CHAPTER 9 SOLAR HOME SYSTEM

9.1 Scope of Work

In the beginning of the preparatory survey, the JPST was supposed to review the report prepared by ADB PPTA Study Team, and conduct an inventory survey (complete survey) on the existing solar home system (SHS) for planning the SHS project as a Japanese ODA loan project component for off-grid electrification. The necessity for planning the SHS project by JPST, however, was disregarded as DOE stated that such project should be funded by grant, not by loan.

DOE prefers that an inventory survey on SHS should be performed before the start of the preparatory survey because the responsibility for maintaining the existing SHS will be transferred to BPC in the future. It was revealed that most of the existing SHSs are located in on-grid area (the area supposed to be electrified by on-grid in the future) while the number of SHSs located in off-grid area is only around 700. The number of SHSs, in which DOE has no information and that require inventory survey, is estimated to be several tens out of 700 SHSs in off-grid area. DOE decided to cancel the inventory survey as it judged that it is not worth spending a large amount of energy to serve very few SHSs.

In addition, the issue on the requirement for survey team member in charge of photovoltaic (PV) generation technology was raised as it was realized that an off-grid component will not be included in the Japanese ODA loan component. Moreover, it was agreed with DOE that the new member in charge for distribution planning will become part of the survey team and will participate in the second site survey.

JPST discussed this issue with DOE and reached a consensus on the following scope of work for the member in charge of PV generation technology during the first site survey:

1) Review of PPTA Report
2) Detailed survey of existing SHS as sampling basis
3) Technical support for the SHS pilot project, which is being implemented as part of the scope of JICA technical assistance to examine the possibility of being under a Japanese ODA loan component.
4) Prepare proposal for the ADB-assisted SHS component, which is planned to be implemented by DOE, based on the issues found during the detailed survey of existing SHS and the experience from the pilot project.

9.2 Review of PPTA Report

The following two reports have been received from DOE:

1) First Mid-Term Report, March 6, 2010
2) Second Mid-Term Report, April 30, 2010

(1) Review of First Mid-Term Report (Photovoltaic Power Generation)

a) Review on Technical Issue

Technical issues found in the report are as follows:

Appendix A

A.1 Table 1 Life-cycle Cost Benefit Analysis of CFL vs WLED Lights

There are two kinds of compact fluorescent lamp (CFL) bulbs. One is the separated type where fluorescent tubes and outer case are separated, and the other is the integrated type. Generally, separated type is commonly used in Bhutan, hence, replacement parts are only fluorescent tubes, which cost less than $9 each. Moreover, light emitting diode (LED) has light condensing characteristics. Its lumen/W is higher than that of fluorescent tubes which possess diffusing light characteristics. When replacing the lamps in the room, two sets of LED lighting apparatus are required for every set of fluorescent lamp.

A.2

Bhutan offers 4.25 kWm^2/day as a solar resource. Taking into account an overall efficiency loss of 56% on the PV panel, and an additional loss of 30% due to battery inefficiency, cabling and environmental factors, the following design components have been selected:

The unit rate in "kWm^2/day" of solar radiation is used. However, the unit of solar radiation should be "kWh/m^2/day". Fifty six percent loss of PV panel is unconfirmed. Generally, 20% of loss of PV panel is used. Also, discharge and charge loss of batteries is generally 10% to 20%. Thus, excessive loss rate is estimated.

A.2.1

Taking efficiency losses into account, the solar panel is required to generate a minimum of 206 watt hours per day in order to achieve an actual 158 watts of useable power at the light fixture terminals. With an effective panel generation efficiency of 56%, the solar energy available for power generation per day is not 4.5 hours but 2.52 hours. With a target of 206 watt hours per day, and 2.52 effective solar hours per day, 80 watt PV panels are required.

The size of the PV panel is calculated as 80 W based on the power consumption of the CFL, though the use of the LED light is recommended. In addition, to cover the 158.4 Wh/day consumption, the required amount of power generation is calculated at 206 Wh/day (unconfirmed). Furthermore, 4.5 kWh/m^2/day (=4.5 h/day: duration of peak solar radiation) is used, though 4.25 kWh/m^2/day is defined as the solar radiation in A2.

Technical background to assume the size of PV panel is to be 80 W.

The required technical grounds to assume the size of the PV panel to be 80 W are uncertain. A necessary size of the PV panel is 55 W though this report estimates the power consumption of three CFL bulbs to be 158.4 Wh/day.

A2.2
A minimum 10 amp charge controller

When the PV panel of 80 W is used, the 6 A charge controller has enough capacity. The 10 A capacity is considered to be over specified, and has no supporting data.

A deep cycle lead acid battery of flooded lead acid design, of not less than 90 AH @C10

The battery capacity is specified as 80 Ah@C20 in Table 2; however, the battery capacity is specified as 90 Ah@C10 without supporting data.

The battery is to be supplied either fully charged, or with electrolyte supplied separately.

Generally, battery fluid is filled at the site as it may leak during its transportation to the site. Procurement of batteries with battery fluid and at fully charged condition should be avoided.

A2.4
The charge controller shall use a pulse with modulation (PWM) strategy.

The function of charge controller is specified as PWM. However, since there is a condition stated as, "*In the case of ON-OFF regulators",* for PWM, "ON-OFF" type does not satisfy the specifications. Furthermore, it is also stated that, "*The charge controller shall not use electro mechanic relays"*. Thus, there is no discrepancy between the specification and this description since electromagnetic type relay is not used in PWM charge controller.

There are discrepancies on descriptions found in the specifications. It is therefore recommended to totally review the specification for the competitive bidding.

PPTA has estimated the number of targeted households to be 1,850 in ten dzongkhags.

Table-9.2.1 Targeted Number of SHS

No.	District	Number of HH
1	Chukha	563
2	Dagana	231
3	Gasa	200
4	Paro	170
5	Haa	44
6	Punakha	16
7	Samtse	177
8	Sarpang	177
9	Trongsa	12
10	Wangdue	260
	Total	1,850

Source: PPTA First Mid-Term Report

b) Review on Operation Side

It is proposed that O&M should be executed by BPC, not by DOE. It is appropriate to train the technician of the BPC branch office to provide technical support on SHS as said office exists in each dzongkhag. However, this seems to be not a proper proposal since the training system to provide the technical know-how on PV system had not been established since the beginning of March, 2010.

It was in May, 2010 that the training system was organized in Begana Training Center to provide technical know-how on PV system by qualified trainers, who were trained by experts from the Philippines under the scope of JICA Technical Corporation.

Also, it mentioned about the O&M organization being operated by a village technician; however, it seems to be an overestimation of the ability of a village technician.

Regarding the O&M, only general explanation has been described and no concrete issues are mentioned. Thus, no review on O&M was done.

c) Review on Economic Aspect

An economic comparison between on-grid and off-grid systems is done based on the electricity cost of one kWh. However, the quantity that can be used is extremely limited in the off-grid system due to direct current supply. Hence, it should be avoided to directly compare the on-grid and off-grid power supply systems.

The first electric appliance that recently electrified family wants to buy is a rice cooker. However, it is impossible to use rice cooker with SHS power supply. Furthermore, the usable amount of electricity generated by one 80 W PV panel is approximately 230 Wh/day. In other words, one kWh is not an appropriate basis for comparing electricity for one hour for on-grid power supply and five day power supply for off-grid power supply.

Therefore, since on-grid and off-grid systems cannot be compared based on the cost of one kWh, the criteria should be:

-- How much money is to be added to the capital for the on-grid system as per the policy?, or
-- Is it possible to extend the distribution line by the target year of 2013?

Moreover, the role of SHS is to provide a temporary power supply until the power supply by on-grid system is available. Accordingly, it is advisable to extend the distribution lines where it is possible to extend even after 2013.

(2) Review of Second Mid-Term Report

In the second mid-term report, no descriptions have been made on the reduction by half of ADB budget for off-grid. Moreover, only few explanations on off-grid system are made. Thus, no review on said report was conducted.

9.3 Detailed Survey of Existing SHSs

(1) Objective of the Detailed Survey of Existing SHSs

The objective of the detailed survey is to reveal the problems on the use of existing SHSs in order to feed back the lessons learned to the SHS project for achieving 100% electrification rate.

The detailed survey is a technical survey which includes an operation check and a measurement of system parameters such as charging and discharging current and voltage, etc. Due to the absence of experience on such technical survey, a five-day training course was conducted for Bhutanese surveyors to learn the survey method.

A detailed survey was conducted for 17 days in Tsirang, Mongar, Bumthang and Wangduephodrang dzongkhags, with a total of 86 survey samples.

In Wangduephodrang, the detailed survey was conducted at the Barefoot College project site to confirm the current level of skills of village technicians.

(2) Overall Result of the Detailed Survey

The types of the SHS vary by dzongkhags. No trouble was found in Mongar because the SHSs were installed after 2009. Many batteries have already expired and faults of charge controllers occur frequently in dzongkhags other than Mongar. CFL bulbs were normally functioning and their quality seemed to be good in general, though a few defective units were found.

This survey revealed that the inventory survey is considered ineffective.

i) The system for regularly replacing batteries is necessary.
Bypassing the charge controller to extend the lighting hours was done when the battery performance has decreased.

ii) Importance of quality of charge controller
The role of charge controller is to protect batteries; however, charge controllers which are harmful to the batteries were found.

iii) The life duration of CFL bulb is longer than expected.

Table-9.3.1 Overall Results of Exiting SHS

Dzongkhag	Nos.of SHSs surveyed	Status of operation
Tsirang	13	Installed by Dzongkhag funded by DoE in 2005. Many charge controler made by TATA BP have faults and they were removed in most cases. Batteries were needed to be replaced becase they had reached their end of life.
Mongar	34	Installed by Dzongkhag funded by DoE after 2009. They worked well.
Bumthang	20	Installed by Thrumshingla National Park ten years ago. They were working, but the number of households whose charge controllers were bypassed was increasing because of the shorter duration of lighting. Batteries require replacement due to its shorter life duration than other component such as PV panels.
Wangduephodrang	19	Installedy by Barefoot in May, 2008. Setting of the voltage of charge contollers which protect batteries was improper. This shortened the life duration of batteries to only two years.

(Prepared by JPST)

(3) Result of Detail Survey by Dzongkhags

a) Tsirang

It has been five years since the SHS was installed, and the service life of the batteries have already expired.

Many charge controllers made by Tata Power are not functioning properly. Thus, many of them are disconnected.

Table-9.3.2 Survey Result of the Existing SHSs in Tsirang Dzongkhag

Installed by (Installation year)	Item	PV panel	Charge controller	Battery	CFL lighting	Problems
Dzongkhag/DOE (2005)	Specification	60W	TATA BP 10A	TATA BP Solar 12-135P (135Ah?)	TATA BP JUNGU 11W x 3 units	Most of charge controller have been removed due to operational problems. Batteries are reached the end of its life duration.
	Nos of defectives / Nos surveyed	0/12	11/12	12/13	8/36	
Individuals (2008)	Specification	N/A	Not used	Volta 32Ah	CFL 5W	Battery voltage of 9 (V) is too low for the proper operation of SHS.
	Nos of defectives / Nos surveyed	0/1	0/9	1/1	0/1	

(Prepared by JPST)

b) Mongar

Mongar's SHSs have been installed one year ago and all are operating properly.

Meanwhile, it has passed almost ten years since the existing SHS was installed by Thrumshing National Park. The service lifetime of the batteries has already expired and thus, these SHSs are expected to stop operating. The charge controllers are disconnected by the owner so that SHS can be utilized through direct connection to battery and lighting load.

Table-9.3.3 Survey Result of the Existing SHSs in Mongar Dzongkhag

Installed by (Installation year)	Item	PV panel	Charge controller	Battery	CFL lighting	Problems
Dzongkhag/DOE (2009-2010)	Specification	Coenergy 60W	SunTechinics STI10	12T-80P (80Ah?)	SunTechinics STI10 11W x 3 units	Good condition because only one year had passed after installation. A piece of glass of PV panel was broken during transportation.
	Nos of defectives / Nos surveyed	1/27	0/27	0/27	14/81	
Thrumshing National Park (2000)	Specification	N/A	TATA BP MCR1210	TATA BP 12-110h	TATA BP 11W x 3 units	Battery damaged, charge controller removed and bypassed.
	Nos of defectives / Nos surveyed	0/6	0/9	1/1	0/1	
Individuals (unknown)	Specification	60W (for12V)	Not used	Volta 32Ah	CFL 5W	Battery does not work due to discharge caused by back current from 12V to 6V PV panel.
	Nos of defectives / Nos surveyed	10W for 6V)	0/9	1/1	0/1	

(Prepared by JPST)

c) Bumthang

Six to ten years have almost passed since the SHSs were installed by Thrumshing National Park. The service lifetime of the batteries are about to expire, hence, some of the SHSs may stop operating. The charge controllers are disconnected by the owner so that SHS can be utilized by direct connection to battery and lighting load.

Table-9.3.4 Survey Result of the Existing SHSs in Bumthang Dzongkhag

Installed by (Installation year)	Item	PV panel	Charge controller	Battery	CFL lighting	Problems
Thrumshing National Park (2000-2004)	Specification	N/A	TATA BP JUNGU	TATA BP 12T-110h	TATA BP 11W x 4 units	Battery damaged, charge controller removed and bypassed.
	Nos of defectives / Nos surveyed	18	11/18	18/18	16/72	
Department of Road (2008)	Specification	N/A	SunTechnics	SunTechnic s	SunTechnics 75Ah	Good condition because only two years had passed after installation.
	Nos of defectives / Nos surveyed	0/1	0/1	0/1	0/3	
Individuals (2008)	Specification	TATA BP 10W	Not used	N/A	TATA BP 11W x 2 units	
	Nos of defectives / Nos surveyed	0/1	0/0	0/1	0/2	

(Prepared by JPST)

d) Wangduephodrang

The 32 sets of SHSs were installed in May, 2008 by Barefoot College. Thus, these should be operating without any trouble. However, owners are complaining that they can use lighting only for 2 hours in a day.

Table-9.3.5 Survey Result of the Existing SHSs in Wangduephodrang Dzongkhag

Installed by (Installation year)	Item	PV panel	Charge controller	Battery	CFL lighting	Problems
Barefoot College (2008)	Specification	N/A	Barefoot SPV 12V, 8A	Exide 40Ah	Barefoot 9W x 2 units	Battery damaged, charge controller removed and bypassed.
	Nos of defectives / Nos surveyed	0/17	10/17	15/17	0/34	
Dzongkhag/DOE (2008)	Specification	N/A	TATA BP 10A	TATA BP N/A	TATA BP 11W x 3 units	
	Nos of defectives / Nos surveyed	0/1	0/1	0/1	0/3	
Individuals (2004)	Specification	N/A	Selco	N/A	Selco 9W x 4 units	
	Nos of defectives / Nos surveyed	0/1	0/1	0/1	1/4	

(Prepared by JPST)

e) Barefoot College's SHS

i) Problems on equipment faults

Faults often occur in Barefoot College's SHS in spite of it being installed only two years ago. Detailed survey revealed that voltage setting of the overcharge protection circuit was extraordinarily high such as high voltage differential (HVD) of 14.7 V, high voltage regulator (HVR) of 13.0 V, and hysteresis voltage of 1.7 V.

Cause: Inappropriate voltage setting of HVD and HVR of charge controllers. The following problems were also determined:

- Insufficient charging of battery
- Progression of sulfation of battery electrodes
- Sulfation reduces the battery capacity
- Lighting can be used for only one or two hours in many households

Countermeasure: Replacement of charge controllers and batteries. However, the following issues are noted:

- Although there were spare parts of charge controller, it is impossible to assemble the charge controllers.
- Even if it is possible to assemble the charge controller, similar problem may occur since the specifications remain the same.
- Charge controllers made by manufacturers other than Barefoot College is necessary to be procured.
- The fund raised by residents is Nu.25,000. With such amount, however, it would be impossible to replace all the charge controllers and batteries,

Therefore, there is no solution for the above issues. Fortunately, this village is planned to be electrified by on-grid system in the near future.

ii) Problems in maintenance

In the concept of O&M in Barefoot College's SHS project, women from villages availed a half year training course in India. They are expected to play a role in the O&M as technicians for sustainable operation.

In reality, the concept does not work due to the following reasons:

- Training course is mainly for assembly of electric substrate of charge controller and lighting.
  Assembly of electric substrate composed of many parts is difficult for women. Moreover, assembly procedure tends to be forgotten without continuous practice.
- Technicians have no information on the basic operation of SHS.
  They can only deal with simple troubles such as loose wiring. No support is provided from outside the village.
- Large amount of spare parts is available, but left unused.
  Such parts cannot be assembled. Even if assembly is possible, troubles still occur. Thus, supply of large amount of spare parts is required, indicating that the defective rate of SHS is significantly high.

When DOE expands the SHS projects at the national level, it is recommended to draw out some lessons from the Barefoot College case.

CHAPTER 10 RECOMMENDATIONS

10.1 Recommendation on Management of Distribution Facilities

(1) Feeder-wise Diagram

At present, line information such as support, transformer capacity, kind of conductor, and line length are arranged and controlled using GIS system. The same information is also used in the MI Power to analyze the status of power system.

The feeder-wise diagram, which may include the number and capacity of transformers, kind of conductors, line length, etc., may be produced by extracting the necessary data from the database of MI Power.

Actually, handwritten diagrams have been prepared at some RECD or RECSD. Thus, only the person who prepared the diagram knows the distribution system.

Feeder-wise diagram, on the other hand, enables any concerned person to understand the distribution line information, including the location of equipment such as sectionalizing switches and ARCB.

(2) Ledger of Distribution Facilities

Together with the feeder-wise diagram, all feeder information should be arranged on a distribution facility ledger. Hence, all information on the distribution line can be utilized by the personnel concerned.

10.2 Recommendation on Data Management by GIS

The problems in present GIS data management, which were pointed out in the interview with GIS personel in DOE and BPC (see section 3.6), can be summirzed in following three categories; (i) consistency of GIS database, (ii) work efficiency and (iii) opportunity of further development

(1) Consistency of GIS database

(a) Functions required to keep consistency of GIS database

A solution to keep the consistency of GIS database using the current standalone GIS is to establish a guideline for formatting and updating data. In reality, however, it is very hard to inform everyone to work on the GIS and have them observe the guideline at any time.

This problem should be solved by embedding the functions of keeping the consistency of the GIS database into the GIS software and not through the manual effort of each GIS personnel. The functions that the GIS software should be equipped with are as follows:

1. Consolidated GIS database
   All GIS data should be consolidated in a single database in order to avoid duplication and scattered data in various PCs, and to enable access to the latest GIS data.

2. Version control
   One of the reasons why it is often difficult to identify the latest data is that various versions of data are created. It is, however, impossible to avoid creating different versions of GIS data in the process of editing and updating GIS data. Although it is possible to record the versions of all GIS data in the data files manually, a version control is a more sophisticated solution which allows tracking revisions and returning to any earlier state of the GIS data.

