THE REPUBLIC OF INDONESIA
PT. PLN (PERSERO)

JICA PREPARATORY SURVEY
FOR
TULEHU GEOTHERMAL POWER PLANT

FINAL REPORT

September 2011

JAPAN INTERNATIONAL COOPERATION AGENCY

WEST JAPAN ENGINEERING CONSULTANTS, INC.

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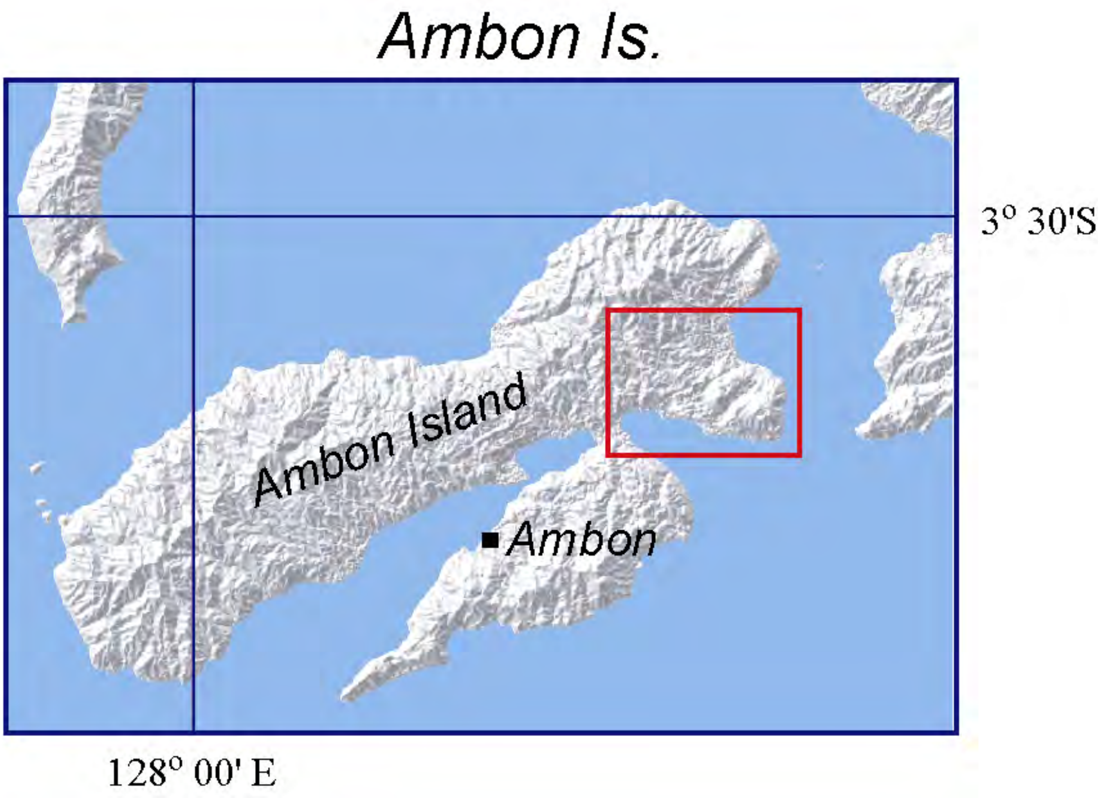

Location of Tulehu Geothermal Field

(Ambon Island, Central Maluku Province)

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Abbreviations and Acronyms	Definitions
AMDAL	Environmental Impact Assessment (Analisis Mengenai Dampak Lingkungan)
BAPPENAS	National Development Planning Agency (Badan Perencanaan dan Pembangunan Nasional)
B/D	Bid Document
BPS	Statistical Bureau of Indonesia (Badan Pusat Statistik)
CB	Circuit Breaker
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CSAMT	Controlled-Source Audito-frequency Magneto-Telluric method
DCS	Distributed Control System
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
E/N	Exchange of Notes
EPC	Engineering, Procurement and Construction
ES	Engineering Service
FCRS	Fluid Collection and Reinjection System
FIRR	Financial Internal Rate of Return
F/S	Feasibility Study
GDP	Gross Domestic Product
GDRP	Gross Domestic Regional Product
GHG	Greenhouse Gas
GOI	Government of Indonesia
GPP	Geothermal Power Plant
ICB	International Competitive Bidding
IGRF	International Geomagnetic Reference Field
IPP	Independent Power Producer
JBIC	Japan Bank for International Cooperation
JICA	Japan International Cooperation Agency
L/A	Loan Agreement
L/C	Letter of Credit

Abbreviations and Acronyms	Definitions
LCB	Local Competitive Bidding
L/Com	Letter of Commitment
LEC	Levelized Energy Cost
m asl	meters above sea level
MEMR	Ministry of Energy and Mineral Resources
MT	Magnetotelluric method
NCG	Non-condensable Gas
NEP	National Energy Policy
ODA	Official Development Assistance
O&M	Operation and Maintenance
PD	Presidential Decree
PDD	Project Design Document
PLN	Indonesian Government-owned Electricity Company (PT. Perusahaan Listrik Negara (Persero))
PLN Geothermal	PT. PLN Geothermal　Subsidiary company of PT. PLN
PPA	Power Purchase Agreement
P/Q	Pre-Qualification
rpm	Revolutions Per Minute
RUKN	National Electricity Development Plan (Rencana Umum Ketenagalistrikan Nasional)
RUPTL	National Electricity Provision Plan (Rencana Usaha Penyediaan Tengah Listrik)
SLA	Subsidiary Loan Agreement
UKL	Environmental Management Effort (Upaya Pengelolaan Lingkungan)
UPL	Environmental Monitoring Effort (Upaya Pemantauan Lingkungan)
VAT	Value Added Tax
WACC	Weighted Average Cost of Capital

EXECUTIVE SUMMARY

Executive Summary

I Study Area

The study area of the study is Tulehu geothermal field, Maluku Province, Indonesia（Fig. 1）。

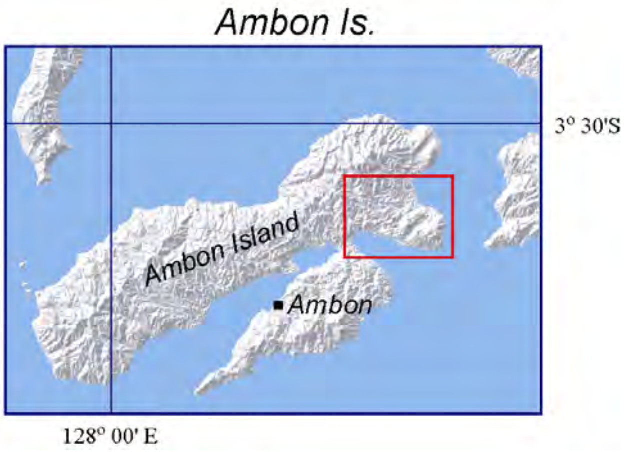


Fig. 1 Study Area

II Confirmation of Necessity of the Project and Power Sector in the Study Area

- The dependable capacity in the Ambon system is only 25 MW, while the installed capacity is 55MW. Accordingly, rental diesel generators are used to mitigate power shortages.
- Power demand projection shows that a power shortage will occur in 2015 in the Ambon system. The immediate development of extra power source is required in the study area.
- Since the Ambon system is expected to increase at an average, steady growth rate of 11% per year, a unit size from 10 MW to 20 MW is probably most suitable for the System.

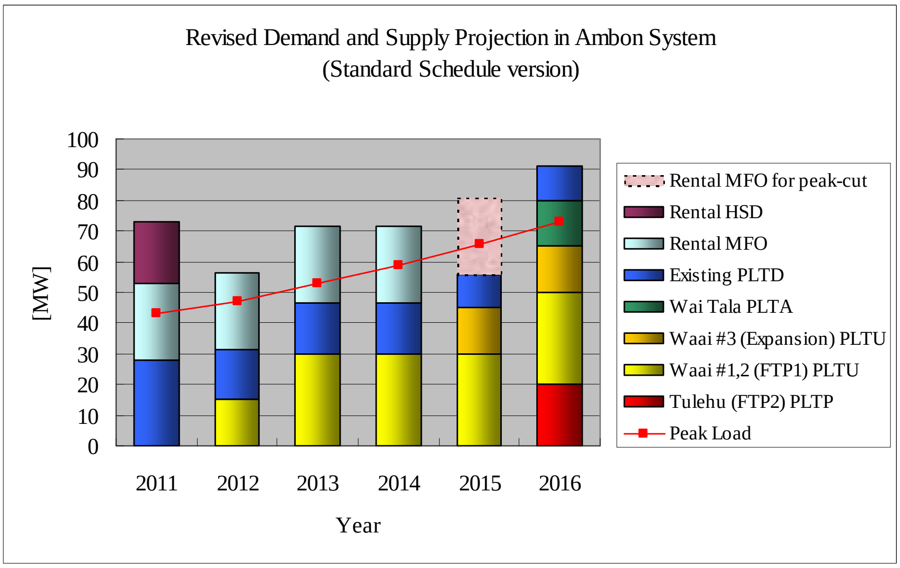


Fig. 2 Power Demand Forecast of the Ambon System

II Study of Geothermal Reservoir in Tulehu

(1) Geology

- In the Tulehu geothermal field, surface geology consists of the following thirteen (13) units; Sandstone unit, Tanjung basalt lava unit, Salahutu-1 dacitic lava unit, Salahutu-2 dacitic lava, Bukitbakar andesite lava unit, Bukitbakar pyroclastic unit, Huwe pyroclastic unit, Mt. Simalopu pyroclastic unit, Mt. Salahutu pyroclastic unit, Mt. Kadera pyroclastic unit, Mt. Eriwakang pyroclastic unit, Limestone unit and Alluvium deposits, in order from old age to young (see Fig.III-3).
- There are four faults trending in northeast-southwest direction are estimated, those are the Wairutung fault, the Band-Hatuasa fault, the Banda fault, and the Huwe fault. There are three faults trending in northwest-southeast directions are, the Sarahutu fault, the Tulehu fault, and the Waiyari fault. There exists the Kadera fault at north of Mt. Kadera, its trend is east-west but its eastern part trends in northeast to southwest. (Fig. 3)
- Geothermal manifestations in the Tulehu field can be classified into two groups by their locations; hot springs around Mt. Terang Alam and hot springs around Mt. Eriwakang. There are hot springs along the coast on the northern foot of Mt. Terang Alam, namely Batu Lompa hot springs and Batu Luda hot spring. These hot springs occur around intersecting point of the Huwe fault with the southeastern extent of the Tulehu fault. Their discharging temperatures are about 40^{o}C to 70^{o}C. Around Mt. Eriwakang, hot springs align along the Banda fault and the Banda-Hatuasan fault (see Fig. III-3). Around intersecting point of the Banda fault with the Tulehu fault, in Mamokeng, some hot springs are identified on the beach and in the sea. Their discharging temperatures are about 40^{o}C. There are Telaga Biru hot springs and Sila hot springs on the northern foot of Mt. Eriwakang, along the Banda fault. Discharging temperatures of hot springs in Telaga Biru are 35^{o}C to 48^{o}C. Discharging temperatures of hot springs in Sila are 38^{o}C to 80^{o}C. Around the riverside of the Yari River, there is Hatuing hot spring along the Banda fault. Discharging temperature of this hot spring is 49^{o}C. Along the Banda-Hatuasa fault, there is Hatuasa hot spa and discharging temperature is 56^{o}C to 60^{o}C. Banda alteration zone occurs along the Banda-Hatuasa fault. Identified secondary minerals are quartz, montmorillonite, kaolinite, illite, alunite, gypsum and so on.

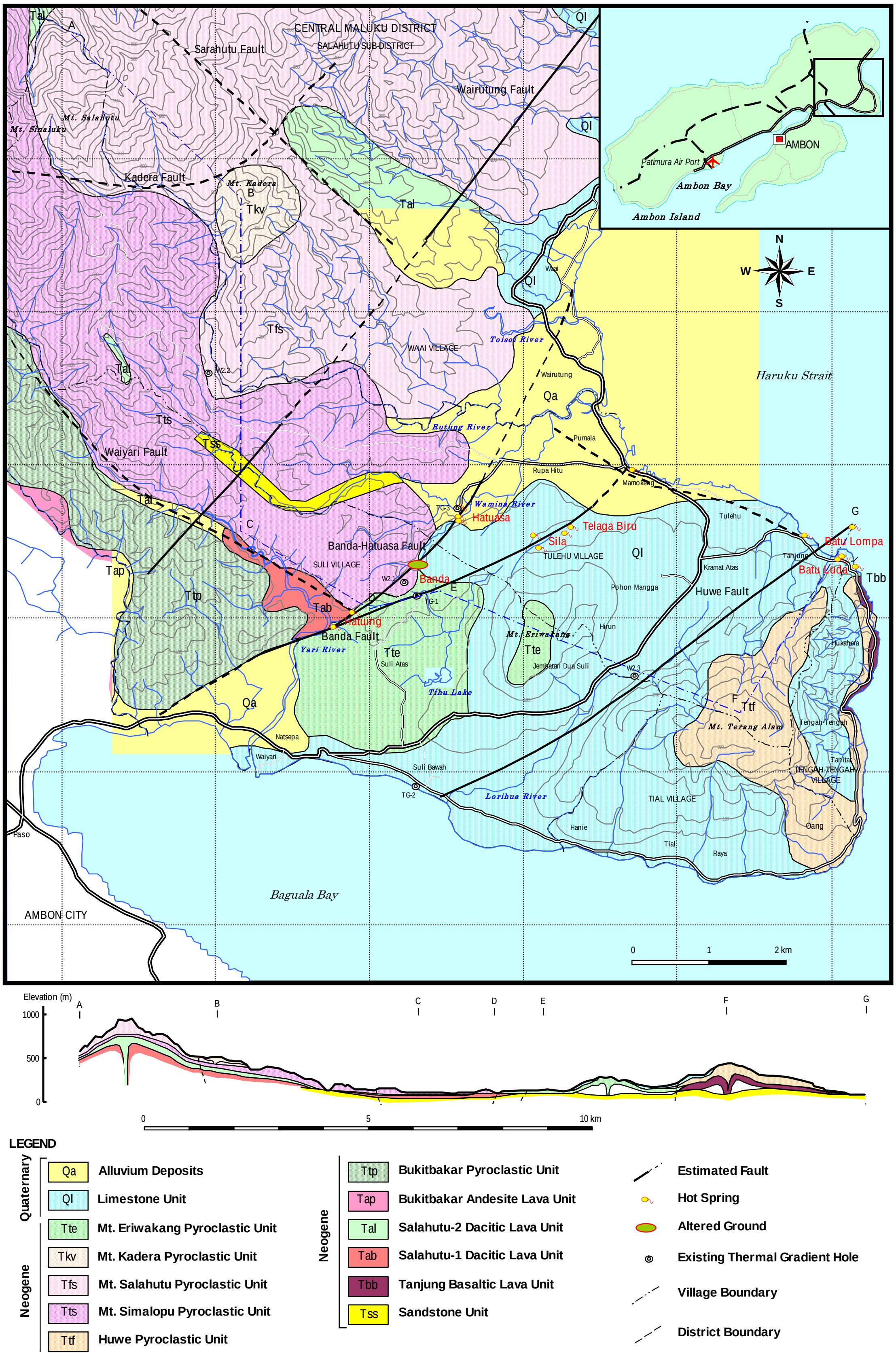


Fig. 3 Geological Map of Tulehu

(2) Geophysical Exploration

- The existing geophysical exploration data (gravity, magnetic and CSAMT survey) were reviewed and gravity lineaments were estimated.
- The extent of geothermal reservoir was delineated by MT survey as shown in Fig. 4.

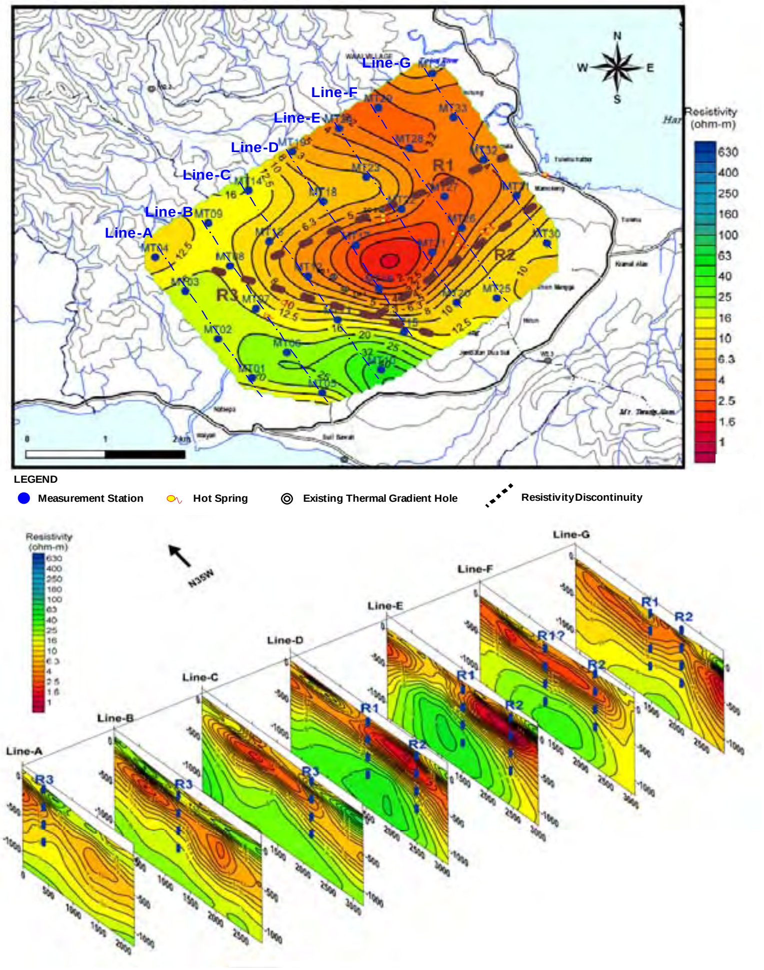


Fig. 4 Resistivity Distribution in Tulehu Geothermal Field

(3) Geochemistry

- NCG contents in steam was calculated based on fumarole gas contents as follows.

NCG(mol%)	NCG(wt%)	CO_2 (vol%)	H_2S(vol%)
0.37	0.88	98	2

- The origin of geothermal fluids in Tulehu can be interpreted as mixture of sea water and metoric water. Some data from hot springs show oxygen shift, and change in Cl/B molar ratio that indicate the possibility of water-rock interactions.

- The reservoir temperature of Tulehu field was estimated to exceed 200°C from geochemical thermometry.

(4) Well Testing Data

- Among the existing wells in Tulehu, a symptom of geothermal activity was found only in Well W2.1.
- An exploratory well TLU-01 was drilled in the vicinity of the well W2.1down to 932 m depth by PLN Geotehrmal.
- The well testing data of TLU-01 showed good permeability. However, the temperature data could not be analyzed by ordinary analysis method since the data was strongly affected by continued compression/release operations.
- The permeability-thickness product of TLU-01 was evaluated to be 5 to 10 darcy-m, which is a pretty high permeability.
- The equilibrium temperature was 228°C at the bottom hole.

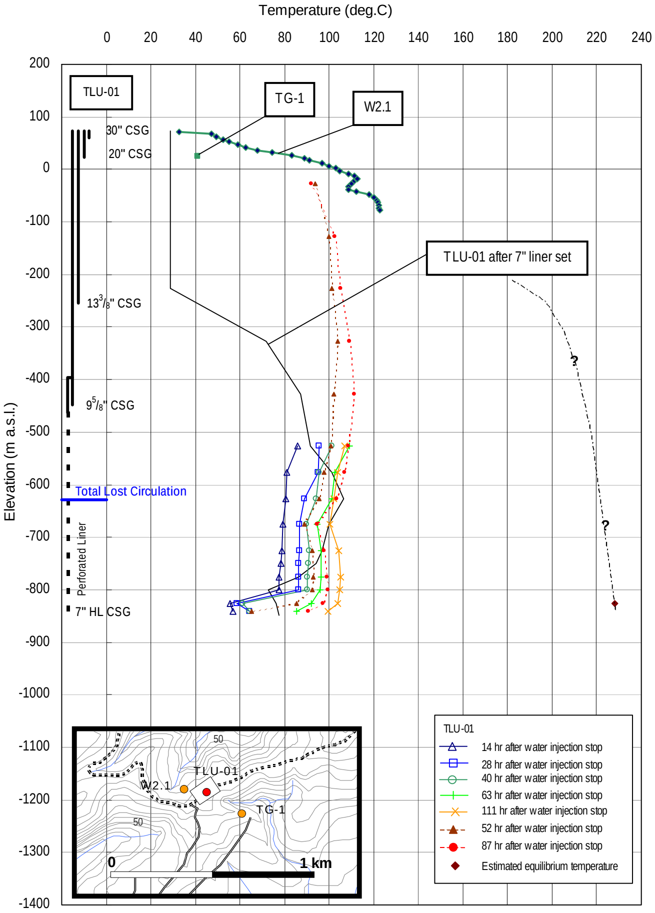


Fig. 5 Temperature profile of TLU-01 and Its Neighboring Wells

(5) Conceptual Model of Tulehu Geothermal Reservoir

- The promising area and hydrological model was constructed by integrating geoscientific data (Fig. 6)
- The conceptual model of geothermal reservoir of Tulehu field was constructed as shown in Fig.7.

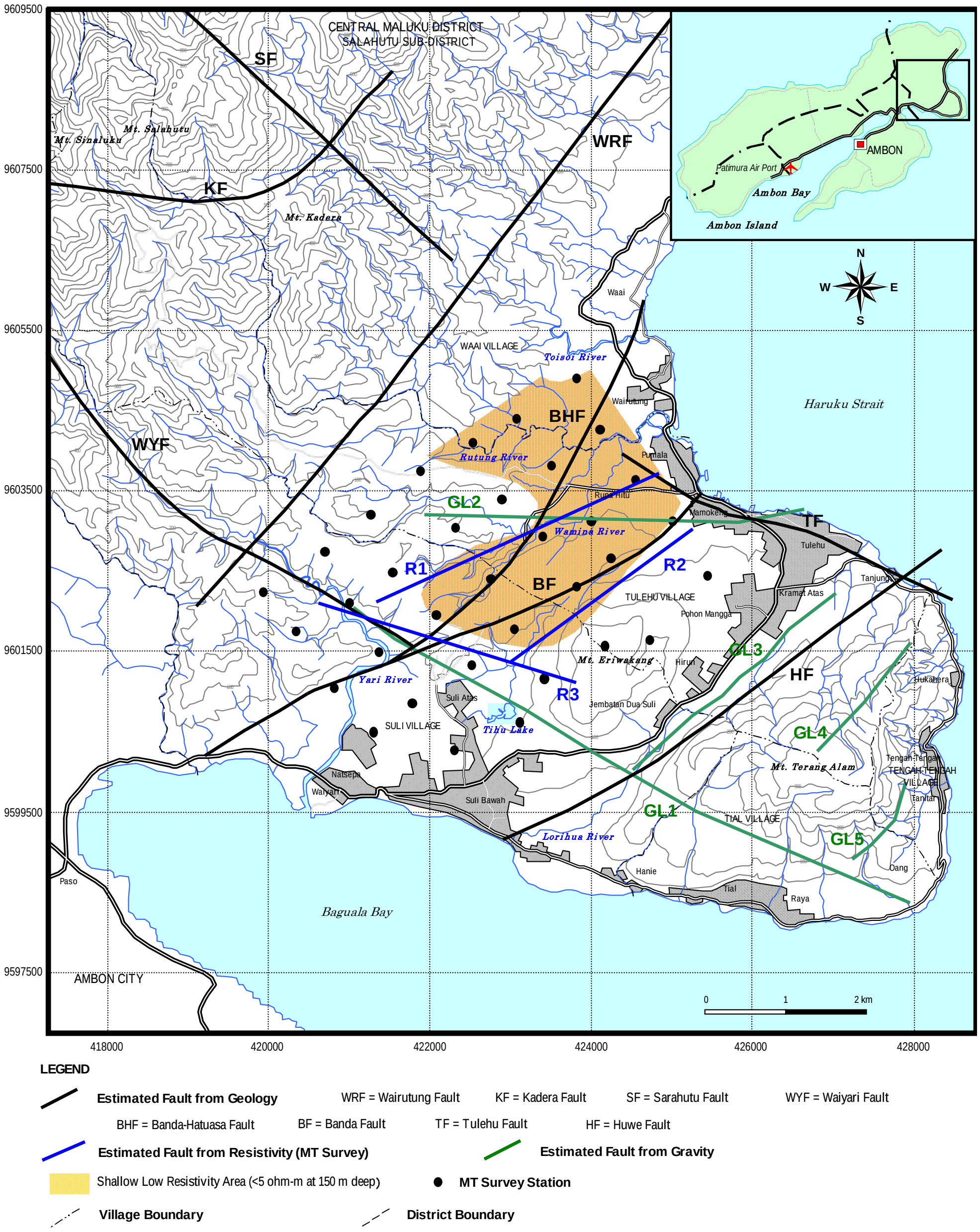


Fig.6 Distribution of Faults and Promising Area

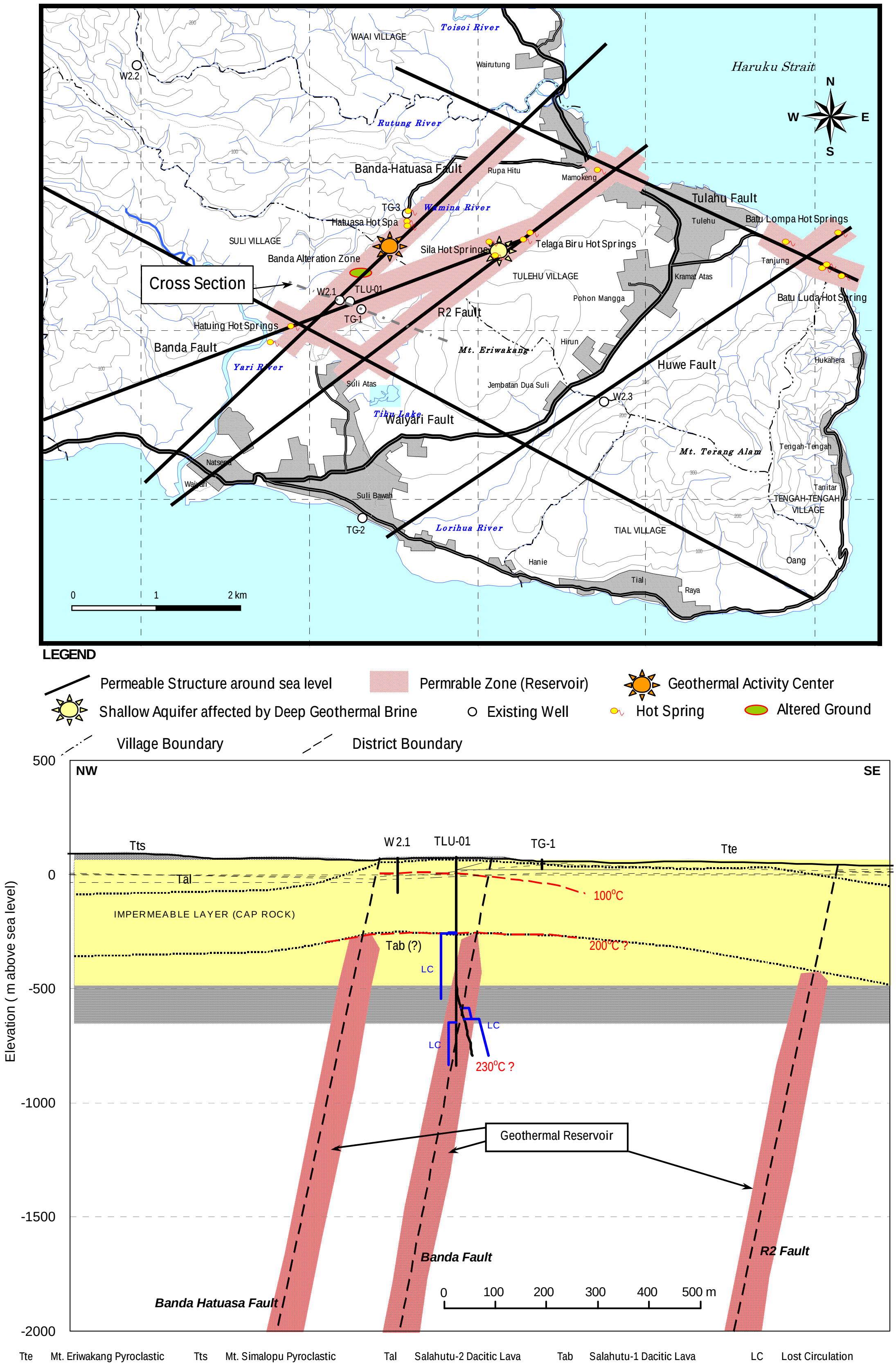


Fig. 7 Conceptual Model of Tulehu Geothermal Reservoir

(7) Resource Potential Evaluation

- The resource potential evaluated by the Stored Heat Method was 30MW.
- From the results of Monte Carlo analysis, the mode of resource potential was 30 MW, which is sufficiently larger than the planned development capacity 20MW. (Fig.8)

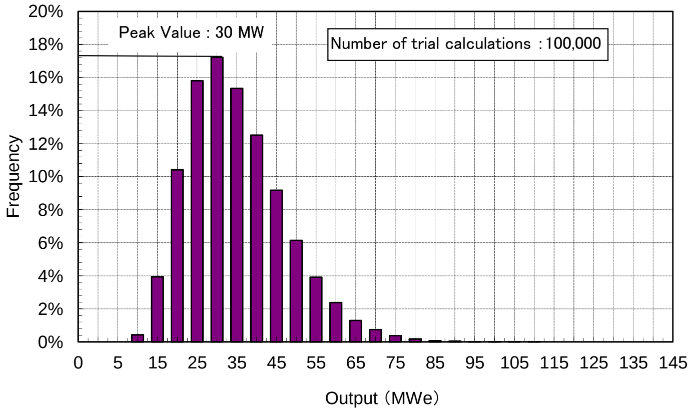


Fig. 8 Result of Monte Carlo Analysis of Tulehu Geothermal Resource Potential

III Geotehrmal Resources Development Plan

(1) Well Productivity and Injectivity

- A borehole simulator was used to estimate the productivity of a well in Tulehu field. (Fig. 9)
- The number of wells necessary to produce 20 MW of power was estimated.（Table-1 & 2）

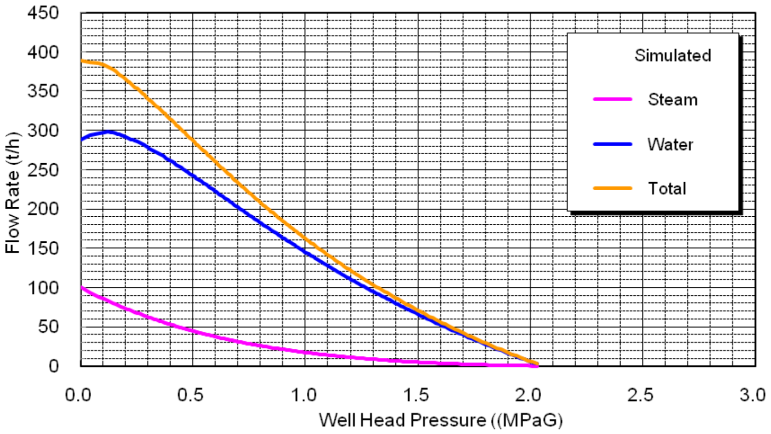


Fig. 9 Result of Estimation of Well Productivity`

Table 1 Result of Well Productivity Estimation

Power Generation Type	Productivity	Injectivity
Single Flash	63 (t/h)	250 (t/h)
Double Flash	82 (t/h)	250 (t/h)

Table 2 Number of Initial Wells Necessary to Produce Power of 20 MW

Power Generation Type	Initial Production Wells	Initial Reinjection Wells
Single Flash	4 (+ 1backup)	6
Double Flash	3 (+ 1backup)	4

(2) Drilling Targets and Specifications

- The drilling targets and drilling pads were selected based on the conceptual model and various study results. (Fig.10）
- The specifications of the drilling were studied. (Fig.11)

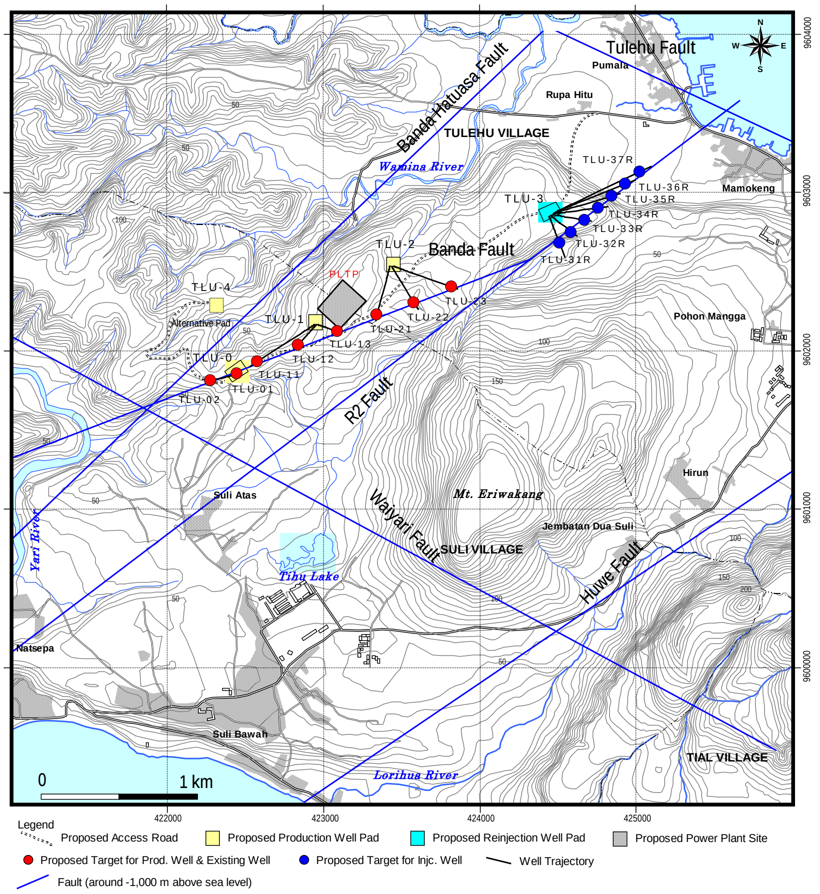


Fig.10 Locations of Drilling Targets and Drilling Pads

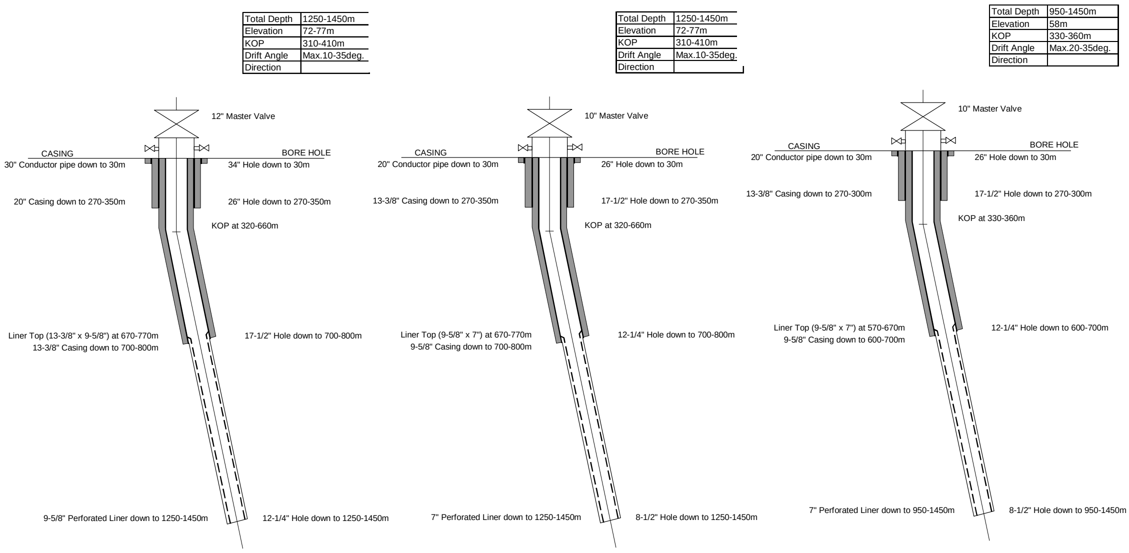


Fig.11 Well Drilling Specifications

(4) Plant Construction Plan, Design of Transmission Lines

- Plant construction plans for the unit capacity of 2 x 10MW or 1 x 20MW, and the plant system of single flash type or double flash type were considered. The system flow diagram of 2 x 10MW double flash is shown in Fig.12.
- Designs of transmission lines to connect to Ambon-Seram system were investigated. (Fig.13)

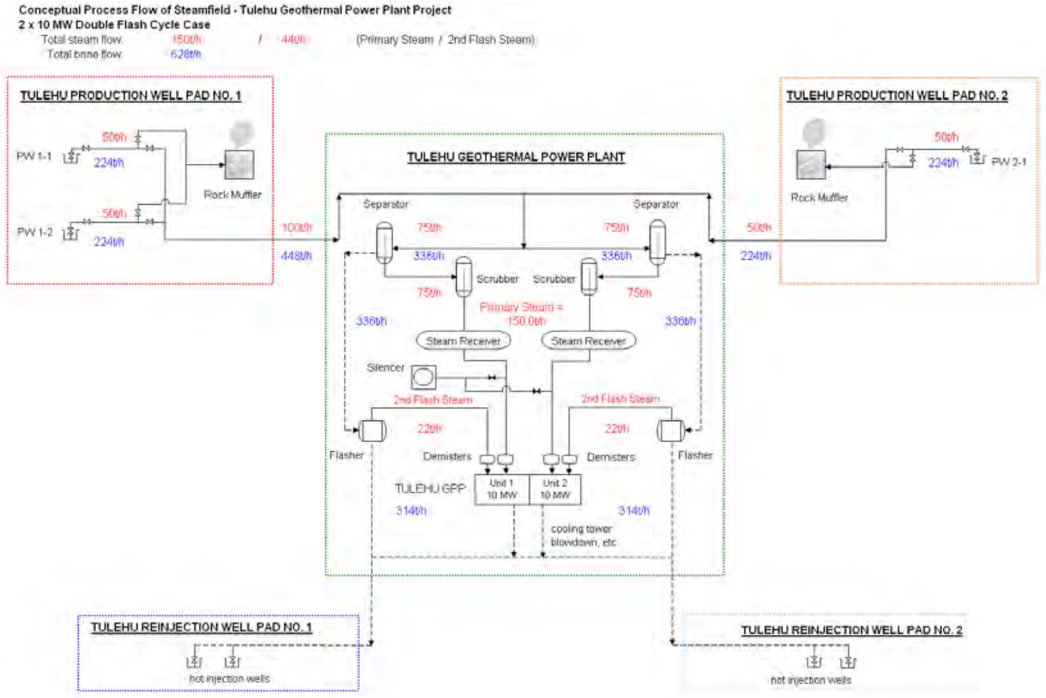


Fig.12 System Flow Diagram. (2x10MW Double Flash System)

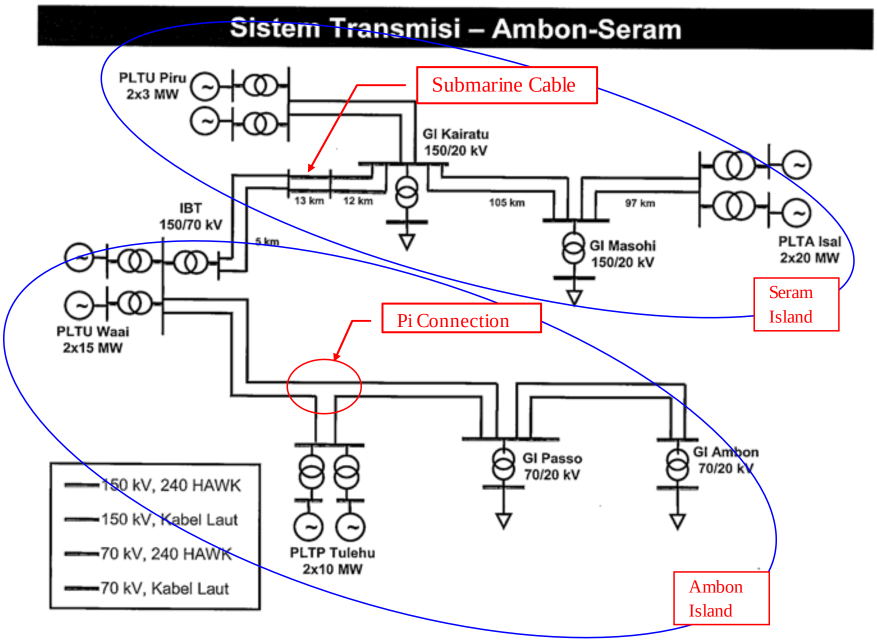


Fig.13 Single Line Diagram of Ambon-Seram Interconnection System

(5) Estimation of Project Cost, Project Implementation Plan, Confirmation of Project Effects

- With respect to the 4 types of power configuration, the respective project cost estimate is made on condition that the finance will be granted from the JICA Yen Loan, and these estimates are summarized in Table-3.
- The results indicated that the projects are financially feasible, except the case of 2 x 10MW single flash system. The project is highly expected to improve the financial condition of PLN Ambon. (Table-4)
- The executing agency of the project is PT. PLN(Persero).
- The project comprises the following work and services with financing from the sources indicated.

	Work & Services	Finance Source
1)	PLN Advance Work (land acquisition, well pad preparation, access road construction, meteorological observation at the Project site)	PLN Own Fund
2)-1	Exploratory Well Drilling & Testing for Tulehu (3 production wells and 1 reinjection well)	JICA ES Loan
2)-2	Additional Well Drilling & Testing for Tulehu	JICA Project Loan
3)	Construction of FCRS	JICA Project Loan
4)	Construction of Geothermal Power Plant (including associated switchyard)	JICA Project Loan

5)	70 kV Transmission Line Connecting Work	PLN Own Fund
6)	Engineering Consulting Services	JICA ES Loan
7)	Exploratory Well Drilling & Testing for future development site (2 production wells and 1 reinjection well)	JICA ES Loan

- Project implementation plans for all 4 cases were studied. For the standard project schedule for the 2 x 10 MW Double Flash case, the project will take 60 months from inception to plant completion. The accelerated version of the project implementation schedule for the 2 x 10 MW Double Flash case will be 8 months shorter at 52 months. The project schedules for the other cases are shown in section IV.7.4 of the main report.
- In the financial/economical evaluations, double flash systems were superior to single flash system because of superiority in investment

Table 3 Summary of Project Cost Estimations

Unit: Million US$	**Single Flash**		**Double Flash**	
Item	10 x 2	20 x 1	10 x 2	20 x1
1 Project Up Stream Works				
1.1 Access Road/Civil Works (PLN portion)	2.53	2.53	2.53	2.53
1.2 Well drilling	46.66	46.66	33.57	33.57
Subtotal	49.19	49.19	36.10	36.10
2 Project Down Stream Works				
2.1 Power Plant	44.00	42.00	46.00	43.80
2.2 FCRS	8.38	7.94	6.62	6.62
2.3 Connecting T/L (PLN)	0.30	0.30	0.30	0.30
Subtotal	52.68	50.24	52.92	50.72
3 Total Project Cost	101.87	99.43	89.02	86.82
4 Administration Cost	4.07	3.98	3.56	3.47
5 Consulting Fee	10.51	10.51	10.51	10.51
6 Contingencies				
6.1 Price Conti. (FC:1.6%, LC:7.9%)	14.71	14.37	13.51	13.16
6.2 Physical Conti.	6.04	5.93	5.39	5.26
Subtotal	20.75	20.30	18.90	18.42
7 Grand Total	137.20	134.22	121.99	119.22
8 Implementation				
9.1 PLN Equity	25.82	25.28	22.96	22.45
9.2 JICA Project Loan, (less than 85%)	99.21	96.77	86.86	84.60
9.3 JICA Consultant Loan, 100%	12.17	12.17	12.17	12.17
Total	137.20	134.22	121.99	119.22
Yen equivalent (Million Yen)				
9.1 PLN Equity	2,053	2,010	1,825	1,785
9.2 JICA Project Loan, (less than 85%)	7,887	7,693	6,905	6,725
9.3 JICA Consultant Loan, 100%	968	968	968	968
Total	10,907	10,670	9,698	9,478
9 IDC+Commitment Charge	1.19	1.16	1.13	1.10

Table 4 Summary of Economic and Financial Evaluations

Economic and Financial Evaluation Summary	Single F 10 MW x 2	Single F 20 MW x 1	Double F 10 MW x 2	Double F 20 MW x 1
Saving and Reduction Effects				
1 Annual Fuel Saving Volume	41.31 Mill/lit	41.31 Mill/lit	41.31 Mill/lit	41.31 Mill/lit
2 Annual Fuel Saving Amount	29.56 MM$	29.56 MM$	29.56 MM$	29.56 MM$
3 Subsidy Reduction	19.97 MM$	20.34 MM$	22.33 MM$	22.66 MM$
Economic Evaluation				
1 EIRR to diesel fuel oil saving	19.64% >12%	19.98% >12%	22.18% >12%	22.57% >12%
2 EIRR to subsidy reduction	13.42% >12%	13.96% >12%	17.17% >12%	17.76% >12%
3 EIRR to willingness to pay at 2500 Rp/kWh	17.47% >12%	17.78% >12%	19.61% >12%	19.97% >12%
4 EIRR to 15 MW x 2 Coal-fired	10.52% <12%	10.94% >12%	13.51% >12%	14.06% >12%
Financial Evaluation				
1 LEC at PP outlet (House service ratio at 5%)	14.89 cent/kWh	14.63 cent/kWh	13.23 cent/kWh	12.99 cent/kWh
2 LEC at Sending end (System loss at 10%)	16.55 cent/kWh	16.26 cent/kWh	14.70 cent/kWh	14.44 cent/kWh
3 WACC	2.56%	2.56%	2.56%	2.56%
4 FIRR at actual selling price at 7.93 cent/kWh	2.35% <2.56%	2.48% <2.56%	3.27% >2.56%	3.41% >2.56%
5 Project FIRR at LEC at sending end	8.90% >2.56%	8.90% >2.56%	8.85% >2.56%	8.86% >2.56%
6 Equity FIRR at LEC at sending end	30.46% >12%	30.43% >12%	29.55% >12%	29.53% >12%

V` Social and Environmental Considerations

Permissions/Explanations

- UKL/UPL were approved by the government of Central Maluku Province.
- A stakeholder meeting was held in Suli village.

Social Environment

- There is no protected areas around the project area.
- No involuntary resettlement is necessary in execution of the project.
- There is no indigenous people and minorities in the project area.

Natural Environment

- The existence of protected species, such as rare or indigenous species, has not been confirmed around the planned project site.
- The effect of implementation of the project on the fauna, flora and ecosystem is considered to be insignificant.

Pollution Control

- There is no H_2S data available, as the project activity still in exploitation stage (drilling activities). H_2S in the geothermal steam will be extracted from the condensers using the gas extractor, and sent to the cooling tower and discharged into the atmosphere from the top where it is diluted and dispersed. This type of treating method is a standard practice employed in geothermal power plants around the world, and in most cases can sufficiently reduce the H_2S concentration at ground level. However, a detailed evaluation should be carried out based on the maximum ground concentration of H_2S calculated through diffusion simulation or wind tunnel experiments.

VI Conclusions and Recommendations

Conclusions

- The geothermal resource potential in Tulehu area is sufficient for a development of 20 MW geothermal power plant.
- Banda-Hatuasa fault, Banda fault, and R2 fault are promising development targets.
- The drilling results of TLU-01 confirmed the existence of high-permeability reservoir. Besides, many data indicated that the reservoir temperature exceeds 200^{o}C from relatively shallow region to deep region.
- It was confirmed that the bottom depth of cap rock layer is approximately -300m a.s.l in the vicinity of TLU-01 drilling site.
- The number of necessary wells for 20 MW power generation was estimated as follows.

Power Generation Type	Initial Wells (Production)	Initial Wells (Reinjection)	Makeup Wells (Production)	Makeup Wells (Reinjection)
Single Flash	4 (+ 1backup)	6	3	4
Double Flash	3 (+ 1backup)	4	3	3

- Based on the geothermal resource study of the currently available data and the development plan, the four (4) sets of plans for the four possible types of geothermal power plant are studied: 2 x 10 MW Single Flash Condensing System, 1 x 20 MW Single Flash Condensing System, 2 x 10 MW Double Flash Condensing System, and 1 x 20 MW Double Flash Condensing System.
- As for the possible use of a geothermal binary system, this is considered only in general terms at this very initial stage of the project study. Most of the factors and conditions for the detailed study of the geothermal binary system cannot be confirmed at this stage in the feasibility study, and further consideration of a geothermal binary system is adjourned until the next Engineering Service stage.
- The double flash system and binary system are more suitable for the Tulehu geothermal project than the single flash system because of effective utilization of the geothermal energy for the Tulehu geothermal fluid which is anticipated to contain a large volume of hot water (anticipated steam-hot water ratio 1:4.5).
- A unit capacity of 10 to 20 MW for Tulehu geothermal power plant could be still tolerable, considering the future scale of the Ambon electric power system.
- The current outputs of geothermal resource study and its development plan are enhanced with some assumptions based on knowledge and experience, since the currently available data and information are limited. The geothermal resource evaluation should be re-examined in the light of additional data as more information on the drilling and testing of the further exploratory wells becomes available and in the light of meteorological observations at the project site. The geothermal resource development plan and the power plant plan will need to be reconsidered accordingly before starting project implementation.
- The project cost estimation was attempted for the four cases of power plant design, and each case was examined by economical and financial evaluations. The results indicated that double flash system would be advantageous for 20 MW power generation in Tulehu field. For the unit capacity of the power plant, the results indicated that both of 2 x 10 MW and 1 x 20MW might be feasible. However, a comprehensive investigation suggested that 1 x 20MW configuration was advantageous for the project implementation.

