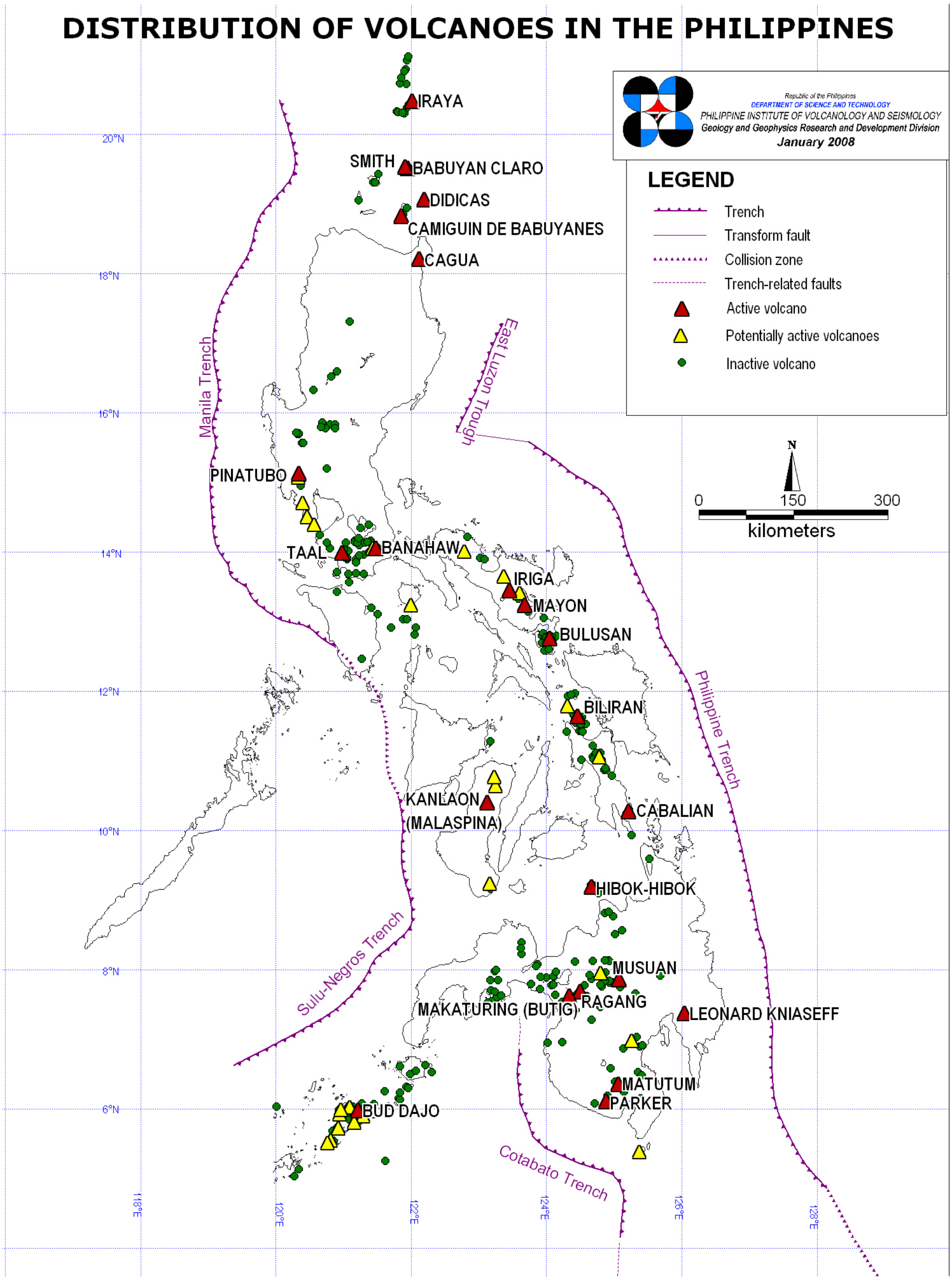
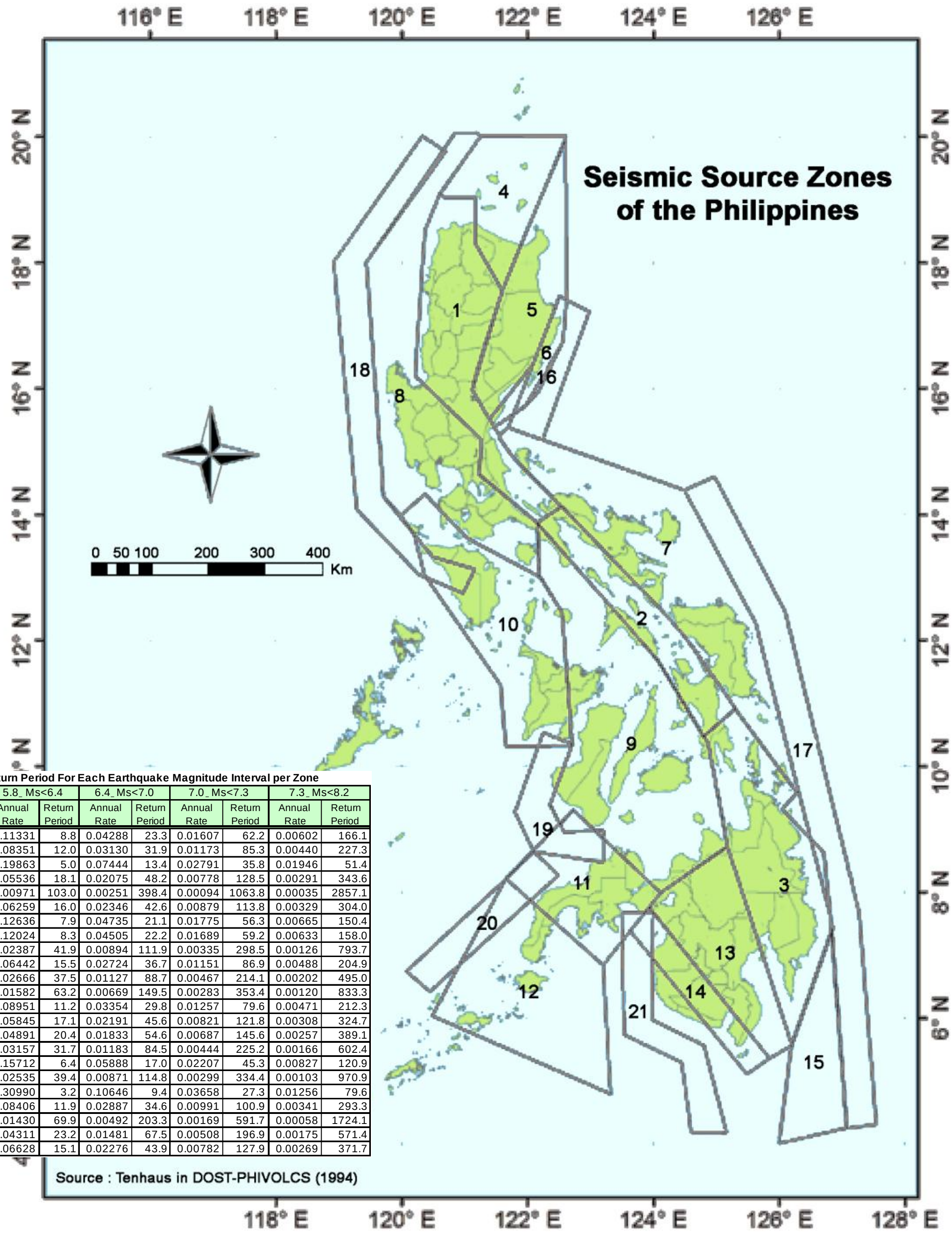


Fig. 4.8-4 Distribution of Active Volcanoes

Source: PHIVOLCS

(5) Seismic Source Zones

A map of seismic source zones of the Philippines is shown below.



Annual Rates and Return Period For Each Earthquake Magnitude Interval per Zone

Zone	5.2_ Ms<5.8		5.8_ Ms<6.4		6.4_ Ms<7.0		7.0_ Ms<7.3		7.3_ Ms<8.2	
	Annual Rate	Return Period	Annual Rate	Return Period	Annual Rate	Return Period	Annual Rate	Return Period	Annual Rate	Return Period
1	0.30526	3.3	0.11331	8.8	0.04288	23.3	0.01607	62.2	0.00602	166.1
2	0.22282	4.5	0.08351	12.0	0.03130	31.9	0.01173	85.3	0.00440	227.3
3	0.52997	1.9	0.19863	5.0	0.07444	13.4	0.02791	35.8	0.01946	51.4
4	0.14769	6.8	0.05536	18.1	0.02075	48.2	0.00778	128.5	0.00291	343.6
5	0.01789	55.9	0.00971	103.0	0.00251	398.4	0.00094	1063.8	0.00035	2857.1
6	0.16699	6.0	0.06259	16.0	0.02346	42.6	0.00879	113.8	0.00329	304.0
7	0.33713	3.0	0.12636	7.9	0.04735	21.1	0.01775	56.3	0.00665	150.4
8	0.32081	3.1	0.12024	8.3	0.04505	22.2	0.01689	59.2	0.00633	158.0
9	0.06367	15.7	0.02387	41.9	0.00894	111.9	0.00335	298.5	0.00126	793.7
10	0.15240	6.6	0.06442	15.5	0.02724	36.7	0.01151	86.9	0.00488	204.9
10a	0.06307	15.9	0.02666	37.5	0.01127	88.7	0.00467	214.1	0.00202	495.0
10b	0.03743	26.7	0.01582	63.2	0.00669	149.5	0.00283	353.4	0.00120	833.3
11	0.23881	4.2	0.08951	11.2	0.03354	29.8	0.01257	79.6	0.00471	212.3
12	0.15595	6.4	0.05845	17.1	0.02191	45.6	0.00821	121.8	0.00308	324.7
13	0.13050	7.7	0.04891	20.4	0.01833	54.6	0.00687	145.6	0.00257	389.1
14	0.08423	11.9	0.03157	31.7	0.01183	84.5	0.00444	225.2	0.00166	602.4
15	0.41920	2.4	0.15712	6.4	0.05888	17.0	0.02207	45.3	0.00827	120.9
16	0.07380	13.6	0.02535	39.4	0.00871	114.8	0.00299	334.4	0.00103	970.9
17	0.90212	1.1	0.30990	3.2	0.10646	9.4	0.03658	27.3	0.01256	79.6
18	0.24471	4.1	0.08406	11.9	0.02887	34.6	0.00991	100.9	0.00341	293.3
19	0.04165	24.0	0.01430	69.9	0.00492	203.3	0.00169	591.7	0.00058	1724.1
20	0.12550	8.0	0.04311	23.2	0.01481	67.5	0.00508	196.9	0.00175	571.4
21	0.19292	5.2	0.06628	15.1	0.02276	43.9	0.00782	127.9	0.00269	371.7

Fig. 4.8-5 Seismic Source Zones of the Philippines

Source: "Mainstreaming Disaster Risk Reduction in Subnational Development and Land Use/Physical Planning in the Philippines", National Economic and Development Authority, United Nations Development Programme, European Commission Humanitarian Aid, 2008

(6) Seismic History

The seismic history (Magnitude ≥ 4.0) of the Philippines over the last 50 years (1960-2010) is shown below.