(b) GIS database network with GIS server
A solution to realize the above-mentioned two functions is to introduce a GIS server. By introducing a GIS server using ArcGIS server software, the GIS database stored in the GIS server can be accessed from PCs equipped with ArcGIS Desktop (ArcInfro/ArcEditor/ArcView). The ArcGIS server allows the administrator of the server to regulate the access to the data files by other users to keep data consistency and control the versions of the data. A schematic of a GIS server-centered GIS database network is shown in Figure-10.2.1.

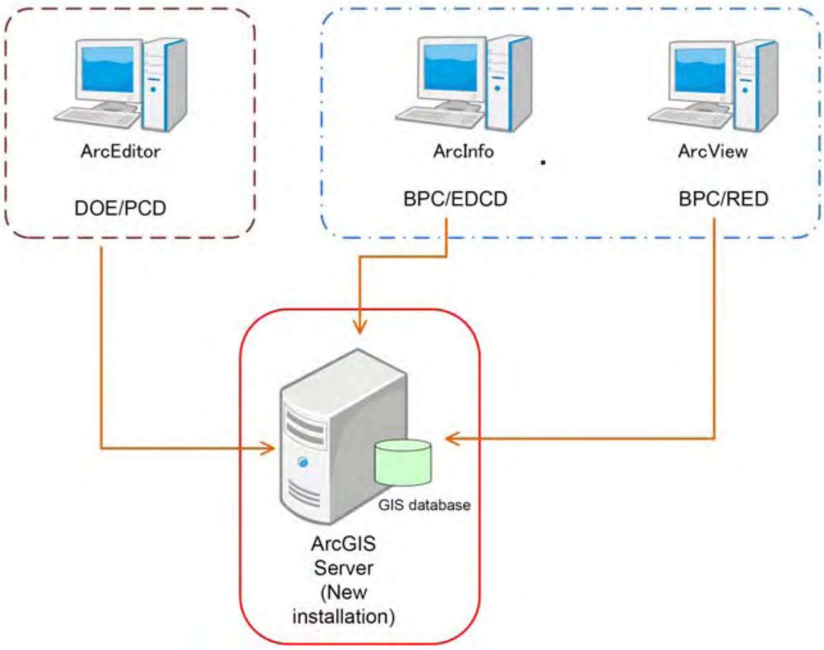


Figure-10.2.1 GIS Database Network with a GIS Server

(2) Work Efficiency

(a) Extended GIS database network

The GIS personnel in BPC HQ have to convert the huge quantity of GPS location data collected at the sites into a usable GIS format and arrange it appropriately. This heavy work load makes it difficult for GIS personnel to pay sufficient attention to appropriate GIS data management. If it is possible to convert and upload the GPS into the GIS server located at the BPC HQ and browse the final output of the GIS map from the RECD/RE-CSD near the sites, it will reduce the data conversion and correction work load of the GIS personnel. Moreover, it will facilitate faster updating work and contribute to reduction in traveling cost since it will eliminate the necessity to bring the collected GPS from the sites to the BPC HQ.

This can be realized by connecting the GIS server located in the BPC HQ with the PCs located in each RECD and RE-CSD. The GIS database in the GIS server can be accessed using Desktop ArcGIS software or web application from each RECD and RE-CSD. Which software should be introduced in the RECD/RE-CSD depends on the skill of the GIS personnel in the RECD/RECSD, the GIS-related tasks of the RECD or RE-CSD personnel, and the budget constraint. Desktop ArcGIS software has various functions of editing GIS data, but it requires a certain level of GIS skill and some amount of installation cost. In the case of web application, this is a web browser-based application for simple tasks such as browsing the GIS maps or uploading the GIS data with low installation cost. Moreover, the web application can be easily introduced in other departments of DOE/BPC because it can be installed in every PC without any extra installation cost. The functions of the web application can be customized using the developers' tool "ESRI Developer Network (EDN)" provided by ESRI if there is a need to meet the various user requirements. A schematic of a GIS server-centered GIS database network extended to RECD/RE-CSD is shown in Figure-10.2.2.

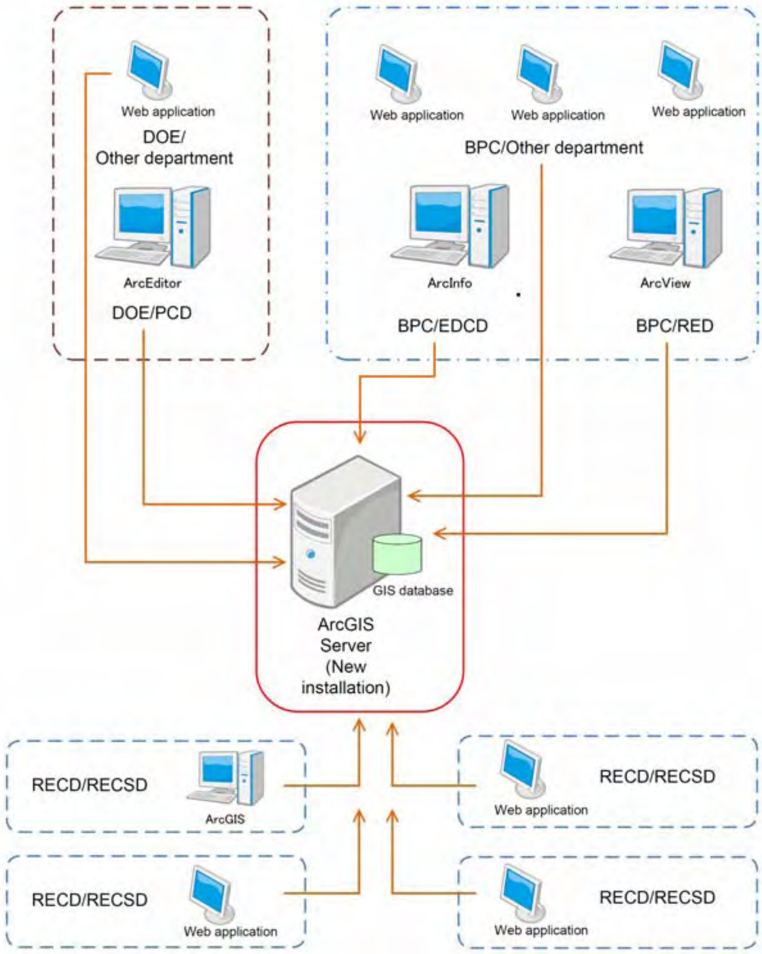


Figure-10.2.2 Extended GIS Database Network with a GIS server

At present, the RECD/RECDSs where the internet connection is available are limited. In future, RECD/RECDSs, can be connected with optical fiber communication network in accordance with the BPC's OPGW and ADSS lines extension plan described in section 10.3.4.

(b) Automatic drawing generating system

Currently, other types of drawings such as single line diagram and load flow diagram that contain similar information about distribution facilities as in GIS maps are created by CAD and load flow analysis software. This causes significant increase of the workload of the GIS personnel when updating the data. Therefore, it is recommended to develop a system that could generate other types of drawings from the GIS database. Figure-10.2.3 shows an example of generating a single line diagram. The most important information for generating single line diagrams is the connection between feeders and the feeders where substations or other facilities are located. It is possible to generate a single line diagram from the GIS database information by adding the connection data of feeders and substations on the GIS database, and eliminating the unnecessary line length and position data using "ArcGIS Schematics", which is an extension of ArcGIS software.

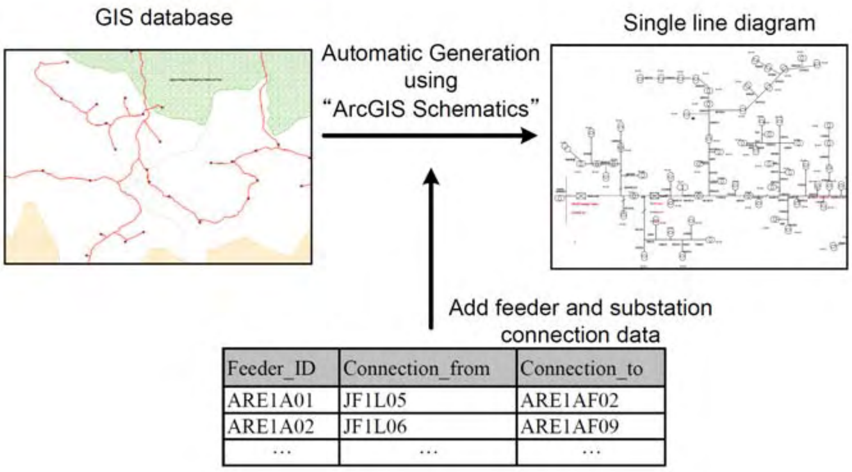


Figure-10.2.3　Automatic Generation of Single Line Diagram from the GIS Database.

On the other hand, there are huge amounts of existing drawings in CAD or other formats made before the introduction of GIS.　Although these drawings are invaluable asset for the O&M of distribution facilities, they are not organically linked to the GIS database.　The development of clickable features on the GIS map linked to the drawing files will contribute to the efficient use of existing drawing data.　This function can be realized by introducing the ArcGIS server and customizing using development tools.

(3) Opportunity for Further Upgrading of GIS Data Management

During the interview with BPC GIS personnel, the absence of GIS experts and few opportunities to upgrade the current GIS data management system were pointed out. It is recommended to employ foreign GIS experts or encourage DOE/BPC GIS personnel to undergo training in foreign countries since there is only limited GIS experience in Bhutan.

For optimizing the GIS database to user's needs during the construction and O&M of distribution facilities, a re-examination of the GIS data structure and GIS database management work flow, which reflect the opinions of the planning and distribution O&M experts, will be required.

10.3 Recommendation on Capacity Building

10.3.1 Capacity Development Tasks and Challenges

There are three areas of capacity that need to be built up for effective and efficient implementation of RE, i.e.: planning, construction supervision and operation.　One of the areas that is crucial to planning and supervision in RE is the enhancement of management information system (MIS) capabilities. RE needs to deal with power supply services in remote areas with few customers. Accurate and timely information is vital for efficient implementation. For instance, delivery of materials to a wrong site or with wrong quantities will cost much more in re-adjustment compared to such incidents in urban areas. Restoration of circuit breakers at a remote location will require more time and loss of power supply as well as more manpower for operation. Accurate information will lessen this wasteful use of resources, and increase availability of power to the customers. Contractors should therefore be well-informed. Much of the present complaints of the civil contractors may arise out of not knowing the exact conditions of work, thus wasting much time and money. Thus, information handling capacity becomes the key word for the improvement of BPC management.

Capacity building programs will consist of training in Bhutan and exposure to best practices abroad, development of manuals and guidelines through consultancy, development of some applications in the case of MIS work and the implementation of the capacity building may require the assistance from donor agencies..

10.3.2 Capacity Development in MIS

In terms of planning and monitoring, there are two targets. First is the system development and human resources to investigate the best use of management information that are already available to all the concerned planners and managers in BPC. Since BPC is introducing SAP as the overall information infrastructure, it is vital to build the database system upon this infrastructure. However, it should have improved facilities to further interface with excel and other types of data management system. For irregular and small scale database, excel will be used widely and continuously. At the same time, there should be an effort to upgrade the excel-based database to organize wide platform with higher reliability and more efficient aggregation and analyses. Strategic MIS will handle the development of overall management information handling system as well as conventional infrastructure.

The second task in data management will involve the integration of GIS system with other MIS application and database. Although GIS provides a great intuitive and prompt access on a scalable map interface to the database, the development and data management using GIS is not open to an average staff or planner. The functions enabled by a larger repertoire of commands will require long time for the training of a specialist. Thus, updating database becomes too expensive to maintain. In addition, the software itself is quite costly. Combination and integration of excel-based data entry or even the use of web-based application will be more efficient.

10.3.3 Construction Supervision and Inventory Control: Getting on with Just-in-Time

The third task of construction supervision has two issues. First, the knowledge and training on just-in-time system will prepare the planners in procurement and inventory control to streamline the process and minimize the delivery time for the target national goal of “Electricity for All by 2013.” The second issue is the inclusion of civil contractors for proper costing and logistic planning to create a win-win situation. More detailed feeder construction information should be delivered to the contractor including material specifications, weights, as well as route and village information before the tender. This is intended to ensure that the contractors will have adequate knowledge of the work they are undertaking.

10.3.4 Capacity Development in Power Supply Operation

BPC will be inaugurating the National Load Dispatch Center (NLDC) in Thimphu next year, 2011. The NLDC will serve as the headquarters of power supply command, and network connectivity of NLDC, WDC/Back-up System, EDC and associated communication systems for data logging and system control are shown in Figure-10.3.1. Since this is the first operation in the country, there is no trained operator yet. Well-trained Japanese experts can transfer the years' worth of know-how on safe and smooth operation of power supply.

At present, there are two data centers in Bhutan's power system. One is the Western Data Center in Malbase, and the other is the Eastern Data Center in Tingtibi. The data from both data centers are gathered at the existing Load Dispatch Center (LDC) in Thimphu. However, the data from the existing LDC in Thimphu is duplicated and backed up in Malbase.

Presently, the interconnecting transmission lines are being constructed to connect Rurichu-Tsirang-Jigmelin. The 220 kV transmission line between Rurichu and Tsirang has been completed and being operated at 66 kV. On the other hand, the 220 kV transmission line between Tsirang and Jigmelin is expected to be completed within 2010. Accordingly, the NLDC will operate and control the whole power system in Bhutan. Moreover, it will serve an important role in the export of power to India. Accordingly, the operation of NLDC is the first experience in BPC, hence, capacity development is a "must" for the BPC personnel concerned.

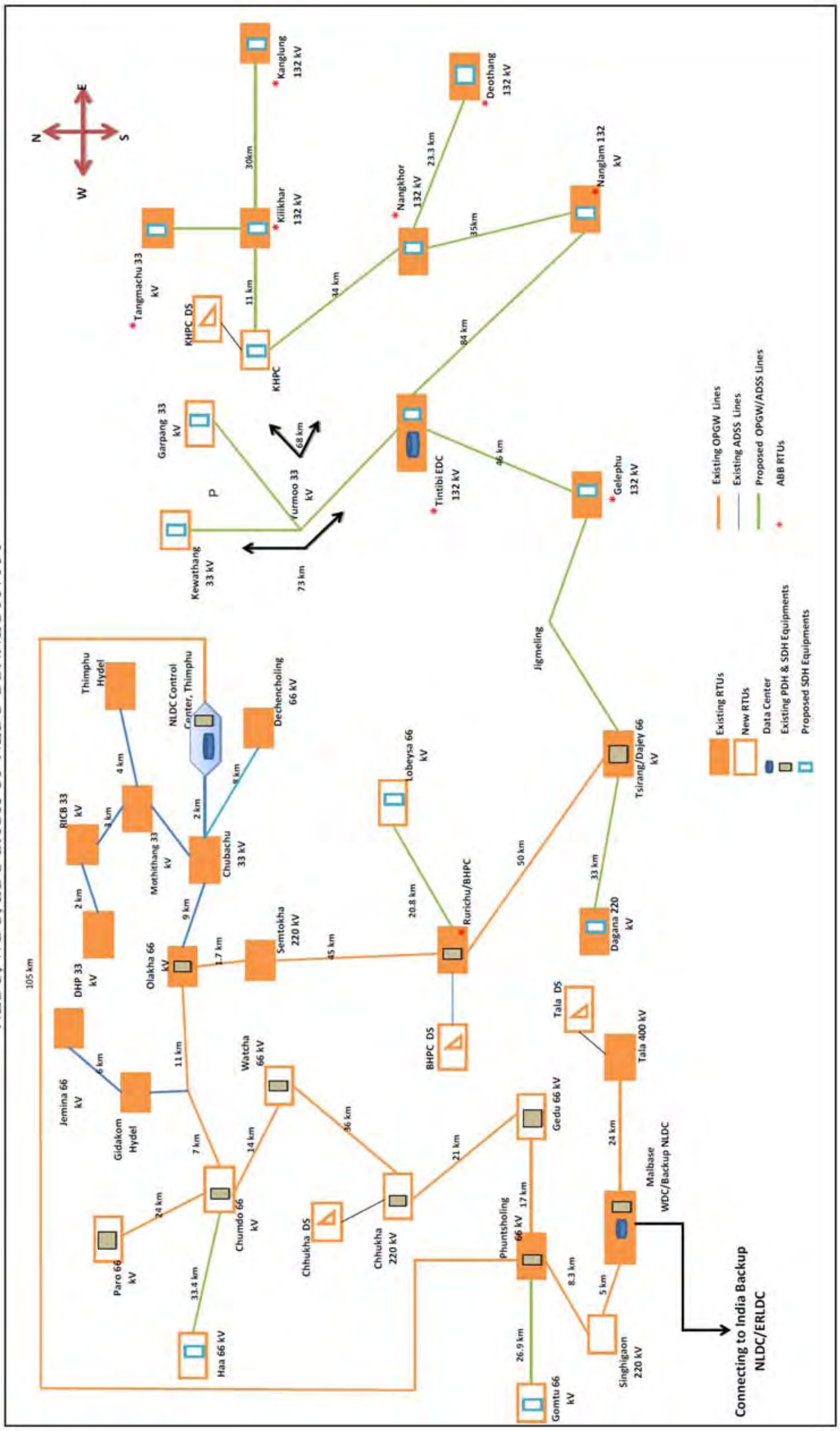


Figure-10.3.1   Network Connectivity of NLDC, WDC/back-up and EDC

10.4 Recommendations on SHS Project

(1) Importance of Sustainability

SHS can support village people by providing lights for longer period at night, as long as proper replacement of batteries is done. However, its disadvantage is the limited lifetime of the batteries. It is important to follow four key points as follows:

1. Accurate design
2. Use of suitable (high-quality) equipment
3. Proper installation
4. Regular maintenance

It seems easy to achieve the above key points but in reality, these are not attainable.

It is impossible to conduct proper training because of lack of experts with appropriate skills in instructing SHS techniques for electrified donor country where SHS is not in use.

(2) SHS Project Referring to Tsirang Model

a) Tsirang Model

An SHS pilot project for studying SHS project as a Japanese ODA loan component has been executed in Tsirang Dzongkhag. This project has been conducted as part of JICA's technical assistance. Experts, who are conversant with problems on rural electrification by renewable energy, employed the following methodology, which is different from those adopted in many developing countries:

Begin with development of human resources before SHS installation.

Review the standard specifications of DOE and optimize it for Bhutan.

This approach can be called "Tsirang Model". When DOE expands the SHS projects at the national level, it is recommended to refer to "Tsirang Model".

b) Methodology for Human Resource Development in Tsirang Model

First of all, the SHS pilot project in Tsirang began with human resource development. This involves a training to enhance trainers' capacity in conducting technical know-how on SHS. Then, a system where the trainers can conduct training for people at dzongkhag or village level should be established as shown in Figure 6.4.1.

