e. Efficiency and development of the private sector: Reducing the role of the government and emphasising the private sector as an instrument for further growth; and

f. People's participation and decentralisation: Strengthening decentralisation and popular participation, as part of this initiative development committees will be established at the sub-district (block) levels.

The 7FYP's outlay is Nu. 15,590.36 million which excludes non-plan outlay in investment projects. Sectoral allocations of plan outlay is shown as follow:

SECTORAL ALLOCATIONS OF THE PLAN OUTLAY

Sector	Nu. in million
His Majesty's Secretariat	27.00
National Assembly of Bhutan	20.85
Royal Advisory Council	14.51
Judiciary	76.83
Royal Audit Authority	36.28
Royal Bhutan Police	376.54
Upkeep of Monastic Institutions and Historical and National Monuments	183.64
Special Commission for Cultural Affairs	124.28
Planning Commission	52.66
Central Statistical Organisation	29.60
National Environment Secretariat	23.52
Dzongkhag Development Commission	19.20
Royal Institute of Management	95.71
National Women's Association of Bhutan	47.08
Royal Civil Service Commission	1323.27
Ministry of Finance	1978.55
Ministry of Foreign Affairs	390.53
Ministry of Home Affairs	310.71
Ministry of Social Services	3526.21
Ministry of Agriculture	2433.63
Ministry of Trade and Industry	1402.36
Ministry of Communication	2684.31
District Administration	355.39
Computer Support Centre	57.69
Total Outlay	15590.36

Source: Achievements in Planned Development, Planning Commission

B.3.4 Development Plan in Sectors

(1) Development Plan on Agriculture and Irrigation Sectors

Bhutan has traditionally been a country of subsistence farmers. Formerly trade took place on the basis of barter but in later years diversification in production and consumption set in. A new road system has meant easier access to more remote markets, and consumption of rice has become increasingly popular outside the traditionally rice-growing areas. The RGOB has also encouraged the production of a wide variety of cash crops for sale in Bhutan, India, Bangladesh and other countries.

The underlying strategy to achieve the implementation of on-going and planned activities of the 7FYP are (Planning Commission):

a. The development of appropriate and sustainable packages of technologies for each agro-ecological zone and farmer;
b. Improvements in the effectiveness of the technology delivery system through strengthening extension activities, by expanding coverage and the distribution of yield increasing inputs such as fertilisers and improve seeds;
c. Improved access to inputs and credit;
d. Expanding cropping area for irrigated cultivation of crops;
e. Strengthening community organisation for the sustainable management of irrigation and other inputs;
f. Ensuring a stable market and better prices for fruit and cash crops;
g. Implementation of land use planning activities; and
h. Promotion conservation ethics and environmentally sound sustainable farming by extending training, incentives and grants.

The principal project in the 7FYP related to the Study is the Irrigation Support Project with total cost of Nu. 10.835 million.

Within the frame work of the national development strategy which is guided by the principle objectives of Self-reliance, Sustainability, Environmental Preservation, Efficiency and Decentralisation of Government, Privatisation, Institutional Strengthening, Manpower Development and Regionally balanced Development, the specific RNR Sector Policy Objectives are:

The overall development programme and policies are laid out in a series of five-year plans designed to co-ordinate the economic and social development of the country. For the RNR sector, the current 7FYP lists as its overall goals:

a. The sustainable development of arable agriculture, animal husbandry and forestry for the enhancement of self-sufficiency in food, fodder and fuel wood, construction materials and other wood products;
b. Improvement of income, living and nutritional standards of the rural population; and
c. Environmental conservation, emphasising integrated crop, livestock and forestry system development within the framework of comprehensive watershed management programmes.

Within the RNR sector, the goals for the arable agriculture sub-sector in the 7FYP are:

a. To achieve sustainable production systems through increasing soil fertility and improving soil and water conservation;
b. To increase production of cereals and oilseed crops leading to greater self-sufficiency; and
c. To increase production of horticultural and grain legume crops, both for export and domestic markets, leading to higher farm incomes, and greater economic growth and export revenues.

Achieving a higher level of food self-sufficiency means - in the context of national food security - access to food for a well balanced diet by all house-holds and a minimum of 70% domestic supply at least of food grains.

(2) Development Plan on Rural Water Supply Sector

Water supply schemes for rural areas are being established in all major towns and in 962 villages. These water schemes will reduce the incidence of water borne diseases and will provide clean drinking water.

The principal projects in the 7FYP related to the Study are the Support to the Rural Infrastructure Programme with total cost of Nu. 234.186 million and the Support to the Urban Infrastructure Programme with total cost of Nu. 138.662 million.

(3) Development Plan on Dzongkhag

With decentralisation in 1982, main rural development activities were decentralised. As a result the following sectors were placed under the Dzongkhag Administration headed by the sectional heads: agriculture, animal husbandry, health, education, public works division, rural credit and social forestry. These sectors are responsible for planning and implementing the rural development activities in the Dzongkhag level under the administration control of Dasho Dzongdag and technical support/guidance of parent departments. Within the framework of decentralisation policy, Dzongkhag is responsible for preparing five year plan as well as annual plan, and submitting to the government for approval and resource allocation. Dzongkhag usually implements annual plan by involving concerned beneficiaries. To monitor the progress of each activity Dzongkhag review and compiles progress report on quarterly basis, and its copy is also submitted to the concerned departments.

B.3.5 Relevant Studies and Projects

The relevant studies and projects related to the agricultural, water rescues and water supply developments, especially for the Study and the Study Area are as follows:

(1) Punakha - Wangduephodrang Valley Development Project (PWVPP; Lobeysa)

The Punakha - Wangduephodrang Valley Development Project (PWVPP) was designed as a follow-on of the first IFAD loan project in Bhutan (Small Farm Development and Irrigation Rehabilitation Project - IFAD I which began in 1981). The objectives of the Project are to improve agricultural production in irrigated and rainfed areas, increase productivity in the livestock sector, strengthen support institutions (applied research, extension, rural credit), and protect the natural environment through pilot activities in erosion control and village forestry. The Project covers 27 Gewogs in three Dzongkhags with a total area of 3,544 ha of agricultural lands and the target group consists of approximately 3,500 farm families. In the pilot command area development component, full beneficiary participation is emphasised in the introduction of improved systems of water management and control (IFAD).

The Project was appraised in late 1987, with the implementation edition of the Appraisal Report issued in November 1988. The IFAD loan was signed in November 1988 and became effective on 1 June 1989. The PWVDP commenced on 1 July 1989 with establishment of a Project Management Unit in Lobeysa, having responsibility for implementing the project programme over a five year period with scheduled completion on 30 June 1994. and it is expanded more two years from 1994. In addition it is proposed to include Gasa Dzongkhag under the project programmes commencing from July 1994.

(2) Renewable Natural Resources Research Centre (RNRRC; Bajo)

The Renewable Natural Resources Research Centre (RNRRC, formerly the Centre for Agriculture Research and Development: CARD) was established in 1982 by the Department of Agriculture with the basic objective to develop and introduce appropriate technologies that can increase the productivity of rice and rice farming system on a sustainable basis. Later in 1984, this Center developed a collaborative arrangement with the International Rice Research Institute (IRRI) and the International Development Research Center (IDRC) with a view of intensifying research on rice-based cropping system in Bhutan.

It has a gross area of 46.83 acres of land. Its activities include introduction and selection of high yielding varieties of rice, wheat, oilseeds, vegetables and other high value crops. It also undertakes evaluation of alternative cropping patterns and component technologies that leads to the intensification of rice-based farming systems and research on rice-wheat, rice-oilseed and rice-vegetable patterns and component technologies. Besides research activities and supplying improved technology which are capable of supporting substantially higher yield, this Center also conducts short training/workshops to the Dzongkhag extension staff and farmers in the improved farming system. As envisaged in the Renewable Natural Resources (RNR) concept, the Center has a proposal to strengthen its research activities in the field like livestock production, agro-forestry, horticulture and dry land cultivation.

(3) National Seed Production Programme (NASEPP; Bajo)

To achieve the self sufficiency in agricultural production by supplying improved quality seeds of different crops the National Seed Production Programme (NASEPP) was established in 1984 with its head office at Paro. The regional Centre of Bajo is a Government farm operated by NASEPP for production of vegetable, paddy, wheat and oil seed crop since it has the most ideal and suitable climate for cultivation of mid-altitude crop seed. The main activity of this regional Center is to multiply improved seeds in the farmer's field and distribute to the farmers after completing processing, grading and packaging at NASEPP, Paro, through District Commission Agent.

Seed growers are categorised into three viz., NASEPP, the Bhutan German Seed Project (BGSP) and the Registered Seed Grower (RSG). The farm had initially 12 acres but it is extended further by another 5 acres on lease from farmers. In 1990, the formation of BGSP was formed within NASEPP and established the maintenance breeding unit in Bajo. The BGSP is now responsible for the maintenance of pre-basic

and basic seed of cereal crops released by RNRRC. Under the IFAD project, construction of a building for the seed processing unit supplied under FAO/DANIDA have been planned. Wheat and paddy seeds produced by the registered seed growers will be processed in this Centre.

(4) Regional Plant Protection Centre (RPPC; Bajo)

The Plant Protection Project (PPP) is a sister project to the Development of Agricultural Support Activities (DASA) project, which commenced in February 1990. These two projects are administered under the same Technical Assistant Agreement between Agrar-und Hydrotechnik Gmbh (AHT) and RGOB and EEC was initiated in 1984. This regional Centre (RPPC) was established in 1990 and carries out research on relevant field problems and guides extension workers in carrying out plant protection activities. It also provides in-service-training to extension workers on all aspects of plant protection. In addition, the Centre carries out survey and surveillance works to identify insects and diseases to build up reference collection for the region. Other activities include training of Dzonkhag extension staff in plant protection technologies, monitoring of the system in the region etc. This Center also conducts research on pest and pest management technique on various farming system in the region. Besides, the Centre also carries out the Nation-wide Weed Control Program.

(5) Regional Agricultural Machinery Centre (RAMC; Bajo)

The Agricultural Machinery Centre (AMC) was established at Bodney Farm, Paro, with the main objective of procuring, manufacturing and conducting trials on appropriate farm implements and machinery. The programme has been successful in Paro, in Wangduephodrang and Punakha the Regional Centres were founded. The Center of Bajo (RAMC) was established and commissioned in 1987, and the main function of this Centre is to improve the farm mechanisation programmes service to farmers in the region. It provides services as a workshop and post sales installation and maintenance. Therefore, it is distributing farm machinery and conducting demonstration of the machinery supplied to farmers. Supply of spare parts and repair works are also done.

Farmers are provided with machines at subsidised prices ranging from 20-70% depending on the type of machinery by this Center. Transportation up to motorable road head, installation and assembling etc. of the machinery supplied in the farmer's field are conducted free of charge. The machinery supplied are: tractor, power tiller, rower thresher, rice huller, oil mill, transplanter, harvester, peddle thresher (Paro manufactured), and other simple agricultural tools.

(6) Natural Resources Training Institute (NRTI; Lobeysa)

The Natural Resources Training Institute (NRTI) was established with financial and technical assistance of Helvetas/SDC. The main objective of this institute is to train the mid-level technical support staff for the three sub-sectors under MOA i.e. Agriculture, Animal Husbandry and Forestry, with the aim of integrating the development approach of the three sub-sectors. The institute also conduct refresher and special courses for in-

service personnel. The first batch of trainees, about seventy, was selected and training has begun from 1992.

(7) Irrigation Action Plan

An Irrigation Action Plan is being developed and field-tested by the Irrigation Sub-Division with assistance of the Asian Development Bank (ADB). The ADB is providing a grant of US$ 350,000 which covers technical assistance, transport, field testing equipment, and a study tour.

(8) National Plan for the Drinking Water Supply and Sanitation

In 1982, Bhutan became a member of WHO and soon afterwards requested the Regional Office for support in preparing a National Plan for the International Drinking Water Supply and Sanitation Decade. The National Plan was being made of RGOB felt it necessary to review the plan in order to orient it further towards its "Decade" approach in 1984. The objective of the plan (1983-1992) was to improve public health by reducing the incidence of water-borne and filth-borne diseases through the provision of safe drinking water and adequate sanitation facilities. The country's primary target in the area of water supply was to provide uninterrupted supply of safe drinking water through adequate numbers of stand posts (public or private) to all by the year 2000. For urban population, full coverage was to be achieved by the year 1992 when the rural population coverage was to be 60%.

(9) Rural Water Supply Project

A Rural Water Supply Programme was initiated in 1974. By 1981, 250 rural water supply schemes had been established and another 962 schemes were completed during the 5FYP period with assistance from UNICEF, DANIDA and EEC. A substantial further extension of rural water supply was planned for in the 6FYP period extending up to 1992. The main aim of this project was accessing to safe drinking water for the rural population through construction of water supply schemes.

(10) Urban Centres Water Supply and Sanitation Project

The Six Urban Centres Water Supply and Sanitation Project (UCWSS) was initiated with a feasibility study financed by the ADB's second multi-project loan under a Technical Assistance Project. The feasibility study which was undertaken by the Danish consultant in 1984, developed the basic project idea and recommended the project for financing based upon as assessment of institutional, technical and financial viability of a combined rehabilitation/extension of the water supply and sanitation in the 6 towns (Thimphu, Paro, Phuntsholing, Gaylegphug, Tashigang and Samdrup Jonkhar). The Planning Commission was the Executing Agency and the NUDC was the Implementing Agency for the project. The goal of the project was to provide safe and adequate water supply and improved sanitation for the inhabitants of the six urban centres for the target year 2000, and thus provide better health conditions and well-being in these communities.

(11) Seven Towns Water Supply Project

A programme for water supply development in the seven smaller towns (Samchi, Sarbhang, Damphu, Deothang, Kanglung, Wangduephodrang and Jakar) was being initiated by this project, comprising a feasibility study on water supply systems for the seven towns. The feasibility study on the provision of treated and safe water to all households has realised by a Danish Government grant financing. The main objectives of this project were the water supply systems in the seven towns consisting of a combination of new works and rehabilitation of existing facilities. The target time for completion and commissioning of all the water systems was the end of 1992, but some town systems may became operational earlier than the end of 1992

(12) Urban Centres Water Supply Consolidation Project

The UCWSS Project, its implementation started in 1987 and was expected to be completed in 1989. It was however, only completed during the period from mid 1991 to mid 1992 after a delay of 2-3 years. The overall objective of this project was to improve public health through achievement of a sustainable and regular supply of sufficient, safe water in six urban centres. In order to attain these objectives, the project would consolidate the six urban centres water supply projects technically and strengthen the institutional capability of the operation and maintenance organisations. The project has started in November 1993 and duration period is 30 months, and the implementation agency is the Department of Works and Housing

B.3.6 Law, Regulation and Customary Practices related to Water Resources Development and Water Use

(1) Irrigation Agricultural Development

According to MOA, there is no special regulation of the water resources development on the international rivers for the purpose of irrigation agricultural development. It is said that in case of the water resources development with dams, some international regulations exist between RGOB and India and/or Bangladesh, but they are not clear.

(2) Water Supply

According to the 7FYP for the Rural Infrastructure Programme, gravity-flow water supply schemes of small and medium size (not exceeding 10 Km in length), will continue to be the (low cost) choice of technology. In new schemes, only sources with less than 10 fecal coliform/100 ml will be used. The water quality of existing schemes will, wherever needed, be improved to contain less than 10 fecal coliform/100 ml. National legislation will be used to lay down the rights and responsibilities of the users and of the implementing agencies in the provision and maintenance of water infrastructure.

The standardisation of designs on construction of rural water supply schemes has been established in 1988. On average, the beneficiary communities contribute 15% of the cost of the schemes in the form of labour. Schemes are designed for a 20 year service period.

(3) Water Tariff Structure

Until now, Thimphu and Phuntsholing have been the only towns where consumers are required to pay for water. Consumers are not billed (Nu./month) but pay at the offices of City Corporations according to a ledger. For example, water services charge of Thimphu is as 50% of the service charges, ranging from Nu. 9.00 to Nu. 40.00 a month according to housing category.

Recent workshop on Better Management of Water and Sewerage recommended the installation of water meters to ensure an efficient and clean drinking water supply system in the six towns which are covered by the DANIDA-funded Urban Water and Sewerage Project (KUENSEL, July 23,1994). The meter system will be applicable to all consumers including government organisations, educational institutions, hospitals and business organisations on a tariff which will be charged according to consumption. It will be introduced in all the six towns under the project. The tariff is aimed at making consumers responsible and accountable and not to overburden them. The idea is to make the system sustainable.

The Urban Water and Sewerage Project in Thimphu is proceeding by the Thimphu City Corporation, recently. This project provides the meter system and the tariff rates for water are risen after 20 m^3 per month as follows:

NEW TARIFF RATES FOR WATER OF THIMPHU

Quantity (m3)	Tariff (Nu M3)
0 - 20	1.25
21 - 40	1.75
over 41	2.50

Source: Thimphu City Corporation, 1994

A household of five persons using a normal amount of water, will have to pay approximately Nu. 25.00 a month.

B.3.7 Problems in Development

Problems are caused by the large number of projects. Their growing complexity and inter-dependence combined with the lack of skilled manpower in Bhutan and the limited size of the civil service makes it increasingly difficult to ensure that proposed projects and activities genuinely fit into the priorities of Bhutan's own forward planning, and to prevent the country being donor-driven.

In the matter of aid utilisation, RGOB faces problems similar to those of the past, namely an acute shortage of trained and experienced personal and of local resources to finance development activities. The former is expected to improve with continuing efforts at administrative reform and decentralisation, use of automation, improved communications, more emphasis on in-country training and devolving government operations to the private sector (Planning Commission).

A second aspect of manpower and financial shortages is its impact on plan implementation. Much emphasis will be put on maintenance and consolidation of existing successful programmes, with high priority on health and education and in further strengthening basic institutions (planning, statistics, survey and mapping, census, management training) including participatory development at the local level. Nevertheless the lack of experienced personnel and of finance will restrict the speed and quality of implementation of projects.

B.4 Socio-economic Situation of the Study Area

B.4.1 Location and Physical Characteristics

The Study Area is located in the inner Himalayas of west-central Bhutan. The Wangduephodrang town is the capital of Wangduephodrang Dzongkhag and the economic and urban centre of the Study Area, and is located at about 27 Km east of Thimphu; however, the road distance from Thimphu to the town is about 85 Km, and it takes 1.5 hours driving. East-west distance and north-south distance of the Study Area are 10 Km and 6.5 Km respectively, and the total area is approximately 65 Km^2.

The elevation of the Study Area, as defined, range between from 1,200 m to 2,400 m above sea level, however, the ridge lines defining the main river watershed reach 3,000 m above sea level or more. There is a little flat land, except for a limited area of low terraces which are subject to flooding during the monsoon seasons. Ground slopes generally range from 10° to 40° with most agriculture practice on slopes of 15°-30°. Within the Study Area the rivers and main tributary streams are in general not steeply incised and cultivation is often possible at very near the water courses.

The climate of the Study Area is characterised by wet warm summers and cool dry winters, and a monsoon related rainfall pattern. Sub-freezing temperatures are rare in the lower valley elevations but are not uncommon at the higher elevations. The mean maximum temperatures range from 16° in January to 30° in August and the mean minimum temperature range from 8° in January to about 20° in July. The absolute minima slightly below freezing occur in December and January at lower elevation. The mean annual rainfalls are within the range of 600 mm - 800 mm, about 75% is highly concentrated in the May to September monsoon season (IFAD).

Wangduephodrang town is situated at an elevation of 1,350 m above sea level and is located on a ridge overlooking the confluence of the Chang Chhu and Dang Chhu rivers. This is one of the oldest human settlements of Bhutan and it is the important district headquarters.

B.4.2 Administrative Unit

The Study Area is situated in the three contiguous Dzongkhangs (districts) of Punakha, Thimphu and Wangduephodrang from north to south. This area is limited as shown in the map which includes Lobeysa, Bajo, Phangyul and Rubeysa such as the Study Sub-areas and Wangduephodrang town from north to south. Administratively, three Dzongkhangs and six Gewogs (blocks) are related to the Study Area, and the Study Sub-areas are under the Dzongkhag and Gewog as follows and shown in the Fig. B.4.1:

STUDY SUB-AREAS AND ADMINISTRATIVE UNIT

Study Sub-area	Dzongkhang (District)	Gewog (Block)
Lobeysa	Thimphu	Babesa
	Wangduephodrang	Thetso
Bajo	Wangduephodrang	Thetso
	Punakha	Lingbukha
	Thimphu	Babesa
Phangyul	Wangduephodrang	Phangyul
Rubeysa	Wangduephodrang	Rubisa
	Wangduephodrang	Jena
	Wangduephodrang	Thetso
Wangduephodrang town	Wangduephodrang	Thetso
Others	Wangduephodrang	*Nisho
	Punakha	*Guma

Note: * means very few area.