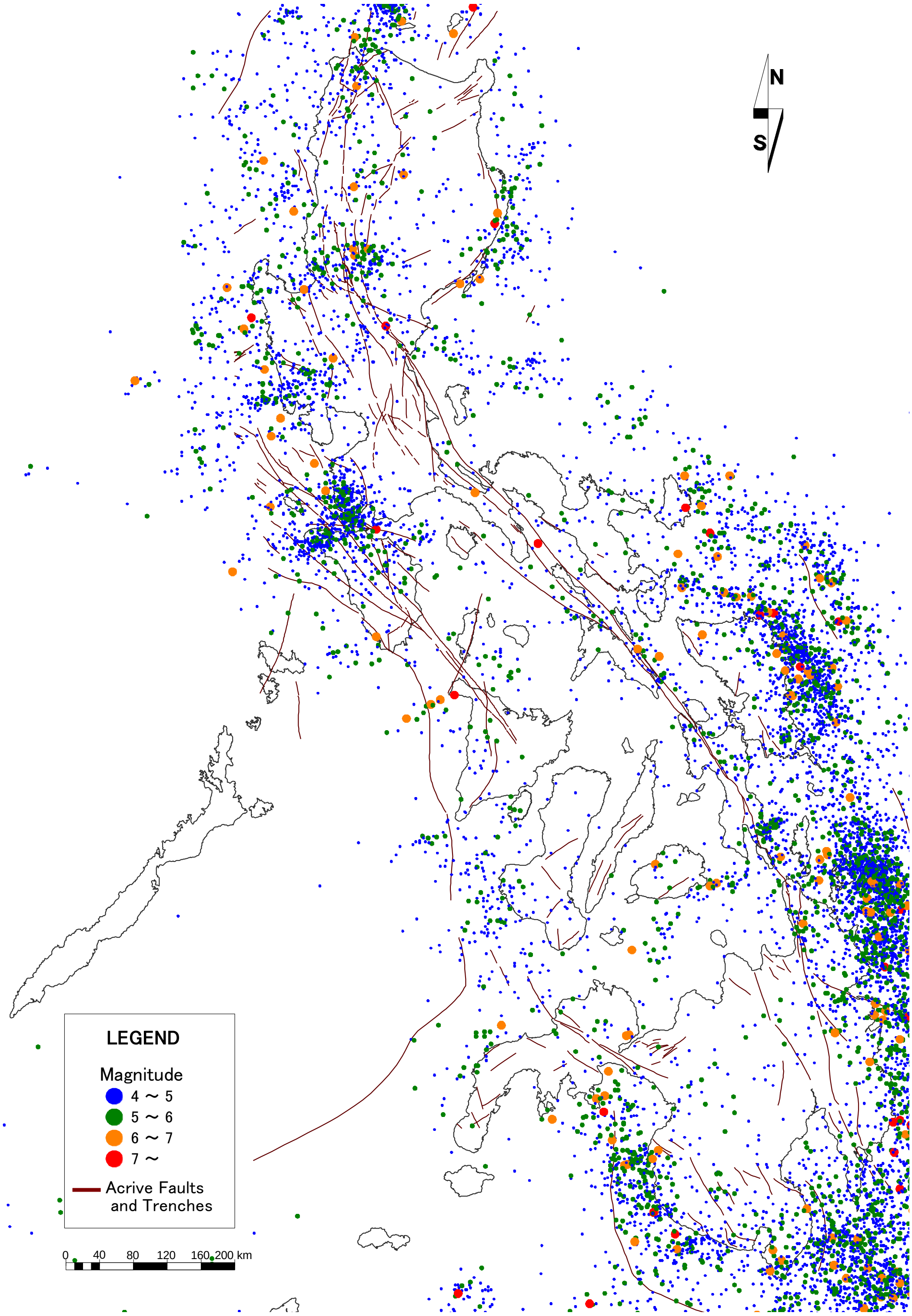


Fig. 4.8-6 Seismic History (Magnitude ≥ 4, 1960-2010)

Source: USGS (United States Geological Survey)

(7) Distribution of Mineral Deposits

As for mineral deposits, the distributions of metallic mineral and non-metallic mineral deposits are shown below.