On the other hand, human resources who can instruct correct SHS technique are quite limited. There are only few experts in Japan as well as in other countries. The Philippines' certified trainers joined the Tsirang Project for conducting human resource development on SHS technique. They were trained under JICA technical assistance and have experience in field SHS projects.

Said experts trained Bhutanese trainers during the first time they were dispatched. In the second dispatch of the experts, the experts supported Bhutanese trainers to learn better teaching method through their training experience. This made it possible for Bhutanese trainers to learn SHS technique.

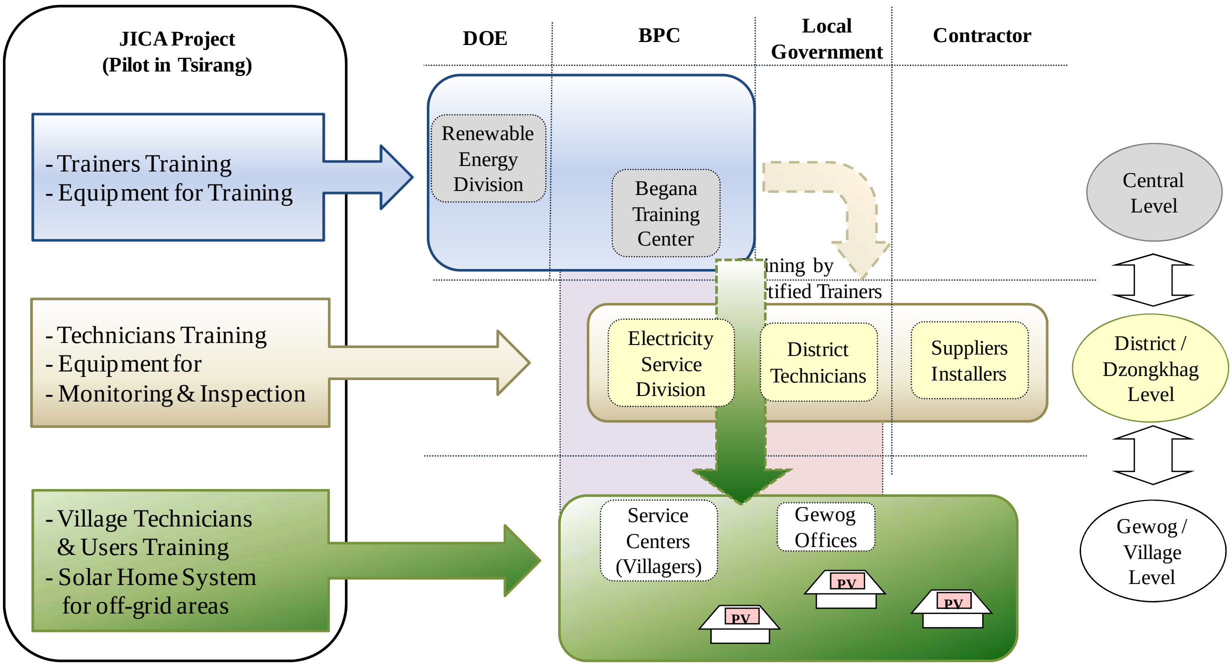
When DOE expands the SHS projects at the national level, it is recommended to conduct abovementioned comprehensive human resource development methodology at dzongkhag level.

Table-10.4.1 Number of Certified Persons

Certification level	First dispatch	Second dispatch	Supplemental training	Total
Certified trainer	3	4*		7
Assitant trainer	2	1		1
Certified technician		1	4	5
Assitant technician			3	3

*: Two persons were promoted from assitant trainers.

Source: Prepared by JPST based on the information from JICA Technical Assistance in Bhutan



Source: Report on JICA Technical Assistance in Bhutan prepared by Ms. Orui (a JICA expert)

Figure-10.4.1 Comprehensive Human Resource Development in Tsirang Model

c) Optimization of SHS in Tsirang Model

The capacity of PV panel and battery is large compared with the small load such as three units of light in the standard specifications used by DOE. Lighter equipment and simple maintenance are crucial points for SHS because transportation by foot to non-electrified villages takes from few hours to few days. The specifications were redesigned and optimized in the Tsirang Model.

1) Introduction of LED Lighting

CFL bulbs have lifetime of two to three years but are not available in ordinary shops. Therefore, LED lighting with longer lifetime and with its price rapidly reduced over the recent years was originally introduced in Bhutan. LED lighting with low electricity consumption realized a downsizing of PV panel and battery.

Although many people requested that lights can be turned on throughout the night, it was impossible for fluorescent lamps which consume high electricity. On the other hand, LED lighting with low electricity consumption of only 0.3 W can be used as night lights.

2) Introduction of Maintenance-free Battery

Although conventional battery needs battery fluid to be filled up periodically, users fail to execute this in many cases. In this project, maintenance-free SHS is realized by the combination of maintenance-free battery and LED lighting.

Table-10.4.2 Comparison of Specifications of Equipment

Equipment	Standard spec of DoE	Spec of Tsirang project
PV panel	80W	46W
Charge controller	10A	8A
Batttery	80Ah	42Ah
Lighting	CFL fluorescent lamp 11W x 3 units Electricity consumption: 36W (Measured value)	LED 2.5W x 4 units and 0.3W x 2 units Electricity consumption: 13W (Measured value)

Source: Prepared by JPST based on the information from JICA Technical Assistance in Bhutan

3) Usage of High Quality Equipment

High quality equipment was employed because it was important to sustain operation of SHS.

(3) Training for Village Technicians

Accessibility is the bottleneck of maintenance personnel from outside the village because SHS is installed at remote villages. Therefore, the idea of training villagers to serve as maintenance technicians are employed in many SHS projects. In reality, this idea is not working well in many cases due to the following problems:

- ✓ It is not easy to improve the technical skills of the person with less interest for such work

In the Barefoot College case, the village women were sent to India to receive half year SHS training. They are then tasked to be in charge for the SHS maintenance.

There were few candidates who passed the qualification exams during the training program for the detailed survey of SHS. This means that it is not easy to master the technical knowledge for nontechnical persons.

- ✓ Misunderstanding concerning maintenance work

The maintenance work has been often misunderstood, considering the principle "when the equipment fails, the defective parts are replaced with spare parts". During such incidents, the whole component of the equipment unit used in SHS has to be replaced. There is no case where only faulty resistor or transistor is replaced. Moreover, the manufacturer is prohibiting the user from such repair method.

On the other hand, the actual maintenance involves simple works as follows:

- ✓ Replacement of fluorescent tubes as consumables

If the LED lighting is used, replacement of bulbs is not required.

- ✓ Replacement of charge controller's fuse by the owners which do not practice careful operation

The number of products that do not use fuse with electronic protection circuit has increased recently.

- ✓ Refilling of battery liquid

Refilling battery liquid is a tiresome maintenance activity. There are many cases where refilling is not done. However, if a maintenance-free battery is used, refilling of battery liquid becomes unnecessary.

- ✓ Fixing loose connection due to loose wiring

This is the only work that village technicians can do by themselves.

- ✓ Identify the specific faulty parts to be replaced

It requires a qualified person with high technical level to perform such task, which is beyond the capacity of village technician.

Therefore, it is important that the training of village technician provide guidance not only on technical aspects but on administrative matters as well.

It is necessary to invite the Philippines' experts again since both the capacity building of village technicians and concrete contents on guidance have not been completed yet.

10.5 Recommendations on Operation/Effect Indicators

10.5.1 Operation/Effect Indicators (OEI)

The OEI are introduced for consistent management and evaluation of project performance before and after the Project. These indicators evaluate the impact of the Project, considering its objectives. Operation indicators are used for quantitative evaluation of the operational condition of the Project output, such as appropriate utilization of equipment and facilities. Effect indicators are used for quantitative evaluation of the expression of project effects, such as direct effects on beneficiaries in target areas.

When setting OEI, the validity of project evaluation needs to be considered. This includes the reliability, accessibility, and handling ability of the data.

JPST recommends that JICA RE-2 Project adopt the same OEI indicators as JICA RE-1 proposed in the SAPROF report except those related to transmission lines, considering the consistency through rural electrification projects.

In the SAPROF report for the JICA RE-1 Project, the setting of OEI indicators, current target values, and data collection methods for OEI were proposed. OEI has been categorized into two indicators for JICA RE-2 project; distribution OEI and OEI for living standards.

10.5.2 Distribution OEI

Distribution OEI is indicated by peak load (kW), sales volume (MWh), distribution loss (%), system average interruption duration index (SAIDI), bill collection rate (%), and electrification ratio (%).

As for peak load, sales volume and distribution losses, the current condition is explained in detail in Chapter 2. The target values have been set from demand forecast.

(1) SAIDI and Outage

SAIDI is used for the evaluation of system reliability. SAIDI is defined by the following formula:

$$\text{SAIDI} = \frac{\sum \text{(Number of Customer Interrupted x Interruption Duration)}}{\text{Total Number of Customers Served}}$$

BPC also records system average interruption frequency index (SAIFI) and customer average interruption duration index (CAIDI) to examine system reliability:

$$\text{SAIFI} = \frac{\text{Total No. of Customer Interruptions}}{\text{Total No. of Customers Served}}$$

$$\text{CAIDI} = \frac{\sum (\text{Number of Customer Interrupted x Interruption Duration})}{\text{Total Nos of Customer Interruptions}}$$

$$= \frac{\text{SAIDI}}{\text{SAIFI}}$$

BPC started to record SAIDI, SAIFI, and CAIDI from January 2005 in all dzongkhags, except for Gasa. Table-10.5.1 shows SAIDI in the country from January to December 2009, which represents all available data at present. Dzongkhag-wise monthly data are shown in Appendix-E.1**.**

Table-10.5.1 System Average Interruption Duration Index (SAIDI) in Distribution lines in 2009

	Value	Unit
Total number of customers in Dec 2009	91,770	(Nos)
Average Monthly SAIDI (Jan-Dec 2009)*	31.5	(Min/Customer)
Cumulative annual SAIDI 2009*	365.8	(Min/Customer)

Note*: Interruptions in upper stream such as transmission line and generation plant are excluded.

Source: CSD Reliability Data, BPC

The target value for SAIDI after the completion of the Project is set at the current level. Table-10.5.2 below shows the annual number of system outage occurrences using data from January to December 2009.

Table-10.5.2 Outage Number of Times by Dzongkhag in 2009

Dzongkhag	2009-01	2009-02	2009-03	2009-04	2009-05	2009-06	2009-07	2009-08	2009-09	2009-10	2009-11	2009-12	Total
Bumthang	21		48	34	48	63	32	24	6	18	14	16	324
Chukha	15	25	26	42	22	27	40	43	38	33	27	18	356
Dagana	12	13	7	16	37	28	2	28	37	28	80	32	320
Haa			1	5			1				1		8
Lhuentse	28	69	133	108	116	183	137	88	90	38	15	50	1,055
PARO	2	1	13	7	11	6	17	16	13	10	12	16	124
Pemagatshel	30	26	86	111	63	212	61	76	75	30	34	51	855
Punakha	2	1	7	1	6	2	8	16	16	15	1	1	76
Samdrup Jongkhar	29	29	40	21	47	65	93	77	46	67	31	32	577
Samtse	5	6	12	10	4	24	16	18	6	8	5	4	118
Sarpang	5	5	29	13	44	22	15	29	25	15	2	6	210
Thimphu	2	10	13	8	20	6	11	9	10	3	18	5	115
Trashigang	11	17	3	3		7	3	1	16		9	4	74
Trashiyangtse	5	6	12	6	5	14	11	8	8	15	11	15	116
Trongsa	10	8	5	3	8	17	8	9	4	4	1	1	78
Tsirang		10	6	26	32	6	30	22	12	10	2	4	160
Wangdue	15	34	13	20	34	62	51	48	24	47	17	14	379
Zhemgang	16	12	21	32	42	104	67	62	18	9	3	16	402
Unkonwn						7							7
Total	208	272	475	466	539	855	603	574	444	350	283	285	5,354

(2) Bill Collection Rate

The bill collection rate is currently available with total charged bill amount and total collected tariff revenue from energy that is sold. The dzongkhag-wise bill collection data are summarized in Table-10.5.3 below.

Table-10.5.3 Energy Sales and Bill Collection Ratios in 2009

Unit: Nu.

Sl.No	Dzongkhag (ESD Office)	Outstanding as of Dec 2008	Amount Billed	Total Collectable	Total Billed Collection	Bill Collection Rate
1	Bumthang	379,191	6,054,871	6,434,062	5,736,632	**89.2%**
2	Chukha	42,655,385	1,462,638,716	1,505,294,102	1,446,619,685	**96.1%**
3	Dagana	83,177	1,385,055	1,468,232	1,195,049	**81.4%**
4	Gelephu	936,542	17,947,020	18,883,562	18,135,250	**96.0%**
5	Haa	1,049,991	12,934,703	13,984,694	12,613,449	**90.2%**
6	Lhuentse	152,831	2,687,286	2,840,117	2,673,789	**94.1%**
7	Mongar	326,895	9,289,111	9,616,006	9,139,994	**95.0%**
8	Paro	1,386,025	40,650,823	42,036,848	38,195,041	**90.9%**
9	Pema Gatshel	198,141	5,029,371	5,227,512	4,800,678	**91.8%**
10	Punakha	1,079,335	11,760,186	12,839,521	11,406,674	**88.8%**
11	Samdrup Jongkhar	414,731	200,685,865	201,100,595	199,871,416	**99.4%**
12	Samtse	526,085	126,851,165	127,377,250	127,055,311	**99.7%**
13	Thimphu	19,121,249	172,572,150	191,693,400	172,417,064	**89.9%**
14	Trashigang	649,550	12,954,790	13,604,340	12,938,825	**95.1%**
15	Trashiyangtse	110,648	3,611,979	3,722,626	3,582,191	**96.2%**
16	Trongsa	383,052	2,828,841	3,211,893	2,812,605	**87.6%**
17	Tsirang	87,785	2,522,477	2,610,261	2,162,165	**82.8%**
18	Wangdue	747,244	15,791,766	16,539,010	13,647,378	**82.5%**
19	Zhemgang	83,065	3,129,040	3,212,105	3,087,684	**96.1%**
	TOTAL	**70,370,921**	**2,111,325,215**	**2,181,696,136**	**2,088,090,880**	**95.7%**

Note: Gasa Dzongkhag does not have Electricity Services Division (ESD). The data of Gasa is included in the that of Punakha.
* Total collectable is the sum of the amount billed for the concerned year and the outstanding from the previous year

Unit tariff is different in each block, which is according to the amount of consumption shown in Section 2.1.3. At present, category-wise energy sold and tariffs collection data are not recorded. Because of this, an accurate average price is not available for energy in Nu./kWh. It would be convenient for future analysis if they modify the database system so that category-wise data are recorded and made available.

(3) Electrification Ratio

The electrification ratios in ARE is defined by the following formulae:

- ✓ Electrification Ratio =

$$\frac{\text{ARE target HH + JICA RE-1/ADB RE-4 target HH + 9th FYP target HH + Electrified HH before 9th FYP}}{\text{Non-electrified HH after ARE + ARE target HH + JICA RE-1/ADB RE-4 target HH + 9th FYP target HH + Electrified HH before 9th FYP}}$$

The electrification ratios after 9th FYP, 10th FYP and Accelerated Rural Electrification (ARE) are calculated as shown in Table-10.5.4.

Table-10.5.4 Electrification Ratio

Dzongkhag	Non-Elec. HH before 9th FYP (2005)*1	Rural Rlec. HHs before 9th FYP (2005)*1	9th FYP Target HHs (2007)*1	JICA RE-1/ADBRE-4 Target HHs (2007)*1	JICA RE-2/ADB RE-5 Target HHs (2010)*2	Electrification ratio after 9th FYP (2007)	Electrification ratio after JICA RE-1/ADB RE-4 (2011)	Electrification ratio after JICA RE-1/ADB RE-4 (2013)
Bumthang	1,112	1,018	390	591	0	66.1%	93.8%	93.8%
Chukha	3,957	3,733	1,034	1,393	629	62.0%	80.1%	88.3%
Dagana	2,755	423	21	3,395	416	14.0%	120.8%	133.9%
Gasa	643	0	256	0	0	39.8%	39.8%	39.8%
Haa	498	1,368	140	148	99	80.8%	88.7%	94.1%
Lhuntse	2,045	720	704	1,332	170	51.5%	99.7%	105.8%
Mongar	4,305	1,809	1,217	1,164	1,646	49.5%	68.5%	95.5%
Paro	1,326	5,226	740	17	43	91.1%	91.3%	92.0%
Pemagatshel	1,536	1,039	956	1,598	168	77.5%	139.5%	146.1%
Punakha	1,183	1,877	754	215	49	86.0%	93.0%	94.6%
Samdrup Jongkhar	5,133	1,034	1,095	1,871	1,062	34.5%	64.9%	82.1%
Samtse	6,876	2,542	1,571	3,998	988	43.7%	86.1%	96.6%
Sarpang	3,694	1,991	1,320	794	730	58.2%	72.2%	85.0%
Thimphu	708	3,253	201	0	0	87.2%	87.2%	87.2%
Trashigang	4,372	5,315	1,935	1,511	82	74.8%	90.4%	91.3%
Trashiyangtse	2,029	1,194	956	847	389	66.7%	93.0%	105.1%
Trongsa	1,980	231	169	1,142	321	18.1%	69.7%	84.3%
Tsirang	3,064	214	0	3,684	93	6.5%	118.9%	121.8%
Wangduephodrang	3,020	1,753	1,032	779	165	58.3%	74.7%	78.1%
Zhemgang	2,428	400	266	0	1,726	23.6%	23.6%	84.6%
Total	**52,664**	**35,140**	**14,757**	**24,479**	**8,776**	**56.8%**	**84.7%**	**100% (*3)**

Note Elec.: Electrified, HH: Household, ARE: Acceralated Rural Electrification
In Dagana, Pemagatshel, Trashiyangste and Tsirang and Zhemgang dzonkhag, the electrification rate exceeds 100%
since the pupulation growth and relocation of HHs are NOT considered in this table
*1 Source: BPC and Final Report – Rural Electrification and Transmission, TA 4916 BHU: Preparing the Bhutan Power, Development Project (TAR: 37399, January 2009
*2 Source: BPC, *3 Including HHs electrified by BPC own fund and off-grid. The electrificaiton ratio by on-grid funded by donors only will be 94.7%.

(4) Household Energy Consumption

Current household energy consumption is shown in Table-10.5.5 below for January (winter), September (summer), and the yearly average in 2009. Dzongkhag-wise detailed data are shown in Appendix-E.4, which are categorized by rural and urban areas. The current average energy consumption is 90.9 kWh/month in rural areas and 118.5 kWh/month for the national average.