Recommendations

- Drill an exploratory well of approximately 1,500m deep (preferably from a drilling pad which is different from TLU-0 pad), and conduct a production test using TLU-01 and the newly drilled well.
- In the production test, the chemical composition of geothermal fluid and the concentration of non-condensable gas should be clarified.
- Run static temperature loggings in TLU-01 once in a month in order to monitor its temperature recovery. The temperature recovery data can be utilized in assessing the possibility of spontaneous fluid production in TLU-01.
- Though the additional exploration well drilling and production testing recommended above, the steam conditions (pressure, temperature, and NCG volume and composition) hot water quantity and scaling characteristics of geothermal fluid will need to be clarified for the power plant basic planning and design for the project implementation.
- The meteorological observation at the project site for two (2) years should be commenced immediately, and the meteorological conditions (temperature, atmospheric pressure, wet bulb temperature, wind direction, wind speed, rainfall, etc,) for the project design should be determined.
- The geothermal power plant plan will need to be reconsidered according to the abovementioned steam conditions, geothermal fluid characteristics, and meteorological conditions, and the optimum plan of power plant system (double flash, single flash or binary) and unit generation capacity should be determined in the process of basic plan and design of the geothermal power plant before starting project implementation.
- Evaluate the environmental impacts of H_2S gas by conducting a diffusion simulation or a wind tunnel experiments based on H_2S concentration and power plant design.

CHAPTER I

I INTRODUCTION

I.1 Study Area

The study area is Tulehu geothermal field in Maluku province, Ambon Island (see Fig. I-1-1).

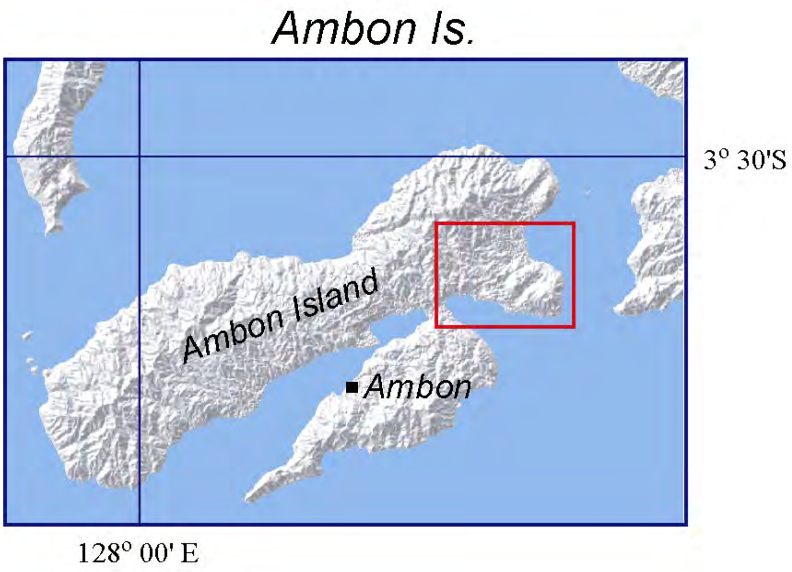


Fig. I-1-1 Study Area

I.2 Background

According to National Electricity General Plan 2008-2027 (RUKN2008-2027) of the Ministry of Energy and Mineral Resources (MEMR), the peak electricity demand in 2008 was 25,407 MW overall in Indonesia and future electricity demand is forecasted to increase at an average rate of 9.1% every year. In order to secure an increasing power supply, the Government of Indonesia (GOI) announced a development program entitled “Crash Program”. Following on the “Crash Program” in 2009, the GOI announced “Crash Program II” in January 2010, which includes 3,977 MW of Geothermal power among renewable energy power developments totaling 10,000 MW. It is well known that Indonesia has the world's largest reserve of geothermal power, equivalent to 27,000 MW. However, only about 1,300 MW of geothermal power have been developed in Indonesia as of today. To achieve the target of Crash Program II, the rapid development of geothermal power is required.

According to RUPTL 2010-2019 (Long Term Electricity Development Plan 2010-2019), the peak demand in the Maluku network (Ambon island), where the Tulehu geothermal field is located, was 36.6 MW in 2010 and it is forecasted to reach 81.1 MW in 2019 at an average annual rate of increase of 9.3%, owing to steady economic growth and an increase in the rate of rural electrification. The installed capacity of existing generating facilities in the network is 55 MW, consisting of diesel power plants with high generating costs and large greenhouse gas emissions. The dependable capacity in this network is only 30 MW out of 55 MW, i.e., the power supply is less than the demand on it. Thus, the development of Tulehu geothermal power plant is expected to resolve the capacity deficit and it to result in a reduction of fossil fuel consumption and greenhouse gas emissions.

The GOI and PT. PLN plan for most of the electrical power in areas in eastern Indonesia like Maluku on Ambon Island to be supplied from geothermal resources. The size of geothermal power plants in eastern Indonesia is less than 20 MW, due to the limited power demand, small size of the network, or scaling for the replacement of diesel power plants. In Ambon Island, the size of the plant is planned to be 20 MW (2 x 10 MW). The power generated by Tulehu geothermal power plant will be transmitted to the demand center of Ambon city.

I.3 Purpose of the Preparatory Survey

The purpose of the Preparatory Survey is to prepare feasibility study documents for the Tulehu geothermal power development project as an ODA Yen loan project. The purpose of the Preparatory Survey is to carry out a geothermal resource assessment, which will verify if the objective geothermal field can produce geothermal energy that is sufficient and suitable for the planned geothermal power development. As a result of the said assessment, the Survey Team is to formulate an implementation program for construction of the geothermal power station and associated transmission/distribution lines and substation. The preceding pre-feasibility study will be reviewed and updated.

I.4 Scope of the Geothermal Power Plant Development

The Tulehu Geothermal Power Plant Project consists of five (5) major components:

1) Construction of steam production facilities
2) Construction of a geothermal power plant
3) Construction of transmission and distribution lines
4) Construction of other appurtenant facilities for the geothermal power plant
5) Consulting services (preparation of bidding documents, assistance in bidding and contracting, construction supervision, environmental management, etc.)

I.5 Executing Agency

The executing agency of the Project is PT. PLN (including PT. PLN Geothermal).

I.6 TOR of the Preparatory Survey

Fig. I-6-1 depicts the flow of the preparatory study. Table I-6-1 shows the overall survey schedule.

The Preparatory Survey covers the following issues.

1) Review and confirmation of necessity of the Project and electricity demand in Indonesia
   - A. Review of the current status of the electricity sector in Maluku Province
   - B. Review of development plan for new power plants and upgrading or removing existing power plants in and around Ambon Island
   - C. Review of the overall scope of the Project in the context of electricity demand and supply, population and electrification in Ambon Island

2) Review of the details of the geothermal resource of the Project
   - A. Review of the existing study results of surface surveys and exploratory well study including geological studies, geochemical studies, geophysical surveys and well logs
   - B. Review of the geological structure of the geothermal reserve of the Project.
   - C. Review of the geological and chemical status and conditions of underground steam and water
   - D. Review of the estimated amount of geothermal energy including heat and water

3）Review of the detailed plans for the construction of the Project
   - A. Review of the scope, cost and schedule of drilling for production and re-injection wells
   - B. Review of the scope, cost and schedule of pipeline construction for steam production and water re-injection into the ground
   - C. Review of the scope, cost and schedule of power plant construction, including the details of turbines and generators for the Project
   - D. Review of the scope, cost and schedule of transmission and distribution lines

4) Calculation of the total project cost and O&M cost, and preparation of an Implementation Program (IP)
   - A. The Total project cost estimate (ODA loan and PT. PLN portions)
   - B. Review of the methods of procurement and implementation for the Project

5) Examination and proposal of an effective scheme for project implementation and O&M

6) Examination of necessary procedures for socio-environmental clearance of the Project in the GOI context, and specification of necessary/additional actions required for the Project based on the requirements in “JICA Guidelines for Confirmation of Environmental and Social Considerations (April 2010)”.

7) Calculation of the Economic/Financial Internal Rate of Return (EIRR/FIRR): identification of Operation and Effect Indicators as per JICA requirements

8) Holding a workshop during the study in which the Preparatory Survey team will present results of the survey of items 1) to 7) above, and collect and incorporate comments from the GOI and PT. PLN into the Draft Final Report.

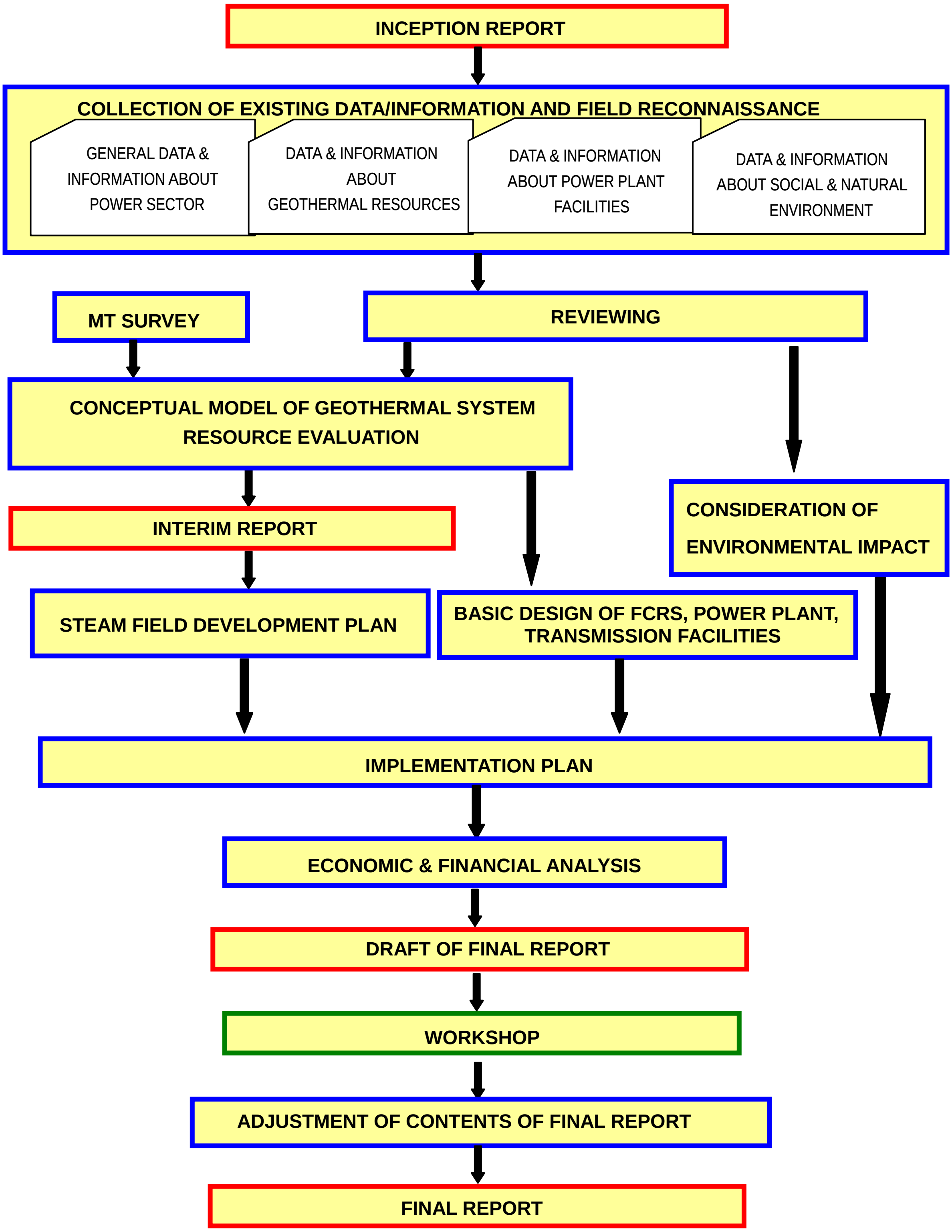


Fig. I-6-1 Flow of the Preparatory Survey

Table I-6-1 Schedule of JICA Preparatory Survey for Tulehu Geothermal Power Plant

Month / Work Item	FY2010									FY2011						
	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10
1. Preparation Work in Japan	□	□														
(1) Collection of Available Data and Information	□	□														
(2) Study on Basic Policy, Contents and Methodology	□	□														
(3) Preparation of the 1st Work in Indonesia		□														
(4) Preparation of Inception Report	□	□														
2. The 1st Work Phase in Indonesia		■														
(1) The 1st Workshop		■														
(2) Discussion with PLN and Relevant Authorities		■														
(3) Site Survey (PP, T/L, Environment, Finance/Economy, Resources etc.)		■														
(4) Collection, Analysis and Study of Resource Related Data		■														
(5) Preparation and Discussion of Draft Interim Report		■														
3. The 1st Work Phase in Japan			□	□												
(1) Arrangement and Study of Collected Data			□													
(2) Reservoir Assessment and Confirmation of Study Items			□	□												
(3) Preparation of Interim Report			□	□												
4. The 2nd Work Phase in Indonesia		■	■	■	■											
(1) The 2nd Workshop				■												
(2) Confirmation of the Latest Power Demand Conditions				■												
(3) Confirmation of Project Implementation Organization w/ Relevant Agencies				■												
(4) Confirmation of Proposed Plant Site and FCRS Lines				■												
(5) Confirmation of Drilling Plan				■												
(7) Environmental Impact Assessment				■	■											
(8) MT Survey		■	■													
5. The 2nd Work Phase in Japan				□	□	□										
(1) Reservoir Assessment (Continued)				□												
(2) Formulation of Project Implementation Plan					□											
(3) Financial Evaluation of the Project					□											
6. The 3rd Work Phase in Indonesia					■	■										
(1) The 3rd Workshop					■	■										
7. The 3rd Work Phase in Japan						□	□	□								
(1) Environmental Impact Assessment						□	□									
(2) Reservoir Assessment (Continued)							□	□								
8. The 4th Work Phase in Japan										□	□	□	□	□		
(1) Analysis of Well Test Data, Evaluation of Well Characteristics													□			
(2)Reevaluation of Reservoir Assessment													□			
(3) Reevaluation of Project Implementation Plan											□	□	□			
(4) Study of Drilling Target, Drilling Program											□	□	□			
(5) Financial Evaluation of the Project													□	□		
10. The 4th Work Phase in Indonesia												■				
(1) The 4th Workshop (Discussion of Well Target and Drilling Program)												■				
11. The 5th Work Phase in Japan														□		
(1) Preparation of Draft Final Report														□		
12. The 5th Work Phase in Indonesia														■		
(1) The Final Workshop														■		
(2) Discussion of Draft Final Report														■		
13. The 6th Work Phase in Japan															□	
(1) Preparation of Final Report															□	
(2) Final Report Submission															□	

I.7 Members of the Study Team

The members of the survey team are listed in Table I-7-1 together with their specialties and assignments.

Table I-7-1 Members of the Study Team

Name	Specialty	Assignment
SHIMADA, Kan’ichi	Survey Project Manager, Geochemist	Team Leader, Project Management, Technical Supervisor, Geothermal Resource Evaluation
SUEYOSHI, Yoshikazu	Drilling Engineer, Civil Engineer	Review of Drilling Plans, Estimation of Drilling Costs, Review of Procurement and Construction Methods
AKASAKO, Hideo	Geologist	Data Collection (Geology), Detailed Review of Geothermal Reservoir
UCHIYAMA, Noriaki	Geochemist	Data Collection (Geochemistry), Scaling Problem, Chemical Properties of Geothermal Fluid.
FUKUOKA, Koichiro	Well Test Engineer	Data Collection (Wells), Review of Logging Data, Resource Estimation
HONDA, Mitsuru	Geophysicist (A)	MT Survey including Data Analysis and Interpretation, Review of Geophysical Data Analysis / Interpretation. Data Analysis and Interpretation of MT data.
NAGANO, Hiroshi	Geophysicist (B)	Data Collection, Review of MT Analysis.
Iri, Shatei	Environmental Engineer	Social and Environmental Considerations
FUNAKOSHI, Yoshimi	Mechanical Engineer	Review of Power Plant Construction Plan, Confirmation of Organization of Project Execution and O&M, Review of Procurement and Construction, Planning on Project Execution, Review on Pipeline Construction Plan
SAKEMURA, Kenji	Electrical Engineer	Design of Electrical aspects and I&C of Power Plant and Transmission Line and Substation
FUJII, Kenji	Economist	Financial and Economic Evaluation

CHAPTER II

II CURRENT STATUS OF THE POWER SECTOR IN THE STUDY AREA

II.1 Outline of the Indonesia Power Sector

Indonesia suffered the largest impact among ASEAN countries in the Asian economic crisis of 1997. The Indonesian economy, however, has shown a great improvement since the crisis, energized by the results of various policy reforms and supported by the inflow of investment from foreign and domestic sources. Thus, the Indonesian economy is expanding steadily, and electric power demand is also increasing rapidly. According to National Electricity Provision Plan 2010 (RUPTL 2010-2019), the peak power demand for the whole country reached 24,609 MW in 2009, showing a 3.4% increase in the Java-Bali system and a 10% increase outside Java-Bali in the last five years. In addition, the aggregate amount of energy demand in 2009 was 133.11 TWh, a 5.4% increase in the Java-Bali system and a 10.4% increase outside Java-Bali in the last five years. RUPTL 2010-2019 estimates that peak demand for the country will increase at an average annual rate of 9.5% and will reach 59,863 MW in 2019. It also estimates that the energy demand will increase at a higher rate than the peak demand and will reach 334.4 TWh in 2019. In order to secure a stable energy supply, the development of power plants to meet these demands is one of the urgent issues confronting the Indonesian power sector. Since the peak demand in the Java-Bali system accounts for 73.4% (as of 2009) of total national demand, power plant development in this system is most important. For this purpose, the Indonesian government promulgated a President Decree in 2006 entitled “Crash Program” with the aim of developing 10,000 MW in the Java-Bali system. Construction work implementing this program is in progress today. Furthermore, power development in systems other than the Java-Bali system is also very crucial because power demand will increase rapidly due to the expansion of rural electrification and the rural economy. Thus, a “Second Crash Program” was promulgated in October 2010 by the Indonesian government. This is also a program to develop 9,522 MW of generating capacity, with 53% (5,007 MW) being developed in systems other than the Java-Bali system. It is to be noted that 54% of this 9,522 MW will be derived from renewable energy, such as geothermal power plants (42%) and mini-hydro power plants (12%), and that IPP-managed power plants can be included in the program.

Another urgent issue that the Indonesian power sector faces is the diversification of energy sources. In light of high oil prices, it is necessary to reduce dependency on oil as an energy source in order to reduce generation costs and to secure a stable energy supply. For this purpose, the Indonesian government worked out a "National Energy Policy (NEP)" in 2002, and set the target of obtaining 5% or more of primary energy from renewable sources by 2020. To achieve this target, the government is placing great reliance on geothermal energy, which is abundant in the country.

II.2 Current Status of Electricity Power Supply and Demand in Indonesia

The energy demand of Indonesia (sales of electric power) in 2009 was 133.11 TWh. To meet this demand, 133.11 TWh of energy was generated by power plants with an aggregate capacity of 30,320 MW. According to RUPTL 2010-2019, the breakdown of this capacity is 11,700 MW of steam power plants (38.6%), 7,521 MW of gas combined-cycle power plants (24.8%), 3,648 MW of hydro power plants (12.0%), 2,618 MW of diesel power plants (8.6%), 3,116 MW of gas turbine plants (10.3%), and 1,105 MW of geothermal power plants (3.6%). In 2009, there were 41.0 million power purchase contracts, marking a 16% increase over 2005. Since many customers are waiting due to the lack of an adequate power supply, the number of contracts would increase at a higher rate than previously, if the power supply were adequate.

The infrastructure of the national electric power system of Indonesia falls into two categories: interconnected electric power systems and isolated electric power systems. The Java-Bali system has already been developed and has established an interconnected electric power system through an ultra-high-voltage (500 kV) power transmission network. The Sumatra system is also interconnected by a 150 kV transmission network running from north to south. However, since the network voltage (150 kV) is relatively low considering the length of transmission lines, the North and South networks have been operating independently. The Java-Bali system and Sumatra system are scheduled to be connected to each other by a 500 kV DC transmission line in 2016. Power supply systems other than these two systems have not been integrated yet and are not completely interconnected with each other. These power systems consist of sub-systems and individually isolated smaller sub-systems, and there are still many independent/isolated regions. 22,906 MW (75.5%) of total installed capacity is concentrated in the Java-Bali system, and 4,598 MW (15.2%) of total capacity is generated in the Sumatra system. Thus, the two systems account for 90.8% of total national capacity.

II.3 Current Status of Geothermal Energy Development in Indonesia

It is said that Indonesia has the world’s greatest geothermal energy potential, which is estimated at more than 27,000 MW and is thought to account for more than 40% of total world potential. Therefore, the development of geothermal power has been eagerly awaited in order to supply energy to satisfy the increasing power demand and to advance the diversification of energy sources. Today, geothermal power plants exist in seven fields in Indonesia, i.e. Sibayak in north Sumatra, Salak, Wayang Windu, Kamojang, and Darajat in west Java, Dieng in central Java, and Lahendong in north Sulawesi, as shown in Table II-3-1. The total geothermal generation capacity is over 1,100 MW as of today. Although this capacity ranks Indonesia as the third largest geothermal producer in the world, it is far from exploiting the huge geothermal potential of the country.

The Indonesian economy has shown a strong recovery from the Asian economic crisis, and has been continuously expanding in recent years. Accordingly, domestic energy demand is also expanding. On the other hand, oil supply has decreased due to depletion of existing oilfields or aging of the production facilities. As a result, Indonesia changed from being an oil-exporting country to being an oil-importing country in 2002.

Under the impetus of this worsening situation, the Indonesian government decided to diversify energy sources and to promote domestic energy sources in order to lower oil dependency. The government worked out a "National Energy Policy” (NEP) in 2002, and set a target of deriving 5% or more of primary energy from renewable sources by 2020. In addition, the government promulgated the “Presidential Decree on the National Energy Policy” (PD No.5/2006) in 2006, raising the NEP from ministerial level policy to the level of presidential policy. On another front, the government enacted a "Geothermal Energy Law" for the first time in 2003 to promote the participation of the private sector in geothermal power generation. Moreover, in 2004 the Ministry of Energy and Mineral Resources (MEMR) worked out the "Road Map Development Plan for Geothermal Energy" (hereinafter “Road Map") to materialize the national energy plan. In this Road Map, high geothermal development targets of 6,000 MW by 2020 and 9,500 MW by 2025 have been set. In 2001, the Indonesian government issued a law restricting the business activities of Pertamina to Oil and Gas. Consequently, Pertamina was changed into Limited company owned by the Indonesian government in 2003 (Government Regulation No.31/2003) and Pertamina Geothermal Energy Ltd. was established in 2006 to carry out geothermal business and accelerate implementation of the plan. Thus, a basic framework for geothermal energy development has been created, and the government has initiated efforts to attain these development targets.

Table II-3-1 List of Geothermal Power Plants in Indonesia

Power Plant	Location	Unit	MW	Turbine Maker	Operation	Steam Supply	Power Generation
Sibayak	North Sumatra	#1	2	Unknown	1996	Pertamina	
		#2	5	Unknown	2007	Pertamina	
		#3	5	Unknown	2007	Pertamina	
Salak	West Java	#1	55	ANSALDO	1994	Chevron Geothermal Indonesia	PLN
		#2	55	ANSALDO	1994		
		#3	55	ANSALDO	1994		
		#4	55	Fuji	1997	Chevron Geothermal Indonesia	
		#5	55	Fuji	1997		
		#6	55	Fuji	1997		
Wayang-Windu	West Java	#1	110	Fuji	2000	Mandala Nusantara Ltd	
		#2	117	Fuji	2009		
Kamojang	West Java	#1	30	MHI	1983	Pertamina	PLN
		#2	55	MHI	1988		
		#3	55	MHI	1988		
		#4	63	Fuji	2008	Pertamina	
Darajat	West Java	#1	55	MHI	1994	Chevron Geothermal Indonesia	PLN
		#2	81.3	MHI	2000	PT. Chevron Geothermal Indonesia	
		#3	110	MHI	2007		
Dieng	Central Java	#1	55	ANSALDO	1999	Geodipa Energi	
Lahendong	North Sulawesi	#1	20	ALSTOM	2001	Pertamina	PLN
		#2	20	Fuji	2007	Pertamina	PLN
		#3	20	Fuji	2009	Pertamina	PLN
Total			***1,138.3 MW**				

II.4 Power Supply and Demand in the Project Area

II.4.1 Power Supply and Demand in Maluku Province

Maluku Province is located in the eastern part of Indonesia and consists of 559 islands, such as the Maluku (Moluccas) Islands, Halmahera (Jailolo) Islands, Kai Islands, etc. with a large sea (Banda sea) to the south. The area of Maluku province as a whole is 581,376 km^2, consisting of a vast sea area of 527,191 km^2 and a land area of 54,185 km^2. The capital city of the province is Ambon city on Ambon Island with 0.28 million of the 1.44 million population of the whole province (as of 2008). Table II-4-1 shows the Area and Population of the Province and Ambon city.

Table II-4-1 Land Area and Population of Maluku Province and Ambon city (2008)

	Land Area (km^2)	Population	Population Growth (annual %)
Ambon City	377	281,293	3.95
Total Maluku	54,185	1,440,014 (1,531,402)	2.30
Total Indonesia	1,910,931	227,345,082 (237,556,363)	1.20

The data in brackets show the results of the 2010 Census
(Source: Maluku in Figures 2009, World Bank Database)

The Gross Domestic Regional Product (GDRP) of Maluku province in 2008 was 6,270 billion Rupiah (Rp), contributing a mere 0.15 % to the national GDP. The GDRP showed a growth rate of 10 % in 2008 in real terms. However, the per capita GDRP is only 25 % of the Indonesian average (see Table II-4-2).

In Maluku province, about 35% of GDRP derives from agriculture. Other main economic activities are hotels and restaurants in Ambon city, public services and so on, as shown in Table II-4-3. In order to support these economic activities, a stable electric power supply is extremely important. The electric power supply in Maluku province is provided by PLN Wilayah “Maluku dan Maluku Utara”, which consists of three Cabangs (branches), namely Cabang Ambon, Ternate and Tual. See Fig. II-4-1. Each system (network) is isolated; that is to say that there is no interconnection between the systems. Table II-4-4 shows the installed and dependable capacity of generation units, and system peak demand in the three Cabangs. Cabang Ambon is the largest system among them. All generation units are Diesel generators according to PLN Wilayah Maluku dan Maluku Utara Statistik 2009. The dependable capacity of the generation units is 119.93 MW, which is only 59% of the total Wilayah installed capacity (203.26 MW). Tulehu geothermal power plant is to be located on Ambon Island, which is the territory of Cabang Ambon.

Table II-4-2 Regional Gross Domestic Production of Maluku Province (in 2008)

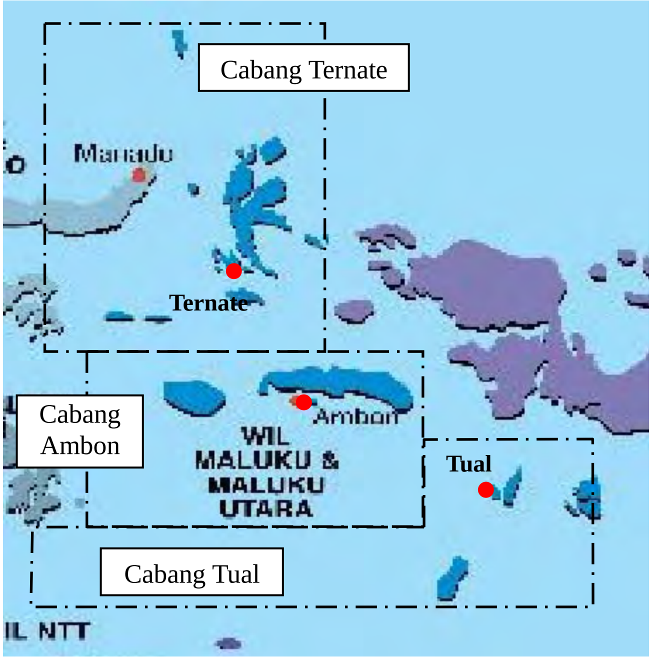
	GDRP (Billion Rp)	%	GDRP Per Capita (×1,000 Rp) (2007)	%
Maluku	6,270	0.15	4,377	24.9
Total Indonesia	4,204,359	100.0	17,581	100.0

(Source: Maluku in Figures 2009, Gross Regional Domestic Product by Provinces 2004-2008; BPS)

Table II-4-3 Breakdown of GDRP of Maluku Province (in 2004)

		Maluku	Total Indonesia
Agriculture		35.7%	15.4%
Mining		0.9%	8.5%
Industry		4.6%	28.3%
Electricity, Gas, Water service		0.7%	1.0%
Construction		1.2%	5.8%
Commercial, Tourism, Restaurant		25.4%	16.2%
Transportation, Communication		8.7%	6.1%
Finance, Real estate		5.3%	8.4%
Public service		17.5%	10.2%
Total		100.0%	100.0%
GDRP (billion Rp)	2004	4,048	2,303,032
	2008	6,270	4,204,359

(Source: Maluku in Figures 2009, Gross Regional Domestic Product by Provinces 2004-2008; BPS)



(Source; RUPTL 2010-2019)

Fig. II-4-1 Wilayah Maluku dan Maluku Utara

Table II-4-4 Installed/Dependable Capacity and System Peak Demand (2009)

Cabang	Installed Capacity (MW)	Dependable Capacity (MW)	Peak Demand (MW)
Ambon	**110.96**	**56.86**	**57.18**
Ternate	66.03	49.95	35.90
Tual	26.27	13.12	10.35
Total	**203.26**	**119.93**	**103.43**

(Source: PLN Wilayah Maluku dan Maluku Utara Statistik 2009)

Table II-4-5 shows the energy production of three Cabangs in 2009. Cabang Ambon supplies 53.9% of the total energy. Energy generated by rental generators accounts for 96.80 GWh out of 468.01 GWh.

Table II-4-5 Energy Production (2009)

Cabang	PLN Generators		Consumed by PLN	Rental Generators	Total Energy Production in the Wilayah	
	A (GWh)	(%)	B (GWh)	C (GWh)	A-B+C (GWh)	(%)
Ambon	**221.87**	**58.4**	**5.49**	**36.11**	**252.48**	**53.9**
Ternate	123.25	32.5	2.73	44.01	164.53	35.2
Tual	34.59	9.1	0.27	16.68	51.00	10.9
Total	379.71	100.0	8.49	96.80	468.01	100.0

(Source: PLN Wilayah Maluku dan Maluku Utara Statistik 2009)

Table II-4-6 shows distribution losses in three Cabangs and a total for Indonesia for reference. Distribution losses in Ambon and Tual system are 13.25% and 12.14%, respectively, and higher than the total losses for Indonesia (7.93%).

Table II-4-6 Distribution Losses (2009)

Cabang	Energy Sales (GWh)	Distribution Losses	
		(GWh)	(%)
Ambon	**252.48**	**33.46**	**13.25**
Ternate	164.53	8.04	4.89
Tual	51.00	6.19	12.14
Wilayah Total	468.01	47.69	10.19
Total Indonesia	-	-	7.93

(Source: PLN Wilayah Maluku dan Maluku Utara Statistik 2009)

II.4.2 Power Supply Demand in Cabang Ambon

Cabang Ambon manages the electrical systems of Ambon Island, Seram Island, Buru Island and other small islands. Table II-4-7 shows peak demand in Cabang Ambon in 2006 to 2009.

Peak demand in Cabang Ambon shows a 15.2% increase in 2007 over the previous year and an 8.8% increase in 2009 over 2008. The average rate of increase from 2006 to 2009 was over 9%. On the other hand, the installed capacity in 2009 was almost the same as in 2006, however, and the dependable capacity has steadily decreased year by year. This decline indicates that facilities are becoming obsolete.

Table II-4-7 Installed/Dependable Capacity and System Peak Demand

Year	Installed Capacity (MW)		Dependable Capacity (MW)		Peak Demand (MW)	
	MW	Growth	MW	Growth	MW	Growth
2006	110.32	-	67.73	-	44.77	-
2007	122.44	11.0%	64.50	▲4.8%	51.58	**15.2%**
2008	110.51	▲9.7%	60.97	▲5.5%	52.57	1.9%
2009	110.96	0.4%	56.86	▲6.7%	57.18	**8.8%**

Note; ▲ indicates negative figures.

(Source; PLN Wilayah Maluku dan Maluku Utara Statistik 2009)

Energy production in Cabang Ambon from 2006 to 2009 is shown in Table II-4-8. Energy by rental generators accounted for 14.3% (=36.10/252.48 GWh) of total energy production in 2009.

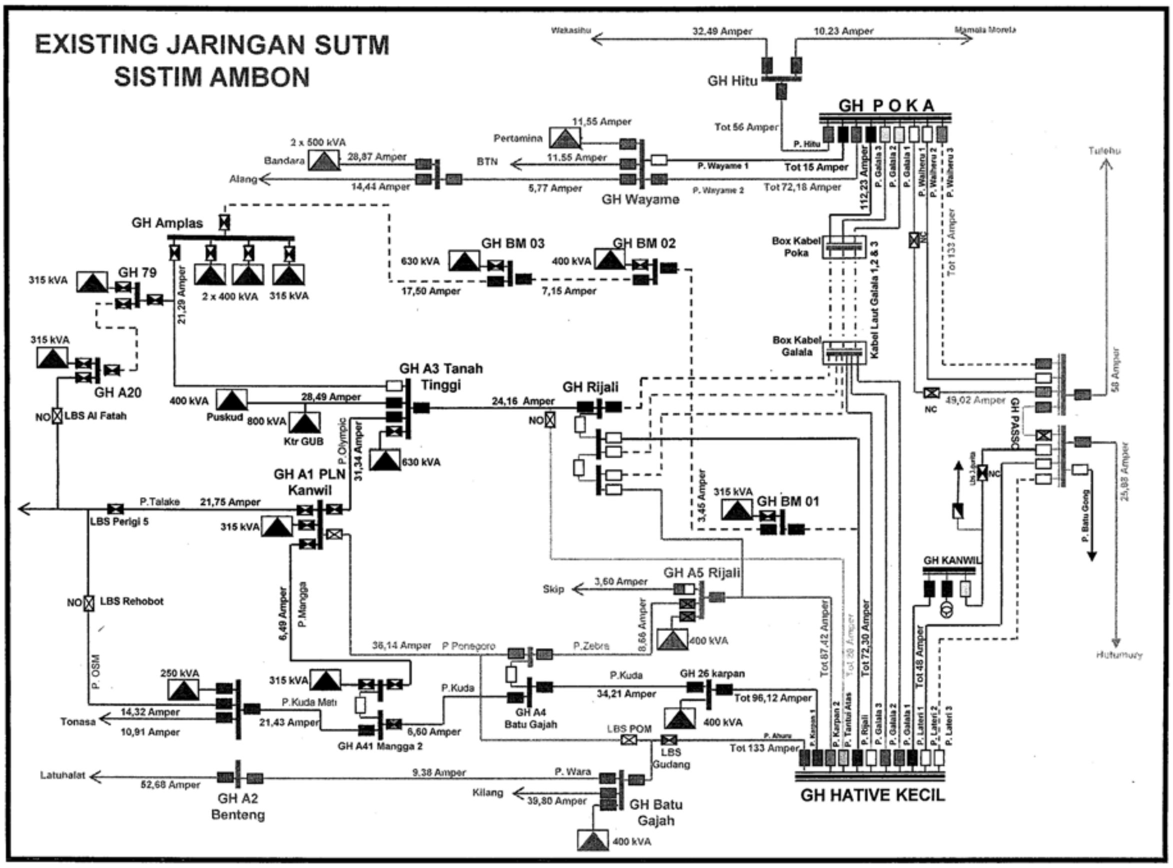
Table II-4-8 Energy Production in Cabang Ambon

Year	PLN Generators		Consumed by PLN		Rental Generators		Total Energy Production	
	(GWh)	Growth	(GWh)	House Rate	(GWh)	Growth	(GWh)	Growth
2006	179.82	-	3.49	-	30.44	-	206.77	-
2007	208.15	15.8%	5.43	2.6%	33.28	9.3%	236.00	11.4%
2008	218.84	5.1%	7.81	3.6%	33.43	0.5%	244.46	3.6%
2009	221.86	1.4%	5.49	2.5%	36.10	8.0%	252.48	3.3%

(Source; PLN Wilayah Maluku dan Maluku Utara Statistik 2009)

II.4.3 Power Supply and Demand in Ambon Island

The electrical system in Ambon Island (hereinafter called the Ambon system) is the largest system in Cabang Ambon and the system that Tulehu geothermal power plant will be connected to. See Fig. II-4-2 “Network Diagram of Ambon System”. The system consists of 20 kV distribution lines only, although there are plans to construct 70 kV Transmission lines in conjunction with the Waai coal-fired power plant (2 x 15 MW) which began in September, 2010. The first transmission line will be constructed from the Waai power plant to the center of Ambon city (Sirimau area).



Note; SUTM: Medium Voltage Overhead (Distribution) Lines

(Source; PLN Wilayah Maluku dan Maluku Utara)

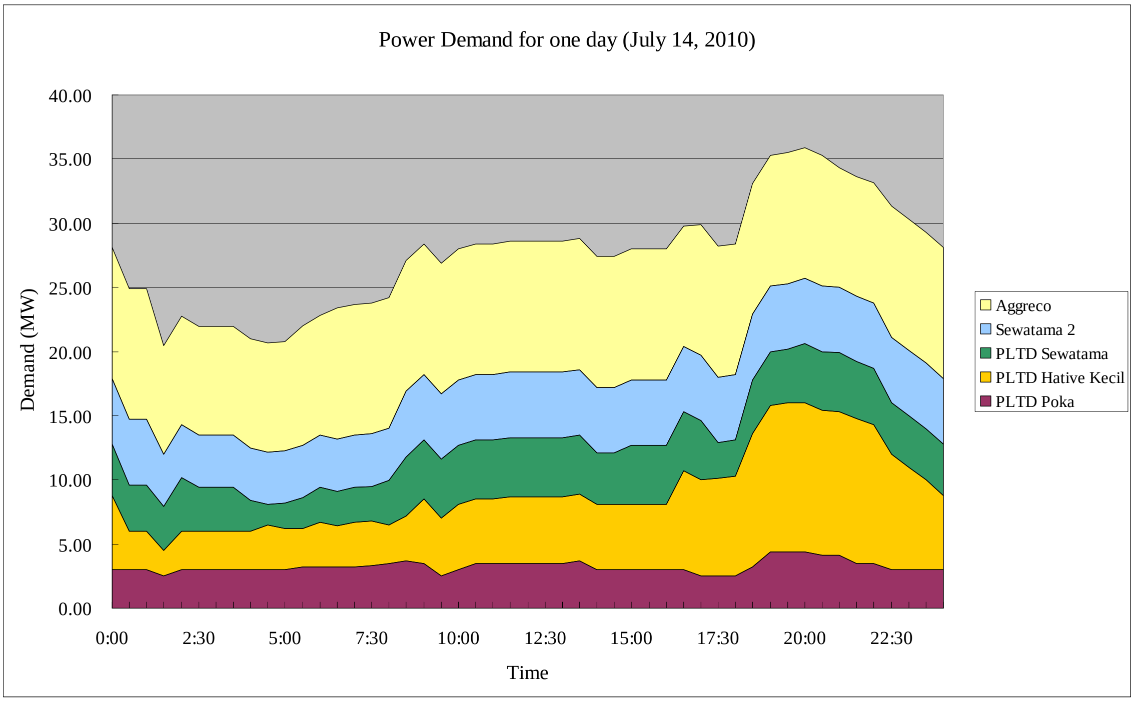
Fig. II-4-2 Network Diagram of Ambon System

The Ambon system accounts for approximately 60% of the power demand in the Cabang Ambon area. Table II-4-9 indicates the minimum and maximum demand on July 14, 2010 with generating units, and Fig. II-4-3 shows the Power demand curve for the day. The peak demand of the day was recorded at 8 pm and it was 35.9 MW. Rental units delivered 55% of the power generation, as shown in Table II-4-9.

Table II-4-9 Minimum and Maximum Demand on July 14, 2010

Property	Power Plant	**Minimum**	**Maximum**		
		01:30	**20:00**		
		MW	MW	Total MW	%
PLN	PLTD Poka	2.5	4.4	16.0	45%
	PLTD Hative Kecil	2.0	11.6		
Rental	PLTD Sewatama	3.4	4.6	19.9	55%
	Aggreco	8.5	10.2		
	Sewatama 2	4.1	5.1		
Total		20.5	**35.9**	**35.9**	100%

(Source: PLN Wilayah Maluku dan Maluku Utara)



(Source; PLN Wilayah Maluku dan Maluku Utara)

Fig. II-4-3 Power Demand for one day (July 14, 2010)

According to PLN Wilayah Maluku dan Maluku Utara Statistik 2009, there are 770 customers awaiting service amounting to 7,606 kVA. Furthermore, hotels, restaurants and other shops in Ambon city have their own generators in order to supply power during the frequent shutdowns of the System. These facts indicate that there is a large hidden potential demand in the system.

Table II-4-10 shows a list of the generating units in the Ambon system. In the Ambon system, there are two power plants, i.e., Poka and Hative Kecil power plants. While the total installed capacity of two plants is 55,072 kW, their dependable capacity is only 24,800 kW, as shown in Table II-4-10. For Poka power plant, the dependable capacity in 2008 was 19,100 kW against a 33,600 kW installed capacity. It decreased in 2009 to only 9,500 kW of the same installed capacity. Thus, the shortfall of supply has been made up with rental generators.

Table II-4-11 shows data for Poka diesel power plant in January to July, 2010. Whereas it was 9,900 kW in January, the dependable capacity of the plant was only 4,600 kW in July. Consequently, generation by PLN generators decreased from 4,441 MWh in January to 1,617 MWh in July, and that by rental generators increased excessively from 3,433 MWh in January to 12,258 MWh in July as shown in Table II-4-11 and Fig. II-4-4.

Table II-4-10 Generating Units in the Ambon System (as of August 10, 2009)

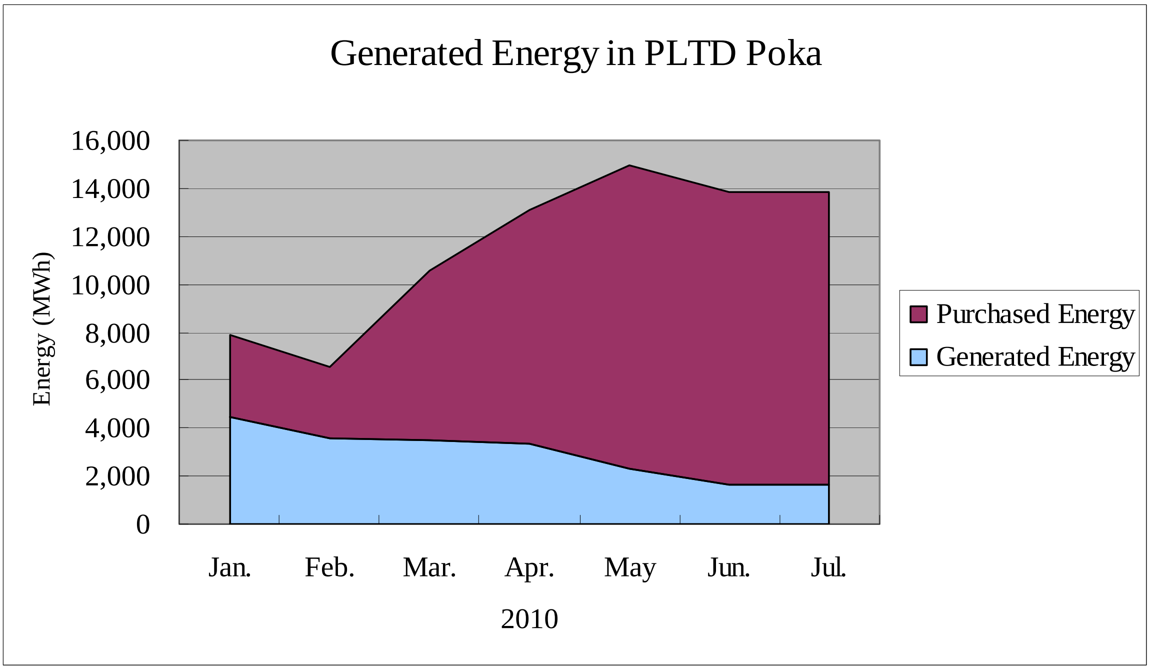
Power Plant	No.	Manufact-urer	Model	Year	Capacity (kW)		Remarks
					Rating	Depend-able	
Poka	1	GMT	A420-14	1988	6,400	4,500	
	2	GMT		1988	6,400	-	Damaged Crank shaft
	3	GMT		1988	6,400	4,000	
	4	Caterpillar	3616	2003	4,700	-	Damaged Crank shaft
	5	Caterpillar		2003	4,700	-	
	6	ABC	12V DZC-100-166A	2005	2,500	1,000	De-rating
	7	ABC		2005	2,500	-	
				Poka Total	33,600	**9,500**	
Hative Kecil	1	SWD	6TM 410RR	1978	2,296	1,800	De-rating
	2	SWD		1978	2,296	1,800	Ditto
	3	SWD		1983	3,280	2,200	Ditto
	4	SWD	12TM 410RR	1986	6,560	5,000	Ditto
	5	SWD		1991	7,040	4,500	Ditto
				Hative Kecil Total	21,472	15,300	
				PLN Ambon Total	**55,072**	**24,800**	
Rental Genset		CAT				5,750	5 units
		Cummins				10,200	12 units
		CAT				5,750	5 units
				Rental Genset Total		21,700	
					Ambon System Total	**46,500**	

(Source; PLN Wilayah Maluku dan Maluku Utara)

Table II-4-11 Data of Poka Diesel Power Plant from January to July in 2010

Description	Unit	Equation	2010						
			Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.
Installed Capacity	(MW)	A	33.6	33.6	33.6	33.6	33.6	33.6	33.6
Dependable Cap.	(MW)	B	9.9	6.4	8.1	7.5	7.5	4.6	**4.6**
Peak Generation	(MW)	C	9.8	6.4	7.8	7.3	6.6	4.1	4.4
Energy	(MWh)	D	**4,441**	3,565	3,473	3,337	2,272	1,615	**1,617**
House Energy	(MWh)	E	223	235	230	211	149	111	110
House Ratio*	%	E'=E/D	5.0%	6.6%	6.6%	6.3%	6.6%	6.9%	6.8%
Average Output*	(MW)	F=D/(24*days)	5.97	5.31	4.67	4.64	3.05	2.24	2.17
Load Factor*	%	G=F/C	60.9%	82.9%	59.9%	63.5%	46.3%	54.7%	49.4%
Purchased Energy	(MWh)	H	**3,433**	2,975	7,092	9,796	12,649	12,216	**12,258**
Delivered Energy	(MWh)	I=D-E+H	**7,651**	6,305	10,335	12,921	14,772	13,720	**13,765**
Fuel for Engine (HSD)	(LTR)	J	1,420	1,128	1,088	1,039	701	486	487
HSD Unit Price	(Rp/LTR)	M	6,091				6,123	6,123	6,123
LO for Engine	(LTR)	P	22,781	12,228	22,573	17,556	18,601	13,585	10,450
LO for Others	(LTR)	Q	-	1,672	-	-	836	209	-
Specific Fuel Consumption (SFC)	(LTR/MWh)	R=J/D	0.3197	0.3162	0.3134	0.3113	0.3084	0.3009	0.3012
Rp. per MWh	(Rp/MWh)	R'=R*M	1,947.2				1,888.1	1,842.3	1,844.3
Specific LO Consumption	(cc/kWh)	S=P/J	5.1296	3.4294	6.4989	5.2605	8.1859	8.4113	6.4643
Fuel for Rental Unit (HSD)	(LTR)	T	900	787	1,863	2,493	3,229	3,116	3,203
Total SFC	(LTR/MWh)	U=(J+T)/I	0.2946	0.2928	0.2793	0.2690	0.2634	0.2604	0.2660
Rp. per MWh	(Rp/MWh)	U'=U*M	1,795				1,612	1,595	1,628

(Source; Poka Diesel Power Plant)



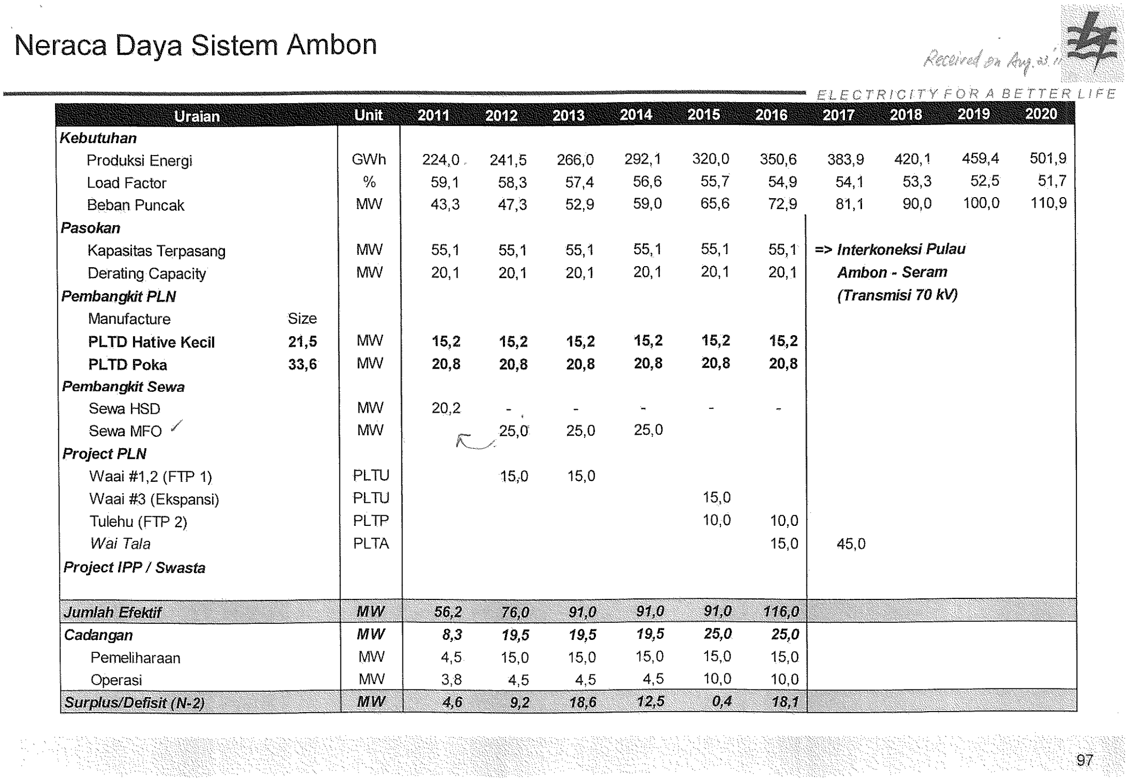
(Source; Poka Diesel Power Plant)

Fig. II-4-4 PLN-Generated Energy and Purchased Energy in 2010

II.4.4 Demand Projection

Based on information supplied by PLN Wilayah Maluku dan Maluku Utara, the latest demand projection from 2011 to 2020 in the Ambon system is shown in Table II-4-12. As shown in Table II-4-12, the peak demand in 2011 is 43.3 MW in the Ambon system and it is expected that the peak demand of the system will be 72.9 MW by 2016, given an average growth rate of 11% per year driven by steady economic growth in the area and improvements in rural electrification. In 2017, the Ambon system will be interconnected with the Seram system. The interconnection will result in further demand in the whole system.