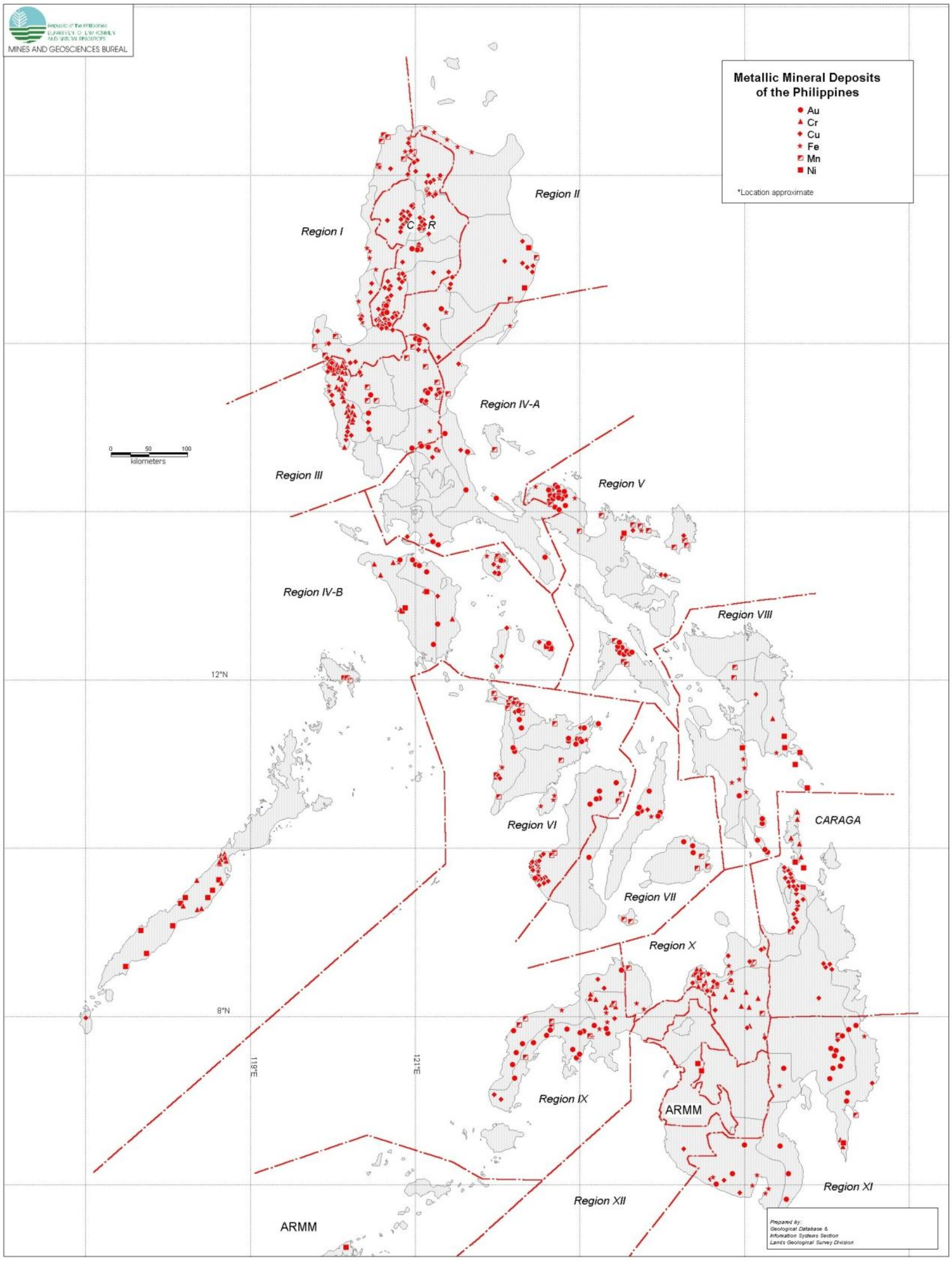


Fig. 4.8-7 Metallic Mineral Deposits of the Philippines

Source: MGB

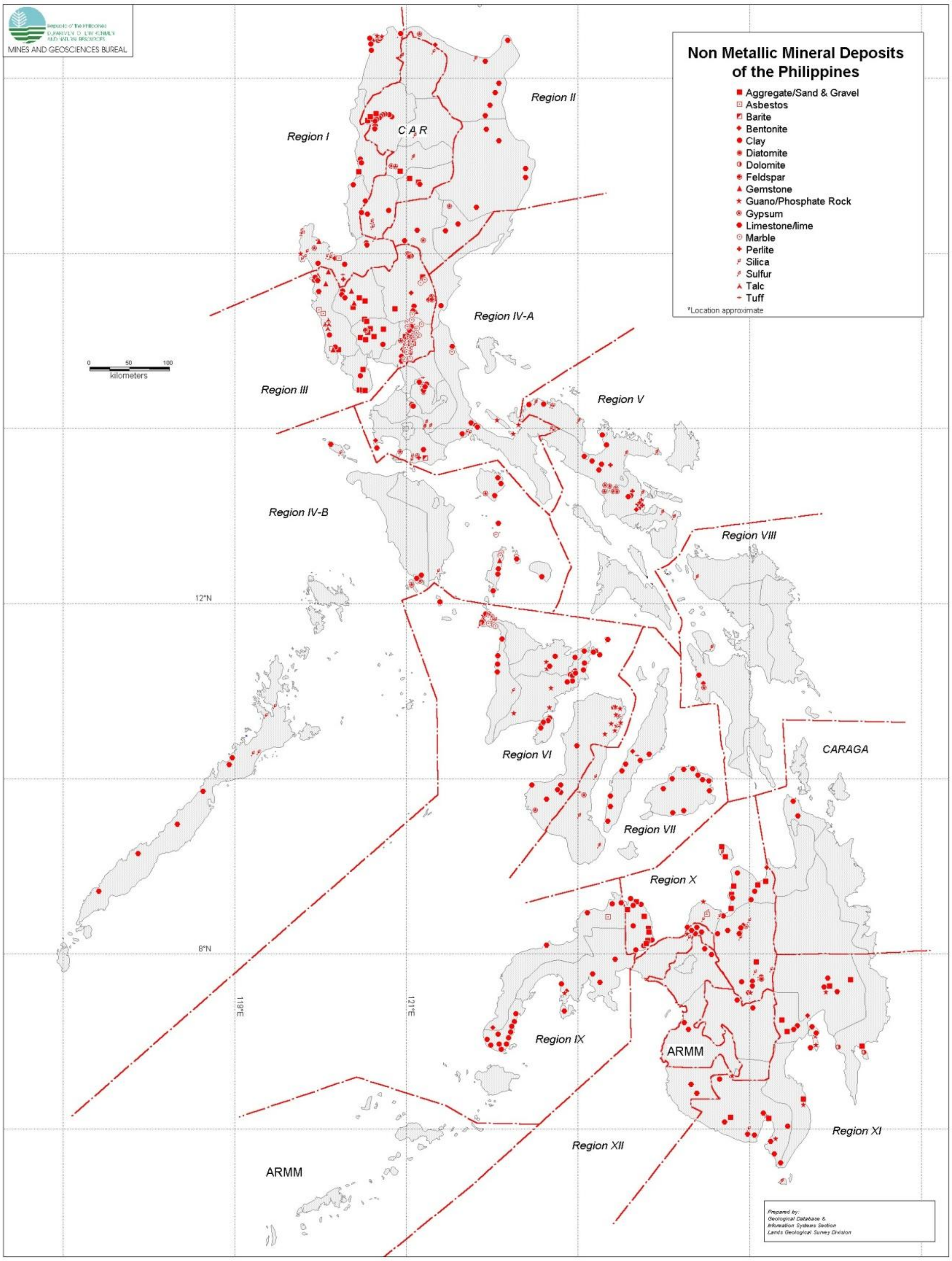


Fig.4.8-8 Non-metallic Mineral Deposits of the Philippines

Source: MGB

4.9 ENVIRONMENTAL IMPACT ASSESSMENT

4.9.1 Policy

In this study, components of environmental impact are scoped to collect necessary GIS data with reference to the IEE (Initial Environmental Examination) checklist. In hydropower development, natural and social environmental components to be scoped are as follows[1].

1) Land cover and vegetation distribution
2) Distribution of endangered plants and animals
3) Biological diversities
4) Other nature or landscape conservation area
5) Community distribution and habitat of indigenous people
6) Natural disaster area suffering from volcanic activities, geological hazard, etc.
7) Historical constructions or cultural heritages

Areas with the above features of 1) to 4) have been comprehensively evaluated and integrated under the NIPAS (National Integrated Protected Areas System Act of 1992), and the National Integrated Protected Areas are designated as nature conservation areas.

Item 5) is administered by the NCIP (National Comission on Indigenous People). As for item 6), disaster areas suffering from active volcanos have a negative impact on hydropower development sites. Geological hazards such as landslides are evaluated after the scoping of each project site because of small and limited impact.
Therefore, as components of environmental impacts for screening hydropower development as shown in Fig.4.9-1, GIS data includes nature conservation areas, communities and habitats of indigenous people, and active volcanoes. GIS data of these components has been collected and prepared at the sites, and saved in the GIS after analysis.

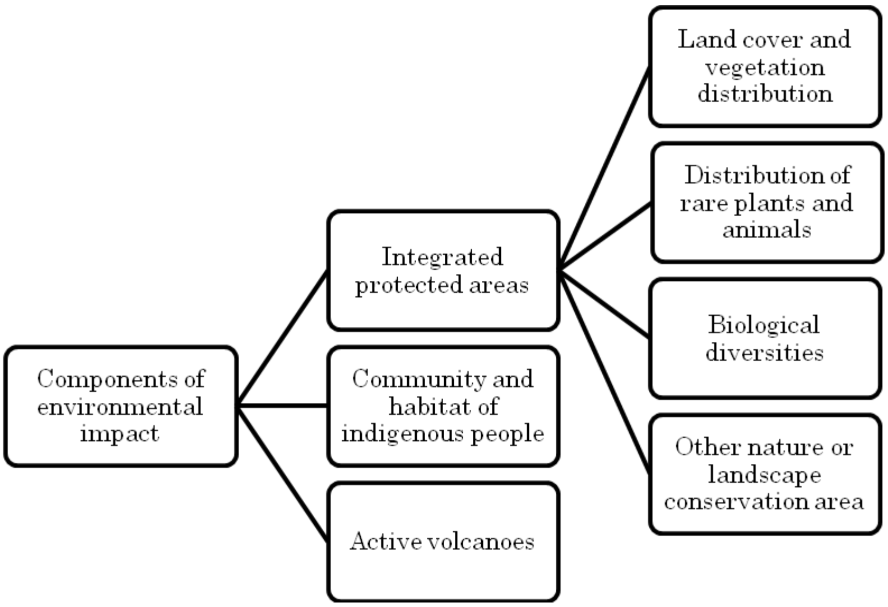


Fig. 4.9-1 Components of Environmental Impact for Screening Hydropower Development

1 Table 2a. List of Environmentally Critical Areas, ANNEX 2-1a, DAO 2003-30

4.9.2 Nature Conservation Areas

The NIPAS was enacted to establish and manage the National Integrated Protected Areas System, in which specific protected areas are designated.

"Section 2 Declaration of Policy" states as follows.

Cognizant of the profound impact of man's activities on all components of the natural environment particularly the effect of increasing population, resource exploitation and industrial advancement and recognizing the critical importance of protecting and maintaining the natural biological and physical diversities of the environment notably in areas with biologically unique features to sustain human life and development, as well as plant and animal life, it is hereby declared the policy of the State to secure for the Filipino people of present and future generations the perpetual existence of all native plants and animals through the establishment of a comprehensive system of integrated protected areas within the classification of national park as provided for in the Constitution.

It is hereby recognized that these areas, although distinct in features, possess common ecological values that may be incorporated into a holistic plan representative of our natural heritage; that effective administration of these areas is possible only through cooperation among the national government, local government and concerned private organizations; that the use and enjoyment of these protected areas must be consistent with the principles of biological diversity and sustainable development.

To this end, there is hereby established a NIPAS, which shall encompass outstanding remarkable areas and biologically important public lands that are habitats of rare and endangered species of plants and animals, bio-geographic zones and related ecosystems, whether terrestrial, wetland or marine, all of which shall be designated as protected areas.

"Section 3 Categories" states as follows.

The following categories of protected areas are hereby established:

- a. *Strict nature reserve;*
- b. *Natural park;*
- c. *Natural monument;*
- d. *Wildlife sanctuary;*
- e. *Protected landscape and seascape;*
- f. *Resource reserve;*
- g. *Natural biotic area, and;*
- h. *Other categories established by law, conventions or international agreements which the Philippine Government is a signatory.*

"Section 12 Environmental impact Assessment" states as follows.

Proposals for activities that are outside the scope of the management plan for protected areas shall be subject to an environmental impact assessment as required by law before they are adopted, and the results thereof shall be taken into consideration in the decision-making process. No actual implementation of such activities shall be allowed without the required Environmental Compliance Certificate (ECC) under the Philippine EIA (Environment Impact Assessment) system. In instances where such activities are allowed to be undertaken, the proponent shall plan and carry them out in such manner as will minimize any adverse effects and take preventive and remedial action when *appropriate. The proponent shall be liable for any damage due to lack of caution or indiscretion.*

Nature conservation areas, which were designated before/after the NIPAS in 1992, are shown in Fig. 4.9-2. The construction of a hydropower plant in these areas is not prohibited by law, but it requires parliamentary approval and needs time for that procedure. Actually, run-of-river type plants can be developed. In Panay of the NIPAS area, Villasiga Hydropower (8MW) is being constructed by a private developer, and Timbabban Hydropower (18MW) is being prepared for construction also by a private developer. In Palawan, Longogan Power Corporation has been permitted by the Palawanco Council for Sustainable Development (PSCD) to develop Longogan Hydropower (6.8MW) located in an environmental critical area. Hydropower sites located in nature conservation areas receive a lower valuation from the environmental point of view.