Table-10.5.5 Household Energy Consumption in 2009

Item	Unit	Rural	Urban	Total
Annual household electricity consumption	MWh/year	51279.8	79414.5	130694.3
Monthly household electricinty consumption in Winter (Jan. 09)	kWh/hh/month	91.4	199.0	129.5
Monthly household electricinty consumption in Summer (Sep 09)	kWh/hh/month	91.3	182.4	117.9
Household electricity consumption (average)	kWh/hh/month	90.9	181.3	118.5

Source: BPC Energy Sale Data

Table-10.5.6 summarizes the distribution OEI.

Table-10.5.6 Summary of Distribution Operation/Effect Index1

Indicator	Unit	Data Source	Current Value (Before Project)	Target Value (After Project)*1
Peak Load	MW	Power Data, DOE	211.0 MW*2	381.5 MW*4
Electricity Consumption (Sales Volume)	GWh/year	Power Data Book, BPC	1,368.17 GWh*2	2,293.5 GWh*5
Distribution Loss	%	Power Data Book 2009, BPC	9.81% (2009)	9.8 % (Current level)
SAIDI (System Average Interruption Duration Index) for distribution line	min/customer /year	Power Data Book 2009, BPC	365.8 (2009)	365.8 (Current level)
Outage Times	Number of times/year	CSD Reliability Data, BPC	5,354 (2009)	4,283 (20% reduction from current level)
Bill Collection Rate	%	BPC ESD	95.7% (2009)	100%
Energy Consumption per Household	kWh/HH /month	Power Data, DOE	118.5 kWh	234 kWh*6
Household Electrification Ratio	%	BPC/PPTA report	84.7% (2011)*3	100% (2013)

*1: For the year 2013. *2: Actual value in 2008/09 *3 After JICA RE-1 and ADB RE-4 projects *4 Assume 12.5% of annual growth rate derived from the average growth rate from 2003 to 2009 *5 Assume 13.8% of annual growth rate derived from the average growth rate from 2003 to 2009 *6 Assume 14.6% of annual growth rate derived from the average growth rate of energy consumption per capita from 2003 to 2009

(Prepared by JPST)

10.5.3 Living Standard OEI

Rural electrification will provide a stable supply of electricity as well as opportunities for commercial business and jobs in many rural areas and it will contribute to poverty reduction. Electricity in rural areas will also improve the lifestyle and living standards of people.

The effect of rural electrification can be indicated by the difference in living standards before the Project commences and after it is completed. However, the living standard comprises complex factors such as household income, health, education, economic activities, accessibility of facilities, communication, transportation, and power. Therefore, it is very difficult to quantitatively measure the direct effect of electrification on living standards of rural householders. Even so, there is a commonly held qualitative hypothesis which states that access to electricity improves living standards. The improvement of living standards resulting from the effect of electrification has to be assessed based on an understanding of its complexity.

(1) Qualitative Evaluation

Results for a qualitative evaluation can be obtained by conducting interviews and/or providing householders with questionnaires comprising "Yes" or "No" questions. Items that could be used to indicate the impact on living standards may include the following:

1 The values of Electrification ratio, Bill Collection Rate and Electricity Consumption (Sales Volume) will be released as the JICA's Ex-ante Evaluation.

Increase in income/savings,

Creation of opportunities for income/employment,

- ✓ Increase in information accessibility (TV, radio, etc.),
- ✓ Increase in study hours spent by family members,
- ✓ Improved safety,
- ✓ Decrease in hours spent on household duties, such as cooking,
- ✓ Decrease of fuel use (kerosene, dry cell batteries, diesel oil, etc),
- ✓ Decrease of fuel wood consumption,
- ✓ Improvement in hygiene,
- ✓ Increased household debt burden for connection charge, tariff, or purchase of electrical appliances,
- ✓ Decrease in communication within the family, and
- ✓ Diminishment of traditional culture.

Evaluation could be done with conventional post-evaluation scheme with support from BPC local offices or local consultants. BPC offices may undertake interviews for the post-evaluation survey when customers come to pay their monthly tariff. However, it is difficult to secure a reasonable sample size (number of households to interview) and to select random samples in a statistically appropriate manner due to time and budget limitation. In addition, qualitative evaluation could simply lead to subjective grading in order to justify the Project.

(2) Quantitative Evaluation

Quantitative evaluation provides a more objective and reliable means of evaluating the effect of electrification than qualitative evaluation. It also allows feedback for the optimization of resource allocation, improvement of effectiveness, and improvement in accountability. Quantitative evaluation enables comparison with the results of projects in other countries, and it also provides a model of good practice for other projects. Compared to qualitative analysis, doing quantitative evaluation requires more input for pre- and post-electrification evaluation.

The living standard indices shown in Table-10.5.9 below can be used as a reference for baseline settings in a pre-evaluation survey.

The evaluation method (i.e. qualitative evaluation or quantitative evaluation) would be selected considering budget and time constraints.

(3) Current Living Conditions

- ✓ Household Numbers
  Electricity will also improve the lifestyle and living standards of people in the rural areas. Thus, it is expected that the migration of people in rural areas towards urban areas will be reduced. Monitoring the number of rural households after electrification is one method that can be used to access this effect. The current value is the total number of households in the villages of 11 JICA targeted dzongkhags, which accounts for 3,187 households. The targeted value is set with 2.5% increase, which is the average household

growth rate of Bhutan[2].

- ✓ Household Income

  The amount of household income is probably one of the most suitable indicators to use in order to quantitatively measure rural household living standards. Production, consumption, and expenditure may also be referred according to data availability with consideration to compatibility.

  Non-electrified household income data are presented in Appendix-G. The average income of non-electrified household was 1,832 Nu./month according to the ADB Household Survey. In comparison, the average income per household in electrified villages was at 13,555 Nu./month according the JICA Household Survey. However, the sample size of electrified households was limited and income data of households in Thimphu brings the average up. The target value for the average post-electrification household income is set with 30% increase above the current value. For the evaluation, the current value is the average income of non-electrified household in 11 JICA targeted dzongkhags, which accounts for 1,967 Nu./month.

- ✓ Commercial Activities

  Electrification will also bring small business opportunities in rural villages. The number of commercial facilities, such as restaurants, shops and industries, is also a suitable indicator to use for quantitative evaluation of rural household living standards. Since the current value was not obtained through the route survey, the total number of restaurants/shops and industries in the village, and the number of pre-electrification (or post-electrification) restaurants/shops and industries should be asked in the post-project evaluation survey. The target is set for a 20% increase of pre-electrification number.

- ✓ Fuel Consumption

  The DOE Power Data Book shows that firewood supply for 2008-2009 in Bhutan is 109,645 m^3. The residential sector is a major consumer of firewood, which accounts for 74.8% of total firewood consumption. The total annual firewood consumption in that sector is estimated at 0.54 million tons in 2005, which translates into a high per-capita firewood consumption of 0.85 ton per capita per year[3].

  Wood collection is a chore that is usually undertaken by women and children. It is known that wood combustion causes eye and respiratory problems due to the smoke and soot generated by use of traditional stoves. It is expected that electrification will improve conditions for family members, as it will relieve them of some of the burden of collecting firewood, allow them to do cooking in a smoke-free environment, and save them the cost of fuel.

  Table-10.5.7 shows the average annual energy consumption in rural households. The average firewood consumption in rural electrified households is about 7.8 tons per household per annum while the average of non-electrified households is about 10.4%. On the basis of that data, the target value of firewood consumption for the average post-electrification household is set at a 25% reduction. The current value is the average firewood consumption of non-electrified household in 11 JICA-targeted dzongkhags, which accounts for 9.3 tons per household per year.

2 JICA Master Plan Study
3 Bhutan Energy Data Directory 2005, TERI

Table-10.5.7 Average Energy Consumption in Rural Households

Fuel	Unit	Rural Non-electrified	Rural Electrified
Wood	ton/hh/annum	10.4	7.8
Electricity	kWh/hh/annum	-	874

Source: Bhutan Energy Data Directory 2005, TERI

✓ Education
Generally, it is said that rural electrification will contribute to the improvement of education in terms of the children's ability to study and to read books at night. The literacy and upper school enrollment rate could be used as indicators of the education status, although the effect will appear slowly. Table-10.5.8 below shows the literacy rate and school enrollment rate for urban and rural areas, and Bhutan as a whole.

Table-10.5.8 Literacy and School Enrollment Rate, 2007

Education Indicators	Urban	Rural	Bhutan
Literacy rate	74.2%	49.0%	55.5%
School enrollment: Middle secondary	85.6%	44.6%	55.4%
School enrollment: Higher secondary	60.1%	17.3%	28.8%

Source: Bhutan Living Standard Survey, 2007

(4) Living Standard Index

Table-10.5.9. summarizes living standard indices for current (pre-electrification) and target post-electrification values.

Table-10.5.9 Summary of Living Standard Index

	Unit	Source	Current	Target
Social status and economic activity				
Nos. of households	hh	JICA Study	3,187	3,267
Household income	Nu./hh/month	JICA Study	1,967	2,557
Consumption of firewood	ton/hh/year	JICA Study	9.3	7.0
Nos. of restaurants/shops	nos.		-	20% increase
Nos. of industry	nos.		-	20% increase
Education				
Rural literacy rate	%	BLSS*2	49.0%	-
Rural school enrollment rate in middle/higher secondary school	%	BLSS*2	middle: 44.6% higher: 17.3%	-

*2: Bhutan Living Standard Survey, 2007

Prepared by JPST

10.5.4 Project Evaluation

Project evaluation is considered to be important for effective project planning, implementation, and feedback in the future.

For objective and reliable evaluation, it is important to conduct a baseline survey before the Project in addition to the post-project evaluation surveys. This provides "before" and "after" project data which can be compared to measure the effect of the Project.

The evaluation criteria were shown earlier in Table-10.4.6 and Table-10.4.8, which provided current and target values for living standard indices.

In addition to these indices, economic evaluation of the project EIRR and FIRR, project cost, and BPC's balance sheets need to be assessed.

Baseline data for the pre-project condition can be found in JICA REMP, SAPROF reports, and other studies such as ADB RE reports and IEMMP.

As for the post-evaluation survey, the required data would be available from DOE and BPC for economic data and distribution indicators mentioned in Sections 10.4.2 above. As for living standard indicators, the qualitative survey mentioned in Section 10.4.3 can be conducted within the framework of conventional post-evaluation surveys together with economic evaluation and distribution line output of the Project.

However, it is preferable to conduct post-project qualitative data collection with additional village surveys in the target areas for post-project evaluation. For project accountability and future feedback, it is to be conducted four to five years after project implementation is completed.

The statistical calculations used for determining the required sample size for the village/household survey is shown in Appendix-E.5. A survey with a sample size of around 350 households would be realistic.

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ANNEX-1

Minutes of the Meeting on the Cost Estimation for the ARE Project Held on 17th March 2010

Minutes of the Meeting on the Cost Estimates for the Accelerated Rural Electrification (ARE) Project Held on 17th March 2010

The ARE project cost estimates are based on the following conditions:

A. Materials

1. Use of telescopic poles in place of steel poles.
2. Use of polymer insulators.
3. Use of All Aluminum Alloy Conductors (AAAC)/HV ABC.
4. Transformer mounted on two poles.
5. Change in specification for service cables.
6. Use of Auto Reclosure Circuit Breaker (ARCB).
7. Use of preform for stay sets.
8. Conductor specification shall be ACSR Dog and Rabbit.
9. Use of continuous ground wire in the lightning prompt areas.

B. Civil Works

The transportation and labor costs have been adjusted to reflect the latest conditions of the ARE.

C. Overall

Purchase of vehicles, tools and equipments under ADB financing.

RGoB overhead and administration cost at 10% of total cost.

Price and physical contingencies at 15%.

Exchange rate 1 US Dollar to Nu. 45

The above conditions were agreed by the Managing Director of BPC, ADB, and the Consultant on 17th March 2010.

(Kaoru Ogino)
Finance Specialist (Energy)

(Hiroki Kobayashi)
Senior Energy Specialist

(Michael Cheng)
PPTA Consultant

(Bharat Tamang)
Managing Director

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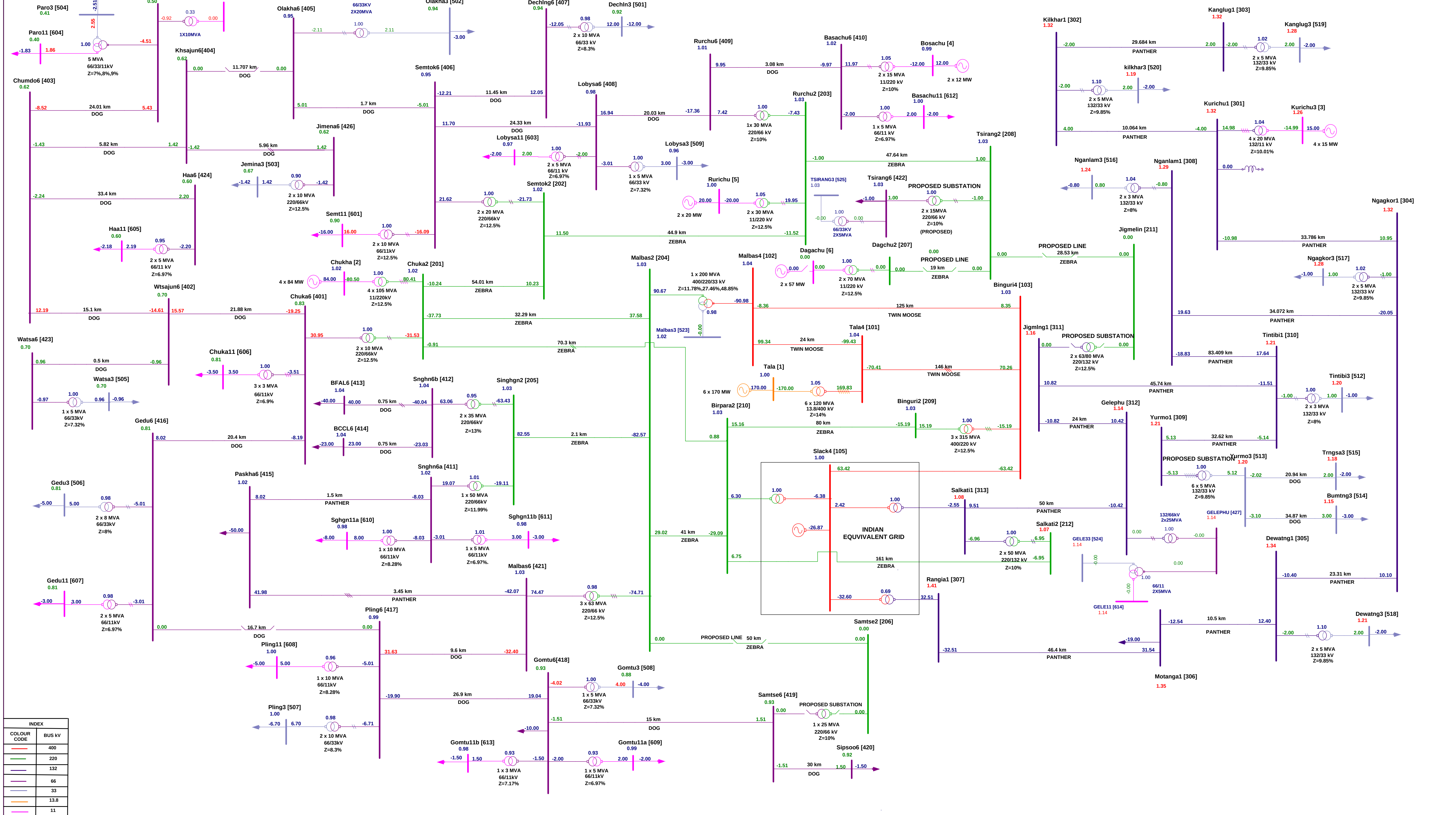
ANNEX-2

Load Flow Results (2008)

Annexture-2



			R2		LOAD FLOW RESULTS (2008)
			R1		
			R0		EXISTING AND PROPOSED TRANSMISSION SYSTEM OF BHUTAN (AS OF NOVEMBER 2009)
Flows in MW and Mvar	APPROVED	REVIEWED	CHECKED	REV.	DATE

འབྲུག་གློག་མེ་ལས་འཛིན།

Bhutan Power Corporation Limited
Engineering, Design & Contract Department
Thimphu : Bhutan

DRAWN MIPOWER | DWG. NO.1E

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APPENDIX

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APPENDIX

APPENDIX-A

DISTRIBUTION LINE MAP

APPENDIX-A DISTRIBUTION LINE MAPS

Dzongkhag-wise and feeder wise figure are shown below. Feeders are basically included in the figure where the source starts.