Thimphu Dzongkhag (approx. 2,046 Km^2) consists of ten Gewogs: Kawang, Chang, Mewang, Geyni, Babesa, Teobesa, Dagala, Lingshi, Naro and Soe, and Thimpu Town. The total number of households in 1990 was 1,864 (MOA), and the total population was estimated as 80,684 (1990, Statistical Yearbook of Bhutan 1990). However, these figures are unreliable, because of number of people per household is too big. According to the Land Use Planning project, the numbers of villages, total households, population and average family member are 101, 8,197, 44,225 and 5.4, respectively.

The other side, Wangduephodrang Dzongkhag (approx. 5,060 Km^2). consists of fifteen Gewogs: Adhang, Daga, Dangchu, Gangtey, Gasa Tsogong, Gasa Tsowog, Jena, Kashi, Nahi, Nisho, Phangyul, Phobji, Rubisa, Sephu and Thetso, and Wangduephodrang Town. The number of villages was 129 and the total number of households in 1991 was around 2,742 (Wangduephodrang Dzongkhag), and the total population was estimated at 59,854 (1990, Statistical Yearbook of Bhutan 1990). According to the Land Use Planning project, the numbers of villages, total households, population and average family member are 168, 2,969, 22,345 and 7.5, respectively.

B.4.3 Structure of Dzongkhags

The total staff and employee of Thimphu Dzongkhag are 366 (1990) and the agricultural related sectors are as follows: Agriculture Sector is 11 and Irrigation Sector is 6 in 1994 (Thimphu Dzongkhag). The total staff and employee of Wangduephodrang Dzongkhag are 252 (1994) and the total staff of agricultural related sectors are as follows: Agriculture Sector is 21 and Irrigation Sector is 4 (Wangduephodrang Dzongkhag). The organisation structure of the Thimphu and Wangduephodrang Dzongkhags are shown in the Fig. B.4.2 and Fig. B.4.3.

B.4.4 Household and Population

The numbers of villages, household and population which correspond to the four Study Sub-areas such as Lobeysa, Bajo, Phangyul and Rubeysa,
are as follows:

NUMBERS OF VILLAGE, HOUSEHOLD AND POPULATION OF STUDY SUB-AREAS

Study Sub-area	Village	Household	Population
Lobeysa	21	177	3,086
Bajo	8	115	983
Phangyul	18	156	1,159
Rubeysa	17	179	1,456

The total number of household for the four Study Sub-areas which included school, public office and institute, RBA firing range, temple, etc., is estimated at 627 at 1995. 70% of total is in the Wangduephodrang Dzongkhag, 25% in the Thimphu Dzongkhag and 5% in the Punakha Dzongkhag. The total population of the Study Sub-areas is estimated at approximately 6,700. The average family member excluding public organisation is approximately 8.2.

According to the Seven Towns Water Supply Study (1989), the Wangduephodrang town's population (exc. RBA) was 3,800 at 1989 expected to grow at a medium rate of 4.0% per year. This projection translate into future population, the estimated populations was approximately 4,630 at 1994, and the population projections at 1995 and 2000 were 4,820 and 5,770 respectively. However, the field survey results of 1995 conducts that the numbers of residents and day visitors of Wangduephodrang town are estimated at 6,035 and 2,320 respectively.

B.4.5 Land Use and Land Tenure

(1) Land Use

The land use map of the country is being prepared by the Planning and Policy Division (PPD) of MOA with the assistance of DANIDA. The present land use in the Study Area is measured on this map which is called as land-use working map (draft map), and confirmed during the site survey. As a result, it is clarified that the Study Area of 65 Km^2 consists mainly of the following four categories:

LAND USE OF THE STUDY AREA

Category	Km^2	%
Forest	40.66	62.5
Agricultural Land	15.70	24.2
Pasture	2.53	3.9
Settlement	0.93	1.4
Others	5.18	8.0
Total	65.00	100.0

Source: PPD DANIDA

The land use characteristics of the Study Area are as follows:

a. Approximately 63% of the Study Area is occupied by the forest land consisting of Coniferous, Broadleaf, Plantation and Scrub forests. Coniferous is found to be dominant in lower part of valley, while Broadleaf in upper part.

b. Agricultural lands are categorised by Wetland, Dry land, Tsheri (shifting cultivation) and Mix cultivated lands, which occupies 24% of the whole Study Area. This indicates much higher rate comparing with the above-mentioned 8.8% for nation-wide value.
c. Most of the Pasture land in the Study Area is found to be of natural pasture.
d. The Agricultural land extend mainly on the steep sloped land along the valley in the Study Area to the maximum extent. Most of them are used for paddy field, but in some areas where irrigation water is not available due to their altitude upland crops are planted under the rainfed condition. The size of each plot is considered quite small, because even in small flat lands the farmers utilise them as paddy fields as much as possible, consequently forming rice terrace consisting of many small plots on steep lands.

(2) Land Tenure

The majority of households own at least some of the land they farm, but the renting-in of same portion of the farmed area is common. Normally farmer would rent-in an additional area of irrigated land to supplement his fully-owned holding. Large holding are rare, and normally these would not exceed four hectares. Landlessness among the rural population is rare (IFAD).

The agricultural land in three Gewogs; Thetso, Rubeysa and Phangyul, in Wangduephodrang Dzongkhag is calculated to be about 1,180 ha with 475 farmers household. An average size of land holding in these Gewogs is calculated to be about 2.5 ha. The small holders of less than 0.49 ha in size is more predominant in the three Gewogs than in whole of the district.

B.4.6 Regional Economy

(1) Outline of Regional Economy

The main occupation in the Study Area is farming and livestock husbandry. The Punakha - Wangduephodrang valley is one of the largest contiguous paddy areas in Bhutan, accounting for about 18% of national rice production from about 12% of the paddy area. Hence, rice production is the most important economic activity in the Study Area and rice is the most important crop in terms of area, production, employment, as a food staple, and as a cash and barter crop.

From the view point of the national and regional economy, the Wangduephodrang town is the commercial distribution point between the Thimphu, the capital of the country and Wangduephodrang Dzongkhang and surrounding areas, acting as a economic service Centre of the Study Area. The Punakha - Wangduephodrang valley is situated in a fertile soil and its products are brought to the market of the town. A small bazaar with many permanent small structures is situated in the town centre. At present, there are a few industries, such as small sawmill and manufacture of furniture in the Study Area.

(2) Agricultural Cropping Outline

The Study Area is located in the dry subtropical zone of the Agro-ecological zones. The temperatures average 12 - 15°C in winter, though there may be ground frost at night, and 26-27°C in summer. Rainfall is relatively low, around 622 mm per year, most of it falling in the months June to August. With this condition principal cropping patterns are as follows (IFAD):

Wheat - Rice; This cropping pattern occupies a considerable proportion (32%) of the winter wetland. Major problems are the risk of rust (*Puccinia striformis*) on the new popular wheat variety Sonalika, and the typically low yields of this and local varieties under the existing conditions.

Mustard - Rice; Local varieties of mustard are given little care after sowing but are hardy and mature rapidly in about 90 days. The normally low yields could possibly be considerably improved by earlier sowing (late October - early November so that flowering is over before risk of cold injury), wider spacing and use of some fertiliser.

Double cropping of paddy has been recently introduced by the IFAD-II project in the Punakha - Wangduephodrang valley. Vegetables are also grown during the winter. Wheat and potatoes are grown as autumn and winter crops on higher altitudes. Mustard is sometimes planted after wheat but not until October when the likelihood of damage from heavy rain has passed.

(3) Agricultural Production

The main crops in the Study Area are paddy, wheat, barley, potato, mustard, etc.

1) Wetland

In the wetland areas paddy is the main crop followed by wheat and the remaining land is sown to mustard. Paddy is prepared with dry seedbeds in April - May for transplanting in June - July. The crop is harvested in October after which wheat is planted on about 50-70% of the land. Part of remaining land is sown to mustard which is more labour intensive than wheat hence the small area. Vegetables, also can be grown during the winter and a wide range of varieties has been grown in the recent past.

Double cropping of paddy requires the first seedbed to be prepared in February under plastic tunnels to overcome the low temperatures. The first or spring crop is harvested in July followed immediately by land preparation and transplanting of the second or main crop resulting in a delay of about 15 days compared with the time of transplanting for the single paddy crop pattern. Under double cropping, mustard or wheat cannot be grown during the winter. The Punakha - Wangduephodrang Valley Project estimates that 3% of the area is under double cropping while 15% has been sown to modern varieties.

2) Dryland

Wheat and potatoes are grown as autumn and winter crops on higher altitude dryland usually some distance from the wetland. As cattle over-summer there, crops are often inadvertently grazed and many are damaged by wild animals (to such an extent that maize cannot be grown). Mustard is sometimes planted after wheat but not until October when the likelihood of damage from heavy rain has passed.

No fertiliser is used on any of these crops although cattle are tethered after the maize harvest before the subsequent crops are planted. Wheat and barley are harvested and brought down unthreshed to be stored in the farmers houses until required.

Agricultural production of major crops of two Dzongkhags are as follows:

AGRICULTURAL PRODUCTION OF MAJOR CROPS, 1988/89

	Thimphu			Wangduephodrang		
Crop	Area (ha)	Yield (t/ha)	Production (t)	Area (ha)	Yield (t/ha)	Production (t)
Paddy	785	2.52	1,979	1,295	3.17	4,099
Maize	61	1.18	72	134	1.40	187
Buckwheat	45	0.73	33	1,311	1.48	1,944
Wheat	660	1.33	880	457	1.76	803
Barley	210	1.24	260	372	0.79	294
Millet	53	1.04	55	36	0.78	28
Mustard	117	0.67	78	182	0.67	122
Potatoes	134	7.79	1,057	214	8.82	1,888

Source: Seventh Plan Development Programme 1992-97, MOA

(4) Marketing

In the past, as in the present, the Study Area was self-sufficient in the production of staple foods, and purchased foods were limited to items not produced in the region such as sugar, salt and tea. Few agricultural products were sold although there was barter among the farm community and with merchants for essential commodities. Major exchange items consisted of livestock products which could be easily stored and transported for much of the year.

The cash marketing of vegetables (including potatoes), fruit and milk products have increased substantially in recent years, although the marketing of cereals is still at a low level. All marketing is undertaken by small private traders, many of them farm women, operating on their own account. In the marketing context, there is no public or private storage capacity in the Study Area, beyond the on-farm storage facilities common to every farm house. Processing is accomplished by a number of small owned rice hulas and smaller number of oil explores (IFAD).

(5) Transport

The Punakha - Wangduephodrang valley relies on Phuntsholing for its supply of imported goods. However, the journey takes one day or sometimes more, it is not generally feasible to carry perishable goods during the summer months. There is

generally an adequate number of trucks transporting goods from Phuntsholing, but normally it is possible to hire only a whole truck. Sometimes several shop-keepers get together and share a vehicle, but it can be difficult to arrange the transport of small consignments and it has to be done on a reserve basis. Some suppliers such as Tashi Commercial Corporation undertake door to door delivery, for example of imported dairy products. Availability of transport is somewhat limited and expensive, as is to be expected away from the main Phuntsholing-Thimphu axis.

(6) Farmer's Income

There is no cottage industry in the Study Area and the off-farm employment opportunities are limited. At any rate, the rural folk appear to have little interest in off-farm wage employment, preferring agricultural work. Consequently, most cash income of farm family is generated from the sales of agricultural commodities.

B.4.7 Social Situation and Infrastructure

(1) Road Network and Transportation System

The Thimphu - Tashigang paved highway is crossing from west to east through the Wangduephodrang town in the Study Area. This all-weather macadam road is connected to Thimphu and linked to the main east-west settlements. Three paved roads are extended from this highway to south and north: Wangduephodrang - Chirang road, Lobeysa - Punakha road and Chuzomsa - Sha Slate Mine road which run along the Pe Chhu river. Another motor road is Wangduephodrang - Punakha road passing on the left bank of the Chang Chhu river, but it is an unpaved road. The main flow of traffic is oriented toward Thimphu, and there are limited flows toward Tongsa and points further east.

In the greater part of the Study Area, villages can only be reached by mule tracks and foot trails, as well as two suspension bridges. Hence, houses and man's back are the main best of burden in the rural areas. There are several bus service having daily or some times per week services to Thimphu, Punakha, Phuntsholing, Tashigang, Daga and other places. In the Wangduephodrang town some jeep taxi is serving from the town to surrounding areas.

(2) Social Infrastructure

Principal social infrastructures existing in the Study Area are as follows:

1) Lobeysa Sub-area

This Sub-area belongs to the Babesa Gewong; a office of the Executive Engineer of Road Maintenance Division (PWD), a office of the Executive Engineer of Wandi Road Division (DOR), Lobesa Primary School, Lobeysa Power Sub-station (MOTI), etc.

2) Bajo Sub-area

This Sub-area belongs to Thetso Gewog; there is no social infrastructure except for agricultural supporting infrastructures.

3) Phangyul Sub-area

This Sub-area belongs to Phangyul Gewog; in just out of the Wangduephodrang town there is Wangduephodrang Prison, and Chhelu Gonpa, etc.

4) Rubeysa Sub-area

This Sub-area belongs to Rubisa Gewog; a Community School, Nyinzegang Gonpa, Balakha Gonpa, etc.

5) Wangduephodrang Town

Wangduephodrang town belongs to Thetso Gewog; which is mainly an institutional town. The District Administration is located inside of the Dzong, the Royal Bhutan Army has a large compound and a Hospital serving to the local population (total population covered about 6,900 in 1992), a Primary School, a Junior High School (total number of students was 589 in 1993), Royal Bhutan Police office, a Post Office, a branch of Bank of Bhutan, Bhutan Government Transport Service office, Hydromet Wireless Station, Wangduephodrang Hydel Power House, a Sunday market site, etc.

(3) Agricultural Supporting Infrastructure

Principal agricultural supporting infrastructures existing in the Study Area are as follows:

1) Lobeysa Sub-area

Natural Resources Training Institute (MOA/SDC), Office of the Project Manager of the Punakha-Wangduephodrang Valley Development Project (MOA/IFAD), Agricultural Extension Centre (Lobeysa), Animal Husbandry Sub-centre (Lobeysa), Office of the Divisional Forest Officer of Wangdi Division (MOA), Office of the Forest Ranch Officer, etc.

2) Bajo Sub-area

In just out of the Wangduephodrang town there is Agricultural Machinery Centre (AMC; Bajo), National Seed and Plant Production Programme (NASEPP; Bajo) office, Agricultural Extension Centre (Bajo), Veterinary Hospital (Bajo), Agricultural Inputs Commission Agent (Rinchengang), etc.

3) Phangyul Sub-area

Office of the Forest Beat Officer (Forest Check Post; Chhuzomsa), Agricultural Extension Centre (Rakizampa), Agricultural Input Supply Outlet (in the Extension Centre), etc.

4) Rubeysa Sub-area

Agricultural Extension Centre (Jalla), Agricultural Input Supply Outlet (Jalla Bridge), etc.

5) Wangduephodrang Town

Office of the Forest Range Officer, Agent (store) of the Food Corporation of Bhutan, Renewable Natural Resources Research Centre (RNRRC), etc.

(4) Water Supply Service

At present Wangduephodrang town has piped water supply system, but it is not adequate. The water source is very far away, from the Pe Chhu river by pipeline, and the water was diverted in an irrigation channel till it reaches the piped scheme. In the Study Sub-areas many rural water supply schemes were constructed by UNICEF programme. However, many of the older schemes are not functioning well and there is also an insufficient supply in the dry season.

(5) Health and Sanitation

According to the RBA Tencholing hospital in Wangduephodrang, and 3 doctors, 8 nurses, 2 technicians, 1 clerk, 11 helpers and 1 ambulance car are working there. The main diseases of the Study Area are diarrhoea or dysentery and these diseases are very common in the region. Approximately 30% of the population treat their drinking water by boiling or use some type of simple home use filter.

There is no sewerage in the Study Area. Domestic waste water is unattended by soil penetration or discharged to river or stream. In rural area 90 % of households do not have any latrine or sewerage. The first public lavatory was constructed near the existing Wangduephodrang town common taps in June 1994, although Sixty small shops did not have latrine.

There is neither garbage collecting system nor dust pan and incinerator. The garbage is disorderly dumped away at steep slopes in the area of the town.

B.5 Women in Development (WID)

B.5.1 Status of Women in Bhutan

Women in Bhutan constitute 48% of the population. Bhutanese women enjoy considerable freedom and are treated equal to men under the law. There is no overt discrimination on

the basis of gender. Some women play as vital a role as men in the rural and urban economy. A few women hold managerial positions in the public and private sectors. Married women who are not employed in the formal sector can often generate as much income as their husbands, in addition to being housewives. Actually in urban areas, women are active in marketing and real estate speculation, and as managers of shops and small-scale enterprises.

(1) Gender Division of Labour

There is a strict division of labour at the household level with women being responsible for all household chores. Both sexes are responsible for child care.

(2) Agriculture

The majority of women in Bhutan are involved in agricultural production. There are few comparative studies of division of labour between the sexes. However, it would appear that the participation of women in the different agricultural activities varies between different regions. Women are usually not responsible for ploughing but both men and women prepare and cultivate the land, weed, harvest, thresh, winnow, broadcast the seeds and transplant the seedlings.

The low levels of literacy amongst women also hinders their access to credit for agricultural production. The MOA provides extension services to both men and women, and have placed special emphasis on reaching women. However, as in the case of health services, the majority of extension workers are men, which restricts women's access to these services, for social reasons.

(3) Land ownership

According to the selected socio-economic data and status of women 1991 of the Central Statistical Office, about 33% of married women have registered land and 56% of women will inherit it to daughter after her death. Similar pattern is released in registered property and heredity.

(4) Water Supply

According to the mentioned data and status, the distance for collecting water in the rural areas is quite far which indicates almost 39% of households have to fetch water from a distance of hundred meters or more and nearly 31% of households have water near by the house or in the house. Approximately 47% households have drinking water from unprotected pond or stream and the remaining 36% of households have protected water. Women are fetching the domestic water for their houses.

B.5.2 Women's Situations in the Study Area

According to the IFAD study report (1987) and field survey results, the overall situations of rural women in the Study Area are as follows:

(1) Household

A feature of farming household is that the head of the household is female, and she presides over the household. It is common for women over 60, especially if widowed, to hand over the responsibilities to one of their daughters. The household consists of about eight people on average. The women live in household with their children, married daughters, unmarried brothers, and their father and mother (if still alive). Matrilocality is a tradition. The husband will move to his wife's mother's house when married.

(2) Women's Work

1) Household Work

The rural women are involved in a host of family chores and activities in the house and farm. The domestic tasks they perform include, on a daily basis: food preparation and processing, washing clothes, fetching water and fuel wood, feeding animals, cleaning the house and the compound. The women in the Study Area scarcely weave. The rural women make local liquor from wheat and another cereals for home consumption.

The fetching of fuel wood is done daily - two headlands may be used per day and it may require up to two hours for fetching. Most women stated that fetching wood is an arduous task because long distances have to be travelled.

2) Agricultural Work

All the women are engaged in agricultural work, and they have a claim on the land, due to matrilineal inheritance of land. Rice farming is the most important farm work in the Study Area and gender role on main works is as follows:

DIVISION OF LABOUR IN RICE FARMING

Work	Male	Female
Transporting	X	-
Ploughing	X	-
Manuring	-	X
Rice Sowing	-	X
Rice Transplanting	-	X
Weeding	(X)	X
Harvesting	X	X
Threshing	X	(X)
Winnowing	-	X
Milling	X	-

From the above mentioned, it is seen that the women have the major labour contribution in rice farming. However, recently some part of the division of labour by gender is being not clear, because of introducing of power tiller.