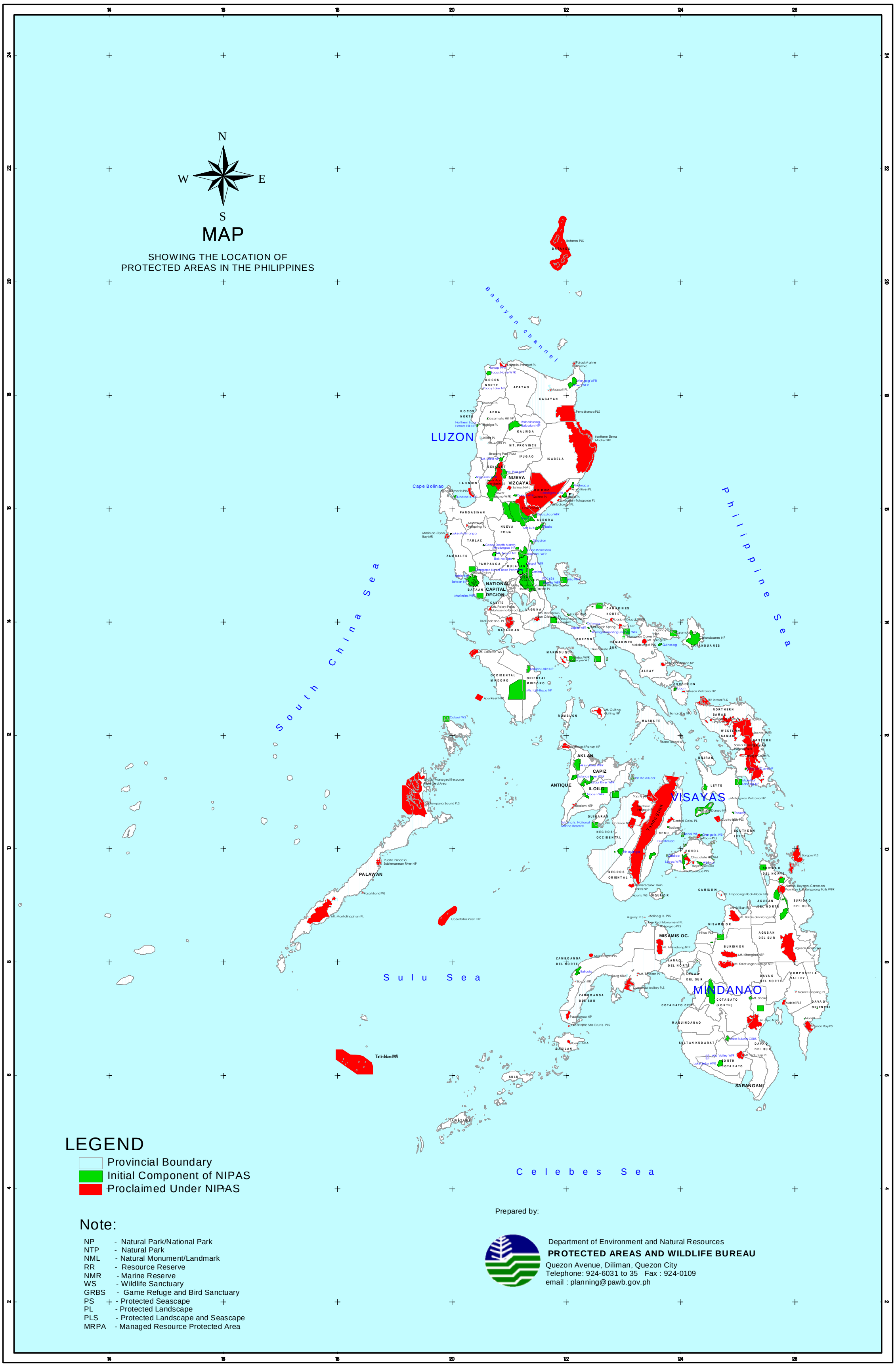
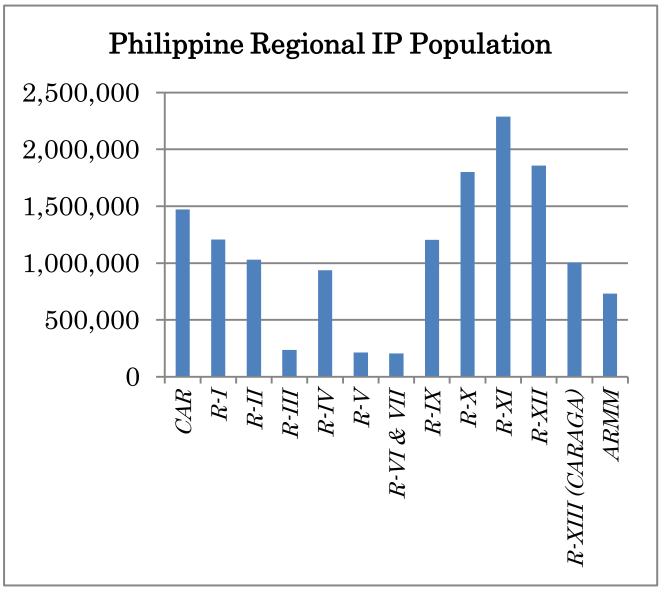


Fig. 4.9-2 Nature Conservation Areas

4.9.3 Communities and Habitats of Indigenous People[2]

There are 109 races identified as indigenous people in the Philippines. "Indigenous peoples" of the Philippines refer to a group of people or homogenous societies identified by self-ascription and ascription by others, who have continuously lived as an organized community on communally bounded and defined territory, and who have, under claims of ownership since time immemorial, occupied, possessed and utilized such territories, sharing common bonds of language, customs, traditions and other distinctive cultural traits, or who have, through resistance to political, Social and cultural inroads of colonization, non-indigenous religions and cultures, become historically differentiated from the majority of the Filipinos.

ICCs (Indigenous Cultural Communities)/IPs (Indigenous Peoples) likewise include peoples who are regarded as indigenous on account of their descent from populations that inhabited the country, at the time of conquest or colonization, or at the time of inroads of non-indigenous religions and cultures, or the establishment of present state boundaries, who retain some or all of their own social, economic, cultural and political institutions, but who may have been displaced from their traditional domains or who may have resettled outside their ancestral domains (Section 3 (h) R.A.8371).



Region	Population
CAR	1,470,977
R-I	1,206,798
R-II	1,030,179
R-III	236,487
R-IV	936,745
R-V	213,311
R-VI & VII	203,912
R-IX	1,203,598
R-X	1,802,266
R-XI	2,289,268
R-XII	1,856,300
R-XIII (CARAGA)	1,004,750
ARMM	730,054
TOTAL	14,184,645

Fig. 4.9-3 Philippine Regional IP (Indigenous Peoples) Population

The Philippine Regional IP Population as in Fig. 4.9-3, Ethnographic Map as in Fig.4.9-4, and Approved CADTs (Certification of Ancestral Domain Titles) / CALTs (Certification of Ancestral Land Titles) and Ancestral Domain/Ancestral Land Areas on Process as in Fig. 4.9-5 are shown below. Hydropower sites located in the habitats of indigenous people receive a lower evaluation from the environmental point of view.

[2] National Commission on Indigenous People, INFO KIT, provided in 2010 June.