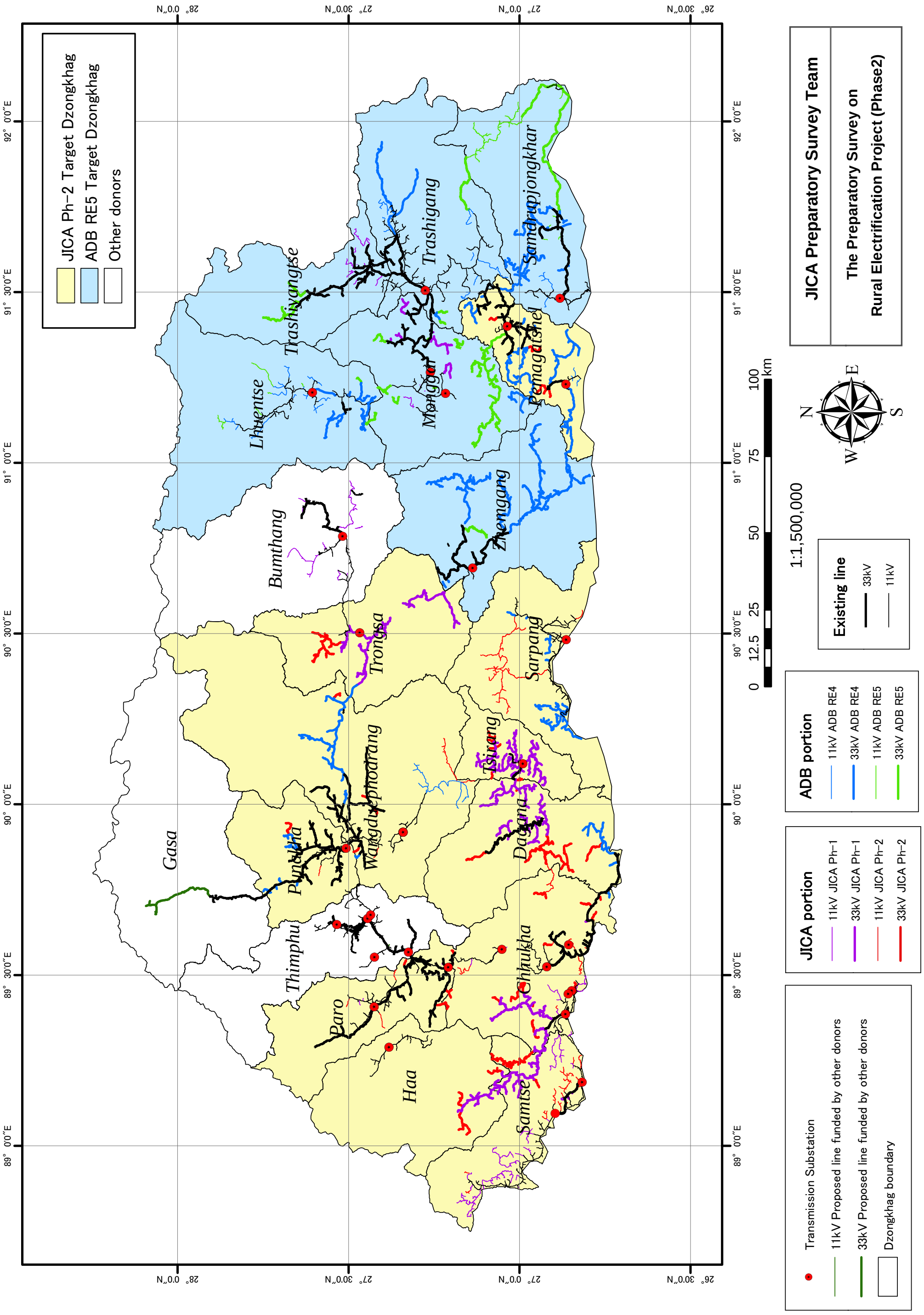

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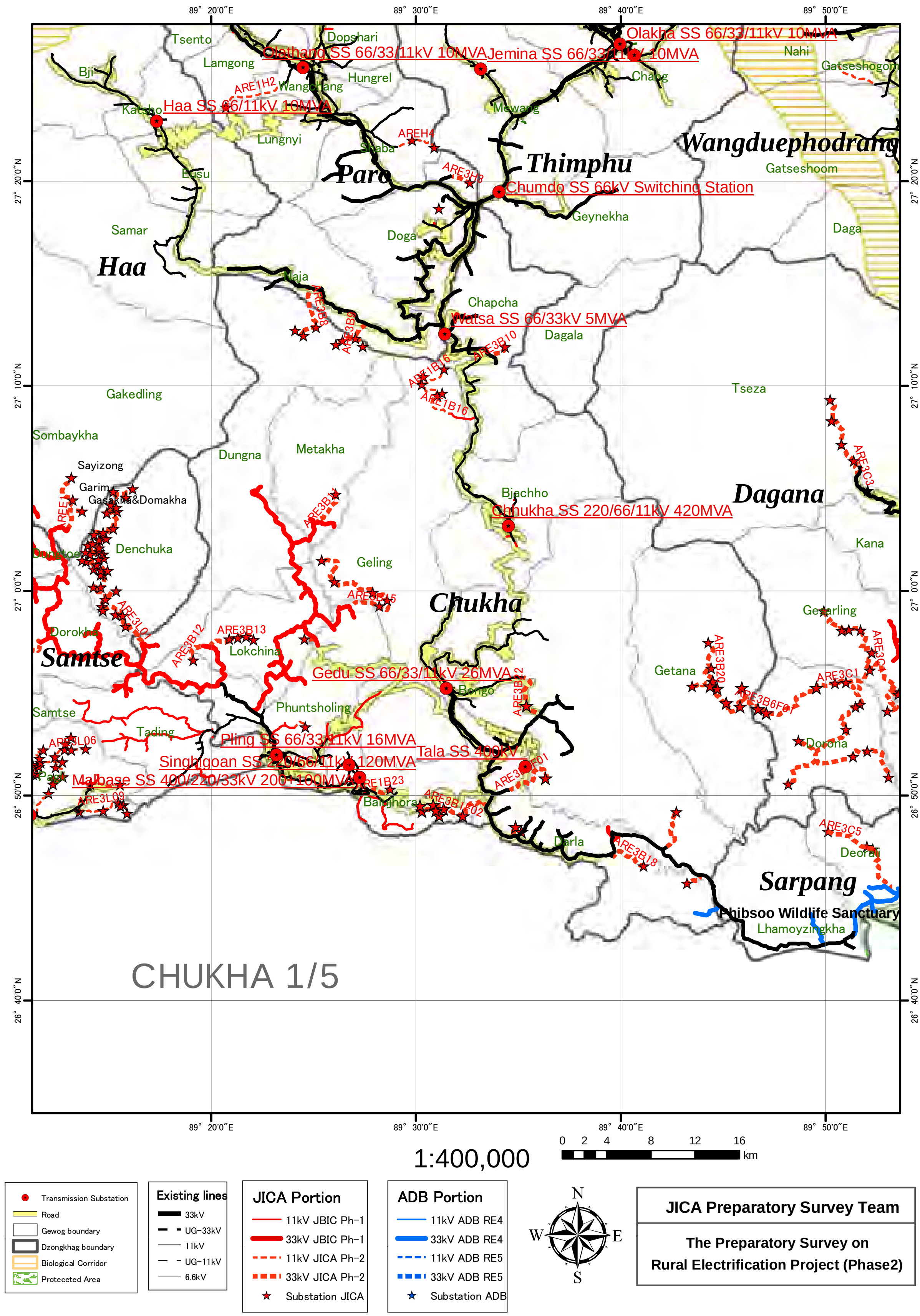
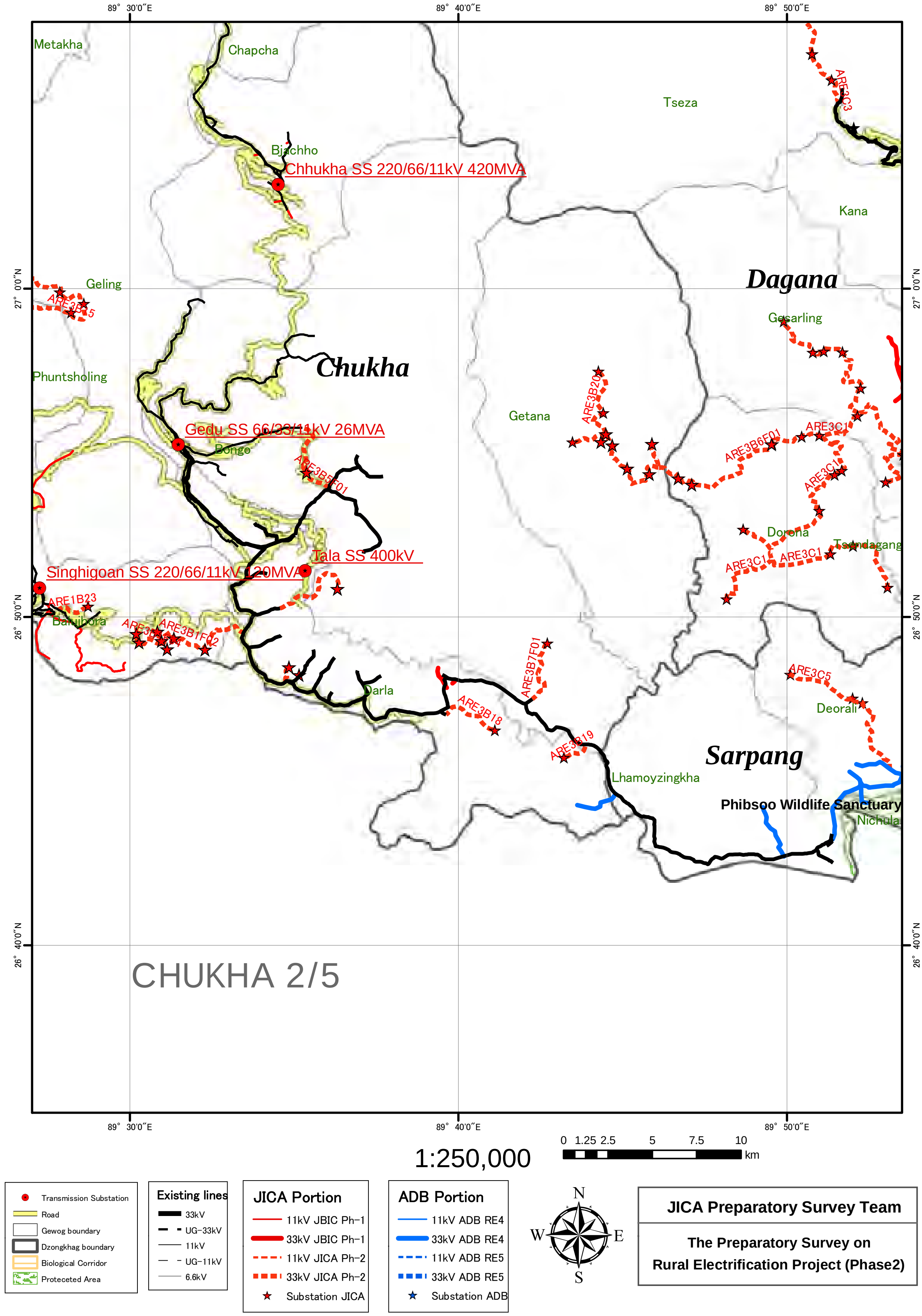
Figure-A1 Distribution Line Figure of Bhutan in ARE Project



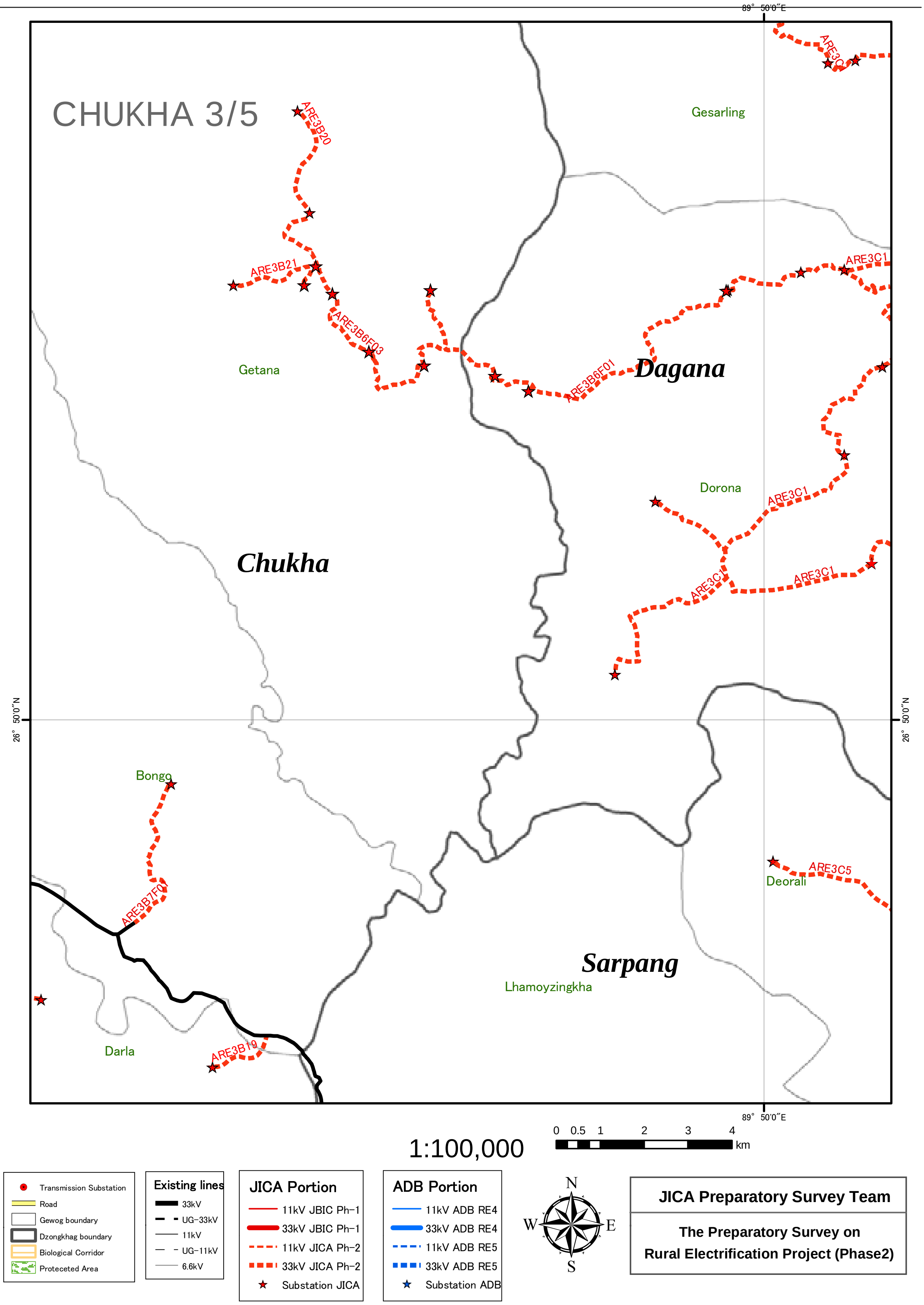
Prepared by JPST

Figure-A2 Distribution Line Figure of Chukha (1/5) (Overall view)



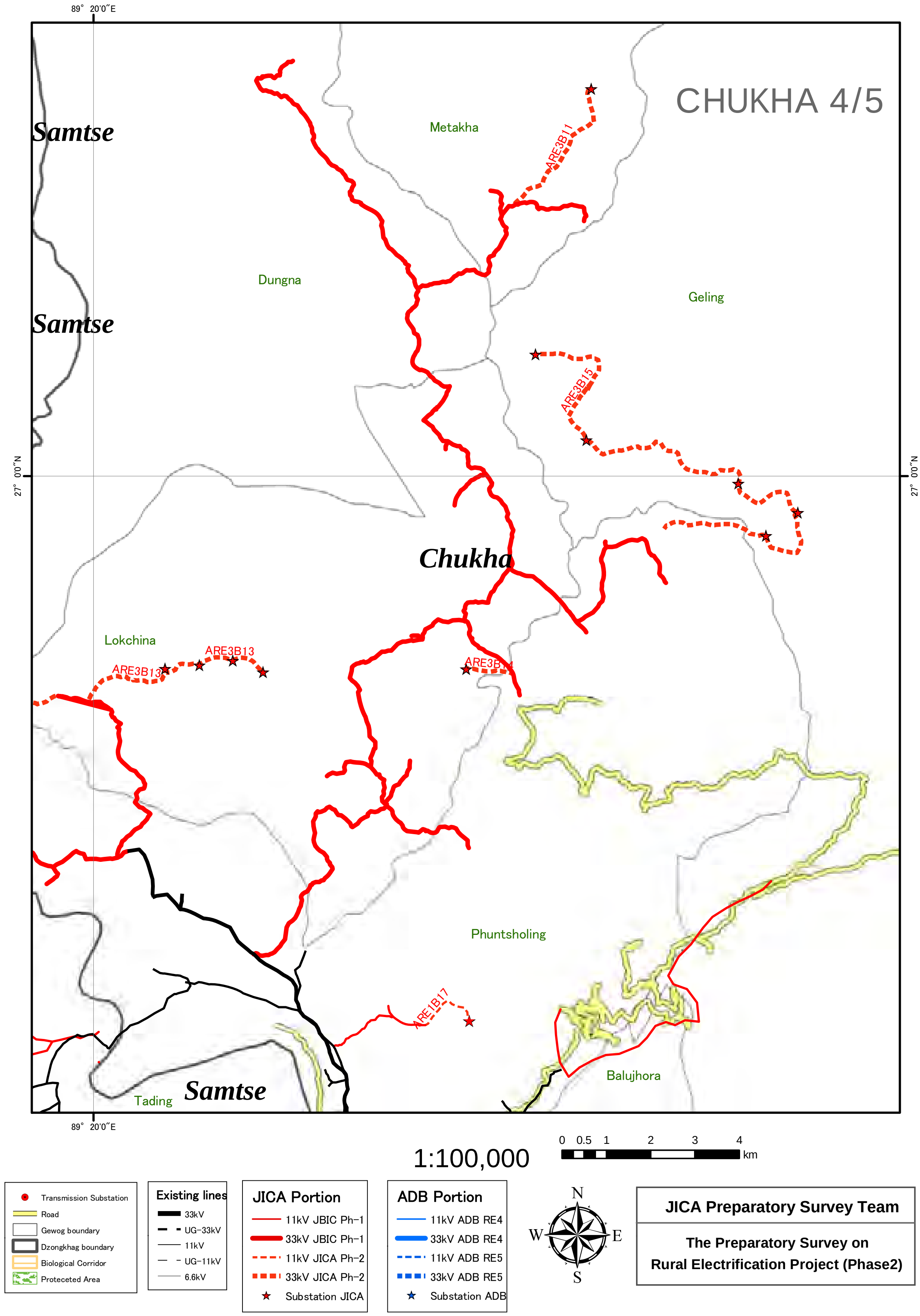
Prepared by JPST

Figure-A2 Distribution Line Figure of Chukha (2/5) (Detail view)