The women take the decision when the farm work should start and also when harvesting should begin. Furthermore, they make decisions about how much paid labour which should be hired (for transplanting they pay 35 Nu. per person per day, inclusive of three meals and drinks; 1994).

a. Farm Labour: Women who need labour to assist them with their farm work repeatedly have neighbouring women to help them in their fields (they take turns). The women workers receive food and drinks. The women seem to appreciate this informal village resource network. A child cannot work full time in the field before the age of 15 years.
b. Gardening: Chili is the universal crop in household gardens with onions, radish, pumpkin, cabbage, tomatoes, cucumber etc. Oranges and apples are common in farm gardens. Income from the gardening surplus plays an important role for the women to obtain cash in a small amount for buying sugar, salt, oil, cloth, etc. for the household.
c. Animals: The animals play an important role in the cropping system (Ploughing and farmyard manure) and in providing protein for the household. Bullocks, cows, pigs and chicken are owned by most women. The products are used in the households. The sale of animal products is an insignificant source of income.
d. Marketing: Almost all women produce market surplus crops. They sell the produces from the garden, and they do it on an unscheduled basis. The women have to travel long distances on foot to get to the local marketplace.

Some women expressed interest in increasing their cash crops to increase their family incomes, but also their social contacts and sense of community participation play an important role. They keep the income for themselves to cover family expenses and pay for farm labour. In addition to marketing food crops and produce, they sell home-made liquor directly to villagers.

3) Problem Identified

All problems mentioned reflect to socio-economic environmental needs of women's status and activities as perceived in the Study Area are as follows:

a. General feeling of being overworked;
b. Fetching firewood from long distances;
c. Working in the fields;
d. Working with the animal;
e. Insufficient time for sales to cover family expenses;
f. Lack of information about credit facility;
g. Lack of extension service;
h. Insufficient agricultural surplus for marketing; and
i. High incidence of diarrhoea.

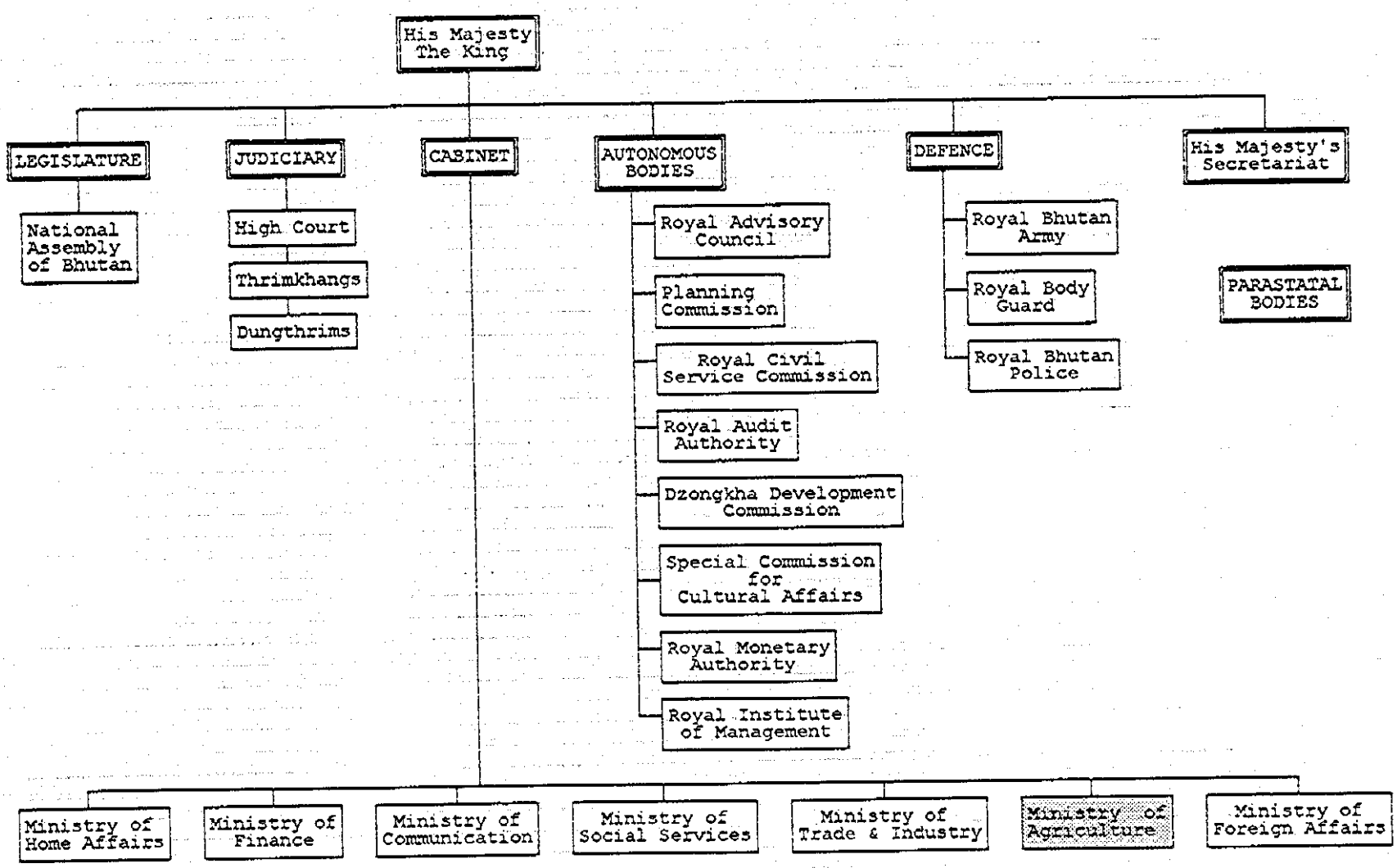
B.5.3 Organisation

The National Women's Association of Bhutan (NWAB) is a non-governmental organisation, which is established with the purpose of motivating both rural and urban

women and to bring them into the mainstream of national development, a goal which is instrumental for the harmonious, sustainable development of the country. The NWAB activities consist of workshops on health, sanitation, basic literacy and nutrition. They have established several weaving-centres and credit facilities specifically for women (Planning Commission).

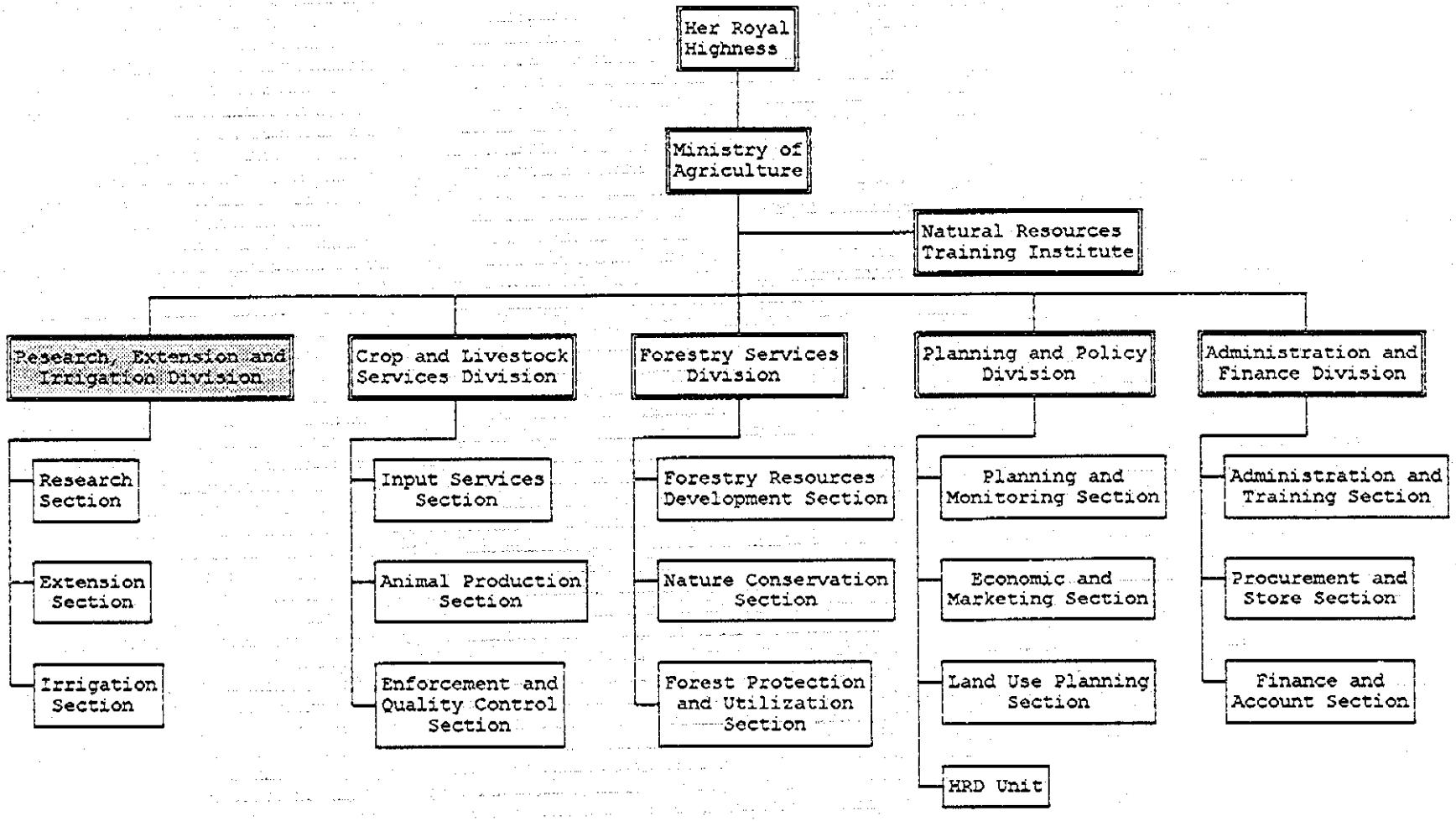
There is no formal women's group in the Study Area. However, women will form informal group when needed e.g. to obtain credit from the neighbouring women and to get labour for farm work. The women in the Study Area do not have an established network to advocate their needs, to support and to educate them in their mutual concerns, and to provide an effective channel for their participation in community affairs. Women gather informally to discuss their lives and work while processing food, walking, fetching water, and working in the field and in their gardens. This natural convening of village women could be used as a base on which a more structured community net work responsive to real women's needs could be established.

APPENDIX B
FIGURES



Source: Seventh Five Year Plan, Planning Commission

Fig. B.1.1 STRUCTURE OF THE GOVERNMENT (1994)



Sauce: Ministry of Agriculture

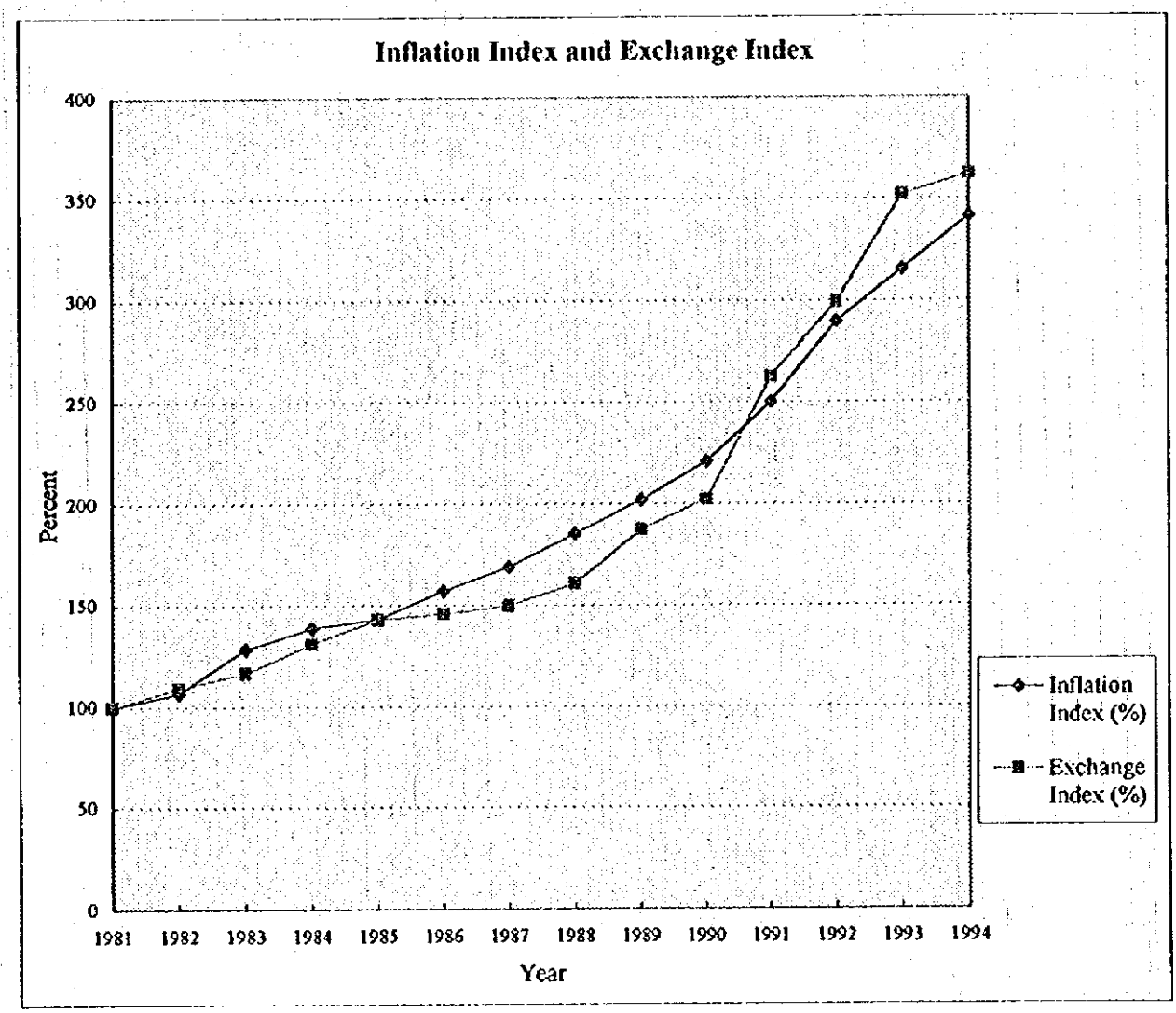
Fig. B.1.2 STRUCTURE OF MINISTRY OF AGRICULTURE (1994)

Fig. B.2.1 INFLATION RATE AND EXCHANGE RATE

Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Inflation Rate (Dic.1979=100)																
CPI at June		105	114	130	150	159	160	176	184	204	222	246	274	318	361	382
Annual Rate (%)			8.6	14.0	15.4	6.0	0.6	10.0	4.5	10.9	8.8	10.8	11.4	16.1	13.5	5.8
CPI at Diceber	100	109	116	124	149	161	166	182	196	215	234	256	290	336	366	396
Annual Rate (%)		9.0	6.4	6.9	20.2	8.1	3.1	9.6	7.7	9.7	8.8	9.4	13.3	15.9	8.9	8.2
Exchange Rate (Nu/US$)																
Annual Average			8.66	9.46	10.1	11.4	12.4	12.6	13.0	13.9	16.2	17.50	22.7	25.9	30.5	31.4
Annual Variation Rate (%)				9.2	6.8	12.5	8.9	1.9	2.8	7.4	16.6	7.8	29.9	14.0	17.6	2.9
End of Period			9.12	9.68	10.5	12.3	12.2	13.2	13.0	15.1	16.9	18.1	25.9	26.2	31.4	31.4
Annual Variation Rate (%)				6.1	8.3	17.5	-1.2	8.3	-1.7	16.2	12.6	7.0	42.8	1.1	19.9	0.1

Source: Statistical Yearbook of Bhutan 1985-1990, CSO
Selected Economic Indicators 1990-1995, RMA

Note: Total CPI indexes is food and Non-food.