Fig. 4.9-4 Ethnographic Map

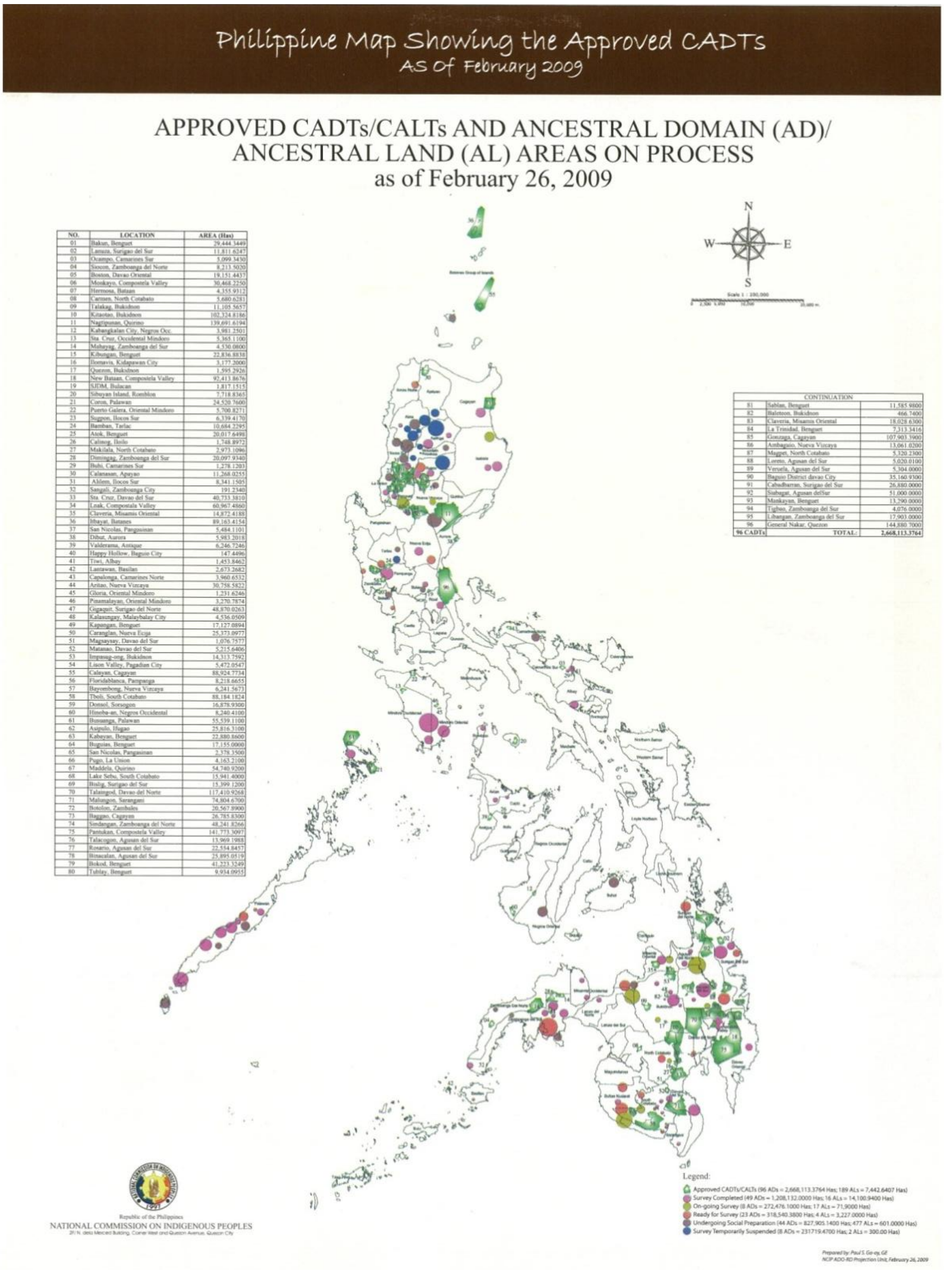


Fig. 4.9-5 CADTs/CALTs and Habitats of Indigenous People

4.9.4 Volcanic Activities

Volcano information in the Philippines is managed by PHIVOLCS. Volcanoes are classified into three categories, namely, active, dormant, and extinct according to the activity level. The classification is based on historical earthquake records in the past 500 years, activity records in the past 10,000 years, etc. It has been found that 23 volcanoes are active at the present, and 5 of them, including Mt. Pinatubo, are energetically active. A distribution map and basic information of active volcanoes are shown respectively in Fig. 4.9-6 and Table 4.9-1.

The hazard range of eruption is different among volcanoes. Mt. Pinatubo at present has the largest hazard range at 30 km in radius, while Mt. Canlaon has a range of 18 km in radius. In this study, hydropower sites located within a 30 km radius from the crater of a volcano are given a lower evaluation on the safe side from the environmental point of view.

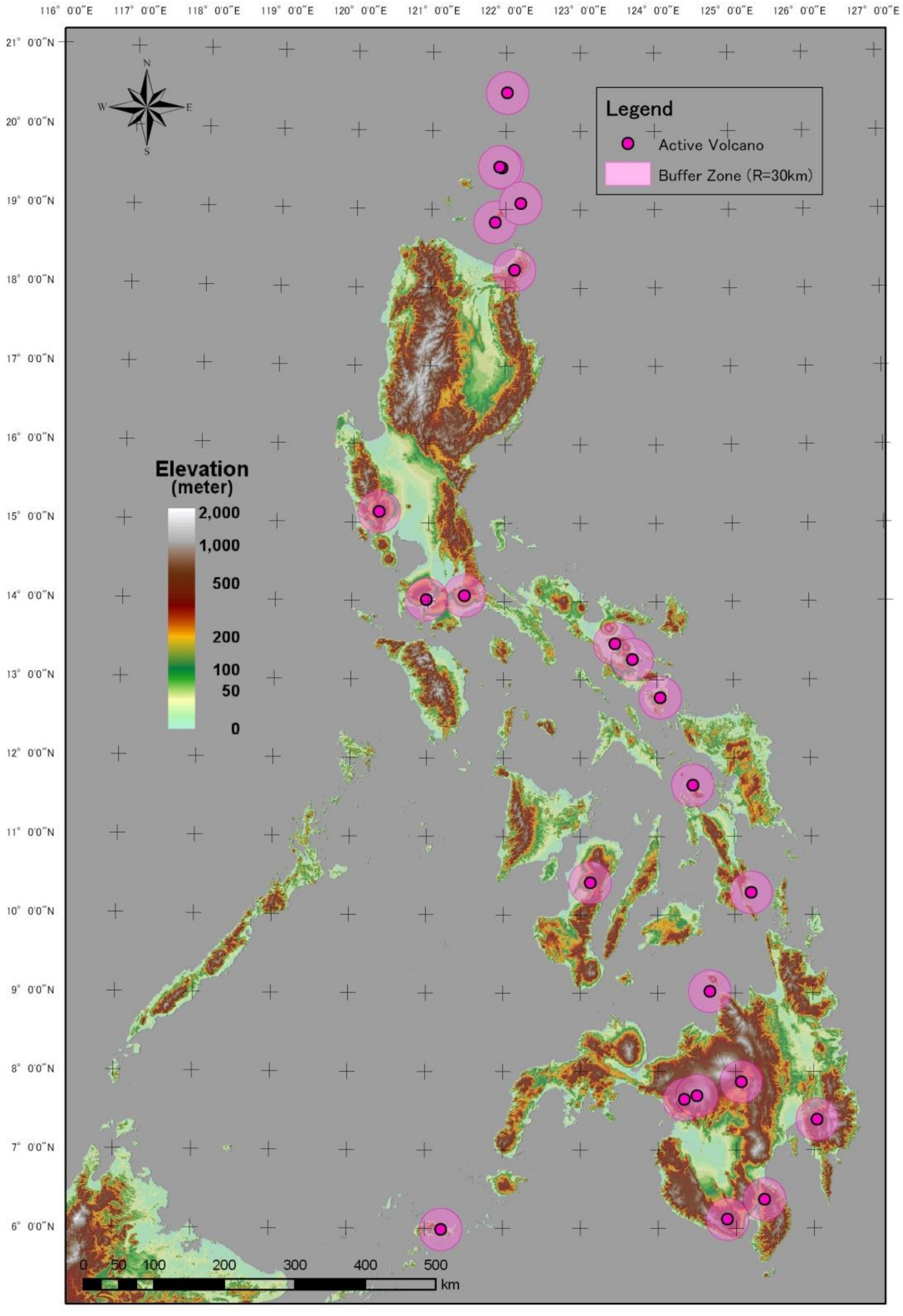


Fig. 4.9-6 Distribution Map of Active Volcanoes

Table 4.9-1 Basic Information of Active Volcanoes

No.	Name of Volcano	Lat (N)	Long (E)	Province	Region	Elevation (EL.m)	Number of Historical Eruptions	Latest Eruption / Activity
1	Babuyan Claro	19.525	121.95	Cagayan (Babuyan Islands)	2	843	4	1917
2	Banahaw Volcano Complex	14.067	121.483	Laguna, Quezon	4A	2169	3	1843
3	Biliran (Suiro)	11.65	124.467	Biliran	8	1340	1	Sept. 26, 1934
4	Bud Dajo	5.983	121.217	Sulu	ARRM	620	2	1897
5	Bulusan	12.77	124.05	Sorogon	5	1565	16	Mar.21, 2009 - Oct.4, 2007
6	Cabalian	10.281	125.214	Southern Leyte	8	945		135±30 years B.P. 14C age of charcoal found beneath pyroclasitic flow unit
7	Cagua	18.222	122.123	Cagayan	2	1160	2	1907
8	Camiguin de Babuyanes	18.833	121.86	Cagayan (Babuyan Islands)	2	712	1	1857
9	Didicas	19.077	122.202	Cagayan (Babuyan Islands)	2	228	6	Jan. 6-9, 1978
10	Hibok-Hibok	9.023	124.675	Camiguin	10	1332	5	Sept. 31, 1948 - Jul. 1953
11	Iraya	20.483	122.017	Batanes	2	1009	1	1454
12	Iriga	13.457	123.457	Camarines Sur	5	1143	2	Jan. 4, 1642
13	Kanloan	10.412	123.132	Negros Oriental	7	2435	26	Jun.3 - Jul. 25, 2006
14	Leonard Kniaseff	7.382	126.047	Compostela Valley	11	1080		1,800 years B.P. (Before Present)
15	Makaturing	7.642	124.342	Lanao del Sur	ARRM	1908	7	1882
16	Matutum	6.367	125.367	Cotabato	12	2286	1	Mar. 7, 1911
17	Mayon	13.257	123.685	Albay	5	2460	48	Nov. 11, 2009 - Jan. 6, 2010
18	Musuan	7.867	125.073	Bukidnon	10	646	2	1867
19	Parker	6.113	124.892	Cotabato	12	1784	1	Jan. 4, 1641
20	Pinatubo	15.133	120.35	Boundaries of Pampanga, Tarlac and Zambales	3	1445	2	Jul. 9 - Aug. 16, 1992
21	Ragang	7.692	124.505	Cotabato	12	2815	7	Jul. 1916
22	Smith	19.54	121.917	Cagayan (Babuyan Islands)	2	688	5	1924
23	Taal	14.017	120.985	Batanes	2	311	33	Oct. 3, 1977

Source: PHIVOLCS

4.10 BASIC DATA ON CONSTRUCTION COST

4.10.1 Unit Costs of Civil Works, Gates and Penstocks

In general, unit costs used for the preliminary study are estimated based on the unit costs of past similar hydroelectric power projects in the relevant country or neighboring countries.
Unit costs of main civil works, gates, screens and penstocks of similar hydroelectric power projects in Southeast Asian countries are summarized in Tables 4.10-1 and 4.10-2.

4.10.2 Unit Costs of Civil Works

(1) Unit Costs of Civil Works

The unit costs applied to this preliminary study are estimated based on the unit costs of past F/S, detailed designs, etc. in the Philippines and Southeast Asian countries.

Since 1:50,000 scale topographic maps are used for the preliminary study, preliminary quantities of structures are calculated by the formulae developed based on past similar construction records. The unit costs consist basically of major kinds of works such as excavations (open, tunnel), concrete and re-bar works. Preliminary construction costs are estimated by means of multiplying preliminary quantities by preliminary unit costs.