Table II-4-12 Demand and Supply Projection in the Ambon System (2011 - 2020)



Neraca Daya Sistem Ambon

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Uraian		Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Kebutuhan												
Produksi Energi		GWh	224,0	241,5	266,0	292,1	320,0	350,6	383,9	420,1	459,4	501,9
Load Factor		%	59,1	58,3	57,4	56,6	55,7	54,9	54,1	53,3	52,5	51,7
Beban Puncak		MW	43,3	47,3	52,9	59,0	65,6	72,9	81,1	90,0	100,0	110,9
Pasokan												
Kapasitas Terpasang		MW	55,1	55,1	55,1	55,1	55,1	55,1	***=> Interkoneksi Pulau***			
Derating Capacity		MW	20,1	20,1	20,1	20,1	20,1	20,1	***Ambon - Seram***			
Pembangkit PLN									***(Transmisi 70 kV)***			
Manufacture	Size											
PLTD Hative Kecil	**21,5**	MW	**15,2**	**15,2**	**15,2**	**15,2**	**15,2**	**15,2**				
PLTD Poka	**33,6**	MW	**20,8**	**20,8**	**20,8**	**20,8**	**20,8**	**20,8**				
Pembangkit Sewa												
Sewa HSD		MW	20,2	-	-	-	-	-				
Sewa MFO ✓		MW		25,0	25,0	25,0						
Project PLN												
Waai #1,2 (FTP 1)		PLTU		15,0	15,0							
Waai #3 (Ekspansi)		PLTU					15,0					
Tulehu (FTP 2)		PLTP					10,0	10,0				
Wai Tala		PLTA						15,0	45,0			
Project IPP / Swasta												
Jumlah Efektif		***MW***	***56,2***	***76,0***	***91,0***	***91,0***	***91,0***	***116,0***				
Cadangan		***MW***	***8,3***	***19,5***	***19,5***	***19,5***	***25,0***	***25,0***				
Pemeliharaan		MW	4,5	15,0	15,0	15,0	15,0	15,0				
Operasi		MW	3,8	4,5	4,5	4,5	10,0	10,0				
Surplus/Defisit (N-2)		***MW***	***4,6***	***9,2***	***18,6***	***12,5***	***0,4***	***18,1***				

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(Source: PT. PLN)

The electrical power in the system is supplied solely by diesel engine generators, which have higher generation costs and emit a lot of greenhouse gases. Furthermore, they are seriously derated, i.e., the dependable capacity in Ambon system is only 25 MW as of August 2010 (see Table II-4-10), while the installed capacity is 55 MW. Thus, rental diesel generators are used to mitigate power shortages. In addition to the power shortages, the necessity of reducing fossil fuel consumption and limiting greenhouse gas emissions makes imperative the immediate development of renewable sources of energy.

According to Table II-4-12, rental MFO generators will be retired in 2014, and after that, power will be supplied by the Waai coal-fired power plant (2 x 15 MW), Tulehu geothermal power plant (20 MW) and other plants. Tulehu geothermal power plant, however, cannot enter commercial operation until 2016 at the earliest, given the standard process for contract bidding, a standard construction period etc. Accordingly, the table requires revision before it can be used as a standard schedule. Table II-4-13 and Fig. II-4-5 show the demand projection, taking into consideration the commencement of operation of Tulehu geothermal power plant in 2016. As shown in the table and figure, additional power will be necessary due to power shortages in 2015.

Since the Ambon system is expected to increase at an average, steady growth rate of 11% per year (72.9 MW in 2016, 110.9 MW in 2019 plus Seram demand), a unit size from 10 MW to 20 MW is probably most suitable for the System.

Table II-4-14 Revised Demand and Supply Projection for Ambon System (2011- 2020)

(Standard Schedule version)

System		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Demand											
Production	GWh	224.0	241.5	266.0	292.1	320.0	350.6	383.9	420.1	459.4	501.9
Load Factor	%	59.1	58.3	57.4	56.6	55.7	54.9	54.1	53.3	52.5	51.7
Peak Load	**MW**	**43.3**	**47.3**	**52.9**	**59.0**	**65.6**	**72.9**	**81.1**	**90.0**	**100.0**	**110.9**
Supply								Interconnection between Ambon system and Seram system.			
Installed Capacity	MW	55.1	55.1	55.1	55.1	55.1	55.1				
Derating Capacity	MW	-20.1	-20.1	-20.1	-20.1	-20.1	-20.1				
PLN Generation											
Hative Kecil 21.5 MW	PLTD	15.2	15.2	15.2	15.2	15.2	15.2				
Poka 33.6 MW	PLTD	20.8	20.8	20.8	20.8	20.8	20.8				
Rental Facility											
Rental HSD	MW	20.2	0	0	0	0	0				
Rental MFO	MW	**25.0*	25.0	25.0	25.0	0	0	* Rental MFO will be in operation one (1) year ahead of their original schedule.			
PLN Projects											
Waai #1,2 (**FTP1)	PLTU		15.0	15.0				** FTP; Fast Track Program			
Waai #3 (Expansion)	PLTU					15.0					
Tulehu (FTP2)**	**PLTP**						**20.0**				
Wai Tala	PLTA						15.0	45.0			
IPP Project											
Total Supply	**MW**	**81.2**	**76.0**	**91.0**	**91.0**	**81.0**	**116.0**				
Existing Maintenance	MW	-8.3	-19.5	-19.5	-19.5	-25.0	-25.0				
Reserve	**MW**	**29.6**	**9.2**	**18.6**	**12.5**	**-9.6**	**18.1**				

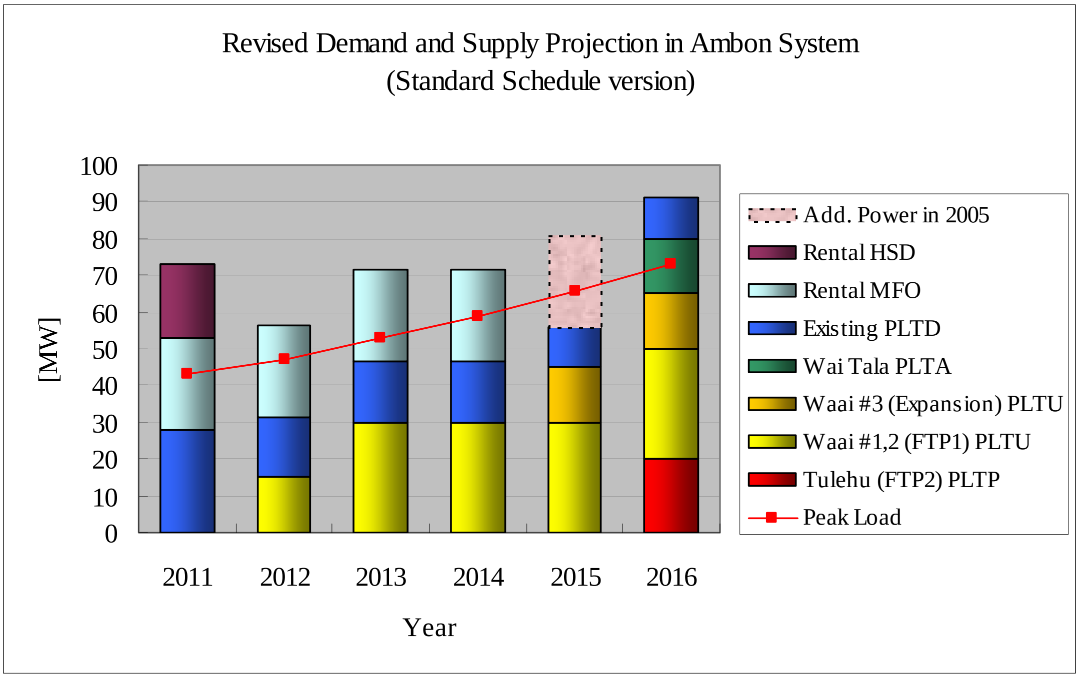


Fig. II-4-5 Revised Demand and Supply Projection for Ambon System

(Standard Schedule version)

CHAPTER III

III GEOTHERMAL RESOURCES IN TULEHU FIELD

The first work in Indonesia to check the conditions of the Tulehu geothermal field and to collect existing data about the geothermal resource was conducted in August 2010. The geothermal resource has been studied using collected data and referring to previous study reports on the Tulehu field. An MT survey was conducted in parallel with the study of existing geoscientific data for clarification of the geothermal structure. The results of the MT survey were compiled with existing data and an integrated interpretation was carried out to reveal the reservoir structure and potential. The resource potential was evaluated and a program of resource development was proposed on the basis of geothermal reservoir model devised during the integrated interpretation. The results of the studies conducted so far are summarized in this chapter.

III.1 Geothermal Resources in Maluku Province

Indonesia is situated on plate boundaries between the Indian-Australian Plate and the Eurasian Plate, and between the Eurasian Plate and the Philippine Sea Plate (see Fig. III-1-1). A typical island-arc system, characterized by a trench (or trough) and a Quaternary volcanic belt, is identified in Indonesia. There are many geothermal fields with considerable potential in and around the volcanic belts (see Fig. III-1-2).

In Maluku Province, the following nine (9) geothermal fields on five (5) islands have been nominated by MEMR (2007), though no Quaternary volcano is identified in these islands (the nearest Quaternary volcano is Banda Api volcano situated about 85 km southeast of Nusalaut Island).

> Kepala Madan (Buru Island), Wapsalit-Waeapo (Buru Island), Batabual (Buru Island), Larike (Ambon Island), Taweri (Ambon Island), Tulehu (Ambon Island), Oma Haruku (Haruku Island), Saparua (Saparua Island), and Nusalaut (Nusalaut Island).

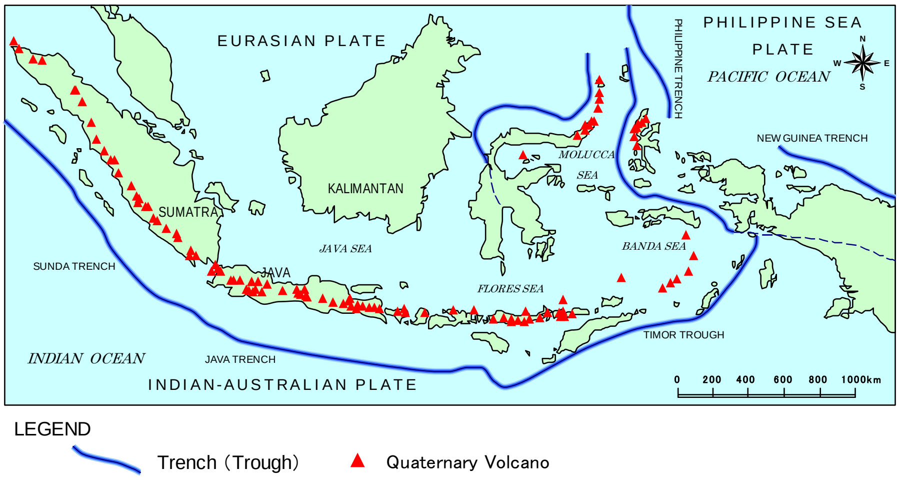


Fig. III-1-1 Distribution of Quaternary Volcanoes in Indonesia

(Source : MEMR (2007))

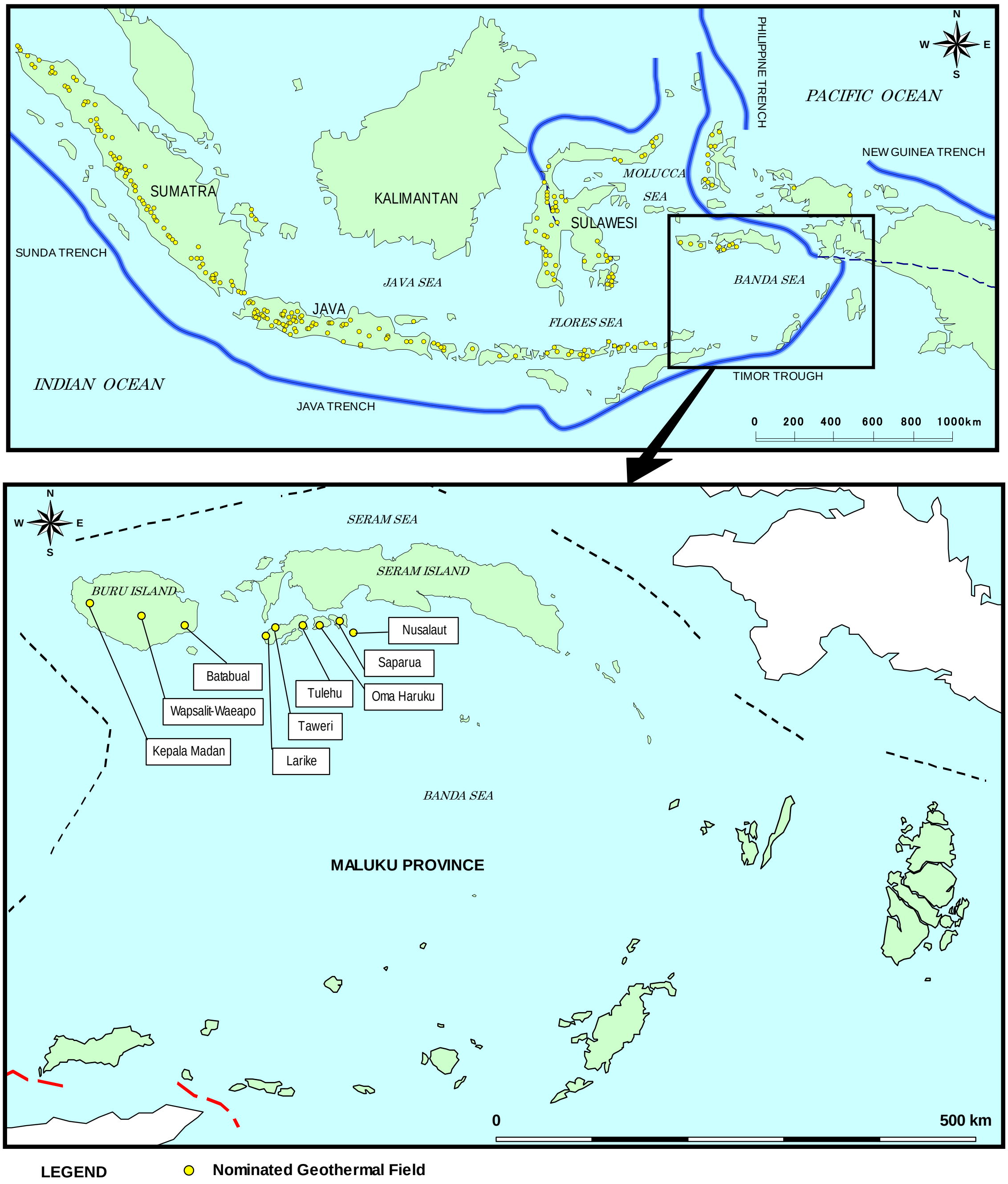


Fig. III-1-2 Geothermal Fields Nominated by MEMR (2007)

III.2 Review of Existing Data and Information about Geothermal Resources

III.2.1 Current Status of Drilling Operations in Tulehu

In the Tulehu geothermal field, six (6) thermal gradient holes have been drilled (see Fig. III-2-1). In 2008, three (3) thermal holes were drilled (TG-1, TG-2 and TG-3). Well TG-1 was drilled near an alteration zone (Banda alteration zone) and its drilled depth is 40 m. Well TG-2 was drilled near the sea, in Suli Bawah, and its drilled depth is 120 m. Well TG-3 was drilled near Hatuasa hot spa and its drilled depth is 40 m. The following borehole bottom temperatures were recorded, TG-1 = 41^{o}C (40 m deep), TG-2 = 36^{o}C (120 m deep), and TG-3 = 31^{o}C (40 m deep). The highest temperature was recorded in TG-1.

In 2009, three (3) thermal holes were drilled (W2.1, W2.2 and W2.3) and their drilled depths are all 150 m. Well W2.1 was drilled near well TG-1 and a borehole bottom temperature of 122.6^{o}C was recorded. Well W2.2 was drilled at the southeastern foot of Mt. Salahutu and a borehole bottom temperature of 32.4^{o}C was recorded. Well W2.3 was drilled at the northeastern foot of Mt. Terang Alam (Mt. Huwe) and a borehole bottom temperature of 27.5^{o}C was recorded.

A drilling site for an exploratory well was chosen near well W2.1, and one (1) exploratory well (TLU-01, with a planned drilling depth of 1200 m) was drilled from December 2010. On 18 February 2011, this well reached a depth of 911 m, but the drilling string became stuck while reaming. Although work to release the drilling string was vigorously attempted, this well was finally side-tracked, from a depth of 521.09 m, toward the east-southeast. The well reached a depth of 932.65 m on 28 June 2011, and on 1 July 2011 7” liner casing was set from a depth of 468 m to a depth of 923 m (from 535 m to 923 m, using perforated liner). After that, a completion test (comprising pressure and temperature logging, injection testing, heating-up testing, and so on) was carried out until 8 July 2011.

Fig. III-2-1 Location of Existing Wells and Drilling Site for Exploratory Well

(Source: PLN Geothermal)

III.2.2 Exploration Data and Information

1. Existing Geological Data

The geology of Ambon Island is mainly characterized by Permian ultrabasic rocks, Triassic sedimentary rocks, Pliocene volcanic rocks (composed of andesite, dacite, tuff breccia, tuff and so on), Pliocene intrusive rocks (granite and diabase), Pleistocene to Holocene coral limestone, and alluvium deposits. The Pliocene volcanic rocks are dominant and cover about 90 % of Ambon Island. On the whole, faults trending northeast and northwest are dominant.

a. Surface geology

In the Tulehu geothermal field, the surface geology consists of the following thirteen (13) units: the Sandstone unit, the Tanjung basalt lava unit, the Salahutu-1 dacitic lava unit, the Salahutu-2 dacitic lava, the Bukitbakar andesite lava unit, the Bukitbakar pyroclastic unit, the Huwe pyroclastic unit, the Mt. Simalopu pyroclastic unit, the Mt. Salahutu pyroclastic unit, the Mt. Kadera pyroclastic unit, the Mt. Eriwakang pyroclastic unit, the Limestone unit and alluvium deposits, in order from older to younger (see Fig.III-2-2).

Sandstone Unit (Tss)

This unit crops out along the Wamina River and consist of fine-grained to coarse-grained sandstone. This unit is covered by the Simalopu pyroclastic unit, though the boundary between them cannot be observed. The age of this unit is estimated to be early Miocene.

Tanjung Basalt Lava Unit (Tbb)

This unit crops out along the coast from Batu Luda hot spring, through Hukahera, to Tengah-Tengah. Rocks are intensively weathered. The lower part of this unit consists of massive lava, while the upper part consists of brecciated andesitic, basaltic and dacitic lava, in cobble to boulder size. The age of this unit is estimated to be late Miocene to early Pliocene.

Salahutu-1 Dacitic Lava Unit (Tab)

This unit crops out along the Yari River, on the northwestern side of Suli Atas. This unit contains beds of andesitic and dacitic volcanic breccia (1 to 15 cm in diameter). This unit is estimated to be younger than the Tanjung basalt lava unit.

Salahutu-2 Dacitic Lava Unit (Tal)

This unit crops out on northwestern side of Waai, and is also identified along upstream valleys of the Yari River and Wamina River. This unit consists of dacite lava flow and its age is estimated to be early to middle Pliocene.

Bukitbakar Andesite Lava Unit (Tap)

This unit crops out on southwestern margin of the Tulehu field. Block andesite, dacite and diorite are dominant. The age of this unit is estimated to be early to middle Pliocene.

Bukitbakar Pyroclastic Unit (Ttp)

This unit crops out on the southwestern side of the Yari River and consists of various volcanic products. The age of this unit is estimated to be middle to late Pliocene.

Huwe Pyroclastic Unit (Ttp)

This unit crops out around the summit of Mt. Terang Alam (Mt. Huwe) to Oang and on the coast in Tengah-Tengah village. This unit covers the Tanjung basaltic lava unit and is unconformably covered by the Limestone unit. The age of this unit is estimated to be late Pliocene.

Mt. Simalopu Pyroclastic Unit (Tts)

This unit crops out on the northeastern side of the Yari River and its thickness is estimated to be about 650 m. Constituent pyroclastics become more fine-grained towards the upper stratigraphic horizon.

Mt. Salahutu Pyroclastic Unit (Tfs)

This unit crops out extensively in the central and northern parts of this field. This unit is regarded as the last eruption product of Salahutu volcano. On surface exposure, the rocks are usually argillized by weathering. This unit is regarded as younger than the Mt. Simalopu pyroclastic unit.

Mt. Kadera Pyroclastic Unit (Tkv)

This unit crops out around Mt. Kadera and consists of volcanic ash and fine-grained sand. This unit covers the Mt. Salahutu Pyroclastic Unit and is older than the Mt. Eriwakang Pyroclastic Unit. The age of this unit is estimated to be middle to late Pliocene.

Mt. Eriwakang Pyroclastic Unit (Tte)

This unit crops out around the summit of Mt. Eriwakang and around Suli Atas. This pyroclastic unit contains shell fossils. The age of this unit is estimated to be middle to late Pliocene.

Limestone Unit (Ql)

This unit crops out mainly in the southeastern part of the field. This unit is coral limestone of Pleistocene to Holocene age and consists of coral colonies and shells. This unit rests unconformably upon the following volcanic rocks.

Alluvium Deposits (Qa)

This unit occurs around Wairutung, Pumala and Mamocong on the eastern coastal part of the field and also around Natusepa around the mouth of the Yari River. This unit consists of clay and gravel.

b. Geological Structure

The following eight (8) faults are estimated in the Tulehu field (see Fig. III-2-2). The Wairutung fault, trending northeast to southwest, is a normal fault dipping southeast (the southeastern side of this fault has subsided against the opposite side). Most of the formations cropping out in this field are intersected by this fault. There is also the Huwe fault trending northeast to southwest between Mt. Eriwakang and Mt. Terang Alam (Mt. Huwe). This fault is a normal fault dipping northwest (the northwestern side of this fault has subsided against the opposite side) and intersects the Limestone unit. There is a depression zone between these two faults. In this depression zone, the Banda-Hatuasa fault and the Banda fault trend northeast to southwest. These two faults are also normal faults dipping northwest.

The Waiyari fault, trending northwest to southeast, lies along the Yari River. This fault is a right-lateral fault. On the eastern side of Mt. Salahutu, there is the Salahutu fault, trending northwest to southeast. This fault is also a right-lateral fault. Along the coast (from Mamokeng to Tanjung), there is the Tulehu fault, trending northwest to southeast,. This fault is a normal fault dipping northeast. And finally, there is the Kadera fault on the southern side of Mt. Salahutu. This fault trends west to east, though its eastern part trends northeast to southwest. The Kadera fault is a normal fault dipping south.

c. Geothermal Manifestations and Altered Ground

Geothermal manifestations in the Tulehu field can be classified into two groups by their location: hot springs around Mt. Terang Alam and hot springs around Mt. Eriwakang. There are hot springs along the coast at the northern foot of Mt. Terang Alam, namely Batu Lompa hot springs and Batu Luda hot spring. These hot springs occur around point of intersection of the Huwe fault with the southeastern extent of the Tulehu fault. Their discharge temperatures are about 40^{o}C to 70^{o}C.

Around Mt. Eriwakang, hot springs align along the Banda fault and the Banda-Hatuasan fault (see Fig. III-2-2). Around the intersection of the Banda fault with the Tulehu fault, in Mamokeng, some hot springs are identified on the beach and in the sea. Their discharge temperatures are about 40^{o}C. The Telaga Biru hot springs and Sila hot springs are found at the northern foot of Mt. Eriwakang, along the Banda fault. The discharge temperatures of the hot springs in Telaga Biru are 35^{o}C to 48^{o}C, while those of the hot springs in Sila are 38^{o}C to 80^{o}C. At the side of the Yari River, Hatuing hot spring is found along the Banda fault. The discharge temperature of this hot spring is 49^{o}C.

Hatuasa hot spa is located along the Banda-Hatuasa fault, with a discharge temperature of 56^{o}C to 60^{o}C. The Banda alteration zone occurs along the Banda-Hatuasa fault. Identified secondary minerals are quartz, montmorillonite, kaolinite, illite, alunite, gypsum and so on.

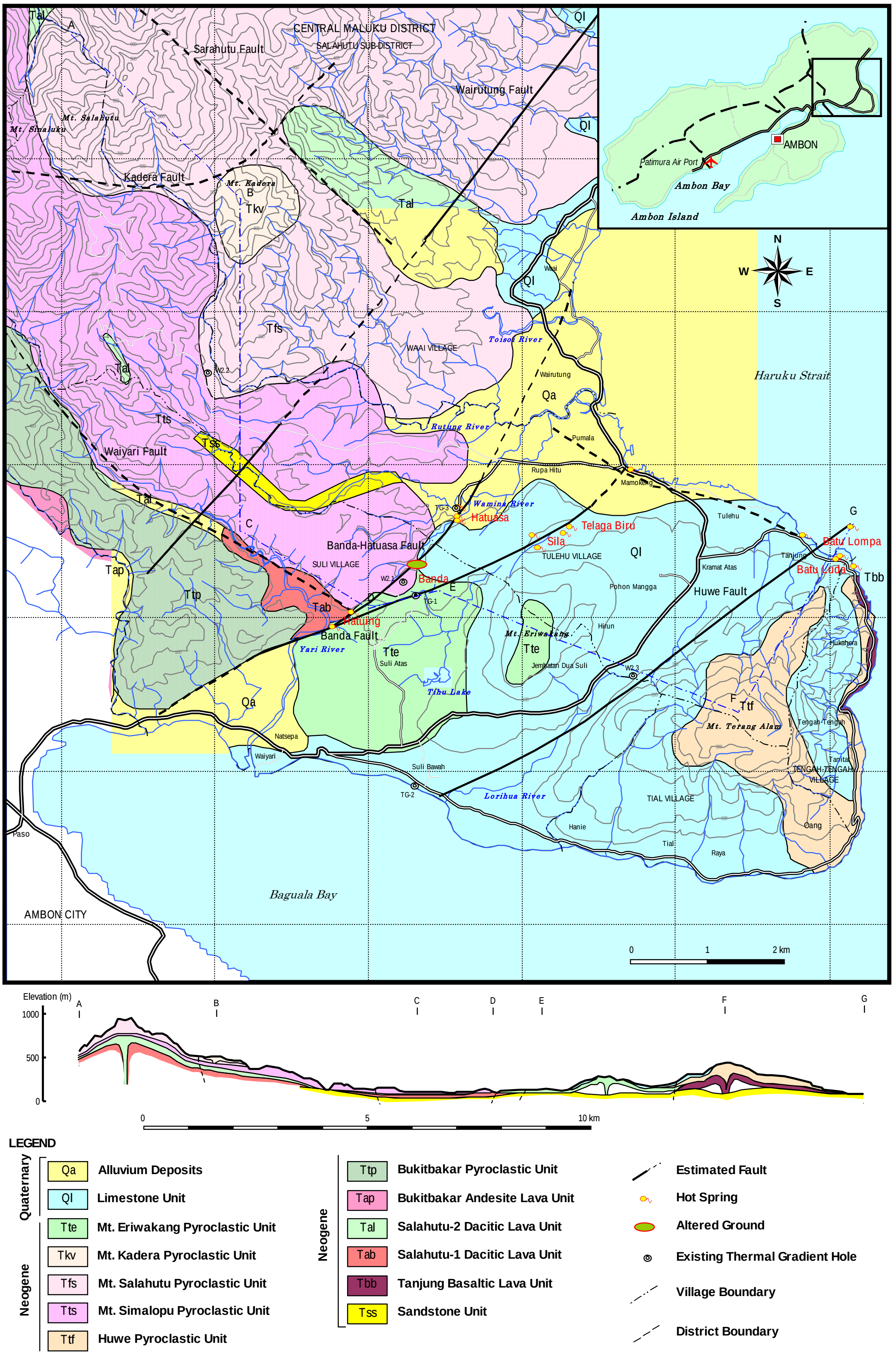


Fig. III-2-2 Geological Map of Tulehu

(Source: PLN Geothermal)

2. Existing Geophysical Exploration Data

a. Gravity Survey

In the Tulehu field, a gravity survey was carried out using a La Coste & Romberg type G-928 gravimeter over an area of 25 km^2 (PLN, 2008). There were 247 gravity stations, and the spacing among the stations ranged from 300 m to 600 m. Generally, the mapping of Bouger anomaly distribution reflects a difference in the density of subsurface materials that elucidates such things as the distribution of basement rocks, intrusive rocks, grabens, geological formation boundaries and faults. A lateral Bouger anomaly variation indicates a gravity lineament, and a gravity lineament can often be correlated with a fault. The Bouger anomaly map of the Tulehu geothermal prospect is shown in Fig. III-2-3. In this map, local high-gravity and local low-gravity are marked with “H” and “L”, respectively, and a gravity lineament is represented as a broken line.

Five gravity lineaments, GL1 to GL5, are estimated. The Bouger anomaly values range from 85 mgal to 106 mgal and a low-gravity anomaly zone extends in the northeastern part of the survey area. A high-gravity anomaly zone is identified in the southwestern part of the survey area, with the gravity lineament GL1 as its northeastern limit. Between gravity lineaments GL3 and GL4, a local high-gravity anomaly zone extends northeast and a low- gravity anomaly zone extends on the northwestern side of gravity lineament GL3.

Gravity lineament GL1 is situated on the southeastern extension of the Waiyari fault, and they have the same trend. Gravity lineament GL2 is considered to reflect the formation boundary between the alluvium deposit and the Limestone unit, considering their distribution. Gravity lineament GL3 is considered to be the Huwe fault, given their locations. It is considered that gravity lineaments GL4 and GL5 indicate unidentified subsurface structures, though their precise nature is still uncertain.

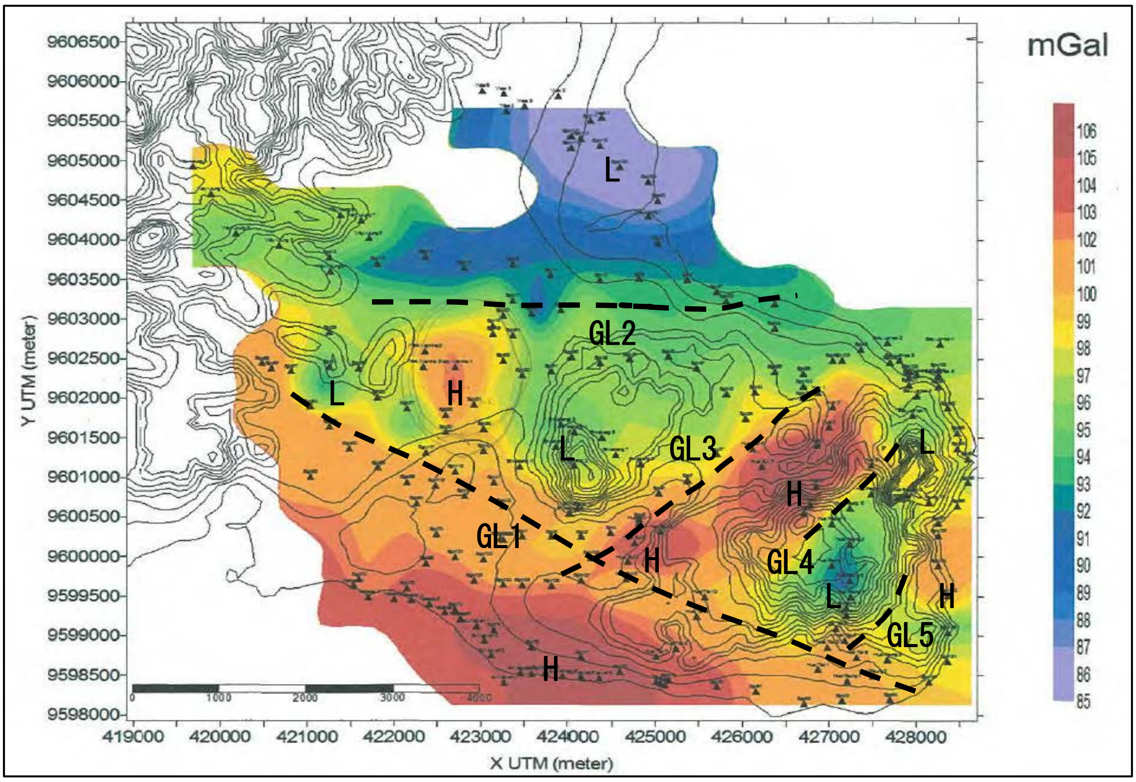


Fig. III-2-3 Bouger Anomaly Map of Tulehu Geothermal Prospect
(Pre-FS report by PLN Geothermal, February 2010)

b. Magnetic Surveying

The magnetic survey was carried out using a Geometrics type G-528 magnetometer over a 25 km^2 area of Tulehu geothermal prospect (PLN, 2008). 247 magnetic stations were deployed at the same locations as the gravity stations. A magnetic survey makes it possible to estimate the subsurface structure and the depths of Curie points from differences in magnetic intensity. Magnetotelluric surveying (electromagnetic surveying) and gravity surveying are mainly used for geothermal exploration these days, with magnetic surveying conducted just as a supplement to gravity surveying. An IGRF residual map is shown in Fig.III-2-4. IGRF residual values are calculated by subtracting the IGRF（International Geomagnetic Reference Field）value from the total magnetic intensity value of each magnetic station.

IGRF residual values are in a range from -600nT to 450nT in the survey area and show a positive anomaly in the north part of the survey area and a negative anomaly in its southern part. Areas showing rapidly changing IGRF residual values in the map may indicate a discontinuity of distribution of magnetic materials, but these have no relevance to faults and formation boundaries in the survey area. The distribution of geothermal manifestations such as hot springs is concentrated in locations that are part of the positive anomaly. Generally, a weak magnetic anomaly is observed in the altered ground in and around the geothermal manifestations. A magnetic anomaly is not detected above the magnetic materials in the survey area, because Tulehu geothermal prospect is located in the lower latitudes. The reduction-to-the-pole filter can be applied to detect the magnetic anomaly above the magnetic material, but no filtered map could be seen in the obtained reports. A low-resistivity anomaly delineated by magnetotelluric surveying indicates the presence of an altered zone. Generation of a reduction-to-the-pole map from existing magnetic data is not necessary, because the magnetotelluric surveying which is part of this preparatory survey, can detect the altered zone more clearly than a magnetic survey.

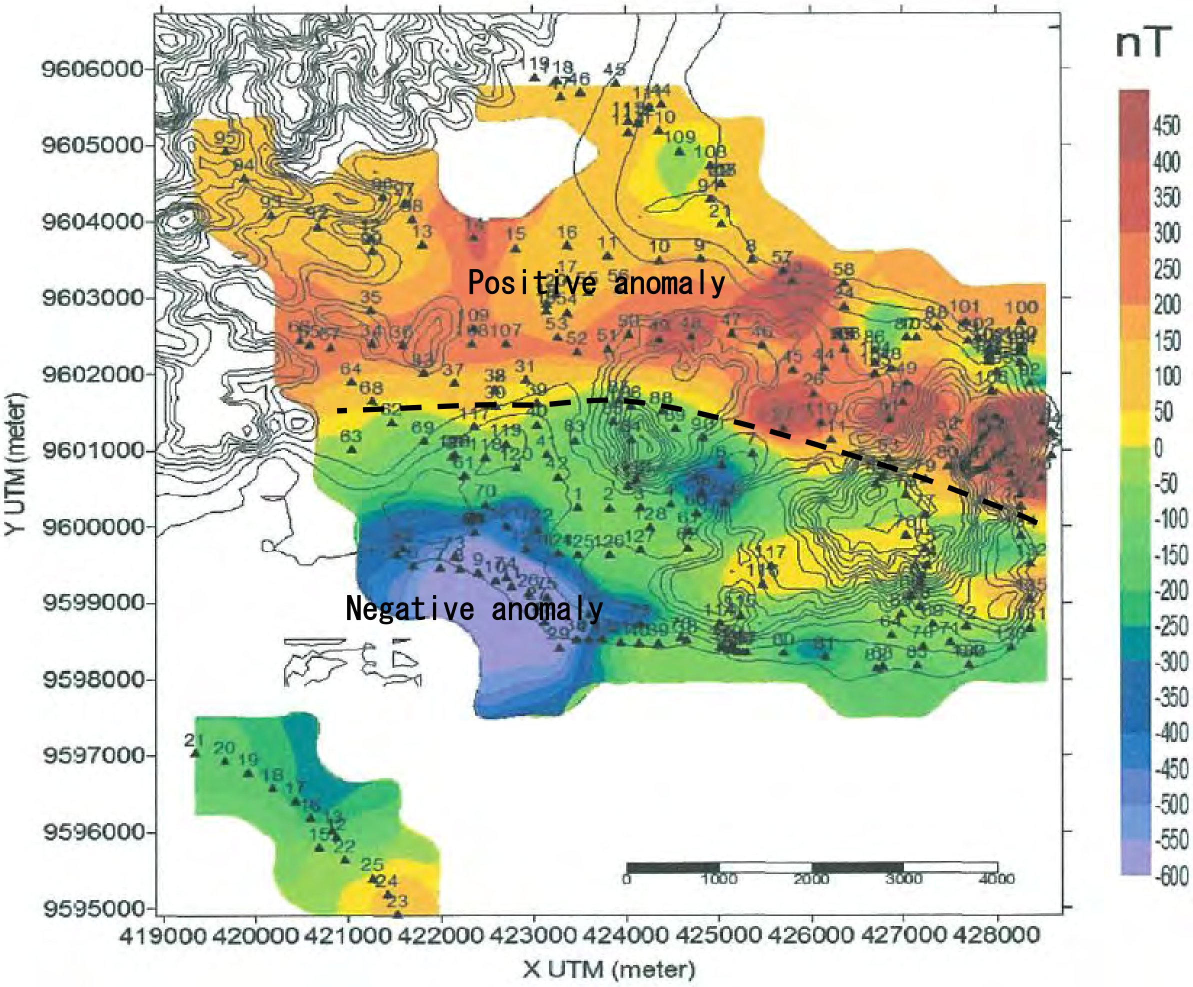


Fig. III-2-4 IGRF Residual Map of Tulehu Geothermal Prospect
(Pre-FS report by PLN Geothermal, February 2010)

c. CSAMT Survey

A Controlled Source Audio-frequency Magneto-Telluric (CSAMT) exploration with approximately 130 sites was conducted in the Tulehu area (PLN, 2008). The locations of the CSAMT sites are depicted in Fig. III-2-5. Many inverted sections that exceeded more than 30 slices are shown in the report. An example of such an inverted resistivity section is shown in Fig. III-2-6.

The general features of the resistivity structure of a geothermal reservoir are characterized by a resistivity distribution with relatively high-resistivity zones overlain by very conductive bodies. The conductive bodies correspond to cap rock, and the relatively resistive zones correspond to the main body of high pressure/temperature reservoir. In the inverted sections shown in the report (PLN, 2008), one can distinguish such typical resistivity distributions that may indicate the extent of the geothermal reservoir in Tulehu area. The site layout shown in Fig III-2-5, however, contains flaws that arouse suspicion about the reliability of CSAMT data analysis. Also, the mesh settings of inverted sections are clearly flawed.

The site layout contains two problems. Firstly, the distances between transmitters and observation sites are too close. Secondly, the layout tells us that two transmitters were utilized, implying that tensor measurements have been conducted at each observation site.

In CSAMT surveying, the distance between observation sites and transmitters should be sufficiently large that the distances exceed 3 times the maximum depth of investigation, in order to avoid the so-called Near Field Effect. The site layout shows that the distances were too close, and some of the sites are located just above the transmitting wire. In such a case, most of the data would be contaminated by the near field effect, and quantitative analysis would be impossible. Although some techniques for correcting the near field effect have been proposed, none of them is able to remove the effect completely. Besides, the fact that two transmitters might have been employed makes the situation more complicated. It implies that tensor measurements might have been done at each site. In this case, the intensity of the near field effect differs along with the direction, and site by site. Thus, it would be more difficult to correct the near field effect. The near field effect must be inevitable, given the site layout shown in Fig. III-2-5, and must actually be nearly impossible to correct for. Thus, it was doubtful whether the acquired CSAMT data were sufficiently reliable to conduct inversion analysis.

For the mesh settings of the inverted resistivity sections, the thickness of the meshes was clearly too thick. In general, the depth of investigation of an CSAMT survey is inevitably limited to less than 1km due to the near field effect. All the inverted sections show that the thickness of the inversion meshes was about 4km. This arouses suspicions about the reliability of the inversion process. Some portions of the resistivity section, where the distances from the transmitter are sufficient, can be informative. However, the transmitters were installed too close to the drilling point of the exploratory well.

Thus it was concluded that the CSAMT resistivity sections should be excluded from the integrated interpretation of the geothermal structure of Tulehu area.

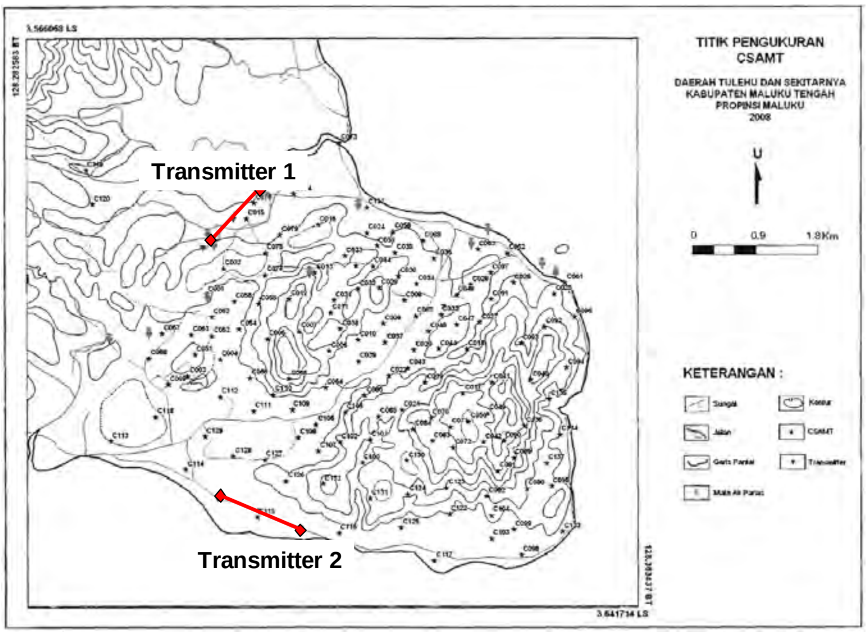


Fig. III-2-5 Site Layout of the CSAMT Survey

(Pre-FS report by PLN Geothermal, February 2010)

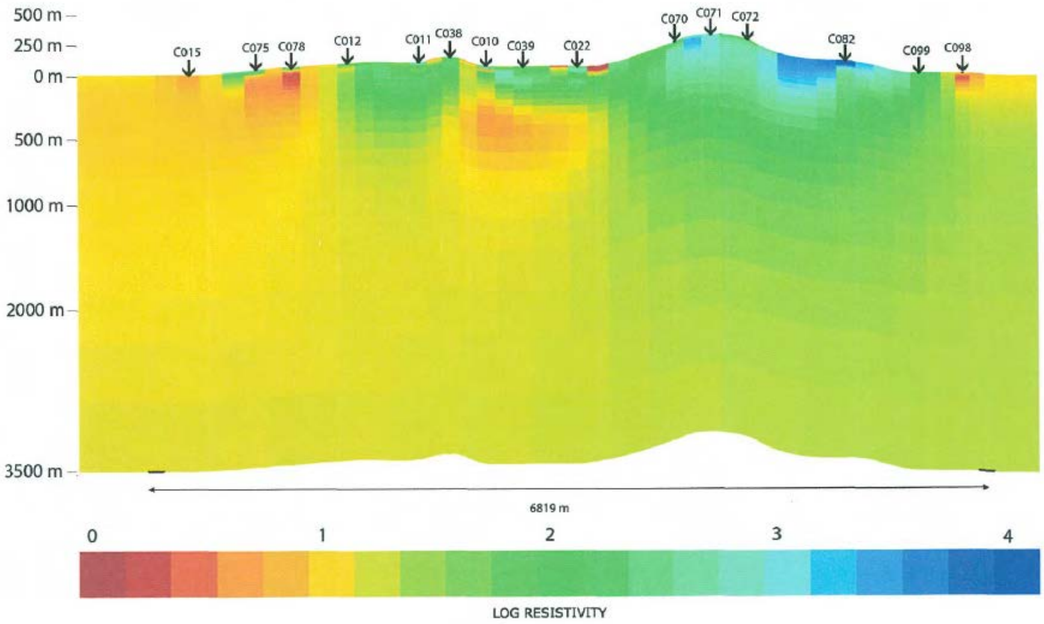


Fig. III-2-6 An example of an Inverted Resistivity Section from the CSAMT Survey

(Pre-FS report by PLN Geothermal, February 2010)

3. Geochemical Data

a. Geothermal Gases from Fumaroles and Hot Springs

In the Pre-FS conducted by PT. PLN Geothermal (2010), chemical analysis of geothermal gases from the hot springs and the fumaroles were carried out as part of the geochemical survey. In general, the geochemical study of geothermal gases is conducted to clarify the characteristics and evaluate the potential of the geothermal resource. Another purpose of such study is to estimate the chemical characteristics of well-discharge. Data on chemical characteristics, namely the content and composition of non-condensable gas (NCG) in geothermal steam, are indispensable for designing a turbine generator for a geothermal power plant. Since a geothermal well has not been drilled in this field, data on the chemical characteristics of geothermal gases from hot springs and fumaroles will be used instead of the NCG data from well discharge testing.

In the first field survey in the Tulehu field, the question as to whether geothermal gas sampling from fumaroles or hot springs can be adequate for power plant design was checked. Unfortunately, adequate hot springs and fumaroles could not be found in the field. Therefore, the chemical characteristics of steam from the geothermal well in this field were assumed using existing chemical data on hot spring gases described in the FS report (2010).