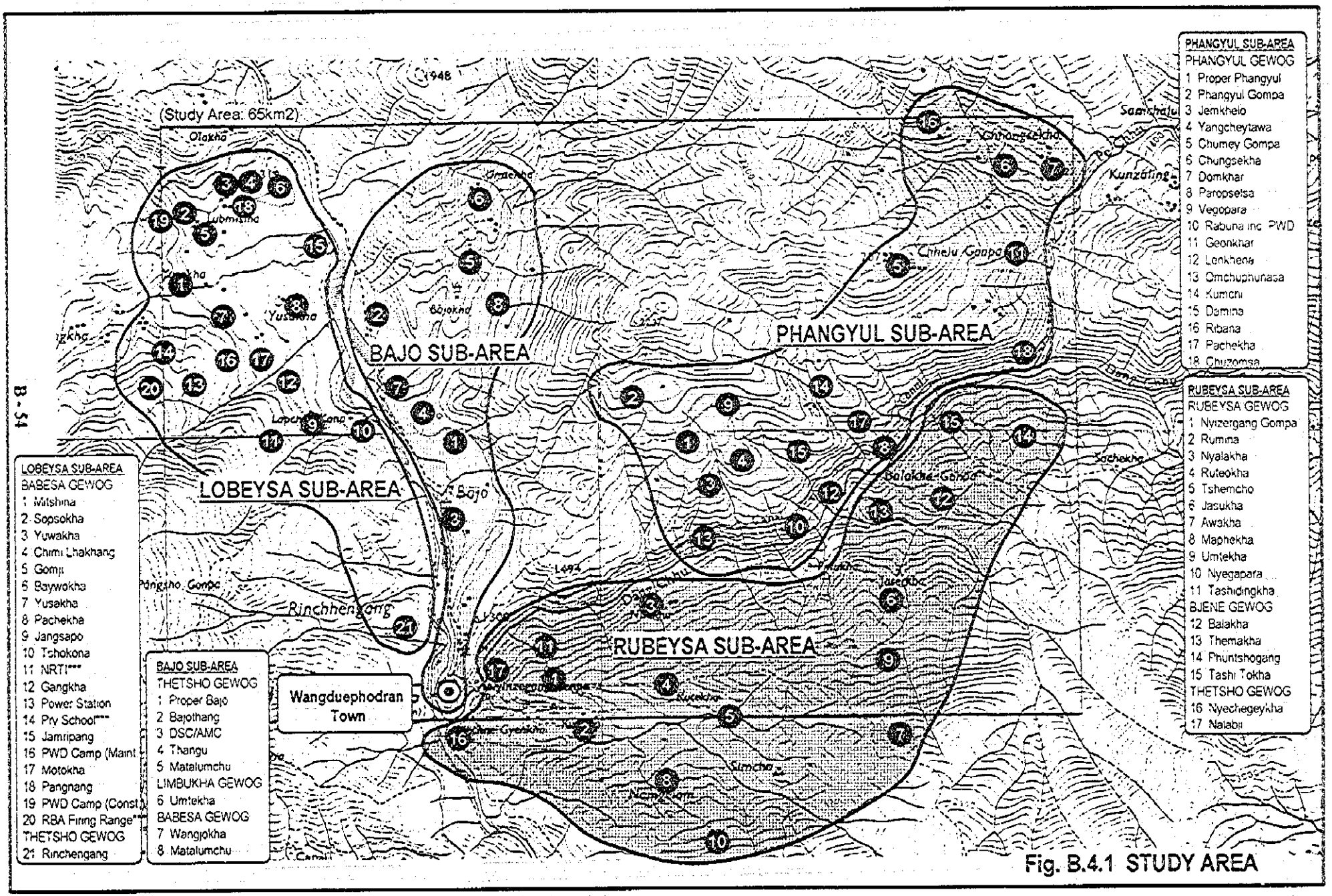
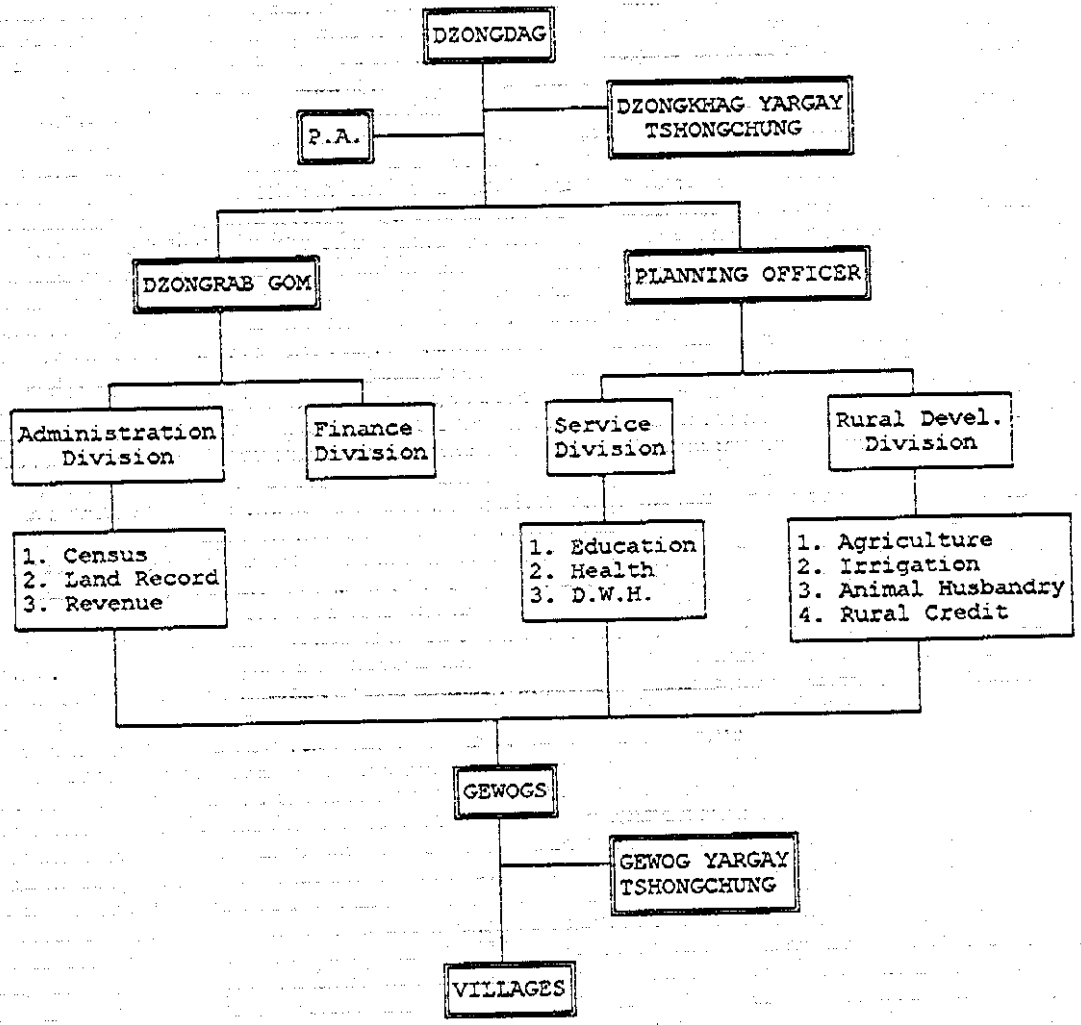
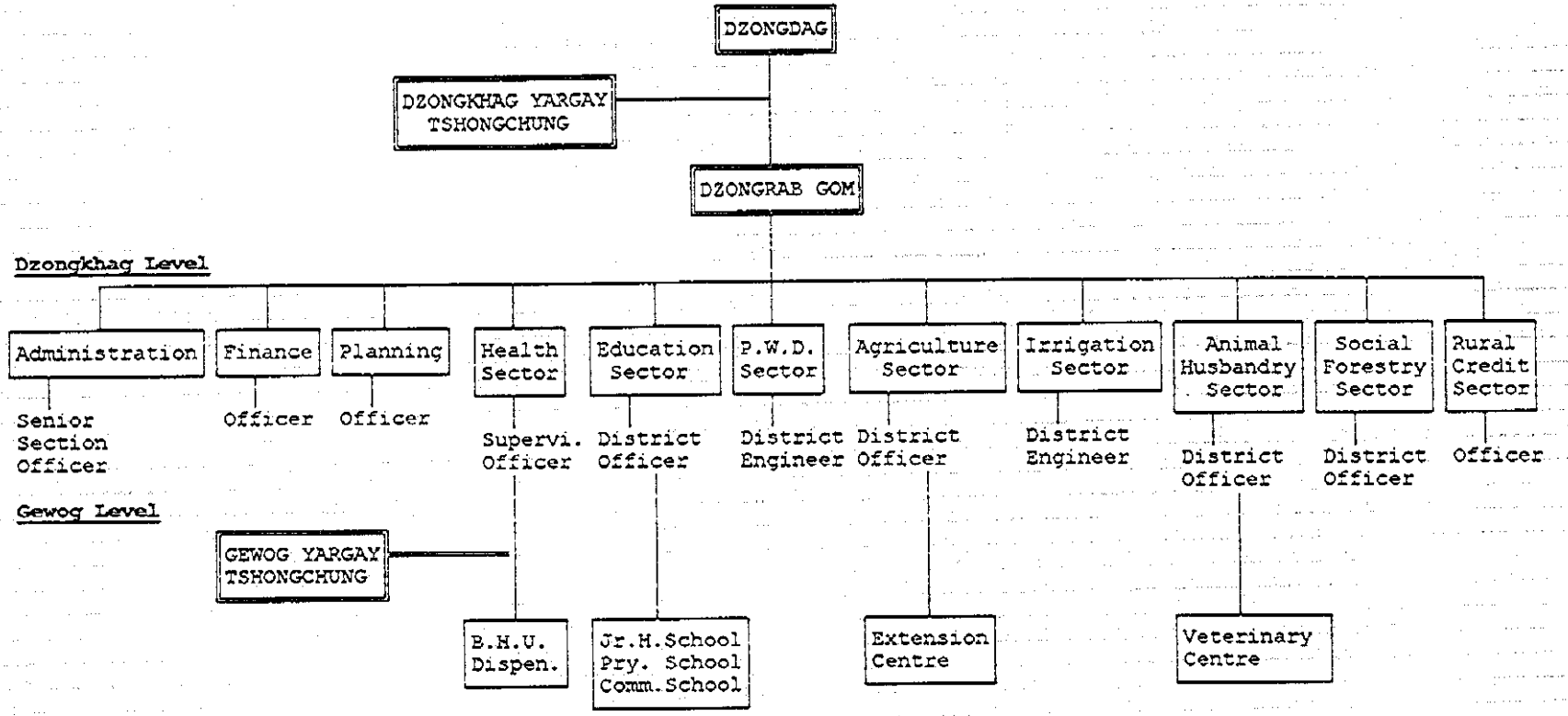


Fig. B.4.1 STUDY AREA



Source: Thimphu Dzongkhag, Planning Officer

Fig. B.4.2 ORGANIZATIONAL CHART OF THIMPHU DZONGKHAG ADMINISTRATION (1994)



Source: Wangduephodrang Dzogkhag, Planning Officer

Fig. B.4.3 ORGANIZATIONAL CHART OF THE WANGDUEPHODRANG DZOGKHAG ADMINISTRATION (1994)

APPENDIX C
GEOPHYSICAL SURVEY AND TEST BORING

THE STUDY
ON
GROUNDWATER DEVELOPMENT
IN
WANGDUEPHODRANG DISTRICT OF BHUTAN

FINAL REPORT

VOLUME III: SUPPORTING REPORT

APPENDIX-C GEOLOGICAL SURVEY AND TEST BORING

TABLE OF CONTENTS

LIST OF FIGURES

APPENDIX-C GEOPHYSICAL SURVEY AND TEST BORING

C.1 GEOPHYSICAL SURVEY

C.1.1 Summary and Location

The areas covered by the geophysical survey are the Lobeysa, Bajo, Phyangyul and Rubeysa sub-areas. The Lobeysa and Bajo sub-areas are situated in flat and/or gentle terrain while the Phangyul and Rubeysa sub-areas are located in mountainous and/or steep terrain (see Fig. C.1.1).

Two kinds of geophysical exploration methods, electric and electro-magnetic, were applied in the Study Area during the Phase 1 field work.

Description		No. / Length Surveyed	AB/2(Depth Sounded)
Lobeysa	Vertical sounding	59 points	100 m
	Horizontal sounding	200 m	30 m
	VLF-EM	3,300 m	-
Bajo	Vertical sounding	101 points	100 m
	Horizontal sounding	200 m	30 m
	VLF-EM	3,500 m	-
Phangyul	Vertical sounding	9 points	100 m
	Horizontal sounding	-	-
	VLF-EM	3,000 m	-
Rubeysa	Vertical sounding	9 points	100 m
	Horizontal sounding	-	-
	VLF-EM	3,000 m	-

In the flat areas of Lobeysa and Bajo, the impounding of rice paddies for the spring rice started in March, causing difficulty in the setting of electrodes and inevitably some scheduled survey points were skipped.

In the steep areas of Phangyul and Rubeysa, due to the uneven ground surface, the horizontal electric sounding work was inapplicable and additional vertical sounding was carried out instead.

Theoretically, the electric exploration method is effective for a horizontally layered geologic structure in a flat terrain. Therefore, it is difficult to perform electric exploration programs in uneven and steep terrains like Phagyul and Rubeysa.

C.1.2 Electric Survey

DC-resistivity method or galvanic resistivity method, also called the Electric Method is the most commonly used method for measuring earth resistivity.

In the electric method, generally, four-terminal electrode arrays are used, since effect of material near the current contacts can be minimized. Current is driven through one pair of electrodes; the potential established in the earth by this current is measured with the second pair of electrodes. A great variety of electrode arrangements have been used to measure earth resistivities

Any one of these arrays may be used to study variations in resistivity with depth or lateral variations in resistivity. In studying the variation of resistivity with depth, as in the case of a layered medium, the spacing between the various electrodes is gradually increased. With larger spacing, the effect of material at depth on the measurement becomes more pronounced. In studying lateral variations such as might be associated with dike-like structures or faults, a fixed separation is maintained between the various electrodes and the array is moved as a whole along a traverse line. The first type of measurement is called a vertical sounding, the second, horizontal profiling.

For the Phase 1 survey, Schlumberger array and Wenner array were employed, the former for vertical sounding and the latter for horizontal profiling. The configurations of electrodes of both arrays are shown in Fig. C.1.2.

(1) Schlumberger Array

The Schlumberger array, which is widely used in measuring earth resistivity, is designed to measure approximately the potential gradient. In the Schlumberger array, two closely spaced measuring electrodes are placed midway between two current electrodes, as shown in Fig. C.1.2. For vertical sounding, the spacing of current electrodes is gradually increased while the midpoint of the electrode array is maintained at the same position. The spacing of potential electrodes is changed only when measuring potential difference becomes too small.

The apparent resistivity for the Schlumberger array can be calculated by the following equation.

$$\rho_a = \pi\left[\left(L^2 - l^2\right)/4l\right]\cdot\left(V/I\right)$$

Where

ρ_a: apparent resistivity (unit:ohm-m)
L: current electrode separation (unit: m)
l: potential electrode separation (unit: m)
I: current (unit: m Amp)
V: potential (unit: m V)

(2) Wenner Array

The Wenner array in which a potential difference is measured, is one of the most commonly used electrode arrays for determining resistivity. In the Wenner array, four electrodes are equally spaced along a straight line, as shown in Fig. C.1.2. The distance between any adjacent electrodes is called the array spacing, "a".

For the current survey, Wenner array measurements were used to study lateral change of resistivity in the earth, called horizontal profiling.

The apparent resistivity of the Wenner array can be calculated by the following equation.

$$\rho_a = 2\pi a \cdot V / I$$

Where

ρ_a: apparent resistivity (unit:ohm-m)
α: electrode separation (unit: m)
I: current (unit: m Amp)
V: potential (unit: m V)

By spreading the electrode interval "α" wider, the corresponding apparent resistivity to the depth of "α" is calculated.

C.1.3 Result of the Electric Survey

In this section, the result of the electric survey at and near the test boring sites is described.

(1) Area of Test Boring TB-1 and 2, Bajo Sub-area (Fig. C.1.3 [1/3])

The TB-1 boring site was selected prior to conducting the geophysical survey. Results of the vertical sounding and the horizontal sounding revealed that the high resistivity layer became shallower towards the TB-1. The depth of the basement rock at TB-1 is 29 meters, the shallowest among these of the five drilling holes. This is conformable to the electric survey result. TB-3 site was designed to drill at the depression of the high resistivity basement rocks, which was indicated by the vertical sounding. After the completion of the horizontal sounding, the best site corresponding to the keel of the depression was found between the two survey points about 40 meters northeast of the drill site. Both methods of electric surveys are very effective when carried out in a timely manner.

(2) Areas of Test Boring TB-2, Bajo Sub-area (Fig. C.1.3 [2/3])

The TB-2 site was selected based on the results of the vertical sounding. The additional survey point 81 was inserted between the survey points 48 and 49. The site selected is just at the deepest depression of the high resistivity basement rock. The successful result of TB-2 suggests that the close spacing of vertical sounding is necessary to pinpoint the drilling site when horizontal survey is not carried out.

(3) Area of Test Boring TB-4, Lobeysa Sub-area (Fig. C.1.3 [3-3])

The TB-4 boring site was primarily selected based on the result of the vertical sounding, and the machine was set at the heel of depression of higher resistivity basement rock. The results of the horizontal sounding suggest that the resistivity is lower closer to the selected site. The result of the drilling was satisfactory. Likewise, the results of the two electric survey methods are conformable and well reflect the underground geo-structure. To pinpoint drilling sites, repeating survey by the two methods may result in more accurate site selection.

(4) Old River Channel Found by Electric Survey (Fig. C.1.4)

In the Bajo sub-area, most electric survey points are arranged on line. Using the resistivity profile, as shown in Fig. C.1.3, zones of low resistivity were delineated and illustrated on the map. By connecting the low resistivity zones for each survey line, a continuous low resistivity zone of crescent shape was mapped. Judging from the size and shape of the crescent, the low resistivity zone might represent a buried old river channel on the middle terrace. This zone may be the future target to exploit groundwater on the middle terrace.

C.1.4 Electro Magnetic Survey

(1) VLF-EM Survey

In order to study anomalous distribution of resistivity in the earth, electromagnetic induction measurement method (EM method) is also used along with DC resistivity method. In the VLF-EM survey, electromagnetic field generated by VLF broadcast stations located at several points around the globe is used as a primary field. They broadcast at frequencies close to 20,000 Hz, which is low compared to the normal broadcast band. The purpose of these stations is to allow governmental communication with submarines, and the low frequency allows some penetration of the conductive ocean water which also allows us to explore a few tens of meters in the ground.

Since the area to be prospected is considerable distance from the transmitter station, the primary electromagnetic field is uniform in the area, allowing rather simple procedure to be used in anomaly prediction.

The NWC station of N.W. Cape, Australia (broadcasting frequency 22.3 kHz, coordinate; 114E09 and 21S47) is used for the survey, since it is the only suitable station for this survey.

The VLF-EM method is a "passive" EM method utilizing existing VLF radio waves as a primary signal source and measuring the resultant electro magnetic field synthesized with the secondary signals excited by the conductor.

The advantage of the VLF-EM is exemption of its own primary signal source. Also, the primary signals from the transmitting station(s) far apart can provide relatively deep penetration compared with the "active" electro-magnetic method.

The equipment employed for the field survey is the EM 16 VLF receiver, a product of GEONICS, Canada. The EM 16 receiver measures the vertical magnetic field using tilt angle and elipticity components.

In order to study anomalous distribution of resistivity in the earth, electromagnetic induction measurement method (EM method) is also used along with DC resistivity method. In the VLF-EM survey, electromagnetic field generated by VLF broadcast stations located at several points around the globe is used as a primary field. They broadcast at frequencies close to 20,000 Hz, which is low compared to the normal broadcast band. The purpose of these stations is to allow governmental communication

with submarines, and the low frequency allows some penetration of the conductive ocean water which also allows us to explore a few tens of meters in the ground.

(2) Results of VLF-EM Survey

The area is physically located in the upper portion of the Mountain and Valley belt meaning wide valleys with river terraces.

Under the young sediments of the terraces and mudflows, two major fracture zones running NNE-SSW and NNW-SSE are geologically inferred.

Taking into account this trend, the VLF signal transmitted from the NWC station in Australia was selected for the measurement.

To utilize the VLF radio wave from Australia, the survey lines are oriented N-S to NNW-SSE to cross the faults inferred by the field geology and aerophoto study.

VLF-EM profiles are shown in Fig. C.1.2.

1) Lobeysa Sub-area (Fig. C.1.5 [1/4])

Weak anomalies were detected in several lines. At line 6, an anomaly was found just on the geologically estimated regional faults. Since the line could not be set perpendicular to the faults, the anomaly was not conclusively identified. Another small fault-like anomaly was found at lines 1 and 2.

2) Bajo Sub-area (Fig. C.1.5 [2/4])

Topographic and electric noises were predominant in this sub-area. Along the foot-hill of the Upper Bajo, a fault-like conductive structure was newly found at lines 1 and 2. The straight foot hill line of the Upper Bajo may be resulted from this fault.

3) Phangyul Sub-area (Fig. C.1.5 [3/4])

No major fault was primarily estimated in this area. A weak but continuous conductive structure (fault or fractured zone) was detected by lines 1 and 2.

4) Rubeysa Sub-area (Fig. C.1.5 [4/4])

Survey lines 2 and 3 were set to cross the geologically estimated major fault. On line 3, a fault covered by mud flows was detected as a broad weak anomaly, but on line 2, due to the thick over burden, no fault was clearly detected by the VLF-EM.

C.2 Test Boring

C.2.1 Summary of Test Boring

In order to evaluate the groundwater potential of the Study Area, four test wells, three in the Bajo sub-area and one in the Lobeysa sub-area, have been drilled during the phase 1 of the program (see Fig.C.2.1).

An additional well has been drilled in the phase II of the program at the office quarter of Forest Department, located in Lobeysa. Therefore, the total numbers of the finally drilled wells in the area is five.

The outline of the drilling works is as follows.

Tb-1

Location:	Bajo sub-area, foot hill, east of Center of Agricultural Research and Development (CARD)
Depth:	33.0 meters
Optimal Quantity:	none

Tb-2

Location:	middle Bajo sub-area, 800 meters north-northwest of T&B-1
Depth:	54.0 meters
Optimal Quantity:	175 liters per minute

TB-3

Location:	Bajo sub-area, about 150 meters east of CARD
Depth:	57.0 meters
Optimal Quantity:	50 liters per minute

TB-4

Location:	Lobeysa sub-area, about 200 meters southeast of the zero-point (road junction)
Depth:	58.8 meters
Optimal Quantity:	110 liters per minute

TB-5

Location:	Lobeysa sub-area, Forest Department's yard
Depth:	81.0 meters
Optimal Quantity:	55 liters per minute

C.2.2 Site Selection

The site selection for the wells was made as follows.

The site of TB-1 was selected at the starting time of the field work, based on the preliminary topographic study. The site is situated on a straight mountain foot, which could presumably be formed by a fault movement.

Other well sites have been selected based on results of a vertical electric sounding using the Schlumberger method. Low resistivity zone maps at the depth of 50 meters have been drawn based on the results of the sounding, and the proposed drill sites have been selected from such low resistivity zones.

Furthermore, a horizontal electric sounding using the Wenner array has been performed for the site selection of TB-3 and TB-4 to reveal depressions of the basement. The results show some depression zones on the basement, which have been judged as good potential zones for groundwater.

The horizontal electric sounding method is effective for prospecting in areas of hydrogeological two-layer model like this study area, consisting of basement rocks and overlying Quaternary system, and the groundwater is unconfined and concentrated on the boundary between the basement and the Quaternary system. Based on results of sounding, resistivity profiles can be made, and depressions on basement can be detected. Such zones are presumable buried ancient river channels, and could be good potential areas for groundwater prospecting.

An additional horizontal electric sounding has been performed for the selection of the TB-5 site.

All of the drilling work has been followed by electric bore-hole logging and pumping tests.

After the completion of all works, water level recorders have been installed in all wells. These wells have been utilized as observation wells for the fluctuation of the groundwater level.

C.2.3 Boring Machine and Boring Method

(1) Boring Machine

Machines utilized for the test boring are listed below:

- Boring machine: THS - 70, manufactured by Tone Boring Co. Ltd., Japan, 1984
- Engine for Boring Machine: V1502-BC, manufactured by Kubota Co. Ltd., Japan
- Mud Pump: NAS-4, Tone Boring Co. Ltd
- Engine for Mud Pump: V1502-BC, by Kubota Co. Ltd
- Mud Mixer: 70E-100, by Tone Boring Co. Ltd.
- Engine for Mud Mixer: E60N, by Kubota

(2) Boring Method

Test wells were drilled using tri-cone bit driven by rotary drilling machines, using bentonite-mud-mixed water.