Kind of works	***Condition***	***Unit***	***Unit cost(US$)***
Intake Dam (Weir) Work Unit Cost			
Excavation	soil : rock=1 : 2	m^3	8.0
Concrete		m^3	100.0
Re-bar works		ton	1,200.0
Intake Work Unit Cost			
Excavation	Open, soil : rock=1 : 2	m^3	8.0
Concrete		m^3	140.0
Re-bar works		ton	1,200.0
Settling Basin Work Unit Cost			
Excavation	Open, soil : rock=2 : 1	m^3	6.0
Concrete		m^3	140.0
Re-bar works		ton	1,200.0
Headrace, Tributary Waterway Work Unit Cost			
Excavation	Open, soil : rock=2 : 1	m^3	6.0
Excavation	Tunnel	m^3	100.0
Concrete	Open	m^3	140.0
Concrete	Tunnel	m^3	140.0
Re-bar works		ton	1,200.0
Head Tank Work Unit Cost			
Excavation	soil : rock=2 : 1	m^3	6.0
Concrete		m^3	140.0
Re-bar works		ton	1,200.0
Surge Tank Work Unit Cost			
Excavation	rock	m^3	140.0
Concrete		m^3	140.0
Re-bar works		ton	1,200.0
Spillway Work Unit Cost			
Excavation	soil : rock=1 : 1	m^3	7.0

Kind of works	***Condition***	***Unit***	***Unit cost(US$)***
Concrete		m^3	100.0
Re-bar works	Open	ton	1,200.0
Penstock Work Unit Cost			
Excavation	Open	m^3	7.0
Concrete	Open	m^3	100.0
Re-bar works	Open	ton	1,200.0
Excavation	Tunnel	m^3	100.0
Concrete	Tunnel	m^3	100.0
Powerhouse Building			
Building volume		m^3	90.0
Powerhouse Foundation Work Unit Cost			
Excavation (Open)	soil : rock=2 : 1	m^3	6.0
Excavation (Semi-underground)	soil : rock=1 : 2	m^3	8.0
Excavation (Underground)	rock	m^3	70.0
Concrete (Open)		m^3	140.0
Concrete (Semi-underground)		m^3	140.0
Concrete (Underground)		m^3	140.0
Re-bar works (Open)		ton	1,200.0
Re-bar works (Semi-underground)		ton	1,200.0
Re-bar works (Underground)		ton	1,200.0
Outlet Work Unit Cost			
Excavation	soil : rock=2 : 1	m^3	6.0
Concrete		m^3	140.0
Re-bar works		ton	1,200.0
Temporary Roads			
Road type			
New Road	length	m	75.0
Road to be improved	length	m	35.0
New Bridge	length	m	4,000.0
Road Construction Unit Cost per m			
Road type			
New Road	length	m	150.0
Road to be improved	length	m	70.0
New Bridge	length	m	10,000.0
Fill Dam Work Unit Cost			
Excavation		m^3	8.0
Embankment		m^3	10.0
Flood Spillway Work Unit Cost			
Excavation		m^3	8.0
Concrete		m^3	100.0
Re-bar works		ton	1,200.0
Gate		ton	7,000.0
Gravity Dam Work Unit Cost			
Excavation		m^3	6.0
Concrete		m^3	100.0
RCC Concrete		m^3	50.0
Gate		ton	7,000.0

(2) Unit Costs of Metal Works

The unit costs of hydraulic equipment such as gates, screens, etc. and penstock steel pipes are estimated as below. The unit costs include costs of fabrication, transportation and installation.

Gate	: 7,000 US$ / ton
Screen	: 7,000 US$ / ton
Steel (Penstock)	: 4,000 US$ / ton
Steel (Spillway)	: 3,000 US$ / ton

4.10.3 Price of Water Turbines, Generators and Transmission Lines

(1) Price of Water Turbines and Generators

The equipment of a hydropower plant is specially designed and manufactured according to respective parameters such as head and water discharge determined by the site conditions and the equipment rating of each different power station. This design method is different from equipment for a thermal power plant or nuclear power plant. There is no standardized equipment for water turbines and generators, except for small equipment. That equipment is unique as it must be made to order, according to the conditions of each individual site. Therefore, the equipment price can be estimated by price approximation based on past price results in the preliminary study stage. Price approximation is studied and investigated as follows.

1) Price of water turbines

The approximations from past price records of water turbines are presented by various companies/institutes as follows.

a) Calculation method Ex. 1 (According to the "Standard of Construction Cost Estimation for Hydro-power Plan" published by the Agency of Natural Resources and Energy and the New Energy Foundation, Japan)

i. Construction cost for Pelton type turbine
$$Ct = 58.4 \times (P/\sqrt{H})^{0.694} \text{ Thousand US\$}$$

ii. Construction cost for Francis type turbine
$$Ct = 57.5 \times (P/\sqrt{H})^{0.589} \text{ Thousand US\$}$$

iii. Construction cost for Francis type turbine
$$Ct = 70.6 \times (P/\sqrt{H})^{0.562} \text{ Thousand US\$}$$

iv. Construction cost for Turgo impulse type turbine
$$Ct = 511.8 \times (P/\sqrt{H})^{0.14} \text{ Thousand US\$}$$

v. Construction cost for propeller type turbine (Tubular, Kaplan and diagonal type)
$$Ct = 42.5 \times (P/\sqrt{H})^{0.66} \text{ Thousand US\$}$$

vi. Construction cost for propeller type (inline type, submersible type) turbine (including generator)
$$Ct = 33.7 \times (P/\sqrt{H})^{0.588} \text{ Thousand USS}$$

Where, P : Power plant's total turbine output in kW, H : Head in m

b) Calculation method Ex. 2 (According to the "Guide Book for Middle and Small Scale Hydro Power") (Calculation formula of blanketed turbines/generators and other auxiliaries)

i. Construction cost of electro-mechanical equipment for a power plant with a Pelton turbine

$$Ct = 243.6 \times (P/\sqrt{H})^{0.612} \text{ Thousand US\$}$$

ii. Construction cost of electro-mechanical equipment for a power plant with a double runner Francis, diagonal or tubular turbine

$$Ct = 80.9 \times (P/\sqrt{H})^{0.725} \text{ Thousand US\$}$$

iii. Construction cost of electro-mechanical equipment for a power plant with a Francis, Kaplan or crossflow turbine

$$Ct = 116.4 \times (P/\sqrt{H})^{0.648} \text{ Thousand US\$}$$

Where, P : Power plant's total turbine output in kW, H : Head in m

c) **Calculation method Ex. 3** (According to the calculation formula by "A" electric power company, Japan and USBR)

The price of a Francis turbine is calculated by "A" company's method as follow.

$$Ct = 58.2 - 4.38\, ln(x) \text{ Thousand US\$/ton} \quad ①$$

(Where, $x = Pt\,max/\sqrt{H}$)

Turbine weight is calculated by the formula in "Selecting Hydraulic Reaction Turbine" by USBR is as follows.

$$w = 15.175\,(Dmax)^{2.33} \text{ (ton)} \quad ②$$

Where, $Dmax$: Biggest dimension of the runner diameter (m)

The biggest runner diameter is calculated as follow by the formula of the USBR.

$$Dmax = (1.782 \times H^{1/2} \times Ns^{2/3}) / N \text{ (m)} \quad ③$$

The price of Francis turbine can be obtained by substituting ③ for ② and substituting ② for ① in the following formula.

$$Ct = (58.2 - 4.38\, ln\, x) \times 15.175 \times [(1.782 \times H^{1/2} \times Ns^{2/3})/N]^{2.33} \text{ Thousand US\$}$$

d) Calculation method Ex. 4 (According to the calculation method by "B" electric power company, Japan)

The calculation formula by "B" electric power company is as follows.

i. Construction cost for Pelton type turbine

$$Ct = 61.0 \times (P/\sqrt{H})^{0.6102} \text{ Thousand US\$}$$

ii. Construction cost for Francis type turbine

$$Ct = 31.6 \times (P/\sqrt{H})^{0.6195} \text{ Thousand US\$}$$

iii. Construction cost for Kaplan type turbine

$$Ct = 20.2 \times (P/\sqrt{H})^{0.7138} \text{ Thousand US\$}$$

Where, P : Turbine unit output in kW, H : Head in m

Simplified expressions for calculating the construction cost for Pelton and Francis turbines are as follows according to the above study.

i. Construction cost for Pelton type turbine

$$Ct = 60.9 \times (P/\sqrt{H})^{0.61} \quad \text{Thousand US\$}$$

ii. Construction cost for Francis type turbine

$$Ct = 40.0 \times (P/\sqrt{H})^{0.589} \quad \text{Thousand US\$}$$

Where, P : Turbine unit output in kW, H : Head in m

iii. Construction cost for Tubular, Kaplan and diagonal type turbine

$$Ct = 29.8 \times (P/\sqrt{H})^{0.66} \quad \text{Thousand US\$}$$

iv. Construction cost for inline propeller type and submersible type turbine

$$Ct = 23.6 \times (P/\sqrt{H})^{0.588} \quad \text{Thousand US\$}$$

v. Construction cost for crossflow turbine

$$Ct = 49.5 \times (P/\sqrt{H})^{0.562} \quad \text{Thousand US\$}$$

vi. Construction cost for Turgo impulse type turbine

$$Ct = 358.3 \times (P/\sqrt{H})^{0.14} \quad \text{Thousand US\$}$$

Where, P : Power plant's total turbine output in kW, H : Head in m

2) Price of generators

The formulas for the preliminary cost estimate of generators are shown below.

a) Calculation method Ex. 1 (According to the "Standard of Construction Cost Estimation for Hydro-power Plan" published by the Agency of Natural Resources and Energy and the New Energy Foundation, Japan)

Construction cost for a generator according to this method is:

$$Cg = 21.7 \times (P/\sqrt{H})^{0.701} \quad \text{Thousand US\$}$$

Where, P : Power plant's total turbine output in kW, H : Head in m

b) Calculation method Ex. 2 (According to the calculation method by "A" electric power company, Japan)

The construction cost for a generator according to the method of "A" electric power company is calculated as follow.

$$Cg = 36.2 - 3.13\, ln(X) \text{ (Thousand US\$/ton)} \text{.... ①}$$

Where, $X = kVA / N$, kVA : Generator capacity (kVA),
N : Rotation number of generator

Total weight of a generator is as follows.

a. In case the turbine is a vertical Francis type (VF)

$$W_G = 16.02 \times (kVA/N)^{0.596} \text{ (ton)}$$

b. In case the turbine is a horizontal Francis type (HF)

$$W_G = 10.45 \times (kVA/N)^{0.537} \text{ (ton)}$$

The above generator weights (W_G) include the generator itself, AVR/Exciter, air cooler, lubrication system and auxiliary piping. Then, the construction cost of the generator can be calculated by substituting the generator weight into the above formula.

c) Calculation method Ex. 3 (According to the calculation method of "B" electric power company, Japan)

The construction cost for a generator according to the method of "B" electric power company is calculated as follow.