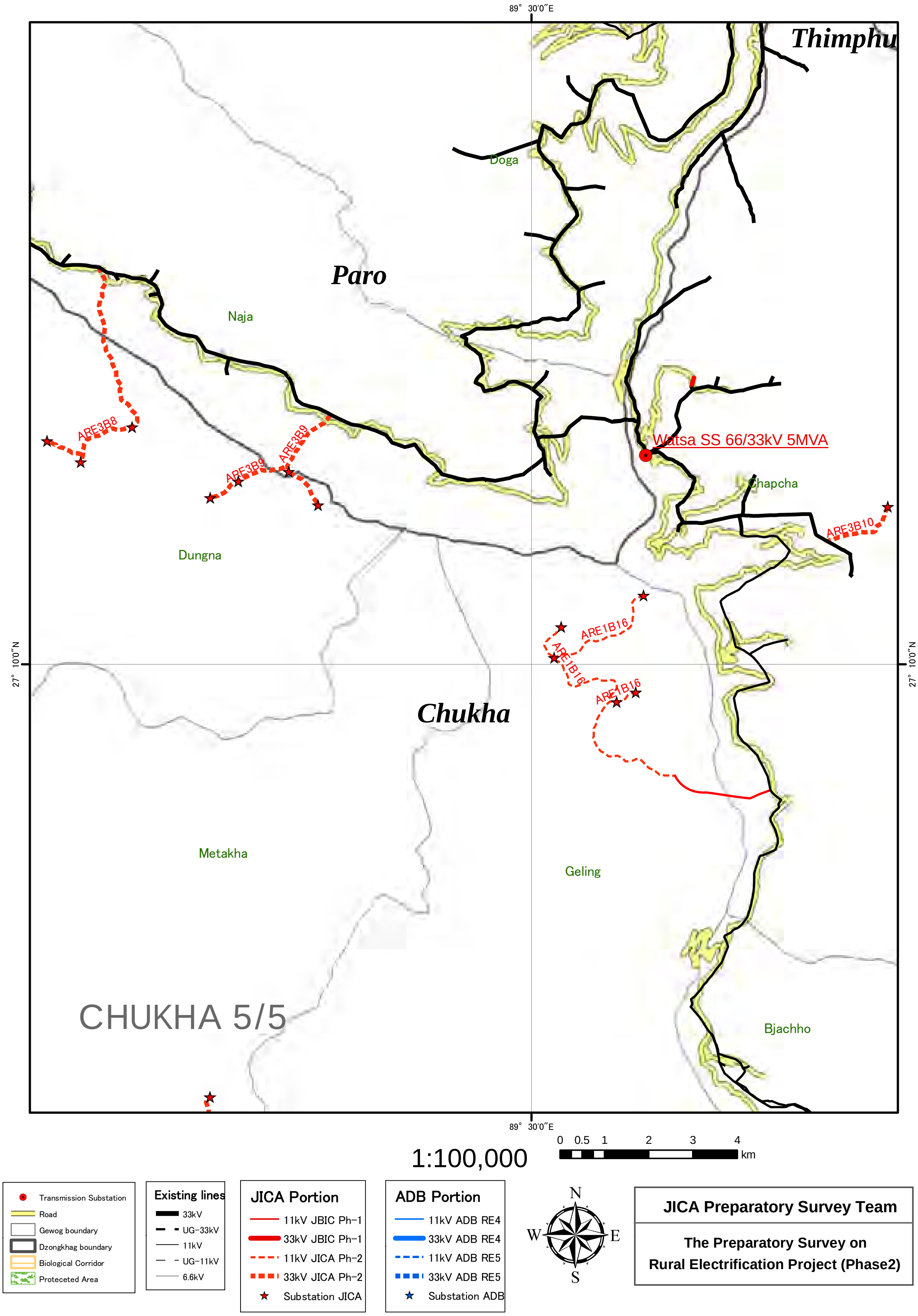
Prepared by JPST

Figure-A2 Distribution Line Figure of Chukha (3/5) (Detail view)



Prepared by JPST

Figure-A2 Distribution Line Figure of Chukha (4/5) (Detail view)



Prepared by JPST

Figure-A2 Distribution Line Figure of Chukha (5/5) (Detail view)

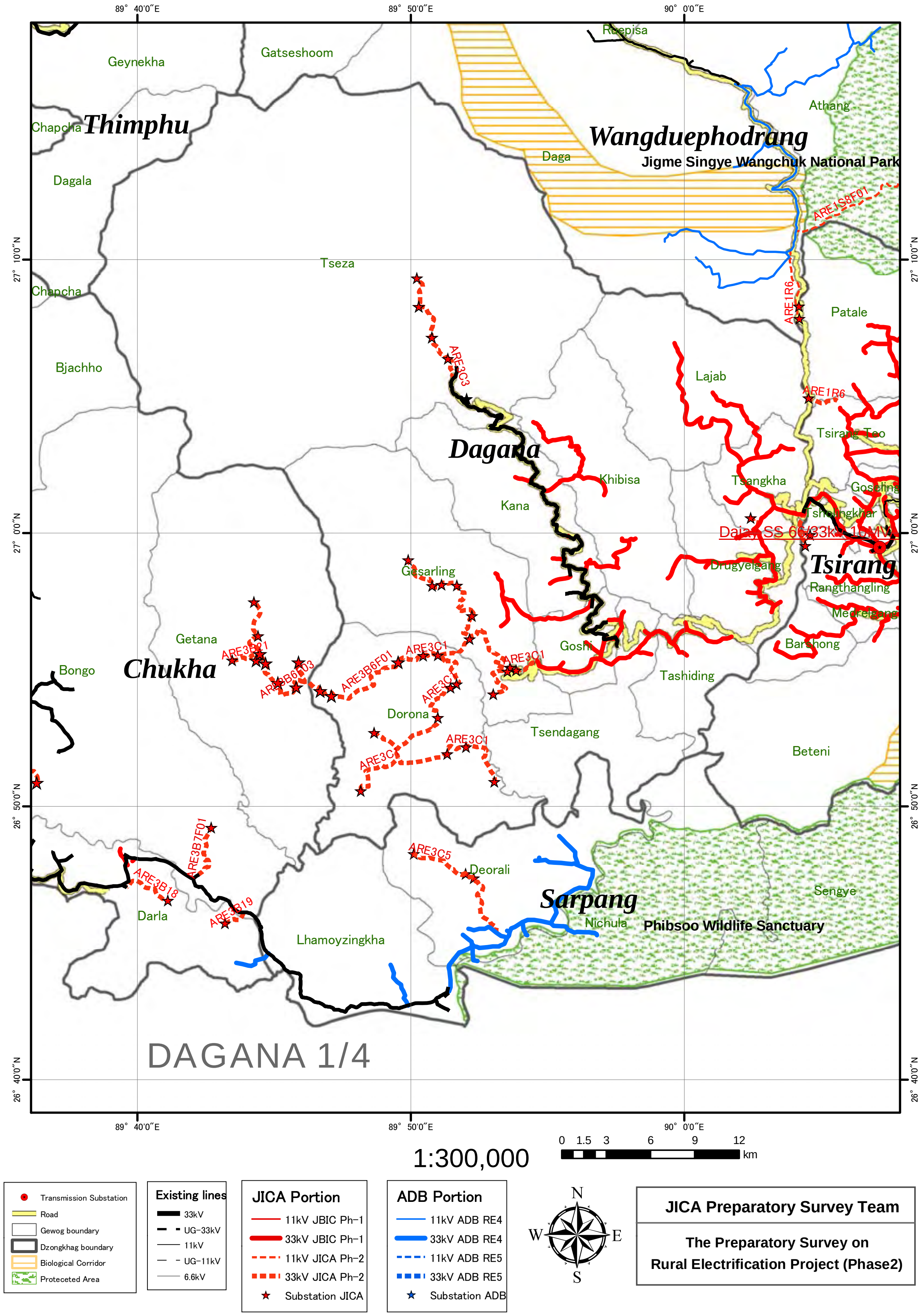


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Figure-A3 Distribution Line Figure of Dagana (1/4) (Overall view)

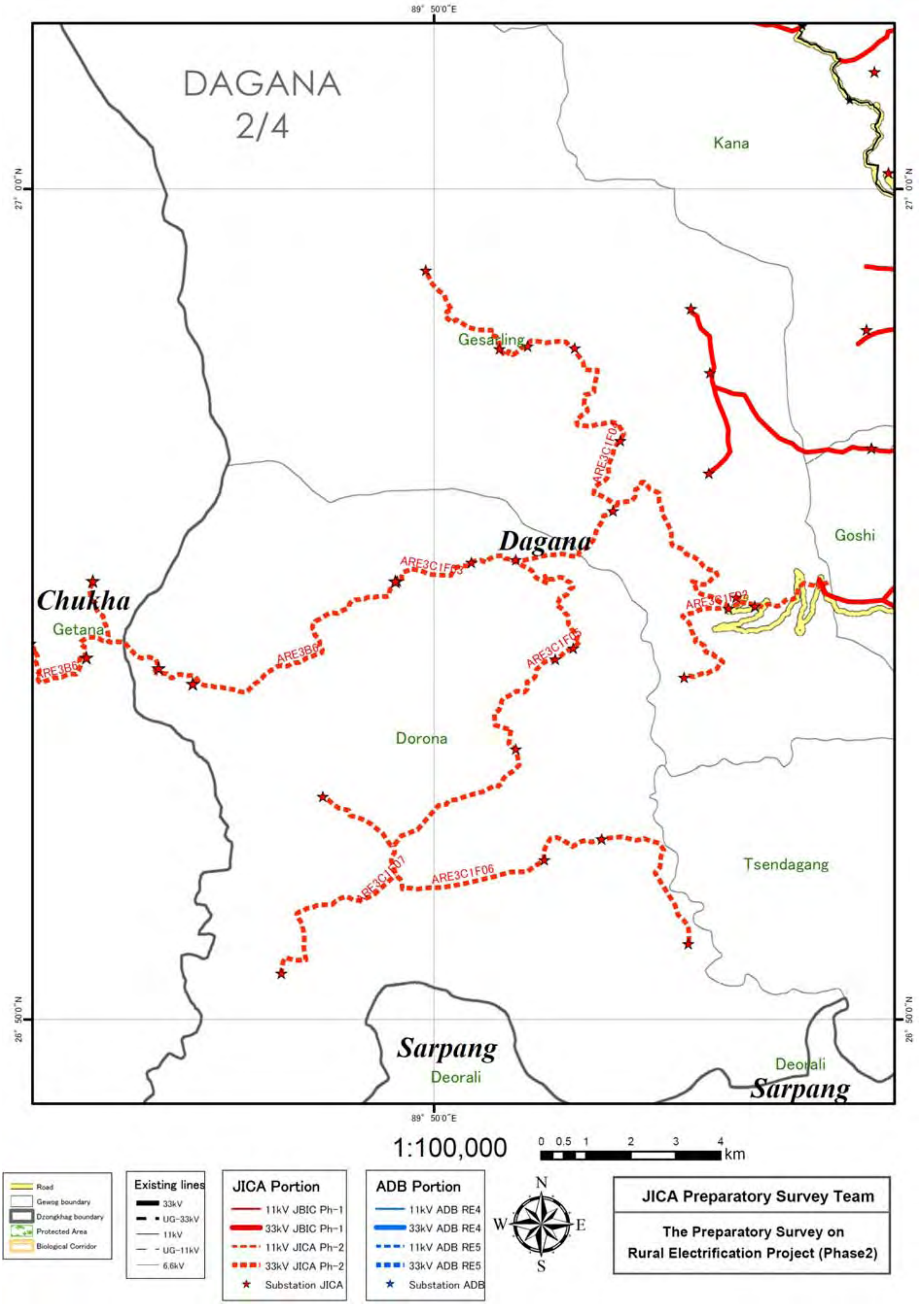

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Figure-A3 Distribution Line Figure of Dagana (2/4) (Detail view)

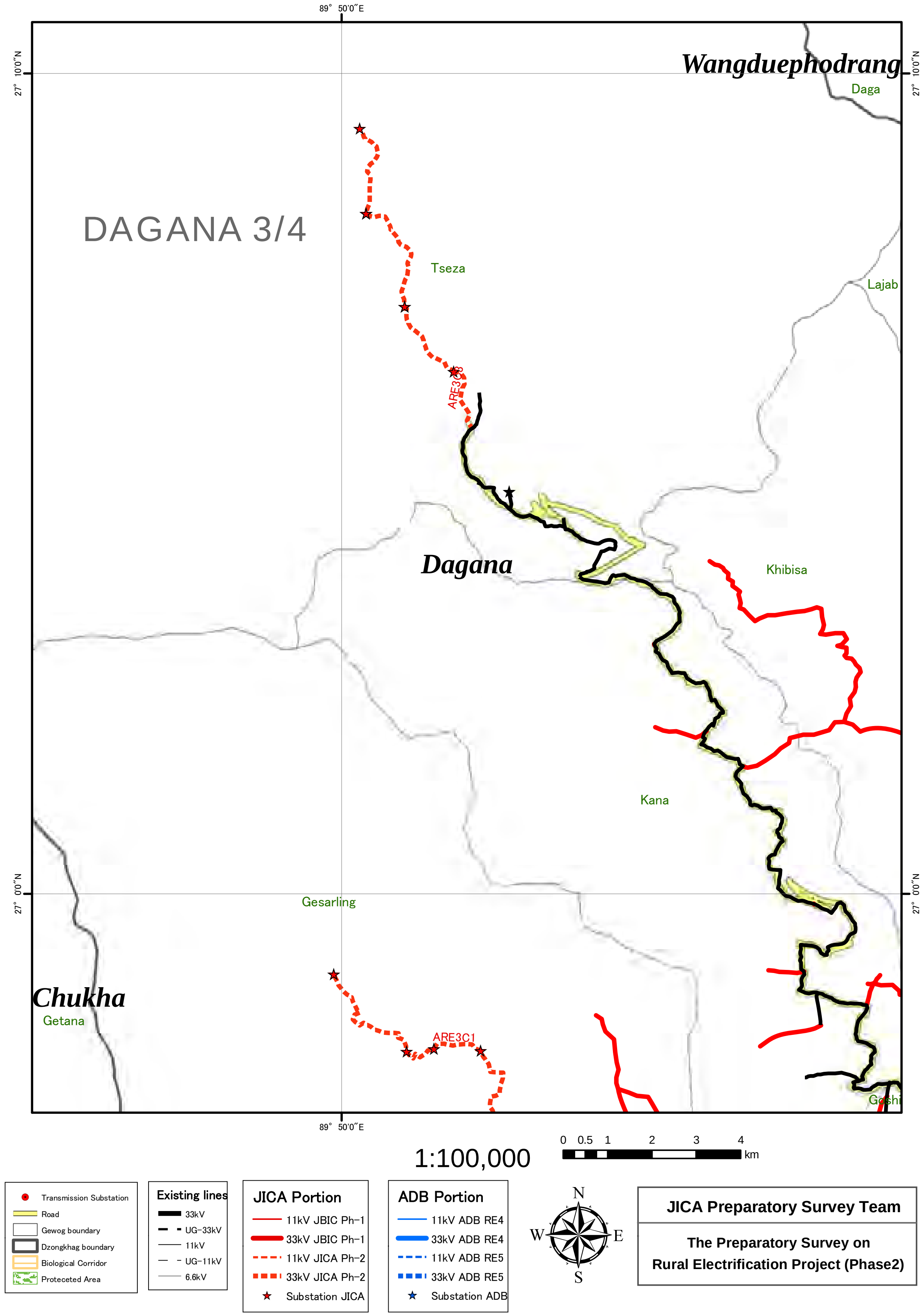

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Figure-A3 Distribution Line Figure of Dagana (3/4) (Detail view)

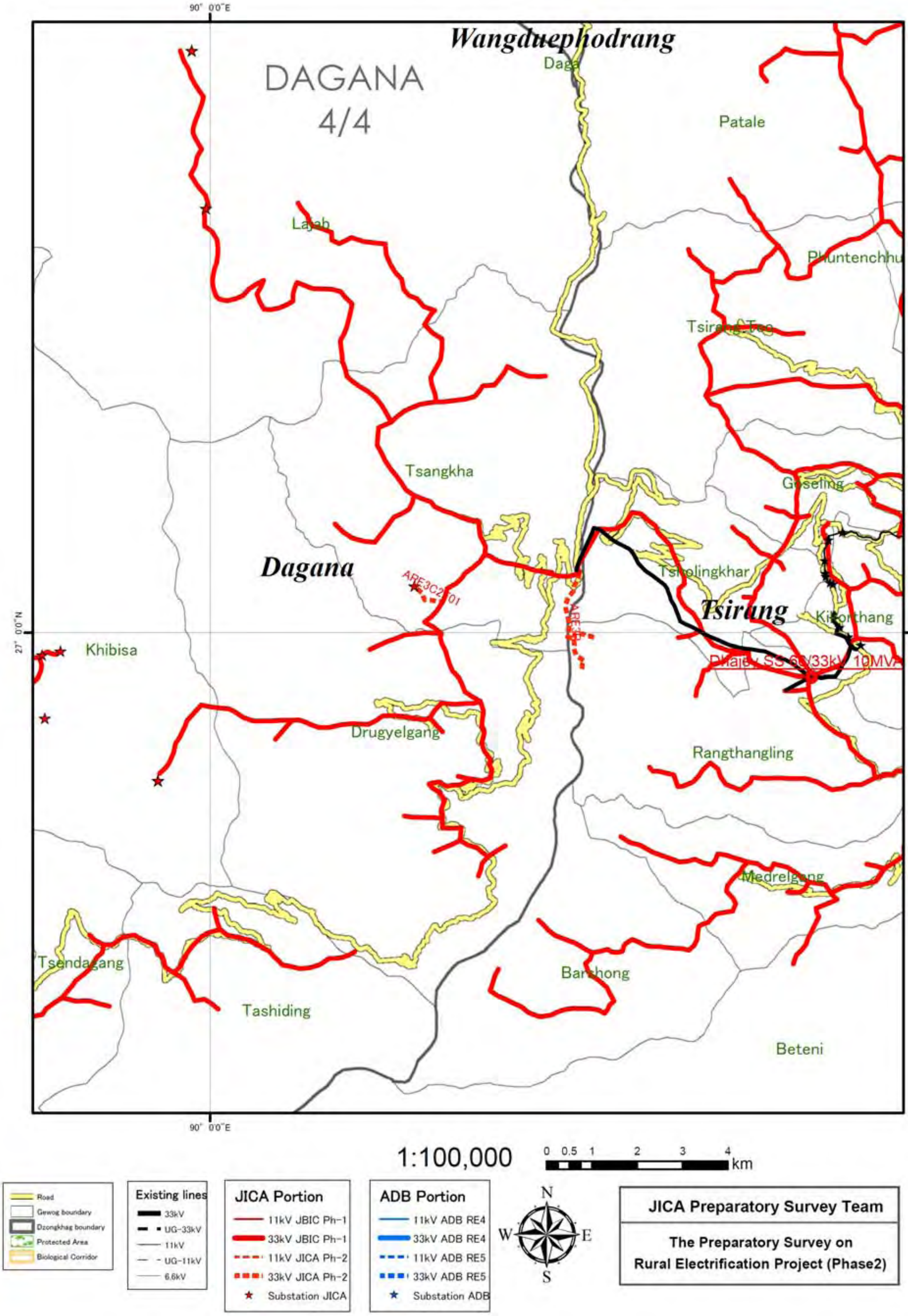

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Figure-A3 Distribution Line Figure of Dagana (4/4) (Detail view)