The sequence of drilling works is as follows:

* Drilling by 9-5/8 inch bit and installing conductor pipe (8 inch)
* Drilling by 5-7/8 inch bit until bed rock or 50 meter depth
* Electrical logging test and casing program
* Reaming bore-hole by 7-5/8 inch bit
* Installing casing pipe (4 inch blind and screen pipe)
* Gravel packing
* Development of bore-hole (water flushing and air lifting)
* Pumping test (step draw down, continuous and recovery test)
* Dismantling conductor pipe and cementation

C.2.4 Well Construction

(1) Well Structure

The site selection for the wells was made as follows.

The site of TB-1 was selected at the starting time of the field work, based on the preliminary topographic study. The site is situated on a straight mountain foot, which could presumably be formed by a fault movement.

Other well sites have been selected based on results of a vertical electric sounding using the Schlumberger method. Low resistivity zone maps at the depth of 50 meters have been drawn based on the results of the sounding, and the proposed drill sites have been selected from such low resistivity zones.

Furthermore, a horizontal electric sounding using the Wenner array has been performed for the site selection of TB-3 and TB-4 to reveal depressions of the basement. The results show some depression zones on the basement, which have been judged as good potential zones for groundwater.

The horizontal electric sounding method is effective for prospecting in areas of hydrogeological two-layer model like this study area, consisting of basement rocks and overlying Quaternary system, and the groundwater is unconfined and concentrated on the boundary between the basement and the Quaternary system. Based on results of sounding, resistivity profiles can be made, and depressions on basement can be detected. Such zones are presumable buried ancient river channels, and could be good potential areas for groundwater prospecting.

An additional horizontal electric sounding has been performed for the selection of the TB-5 site.

All of the drilling work has been followed by electric bore-hole logging and pumping tests.

After the completion of all works, water level recorders have been installed in all wells. These wells have been utilized as observation wells for the fluctuation of the groundwater level.

(2) Well Construction Work

1) Outline of Work Items

* Drilling work:	5 test wells, total depth of 283.8 meters were drilled for 4 inch (100 mm) casing pipes
* Appurtenant work:	Sampling of geological specimens
	Electrical logging test
	Pumping test
	Water analysis

Installation of tide recorder
Fencing work

2) Details of Construction Work

a) Drilling work
Drilling depth, drilling diameter, and depth of casing installed for each well are given in the well logs. (Fig. C.2.2)

b) Sampling of geological specimens
Sludge samples have been collected from the mud water of drilling at every one meter drilled, washed by fresh water, dried, and kept in plastic bags.

c) Electric logging test
The test has been carried out at every one meter below the conductor pipes installed, using the Normal Arrangement Method (22.5 cm for short and 45.0 cm for long in electrode separation) at each well prior to the installation of casing pipes.

d) Pumping test
The pumping tests consisting of the a step drawdown test, continuous test, and recovery test, have been performed. These tests have been carried out after the completion of each well. Submersible motor pumps, which have 60 meters pumping head and 100 liter per minute capacity, have been installed at the depth of 40 meters in each well for the tests. However, the tests for TB-1 have not been carried out because no water was encountered in this well.

C.2.5 Result of Test Boring

(1) Geology of Bore-hole

1) Bajo

This area is generally covered with alluvium river terrace deposits of the Chang Chhu River, and the geology of the bore-hole is mainly of boulder beds intercalated with few thin sand layers. Bedrock of biotite schist is seen around 45 meters below the ground surface at the middle terrace area. No impermeable bed such as mud or silt bed has been found in the terrace deposit in the area.

2) Lobeysa

The area of TB-4 is considered as an ancient valley area filled up by mud flow deposits which consist of an upper muddy member continuing until 30 meters depth. The rocks below this depth, boulders or blocks of rocks become much superior. No bed rock has been encountered in this bore-hole. Judging from the electric logging, several horizons of aquifer may exist. But the most productive horizon may be the one from 45 to 55 meters in depth, suggesting the best yield of groundwater may be just above the basement rock.

TB-5 has been drilled in the other valley filled by mud flow deposits. The peculiarity of the geology in TB-5 is the occurrence of a thick cohesive clay layer. The clay is brown in color, and sticky, suggesting the nature of aquitard, Some circulation loss

of drilling mud-water has occurred in the upper and lower boundaries of the clay layer.

The results of the electric logging shows a low resistivity zone at the clay member, and a high resistivity zone at the sandy or pebbly member which causes the circulation loss.

(2) Results of Electric Logging

Only the electric logging has been carried out for each bore-hole, and the results of the tests are given in each well log (Fig. C.2.2). Referring to the results of the electric logging, the depths of the screen pipe position have been decided.

(3) Results of Pumping Test

The step drawdown test, continuous pumping test, and recovery test have been conducted for each bore hole. The results are shown in Fig. C.2.3.

APPENDIX C
FIGURES

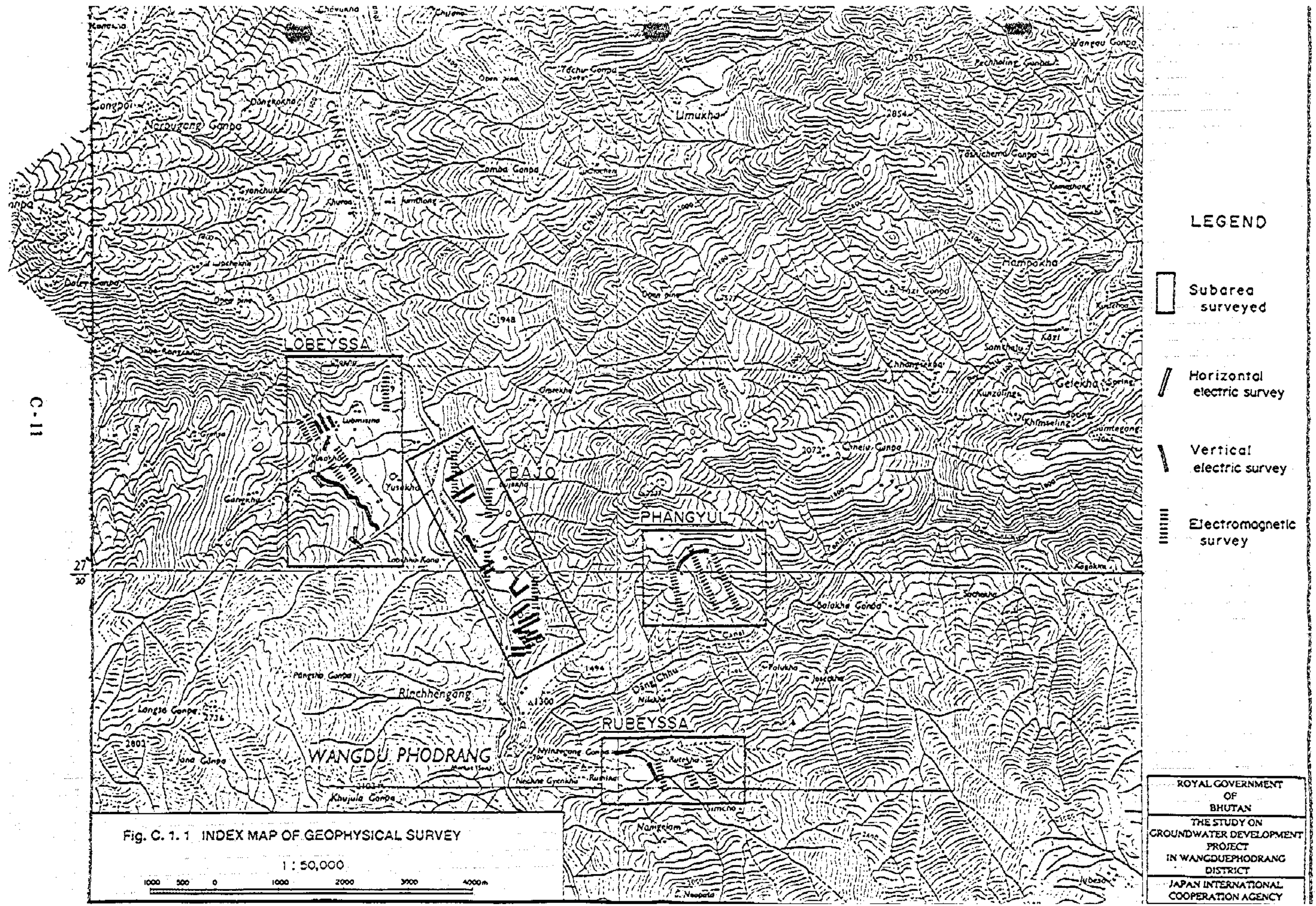


Fig. C. 1. 1 INDEX MAP OF GEOPHYSICAL SURVEY

1 : 50,000

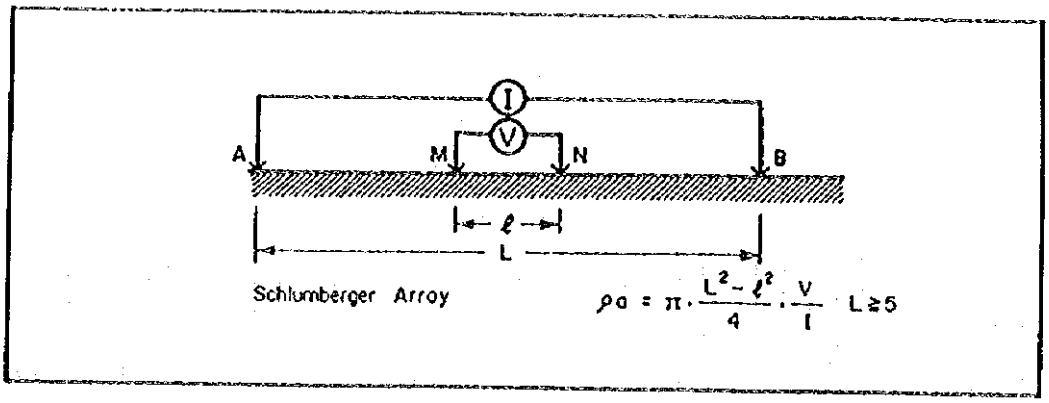
1000 500 0 1000 2000 3000 4000m

ROYAL GOVERNMENT OF BHUTAN

THE STUDY ON GROUNDWATER DEVELOPMENT PROJECT IN WANGDUEPHODRANG DISTRICT

JAPAN INTERNATIONAL COOPERATION AGENCY

Schlumberger Array



(1) SCHLUMBERGER ARRAY

Apparent Resistivity : $\rho a = \pi [(L^2 - \ell^2) / 4\ell] \cdot [V/I]$, $L \geq 5\ell$

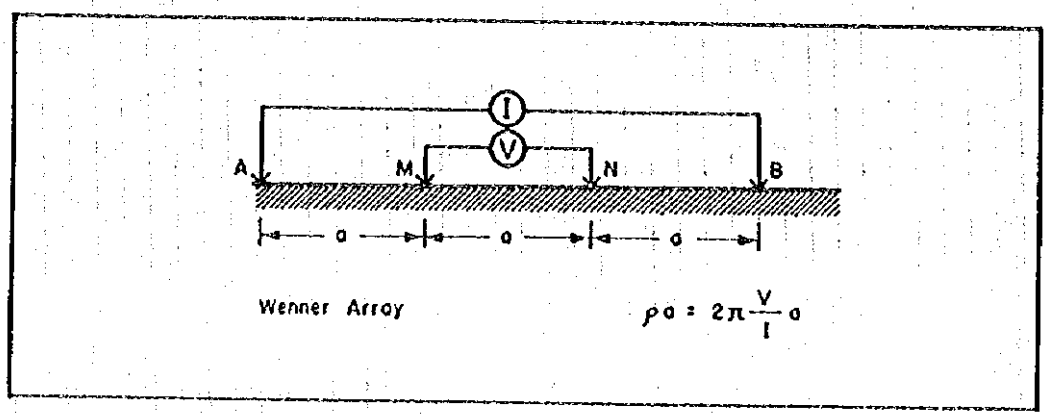
Where, L = Current Electrode Interval

ℓ = Potential Electrode Interval

I = Current

V = Potential Difference

Wenner Array



(2) WENNER ARRAY

Apparent Resistivity : $a = 2\pi a \cdot V / I$

Where, a = Electrode Interval

I = Current

V = Potential Difference

Fig. C. 1. 2 ELECTRODE ARRAY

ROYAL GOVERNMENT OF BHUTAN
THE STUDY ON GROUNDWATER DEVELOPMENT PROJECT IN WANGDUEPHODRANG DISTRICT
JAPAN INTERNATIONAL COOPERATION AGENCY

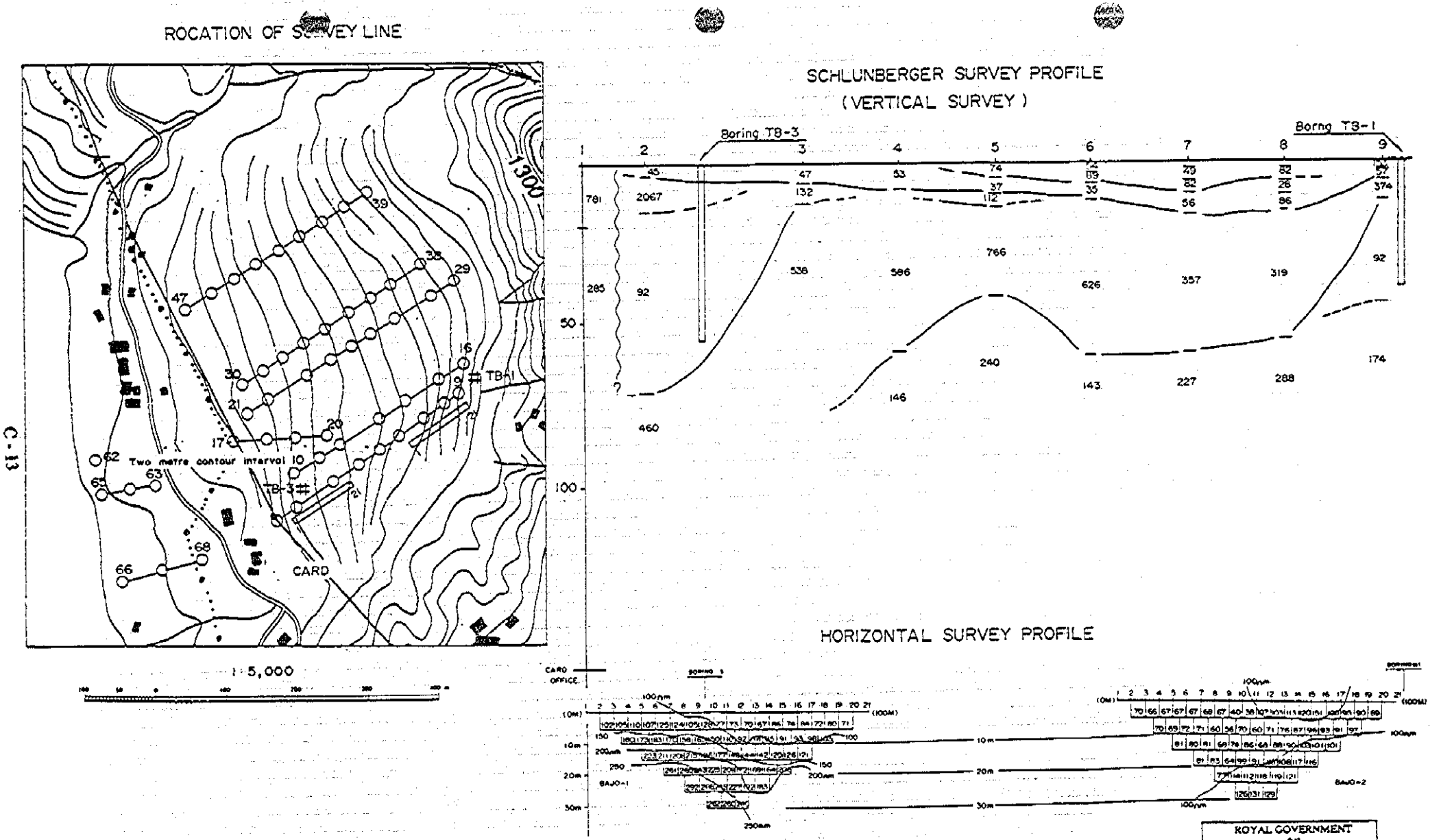
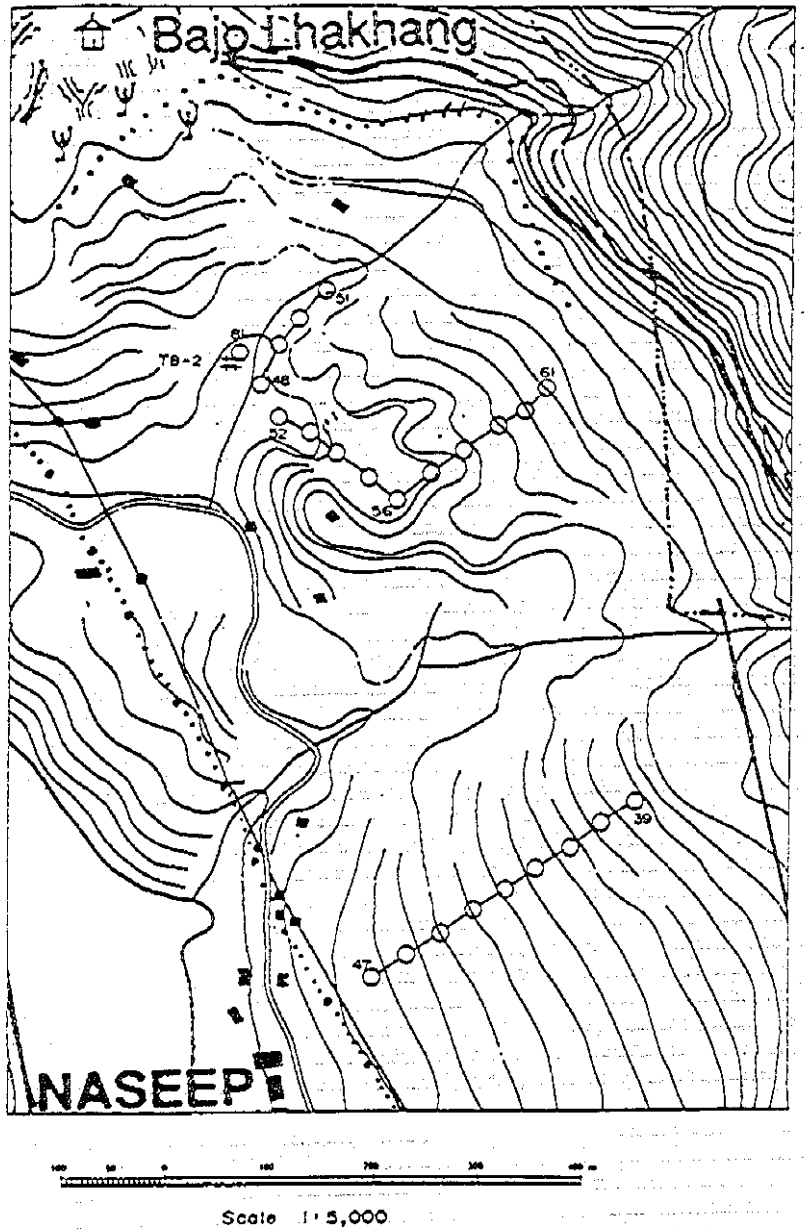


Fig. C. 1. 3 RESULT OF ELECTRIC SURVEY (1/3), (TB-1 AND 3, BORING SITE : BAJO)

ROYAL GOVERNMENT OF BHUTAN
THE STUDY ON GROUNDWATER DEVELOPMENT PROJECT IN WANGDUEPHODRANG DISTRICT
JAPAN INTERNATIONAL COOPERATION AGENCY