In case the generator is a synchronous type, (synchronous type is adopted for all sites)

$$Cg = 390.6 \times (kVA/N)^{0.5881} \quad \text{Thousand US\$}$$

Where, *kVA* : Capacity of a generator (kVA),
N : Rotation number of generator

Formula a) is a function with a parameter of $P/\sqrt{H}$, and the estimated cost is a very rough value. By the general method, with a formula having a function with a parameter of kVA/N, such as b) and c), the estimated cost is more accurate than Formula a).

A simplified expression for calculating the construction costs for a generator is as follow, according to the above study.

$$Cg = 390.9 \times (kVA/N)^{0.588} \quad \text{Thousand US\$}$$

If the above expression is adopted as the cost estimation formula, it becomes complicated to calculate, because the rotational speed must be calculated as a parameter.

Therefore, the rotational speed for only the calculation of the generator price, which is different from the actual speed, is temporarily determined, and then the generator price is calculated by using this value. This speed shall be 85% of one obtained from the limit of the specific speed.

Moreover, for expediency, it is assumed that 1.12 times the water turbine output is the generator capacity, though the capacity of a generator is actually calculated by multiplying the generator efficiency by the water turbine output and dividing by the generator power factor. (0.95 / 0.85 ≒ 1.12, when the generator efficiency is 95% and power factor is 0.85).

3) Price of other electro-mechanical items

The preliminary prices of other electro-mechanical items such as control equipment, overhead traveling cranes, switchgear and sometimes including inlet valves are considered as 30% of the total of the turbine and generator prices. Then, the total of all electro-mechanical items for the power plant is calculated roughly.

(2) Price of Transmission Lines

The unit costs of transmission lines in the Philippines are estimated by referring to unit costs per km by the NGCP as follows. The unit cost includes civil works such as the foundation of towers, assembling of towers, and installation of towers.

Type of Transmission Line	Unit Cost (US$/km)
69 kV	27,000.00
115 kV	35,000.00
230 kV	119,000.00

Table 4.10-1 Unit Construction Costs of Hydropower Projects in the Philippines

			Year	1985	Pre-F/S	1993	F/S	1997	F/S	2003	F/S	2004	M/P	2004	Pre-F/S	2006	F/S	2006	F/S	2007	F/S	Max	Min
Structure		condition	unit	PhP	US$	PhP	US$	PhP	US$	PhP	US$	PhP	US$	PhP	US$	PhP	US$	PhP	US$	PhP	US$	US$	US$
Dam																							
	Excavation	soil	m3	Fill dam	6.00		3.2											320.0	6.0			6.0	3.2
	Excavation	rock	m3	Concrete dam	8.00		11.6											850.0	16.0			16.0	8.0
				trench	12.00																	12.0	12.0
	Embankment	earth	m3	earthfill dam	8.00	earth/random fill	4.1															8.0	4.1
	Embankment	rockfill		rockfill dam	12.00	rockfill	11.4															12.0	11.4
	Backfill	normal	m3															213.0	4.0			4.0	4.0
	Backfill	compacted	m3															425.0	8.0			8.0	8.0
	Backfill		m3																				
	Concrete	Class A	m3															6,000.0	112.7			112.7	112.7
	Concrete	Fill	m3																80.0			80.0	80.0
	Re-bar		kg															62.0	1.2			1.2	1.2
	Re-bar	concrete crest	kg																				
Weir																							
	Excavation	soil	m3						4.9	67	1.34	136.00	2.52	80.0	1.50					70.00	1.58	4.9	1.3
	Excavation	rock	m3						7.3	453	9.06			279.0	5.20					417.00	9.41	9.4	5.2
	Embankment	earth	m3						9.8											86.00	1.94	9.8	1.9
	Backfill	normal	m3																				
	Backfill	compacted	m3											55.0	1.00							1.0	1.0
	Backfill		m3																				
	Concrete	Reinforcement	m3						73.7	2,920.00	58.40	2,712.00	50.22	4,300.0	79.60		100.0					100.0	50.2
	Concrete	Lean	m3						46.0													46.0	46.0
	Concrete	Mass	m3						59.9														
	Re-bar		ton						608.9	34,900.00	698.00	30,900.00	572.22	33,823.0	626.40		1,160.0			60,000.00	1,354.40	1,354.4	572.2
Intake/Settling basin																							
	Excavation	soil	m3						4.9	67	1.34	136.00	2.52	80.0	1.50		6.0					6.0	1.3
	Excavation	rock	m3						7.3	453	9.06			279.0	5.20		16.0					16.0	5.2
	Concrete	Reinforcement 3000psi	m3						73.7	2,920.00	58.40	3,134.00	58.04	4,300.0	79.60		100.0			5,404.00	121.99	122.0	58.0
	Concrete	Reinforcement 2400psi	m3						59.9											4,738.00	106.95	107.0	59.9
	Re-bar		ton						608.9	34,900.00	698.00	30,900.00	572.22	33,823.0	626.40		2,070.0			60,000.00	1,354.40	2,070.0	572.2
Headrace Channel																							
	Excavation	rock	m3																				
	Excavation	soil	m3									136.00	2.52									2.5	2.5
	Concrete	Reinforcement	m3		160.00							3,134.00	58.04				112.7					160.0	58.0
	Re-bar		ton									30,900.00	572.22				1,160.0					1,160.0	572.2
Headrace Tunnel																							
	Excavation		m3				44.3	Cl 1-2-3	72.5	5,940.00	118.80			11,000.0	203.70							203.7	44.3
	Excavation		m3					Cl 4	74.6													74.6	74.6
	Concrete	lining	m3				81.4	incl. contact grouting	89.6	2,920.00	58.40			4,300.0	79.60							89.6	58.4
	Form work		m2						12.8													12.8	12.8
	Re-bar		ton				698.1		650.5	34,900.00	698.00			33,823.0	626.40							698.1	626.4
	Grouting		m			consolidation	12.9															12.9	12.9
	Shotcrete		m3			t=15cmw/wiremesh	298.4	t=10-15cm	118.6													298.4	118.6
	Shotcrete		m3			t=5cm	425.8															425.8	425.8
	Mesh reinforcement		ton						447.1													447.1	447.1
	Rockbolts		pcs			l=2.4m, d=25mm	20.3	l=2.5m, d=25mm	94.8													94.8	20.3
	Steel Ribs		ton				1,181.6		2,002.6													2,002.6	1,181.6
Headtank																							
	Excavation	soil	m3		6.00					453	9.06	136.00	2.52	80.0	1.50		6.0					9.1	1.5
	Excavation	rock	m3							67	1.34			279.0	5.20		16.0					16.0	1.3
	Concrete	Reinforcement	m3		90.00					2,920.00	58.40	3,134.00	58.04	4,300.0	79.60		112.7					112.7	58.0
	Formwork															20% of Concrete & Re-bar works							
	Re-bar		ton							34,900.00	698.00	30,900.00	572.22	33,823.0	626.40		1,160.0					1,160.0	572.2
Surge tank																							
	Excavation	shaft	m3		80.00		132.7		49.9													132.7	49.9
	Backfill		m3						3.0														
	Shotcrete					t=5cm	425.8															425.8	425.8
	Rockbolts		pcs					l=2.5m, d=25mm	94.8													94.8	94.8
	Concrete	lining	m3		90.00		89.0		73.7			3,134.00	58.04									90.0	58.0
	Re-bar		ton				698.1		650.5													698.1	650.5
	Steel liner		ton		3,000.00							30,900.00	572.22									3,000.0	572.2
Penstock																							
	Excavation	soil	m3		6.00				4.9			136.00	2.52	80.0	1.50	soil	8.0					8.0	1.5
	Excavation	rock	m3						7.3							rock	16.0					16.0	7.3
	Fabrication		ton											279.0	5.20		2,070.0					2,070.0	5.2
	Delivery		ton														90.0					90.0	90.0
	Installation		ton														1,410.0					1,410.0	1,410.0
	Concrete	foundation	m3		90.00							3,134.00	58.04				80.0					90.0	58.0
	Concrete	anchor block, saddle	m3											4,300.0	79.60		112.7					112.7	79.6
	Formwork															20% of Concrete & Re-bar works							
	Re-bar		ton									30,900.00	572.22	33,823.0	626.40		1,160.0					1,160.0	572.2
	Steel pipe		ton		4,000.00					111,000.00	2,220.00	480,000.00	8,888.89	111,000.0	2055.60		3,570.0					8,888.9	2,055.6
Penstock Tunnel																							
	Excavation		m3			horizontal	44.3															44.3	44.3
	Excavation		m3			inclined	153.1															153.1	153.1
	Shotcrete		m3			t=5cm	425.8															425.8	425.8
	Rockbolts		pcs			l=2.5m, d=25mm	21.2															21.2	21.2
	Concrete	backfill	m3		75.00	backfill	83.9															83.9	75.0
						lean mix	50.2															50.2	50.2
Powerhouse																							
	Excavation	soil	m3				3.2		4.9	67	1.34	136.00	2.52	80.0	1.50		8.0					8.0	1.3
	Excavation	rock	m3		12.00		11.6		7.3	453	9.06			279.0	5.20		16.0					16.0	5.2
	Embankment		m3																			0.0	0.0
	Concrete	Reinforcement	m3			in structure	61.9		73.7	2,920.00	58.40	3,134.00	58.04	4,300.0	79.60		112.7					112.7	58.0
						superstructure	66.3															66.3	66.3
						substructure	61.9															61.9	61.9
	Formwork															30% of Concrete & Re-bar works							
	Re-bar		ton				698.1		608.9	34,900.00	698.00	30,900.00	572.22	33,823.0	626.40		1,160.0					1,160.0	572.2
Powerhouse Building																							
			m3		180.00					4,300.00	86.00											180.0	86.0
			m2				1,074.0							22,500.0	416.70							1,074.0	416.7
Access road																							
	concrete & drainage		km															12,000,000.0	225,479.0			225,479.0	225,479.0
	all weather w darinage		km						56,641.6	7,980,000.00	159,600.00					4,200,000.0	78,918.0	4,200,000.0	78,918.0			159,600.0	56,641.6
	Improvement of Existing Road		km						4,519.5													4,519.5	4,519.5
			km	flat	220,000.00																	220,000.0	220,000.0
			km	hilly land	250,000.00																	250,000.0	250,000.0
			km	improvement of existing road	90,000.00																	90,000.0	90,000.0
Transmission line																							
	with rightway permits		km													1,000,000.0	18,790.0	12,000.0	2,254.8				
		69 kV	km		23,000.00					600,000.00	12,000.00			4,425,000.0	81944.40							81,944.4	12,000.0
		115kV	km		34,000.00																	34,000.0	34,000.0
		230kV	km		111,000.00																	111,000.0	111,000.0
		500kV	km		678,000.00																	678,000.0	678,000.0
Transformer																							
		11kV-36kV	KVA							2,500.00	50.00						30.1	1,600.0	30.1			50.0	30.1
Gate, Trashrake																							
	Gates		ton									547,000.00	10,129.63			Intake				327,346.00	7,389.30	10,129.6	7,389.3
			ton													Sluice	3,570.0			292,167.00	6,595.19	6,595.2	3,570.0
			m2							136,000.00	2,720.00			47,350.0	876.90								
	Screen		ton									10,000.00	185.19				3,570.0					3,570.0	185.2
			m2							57,800.00	1,156.00			71,247.0	1319.40							1,319.4	1,156.0