Table III-2-1 shows the chemical data on geothermal gases from the hot springs in and around the field. The content of oxygen, which is rare in geothermal gases in general, is high, as this table shows. The content of nitrogen is also high. It is judged that these oxygen and nitrogen gases indicate that air is mixing with the geothermal gases. Hydrogen sulfide gas has not been analyzed in this field. The content of hydrogen sulfide gas in the geothermal gases in this field seems to be low, because there was no smell of hydrogen sulfide gas at hot springs in this field during the field survey, and the temperatures of the gases were reported to be relatively low. Since the gas compositions in this table were considered to be influenced by mixing with air, it seemed to be difficult to clarify the characteristics and the degree of promise of the geothermal resources using these data.

However, data on the chemical characteristics of the geothermal steam, such as the content and composition of NCG, are necessary for the conceptual design of the turbine-generator. When a geothermal well discharges steam successfully, these data can be obtained by chemical analysis of the steam discharged from the well. Since the first exploratory well in this field has not been drilled yet, the chemical characteristics of the geothermal steam from wells in this field were assumed using the chemical data on the natural gases released from hot springs shown in Table III-2-1.

Table III-2-1 Chemical Composition of Gases from Hot Springs and Fumaroles in and around Tulehu Geothermal Field

Sample No.	CO_2	O_2	N_2	Ar	CH_4	Location	
TLH-3	1.83	32.62	66.48	0.00	0.07	Close to Tulehu Beach	Tulehu
BTL-1	27.71	30.73	38.61	0.00	2.95	Batu Lompa Beach	
HTS-3	47.38	10.55	41.68	0.00	0.39	Hatuasa	
BTL-3	8.85	3.95	6.35	0.00	0.00	Batu Lompa Beach 2	
HRK-1	95.57	2.33	1.72	0.38	0.00	Haruku	Haruku
OMA	16.07	29.08	54.66	0.00	0.18	Oma	
OMA-2	96.01	0.80	2.71	0.00	0.48	Oma	

(Pre-FS report by PLN Geothermal, February 2010)

Chemical data on the geothermal gases of TLH-3 was used on the presumption that the gases of THL-3 were derived from the geothermal reservoir. Considering the air contamination of geothermal gases, TLH-3 gases show the chemical characteristics that are normally associated with geothermal fields. There is a reasonable possibility that these gas data reflect those of the reservoir fluid in this field. Since high contents of oxygen and nitrogen gases in TLH-3 gas are considered to be due to air contamination, the CO_2 content was calculated, disregarding these gas components. This gas was considered to be sampled from the hot spring of THL-3. The hot spring water of THL-3 is judged to be formed by water-rock interaction and is neutral in pH. In general, the CO_2/H_2S ratio in steam separated from geothermal water of neutral pH is comparatively large. The ratio of CO_2/H_2S in the steam is generally 10-100 in molar ratio. Furthermore, since H_2S gas has a tendency to dissolve in seawater, the H_2S content in steam from geothermal water originating from seawater is generally low. In this case, the molar ratio of these gases was assumed to be 50, because the hot spring water of THL-3 was regarded as originating from seawater. On the basis of these assumptions, the following content and composition of noncondensable gases (NCG) in the geothermal steam were calculated.

NCG(mol%)	NCG(wt%)	CO_2 (vol%)	H_2S(vol%)
0.37	0.88	98	2

It is difficult to judge if the chemical data calculated from the THL-3 data approximates the chemical characteristics of the steam from future wells in the Tulehu field, because the sampling conditions and reservoir structure are uncertain at present. The characteristics of the steam were calculated only to set working assumptions.

Limestone, which extends in and around this field, is thought to increase the CO_2 content in geothermal steam generally. If limestone is included among the rocks of the geothermal reservoir and geothermal wells tap the reservoir, the NCG content of the steam is likely to be high and must be quite different from that estimated from the THL-3 data. It is difficult to judge whether the estimated content and composition of the gases represent those of the reservoir targeted for future power development. Even if the conceptual design of the geothermal plant is carried out on the basis of these data, it will be necessary to review the design based on the measured chemical characteristics of well discharge after the completion of well-drilling and well discharge testing.

b. Hot Spring Water

In the Pre-FS conducted by PT.PLN Geothermal (2010), chemical and isotopic analyses of hot spring waters were carried out as a part of the geochemical survey. In general, the geochemical study of hot spring water is conducted to (1) detect the presence of a geothermal resource, (2) to identify the origin of the geothermal fluid, (3) to estimate the reservoir fluid temperature, (4) to estimate the reservoir extent and fluid behavior in the reservoir and (5) to predict operation trouble with scaling and corrosion.

The chemical composition and chemical type of the hot spring waters in and around this field are shown in Table III-2-2 and Fig. III-2-7. Fig. III-2-8 depicts the diagram of the hydrogen and oxygen-18 isotope ratios of the waters. Calculated geochemical temperatures are shown in Table III-2-3.

(1) Detection of Geothermal Resource Presence

As shown in Fig. III-2-7, the hot spring waters in this field were classified into Cl-type or Cl-HCO_3-type. The highest concentration of Cl ions in hot spring water was reported to be 5,730 mg/L. Geothermal water which originates from meteoric water and is formed by water-rock interaction contains less than a few thousand mg/L of Cl ions in general. It is thought that these high contents of Cl ions in the waters are caused by admixture of seawater with meteoric water.

As shown in Fig. III-2-8, the isotope data indicates clearly that some of the geothermal waters in and around this field were formed by admixture of seawater with meteoric water. However, there are hot spring waters with a relatively large oxygen-18 shift that indicates interaction of hot water with reservoir rocks under high-temperature conditions. The hot spring water at Sila shows a large oxygen-18 shift, as shown in Fig. III-2-9. Since an oxygen-18 shift occurs in a geothermal reservoir with a high temperature, there is a possibility that high-temperature geothermal fluid is present in this field. However, since an oxygen-18 shift might occur in carbonates such as limestone etc even when the temperature is low, the presence of high-temperature geothermal water cannot be judged only from these isotope data.

The Cl/B molar ratio is about 130 in the hot spring water at Sila, whose oxygen-18 shift is relatively large, though the Cl/B molar ratio of seawater is about 1200. Geothermal water with a low Cl/B ratio is regarded as having derived from seawater through water-rock interaction under high temperature conditions. Moreover, the geochemical temperatures (Na-K-Ca) shown in Table III-2-3 probably indicate that the altered hot-spring water is derived from a geothermal reservoir with a temperature higher than 200°C. From these interpretive results, it is reasonable to consider that geothermal water originating from a mixture of seawater and meteoric groundwater is found in the geothermal reservoir in this field. The quantity of fluid held in the geothermal reservoir water cannot be estimated yet and should be estimated after well-drilling and testing.

Table III-2-2 Chemical Composition of Hot Spring Waters in and around Tulehu Geothermal Field

No.	Code	SiO_2 (ppm)	Al (ppm)	Fe (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	K (ppm)	Li (ppm)	NH_3 (ppm)	Cl (ppm)	SO_4 (ppm)	HCO_3 (ppm)	H_2S (ppm)	B (ppm)	pH lab.	flow rate (l/min.)	water temp. (°C)	Location	
1	TLH-1	149.9	0	1.06	145.3	16.55	373.8	39.73	0.18	2	473.86	0	655.44	1.33	1.64	6.2	6	57	Beach behind Tuluhu Hospital	Tulehu
2	TLH-3	178.9	0	0.77	262.03	18.6	1062.1	152.8	0.79	3	1826.44	1.2	474.76	1	4.8	6.4	1.3	78	Batu Lompa Cape	
3	TLH-4	82.98	0	0.09	265.78	119.36	1961.19	148.6	0.13	0.75	3128.92	258.93	520.9	2	1.26	6.9	2.8	40	Mamokeng Beach	
4	SL-1	183.4	0	0.2	702.5	9.5	2824.64	302.6	1.2	1.36	5282.24	64.47	120.65	1.99	12.05	6.6	0.3	90	Sila	
5	SL-2	86.75	0	0	288.38	5.24	1115.52	103.7	0.52	1.41	2055.75	15.48	151.35	1.99	4.78	7.6	-	38	Sila	
6	HTS-1	163.4	0	0.05	312.6	9.39	1040.64	96.28	0.54	4.69	1811.54	25	423.78	13.39	3.46	6.4	7.5	60	River of Hatuasa	
7	HTS-2	155.5	0	0.08	299.2	8.85	997.92	91	0.51	5.63	1741.85	23.03	395.11	13.39	4.26	6.5	23.8	60	Hatuasa Hot Spring Pool	
8	HTS-3	172.8	0	0.14	288.2	9.22	966	92.06	0.53	4.69	1741.85	21.05	441.86	12.68	7.49	7.3	15	60	Hatuasa	
9	BTL	179.4	0	1.64	969	418.5	8788	715	3.47	7.81	14989.6	833.33	188.4	10.63	24.55	6.6	0.5	49	Batu Lompa Island	
10	Suli Beach	92.19	0	0	52.3	4.26	173.6	9.39	0.05	1.88	226.99	10.12	198.36	1.66	0.46	8.3	23.5	35	Suli Beach	
11	SLM-1	181.3	0	0.1	213.2	22.7	1107	89.3	0.54	1.5	1811.85	3.87	442.55	1.99	6.14	6.4	1.5	61	Hatuing	
12	SLM-2	124.5	0	1.65	492	9.15	2096	203.6	1.04	4.69	3818.82	72.62	153.94	5.32	6.9	5.9	7	70	Hatuing	
1	OMA-1	208.3	0	2.97	289	308	3436	217.4	0.3	1.56	5400.7	815.79	575.19	4.65	2.09	6.7	1.5	65	Oma	Haruku
2	OMA-2	239.4	0	0.57	64.02	4.63	768	70.24	0.48	3.5	1067.94	85.71	396.75	1.33	2.85	6.8	15	72	Oma	
3	HRK-1	100.1	0	0.2	63.08	10.2	862	72.66	0.48	5	1118.92	95.39	532.52	2.66	2.09	7.8	3	85	Haruku	

(Pre-FS report by PLN Geothermal, February 2010)

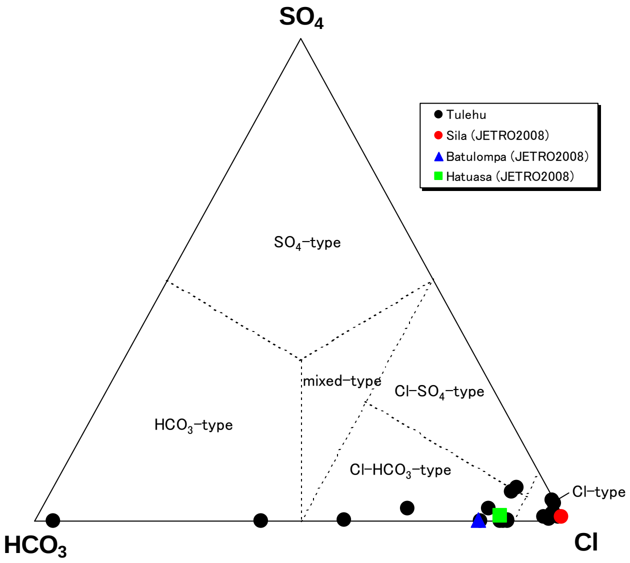


Fig. III-2-7 Trilinear Diagram of Major Anions in and around Tulehu Field
(METI-JETRO Report on geothermal development in east Indonesia, March 2009)

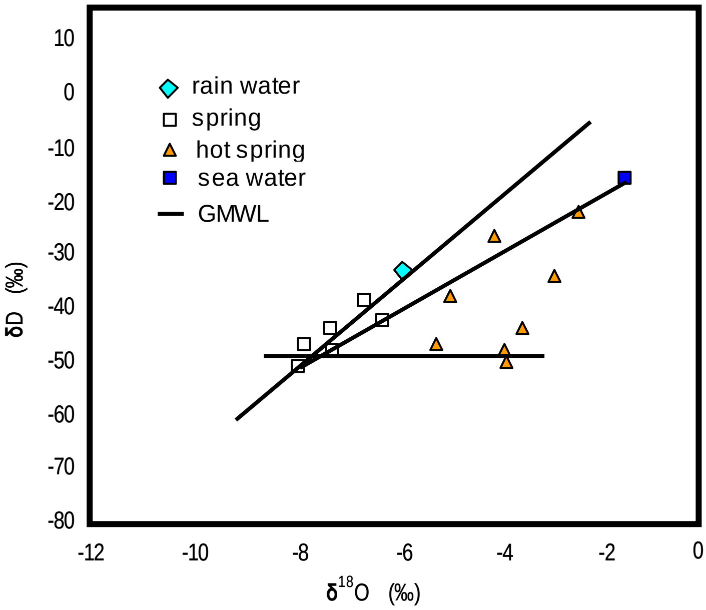


Fig. III-2-8 Hydrogen and Oxygen-18 Diagram of Hot Spring Waters in and around Tulehu Field
(Pre-FS report by PLN Geothermal, February 2010)

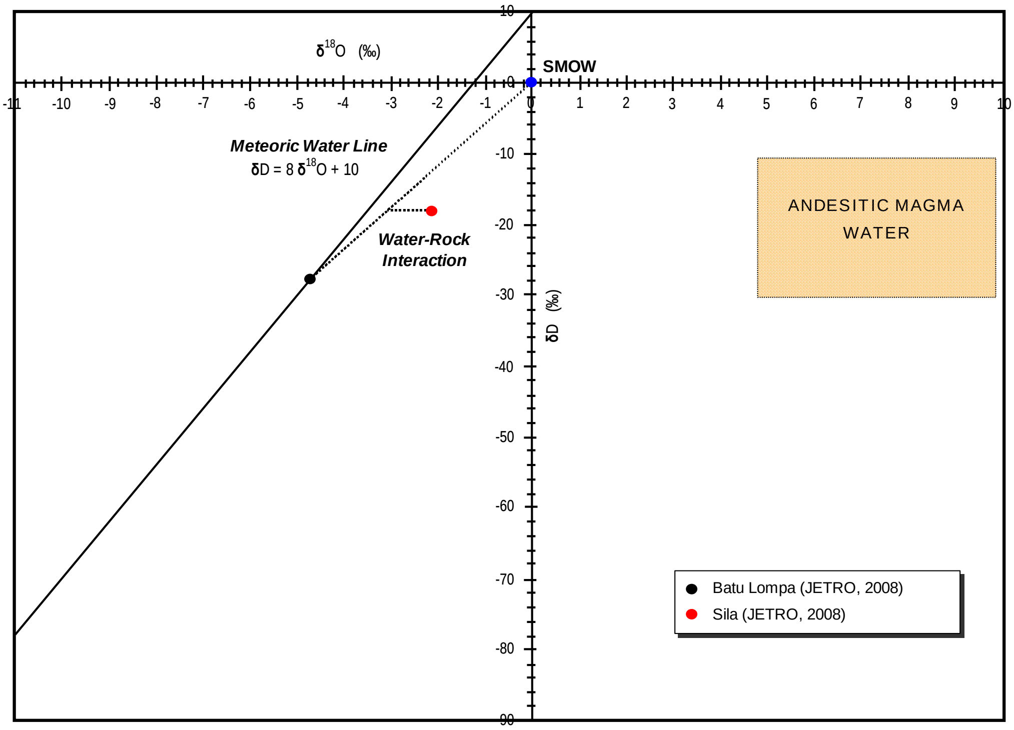


Fig. III-2-9 Hydrogen and Oxygen-18 Diagram of Hot Spring Waters at Sila
(METI-JETRO Report on geothermal development in east Indonesia, March 2009)

Table III-2-3 Geochemical Temperatures of Hot Springs in and around Tulehu field

No.	Code	Temperature (^oC)			Location	
		Na-K (Fournier)	Na-K (Giggenbach)	Na-K-Ca		
1	TLH-1	222.42	237.37	119.00	Beach behind Tuluhu Hospital	Tulehu
2	TLH-3	250.43	263.26	179.96	Batu Lompa Cape	
3	TLH-4	194.45	211.24	189.19	Mamokeng Beach	
4	SL-1	223.11*	238.01	199.84	Sila	
5	SL-2	210.95	226.69	157.58	Sila	
6	HTS-1	210.56	226.32	150.32	River of Hatuasa	
7	HTS-2	209.35	225.20	148.38	Hatuasa Hot Spring Pool	
8	HTS-3	213.04	228.64	149.59	Hatuasa	
9	BTL	200.07	216.51	269.02	Batu Lompa Island	
10	Suli Beach	169.56	187.74	81.72	Suli Beach	
11	SLM-1	199.38	215.87	160.01	Hatuing	
12	SLM-2	214.66	230.15	185.09	Hatuing	
1	OMA-1	180.80	198.38	219.92	Oma	Haruku
2	OMA-2	209.60	225.43	182.92	Oma	
3	HRK-1	202.91	219.17	187.47	Haruku	

(Pre-FS report by PLN Geothermal, February 2010)

(2) Geothermal Reservoir Temperature

In the previous study, geochemical thermometers were applied to estimate the geothermal reservoir temperature in this field. It is possible that the estimated temperatures are influenced by conductive cooling and dilution during the ascent of the geothermal fluid from the reservoir. Exact estimation of the reservoir temperature by geochemical thermometers is considered to be difficult. If the geochemical thermometers are applied adequately, the reservoir temperature is regarded as being higher than the estimated temperature, considering the subsurface cooling of the fluid by conduction and/or dilution. Since the Na-K-Ca temperature at Sila indicates 200^{o}C, the reservoir fluid temperature should be higher than 200^{o}C. A more accurate estimate of the temperature of the reservoir fluid must be made in the future to enable the resource development program to be drawn up. Application of the fluid mixing model or oxygen-18 (H_2O-SO_4) isotope thermometer should be considered as a geochemical approach. The exact temperature of the geothermal reservoir in this field will be revealed by exploratory well drilling.

(3) Reservoir Fluid Extent and Beha

Although the chloride ion contents in hot spring waters north of Mt. Eriwakang are not constant, the Cl/B molar ratio of these waters shows a constant value of about 130. This constant Cl/B ratio may indicate that the hot spring waters in this area are derived from a common geothermal reservoir. These hot springs seems to be distributed along geological structures such as faults etc. The relationship between the characteristics of the hot springs and the location of the faults should be carefully studied in the integrated interpretation.

In geochemical study, reservoir rocks are assumed on the basis of the Cl/B ratio. However, reservoir rocks in this field could not be identified using the Cl/B ratio of the hot spring waters due to the peculiar, disturbing chemical characteristics of intrusive seawater. However, the high content of carbonate ions in the hot spring waters shows a possibility that these waters were influenced by sedimentary rocks or limestone. The reservoir rocks could not be clarified using only chemical data. Whether sedimentary rock or limestone are included among the reservoir rock or not should be revealed by exploratory well drilling. If there is sedimentary rock or limestone in the reservoir, there is a possibility of serious problems occurring in this field, such as carbonate scaling in production wells and pipelines, and high NCG content.

(4) Scale Deposition and Corrosion Trouble

According to the chemical characteristics of geothermal reservoir fluid assumed from the characteristics of hot spring waters, there is no possibility of corrosion trouble occurring in this field. Regarding scaling problems, carbonate scale will be formed when production wells tap a sedimentary rock reservoir. Silica scale deposition depends on the operating conditions for production wells. However, silica scale from the geothermal water in this field seems to deposit easily due to the relatively high content of salts dissolved in the water. Mineral acid injection into the reinjection line is considered to be effective to prevent silica scale deposition, because the silica content in water separated from geothermal fluid of about 200^{o}C must not be so high. Adequate countermeasures against such scaling trouble should be considered on the basis of the chemical characteristics of well discharge after completion of well discharge testing.

4. Well Testing Data

a. TG-1

Well TG-1 is a thermal gradient hole drilled to a depth of 40 m on the southern side of the Banda alteration zone (see Fig. III-2-1). Tuffaceous clay is identified from the surface to a depth of 17 m (see Fig. III-2-10). This layer will correspond to the Eriwakang pyroclastic unit. From a depth of 17 m to the borehole bottom (40 m deep) is a layer of silicified dacite. This dacite will correspond to the Salahutu-2 dacitic lava unit. The measured temperature at the bottom is 41°C.

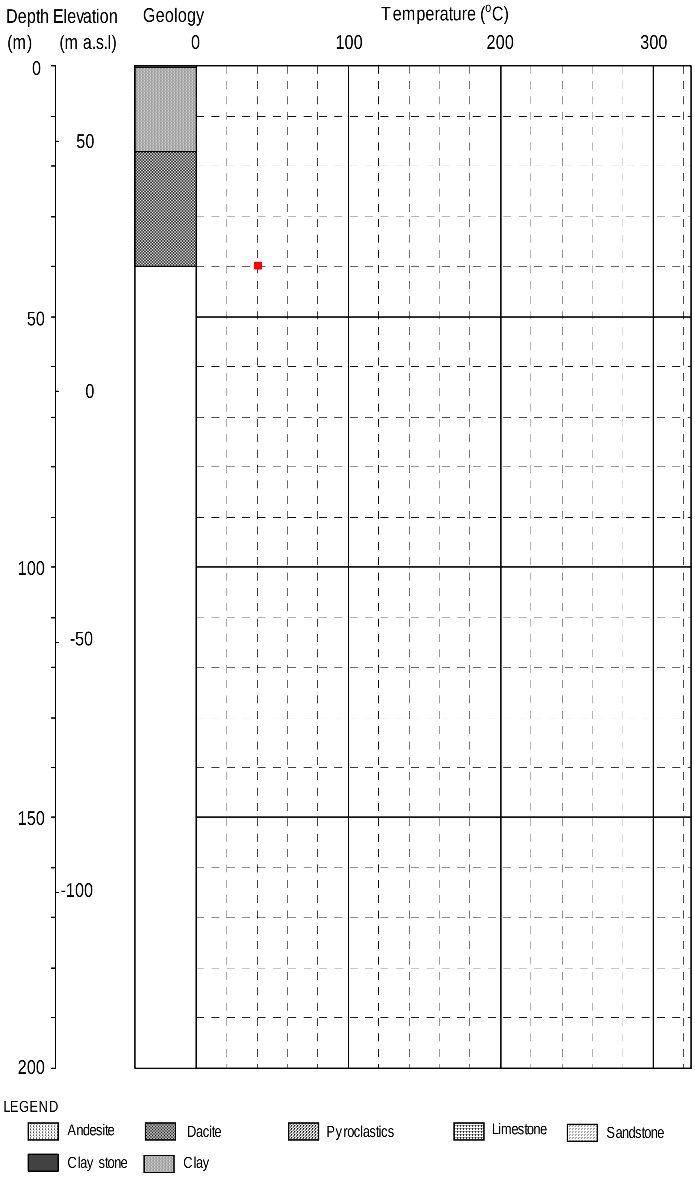


Fig.III-2-10 Columnar Section of TG-1

b. TG-2

Well TG-2 is a thermal gradient hole drilled to a depth of 120 m near the seaside in Suli Bawah (see Fig. III-2-1). A sandy clay layer is identified from the surface to a depth of 10 m and a sand layer lies under this layer to a depth of 33 m (see Fig. III-2-11). These deposits will be surface soil. A coral limestone layer extends under the sand layer to a depth of 51 m and this layer will correspond to the Limestone unit. From a depth of 51 m, there is a clay layer to a depth of 110 m and dacite is identified under this layer to the borehole bottom (120 m deep). This clay layer and dacite layer will correspond to the Eriwakang pyroclastic unit and the Salahutu-2 dacitic lava unit, respectively. The measured temperature at the bottom is 36°C.

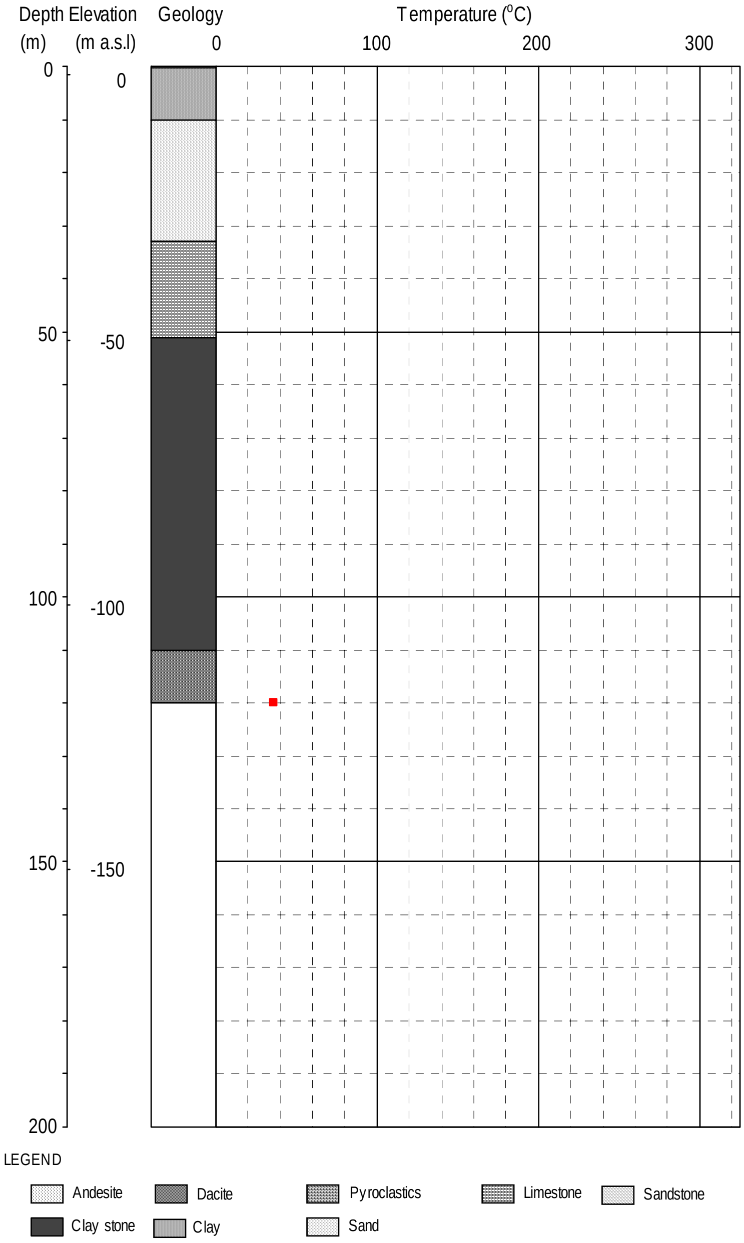


Fig.III-2-11 Geological Column of thermal gradient well TG-2

c. TG-3

Well TG-3 is a thermal gradient hole drilled to a depth of 40 m near the Salahutu hot spa (see Fig. III-2-1). There is a clay layer from the surface to a depth of 15 m, and a sandy clay layer extends from there to a depth of 25 m (see Fig. III-2-12). These deposits will be alluvium deposits. From a depth of 25 m to the borehole bottom (40 m deep), there is a dacite layer which corresponds to the Salahutu-2 dacitic lava unit. The measured temperature at the bottom is 31°C.

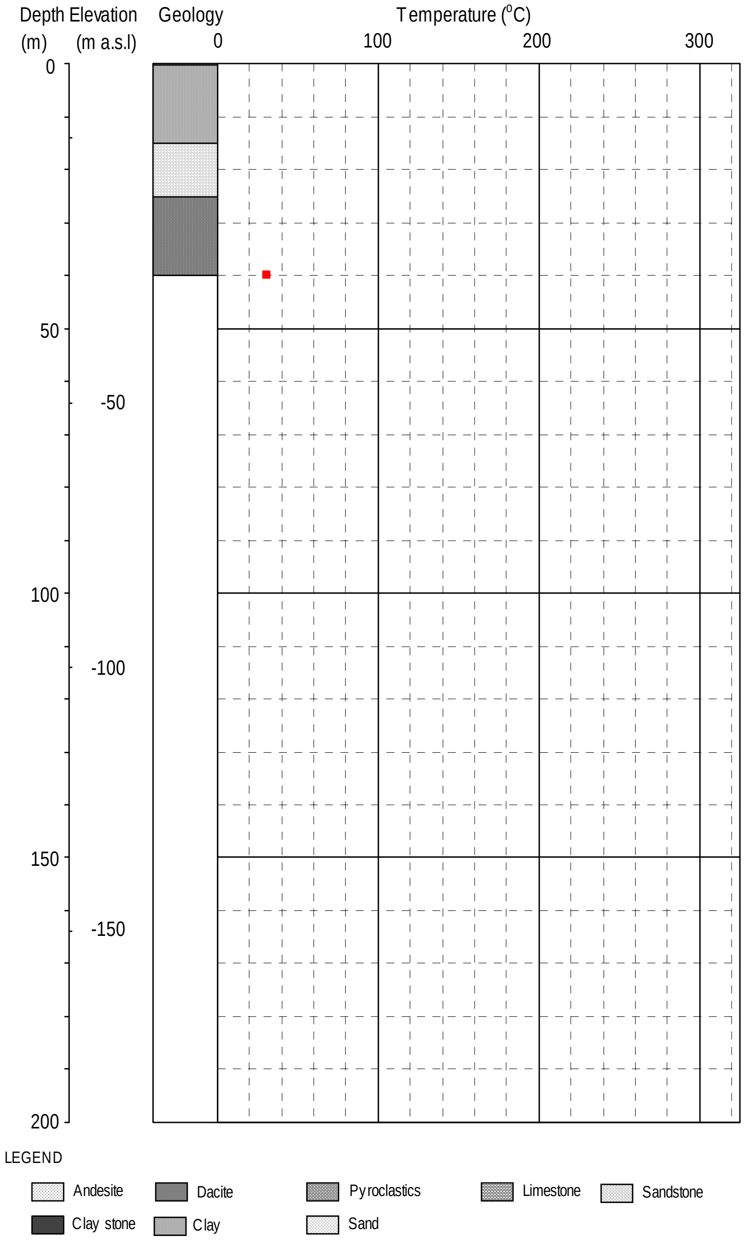


Fig.III-2-12 Columnar Section of TG-3

d. W2.1

Well W2.1 is a thermal gradient hole drilled to a depth of 150 m near well TG-1 (see Fig. III-2-1). A pyroclastic layer extends from the surface to a depth of 69 m (see Fig. III-2-13) and will correspond to the Simalopu pyroclastic unit. There is a claystone layer from a depth of 69 m to a depth of 71.6 m, and a dacite layer extending from there to a depth of 84 m. These layers will correspond to the Salahutu-2 dacitic lava unit. A claystone layer extends from a depth of 84 m to a depth of 89.7 m, and a dacite layer from a depth of 89.7 m to the borehole bottom (150 m deep). These layers will correspond to the Salahutu-1 dacitic lava unit. On the whole, the underground temperature increases with increasing depth, though it decreases from a depth of 90 m to a depth of 110 m. The measured temperature at the bottom is 122.6°C.

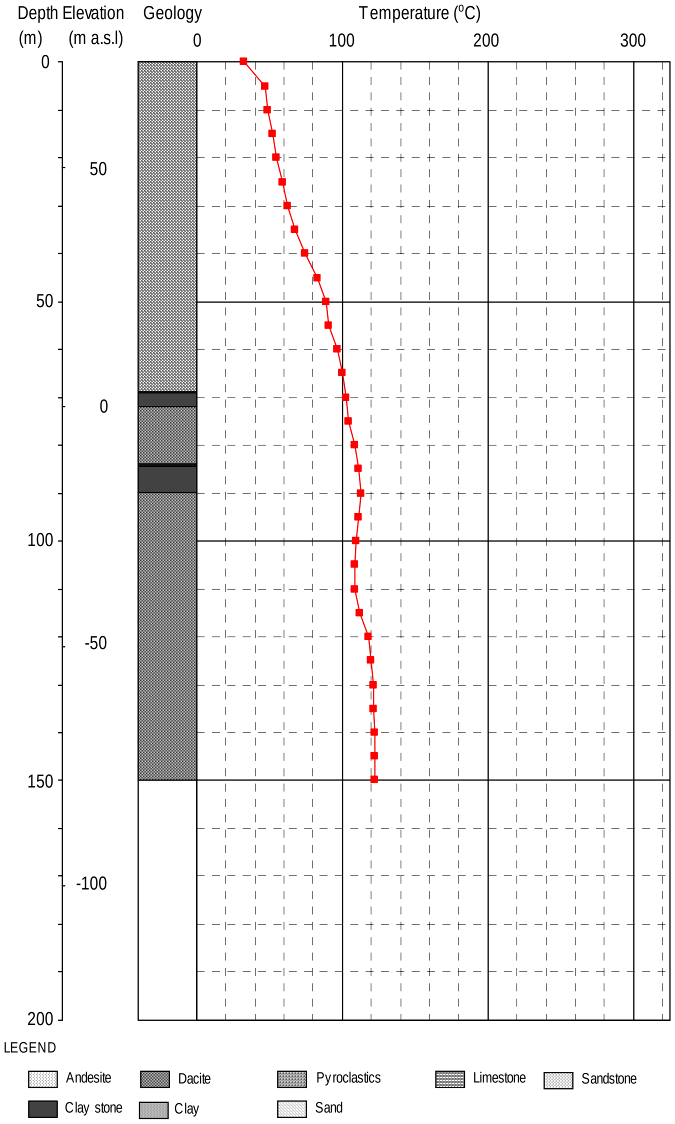


Fig.III-2-13 Columnar Section of W2.1

e. W2.2

Well W2.2 is a thermal gradient hole drilled to a depth of 150 m on the upstream portion of the Rutung River (see Fig. III-2-1). A pyroclastic layer extends from the surface to a depth of 7 m (see Fig. III-2-14) and will correspond to the Salahutu pyroclastic unit. A dacite layer reaches under this layer to a depth of 69.6 m, and this will correspond to the Salahutu-2 dacitic lava unit. There is claystone from a depth of 69.6 m to a depth of 74.7 m, and a dacite layer extends under this claystone, to a depth of 132.5 m. These formations will correspond to the Salahutu-2 dacitic lava unit or the Salahutu-1 dacitic lava unit. From a depth of 132.5 m to a depth of 135.7 m, a thin sandstone bed is identified and a dacite layer extends under this sandstone bed to the borehole bottom (150 m deep). These formations will correspond to the Salahutu-1 dacitic lava unit. On the whole, underground temperature increases with increasing depth, though not remarkably. The measured temperature at the bottom is 32.4°C.

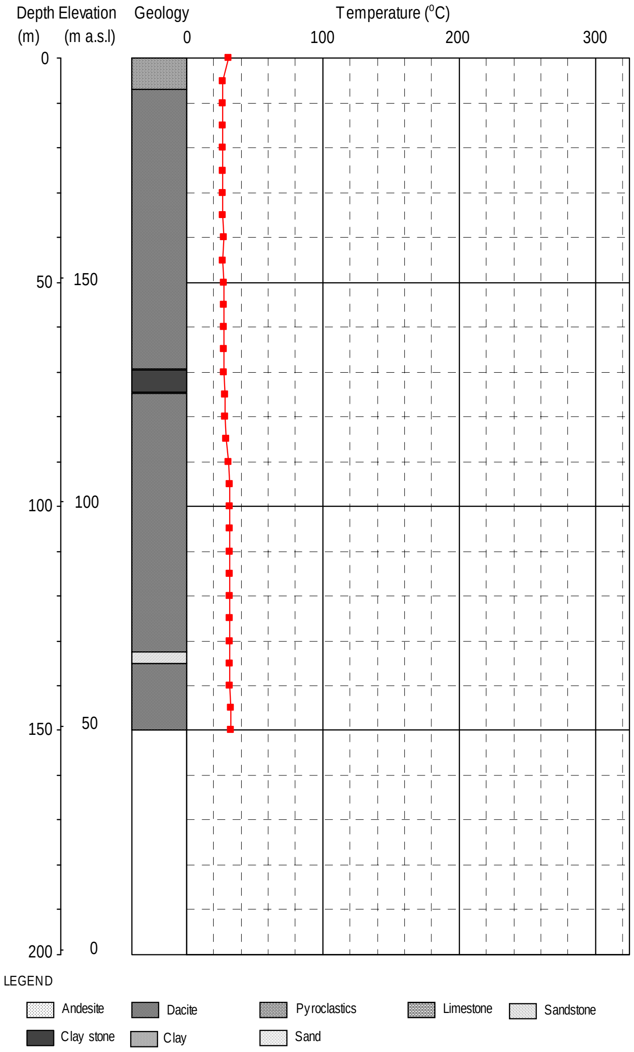


Fig.III-2-14 Columnar Section of W2.2

f. W2.3

Well W2.3 is a thermal gradient hole drilled to a depth of 150 m at the northwestern foot of Mt. Terang Alam (see Fig. III-2-1). A coral limestone layer extends from the surface to a depth of 55 m, with an inserted pyroclastic bed from a depth of 44.5 m to a depth of 53.4 m (see Fig. III-2-15). These formations correspond to the Limestone unit. From a depth 55 m to a depth of 111.4 m, there is a pyroclastic bed, corresponding to the Huwe pyroclastic unit. From a depth of 111.4 m to the borehole bottom (150 m deep), there is dacite interstratified with a pyroclastic bed from a depth of 112.3 m to a depth of 122.4 m. This formation will correspond to the Salahutu-2 dacitic lava unit. The underground temperature is quite constant from near the surface to the borehole bottom. The measured temperature at the bottom is a relatively low 27.5°C.

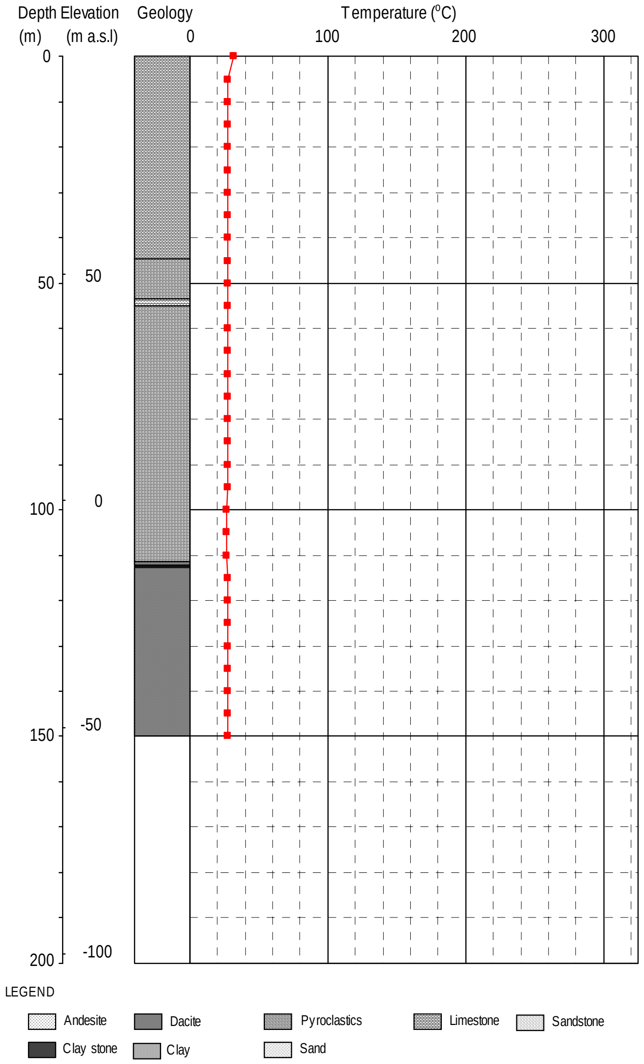


Fig.III-2-15 Columnar Section of W2.3

g. TLU-01

(1) Geology

Well TLU-01 is the first exploratory well in this field and is located between well TG-1 and well W2.1 (see Fig. III-2-1). As sandstone of the Neogene is observed along a valley (elevation of about 50 m) about 1.4 km northwest from the drilling site, it was predicted that well TLU-01 must reach this sandstone formation at a relatively shallow depth. However, the sandstone formation was not encountered.

A pyroclastic layer extends from the surface to a depth of 64 m (see Fig. III-2-16) and will correspond to the Simalopu pyroclastic unit. An altered andesite layer extends from there to a depth of 85 m. This layer will correspond to the Salahutu-2 dacitic lava unit. There is a pyroclastic layer from a depth of 85 m to a depth of 911 m in the original hole and to a depth of 932.67 m in the side-tracked hole, though an andesite layer occurs from a depth of 459 m to a depth of 471 m. In this report, all of these volcanic rocks are temporally correlated with the Salahutu-1 dacitic lava unit, though there is still some uncertainty about the correlation.

(2) Lost circulation zone and permeability

Partial lost circulation occurs at a depth of 330 m while drilling and total lost circulation happened for a time (from 332 m to 350 m). From a depth of 350 m, partial lost circulation occurs continuously until a depth of 618 m. This partial lost circulation was stopped by the setting of $9^5/_8$” casing (depth of casing shoe = 616 m) in the original hole. In the original hole, partial lost circulation occurs again at a depth of 725 m and continues to the bottom (911 m). Remarkable drilling breaks are detected from 735 m to 737 m and from 740 m to 750 m. These drilling break ranges can be correlated with lost circulation zones. In the side-tracked hole, partial lost circulation starts around a depth of 644 m (vertical depth = 643.59 m) and total lost circulation happens around a depth of 703 m (vertical depth = 702.15 m). Partial lost circulation and total lost circulation alternately occur until a depth of 932.67 m (vertical depth = 930.75 m) at the bottom of the hole.

The depths of lost circulation zones and their contribution to water loss are estimated from the injection test data. Measured velocity while injecting water at a rate of 600 l/min. and estimated water loss percentage are shown in Fig. III-2-17. Remarkable velocity declines were detected at depths of around 700 m and around 900 m. Considering the occurrence of total lost circulation at a depth of 703 m while drilling, there are major lost circulation zones at depths of 703 m and of around 900 m.

On the other hand, the velocity values increased in the depth interval from 700 m to 850 m. The increase in flow velocity inside a borehole is an indication of inflow from the surrounding formation. However, it is unlikely for formation water to flow into a borehole during water injection at a 600 L/min flow rate. Thus the velocity reversal was interpreted as an indication of change in borehole diameter due to the collapse of the borehole wall which was formed during the drilling of TLU-01.

The injectivity index (I.I.) of TLU-01 was evaluated from the multi-rate injection test data. The results of the evaluation are shown in Fig. III-2-18. The injectivity index of TLU-01 was calculated to be 28.3 $m^3/h/kg/cm^2$, which is a pretty high injectivity. The injectivity index shows that TLU-01 must have encountered a high-permeability structure.

A fall-off test was carried out after the multi-rate injection test. Using data obtained from this test, the permeability-thickness (kh) was estimated to be 5.3 to 9.6 darcy-m (see Fig. III-2-19). These values indicate that well TLU-01 has good permeability.

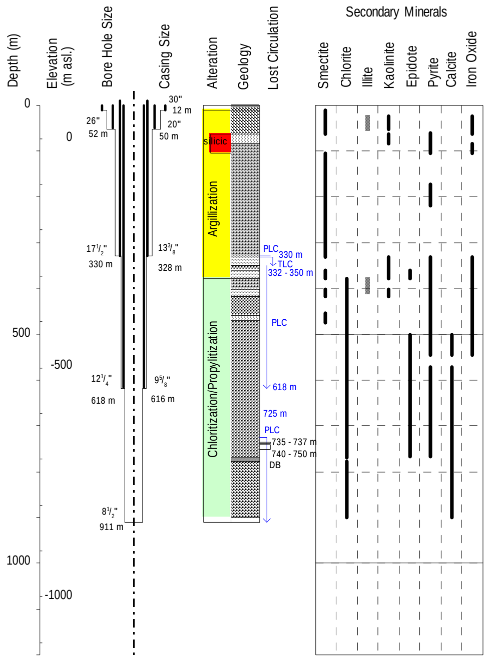
(3) Alteration

An argillized layer characterized by the occurrence of smectite is identified around the surface to a depth of 378 m. As lost circulation while drilling starts around the bottom of this layer, this layer must be impermeable layer (cap rock). An intensively silisified zone is recognized from a depth of 64 m to a depth of 85 m. As a secondary mineral, smectite (which usually indicates a temperature condition lower than 200^oC) is recognized from the surface to a depth of 475 m. On the other hand, chlorite and epidote (which usually indicate a temperature condition higher than 200^oC) are recognized from a depth of 378 m and from a depth of 360 m, respectively, to the bottom of the hole. The occurrence of these secondary minerals, when they result from present hydrothermal alteration, suggests that the subsurface temperature from a depth of around 360 m to the bottom of the hole can be expected to be higher than 200^oC.

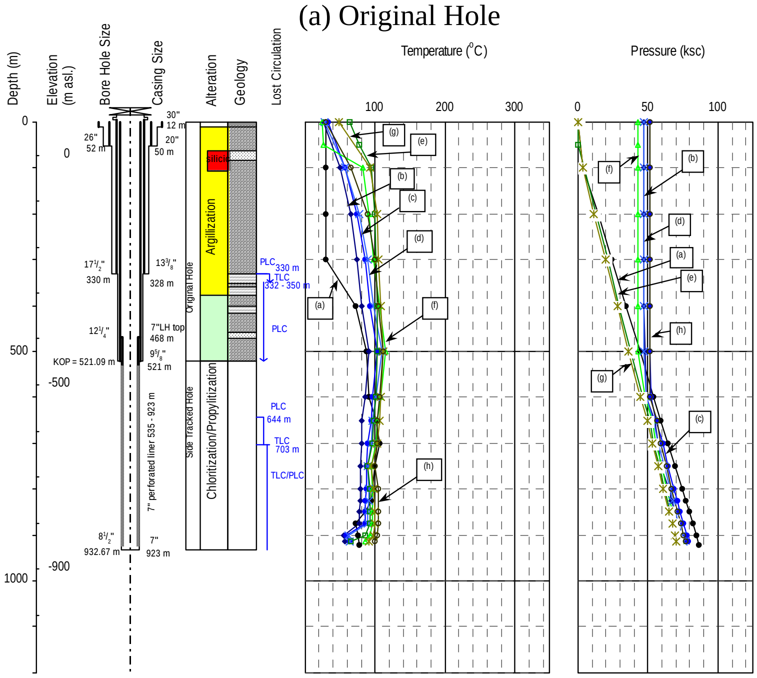
(4) Temperature

After the injection test, a heating-up test was conducted. In this test, pressure and temperature logging is carried out, at 14 hours, 28 hours, 40 hours, 52 hours, 63 hours, 87 hours, and 111 hours after water injection stops (see Fig. III-2-16 and Table III-2-4). The highest temperature of 115.42^oC was recorded at a depth of 500 m (water level = 550 m) 63 hours after water injection stopped. On the whole, temperature recovers very slowly. A considerable amount of drilling fluid was injected into this well to maintain suitable borehole conditions while drilling under lost circulation conditions. The cooling effect of this drilling fluid injection must result in very slow temperature recovery.

Calculated equilibrium temperatures based on measured data are given in Table III-2-4. Equilibrium temperature (original subsurface temperature before drilling) is usually estimated using the relationship between measured temperatures and standing times after the last water injection. As the water level of TLU-01 was changed by about 550 m by repeated confinement of compressed air and release of confined air during the heating-up test, the time that elapses after water injection stops cannot be regarded as “standing time”. Therefore, there is a possibility that the estimated equilibrium temperatures are different from the original subsurface temperatures before drilling. However, it is considered that the effect of the changing water level is rather small around the bottom of the well. Sufficient coincidence is recognized between measured temperatures and the calculated temperature at a depth of 900 m (see Fig. III-2-20), though those at the other depths do not coincide very well. This may suggest that the calculated temperature (about 230^{o}C) at a depth of 900 m approaches the original subsurface temperature before drilling. Judging from the occurrences of secondary minerals (especially chlorite and epidote), a temperature exceeding 200^{o}C is expected below a depth of about 360 m. Although they must be further examined, these data suggest that temperatures at a depth of 360 m (about –287 m above sea level) and at a depth of 900 m (about –825 m above sea level) reach around 200^{o}C and around 230^{o}C, respectively (see Fig. III-2-21).