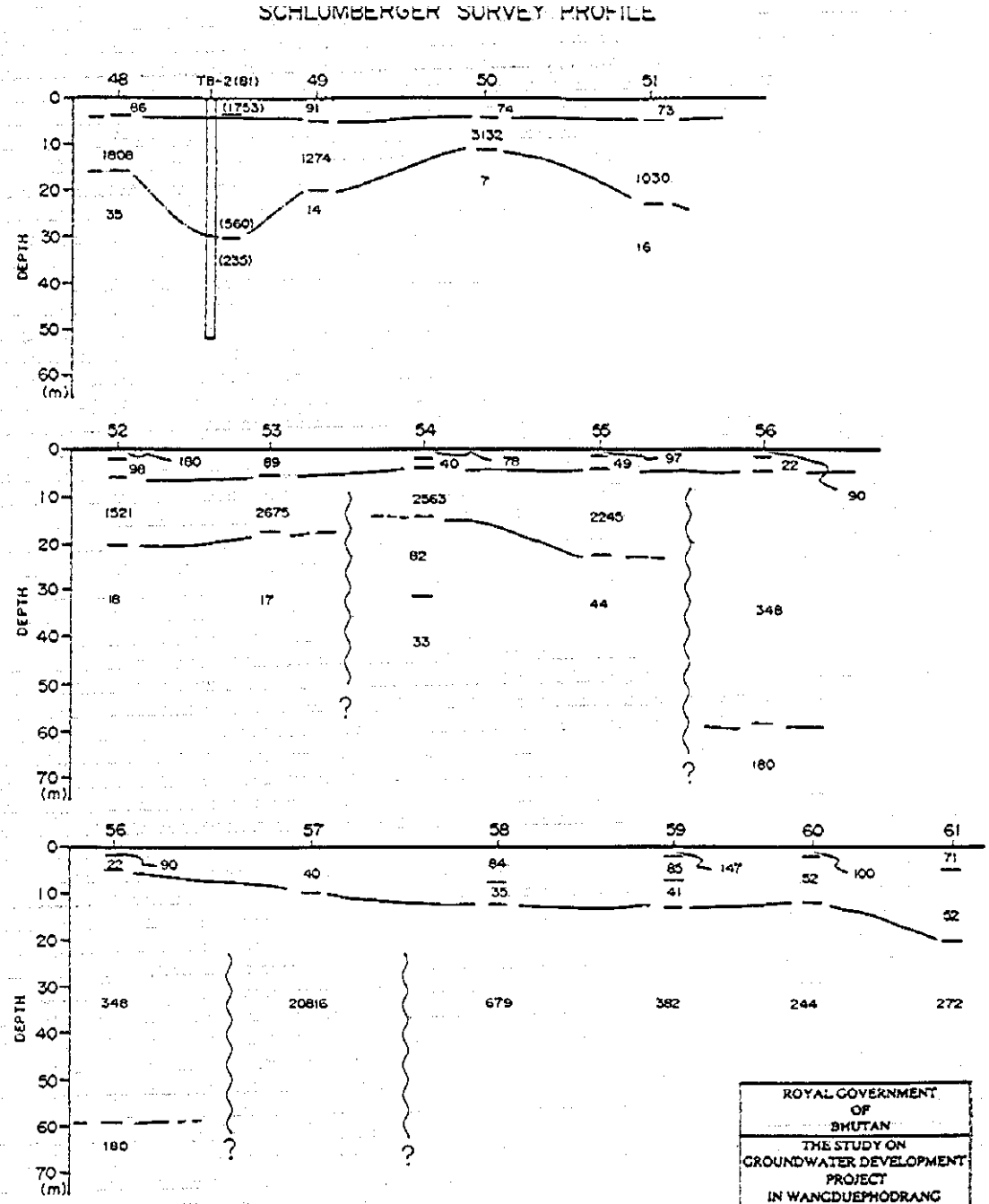


Fig. C. 1. 3 RESULT OF ELECTRIC SURVEY (2/3), (TB-2, BORING SITE : BAJO)

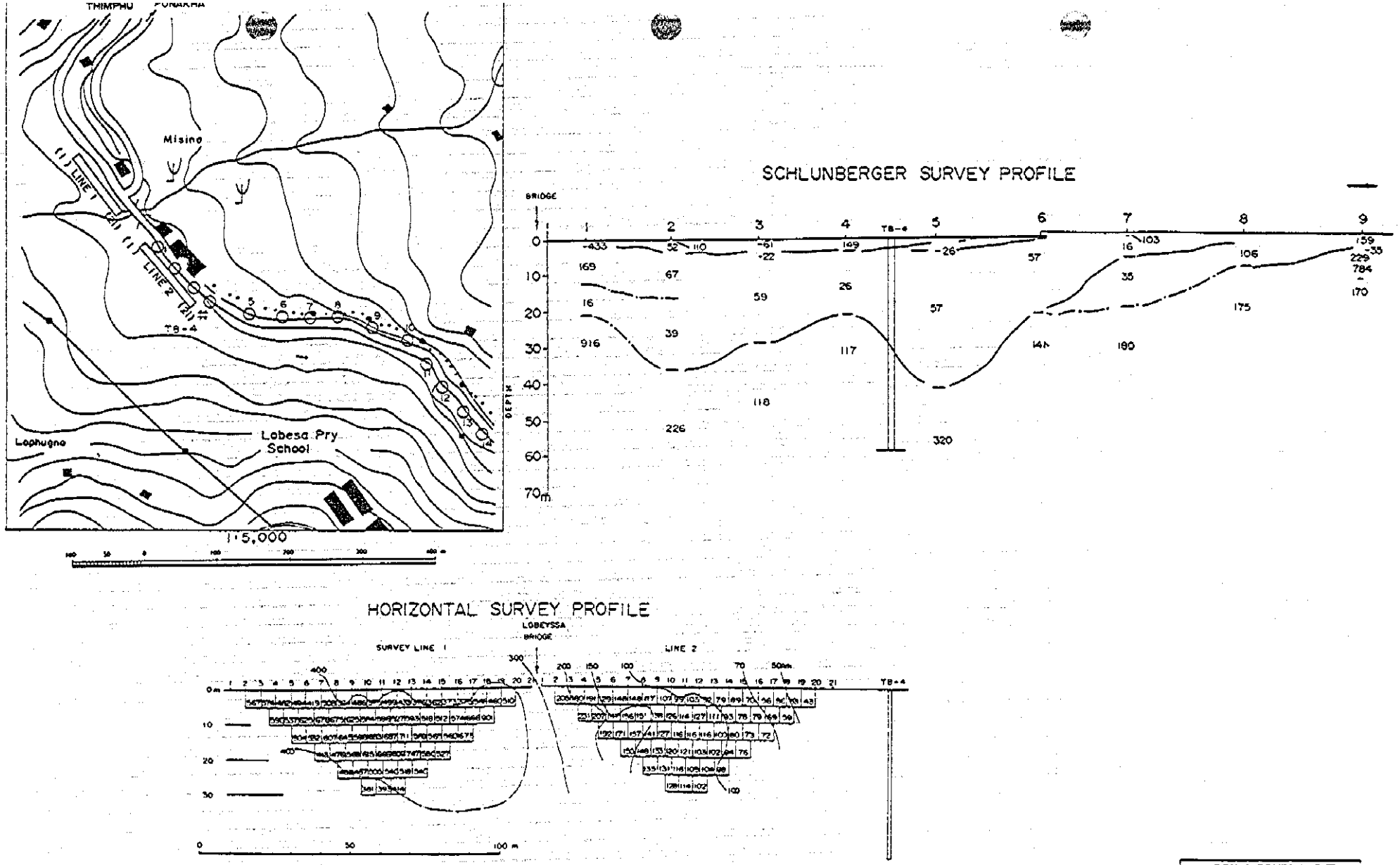
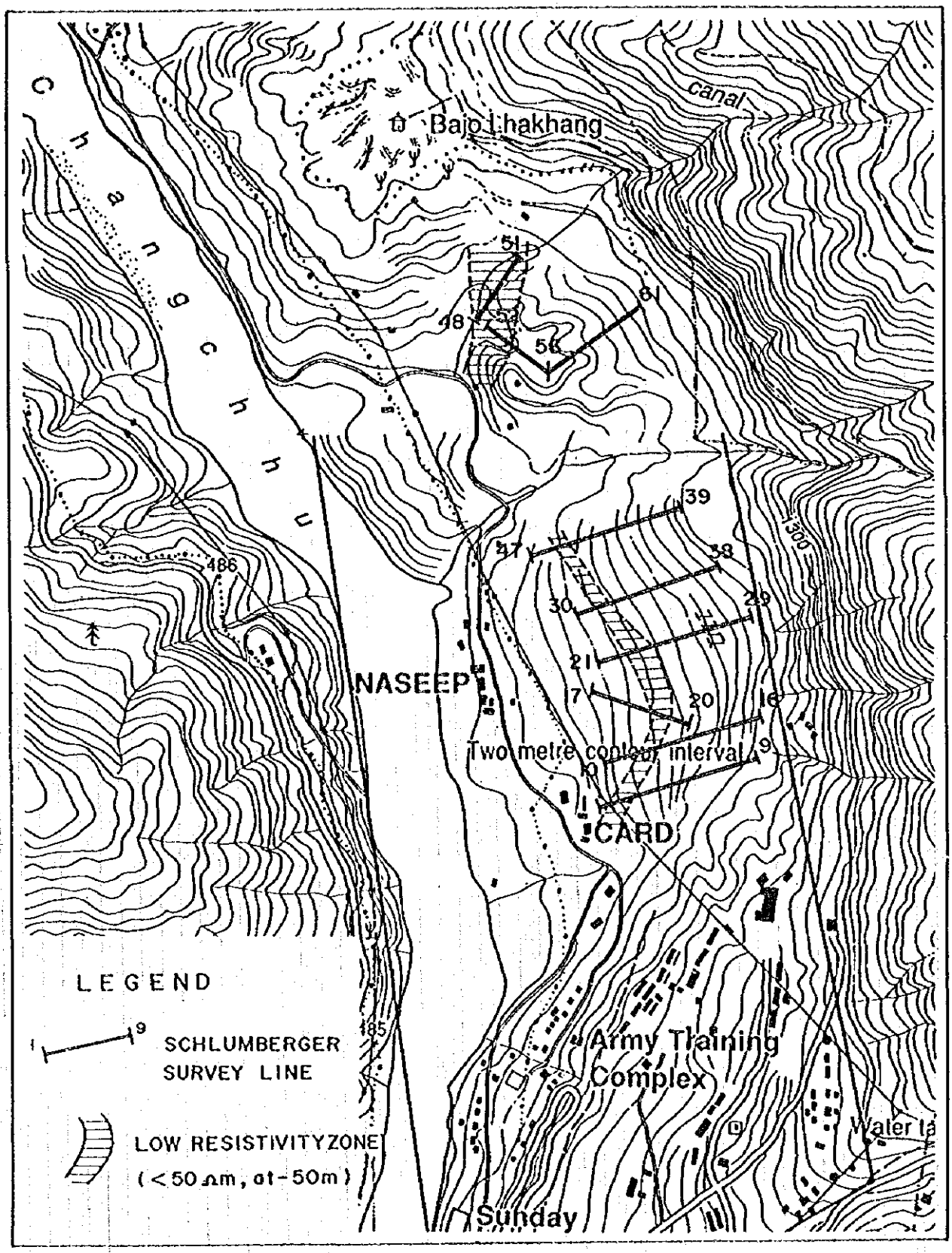


Fig. C. 1. 3 RESULT OF ELECTRIC SURVEY (3/3), (TB-5, BORING SITE : LOBEYSA)

ROYAL GOVERNMENT OF BHUTAN
THE STUDY ON GROUNDWATER DEVELOPMENT PROJECT IN WANGDUEPHODRANG DISTRICT
JAPAN INTERNATIONAL COOPERATION AGENCY



ROYAL GOVERNMENT OF BHUTAN
THE STUDY ON GROUNDWATER DEVELOPMENT PROJECT IN WANGDUEPHODRANG DISTRICT
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. C. 1. 4 OLD RIVER CHANNEL FOUND BY ELECTRIC SURVEY