Table 4.10-2 Unit Construction Costs of Hydropower Projects in Southeast Asia

	Stage of Study Country Submission year		Pre-FS 2006	FS Lao PDR 2007.1		FS Lao PDR 2008.6		FS Lao PDR 2008.6		FS Lao PDR 2006.7		DD Indonesia 2008		DD Lao PDR 2006.9	Lao PDR 2005.5	FS Lao PDR 2009
Work item	description	unit	unit price US$	US$	US$	US$	US$	US$	US$	US$	US$	US$	US$	US$	US$	US$
Civil Works																
Access road						unpaved 2 lanes						2 lanes paved				
	new construction	km	178,361	150,000 -	300,000	148,500						266,000				150000
	up-grade existing rough road	km				74,250										70000
Temporary access roa	construction	km								57,353 -	102,000					1 lane 75000
																2 lane 100000
Bridge				Road	Pedestrain	1 lane										Temporary 4000
		m	7,579	2,000	6,000	11,138										Permanent 10,000.00
Coffer dam	removal - excavation and disposal to spoil	m3												2.64		2.60
	impervious fill	m3													6.60	6.00
	Compacted common fill	m3												1.60		1.60
	Compacted rockfill	m3												2.50		2.50
Open Excavation																
	common	m3		3.50 -	10.00	3.00		2.50		6.58 -	10.00	2.24 -	6.43	2.20	4.90	4.00
	weathered rock	m3							(underwater)			3.26 -	7.21	4.40		5.00
	rock	m3		6.50 -	10.00	7.00 -	8.00	6.50	12.00	20.00		5.51 -	9.86	8.00	7.60	8.00
	Boulder	m3				11.00				10.00 -	15.00					12.00
	sand, stone in riverbed	m3								6.50						6.00
	Dental	m3				19.00										15.00
Rock Support	Shotcrete	m3														
	Rockbolt	m														
Embankment, Backfill																
	embankment fill	m3			5.00									2.50		2.50
	compacted backfill	m3			3.50									7.00		7.00
	Rock fill	m3			4.00											2.50
	Rip rap	m3			20.00									15.00		15.00
Main Dam																
				from excavation	from quarry*1	coffer dam										
Fill-type Dam	Rockfill	m3	11.32	6.00 -	10.00	4.00 -	5.00	6.00 -	6.50					3.0 - 7.0		
	Filters, Transition	m3		15.00		21.00 -	28.00	12.00 -	25.00							
	Clay core	m3		6.00		4.00 -	5.00	3.50								
RCC-type Dam	Concrete	m3						60.00				54.50 -	55.38	45.00	40.00	50.00
Conventional -type Dam	Concrete	m3				124.00										
	Curtain grout	m		26.25		38.00 -	41.00					54.25 -	52.45	63.00	131.90	70.00
	(incl. drilling, grouting)	kg/m		25.00								25.00 -	23.26			
	Consolidation grout	m		26.25								30.53 -	44.90	42.50	105.50	60.00
	(incl. drilling, grouting)	kg/m		25.00								19.70 -	33.54			
	Drilling for foundation drainage	m												35.00		40.00
Dam Instrumentation		LS												350,000		300,000
Concrete Works																
			Intake weir	normal	thin					P/H						
Structural	Concrete (w/o re-bar)	m3	278.40	160.00	180.00	131.00 -	152.00	130.00 -	150.00	200.20		78.97	82.86	100.00		140.00
Foundation, Pier, Wall	Concrete (w/o re-bar)	m3		110.00 -	120.00	118.00	128.00	120.00				68.78 -	72.87	80.00		100.00
Plain	Concrete	m3		80.00								56.43	61.59	70.00		70.00
						Powerhouse										
Reinforced concrete	incl. concrete, formwork, re-bar	m3				275.88				641.35		122.68 -	189.84			
		kg/m3				124.89				38.46		31.58 -	42.12			
	Rebar	ton		1,200	1,200	1,023 -	1,106	950		1,500	high yield	987.63 -	990.08	1,000 - 800	895.00	1,200.00
Tunnel																
				D&B	TBM											
Excavation	Excavation (w/o rock support)	m3		80.00	85.00	55.00 -	51.00			67.11 -	98.33	40.82 -	73.66			70.00
	Excavation (w/t rock support)	m3				86.79				102.42						100
Rock support				8cmw/t w.mesh	10cmw/t w.mesh	15cmw/t w.mesh										5cm 300
	Shotcrete	m3		346.25	347.50	413.33				540.80		291.70 -	574.10		176.00	10cm 350.00
																15cm 400
				D28mm, L=3-6m						D25mm, L=2m	D25mm, L=4m				D25-3m	
	Rockbolt	m		22.50		26.00 -	28.00			21.00 -	17.50	11.80 -	22.96		14.93	20.00
	Steel rib	ton		1,850								2,252.93 -	3,218.32			1,800.00
											invert					
Lining	Concrete lining	m3				179.00				200.23 -	164.22	93.93 -	146.78			140.00
	Overall Concrete Lining	m3		150.00 -	160.00					287.68 -	261.04	95.58 -	299.14			250.00
	(incl. concrete, re-bar, formwork)	kg/m3								50.00 -	32.26	1.67 -	48.65			
	Backfill Concrete	kg/m3														100.00
	Re-bar	ton														1,200.00
Grout	Consolidation grout	m										64.41 -	88.85			70.00
	(incl. drilling, grouting)	kg/m										50.00 -	72.73			
	Curtain grout	m										47.07 -	94.80			60.00
	(incl. drilling, grouting)	kg/m										15.63 -	60.00			
Pressure Shaft																
Excavation				Raise borer	Top down							surge tank H=78m, ID=15m				Raise 120.00
	Excavation	m3		120.00	220.00							17.73				Top 220.00
Rock support				8cm w/t w. mesh	12cm w/t w. mesh							10cm w/t w. mesh				
	Shotcrete	m3		346.25	367.50							296.00				350.00
				D28mm, L=3-6m								D25mm, L=5m				
	Rockbolt	m		22.50								13.58				20.00
	Steel rib	t		1,850												1,800.00
												surge tank				
Lining	Concrete lining	m3		160.00								85.22				140.00
	Overall Concrete Lining	m3										150.98				150.00
	(incl. concrete, re-bar, formwork)	Kg/m3										48.14				
Grout	Consolidation grout	m														70.00
	(incl. drilling, grouting)	kg/m														
	Curtain grout	m														60.00
	(incl. drilling, grouting)	kg/m														
Others																
Maisonry		m2														50.00
Hydro-Mechanical Works																
						draft tube gate	Intake service gate							7,000		
Gate		ton				7,164 -	8,699									7,000
						11,615	radial gate									
Trashrack		ton				7,164								13,000		7,000
					incl. lifting beam											
Stoplog		ton		4,085 -	7,778		7,164							5,000		5,000
Valve		ton												10,000		10,000
Bridge	Simple I beam	ton														5,000
					penstock											
Steel liner		ton	1,854	4,000 -	4,500							4,300	supply & shipment	3,500		3,500
												925$/m for fabrication & installation				3,800
Bifurcation		ton														5,200
Gantry Crane		LS														250,000
Transmission Line Works																
Transmission Line	115kV Double Circuit					99,000.00										