(a) Original Hole



(a) 2011/7/2-3, 44 hrs. after injection stop, after 7" liner set, WL = 60 m

(b) 2011/7/3-4, 14 hrs. after injection stop, confining air at WHP = 47.5 kscg, WL = 600 m

(c) 2011/7/4, 28 hrs. after injection stop, confining air at WHP = 51 kscg, WL = 600 m

(d) 2011/7/5, 40 hrs. after injection stop, confining air at WHP = 46.99 kscg, WL = 600 m

(e) 2011/7/5, ST.52 hrs. after injection stop, after releasing confined air, WHP = 0 kscg, WL = 60 m

(f) 2011/7/6, 63 hrs. after injection stop, after compressing to confine air, WHP = 43.01 kscg, WL = 550 m

(g) 2011/7/7, 87 hrs. after injection stop, after releasing confined air, WHP = 0 kscg, WL = 60 m

(h) 2011/7/8, 111 hrs. after injection stop, after compressing to confine air, WHP = 51 kscg, WL = 600 m

(b) Side Tracked Hole

Legend

▨ **Dacite** ░ **Andesite** ▩ **Andesitic breccia** ▦ **Tuff breccia** ▤ **Tuff** ■ **No cuttings**

TLC **Total Lost Circulation** PLC **Partial Lost Circulation** DB **Drilling Break**

Fig.III-2-16 Columnar Section of TLU-01

(Source: PLN Geothermal)

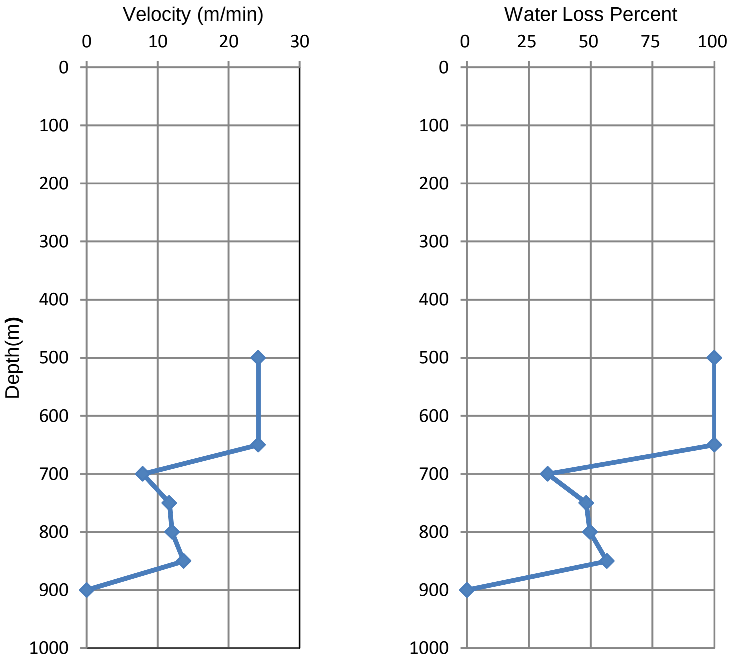
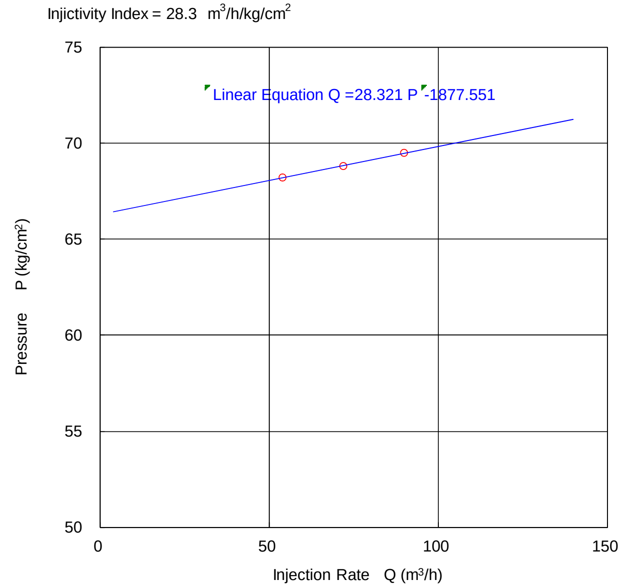


Fig.III-2-17 Velocity of Injected water and Water Loss Percentage for TLU-01

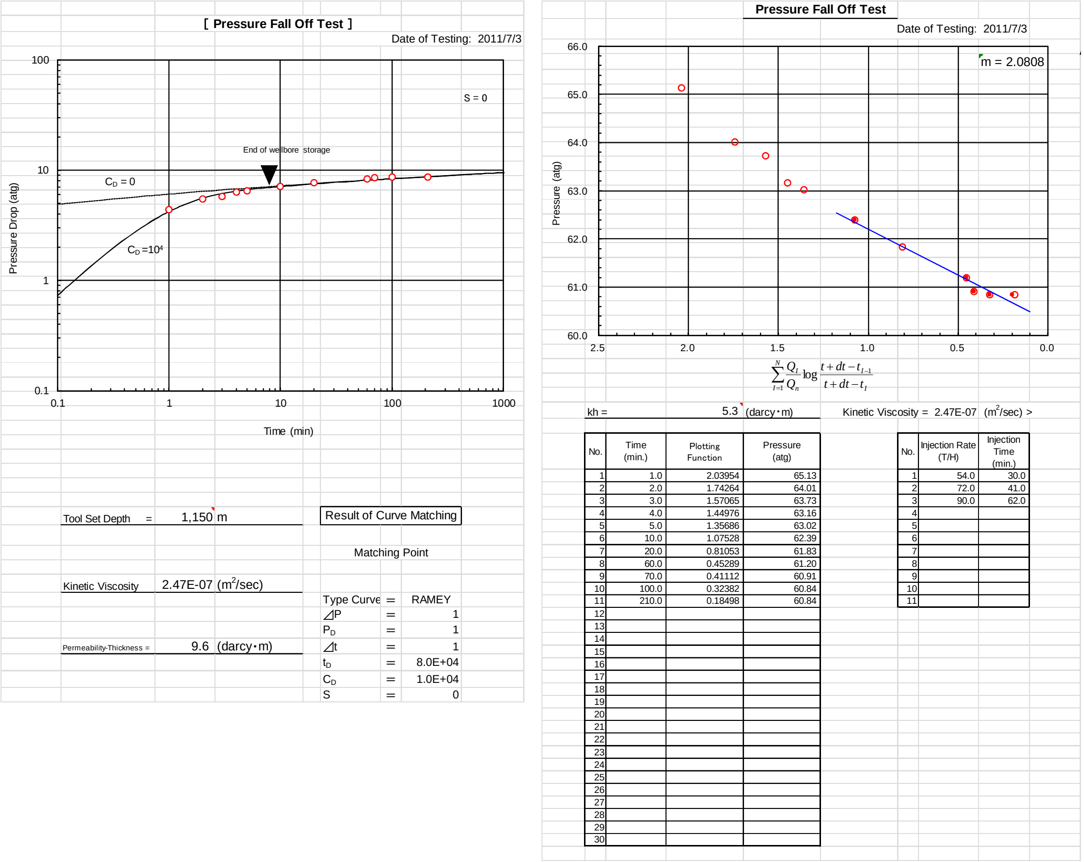
(Source: PLN Geothermal)



Data

Injection Rate (m^3/h)	Pressure (kg/cm^{2}G)	Remarks	Injection Rate (m^3/h)	Pressure (kg/cm^{2}G)	Remarks
0.0	60.84				
54.0	68.23				
72.0	68.79				
90.0	69.50				

Fig. III-2-18 Results of Injectivity Index Evaluation for TLU-01



[Pressure Fall Off Test]

Date of Testing: 2011/7/3

Tool Set Depth = 1,150 m

Kinetic Viscosity 2.47E-07 (m^2/sec)

Permeability-Thickness = 9.6 (darcy･m)

Result of Curve Matching

Matching Point

Type Curve	=	RAMEY
⊿P	=	1
P_D	=	1
⊿t	=	1
t_D	=	8.0E+04
C_D	=	1.0E+04
S	=	0

Pressure Fall Off Test

Date of Testing: 2011/7/3

kh = 5.3 (darcy･m)

Kinetic Viscosity = 2.47E-07 (m^2/sec) >

No.	Time (min.)	Plotting Function	Pressure (atg)
1	1.0	2.03954	65.13
2	2.0	1.74264	64.01
3	3.0	1.57065	63.73
4	4.0	1.44976	63.16
5	5.0	1.35686	63.02
6	10.0	1.07528	62.39
7	20.0	0.81053	61.83
8	60.0	0.45289	61.20
9	70.0	0.41112	60.91
10	100.0	0.32382	60.84
11	210.0	0.18498	60.84
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			
26			
27			
28			
29			
30			

No.	Injection Rate (T/H)	Injection Time (min.)
1	54.0	30.0
2	72.0	41.0
3	90.0	62.0
4		
5		
6		
7		
8		
9		
10		
11		

(a) Curve Matching Analysis (b) Analysis with the superposition method

Fig.III-2-19 Estimated Permeability-Thickness Values for TLU-01

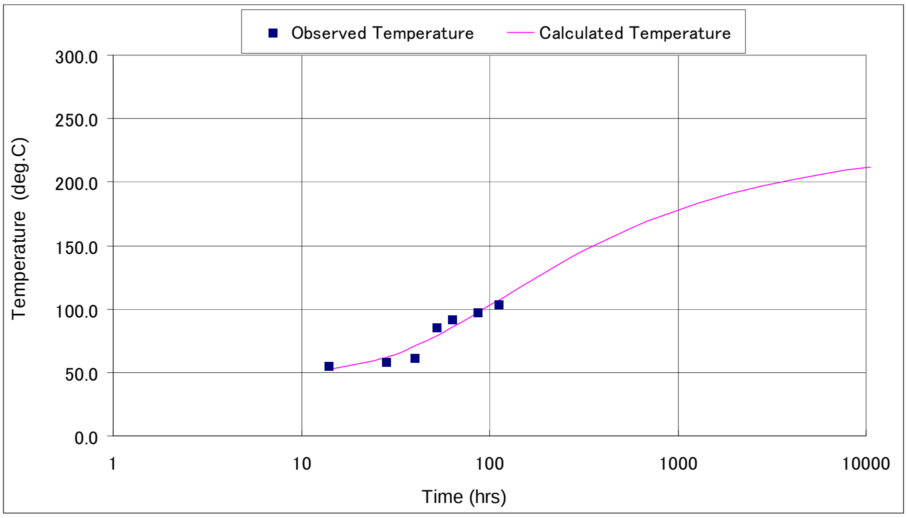


Fig.III-2-20 Calculated Equilibrium Temperature of TLU-01 at Depth of 900 m

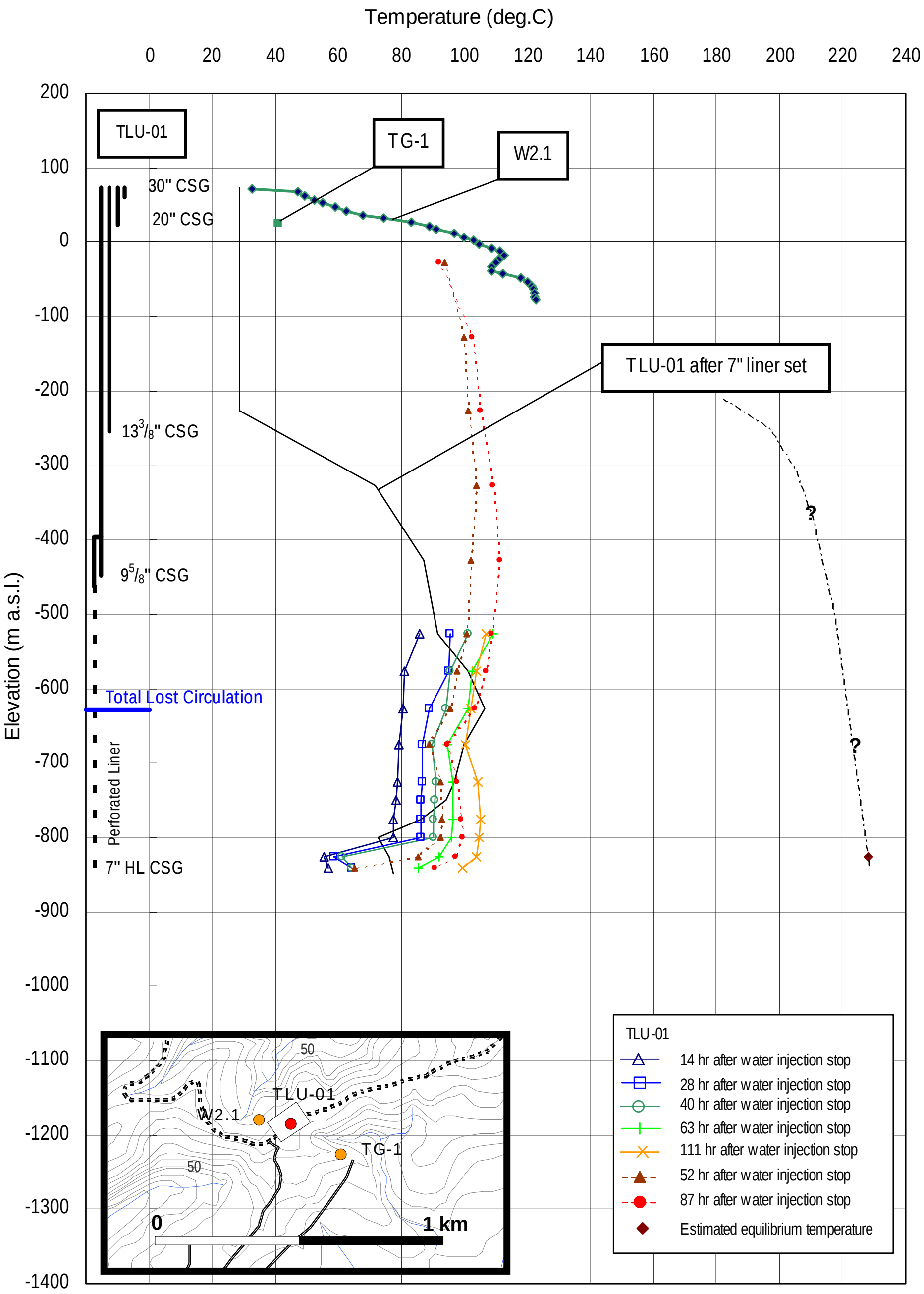


Fig.III-2-21 Temperature Profiles of TLU-01 and Its Neighboring Wells

Table III-2-4 Pressure and Temperature Logging Data for TLU-01

				Heating Up Test														Estimated Equilibrium Temperature
Date		2011/7/2-3		2011/7/3-4		2011/7/4		2011/7/5		2011/7/5		2011/7/6		2011/7/7		2011/7/8		
Depth	Elevation	Temp.	Pressure	Temp.	Pressure	Temp.	Pressure	Temp.	Pressure	Temp.	Pressure	Temp.	Pressure	Temp.	Pressure	Temp.	Pressure	
(m)	(m)	(^{o}C)	(kscg)	(^{o}C)	(kscg)	(^{o}C)	(kscg)	(^{o}C)	(kscg)	(^{o}C)	(kscg)	(^{o}C)	(kscg)	(^{o}C)	(kscg)	(^{o}C)	(kscg)	(^{o}C)
0	73	28.76	0.00	25.56	47.50	33.77	51.00	28.16	46.99	63.83	0.00	23.55	43.01	47.80	0.00	28.76	51.00	
50	23									77.65	0.00	26.36	43.01					
100	-27	28.76	3.94	49.80	47.50	56.81	51.00	56.91	46.99	93.88	3.94	83.26	43.01	92.08	3.24	64.83	51.00	
200	-127	28.76	14.21	64.93	47.50	74.05	51.00	76.95	46.99	99.79	12.81	91.68	43.01	102.70	11.54	88.87	51.00	
300	-227	28.76	23.99	73.65	47.50	85.07	51.00	89.07	46.99	101.20	21.18	98.69	43.01	105.20	20.12	99.69	51.00	
400	-327	72.04	34.26	80.76	47.50	92.48	51.00	97.79	46.99	103.70	29.47	106.51	43.01	108.91	28.07	105.10	51.00	
500	-427	87.17	44.32	91.78	47.78	102.70	51.21	109.41	46.99	102.30	37.56	115.42	43.01	111.32	36.02	110.92	51.00	
600	-527	91.68	54.30	85.67	48.91	95.69	52.40	101.10	48.89	100.70	45.93	108.91	47.65	108.61	44.32	106.91	51.00	
650	-577	101.30	59.37	81.06	54.67	94.89	55.78	95.69	54.23	97.89	51.14	102.70	52.99	106.91	49.80	103.70	56.20	135
700	-626	106.31	64.43	80.66	57.14	88.87	60.35	94.08	57.05	95.39	53.95	101.00	55.67	103.20	52.69	102.30	58.81	122
750	-676	99.90	69.71	79.16	59.32	86.87	64.57	89.58	61.20	89.07	58.38	94.69	60.03	94.48	57.26	100.30	62.96	120
800	-726	96.69	74.56	78.76	65.15	86.87	68.65	90.98	65.56	92.38	61.90	96.19	63.76	97.69	60.98	104.30	66.90	131
825	-751	94.28	76.95	78.25	67.05	86.17	70.62	90.48	67.38									
850	-776	86.17	79.34	77.65	69.23	86.07	72.80	90.18	69.49	92.98	66.05	96.49	67.76	99.19	65.42	105.10	70.83	137
875	-800	72.84	81.87	77.65	71.48	86.07	75.12	90.18	71.96	92.38	68.51	96.09	70.09	99.29	67.53	104.70	73.37	136
900	-825	76.15	84.41	55.41	73.66	58.42	77.58	61.22	74.14	85.57	70.20	92.08	71.98	97.09	69.21	103.70	75.19	228
915	-840			56.71	75.21	64.43	78.78	64.23	75.61	65.03	71.82	85.27	73.39	90.48	70.41	99.59	76.60	
923	-848	77.25	86.80															
Elapsed Time after Water Injection Stop		44 hours		14 hours		28 hours		40 hours		52 hours		63 hours		87 hours		111 hours		
Water Level		60 m		600 m		600 m		600 m		60 m		550 m		60 m		600 m		
Well Head Pressure		0 kscg		48 kscg		52.47 kscg		48 - 46 kscg		0 kscg		44 kscg		0 kscg		51 kscg		
Maximum Temperature		106.3^{o}C @700 m		91.8^{o}C @500 m		102.7^{o}C @500 m		109.4^{o}C @500 m		103.7^{o}C @400 m		115.4^{o}C @500 m		111.3^{o}C @500 m		110.9^{o}C @500 m		

(Source: PLN Geothermal)

III.2.3 MT Survey

1. Methodology

The objective of the Magnetotelluric (MT) survey was to detect promising zones for geothermal development by studying the detailed subsurface resistivity distribution obtained from the MT survey results. In particular, delineating the locations of faults and fracture systems by studying resistivity discontinuities, and outlining the cap rock zones of geothermal reservoirs by studying low resistivity zones at relatively shallow depths, are important in selecting future drilling targets.

Measuring stations were placed in a grid configuration with stations separated by approximately 700 m to 800 m in order to detect fault systems, which often provide passages for geothermal fluids. The total number of stations in each survey was 34. Based on our experience in many geothermal fields, the depth of geothermal reservoirs that are economically viable as drilling targets is expected to be between approximately 1,000 m and 2,500 m. Therefore, to obtain the resistivity information from this depth and from deeper levels, more than 50 frequencies in the range from 320 Hz to 0.001 Hz were utilized for MT data acquisition. With this frequency range, the investigation depth was considered to reach levels deeper than 2.5 km even in a conductive environment. In addition, three-dimensional resistivity inversion with smoothness constraint was conducted to estimate the detailed subsurface resistivity structure in the Tulehu geothermal field.

2. Procedure

A remote-reference Magnetotelluric (MT) survey was carried out in an area of about 13 km^2. In this area, 34 measuring stations were located. At these stations, three components of the magnetic signal (*Hx*, *Hy*, *Hz*) and two components of the electric signal (*Ex*, *Ey*) were measured. Apparent resistivity values and impedance phase values at more than 50 frequencies ranging from 320 Hz to 0.01 Hz were calculated and checked for every station, during the field work.

a. Survey area and station configuration

The station location map for the MT survey in the Tulehu geothermal field is shown in Fig. III-2-22. As shown in the map, measuring stations were basically placed in a grid configuration in order to delineate the detailed subsurface resistivity structures. The intervals between measuring stations were approximately 750 m. The total number of measuring stations was 34, and the location of each station was determined by GPS readings conducted prior to the actual MT measurements. The locations of the MT stations are listed in Table III-2-5. Data acquisition in the field and logistic coordination were carried out by PT. Elnusa TBK and the supervisory services were provided by West JEC. PT. PLN was responsible for acquiring permissions for the fieldwork and for assisting with the fieldwork in the Tulehu geothermal field.

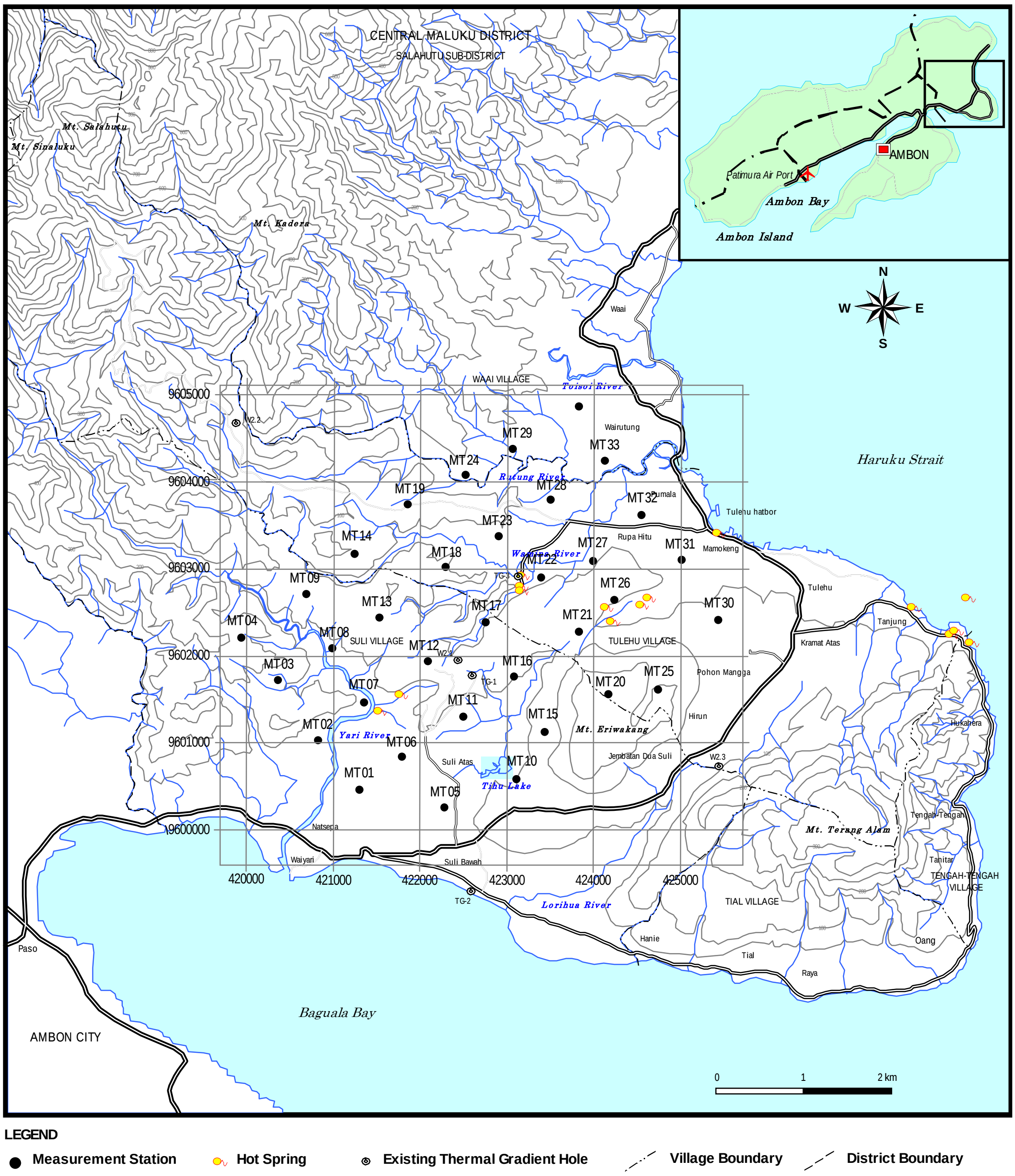


Fig.III-2-22 Location Map of MT Survey Stations

Table III-2-5　Locations of MT Stations

[redacted]

b. Remote reference site

The remote reference site should be located in a quiet place free of noise or with a low noise level in order to eliminate artificial electromagnetic noise from the actual electromagnetic signals at each measuring station. The ideal site must be free of pipelines, running water, generators, power lines and far from human activity. A site roughly 10 km north of the Tulehu survey area was selected as the remote reference site, because data previously acquired at the site was not contaminated with artificial electromagnetic noise and seemed to be suitable for use as remote reference data. Therefore the site was utilized as a remote reference site until the end of the survey period.

c. Data acquisition

To assure data quality, the MT survey was carried out in the Tulehu field using the remote reference method. Daily, two or three arrays (occasionally one, excluding the fixed remote station) were deployed for data acquisition. Time series data corresponding to two components of the electric field (*Ex*, *Ey*) and three components of the magnetic signals (*Hx, Hy, Hz*) were recorded. Similar data series were simultaneously recorded at the remote station except for the vertical magnetic component (*Hz*). The spacing between electrodes for measuring *Ex* and *Ey* is basically 100 m.

The time series data were recorded basically during the night from 14:00 P.M. to 8:00 A.M. of the following day, since there is presumed to be less artificial noise during the night than during the daytime. The frequency of measured data ranged from 320 Hz to 0.001 Hz. From this frequency range, MT parameters at more than 50 frequencies were calculated. Time series of the field data were acquired at the local and at the remote station simultaneously. The time series data were saved on a USB memory device of 1 GB capacity. Measured data at each station were transferred to a portable computer using the USB memory device and were archived on an external hard disk drive in the field residence. The MT layout sketch is shown in Fig. III-2-23.

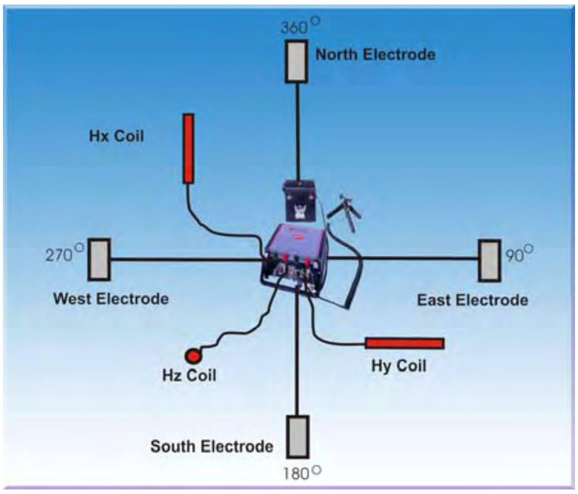


Fig.III-2-23 MT Equipment Layout

d. Data processing in the field to control data quality

Data processing using the remote reference technique was carried out by members of PT. Elnusa TBK on the time series acquired from the remote site and on those from the measuring stations in the Tulehu survey area. After data processing, the following MT parameters were calculated: apparent resistivity versus frequencies, impedance phase versus frequencies, standard deviations of apparent resistivity and impedance phase values, and the other MT parameters such as coherencies. With reference to these parameters on the display, cross-power data were edited of noise to reduce the standard deviation and enhance resistivity continuity. After this editing was done by PT. Elnusa TBK, West JEC evaluated the data quality for each measuring station. The standard deviation of the fair data is not small at low frequencies, but it is still possible to trace apparent resistivity changes. In a situation like this, the sounding curve passes quality control. When data quality was not good enough for data analysis, re-acquisition of data was carried out at the same station or - in the worst case - the station was moved to a new site (an adjacent area).

Cross-power data at each frequency, consisting of a minimum of 40 time-segments (entire measurement time divided by 40), was created after the remote reference data processing. Some segments could be rather noisier than others for various reasons such as signal strength, wind noise, artificial electromagnetic noise and so on, so cross-power editing was carried out to improve the data quality by selecting good time segments. This work was carried out every night in the base-camp after the daytime fieldwork by geophysicists of PT. Elnusa TBK, and after the work by PT. Elnusa TBK, a geophysicist of West Japan Engineering Consultants, Inc. made a check of every item of edited data.

e. Data analysis

The final objective of the data analysis is to obtain the horizontal and vertical resistivity distributions over the explored area. The resistivity distribution will assist interpretation from the standpoint of electrical resistivity structure.

(1) Outline of Analysis

The apparent resistivity is calculated from the ratio of the magnitudes of the electric and magnetic fields using the well-known Cagniard equation (Cagniard, 1953). This equation is obtained from Maxwell’s equations assuming a plane wave,

$$\rho_a = \frac{0.2}{f}\left|\frac{E}{H}\right|^2 \qquad [1]$$

where ρ_a, f, E and H are apparent resistivity in ohm-m, frequency in Hz, electric field magnitude in mV/km and magnetic field magnitude in nT, respectively. The effective depth of MT exploration is dependent upon the resistivity of the rock and the frequencies being measured. The effective depth of penetration can be determined from the following equation,

$$\delta = 355 \times (\rho / f)^{1/2} \qquad [2]$$

where δ, ρ and f are effective penetration depth in meters, apparent resistivity in ohm-m and frequency in Hz, respectively. When the resistivity changes with depth, the apparent resistivity varies with frequency. The penetration of the electromagnetic wave into the earth medium will depend on its frequency. Deep penetration is made with low frequencies whereas the contrary is true with high frequencies. This means that the resistivity structure from the shallow zone to the deep zone can be analyzed with data from higher to lower frequencies.

In general, apparent resistivity at each frequency varies with respect to the orientation of the measurements. The electric field *Ex* is partly induced by *Hy*, but also partly produced by currents induced by *Hx*, which have been affected by the structure underground. The same is true for *Ey*, thus the mathematical relations can be written as follows,

$$\begin{aligned} Ex &= ZxxHx + ZxyHy \\ Ey &= ZyxHx + ZyyHy \end{aligned} \qquad [3]$$

where *Ex*, *Ey*, *Hx*, *Hy* and *Z* are the component of E in the x direction (in mV/km), the component of E in the y direction (in mV/km), the component of H in the x direction (in gamma), the component of H in the y direction (in gamma) and impedance tensor elements relating *Ei* to *Hj* (in ohm-m), respectively. The vertical magnetic field *Hz* is given by the following equation,

$$Hz = A \cdot Hx + B \cdot Hy \qquad [4]$$

where *A* and *B* are constant values. The impedance tensor elements *Zij* are parameters which contain resistivity information. Apparent resistivity values can be calculated from the impedance tensor elements using the Cagniard equation.

(2) Remote Reference Data Processing

In the Tulehu survey, the remote reference technique was employed to reduce non-coherent noise in the time series data. In this technique, the measuring time and band numbers written in the time series data during data acquisition are referenced to synchronize the data at the measuring station with that at the remote reference site. In the Tulehu survey, more than 40 cross-power data were created from remote reference processing and the impedance tensor elements were calculated using the following equations:

$$\left.\begin{aligned}
Zxx &= (< ExHxr^* >< HyHyr^* > - < ExHyr^* >< HyHxr^* > \\
&\quad /< HyHxr^* >< HxHyr^* > - < HyHyr^* >< HxHxr^* > \\
Zxy &= (< ExHxr^* >< HxHyr^* > - < ExHyr^* >< HxHxr^* > \\
&\quad /< HyHxr^* >< HxHyr^* > - < HyHyr^* >< HxHxr^* > \\
Zyx &= (< EyHxr^* >< HyHyr^* > - < EyHyr^* >< HyHxr^* > \\
&\quad /< HyHxr^* >< HxHyr^* > - < HyHyr^* >< HxHxr^* > \\
Zyy &= (< EyHxr^* >< HxHyr^* > - < EyHyr^* >< HxHxr^* > \\
&\quad /< HyHxr^* >< HxHyr^* > - < HyHyr^* >< HxHxr^* >
\end{aligned}\right\} \qquad [5]$$

where *Ex*, *Ey*, *Hx*, *Hy*, *Hxr* and *Hyr* are the component of E at the station in the x direction (in mV/km), the component of E at the station in the y direction (in mV/km), the component of H at the station in the x direction (in gamma), the component of H at the station in the y direction (in gamma), the component of H at the remote site in the x direction (in gamma) and the component of H at the remote site in the y direction (in gamma), respectively. In the above equations, "*" indicates a conjugate complex. Apparent resistivity values (ρ_{xy}, ρ_{yx}) and phase values (ϕ_{xy}, ϕ_{yx}) were calculated using the following equations.

$$\left.\begin{aligned}\rho_{xy} &= (1/5f)|Zxy|^2 \\ \rho_{yx} &= (1/5f)|Zyx|^2 \\ \phi_{xy} &= \tan^{-1}(\mathrm{Im}(Zxy)/(\mathrm{Re}(Zxy)) \\ \phi_{yx} &= \tan^{-1}(\mathrm{Im}(Zyx)/(\mathrm{Re}(Zyx))\end{aligned}\right\} \qquad [6]$$

(3) Static Shift Correction for MT

Very small-scale inhomogeneities (that is, with dimensions much less than the skin depth at the highest recorded frequency) can produce a shift of the MT apparent resistivity sounding curve, moving it parallel to the undistorted curve on a log-scale apparent resistivity versus log-scale frequency plot. This parallel shift is commonly referred to as a static shift. Removing this effect from the data is important in interpreting the subsurface resistivity structure. As the static shift is caused by very small-scale inhomogeneities just below the ground surface, high frequency apparent resistivity data at a station located over a very small-scale inhomogeneity is very different from that at adjacent stations. The following method was employed to remove the static shift effect in the data processing.

- First, a distribution map of the invariant resistivity at high frequency is made after a calculation of the invariant apparent resistivity value at each station.
- Then small-scale disturbances in the invariant apparent resistivity distribution are observed in the invariant apparent resistivity distribution map.
- When abrupt resistivity changes between adjacent stations are observed in the invariant apparent resistivity distribution at high frequency, the distorted apparent resistivity value is shifted up or down to match the invariant apparent resistivity values at adjacent stations. For this process, a smoothing technique with weights at each station or a median filter technique is applied to obtain smoothly distributed invariant apparent resistivity values.
- Static shift correction factors are estimated from the difference between the shifted values in the previous step and the original values.

Apparent resistivity data corrected using static shift correction factors was used for the three-dimensional resistivity inversion analysis. The static shift correction factors are listed in Table III-2-6.

Table III-2-6 Static Shift Values for MT Survey

[redacted]

(rotated angle : N35^{o}W)

(4) Three-dimensional Resistivity Modeling

In three-dimensional resistivity modeling, it is assumed that a subsurface body consists of rectangular parallelepiped blocks of resistivity, as shown in Fig. III-2-24. Resistivity values for every resistivity blocks are determined by iterating the calculation to minimize the value of $\Sigma(\log(\rho_{obs}) - \log(\rho_{cal}))^2$ + Σ(observed phase values – calculated phase values)^2, where ρ_{obs} and ρ_{cal} are observed apparent resistivity values and calculated apparent resistivity values, respectively. This analysis is expected to lead to a more accurate subsurface resistivity model than that derived from 1-D and 2-D resistivity analysis.

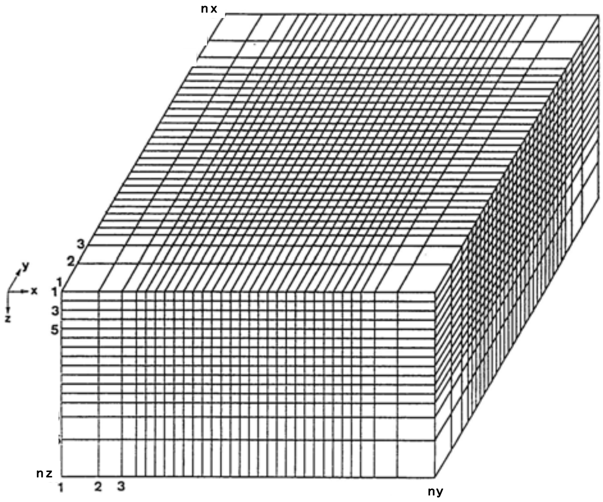


Fig.III-2-24 Three-Dimensional Mesh for Finite Difference 3-D Resistivity Modeling

In the forward modeling of the electromagnetic field, the earth is divided into a number of blocks of constant conductivity and so the forward modeling method needs to have the ability to handle a wide variety of conductivity distribution. The 3-D electromagnetic field can be explained by Maxwell's equations,

$$\nabla \times E = i\omega\mu H \qquad [7]$$

$$\nabla \times H = \sigma E \qquad [8]$$

where ω, μ and σ are angular frequency, magnetic permeability and electric conductivity, respectively. The displacement current is ignored because it is very small. From equations [7] and [8], the following equations are derived.

$$\nabla \times (\nabla \times H) = \nabla \times \sigma E = \sigma \times \nabla \times E = k^2 H \qquad [9]$$

$$\nabla \times (\nabla \times E) = \nabla \times i\omega\mu H = i\omega\mu \times \nabla \times H = k^2 E \qquad [10]$$

$$k^2 = i\omega\mu\sigma$$

After introducing the orthogonal coordinate system, [9] and [10] lead to equation [11] and equation [12], respectively.

$$\left.\begin{aligned}
&\partial^2 Hx / \partial y^2 + \partial^2 Hx / \partial z^2 - \partial^2 Hy / \partial x \partial y - \partial^2 Hz / \partial x \partial z - k^2 Hx = 0 \\
&\partial^2 Hy / \partial x^2 + \partial^2 Hy / \partial z^2 - \partial^2 Hx / \partial y \partial x - \partial^2 Hz / \partial y \partial z - k^2 Hy = 0 \\
&\partial^2 Hz / \partial x^2 + \partial^2 Hz / \partial y^2 - \partial^2 Hx / \partial z \partial x - \partial^2 Hz / \partial z \partial y - k^2 Hz = 0
\end{aligned}\right\} \quad [11]$$

$$\left.\begin{aligned}
&\partial^2 Ex / \partial y^2 + \partial^2 Ex / \partial z^2 - \partial^2 Ey / \partial x \partial y - \partial^2 Ez / \partial x \partial z - k^2 Ex = 0 \\
&\partial^2 Ey / \partial x^2 + \partial^2 Ey / \partial z^2 - \partial^2 Ex / \partial y \partial x - \partial^2 Ez / \partial y \partial z - k^2 Ey = 0 \\
&\partial^2 Ez / \partial x^2 + \partial^2 Ez / \partial y^2 - \partial^2 Ex / \partial z \partial x - \partial^2 Ez / \partial z \partial y - k^2 Ez = 0
\end{aligned}\right\} \quad [12]$$

In a finite-difference scheme on a staggered grid (see Fig. III-2-25), the solution region (including air layers) is discretized into rectangular cells. To calculate the magnetic fields (Hx, Hy and Hz) using equation [11], the following equations should be solved simultaneously.

$$\begin{aligned}
iw\mu Hx(i,j,k)\, dy\, dz = &<\rho zz>\{Hy(i+1,j,k) - Hy(i,j,k) - Hx(i,j+1,k) + Hx(i,j,k)\} / dz \\
&- <\rho zz>\{Hy(i+1,j-1,k) - Hy(i,j-1,k) - Hx(i,j,k) + Hx(i,j-1,k)\} / dz \\
&- <\rho yy>\{Hx(i,j,k+1) - Hx(i,j,k) - Hz(i+1,j,k) + Hz(i,j,k)\} / dy + <\rho yy>\{Hx(i,j,k)
\end{aligned}$$

$$- Hx(i,j,k-1) – Hz(i+1,j,k-1) + Hz(i,j,k-1)\} / dy \qquad [13]$$

$$\begin{aligned} i w \mu Hy(i,j,k)\, dx\, dz = {} & <\rho xx>\{Hz(i,j+1,k) - Hz(i,j,k) - Hy(i,j,k+1) + Hy(i,j,k)\} / dx \\ & - <\rho xx>\{Hz(i,j+1,k-1) - Hz(i,j,k-1) - Hy(i,j,k-1) + Hy(i,j,k-1)\} / dx \\ & - <\rho zz>\{Hy(i+1,j,k) - Hy(i,j,k) - Hx(i,j+1,k) + Hx(i,j,k)\} / dz + <\rho zz>\{Hy(i,j,k) \\ & - Hy(i-1,j,k) - Hx(i-1,j+1,k) + Hx(i-1,j,k)\} / dz \qquad [14] \end{aligned}$$

$$\begin{aligned} i w \mu Hz(i,j,k)\, dx\, dy = {} & <\rho yy>\{Hx(i,j,k+1) - Hx(i,j,k) - Hz(i-1,j,k+1) + Hz(i,j,k)\} / dy \\ & - <\rho yy>\{Hx(i-1,j,k+1) - Hx(i-1,j,k) - Hz(i,j,k) + Hz(i-1,j,k)\} / dy \\ & - <\rho xx >\{Hz(i,j+1,k) - Hz(i,j,k) - Hy(i,j,k+1) + Hy(i,j,k)\} / dx + <\rho xx>\{Hz(i,j,k) \\ & - Hz(i,j-1,k) - Hy(i,j-1,k+1) + Hy(i,j-1,k)\} / dx \qquad [15] \end{aligned}$$

In the above equations, $<\rho xx>$, $<\rho yy>$ and $<\rho zz>$ are respectively given by the following formulas: $\{\rho(i-1,j,k) + \rho(i,j,k)\} / 2.0$, $\{\rho(i,j-1,k) + \rho(i,j,k)\} / 2.0$ and $\{\rho(i,j,k) + \rho(i,j,k-1)\} / 2.0$. The symbols dx, dy and dz represent grid spacing in the x, y and z directions, respectively.

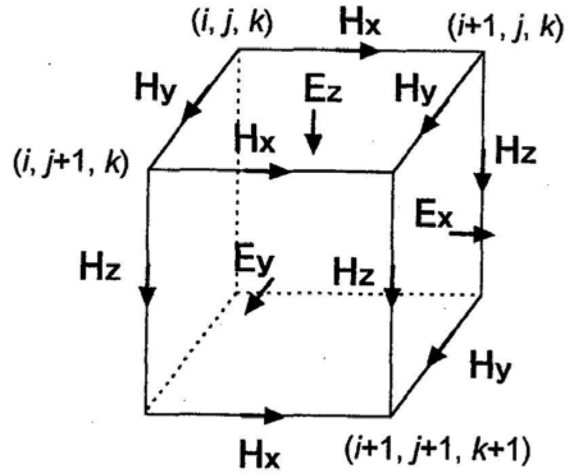


Fig.III-2-25 Staggered Grid Configuration

In solving equation [13], [14] and [15] simultaneously, the tangential magnetic fields on the boundaries of the model for the appropriate source polarization will be assigned. These boundary values come from a one-dimensional (horizontally layered) calculation. The values obtained at the positions corresponding to the boundaries of the 3-D model are then used as boundary values for the 3-D electromagnetic forward modeling of MT data. In addition, several air layers were added on the top of the earth model with an approximately logarithmically increasing thickness for each layer. These layers should extend far enough above the ground to allow the longest wavelength perturbations to be damped out (it is usual to use three times the largest wavelength of the horizontal conductivity variations in the earth model). These air layers are given a finite, but high, resistivity value of 10^6 ohm-m. At the top of the air layers, an one-dimensional plane-wave impedance for outgoing fields is used. Likewise, an one-dimensional plane wave impedance for a layered media is used at the bottom of the earth model.

Although the topography was not considered in the forward modeling, we could assume that topographic effects were accounted for as part of the static shift. In addition, little correlation has been found between topographic variation and apparent resistivity variations. Thus the topographic effects are considered to have little impact on the data analysis. Once the magnetic field values (Hx, Hy and Hz) are obtained from equations [13], [14] and [15], the electric field values (Ex and Ey) can be calculated by using equation [8]. Finally, apparent resistivity and impedance phase values for the appropriate source polarization can be calculated with the following equations.

$$\left.\begin{aligned}\rho xy &= 1/i\omega\mu \cdot \left|Ex/Hy\right| \\ \phi xy &= \arg(Ex/Hy)\end{aligned}\right\} \qquad [16]$$

$$\left.\begin{aligned}\rho yx &= 1/i\omega\mu \cdot \left|Ey/Hx\right| \\ \phi yx &= \arg(Ey/Hx)\end{aligned}\right\} \qquad [17]$$

(5) Three-dimensional Inversion Scheme

The scheme used in the three-dimensional (3-D) resistivity inversion is based on linearized least-squares inversion with a smoothness constraint. For this method, we minimize the following function *U*.

$$U = (W\Delta d - WA\Delta m)^T (W\Delta d - WA\Delta m) + \alpha (C\Delta m)^T (C\Delta m) \qquad [18]$$

In the above equation, *W* is a weighting matrix, *Δd* is a vector of differences between modeled responses and observed data, *Δm* is the correction vector to the model parameter, *A* is the Jacobian matrix, α is a smoothing factor, and *C* is a roughening matrix. The first term on the right hand side of equation [18] shows the data misfit and the second term shows the roughness of the 3-D resistivity model blocks. The correction vector to the model parameter, *Δm*, which minimizes the function *U*, can be obtained by solving equation [19]. Since the relation between model parameters and model response is non-linear, equation [19] is solved iteratively to obtain the final 3-D resistivity model.

$$\{\{(WA)^T (WA) + \alpha C^T C\} \Delta m_{K+1} = (WA)^T \Delta d \qquad [19]$$

In this equation, Δm_{k+1} represents the correction vector to the model parameter at the (k+1)th iteration and A is a Jacobian matrix consisting of partial derivatives of the MT responses with respect to the model parameters. The final 3-D model parameters (resistivity values in the 3-D resistivity model blocks) can be obtained to solve equation [19] repeatedly until the misfit value between the observed data (apparent resistivity and phase) and calculated data obtained from the 3-D resistivity model becomes small.

(6) General Resistivity Structure in Volcanic Geothermal Fields

When a resistivity survey is undertaken for geothermal exploration, detection of a low resistivity zone (layer or area) and a resistivity discontinuity will be focused on. A low resistivity zone is usually defined as a zone giving a resistivity of lower than 10 ohm-m (or 5 ohm-m). Rocks constituting a subsurface solid body are usually resistive bodies giving a resistivity of some hundreds of ohm-m or higher than that value. However, hydrothermal alteration changes constituent minerals in the rocks. Under relatively low temperature conditions (less than 200°C), hydrothermal alteration brings about the occurrence of smectite and/or interstratified clay minerals (for example, chlorite-smectite interstratified mineral or illite-smectite interstratified mineral). As smectite and the smectite component in interstratified clay minerals have exchangeable cations, hydrothermal alteration changes the rock property from resistive to conductive. Therefore, a detected low resistivity zone is regarded to be a geothermal anomaly indicating the presence of geothermal resources.

Analysis of resistivity data from a geothermal field in a volcanic region usually yields a resistivity structure composed of three zones (or layers), namely a resistive overburden, a low resistivity zone and a resistive zone at depth, from the shallower portion to the deeper portion (as shown in Fig. III-2-26). A resistive overburden is a resistive zone near the ground surface. A low resistivity zone is very conductive and lies below the resistive overburden. A resistive zone at depth lies below the low resistivity zone and is relatively resistive compared with the low resistivity zone. A resistive overburden usually shows a resistivity of several hundreds of ohm-m or some thousands of ohm-m. This overburden is composed of resistive rocks such as volcanic ash, alluvium, fresh volcanic rocks and so on. Information concerning this shallow zone is of little importance in studying the geothermal structure compared with the other two zones.

A low resistivity zone is not generally correlative with a particular geological formation, but this zone is usually correlative with an argillized zone characterized by occurrence of smectite and interstratified clay minerals containing a smectite component. In many cases, this zone will prove to be the cap rock of a geothermal reservoir. A resistive zone under the low resistivity zone gives intermediate resistivity of several tens of ohm-m to some hundreds of ohm-m. This zone also is not correlative with geological formations, because the resistivity of rocks in geothermal fields is strongly affected by the degree of hydrothermal alteration, porosity, electrolytes and temperature rather than rock types generally. This relatively resistive zone below a low resistivity zone often reflects a relatively fresh rock body or alteration products formed under high-temperature conditions such as chlorite, illite, epidote and so on. The geoelectrical features of a low resistivity zone and a resistive zone at depth in and around a geothermal reservoir are as follows.

- A remarkable resistivity discontinuity can be continuously mapped from station to neighboring station. An uplifted structure is clearly recognized along the resistivity discontinuity. The resistivity discontinuity usually reflects fractured zones along a fault.
- Resistivity values for the low resistivity zone along the resistivity discontinuity are smaller than those in the surrounding area and the low resistivity zone generally and usually indicate the cap rock of the reservoir in geothermal fields. Such a zone is marked ρ_α in Fig. III-2-26.
- A high temperature zone is usually identified in a resistive zone under the low resistivity zone. Moreover, an uplifted resistive zone is usually detected around the center of geothermal activity. This uplift-structure will have resulted from the following temperature condition: subsurface temperature is quite high at a shallower depth around the activity center and secondary minerals resulting from alteration (for example, illite, chlorite, and so on) do not decrease rock resistivity, unlike smectite.

In most volcanic geothermal fields, the geothermal reservoir occurs along a fractured zone resulting from faulting. In this case, hot water flowing up along the fractured zone from a deep geothermal reservoir creates an argillized zone characterized by smectite and/or interstratified clay minerals extending over the reservoir. This argillized zone will be detected as a low resistivity zone extending over an uplifted resistive zone (see Fig. III-2-26). And this low resistivity zone can be regarded as an impermeable zone (cap rock). For drilling target selection, consideration not only of the distribution of low resistivity zones, but also of geological and hydrological information will be required.