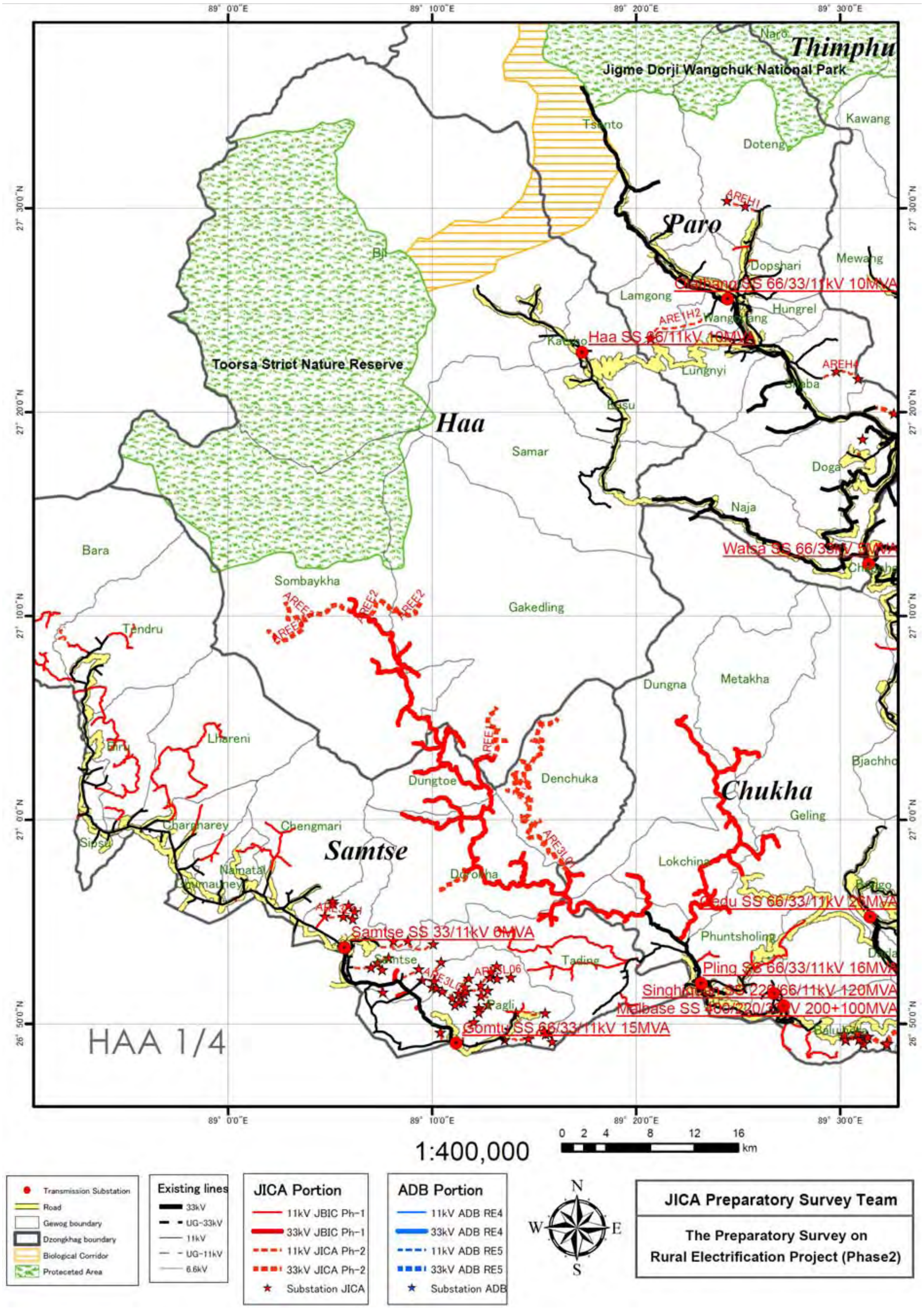

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Figure-A4 Distribution Line Figure of Haa (1/4) (Overall view)

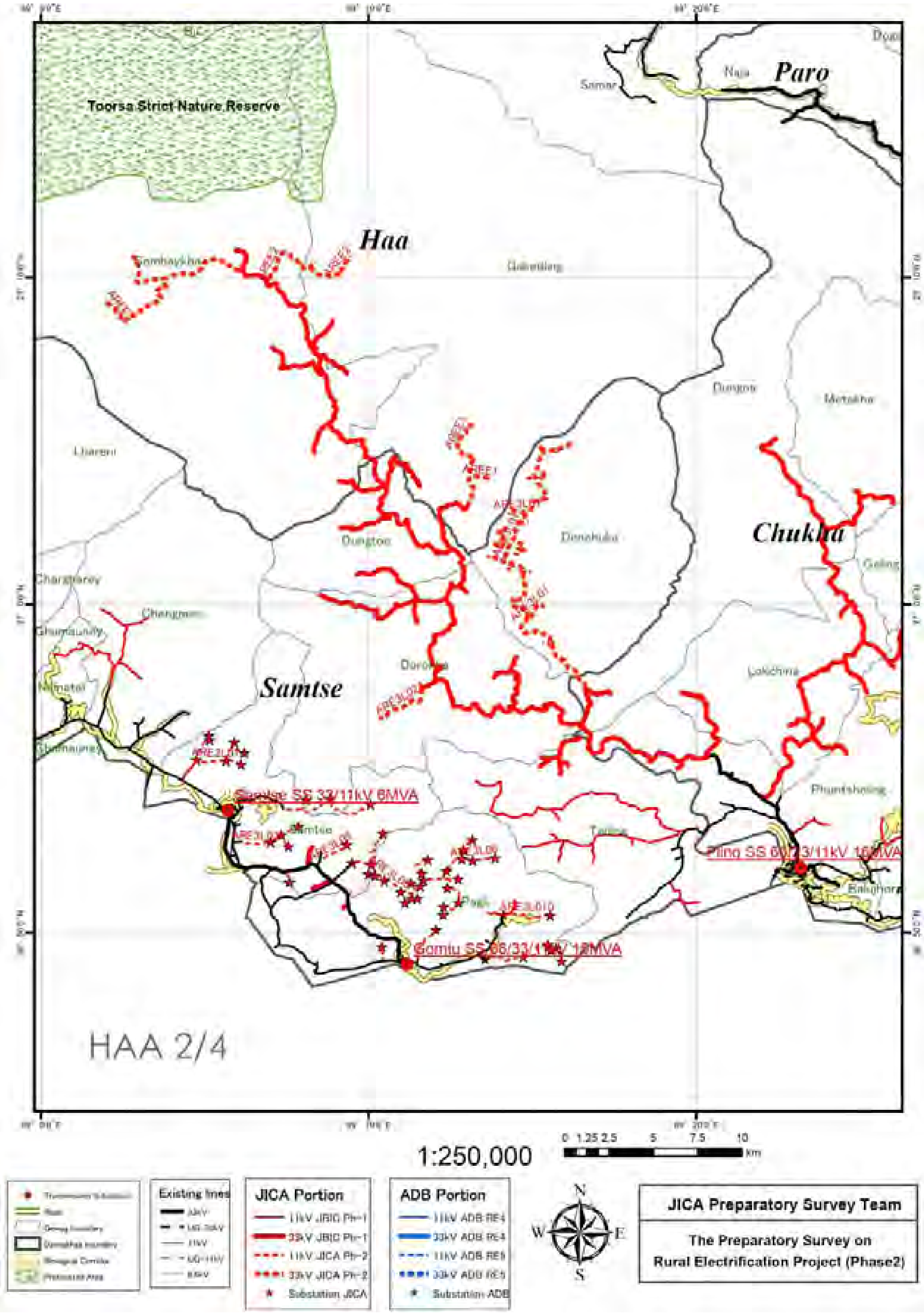

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Figure-A4 Distribution Line Figure of Haa (2/4) (Detail view)

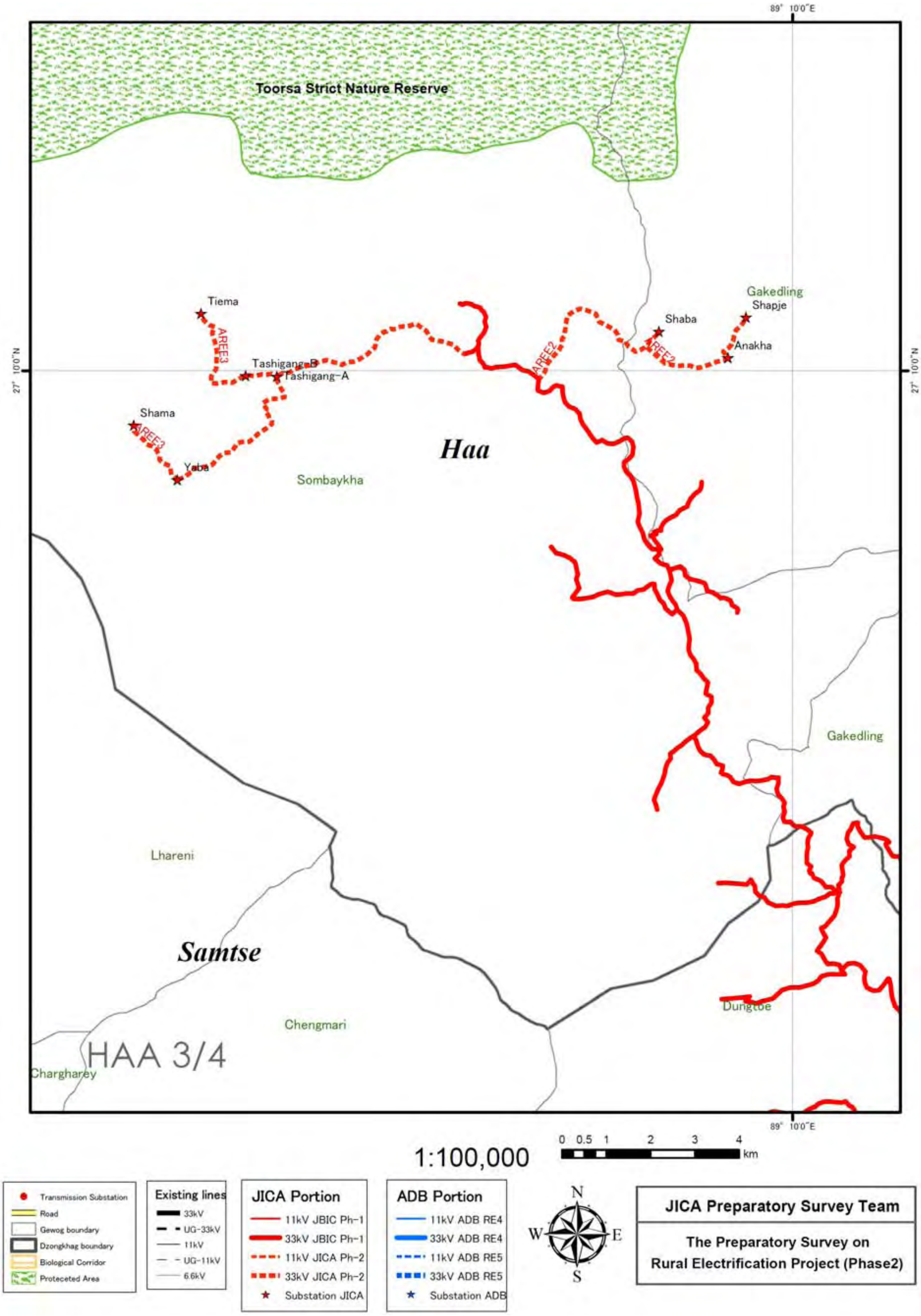

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Figure-A4 Distribution Line Figure of Haa (3/4) (Detail view)

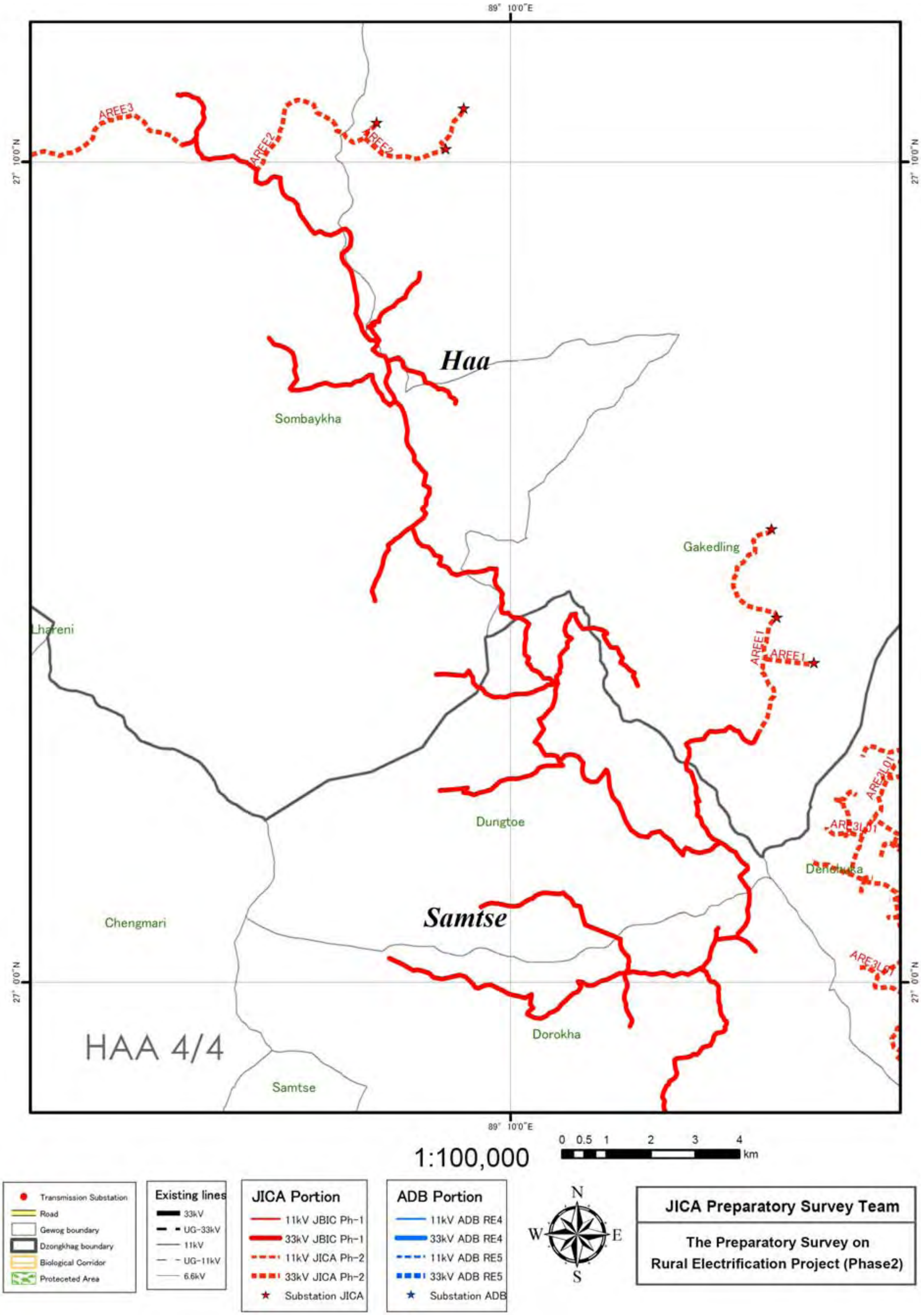

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Figure-A4 Distribution Line Figure of Haa (4/4) (Detail view)

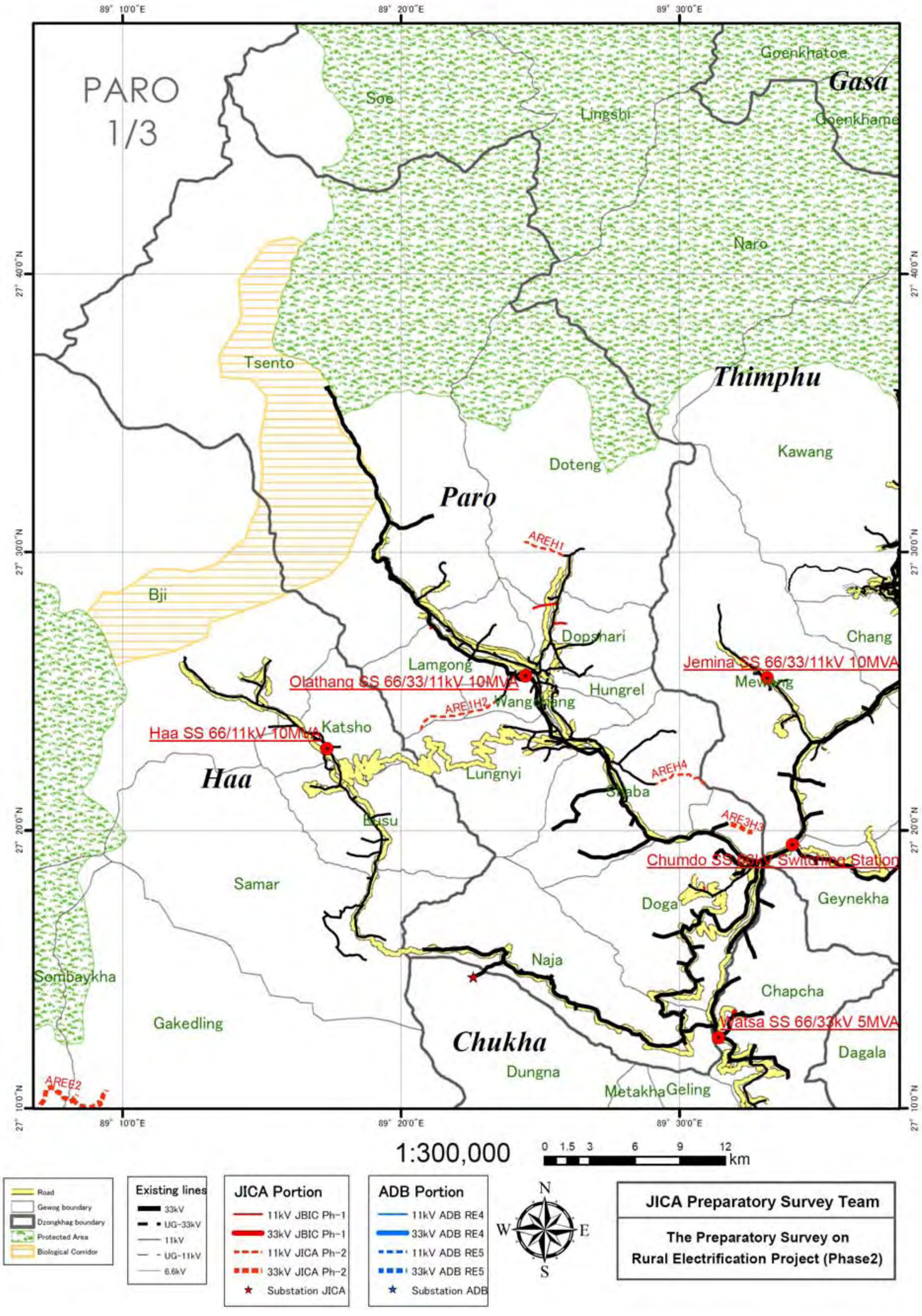

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Figure-A5 Distribution Line Figure of Paro (1/3) (Overall view)