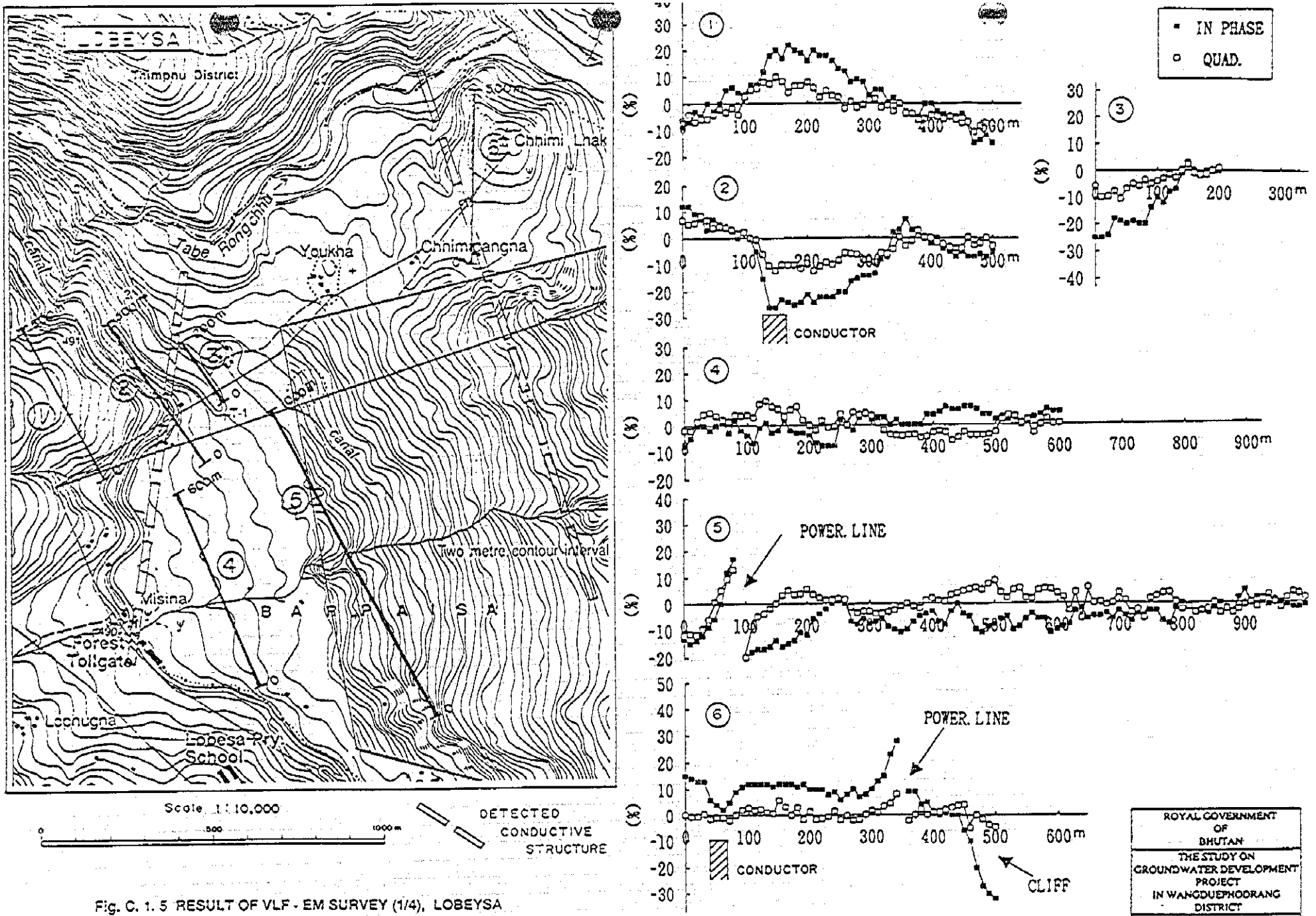


Fig. C. 1. 5 RESULT OF VLF - EM SURVEY (1/4), LOBEYSA

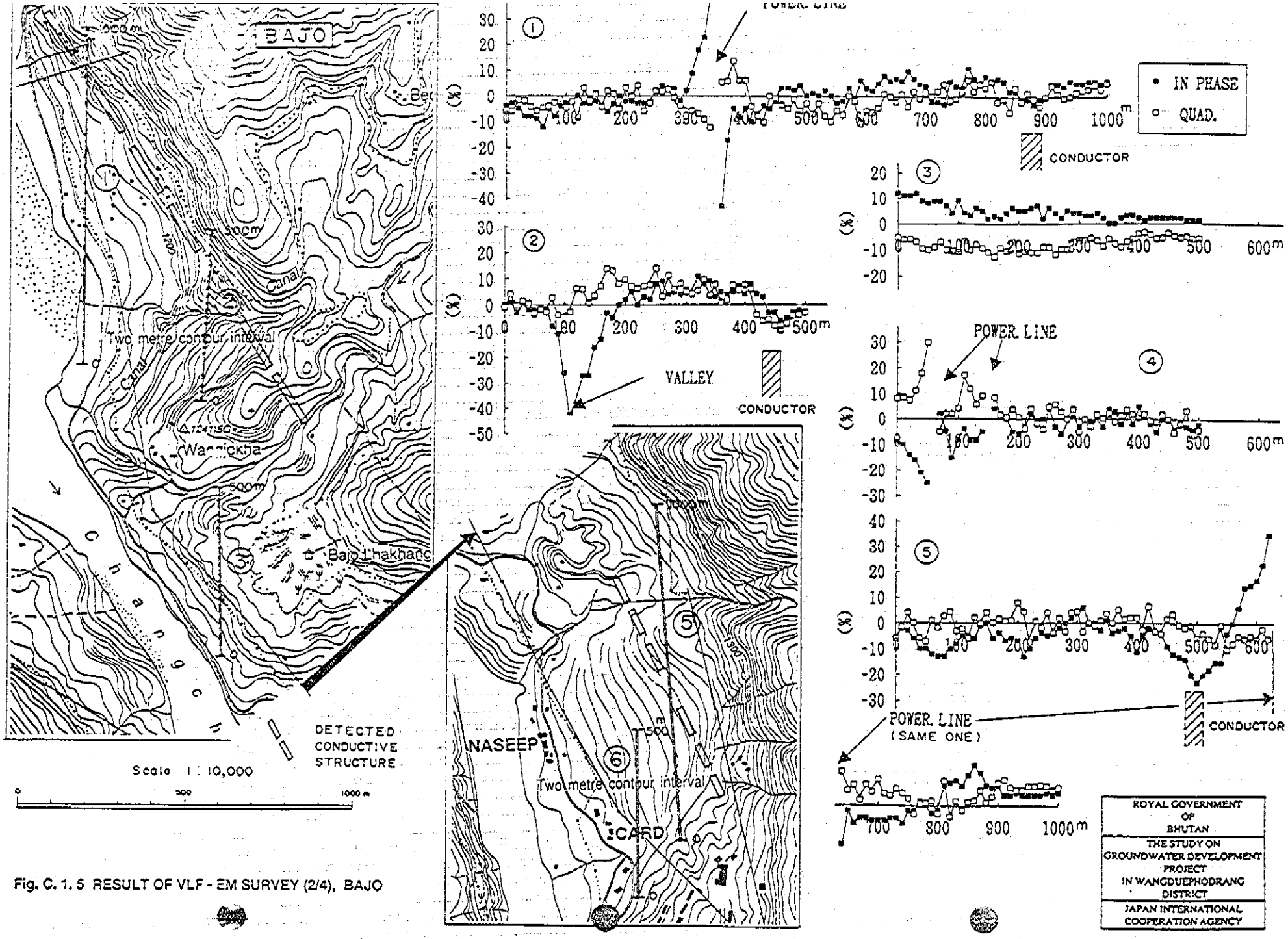


Fig. C. 1. 5 RESULT OF VLF - EM SURVEY (2/4), BAJO

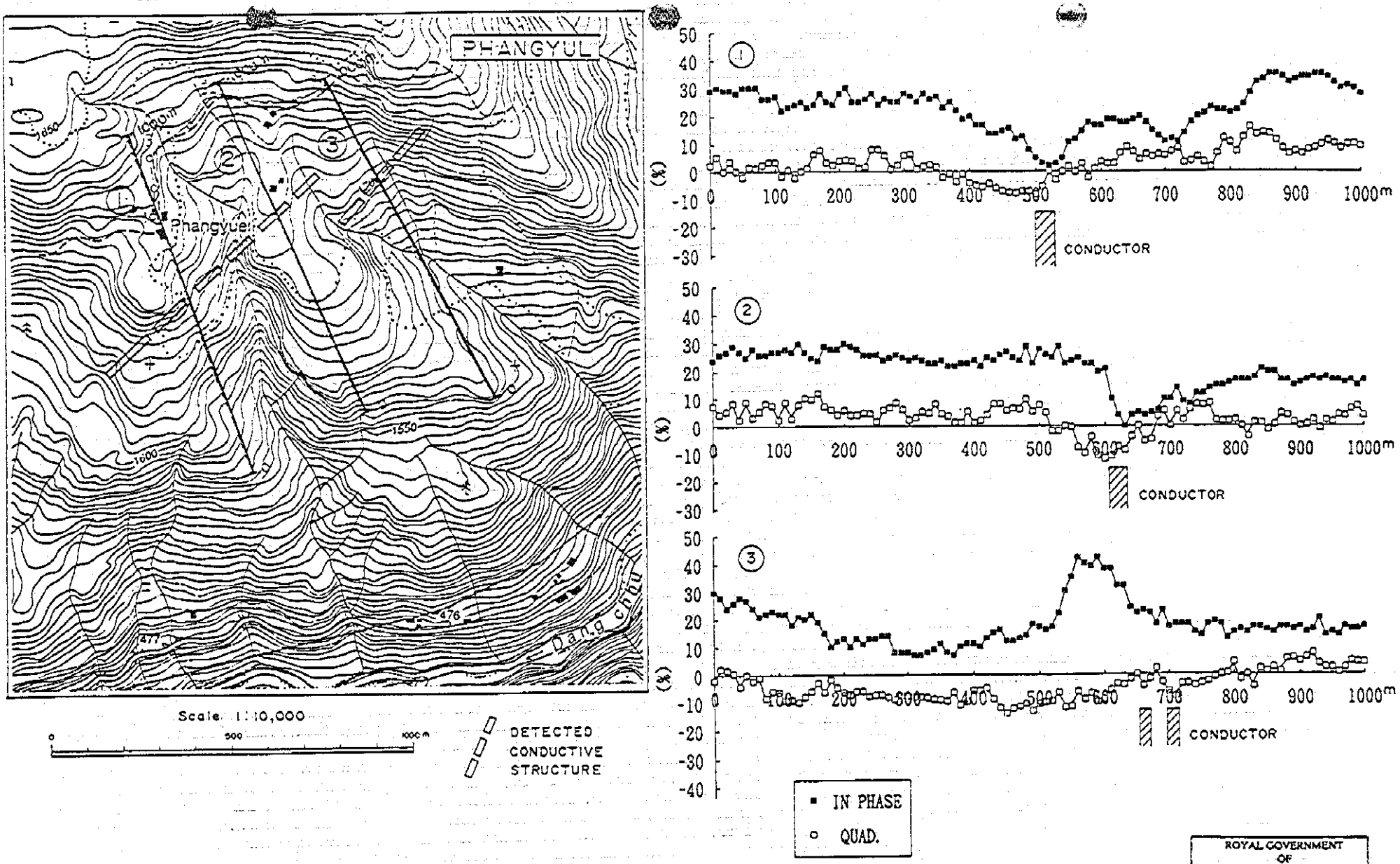
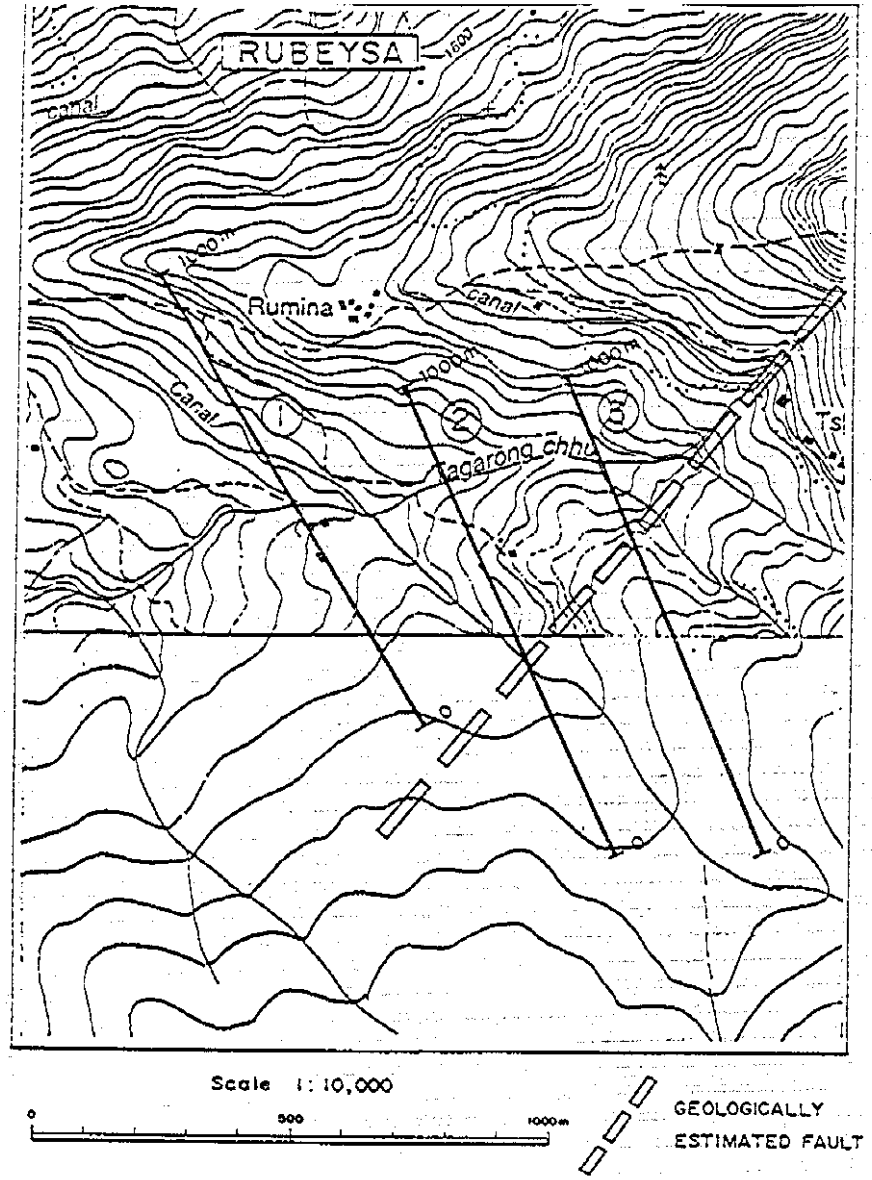


Fig. C. 1. 5 RESULT OF VLF - EM SURVEY (3/4), PHANGYUL

ROYAL GOVERNMENT OF BHUTAN
THE STUDY ON GROUNDWATER DEVELOPMENT PROJECT IN WANGDUEPHODRANG DISTRICT
JAPAN INTERNATIONAL COOPERATION AGENCY



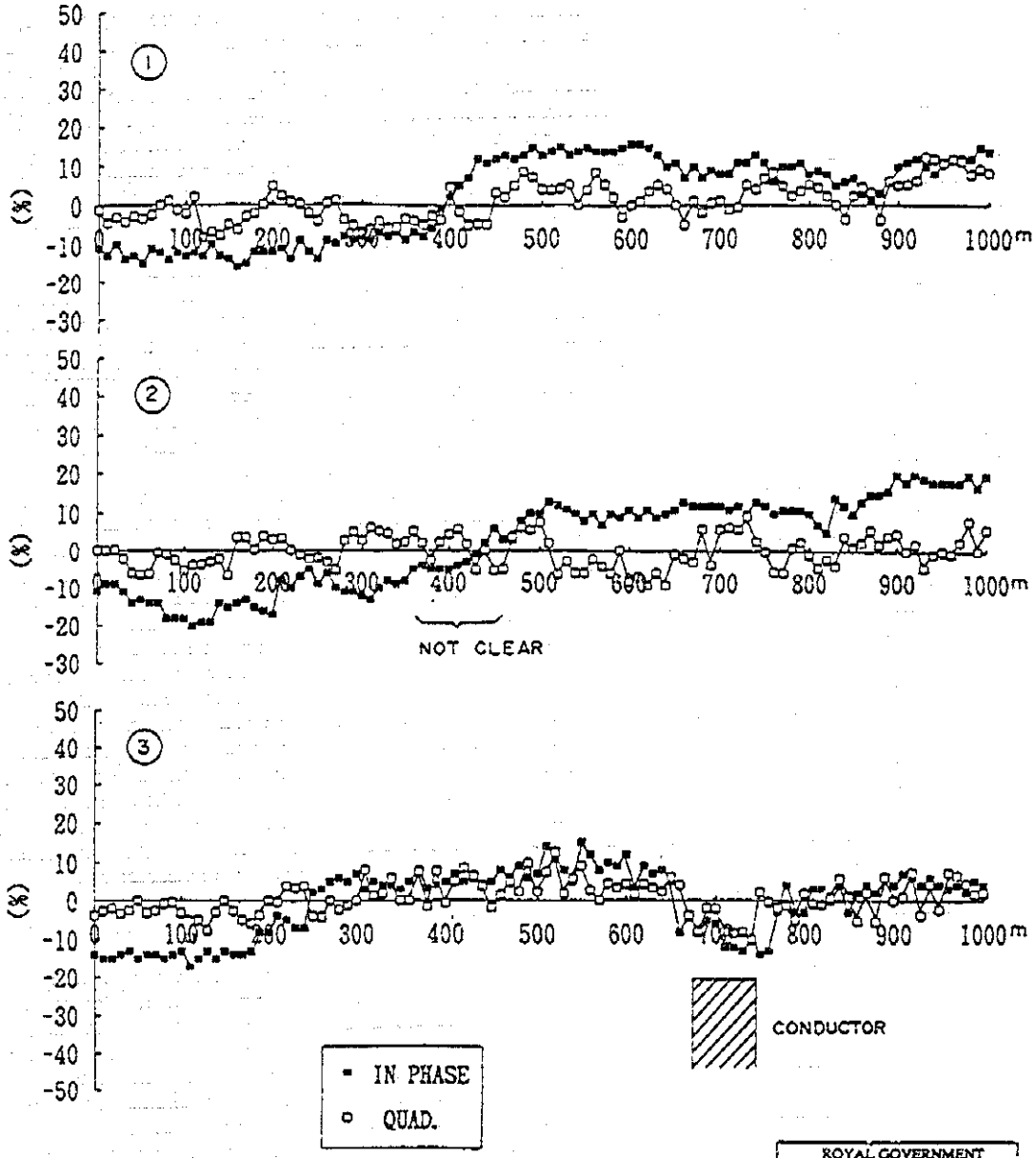
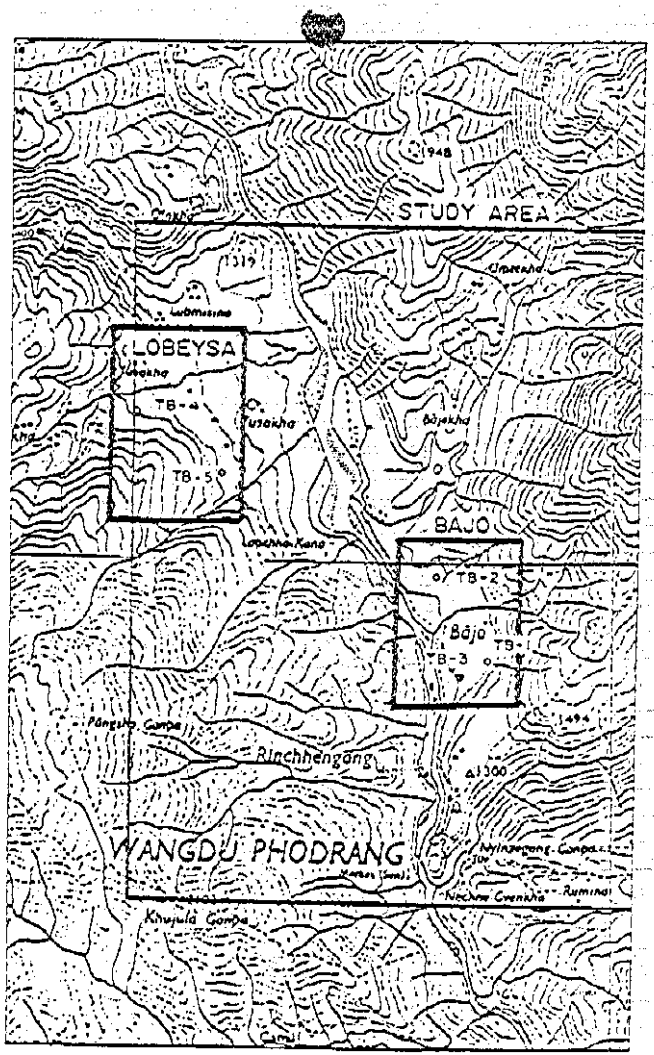
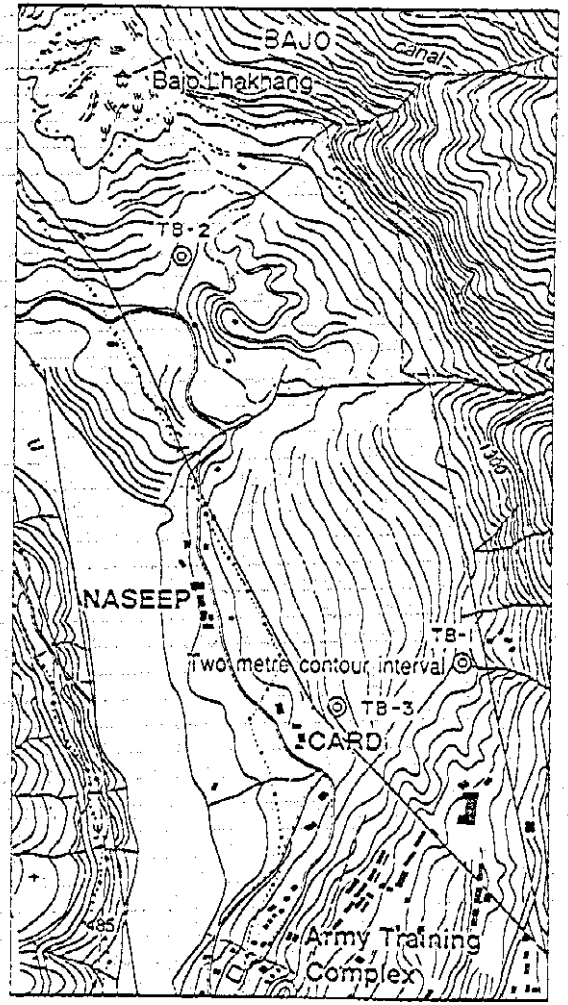


Fig. C. 1. 5 RESULT OF VLF - EM SURVEY (4/4), RUBEYSA

ROYAL GOVERNMENT OF BHUTAN
THE STUDY ON GROUNDWATER DEVELOPMENT PROJECT IN WANGDUEPHODRANG DISTRICT
JAPAN INTERNATIONAL COOPERATION AGENCY





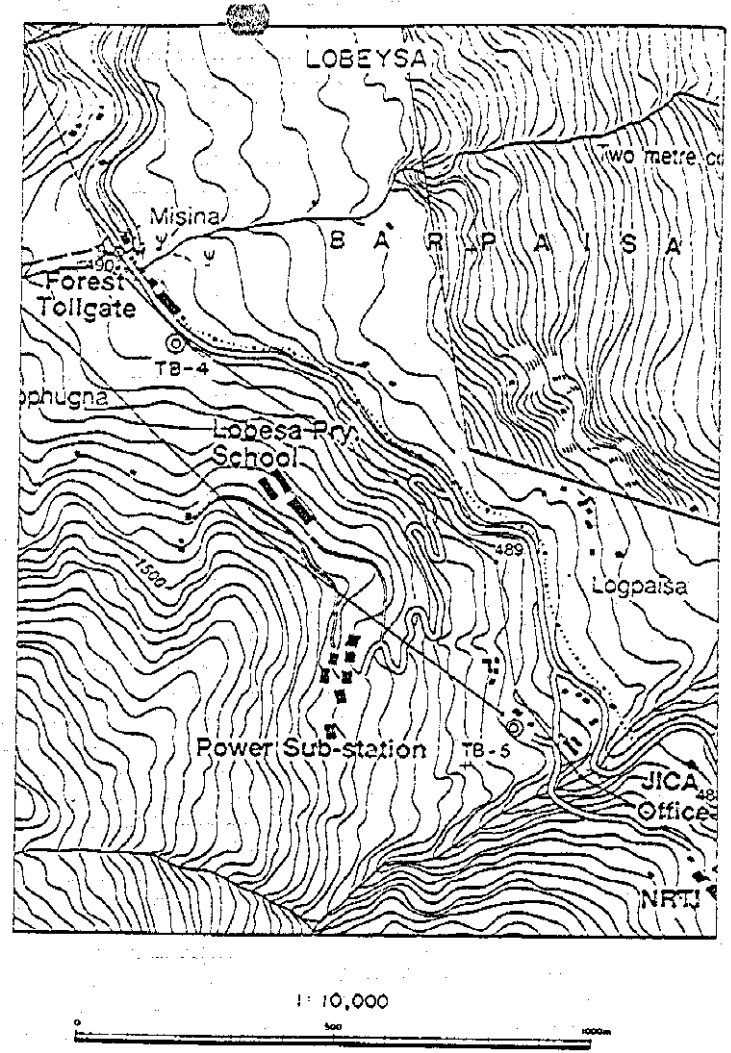


Fig. C. 2. 1 LOCATION MAP OF TEST BORING SITE

◎ TB-1 ··· Test Boring No.

ROYAL GOVERNMENT OF BHUTAN
THE STUDY ON GROUNDWATER DEVELOPMENT PROJECT IN WANGDUEPHODRANG DISTRICT
JAPAN INTERNATIONAL COOPERATION AGENCY

WELL LOG

DATA NO.

PROJECT NAME	THE STUDY ON GROUND WATER DEVELOPMENT, WANGDI PHODRANG DISTRICT, BHUTAN		
AREA AND LOCATION :	BAJO	WELL NO.	TB - 1
ELEVATION :	1,241 m	LONGITUDE	LATITUDE
TOTAL DEPTH :	33.0 m	DRILLING RIG :	TONE THS - 70
DRILLING STARTED :	MARCH 5, 1994.	DRILLED BY :	Y. KIMURA
WELL COMPLETED :	MARCH 20, 1994.	LOGGED BY :	T. KOGO.

STATIC WATER LEVEL : NOT OBSERVED	m	WATER TEMPERATURE :	°C
DYNAMIC WATER LEVEL	m	ELECTRIC CONDUCTIVITY :	μs/cm
PUMPING RATE :	l/min( ) m³/day	pH :	

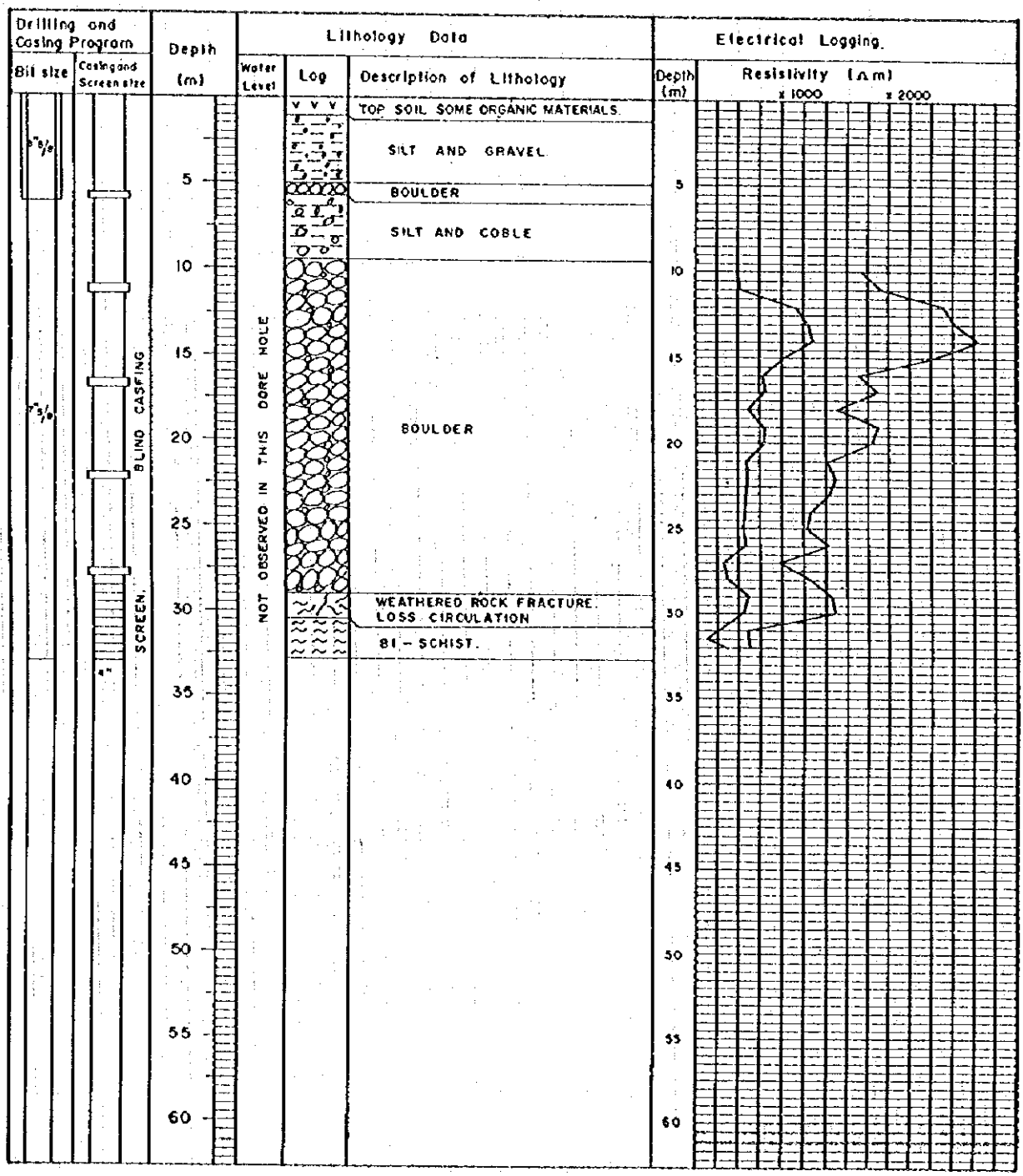


Fig. C. 2. 2 WELL LOG, (1/5), TB - 1

WELL LOG

DATA NO.