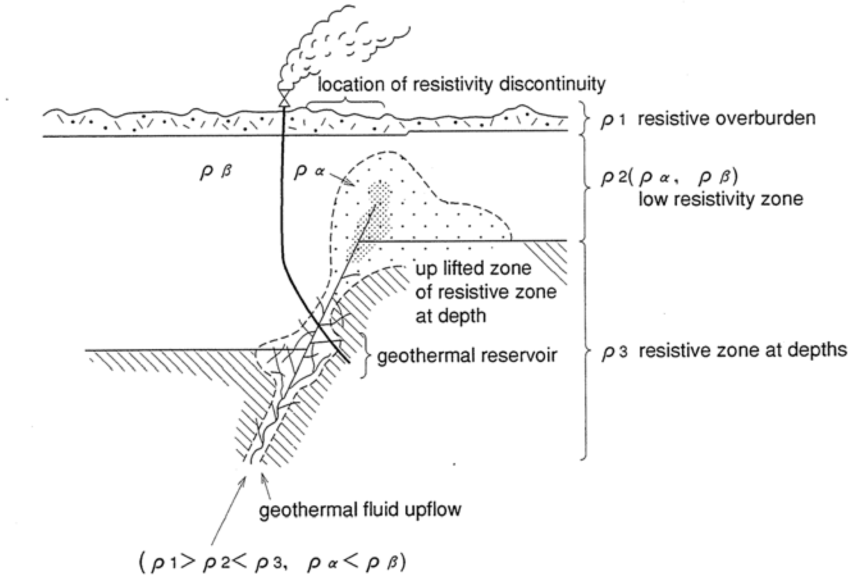


Fig.III-2-26 Typical Resistivity Structure in and around a Geothermal Reservoir

3. Results of MT Survey

a. Apparent resistivity

As described previously, electromagnetic frequencies are related to penetration depths in MT theory. Namely, the apparent resistivity at high frequencies reflects the resistivity structure in the shallow zone and that at low frequencies reflects the resistivity structure in the deep zone. Thus, apparent resistivity contour maps at 100 Hz, 1 Hz and 0.1 Hz are made. Apparent resistivity values of determinant mode are used in these maps, since determinant mode apparent resistivity values are averages of ρ_{xy} and ρ_{yx} apparent resistivity values. However, since the penetration depths of electromagnetic signals at every station differ from each other, and the apparent resistivity value is a sort of accumulated resistivity from ground surface to the penetration depth, an interpretation based on the apparent resistivity maps at different frequencies is often misleading concerning the actual subsurface resistivity structure. Here, to avoid being misleading, only a general description will be attempted from the apparent resistivity maps at different frequencies. An objective discussion of the subsurface resistivity structure will be presented in connection with the maps and sections obtained from 3-D resistivity inversion.

An apparent resistivity map (determinant mode, 100 Hz) is shown in Fig. III-2-27. The apparent resistivity values at 100 Hz range from 5 ohm-m to 65 ohm-m, approximately. The resistivity information is from the surface to the penetration depth, which is roughly in the range of 80 m to 290 m. In this apparent resistivity map at a frequency of 100 Hz, a low apparent resistivity zone of less than 8 ohm-m is distributed widely from the central portion to the eastern portion of the survey area around stations MT16, MT17, MT21, MT22, MT26 and MT27. The low apparent resistivity zone shows a strong tendency to extend in an approximately NE-SW direction. Since some geothermal manifestations including hot springs are located inside of this low apparent resistivity zone, this low anomaly is likely to indicate a hydrothermally altered zone related to the geothermal manifestations.

An apparent resistivity map (determinant mode, 1 Hz) is shown in Fig. III-2-28. The apparent resistivity values at 1 Hz range from 3 ohm-m to 32 ohm-m approximately. The resistivity information is from the surface to the penetration depth, which is roughly in the range of 600 m to 2,000 m. The pattern of apparent resistivity distribution in this map is similar to that at 100 Hz, while the apparent resistivity values are slightly lower than those at 100 Hz. However, in this map, a low apparent resistivity zone of less than 8 ohm-m is more widely distributed in the northern and western portions of the survey area compared to the low apparent resistivity zone distributed at a frequency of 100 Hz.

An apparent resistivity map (determinant mode, 0.1 Hz) is shown in Fig. III-2-29. The apparent resistivity values at 0.1 Hz range from 20 ohm-m to 65 ohm-m approximately. The resistivity information is from the surface to the penetration depth, which is greater than 5,000 m. The pattern of apparent resistivity distribution in this map differs from the patterns at 100 Hz and 1 Hz, and no low resistivity zone of less than 10 ohm-m can be detected, though a relatively low apparent resistivity zone of less than 25 ohm-m is recognized around the stations MT16, MT20 and MT21.

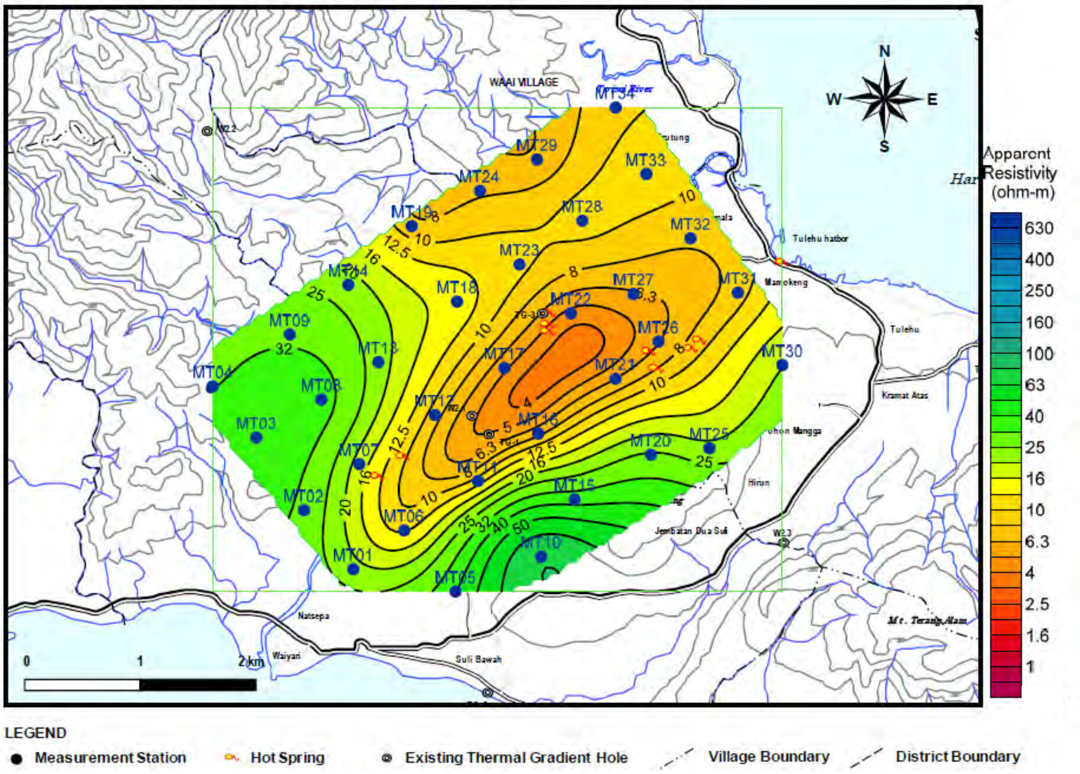


Fig.III-2-27 Apparent Resistivity Map at a Frequency of 100 Hz

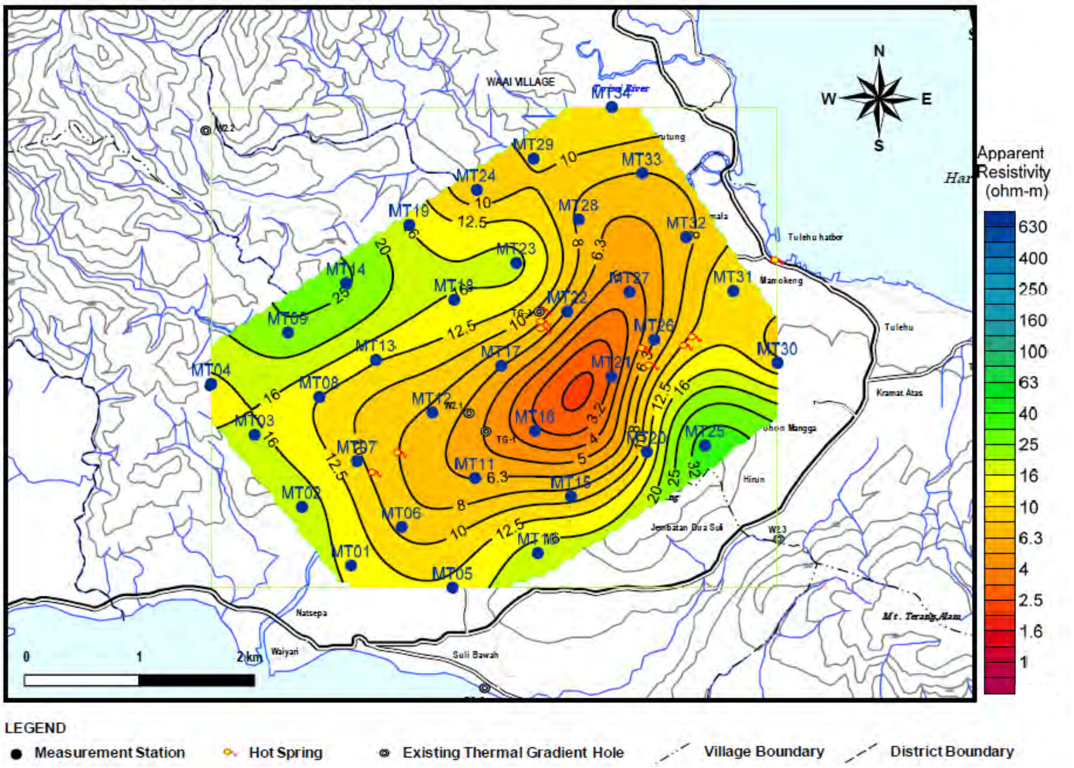


Fig.III-2-28 Apparent Resistivity Map at a Frequency of 1 Hz

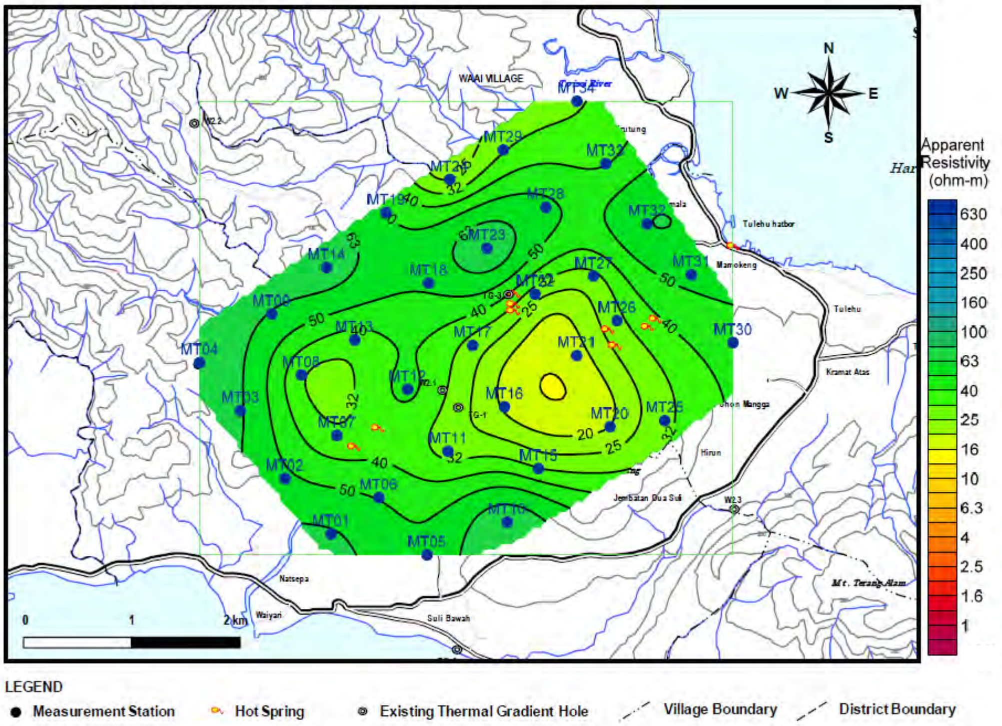


Fig.III-2-29 Apparent Resistivity Map at a Frequency of 0.1 Hz

b. Three-dimensional MT inversion analysis

Three-dimensional resistivity inversion with smoothness constraints has been conducted with MT data acquired in the Tulehu geothermal field. The data used for the 3-D inversion were apparent resistivity and impedance phase values which are rotated to a N35^{o}W direction, in a frequency range between 100 Hz and 0.1 Hz approximately. The 3-D inversion scheme used in this work was based on the linearised iterative least-squares (Gauss-Newton) method with smoothness regularization. Forward modeling for a given, arbitrary 3-D earth was done using the staggered grid finite difference method (Mackie *et al*., 1994).

On the basis of the results obtained from the 3-D resistivity inversion, resistivity maps at different depths, namely 100 m, 150 m, 250m, 350 m, 500m, 750 m, 1,000m, 1,500 m, 2,000 m and 2,500 m were drawn. These maps are shown in Fig. III-2-30 to Fig. III-2-39. In addition, resistivity sections along lines A, B, C, D, E, F and G (refer to Fig. III-2-40) were prepared and these resistivity sections are shown in Fig. III-2-41. The resistivity model derived from the three-dimensional resistivity inversion roughly reveals three layers: a very shallow high resistivity layer of about 5 to 50 ohm-m, an intermediate low resistivity layer of less than 5 ohm-m underlying the upper high resistivity layer, and a deep high resistivity layer with values roughly greater than 20 ohm-m underlying the low resistivity layer.

(1) Resistivity Discontinuity

The resistivity discontinuity is a structure exhibiting a big lateral change in resistivity. If such structures are distributed continuously along a line, a fault and/or fractured zone will be expected along the resistivity discontinuities. In general, geothermal fluid is often reserved in and around the fault/fractured zone, so detecting the resistivity discontinuities is important in studying the geothermal structure in the survey area. In the Tulehu geothermal field, three resistivity discontinuities, R1, R2 and R3 can be recognized based on the 3-D resistivity inversion results.

Resistivity discontinuity R1 runs in the central portion of the survey area and its trend is in a ENE-WSW direction. Resistivity discontinuity R2 runs in the southeastern portion, trending in a NE-SW direction. Resistivity discontinuity R1 is clearly defined in the resistivity distribution at depths of 100 m and 150 m (see Figs. III-2-30 and III-2-31). Resistivity discontinuity R2 is defined in the resistivity distribution at depths of 100 m, 150 m, 700 m and 1,000 m (see Figs. III-2-30, III-2-31, III-2-35 and III-2-36). In addition, the features of resistivity discontinuities R1 and R2 are also depicted in the apparent resistivity map at a frequency of 100 Hz. Indications of resistivity discontinuities R1 and R2 are clear at shallow depths and a low resistivity zone of less than 5 ohm-m is recognized in between the discontinuities R1 and R2 at depths of 100 m and 150 m. This low resistivity zone must correspond to an argillized zone characterized by the occurrence of smectite and/or interstratified clay minerals. Moreover, some hot springs are situated around resistivity discontinuities R1 and R2. Therefore, detected resistivity discontinuities R1 and R2 must correspond to a fractured zone controlling the geothermal fluid.

Resistivity discontinuity R3 runs in the western portion of the survey area, trending in a NNW-SSE direction. Resistivity discontinuity R3 can be defined in the resistivity distributions at depths of 150 m and 250 m (see Figs. III-2-31 and III-2-32). Although the features of resistivity discontinuity R3 are relatively weak compared to those of resistivity discontinuities R1 and R2, resistivity discontinuity R3 may possibly indicate a fault or a fracture zone.

(2) Low Resistivity (Conductive) Zones

A remarkably low resistivity zone of less than 5 ohm-m extends between resistivity discontinuities R1 and R2 in a NE-SW direction at depths of 100 m and 150 m (see Figs. III-2-30 and III-2-31). As there are some hot springs and altered ground in this low resistivity zone, it must have resulted from an argillized rock containing a considerable amount of smectite and/or interstratified clay minerals, and affected by geothermal activity. This low resistivity zone is similar to those indicating the cap rock of the geothermal reservoir detected in many geothermal fields, and thus the low resistivity zone is considered to be an impermeable zone functioning as a cap rock of the geothermal reservoir in the Tulehu geothermal field.

(3) High resistivity (resistive) zone at depth

At depths of 750 m and 1,000 m, a high resistivity zone is identified around resistivity discontinuity R1 and between resistivity discontinuities R1 and R2, though the western and southern portions of the survey area show rather low resistivity (see Figs. III-2-35 and III-2-36). As mentioned above, a low resistivity zone extends over this high resistivity zone. As mentioned previously, a high temperature zone can be expected in a high resistivity zone with an overlying low resistivity zone. Therefore, this uplifted relatively high resistivity zone, detected at depths of 750 m and 1,000 m, is indicative of a higher temperature zone at depth compared with the surrounding area. In particular, the high resistivity zone around resistivity discontinuity R1 must be the most prospective zone. In addition, a high resistivity zone showing greater than 25 ohm-m seems to be distributed right across the northern portion of the survey area around MT stations MT14 and MT19. However, no low resistivity zone overlays the northern portion of this relatively high resistivity zone.

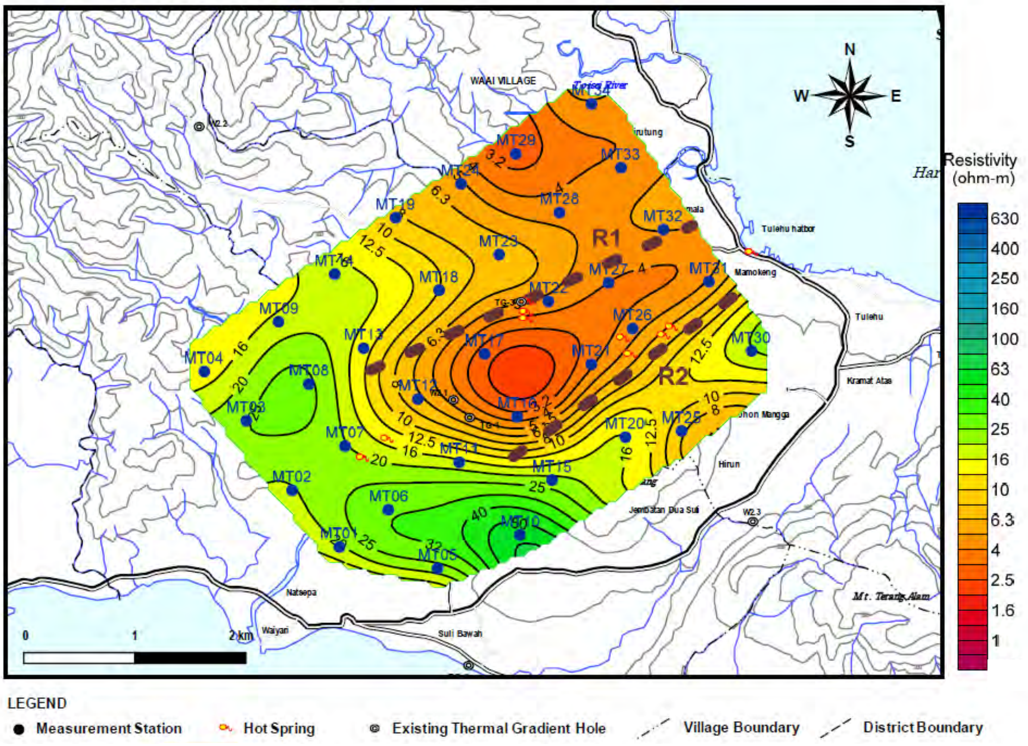


Fig.III-2-30 Resistivity Map at a Depth of 100 m

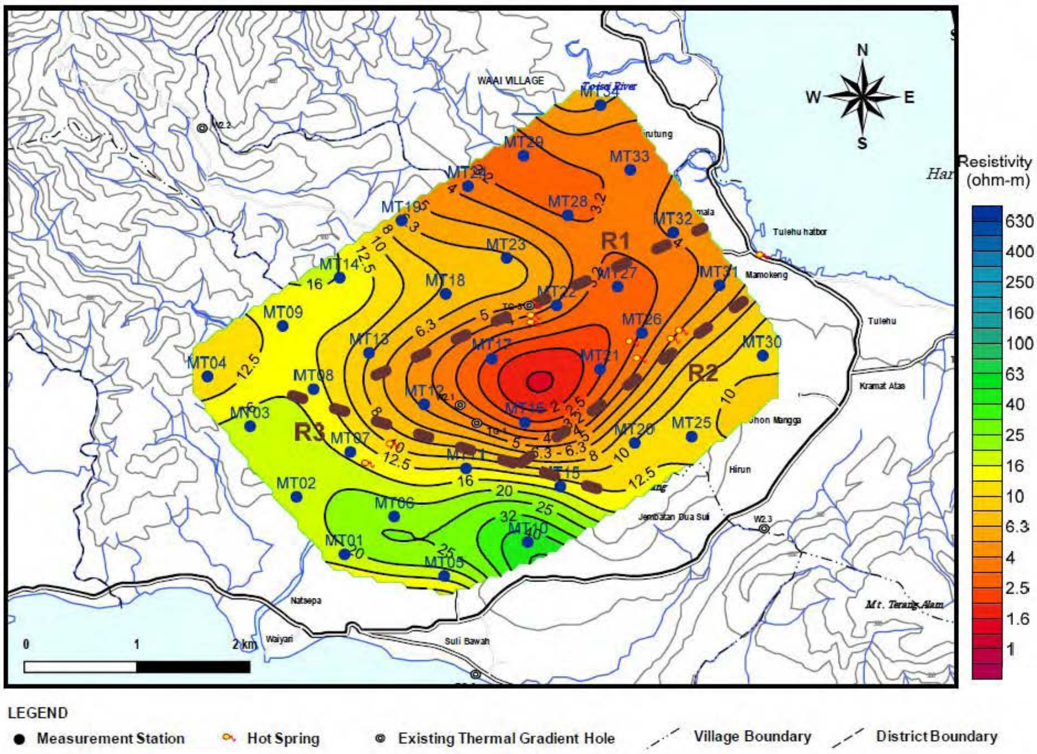


Fig.III-2-31 Resistivity Map at a Depth of 150 m

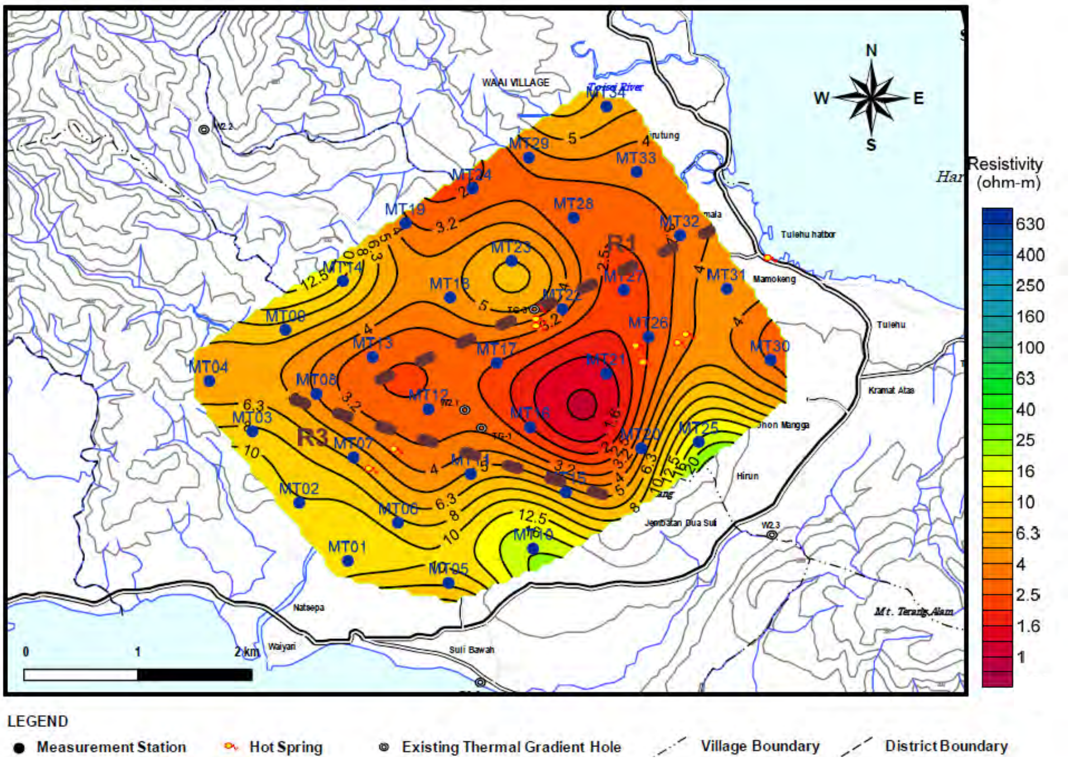


Fig.III-2-32 Resistivity Map at a Depth of 250 m

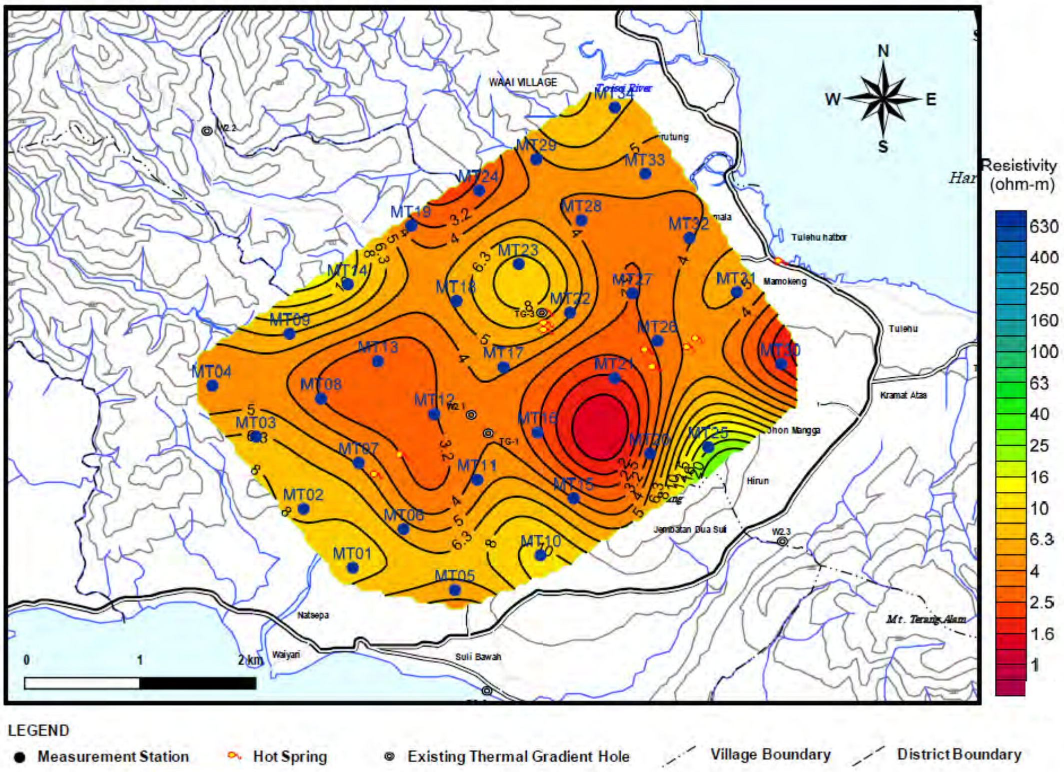


Fig.III-2-33 Resistivity Map at a Depth of 350 m

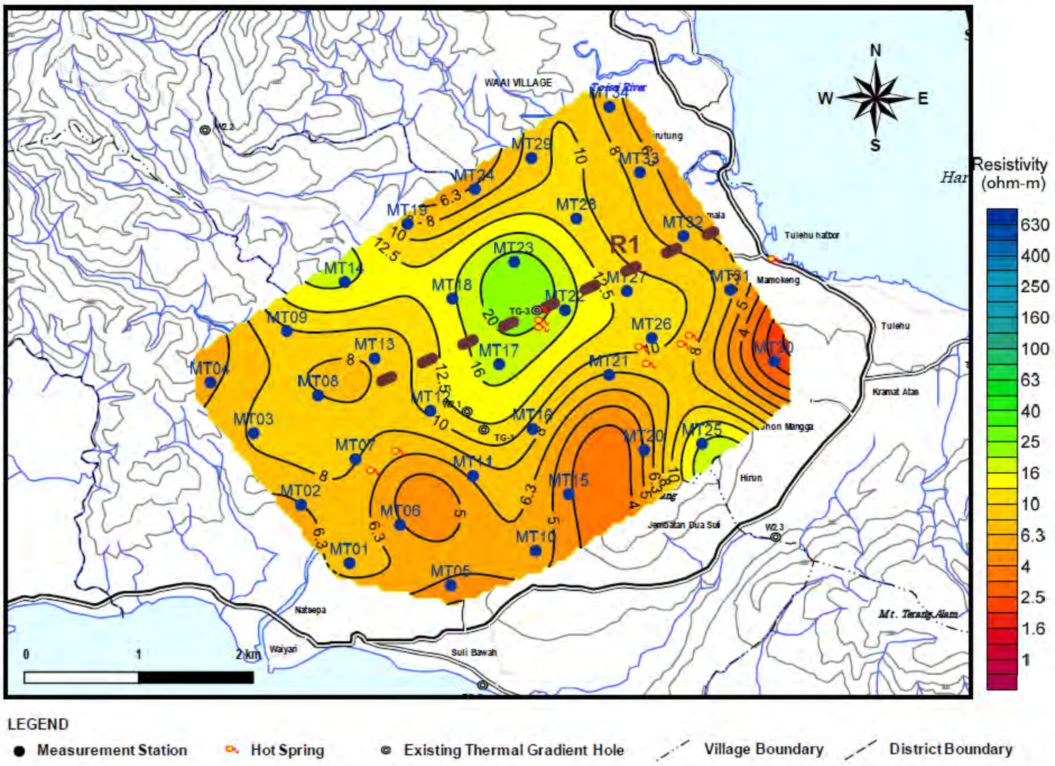


Fig.III-2-34 Resistivity Map at a Depth of 500 m

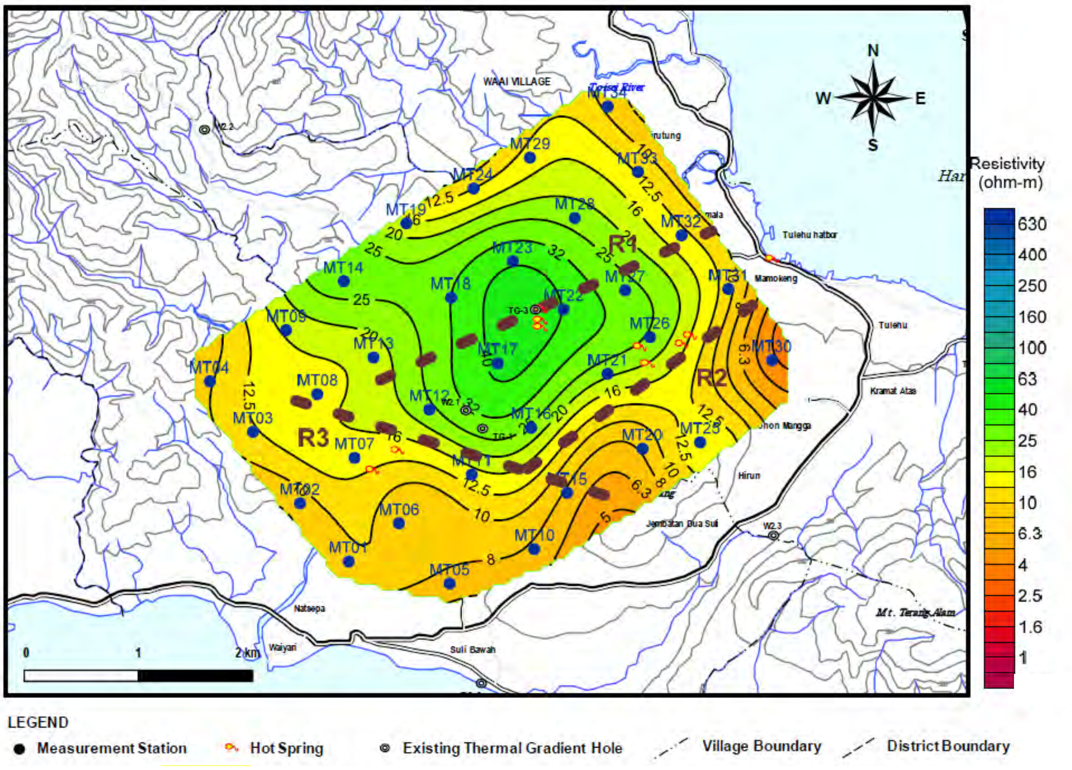


Fig.III-2-35 Resistivity Map at a Depth of 750 m

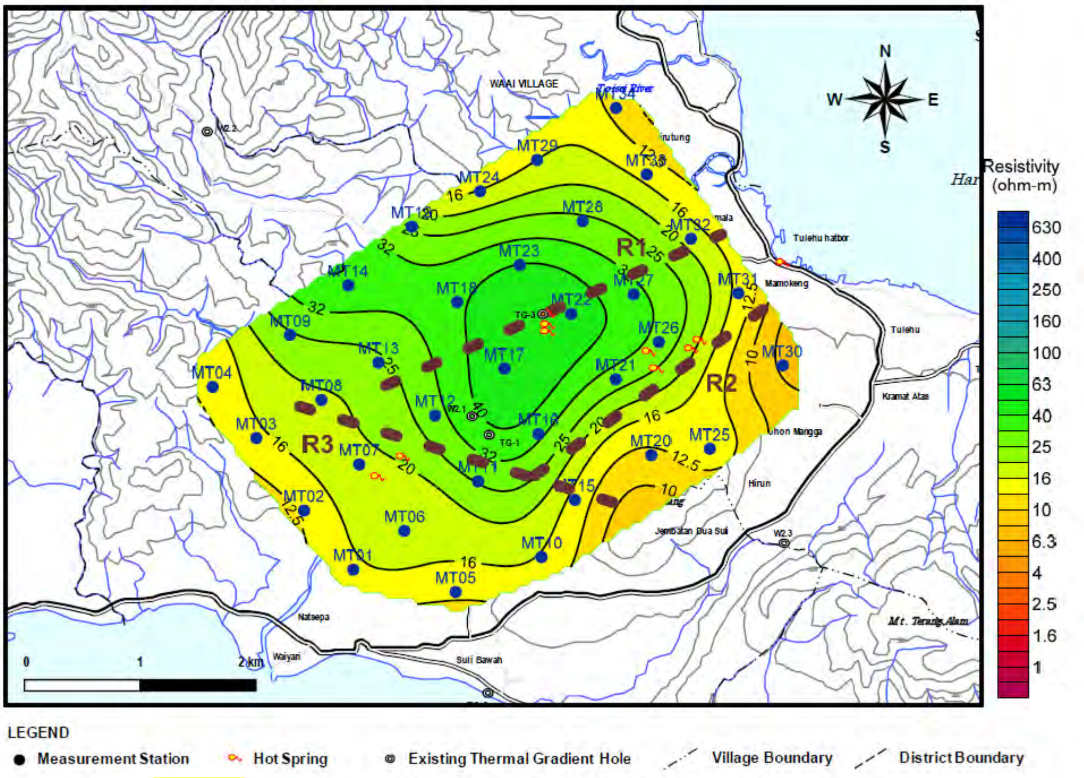


Fig.III-2-36 Resistivity Map at a Depth of 1,000 m

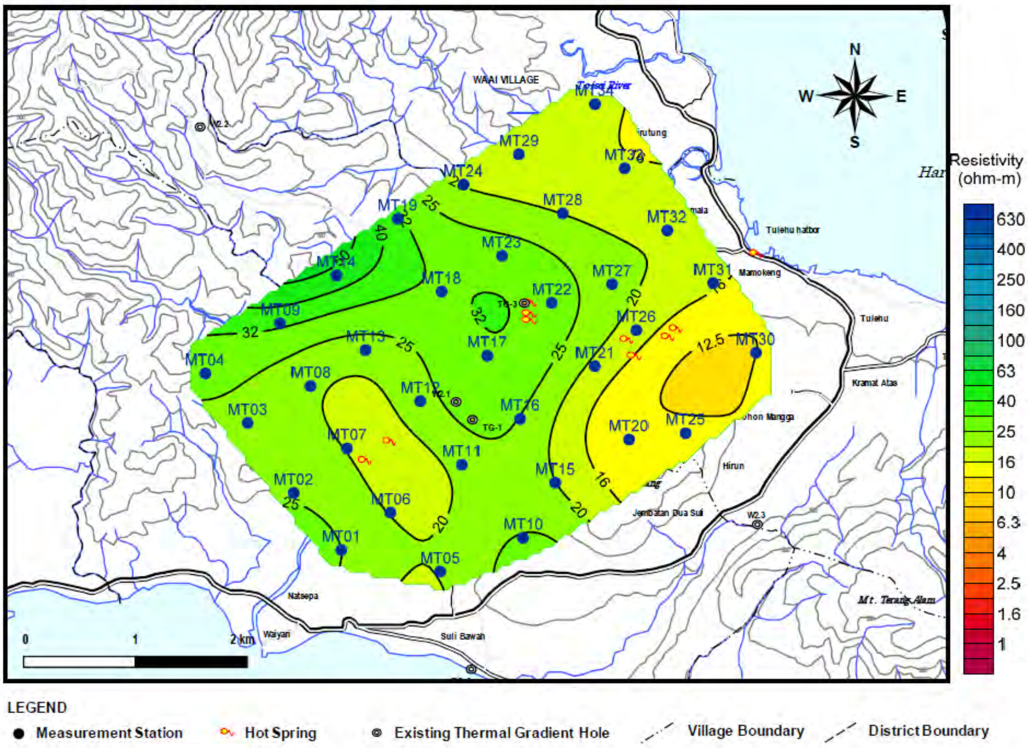


Fig.III-2-37 Resistivity Map at a Depth of 1,500 m

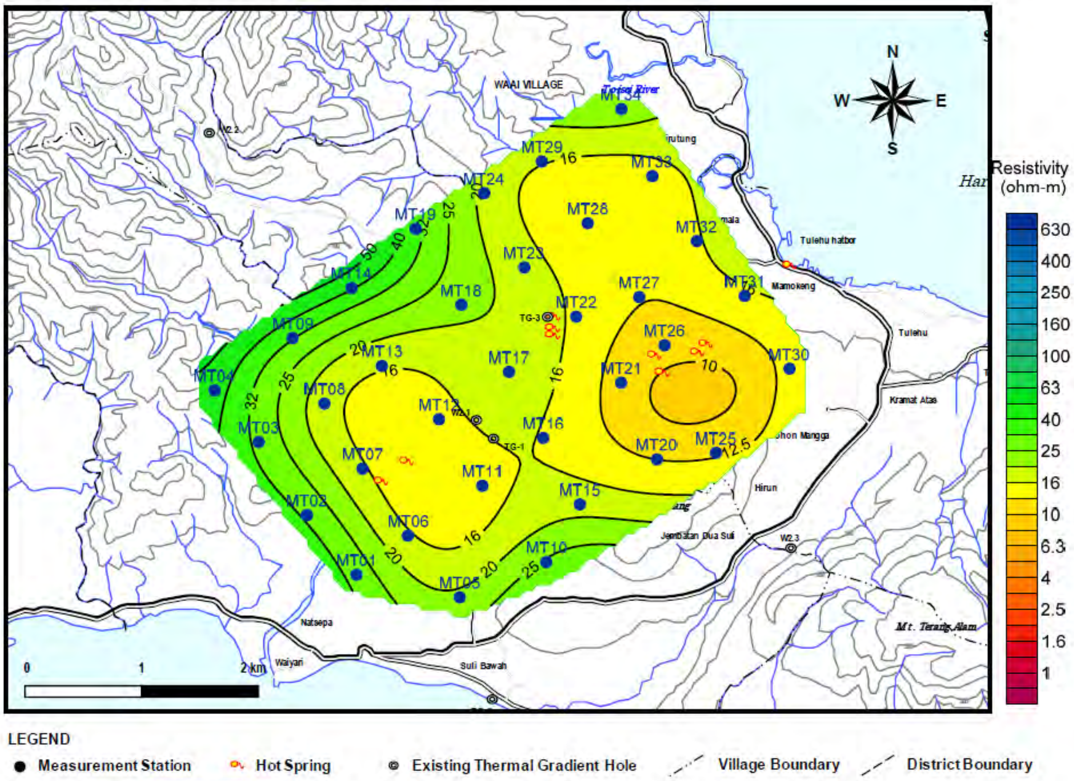


Fig.III-2-38 Resistivity Map at a Depth of 2,000 m

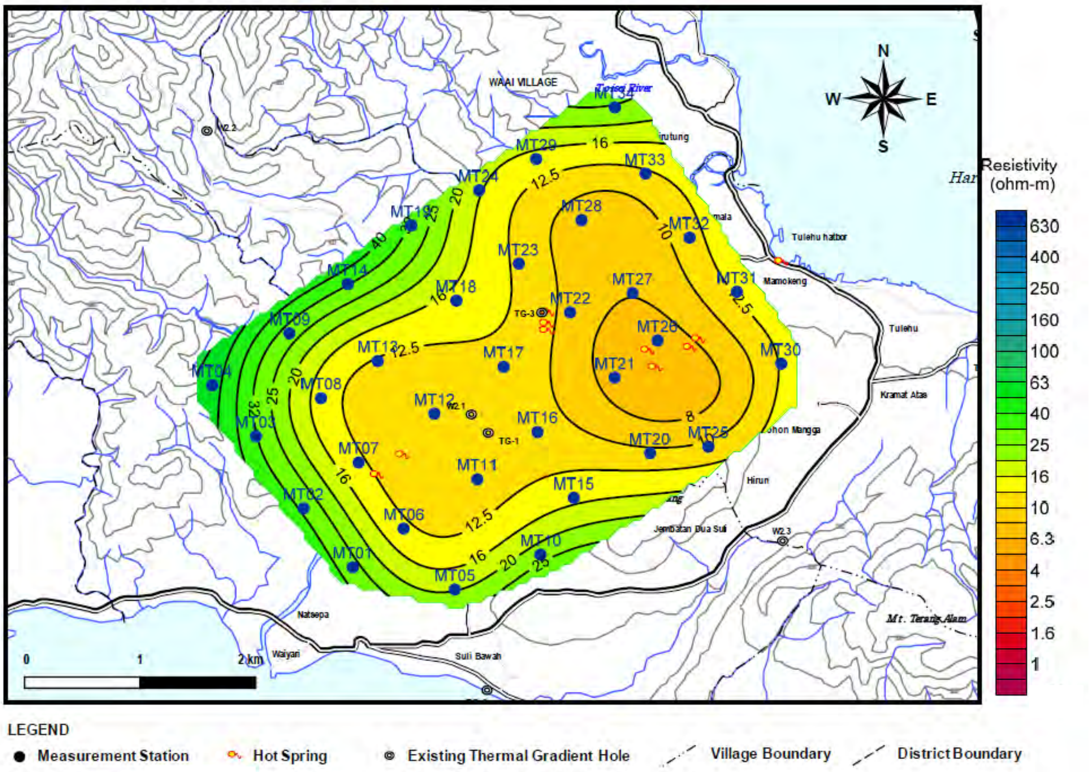
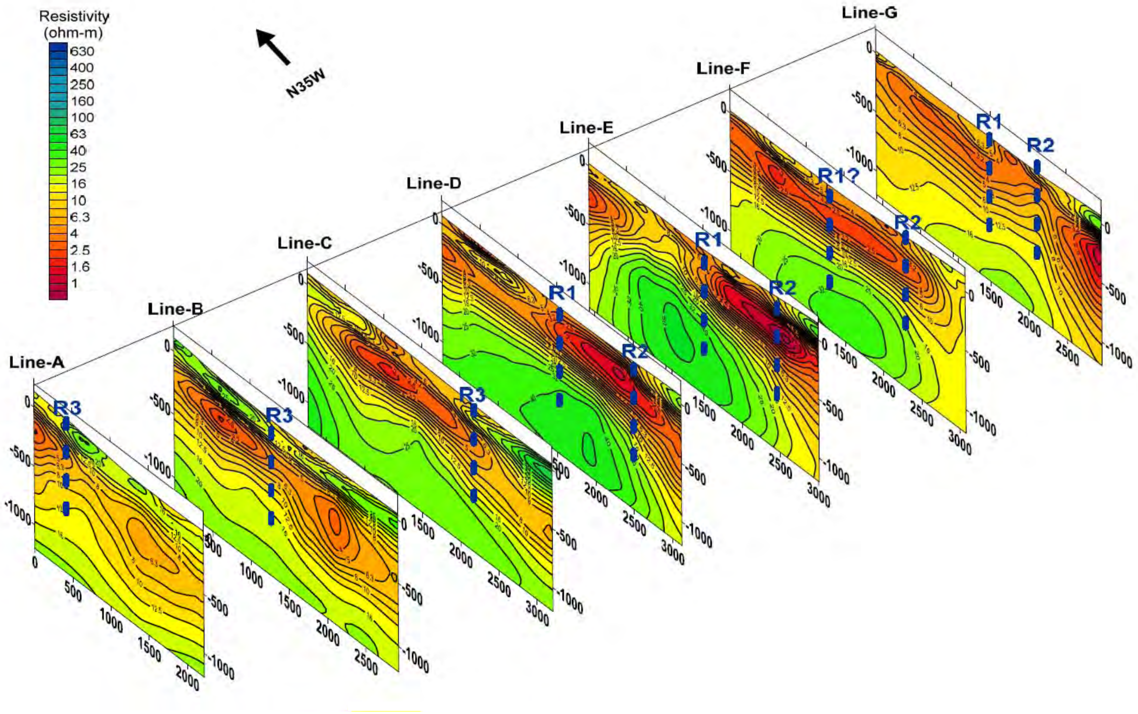


Fig.III-2-39 Resistivity Map at a Depth of 2,500 m

Fig.III-2-40 Location of Resistivity Section Lines



[Location of each line is given in Fig. III-2-40]

Fig.III-2-41 Resistivity Sections

c. Summary

Resistivity discontinuity R1, trending ENE-WSW in the central part of the survey area, and resistivity discontinuity R2, trending NE-SE in the southeastern part, are detected at relatively shallow depths. Between resistivity discontinuities R1 and R2, a remarkably low resistivity zone, extending in a NE-SW direction, is detected at relatively shallow depths of 100 m and 150 m (see Figs. III-2-30 and III-2-31). This low resistivity zone will reflect argillized rock which can be regarded as a cap rock (impermeable layer).

Under this low resistivity zone, an up-lifted, relatively high resistivity zone is detected at depths of 750 m to 1,000 m (see Figs. III-2-35 and III-2-36). This high resistivity zone corresponds to a high-temperature zone. Judging from the distribution of the low resistivity zone and the high resistivity zone, it is considered that resistivity discontinuity R1 is the main fracture zone controlling geothermal activity in the Tulehu field. Although the features of resistivity discontinuity R1 diminish with increasing depth, a fracture zone controlling geothermal fluids is probably distributed around R1 even at depth.

III.3 Conceptual Model of Geothermal Resources

III.3.1 Prospective Area

As mentioned previously (in Section III.2.3), rocks in and around a geothermal reservoir of a water-dominated type are altered through water-rock interaction. As the temperature of hot water decreases toward the margins from the center of the reservoir, lower temperature phases of hydrothermally altered secondary minerals are seen toward the margins. When the alteration temperature is lower than 200°C, the resulting secondary minerals are mainly comprised of smectite, chlorite-smectite interstratified mineral, illite-smectite interstratified mineral, quartz (chalcedony and/or cristobalite, when the temperature is lower than 100°C), halloysite, and so on. Among these secondary minerals, smectite and the smectite component in interstratified clay minerals contain exchangeable cations. Therefore, when argillized rock is mainly composed of smectite and/or interstratified clay minerals containing a smectite component, the resistivity of the argillized rock is low. On the other hand, the resulting secondary minerals are mainly composed of chlorite, illite, epidote and so on, when the alteration temperature is higher than 200°C. These secondary minerals show less resistivity than the original rocks.

In most geothermal fields, a low resistivity zone is detected above the geothermal reservoir, a relatively high resistivity zone is also detected under the low resistivity zone, and a productive zone is identified in the relatively high resistivity zone extending under the low resistivity zone. In these cases, the low resistivity zone shows the features of an impermeable zone (cap rock). For example, lost circulation while drilling rarely occurs and the temperature profile is of the conductive type in the low resistivity zone. Moreover, the secondary minerals identified in the low resistivity zone are usually smectite, chlorite-smectite interstratified mineral and/or illite-smectite interstratified mineral. The temperature at the bottom of such a low resistivity zone is about 200°C.