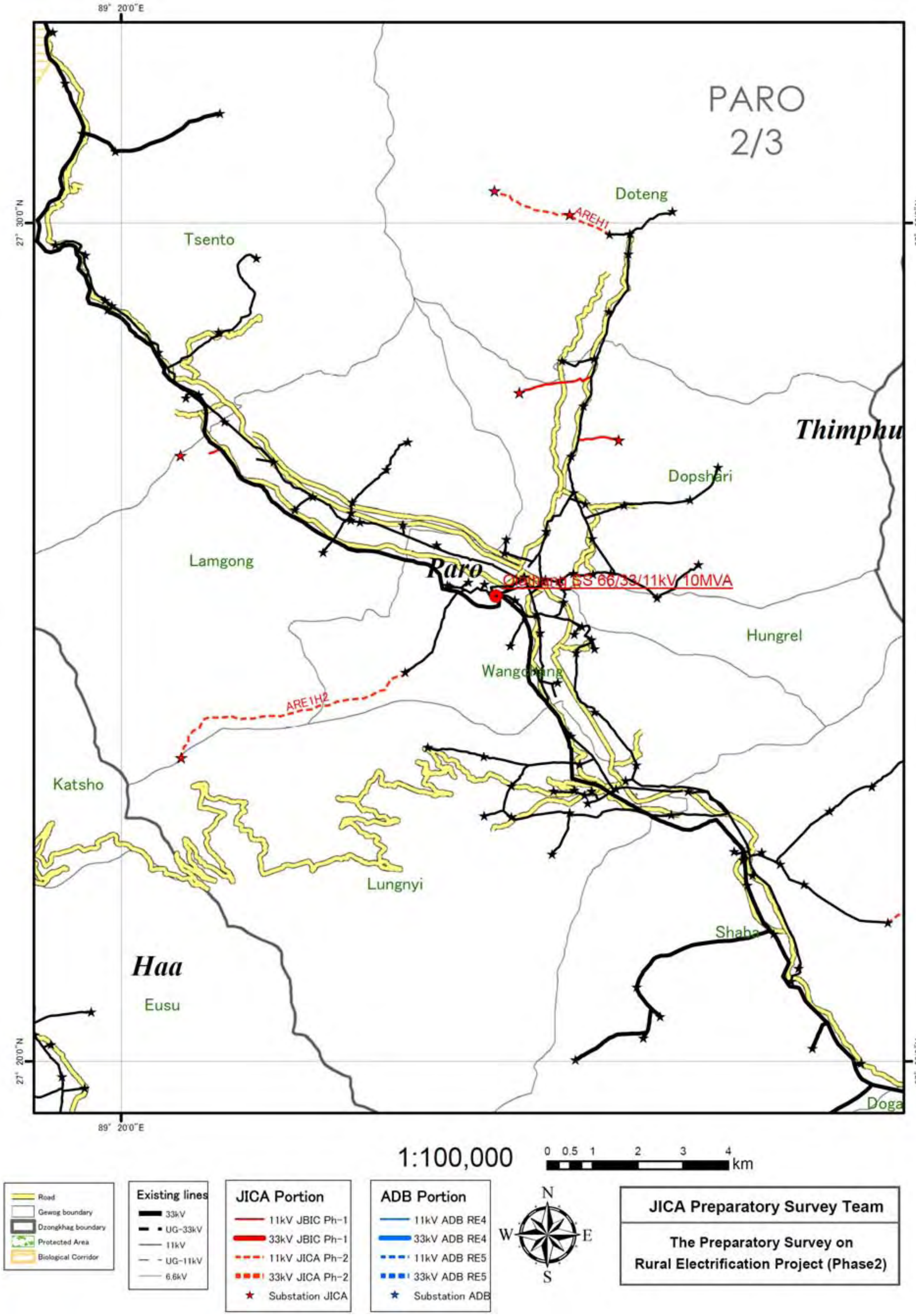

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Figure-A5 Distribution Line Figure of Paro (2/3) (Detail view)

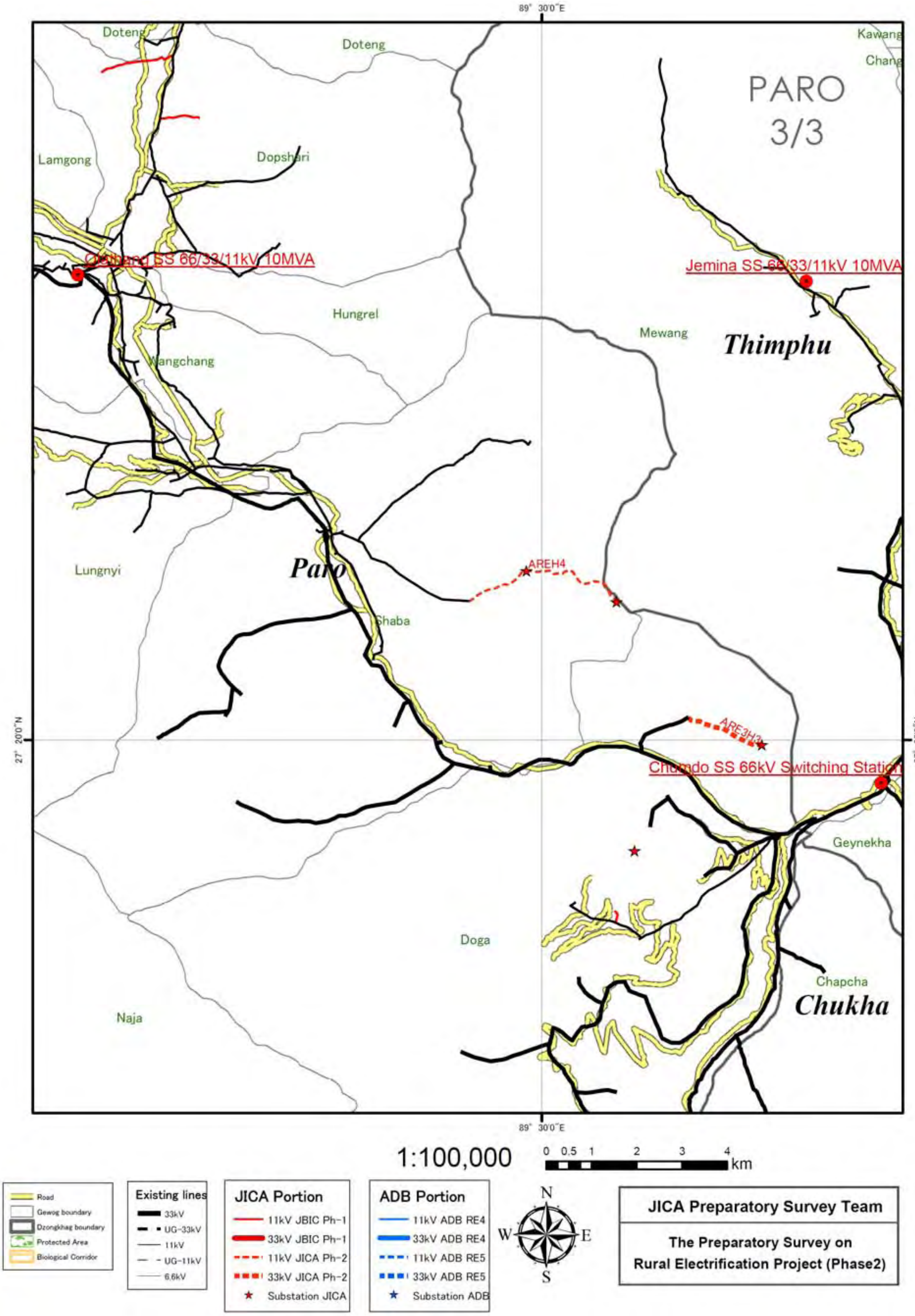

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Figure-A5 Distribution Line Figure of Paro (3/3) (Detail view)

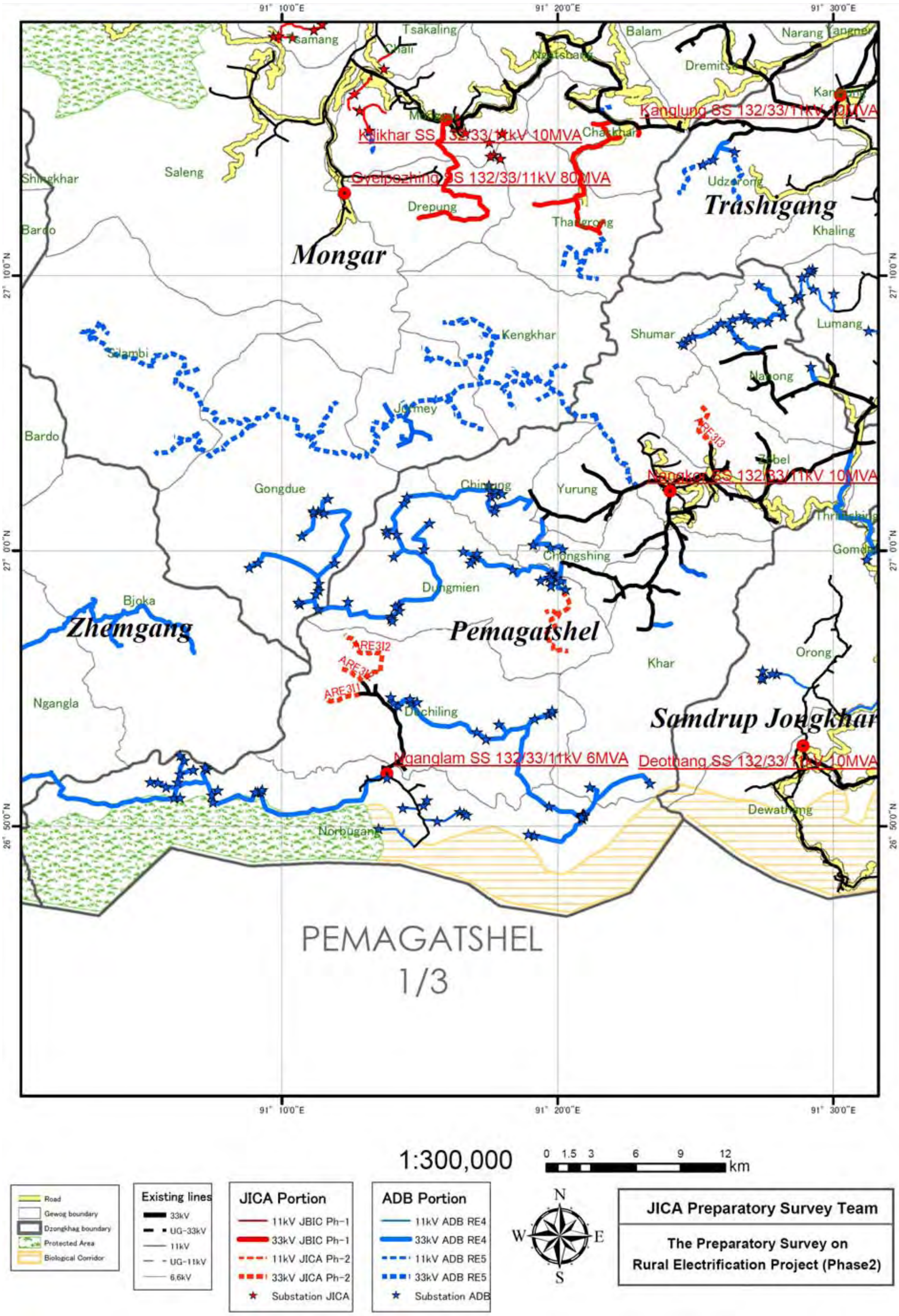

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Figure-A6 Distribution Line Figure of Pemagathel (1/3) (Overall view)

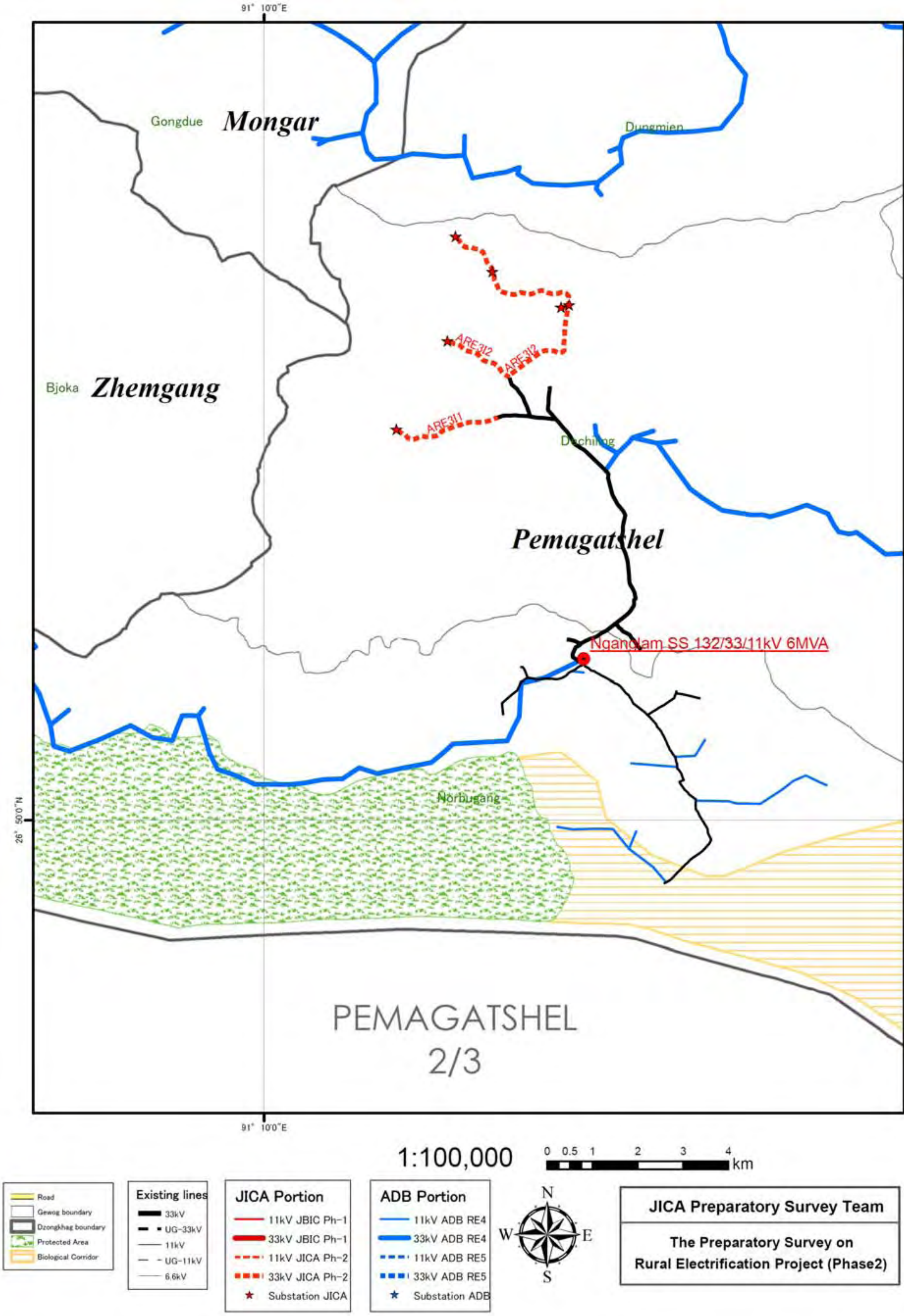

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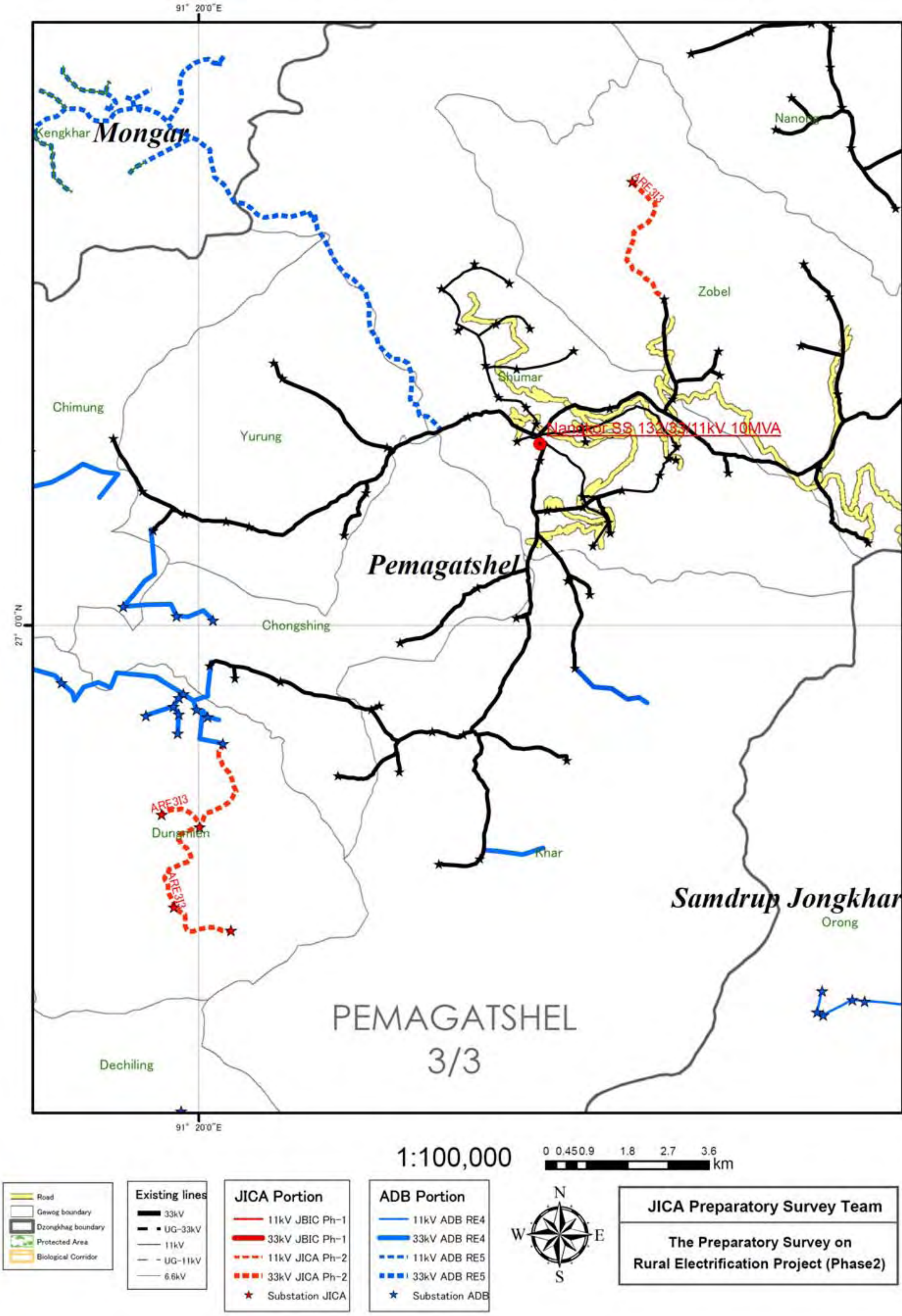
Figure-A6 Distribution Line Figure of Pemagathel (2/3) (Detail view)



Prepared by JPST

Figure-A6 Distribution Line Figure of Pemagathel (3/3) (Detail view)