PROJECT NAME	THE STUDY ON GROUND WATER DEVELOPMENT, WANGDI PHODRANG DISTRICT, BHUTAN		
AREA AND LOCATION :	BAJO	WELL NO.	TB-2
ELEVATION :	1,227 m	LONGITUDE	LATITUDE
TOTAL DEPTH :	54.0 m	DRILLING RIG :	TONE THS-70
DRILLING STARTED :	MARCH 29, 1994.	DRILLED BY :	Y. KIMURA.
WELL COMPLETED :	APRIL 20, 1994.	LOGGED BY :	T. KOGO.

STATIC WATER LEVEL :	28.55 m	WATER TEMPERATURE :	18 °C
DYNAMIC WATER LEVEL	29.87 m	ELECTRIC CONDUCTIVITY :	270 μs/cm
PUMPING RATE :	175 l/min (252) m³/day	pH :	8.8

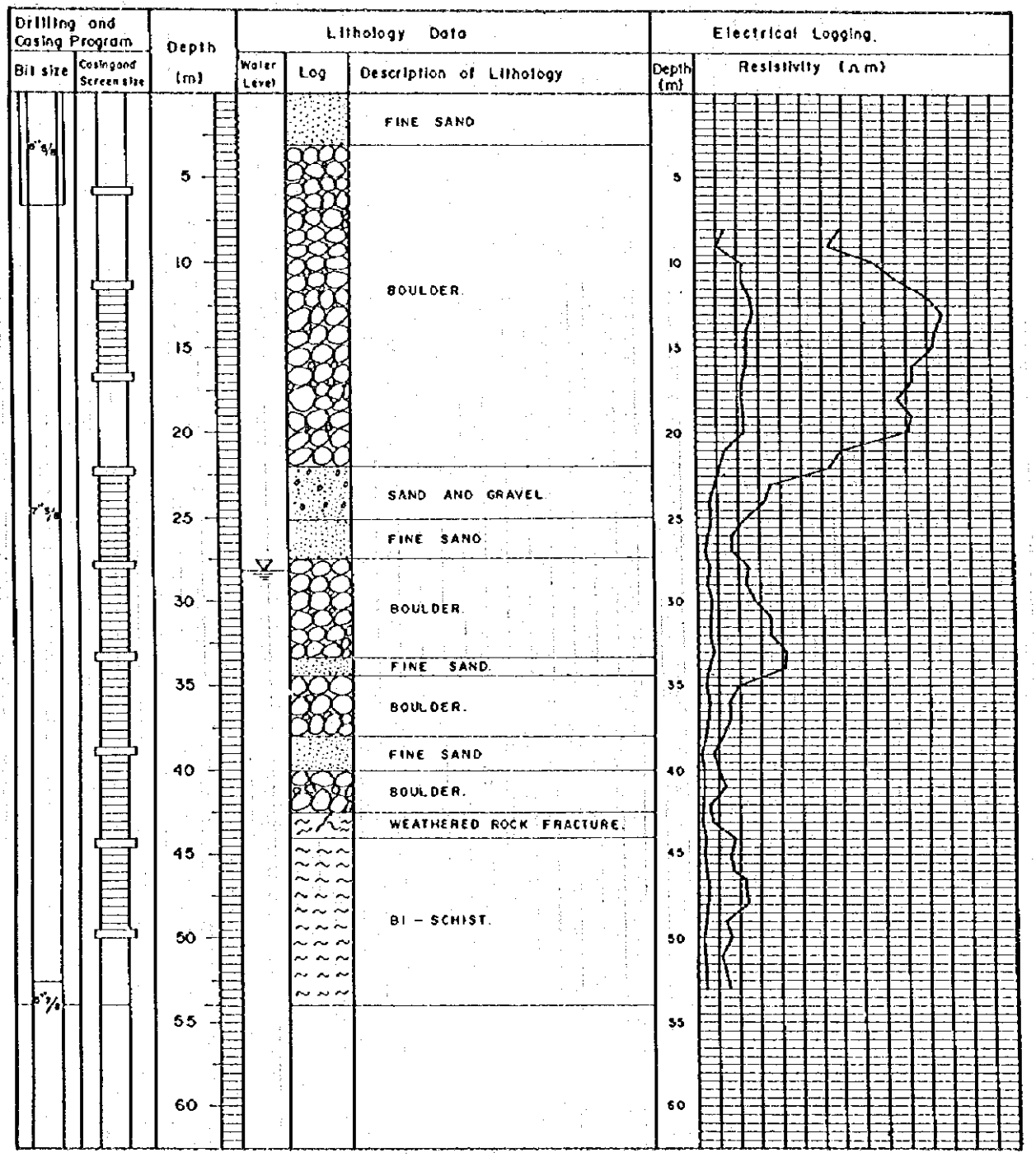


Fig. C. 2. 2 WELL LOG, (2/5), TB - 2

WELL LOG

DATA NO.

PROJECT NAME	THE STUDY ON GROUND WATER DEVELOPMENT, WANGDI PHODRANG DISTRICT, BHUTAN		
AREA AND LOCATION :	BAJO (CARD FARM)	WELL NO.	TB - 3
ELEVATION :	1223 m	LONGITUDE	LATITUDE
TOTAL DEPTH :	57.0 m	DRILLING RIG :	TONE THS 70
DRILLING STARTED :	APRIL 20, 1994.	DRILLED BY :	Y. KIMURA.
WELL COMPLETED :	MAY 10, 1994.	LOGGED BY :	T. KOGO.

STATIC WATER LEVEL :	28.33 m	WATER TEMPERATURE :	°C
DYNAMIC WATER LEVEL	32.55 m	ELECTRIC CONDUCTIVITY :	μs/cm
PUMPING RATE :	50 l/min (72 m^3/day	pH :	

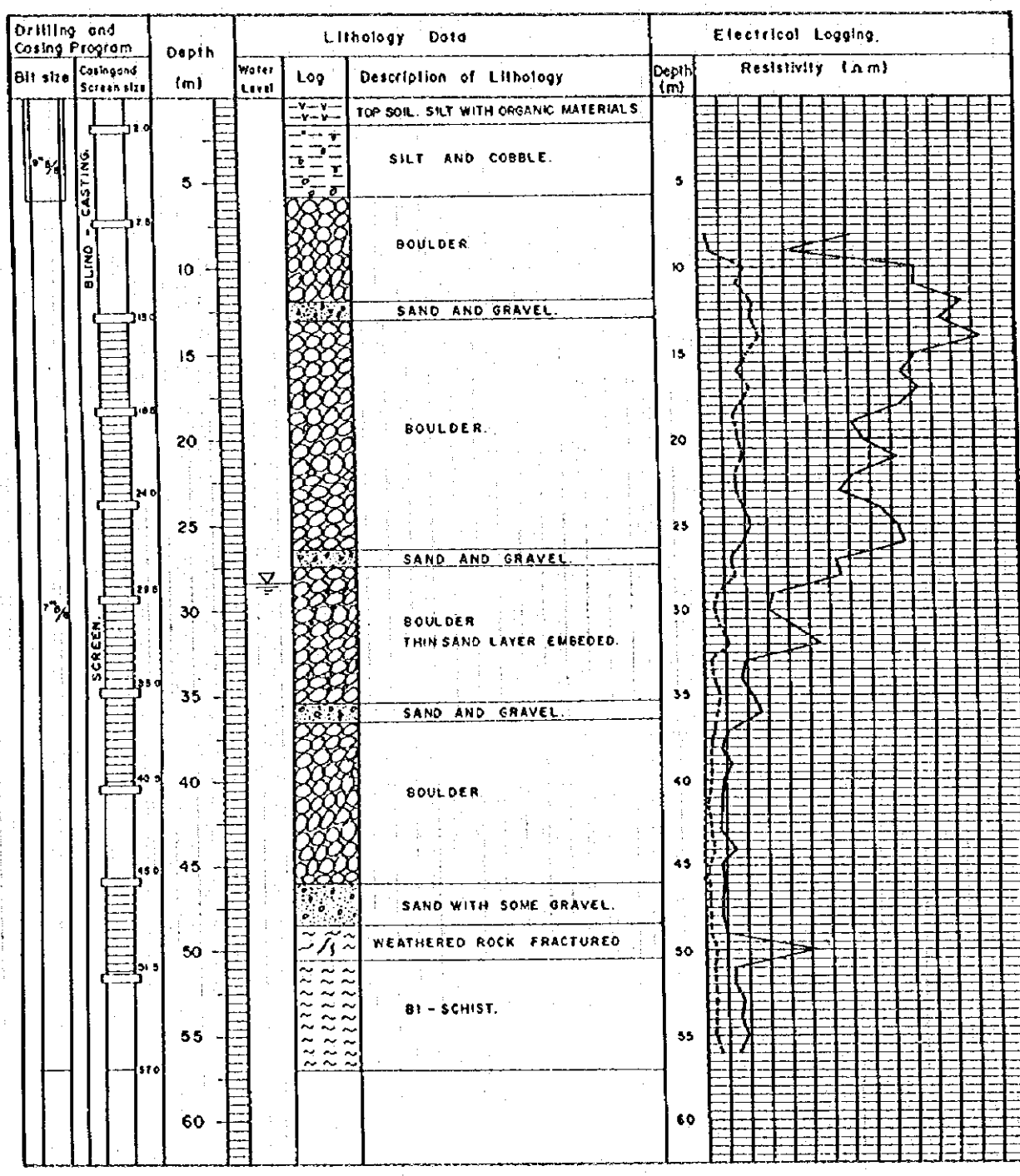


Fig. C. 2. 2 WELL LOG, (3/5), TB - 3

WELL LOG

DATA NO.

PROJECT NAME	THE STUDY ON GROUND WATER DEVELOPMENT, WANGDI PHODRANG DISTRICT, BHUTAN		
AREA AND LOCATION :	LOBEYSA.	WELL NO.	TB - 4
ELEVATION :	m	LONGITUDE	LATITUDE
TOTAL DEPTH :	58.8 m	DRILLING RIG :	THS - 70
DRILLING STARTED :	MAY 10, 1994.	DRILLED BY :	Y. KIMURA.
WELL COMPLETED :	MAY 24, 1994.	LOGGED BY :	T. KOGO.

STATIC WATER LEVEL :	9.23 m	WATER TEMPERATURE :	°C
DYNAMIC WATER LEVEL	17.24 m	ELECTRIC CONDUCTIVITY :	μs/cm
PUMPING RATE :	110 l/min(158)m³/day	pH :	

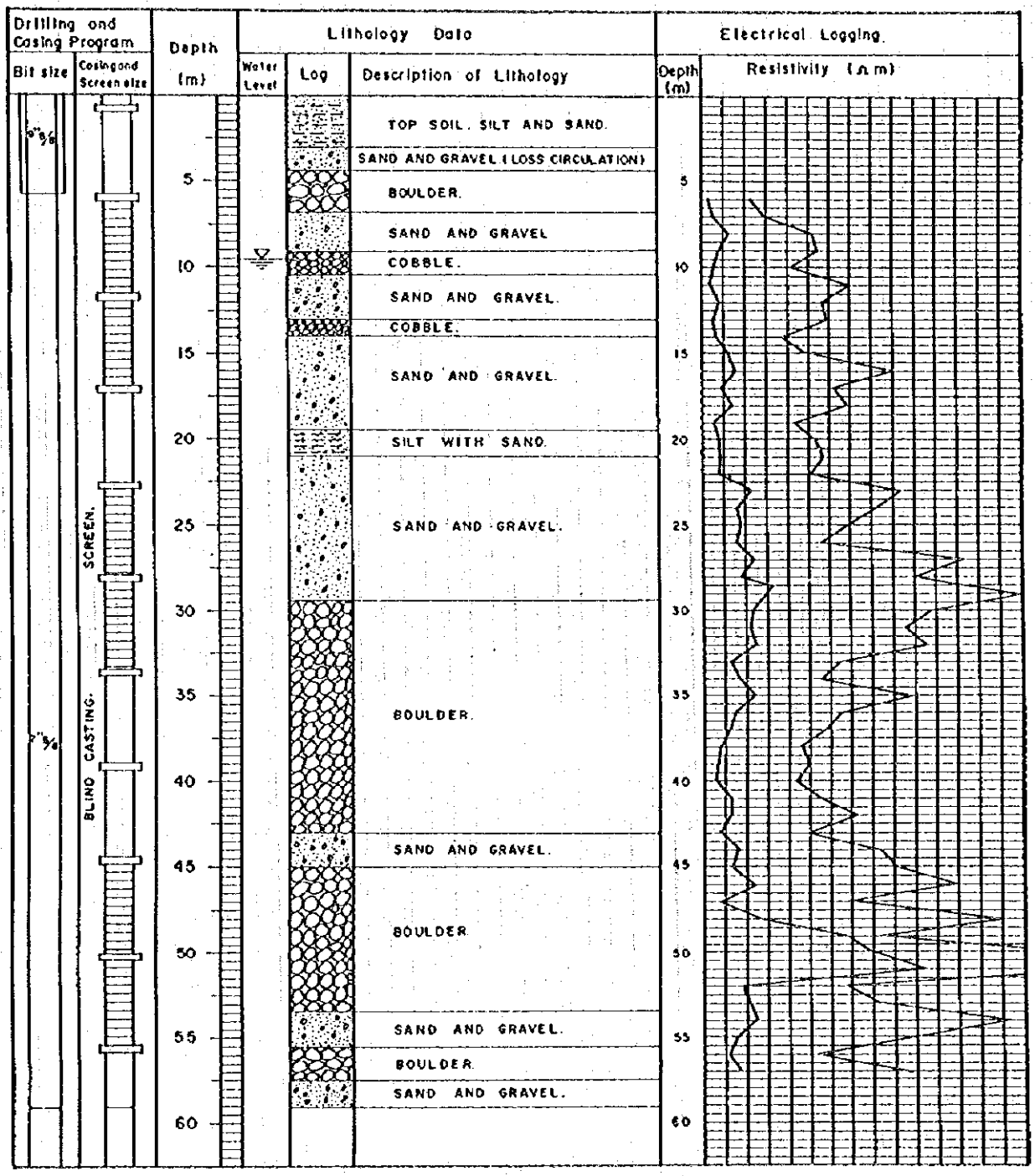


Fig. C. 2. 2 WELL LOG, (4/5), TB - 4

WELL LOG (TB-5)

DATA NO

PROJECT NAME: THE STUDY ON GROUND WATER DEVELOPMENT, WANGDI PHODRANG DISTRICT, BHUTAN			
AREA AND LOCATION	LOBEYSA FOREST OFFICE	WELL NO	NO. 5
ELEVATION m	LONGITUDE	LATITUDE	
TOTAL DEPTH 61.0 m	DRILLING RIG	TONE "THS-70"	
DRILLING STARTED NOV. 23, 1994	DRILLED BY	Y. KIMURA	
WELL COMPLETED DEC. 28, 1994	LOGGED BY	T. KOGO	

STATIC WATER LEVEL -47.80 m		WATER TEMPERATURE 24	°C
DYNAMIC WATER LEVEL -51.95 m		ELECTRIC CONDUCTIVITY	μ S/cm.
PUMPING RATE 55.0 l/min (79.2) m³/day		PH 5.2	

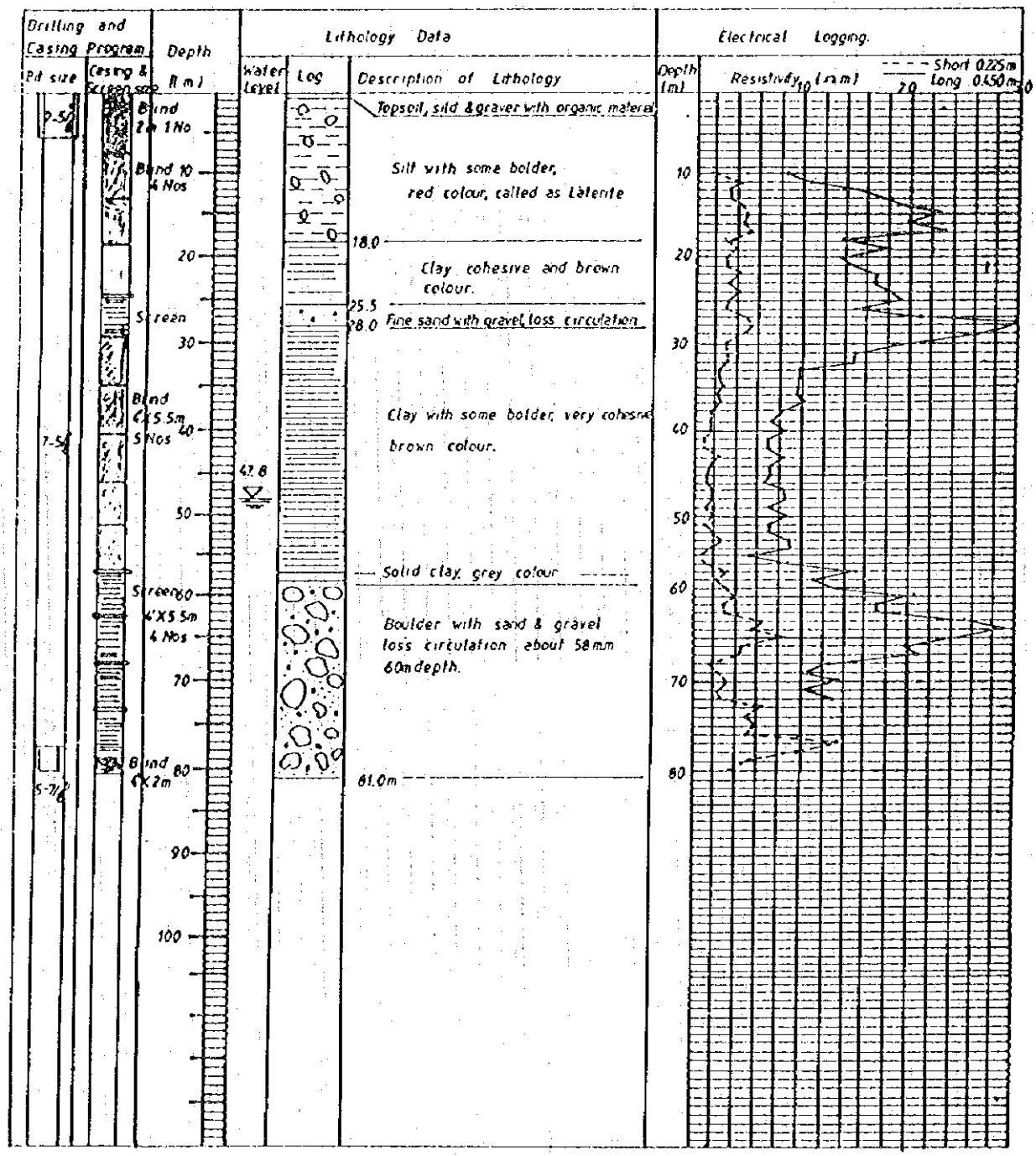


Fig. C. 2. 2 WELL LOG, (5/5), TB - 5