From these considerations, it can be seen that a low resistivity zone of considerable extent at a shallow depth, together with an underlying high resistivity zone, will characterize a prospective area for geothermal development. In the Tulehu field, a three-layered structure is detected by MT survey: a high resistivity zone near the ground surface, a low resistivity zone at a shallow depth and a high resistivity zone at the deepest depth. This means that geothermal resources will be expected in this field. The proposed prospective area is shown in Fig. III-3-1. A remarkable low resistivity zone (with resistivity lower than 10 ohm-m) extends on the northwestern side of Mt. Eriwakang. The most active geothermal manifestations and altered ground are situated in this low resistivity zone: the Sila hot springs, the Telaga Biru hot springs, the Hatuasa hot spa and the Banda alteration zone. The most prospective geothermal resource will extend under this low resistivity zone. An area of about 7 km^2 will be proposed as the minimum extent of the prospective area, an area that corresponds approximately to a low resistivity zone of less than 6.5

ohm-m at a depth of 150 m (see Fig. III-3-1). An area of about 10 km2 will be proposed as the maximum extent of the prospective area, an area that corresponds approximately to a low resistivity zone at a depth of 150 m, of which the resistivity is lower than 10 ohm-m. Judging from the resistivity map at a depth of 1,000 m (see Fig. III-2-36), a relatively high resistivity zone (resistivity higher than 40 ohm-m) extends under the low resistivity zone along the Wamina river. The Hatuasa hot spa and the Banda alteration zone are situated in this high resistivity zone. It is considered that the center of geothermal activity in the Tulehu field is in this high resistivity zone. Considering the chemistry of the hot spring waters, it must be noted that the hot water from the Sila hot springs is derived from a geothermal reservoir with the highest temperature in this field. Therefore, there is a possibility that there is another center of geothermal activity around the Sila hot springs.

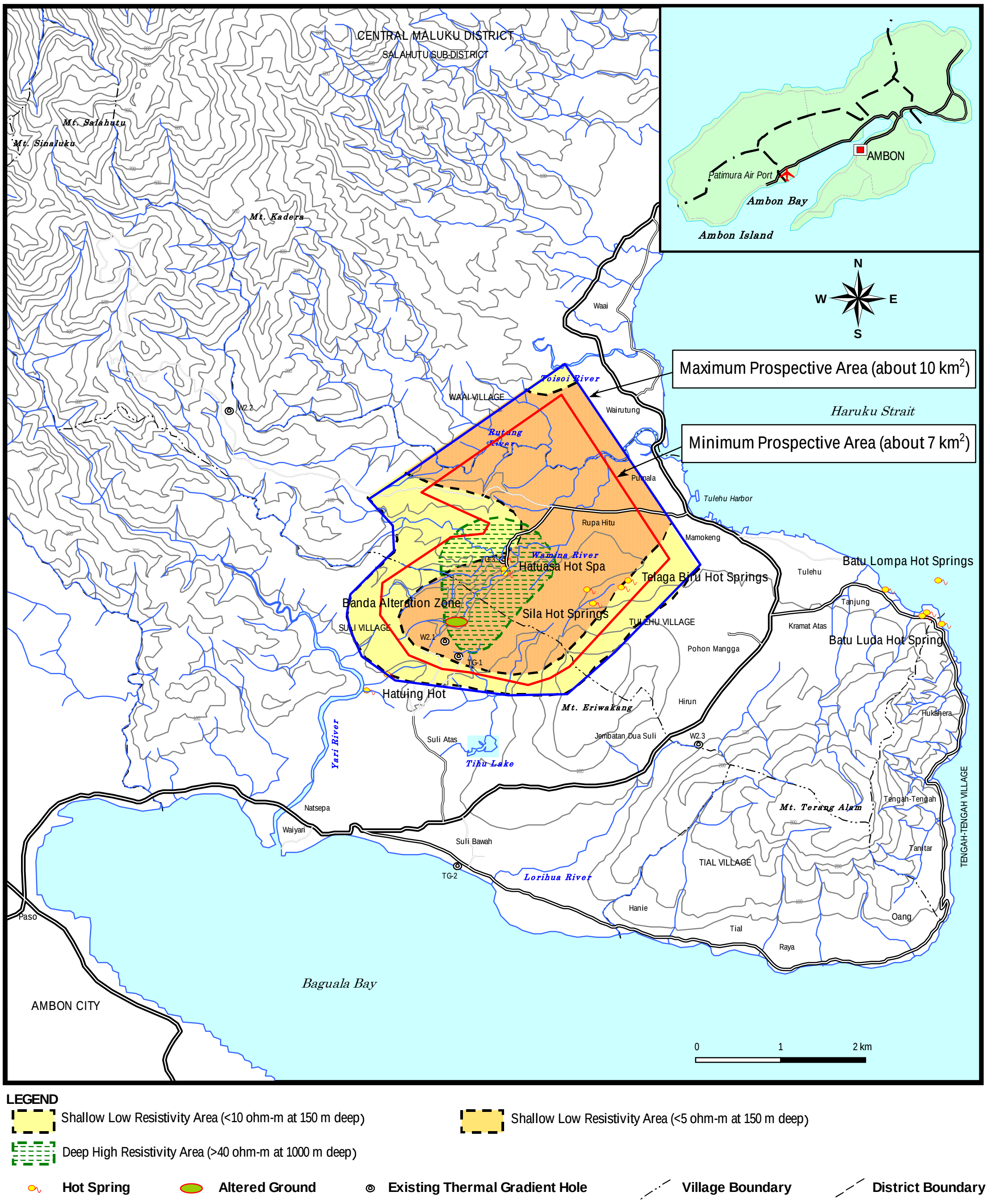


Fig.III-3-1 Proposed Prospective Area

III.3.2 Permeable and Impermeable Structures Controlling Geothermal Activity

Generally, a fractured zone resulting from faulting is a major permeable zone controlling geothermal activity in volcanic terrain. An intensively argillized layer is an impermeable layer, constituting a cap rock. In the Tulehu field, various kinds of geothermal exploration were carried out, and faults or fault-like structures were estimated. Faults or fault-like structures estimated from geological data, resistivity data (MT survey) and gravity data are shown in Fig. III-3-2. In and around the proposed prospective area, five faults were estimated from geological data: Waiyari fault, Banda Hatuasa fault, Banda fault, Tulehu fault and Huwe fault. From resistivity data, three faults were estimated: R1, R2 and R3. From gravity data, three faults were estimated: GL1, GL2 and GL3.

The Waiyari fault trends northwest to southeast along the Yari River. The fault-like structure GL1 is situated on the southeastern extension of the Waiyari fault. They are not different structures, but can be regarded as the same one: the Waiyari fault must extend around Oang in Tial village. The Waiyari fault was regarded as a right-lateral-slip fault. However, a high Bouger anomaly area extends on the southwestern side of the fault-like structure GL1 and a depression zone extends on the northeastern side. Judging from this, the Waiyari fault may dip northeast and have not only a lateral slip component but also a vertical slip component. Moreover, the fault-like structure R3 was detected by MT surveying near these structures. This structure will also be correlated with the Waiyari fault.

The Banda Hatuasa fault, trending northeast to southwest, is a normal fault dipping northwest. Near this fault, the fault-like structure R1 was detected by MT surveying. This structure can be correlated with the Banda Hatuasa fault, and the location of R1 will be regarded as indicating the location of the Banda Hatuasa fault at a deep level.

The Banda fault, trending northeast to southwest, is a normal fault dipping northwest. Near this fault, the fault-like structure R2 was detected by MT surveying. Considering the location of the MT stations, the northern half of R2 can be regarded as coinciding with the Banda fault. However, its southern half is located on the southeastern side of the fault. Considering the dipping direction of the Banda fault, the southern half of R2 will be regarded as a different structure branching off from the Banda fault and will be referred to as the R2 fault.

The Tulehu fault trends northwest to southeast along the coast from Mamokeng to Tanjung. This fault is a normal fault dipping northeast. Around this fault, no fault-like structure is estimated from geophysical exploration. This must be due to the fact that the location of this fault is outside, or in a marginal part, of the exploration area.

The Huwe fault trends northeast to southwest between Mt. Eriwakang and Mt. Terang Alam (Mt. Huwe). This fault is a normal fault dipping northwest. There is a depression zone on the northwestern side of the fault. Near the fault, the fault-like structure GL3 is estimated from the gravity data. This structure can be regarded as coinciding with the Huwe fault.

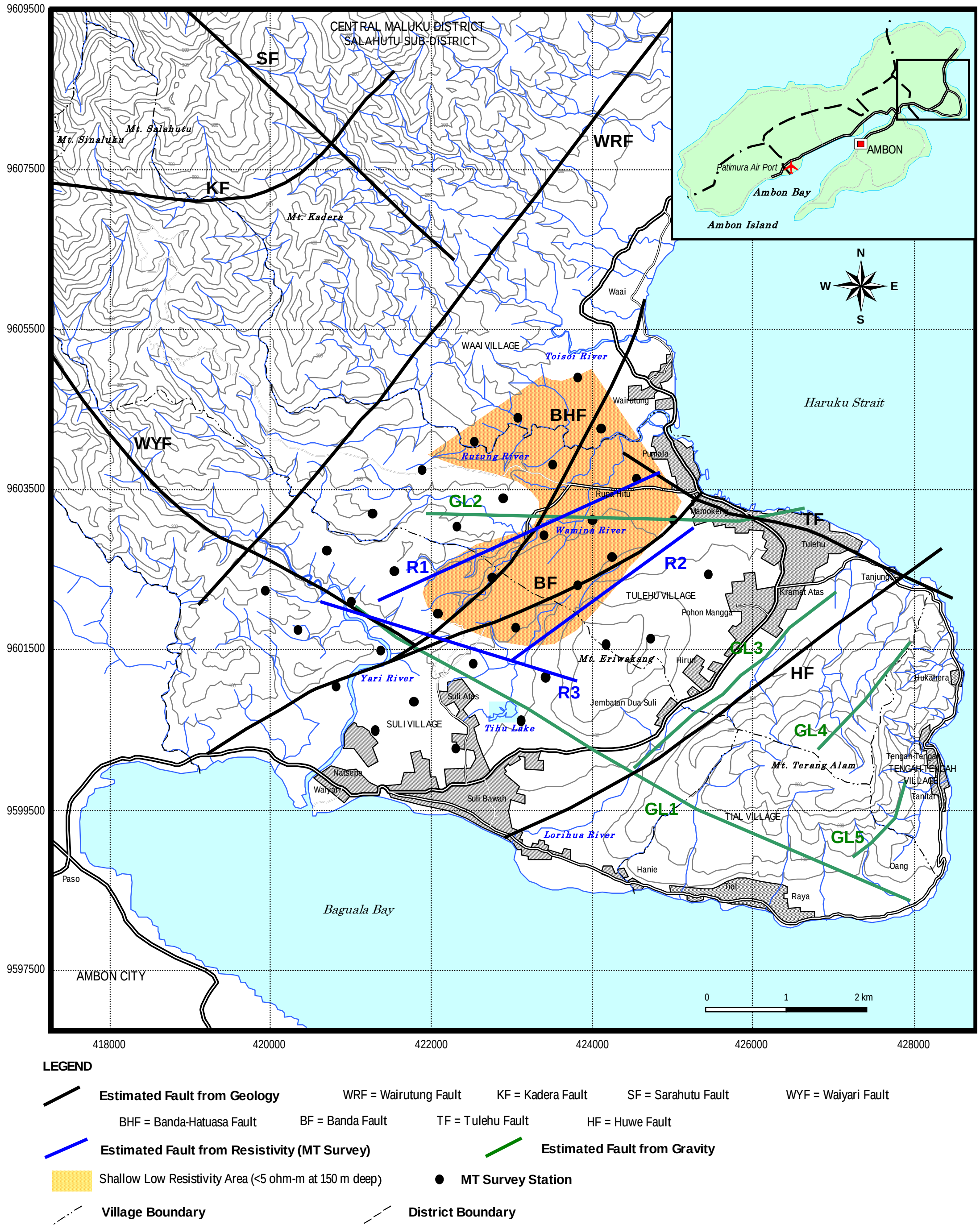


Fig.III-3-2 Faults Estimated from Geothermal Exploration

From the considerations above, six permeable structures are estimated in and around the prospective area. For convenience, each of these structures will be referred by the name of the related fault in subsequent description, as shown in Fig. III-3-3: the Waiyari fault, the Banda Hatuasa fault, the Banda fault, the R2 fault, the Tulehu fault and the Huwe fault. As hot springs and altered ground occur along these faults, it is considered that these faults control the geothermal activity near the ground surface.

The Waiyari fault limits the southwestern end of the estimated prospective area (the low resistivity zone). It is tentatively assumed that the strike-dip of this fault is S61.7°E85°NE. The Hatuing hot springs occur around the point of intersection of this fault with the Banda Hatuasa fault.

The Banda Hatuasa fault is detected as the remarkable resistivity discontinuity R1 by MT surveying. This fault is situated around the northwestern margin of the minimum prospective area. It is tentatively assumed that the strike-dip of this fault is N46.4°E80°NW. The Hatuasa hot spa and the Banda alteration zone are situated along this fault.

The Banda fault can be divided into two parts, based on its trend, the northern part and the remaining part. The northern part of this fault is detected as the remarkable resistivity discontinuity R2 by MT surveying. However, the remaining part cannot be detected by MT surveying. The presence of a remarkable low resistivity layer at a shallow depth must hide this structure. It is tentatively assumed that the strike-dip of this fault is N53°E80°NW in the northern part and N69°E80°NW in the remaining part. The Sila hot springs, the Telaga Biru hot springs and the hot springs on Mamokeng beach are situated along this fault. As shown in Fig. III-3-5, it is considered that the exploration well TLU-01 crosses the Banda fault around a depth of 740 m and that the observed lost circulation below a depth of 330 m results from a permeable zone along the Banda fault.

The R2 fault is detected by MT surveying. This fault branches out from the Banda fault around the Sila hot springs. This fault is situated around the southeastern margin of the minimum prospective area. It is tentatively assumed that the strike-dip of this fault is N53°E80°NW.

The hot springs on Mamokeng beach, the Batu Lompa hot springs and the Batu Luda hot springs aligned along the Tulehu fault. It is tentatively assumed that the strike-dip of this fault is S65°E80°NE.

The Huwe fault is detected as the gravity lineament GL3, and a depression zone extends on the northwestern side of this fault. The Batu Lompa hot springs occur around this fault. It is tentatively assumed that the strike-dip of this fault is N56°E80°NW.

A major impermeable structure in the Tulehu field must be an argillized layer corresponding to the low resistivity zone detected by MT surveying. The bottom of the impermeable zone around the drilling site of TLU-01 is at an elevation of about 300 m below sea level (see Fig. III-3-4) and this was confirmed by the drilling of TLU-01. In addition, the detected lost circulation zones of TLU-01 can be correlated with the Banda fault.

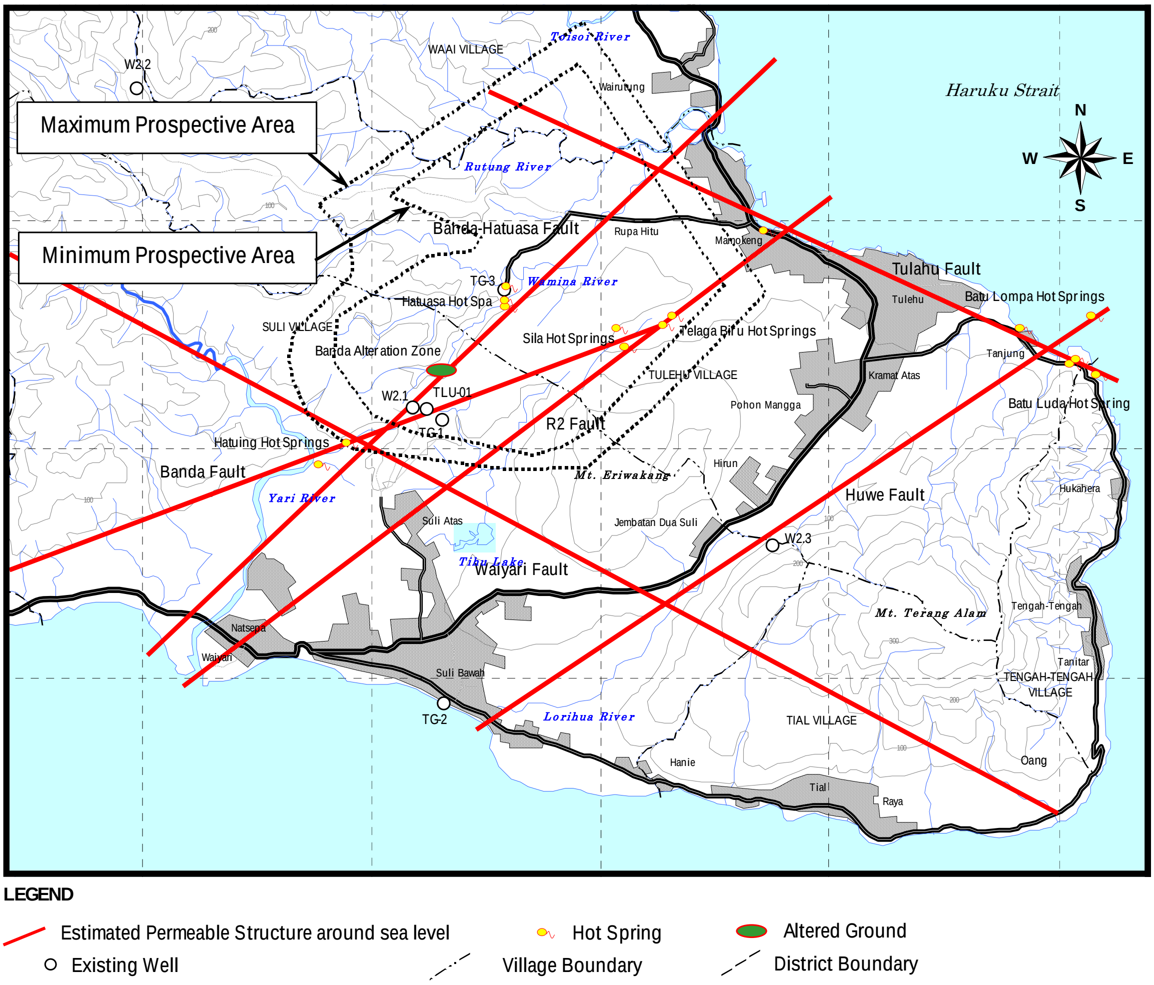


Fig.III-3-3 Estimated Major Permeable Structures

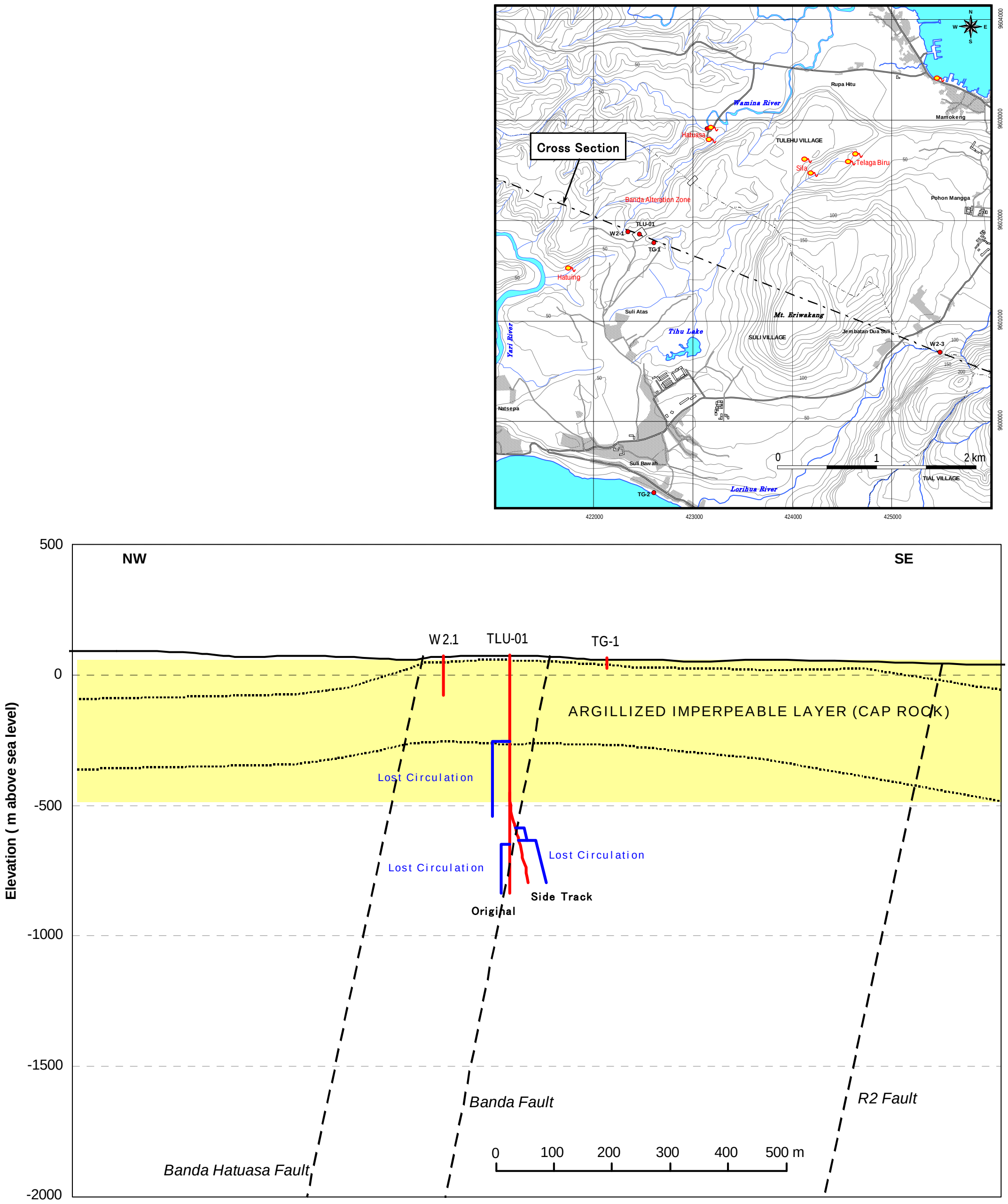


Fig.III-3-4 Extent of Estimated Impermeable Zone along MT Survey Line D

III.3.3 Conceptual Model

A tentative model for the geothermal system in the Tulehu geothermal field based on the obtained data and information is presented in Fig.III-3-5. The prospective area for a geothermal development extends on the northwestern side of Mt. Eriwakang. From the resistivity maps, it is considered that the centers of geothermal activity is found along the Banda Hatuasa fault between the Hatuasa hot spa and the Banda alteration zone. And it is expected that geothermal reservoir extends along the Banda Hatuasa fault from this center. Hot waters from the Hatuasa hot spa do not show any features in their chemistry indicating the existence of prospective geothermal resources. However, this can easily be explained by the presence of the impermeable zone, corresponding to the low resistivity zone detected in the present MT survey; this impermeable zone prevents the up-flow of deep geothermal fluid. In addition, a temperature of 200°C will be expected around the bottom of the detected low resistivity zone. Therefore, the Banda Hatuasa fault can be regarded as a main target for steam field development in this field.

The chemistry of hot waters from the Sila hot springs indicates that they are derived from a deep geothermal reservoir. The Sila hot springs occur around the point where the R2 fault branches off from the Banda fault. Therefore, it will be expected that the geothermal reservoir also extends along the Banda fault and the R2 fault. At present, the location of the up-flow center of this system along the Banda fault is still uncertain.

On the basis of these considerations, the following conceptual model is proposed. Geothermal fluid with sufficient temperature flows up from a deeper part around the estimated geothermal activity center between the Hatuasa hot spa and the Banda alteration zone. This fluid spreads along permeable zones constitutuing the Banda Hatuasa fault. Although the location of its up-flow center is uncertain, the geothermal reservoir also extends along the R2 fault and the Banda fault. The underground temperatures measured from wells W2.2 and W2.3 (where temperature increase with depth is scarcely identified) suggest that there are recharge areas around Mt. Terang Alam and around Mt. Salahutu.

It must be noted that the following topics still remain to be examined through discharge testing of the planned exploratory well. The high carbonate ion content of most of the hot spring waters in this field revealed by geochemical study suggests the possibility that the hot spring waters were influenced by sedimentary rocks or limestone. However, such rocks are identified only near the ground surface in this field. Whether sedimentary rocks or limestone extend to greater depths or not should be examined by chemical analysis of the discharged fluid from the exploratory well. If the reservoir is located in sedimentary rocks or limestone, there is a possibility of encountering serious problems in this field, such as carbonate scaling in production wells and pipelines and a high NCG content.

Regarding the scaling problem, carbonate scale will be formed when production wells tap into sedimentary rock reservoir. Silica scale deposition depends on the operating conditions of the production well. However, silica scale from the geothermal water in this field seems to deposit easily due to the relatively high content of salts dissolved in the water. Mineral acid injection into the reinjection line is considered to be effective in preventing silica scale deposition, because the silica content in water separated from geothermal fluid of about 200^{o}C must not be so high. Adequate countermeasures against such scaling troubles should be considered based on the chemical characteristics of the well discharge after completion of well discharge testing.

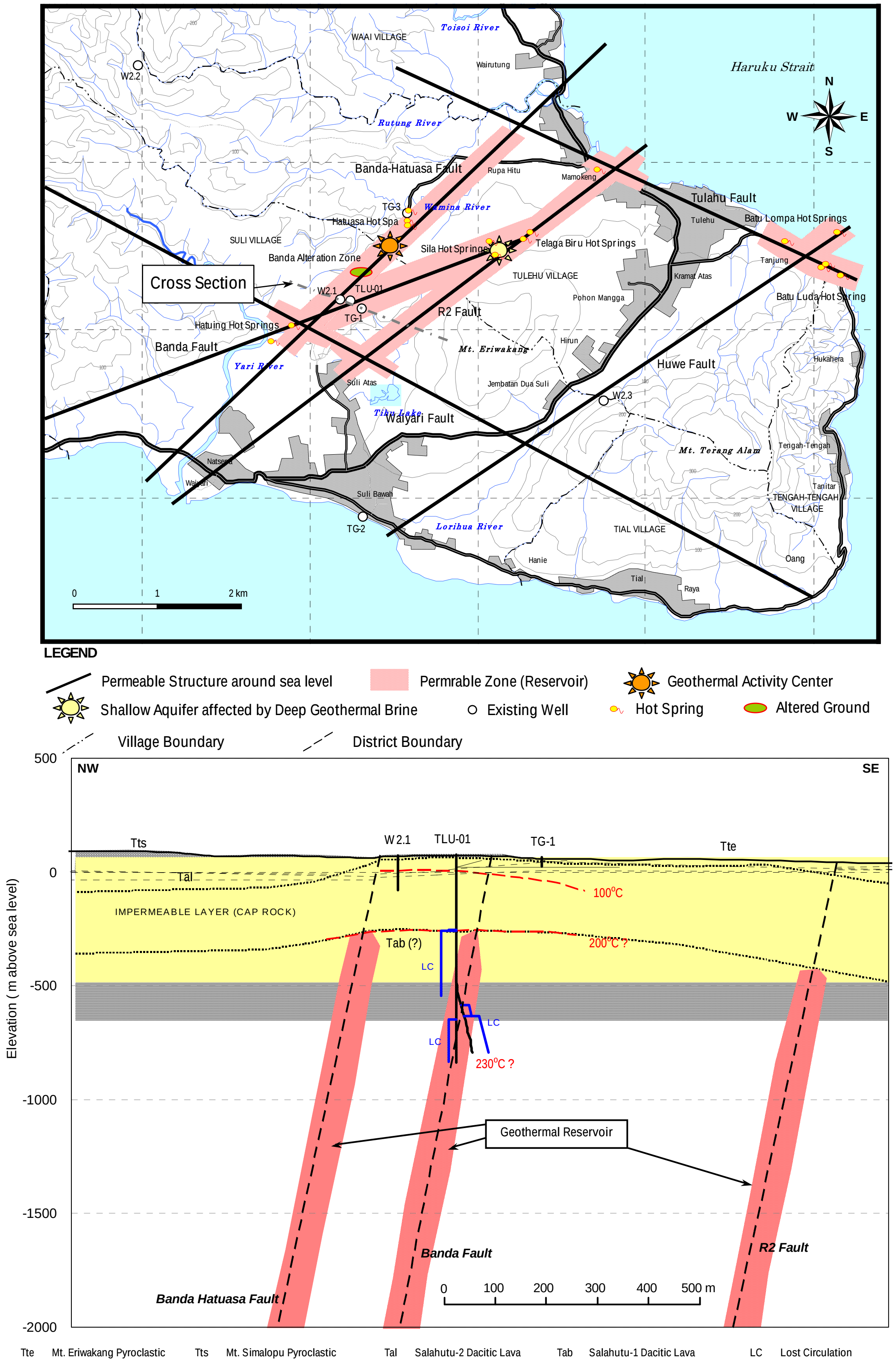


Fig.III-3-5 Conceptual Model of the Geothermal System in Tulehu Field

III.4 Evaluation of Geothermal Resource Potential in Tulehu Field

1. Method of Resource Evaluation

The stored heat method, a type of volumetric method, gives a general estimate of geothermal resource potentials which are usually estimated on the conservative rather than the optimistic side because the method ignores the recharge of geothermal fluids from the surrounding hydrothermal system. The stored heat method applies the following equations.

Stored Heat (S.H.) = $(T_r - T_a) \times \{(1-\phi)\, C_{pr}\, \rho_r + \phi\, C_{pw}\, \rho_w\} \times V$

Heat Recovery (H.R.) = S.H.× Recovery Factor

Power Output = (H.R. × C.E.) / (Lf × P.L.)

Tr :Reservoir Temperature (°C)
Ta : Abandonment Temperature (°C)
ϕ : Porosity (%)
ρr : Rock Density (kg/m^3)
ρw : Fluid Density (kg/m^3)
C_{pr} : Rock Specific Heat (kJ/kg･°C)
C_{pw} : Fluid Specific Heat (kJ/kg･°C)
V : Reservoir Volume (km^3)
C.E. : Conversion Efficiency (%)
Lf : Plant Life (year)
P.L. : Load Factor (%)

In order to compensate for the uncertainty of each reservoir parameter mentioned above, a statistical analysis called Monte Carlo Analysis is usually combined with the stored heat method. As shown in Fig. III-4-1, Monte Carlo Analysis considers the acceptable ranges of each parameter and statistically evaluates the most likely estimate of resource potential by providing frequency and probability distributions for the power capacity of the development area.

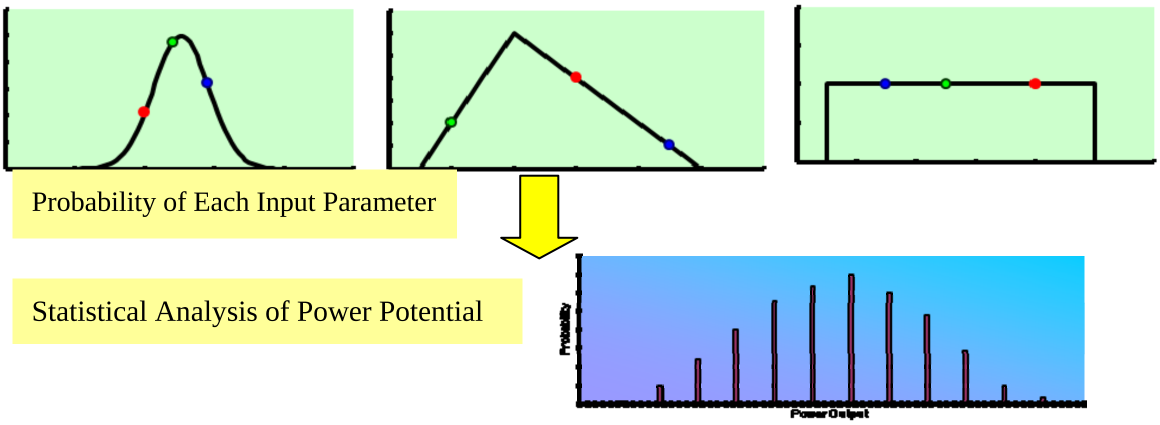


Fig. III-4-1 Monte Carlo Analysis for Stored Heat Resource Potential

2. Resource Potential Evaluation by Stored Heat Method

Based on the reservoir conceptual model, the prospective development area was estimated to be in the range of 7 km^2 to 10 km^2. Assuming that the thickness of the reservoir is about 1.5 km, the volume of the reservoir is indicated to be about 12.75 km^3, simply by multiplying the prospective development area by the reservoir thickness. The reservoir temperature and reinjection temperature were estimated to be 220°C and 180°C on average, respectively. Representative values for the rock properties of density, specific heat, and porosity of the rocks are assumed as 2,500 kg/m^3, 0.85 kJ/kg°C, and 7.5%, respectively. A recovery factor of 20 % and a conversion efficiency of 13 % were assumed. Plant life and load factor were estimated to be 30 years and 85 %, respectively. These assumptions for the prospective reservoir properties give a resource potential of 34.6 MW through the following calculations.

Stored Heat = $(T_r - T_a)\ \{(1-\phi)C_{pr}\rho_r + \phi C_{pw}\rho_w\}V$

$= (220-180)\ \{(1-0.075)\ x\ 0.85\ x\ 2500 + 0.075\ x\ 4.52\ x\ 806\}\ (1.28\ x\ 10^{10})$

$= 1.14\ x\ 10^{15}$ (kJ)

Heat Recovery = Stored Heat × Recovery Factor

$= 1.14\ x\ 10^{15}\ x\ 18.75\%$

$= 2.14\ x\ 10^{14}$ (kJ)

Power Output = (H.R. x C.E.) / (Lf x P.L.)

$= (2.14\ x\ 10^{14}\ x\ 13\%) / (85\%\ x\ 30$ year)

$= 1.09\ x\ 10^{12}$ (kJ/year)

= 34.6 (MJ/sec)

= 34.6 (MW) [1 W = 1 J/sec]

where

T_r, T_a : Reservoir Temperature (°C), Abandonment Temperature (°C)

ϕ : Porosity (%)

ρ_r, ρ_w : Rock Density (kg/m^3), Fluid Density (kg/m^3)

C_{pr}, C_{pw} : Rock Specific Heat (kJ/kg・°C), Fluid Specific Heat (kJ/kg・°C)

V : Reservoir Volume (km^3)

C.E. : Conversion Efficiency (%)

Lf : Plant Life (years)

P.L. : Load Factor (%)

3. Monte Carlo Analysis

Table III-4-1 shows the variations in reservoir parameters for the stored heat calculations, to which Monte Carlo Analysis is applied. The minimum and maximum areal extensions of the reservoir were assumed to be 7 km^2 and 10 km^2, respectively, based on the conceptual model. The thickness of the reservoirs was assumed to be greater than 1 km and less than 2.0 km, and most likely to have a thickness of 1.5 km.

Therefore, the reservoir has a volume that ranges from the minimum estimate of 7 km^3 to the maximum estimate of 20 km^3. The most likely average reservoir temperature was assumed to be 220^{o}C within the expected range of 200^{o}C to 240^{o}C. The average rock porosity was assumed to lie within the range of 5% to 10%. The recovery factor was assumed to vary within the range of 12.5% to 25%. The most likely average rock density was assumed to be 2500 kg/m^3, within the expected range of 2400 kg/m^3 to 2600 kg/m^3. The average rock specific heat was assumed to vary from 0.70 kJ/kg^{o}C to 1.0 kJ/kg^{o}C. The range of the heat-electricity conversion efficiency was assumed to be from 12% to 14%. The other three parameters, abandonment temperature, plant life and capacity factor, are fixed at 180^{o}C, 30 years and 85 %, respectively.

Table III-4-1 Input Parameters for Monte Carlo Analysis

Parameter	min.	most likely	max.
Reservoir Area (km^2)	7.00	-	10.00
Reservoir Thickness (m)	1000	1500	2000
Rock Density (kg/m^3)	2400	2500	2600
Porosity (-)	0.05	-	0.10
Recovery factor (-)	0.125	-	0.250
Rock Specific Heat (kJ/kg^{o}C)	0.70	-	1.00
Average Reservoir Temperature (^{o}C)	200	220	240
Average Reservoir Pressure (MPa)	-	11.96	-
Heat-Electricity Conversion Efficiency (-)	0.12	-	0.14
Plant Life (year)	-	30	-
Load Factor (-)	0.80	0.85	0.90
Abandonment Temperature (^{o}C)	-	180	-

Fig. III-4-2 shows the frequency (probability) distribution. The mode (the most frequently arising class mark, or peak value) was 30 MW (its frequency was about 17.2%). The residual frequency polygon, subtracting the cumulative frequency from the total frequency, is shown in Fig. III-4-3. And the obtained numerical values are summarized in Table III-4-2. From these figures and table, it is deduced that the Tulehu field has potential of not less than 20 MW with a likelihood of 85.2 % and that the most likely potential is 30 MW. Consequently, it was concluded that the reservoir must have enough capacity to sustain a 20 MW power development.

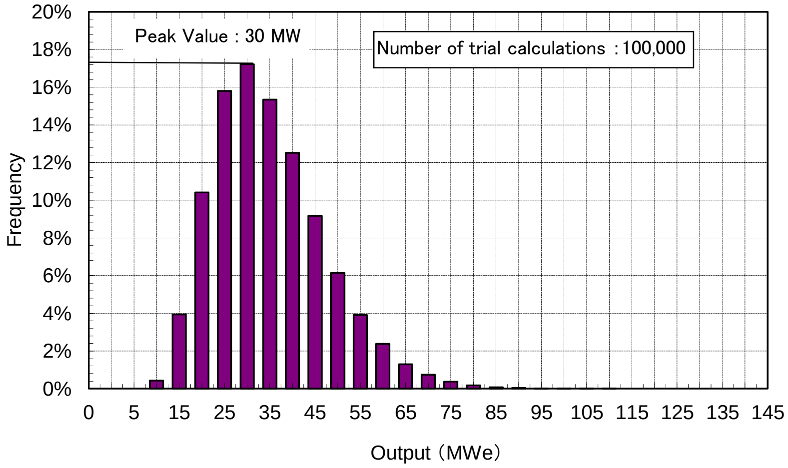
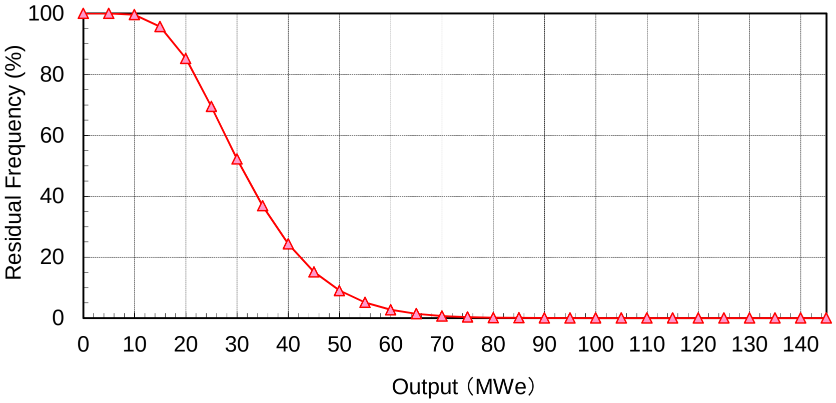


Fig. III-4-2 Frequency Distribution of Geothermal Power Potential in Tulehu



[Residual frequency] = [Total frequency] – [Cumulative frequency]

Fig. III-4-3 Residual Frequency Polygon of Geothermal Power Potential in Tulehu

Table III-4-2 Result of Monte Carlo Analysis of the Geothermal Resource Potential in Tulehu

Resource Potential	Probability
Larger than 10 MW	99.6 %
Larger than 20 MW	85.2 %
Larger than 30 MW	52.2 %
Larger than 40 MW	24.3 %
Larger than 50 MW	9.0 %
Larger than 60 MW	2.7 %
Larger than 70 MW	0.7 %

CHAPTER IV

IV GEOTHERMAL FIELD DEVELOPMENT

Chapter IV presents a summary of a geothermal field development scenario for the Tulehu field based on the results of resource study.

IV.1 Well Productivity and Injectivity

Well productivity, which is a necessary factor in establishing the number of wells required to generate a power output of 20 MW for this project, was predicted using the wellbore simulator WELLFLOW (Itoi et al., 1983, 1988; Sekoguchi et al., 1967; Tokita et al., 2002, 2004, 2005) that was developed at Kyushu University and modified by West JEC. West JEC has already applied WELLFLOW to many geothermal fields so far to analyze the productivity of production wells, and their experience has confirmed its reliability and utility. The WELLFLOW program establishes the deliverability curve of a well based on the reservoir pressure, temperature, and permeability-thickness products (kh) at the feed depth. A wellbore model for WELLFLOW including the surrounding formation is shown in Fig. IV-1-1. The relationship between well-head pressure, steam mass flow rate and water mass flow rate with specific enthalpy can be calculated, and then the power output of the well can be estimated assuming the turbine inlet pressure. Assumptions to simplify the development of computer code are made, such as assuming that the flow in the reservoir surrounding a well is in a steady state and that the reservoir is of a homogeneous porous type. The flow is described as a radial flow, which obeys Darcy’s law. The geothermal fluid is treated as pure water, and the fluid is either a water single-phase or a vapor and water two-phase system, depending on the fluid pressure and temperature. Accordingly, flow rates for the single-phase and the two-phase flows are represented in the equations of conservation of mass and momentum.

As the Tulehu geothermal field is in an early stage of development, there is only one deep well (TLU-01), and information on the thermodynamic condition of the reservoir is still not clearly delineated. Consequently, well productivity was estimated based on the assumptions listed in Table IV-1-1. The assumptions on reservoir conditions were made based on the results of the resource potential evaluation. The “kh” value was assumed to be 2 (darcy-m), which corresponds to a rather low-productivity well, in order to make the estimation somewhat conservative. The assumed casing program for production wells is shown in Fig. IV-1-2.

The results of a simulation run are shown in Fig. IV-1-3. The figure indicates the production characteristics for a well with various well-head pressure settings. From the results, it can be seen that the vapor/brine ratio in the Tulehu field is rather low (approximately steam 1 against brine 5). This result raises an important issue, namely that the design of reinjection wells have great importance in planning the Tulehu field development.

The results of simulation indicate that when the well-head pressure is set to 0.2 MPaG, then 63 t/h of steam and 280 t/h of brine will be produced from the well. When the well-head pressure is set to 0.5 MPaG, then the steam flow rate will be 43 t/h, and the brine flow rate will be 239 t/h. These production characteristics will be utilized in estimating the required number of wells for power generation of 20 MW.

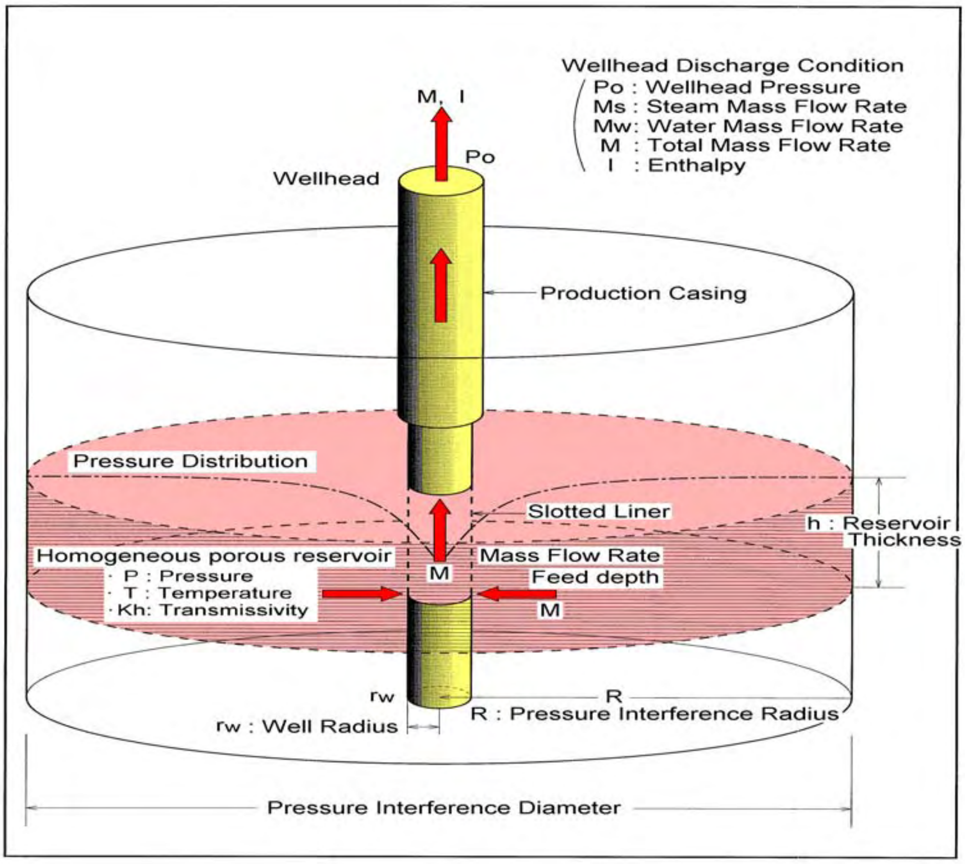


Fig. IV-1-1 Mathematical Model of Wellbore and Surrounding Formation for WELLFLOW

Table IV-1-1 Input Parameters for WELLFLOW

Parameters	Values
Reservoir Pressure	11.5 (MPaA)
Reservoir Temperature	230 (^{o}C)
Permeability-Thickness (kh)	2 (darcy-m)
Production Casing Depth	850 (m)
Feed Point Depth	1200 (m)
Production Casing Diameter	0.342 (m) 13 3/8’’
Liner Diameter	0.273 (m) 10 3/4”
Skin Factor	0.0

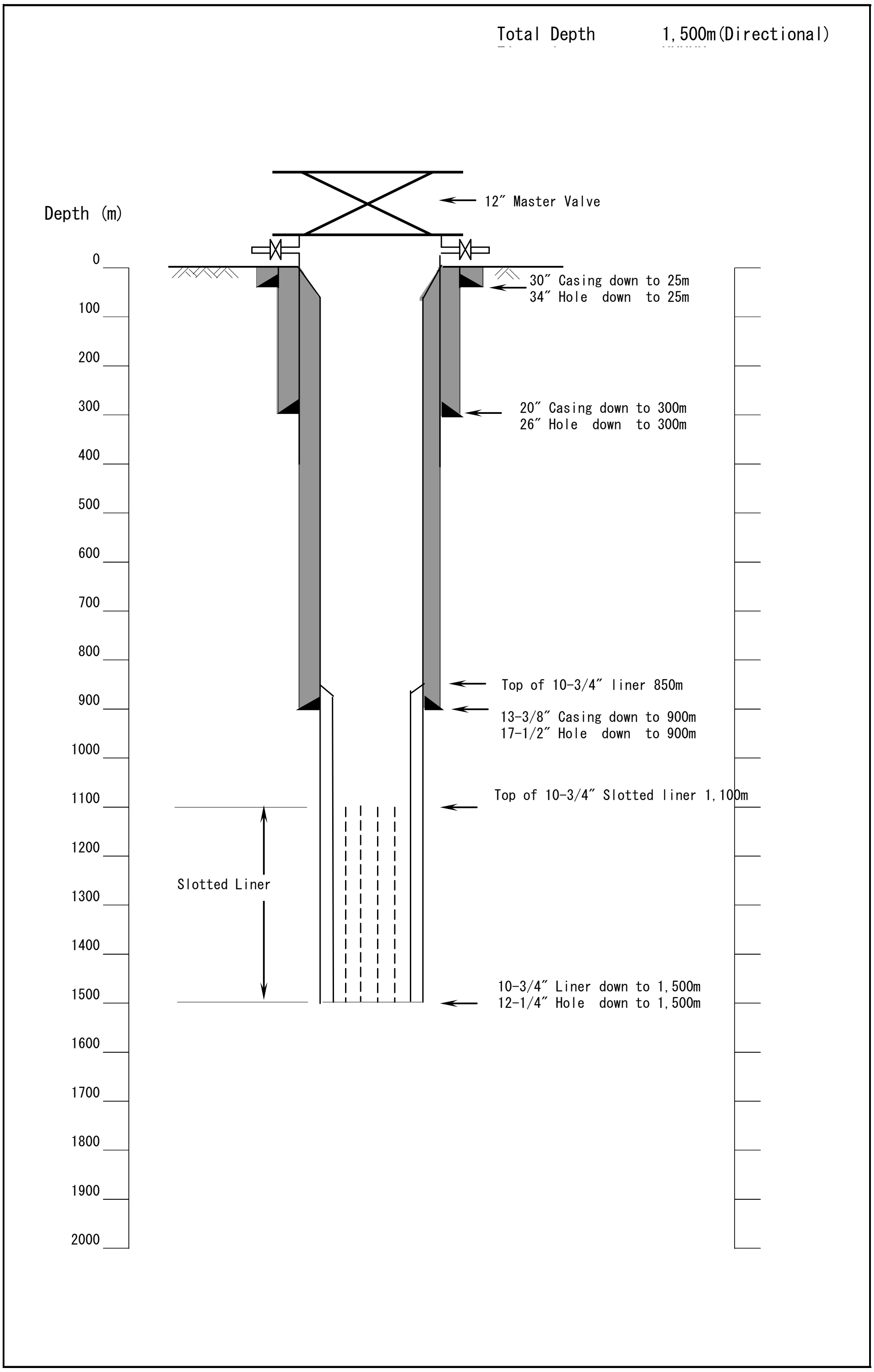


Fig. IV-1-2 The Assumed Casing Program for Drilling of Production Wells

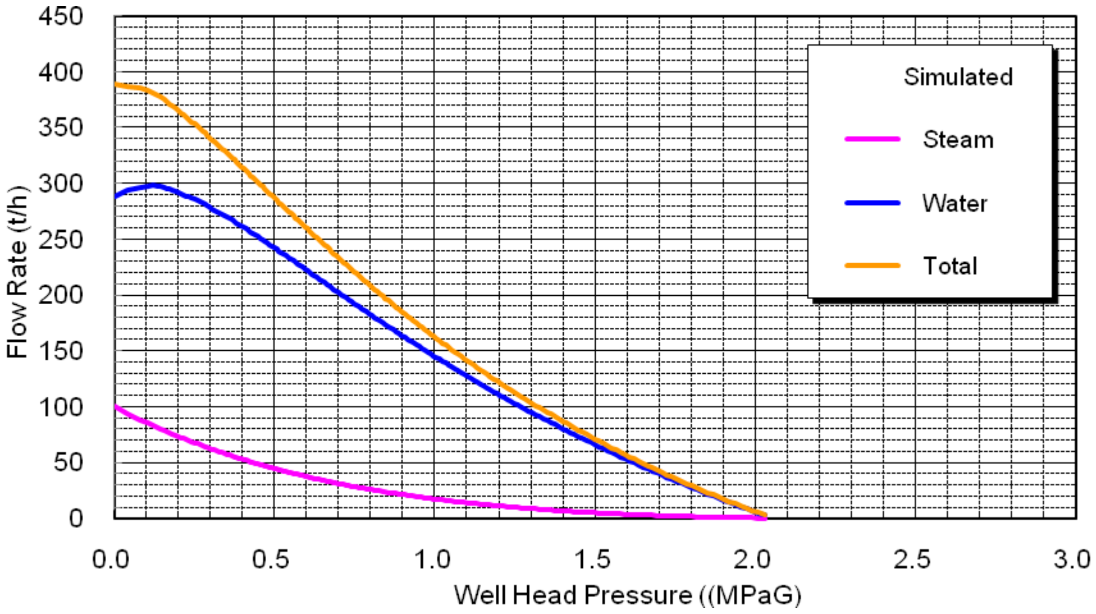


Fig. IV-1-3 Simulated Well Production Characteristics for a Production Well in Tulehu.

IV.2 Number of Wells Necessary to Generate 20 MW of Power

The results of well productivity estimation were applied in evaluating the number of wells necessary to generate 20 MW of power for 30 years. For the evaluation, the productivity for a well-head pressure 0.2 MPaG was adopted so that the estimate can be somewhat on the pessimistic side, where the reservoir pressure is not high and the well-head pressure should be kept low for connection with production pipelines.

The steam consumption for generating one megawatt (1MW) was determined to be 10 t/h, based on the catalogue specifications of turbines that are commercially available. If this is the case, the necessary amount of steam for 20 MW power generation is 200 t/h. As a single production well would produce 63 t/h steam and 280 t/h brine, the necessary number of production wells is calculated to be four (4). It is quite likely that some of the well drilling for production wells would fail. Assuming the success ratio for production well drilling to be 80%, then the necessary number of production wells would be five (5).

The total amount of brine that would be produced from the four production wells would be 1,120 t/h. Thus, approximately 1,200 t/h of reinjection capacity would be necessary for stable power generation of 20 MW in Tulehu field. Ideally, injectivity should be same as productivity, since both of them are controlled by the permeability of surrounding formations. As a single production well would produce 280 t/h brine, the injectivity of a well can be estimated to be around 280 t/h. However, to be more conservative, the injectivity of a single reinjection well was assumed to be 250 t/h. Thus six (6) reinjection wells would be necessary.

As previously mentioned, the vapor-to-brine ratio in the Tulehu field is approximately five to one (vapor 1 : brine 5). This ratio suggested the idea of utilizing what is known as a “double flash" system that enhances the amount of steam production by 30 % through a further evaporation of the brine. Using this system, the steam productivity from a single well would increase to 82 t/h (63 x 1.3 = 81.9 t/h), and the brine flow rate would decrease down to 261 t/h (280 – (82-63) = 261 t/h). The necessary number of production wells decreases to three (3) wells (82 x 3 = 246 t/h). The necessary reinjection capacity also decrease to four (4), because the total brine production from three production wells decreases to 783 t/h. In this case, four reinjection wells can process 1,000 t/h (250 x 4 = 1,000 t/h) of brine.

The assumed well productivity and injectivity of a well is shown in Table IV-2-1, and the results of the above-mentioned estimation are summarized in Table IV-2-2. For a single flash system, the necessary number of initial production wells would be four (4), and for a double flash system, three (3) production wells would be necessary to commence generation of 20 MW of power.

Table IV-2-1 Assumed Well Productivity and Injectivity at Well-head Pressure of 0.2MPaG

Type of Power Generation	Productivity	Injectivity
Single Flash Type	63 (t/h)	250 (t/h)
Double Flash Type	82 (t/h)	250 (t/h)

Table IV-2-2 Necessary Number of Initial Wells

Type of Power Generation	Initial Production Wells	Initial Reinjection Wells
Single Flash Type	4 (+ 1 backup)	6
Double Flash Type	3 (+1 backup)	4

The productivity and injectivity of a well decline with time. When the total productivity declines below the rated power output or necessary injection capacity, then make-up wells are drilled. In evaluating the required number of make-up wells, the same decline rate was adopted (3%/year) for both of production capacity and reinjection capacity. The estimates for the timing and the total number of make-up wells are summarized in Fig. IV-2-1 and Table IV-2-3 for an ordinary single flash system. The same estimates for a double flash system are shown in Fig.IV-2-2 and Table IV-2-4.

For an ordinary single flash system, the initial number of production wells is five (5) wells, taking into account the success ratio of 80%. After the drilling of five wells, four (4) wells would start producing steam in a total amount of 253 t/h. Then the production rate would decline at a rate of 3%/year. The production would decline below 200 t/h seven (7) years after the commencement of power generation. A make-up well for production will be introduced at this time, and the new well will produce 63 t/h of steam. The total steam production will recover to 261.8 t/h. Likewise, make-up wells would be necessary in the 16th year and 25th year of power generation. In total, three make-up (3) production wells would be necessary to sustain the 20 MW power generation. The power generation starts with six (6) reinjection wells that possess a 1,500 t/h reinjection capacity. This capacity declines at a rate of 3%/year. The necessary reinjection capacity is 1,200 t/h. The actual reinjection capability will decline below 1,200 t/h seven (7) years after the commencement of power generation. A reinjection well needs to be introduced at this time, and the total reinjection capability will recover to 1426 t/h. In the same manner, reinjection wells will be required in the 14th year, 20th year, and 27th year of power generation. A total of four (4) make-up wells will be necessary for reinjection.

For a double flash system, the same estimation was made as for the single flash system. Four (4) drilling operations will be attempted, and, with a success ratio of 80%, will result in the commencement of power generation with three production wells. The total production capability will be 247 t/h. The production rate will decline at a rate of 3%/year. Make-up wells for production will be necessary in the 6th year, 19th year, and the final 30th year of power generation. For reinjection wells, the power generation starts with four (4) wells with a total reinjection capacity of 1,000 t/h. Make-up wells for reinjection will decline at a rate of 3%/year and decline below the necessary 800 t/h of reinjection capacity in the 7th year. Accordingly, make-up wells will be necessary in the 7th year, 16th year and 25th year. In total, three (3) make-up production wells and three (3) make-up reinjection wells will be required to generate 20 MW of power for 30 years.

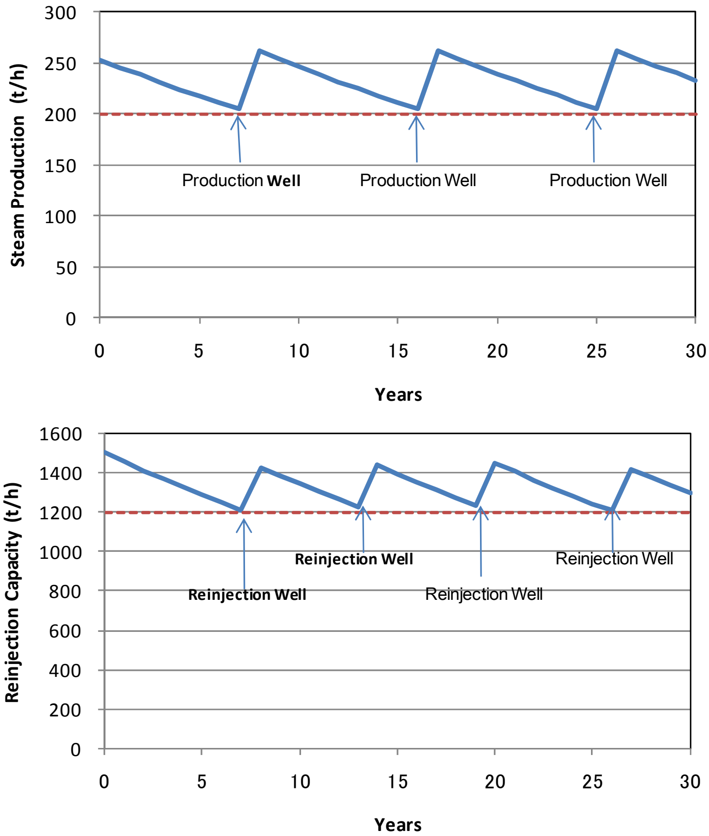


Fig. IV-2-1 Results of Estimation for Make-up wells (Single Flash System)

Table IV-2-3 Results of Estimation for Make-up wells (Single Flash System)

Years	Steam Production	Reinjection Capacity	Make Up Wells Production	Make Up Wells Reinjection
0	253	1500	0	0
1	246	1455	0	0
2	238	1411	0	0
3	231	1369	0	0
4	224	1328	0	0
5	218	1288	0	0
6	211	1249	0	0
7	205	1212	0	0
8	262	1426	1	1
9	254	1383	0	0
10	246	1341	0	0
11	239	1301	0	0
12	232	1262	0	0
13	225	1224	0	0
14	218	1437	0	1
15	212	1394	0	0
16	205	1353	0	0
17	262	1312	1	0
18	254	1273	0	0
19	247	1234	0	0
20	239	1447	0	1
21	232	1404	0	0
22	225	1362	0	0
23	219	1321	0	0
24	212	1281	0	0
25	206	1243	0	0
26	263	1206	1	0
27	255	1419	0	1
28	247	1377	0	0
29	240	1336	0	0
30	233	1296	0	0
		total	3	4

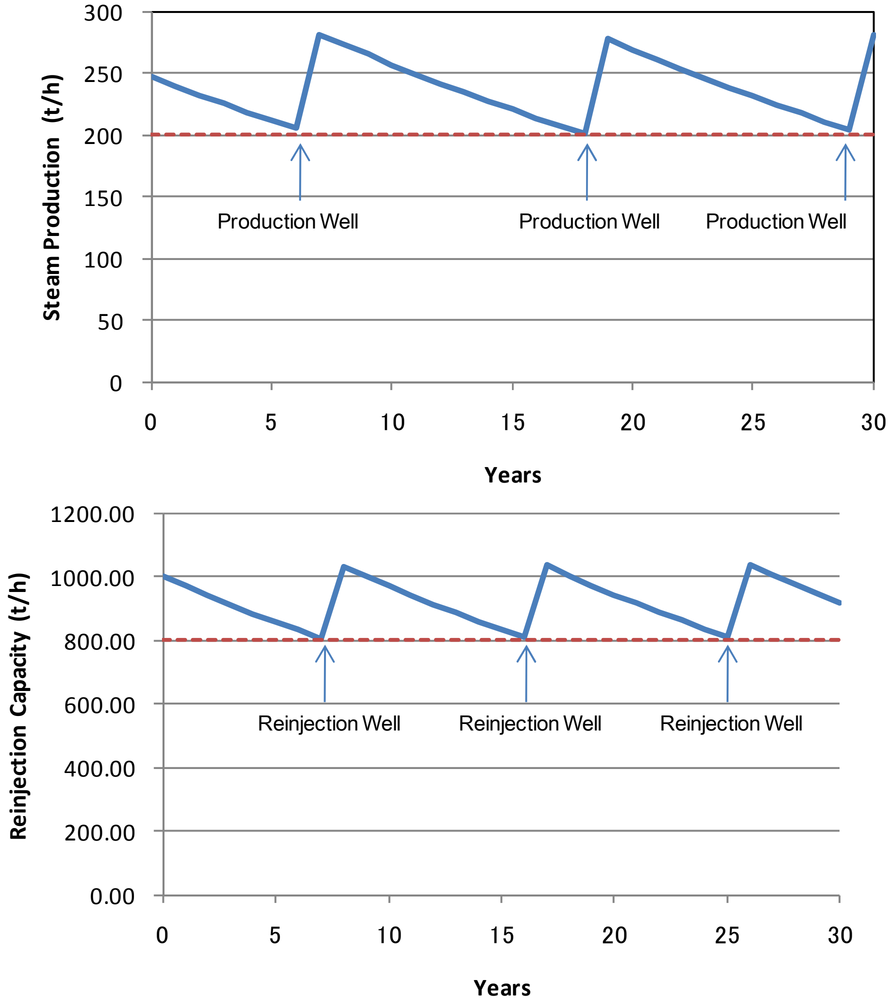


Fig. IV-2-2 Results of Estimation for Make-up wells (Double Flash System)

Table IV-2-4 Results of Estimation for Make-up wells (Double Flash System)

Years	Steam Production	Reinjection Capacity	Make Up Wells Production	Make Up Wells Reinjection
0	247	1000	0	0
1	240	970	0	0
2	232	941	0	0
3	225	913	0	0
4	219	885	0	0
5	212	859	0	0
6	206	833	0	0
7	282	808	1	0
8	273	1034	0	1
9	265	1003	0	0
10	257	973	0	0
11	250	943	0	0
12	242	915	0	0
13	235	888	0	0
14	228	861	0	0
15	221	835	0	0
16	214	810	0	0
17	208	1036	0	1
18	202	1005	0	0
19	278	975	1	0
20	270	945	0	0
21	261	917	0	0
22	254	890	0	0
23	246	863	0	0
24	239	837	0	0
25	231	812	0	0
26	225	1038	1	1
27	218	1006	0	0
28	211	976	0	0
29	205	947	0	0
30	281	919	0	0
		total	3	3

IV.3 Drilling Strategy

IV.3.1 Drilling Targets and Drilling Pads

The Tulehu geothermal field is located in Tulehu Village and Suli Village in Maluku province, Ambon Island, and its topographic condition is relatively flat. In this area, one drilling pad (TLU-0) has already been constructed by PLN for an exploratory well. In order for heavy-duty drilling equipment to be transported easily to the site, the existing road has been upgraded, and an extension of the road right up to the site has been newly constructed. At this pad, the first exploratory well TLU-01 has been drilled.

Based upon the field development scenario stated above (sustainable geothermal power generation of 20 MW for thirty (30) years, seven (7) production wells, four (4) start-up production wells and three (3) make-up production wells will be required for a single flash generating system. For a double flash generating system, six (6) production wells, three (3) start-up production wells and three (3) make-up production wells will be required. Therefore, the following drilling pad capacity for these production wells will be required. For a single flash generating system, sufficient space for the drilling of seven (7) production wells. For a double flash generating system, sufficient space for the drilling of six (6) production wells.

For reinjection wells, ten (10) wells will be required for a single flash generating system, six (6) start-up wells and four (4) make-up wells. For a double flash generating system, seven (7) wells will be required, four (4) start-up wells and three (3) make-up wells. Assuming that, as a rule, the future make-up reinjection wells will be prepared by side-tracking from the original (previously drilled) reinjection wells, the following drilling pad capacity for reinjection wells will be required. For a single flash generating system; sufficient space for the drilling of seven (7) reinjection wells, as six (6) reinjection wells must be in operation. For a double flash generating system; sufficient space for the drilling of five (5) reinjection wells, as four (4) reinjection wells must be in operation.

As mentioned in section III-3, the major drilling targets will be located along the Banda Hatuasa fault, Banda fault and R2 fault in the Tulehu field. Hot springs occur on these faults. Among these hot springs, the Hatuasa hot spa on the Banda Hatuasa fault is utilized as a hot spa resort, but the other hot springs are not utilized. Judging from the chemistry of hot waters, it is believed that there is no direct connection between deep geothermal brine and the hot water from the Hatuasa hot spa, as the hot water does not contain deep geothermal brine. However, the possible impact from geothermal development along the Banda Hatuasa fault on the Hatuasa hot spa has not yet been examined. On the other hand, every well will cross the Banda fault on the way, if it is drilled targeting the R2 fault from the given pads (considering topographic condition). Given these conditions, it is deduced, at the present, that the targets on the Banda fault should have the first priority for geothermal development in the Tulehu field.

Proposed drilling targets were selected in light of the following considerations.

1) All targets are located along the Banda fault.
2) Targets for production wells and for reinjection wells are respectively located on the

western side and on the eastern side of the Sila hot spring, as an up-flow area is expected around the Sila hot spring, judging from the hot water chemistry.

3) Targets for production wells are located in such a way as to maintain spacing of more than 300 m, in consideration of the interference problem (adequate spacing must be confirmed through future discharge testing).
4) Targets for reinjection wells are located in such a way as to maintain spacing of more than 150 m, in consideration of the interference problem (adequate spacing must be confirmed through future discharge testing).
5) All of the targets are located together with the drilling pads to ensure a drilling depth of less than 1500 m, as a rule.

Proposed locations for the drilling targets and drilling pads, based on the above considerations, are shown in Fig. IV-3-1. Seven (7) targets were proposed for the future production wells, excluding the drilled exploration well TLU-01. As the existing pad (TLU-0 pad) of exploration well TLU-01 is close to the Banda fault, there is only one possible target (TLU-02) to drill from this pad. Therefore, new drilling pads will be required for the future production wells. To ensure a drilling depth of less than 1500 m, only three (3) targets can be drilled from a single pad. As seven (7) production wells for a single flash generating system or six (6) production wells for a double flash generating system will be required in total, two (2) new pads are required for the future production wells. Proposed locations of the new pads (TLU-1 and TLU-2) are shown in Fig. IV-3-1. Considering topographic conditions, the site for the future geothermal power plant will be located between the TLU-1 pad and the TLU-2 pad. Proposed drilling pad TLU-3 is for the future reinjection wells. To drill to the proposed target TLU-37R, a drilling depth of about 1650 m is required, though the drilling depths to the other targets are less than 1500 m. It is still uncertain whether well TLU-01 can be used as a production well or not. The target TLU-11 is proposed as a target for an alternative well, if well TLU-01 is not available for steam production. The tentative scope of the proposed drilling pads and power plant site is summarized in Table IV-3-1. A typical drilling pad layout, including the drilling rig equipment arrangement is shown in Fig. IV-3-2.

The target TLU-12 will be proposed as a drilling target for the next well (production well). And targets following this will be TLU-13, TLU-21, TLU-22 and TLU-23, in order of priority. Among reinjection wells, the target TLU-31R will have the first priority. The targets following this will be TLU-32R, TLU-33R, TLU-34R, TLU-35R, TLU-36R and TLU-37R, in order of priority. It is recommended that long-term discharge testing be done after the drilling of three or four wells. Based on the results of this discharge test, target locations will need to be reconsidered.

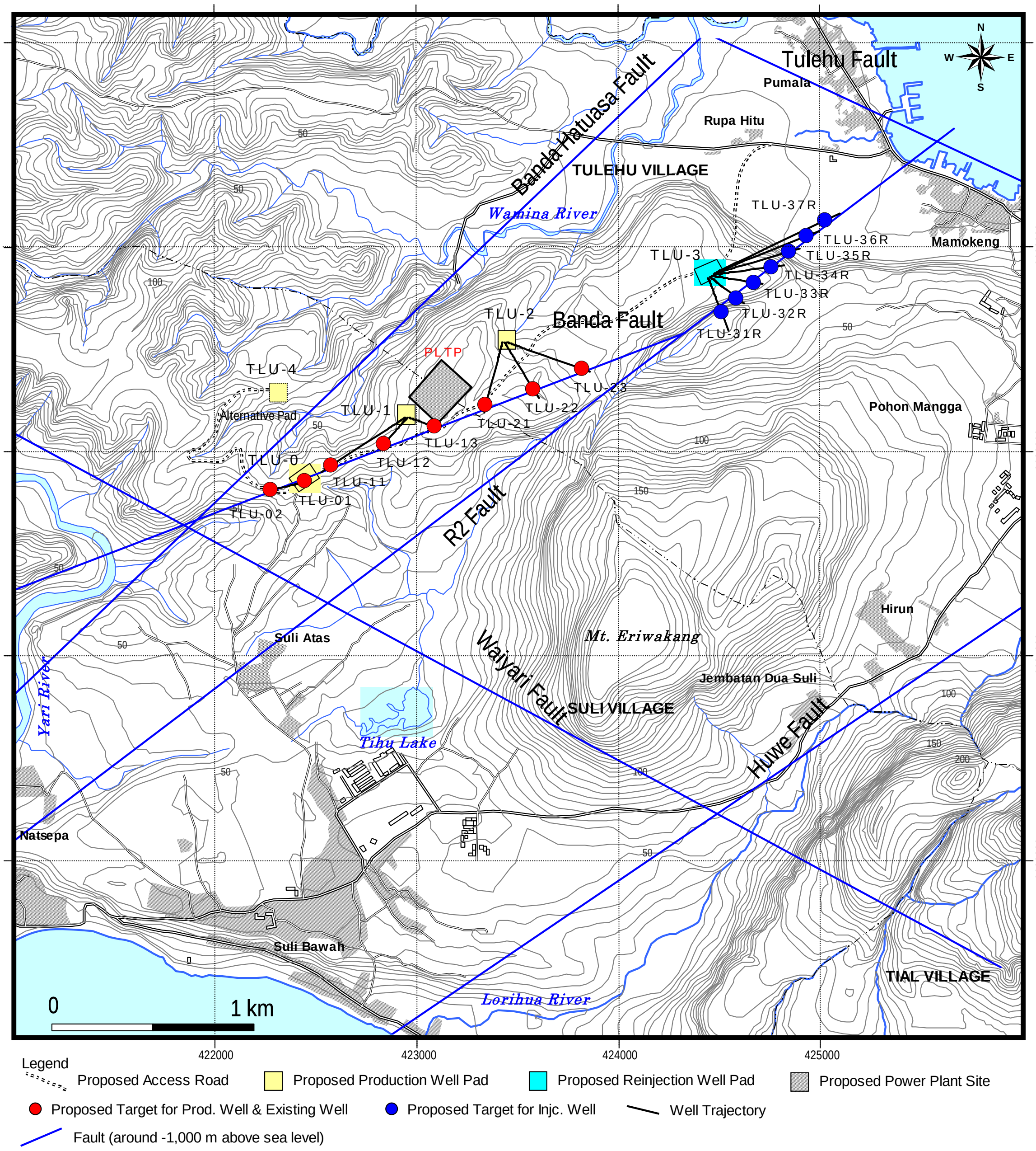


Fig. IV-3-1 Tentative Drilling Pads, P/P Location and Drilling Targets

Table IV-3-1 Required Size of Well Pads and Access Road

Item	Size	Note
Production Pad TLU-1	100m x 70m	3 Production Wells
Production Pad TLU-2	100m x 70m	3 Production Wells
Reinjection Pad TLU-3	130m x 80m	7 Reinjection Wells
Access Road	5m x 3,000m	Newly constructed

Note: (Start-up wells + *Make-up wells*)

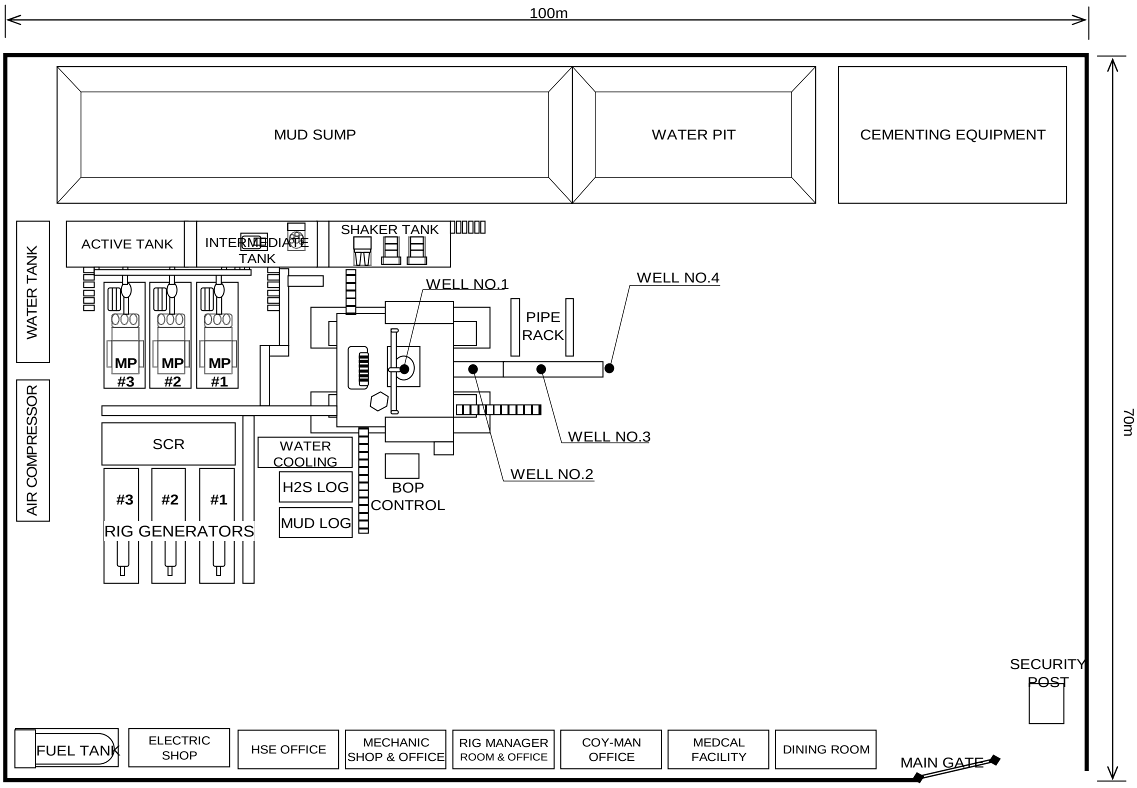


Fig. IV-3-2 Typical Rig Layout (Not to Scale)

IV.3.2 Well Specifications

The locations of drilling targets and the well trajectories to reach them are shown in Fig. IV-3-1, Fig. IV-3-3 and Fig. IV-3-4. Well specifications for each drilling target are given in Table IV-3-2, Fig. IV-3-5, Fig. IV-3-6 and Fig. IV-3-7.

Production Wells

In Tulehu geothermal field, exploratory well TLU-01 has been drilled successfully to a depth of 927m, and several well logging operations, including Temperature/Pressure, Water Injection and

Temperature Recovery, have been completed. Based on the results of this drilling and logging, it is expected that well TLU-01 has a sufficient formation temperature and permeability for production steam, even though the temperature recovery was not so fast due to the cooling effect of drilling mud and fresh water that was injected during drilling.

On another front, based upon the field development scenario and well-flow calculations stated above for geothermal power generation of 20MW, big-hole completion will be recommended for the production well. In other geothermal fields in Indonesia, big-hole completion (10-3/4” slotted liner completion) is currently a kind of standard for production well drilling and such wells have been successfully drilled with a good production rate. Similar results will also be expected when production wells are drilled with a big-hole completion casing program in Tulehu geothermal field. However, on the other hand, the drilling cost for big-hole completion will be much more expensive than that for standard-hole completion (7” slotted liner completion). Therefore, whether big-hole completion will be much more economically effective than standard-hole completion or not should be carefully examined.

A tentative production well casing program of both big-hole completion and standard-hole completion for Tulehu are shown in Fig. IV-3-5 and Fig. IV-3-6.

Reinjection Wells

In Tulehu geothermal field, reinjection wells will be provided to inject the separated brine and condensate into the reservoir to support reservoir pressure and mass production. A tentative reinjection well casing program for Tulehu is shown in Fig. IV-3-7. A 7” slotted liner standard completion program will be recommended. The depth at which the casings are set should be decided on the basis of the geoscientific parameter set for each of the wells to be drilled.

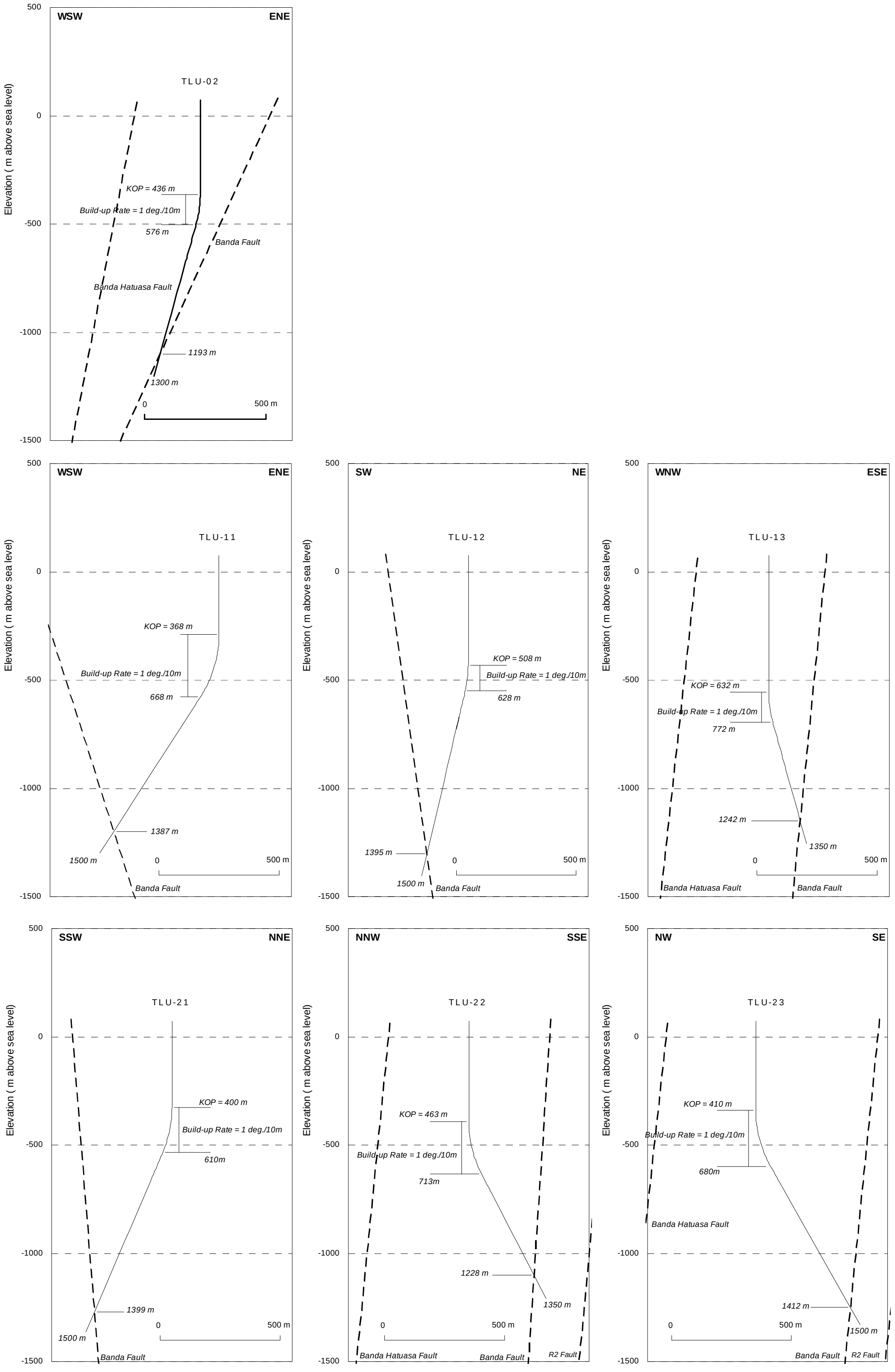


Fig. IV-3-3 Cross Sections along the Drilling Direction of Production Wells

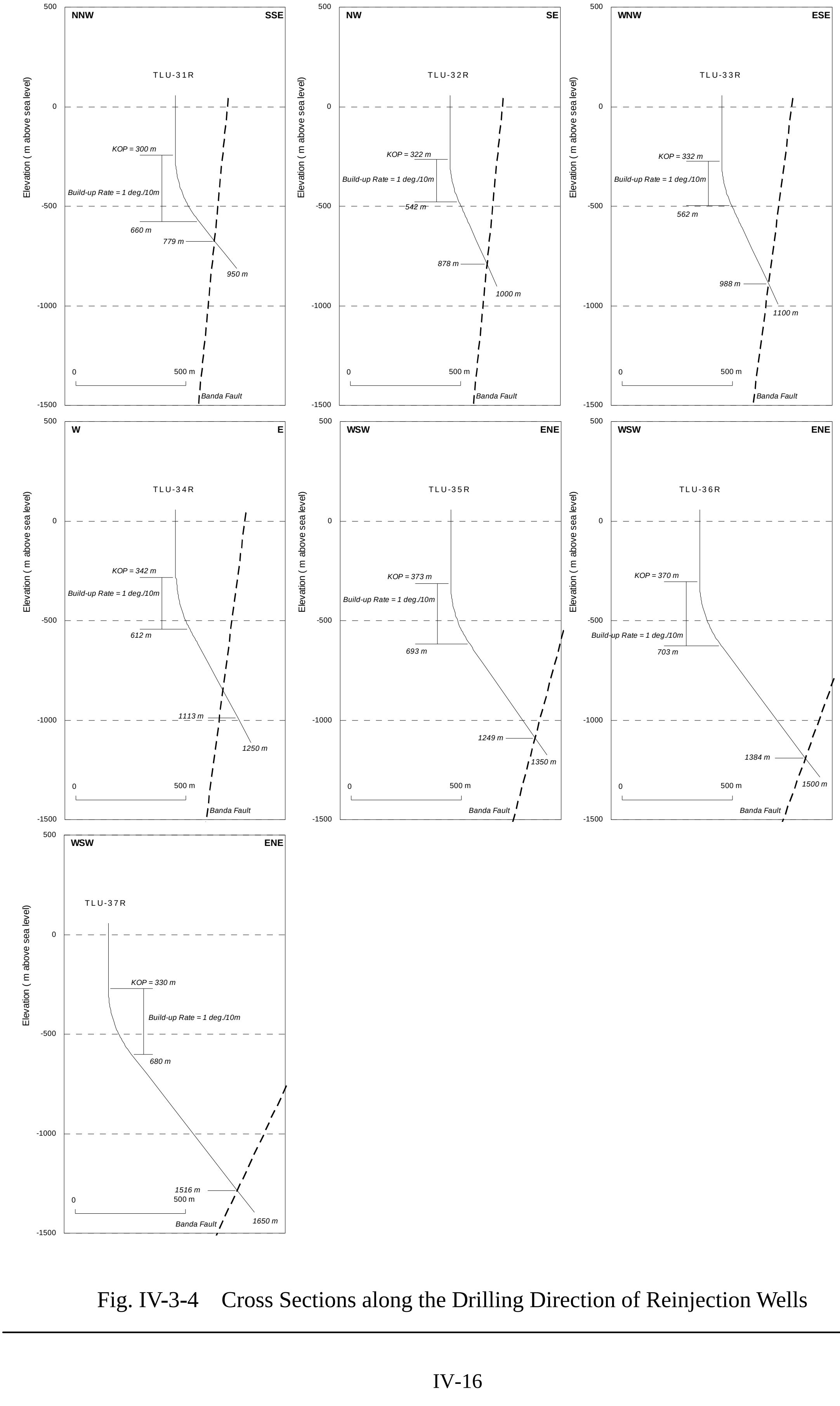


Fig. IV-3-4 Cross Sections along the Drilling Direction of Reinjection Wells

Total Depth	1250-1450m
Elevation	72-77m
KOP	310-410m
Drift Angle	Max.10-35deg.
Direction	

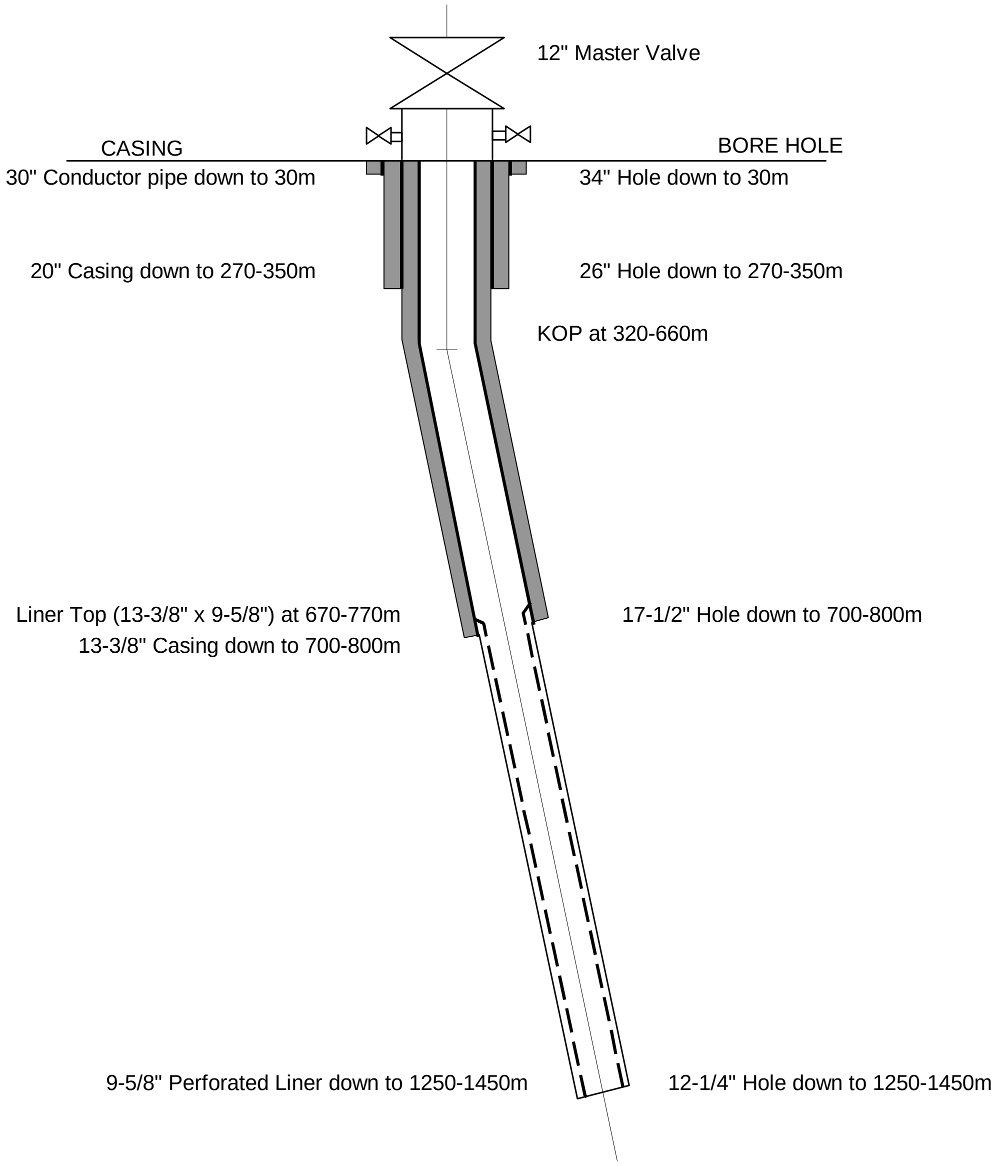


Fig. IV-3-5 Tentative Production Well Casing Program – Big Hole

Total Depth	1250-1450m
Elevation	72-77m
KOP	310-410m
Drift Angle	Max.10-35deg.
Direction	

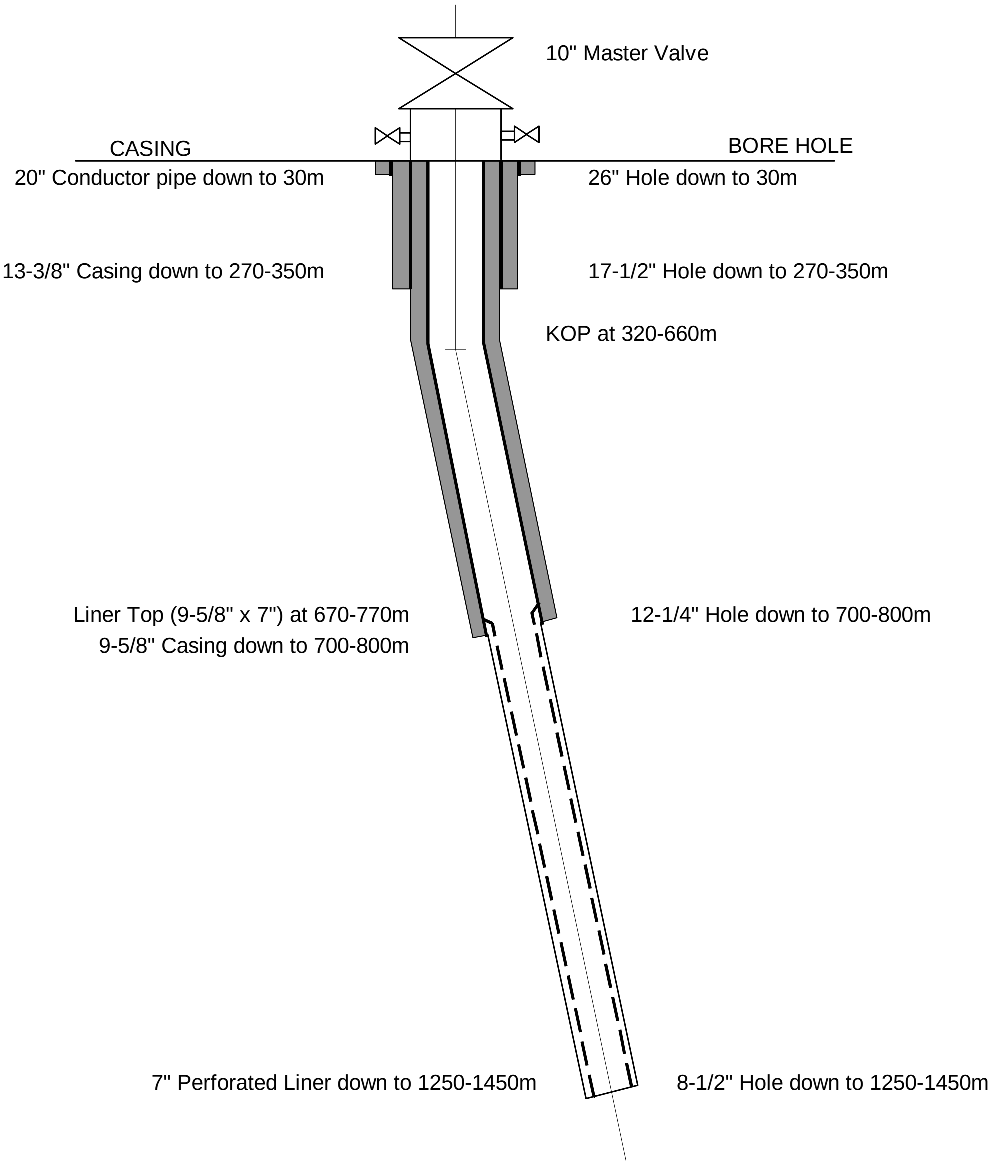


Fig. IV-3-6 Tentative Production Well Casing Program – Standard Hole

Total Depth	950-1450m
Elevation	58m
KOP	330-360m
Drift Angle	Max.20-35deg.
Direction	

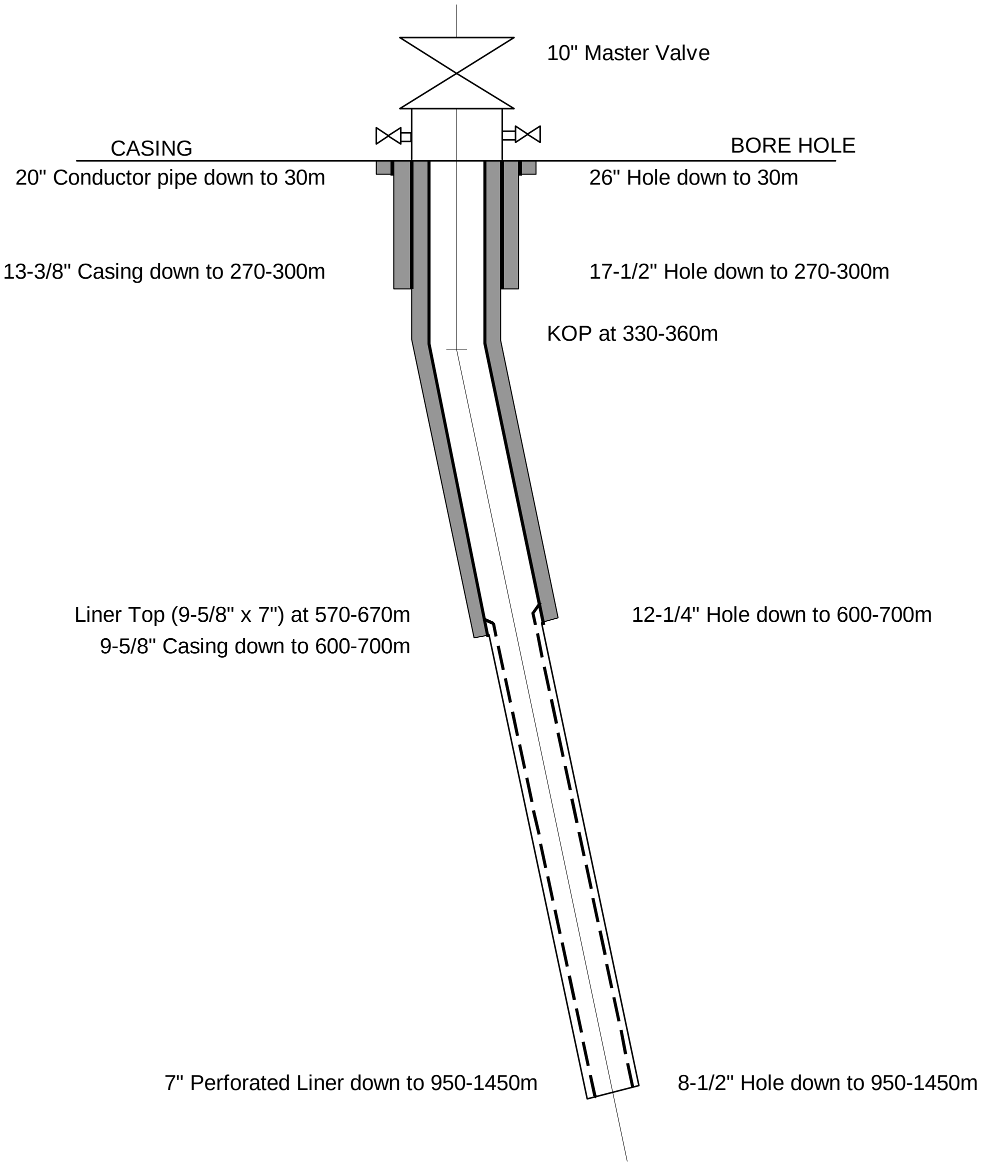


Fig. IV-3-7 Tentative Reinjection Well Casing Program

Table IV-3-2 Proposed Well Specifications

		TLU-01	TLU-02	TLU-11	TLU-12	TLU-13	TLU-21	TLU-22
Location	Easting (m)	422463.89	422456	422960	422970	422980	423440	423450
	Northing (m)	9601866.54	9601861	9602180	9602180	9602180	9602550	9602550
	Elevation (m)	72.78	72.78	77	77	77	72	72
Azimuth (deg. from true North)			257.32	237.27	221.27	109.93	194.84	148.26
KOP (m)			436	368	508	632	400	463
Build-up Rate (deg./10m)			1	1	1	1	1	1
Maximum Drift Angle (deg.)			14	30	12	14	21	25
Total Depth (m)			1300	1500	1500	1350	1500	1350
Vertical Depth (m)			1277.11	1375.02	1480.07	1331.44	1436.22	1282.46
Throw (m)			192.17	492.76	193.82	156.85	357.00	322.89
Target	Easting (m)		422294	422594	422857	423103	423358	423593
	Northing (m)		9601824	9601945	9602051	9602135	9602240	9602319
	Elevation (m)		-1100	-1200	-1300	-1150	-1270	-1100
Remarks			Banda Fault @1193 m	Banda Fault @1387 m	Banda Fault @1395 m	Banda Fault @1242 m	Banda Fault @1399.2 m	Banda Fault @1228 m

		TLU-23	TLU-31R	TLU-32R	TLU-33R	TLU-34R	TLU-35R	TLU-36R
Location	Easting (m)	423460	424455	424464	424472	424481	424489	424498
	Northing (m)	9602550	9602865	9602871	9602876	9602882	9602887	9602893
	Elevation (m)	72	58	58	58	58	58	58
Azimuth (deg. from true North)		109.25	158.74	128.29	99.21	82.71	73.64	68.16
KOP (m)		410	300	322	332	342	373	363
Build-up Rate (deg./10m)		1	1	1	1	1	1	1
Maximum Drift Angle (deg.)		27	36	22	23	27	32	34
Total Depth (m)		1500	950	1000	1100	1250	1350	1500
Vertical Depth (m)		1400.75	871.40	961.29	1051.11	1170.58	1233.79	1344.14
Throw (m)		434.72	279.88	213.29	255.76	352.10	435.22	543.63
Target	Easting (m)	423833	424520	424595	424681	424768	424855	424942
	Northing (m)	9602420	9602698	9602767	9602842	9602918	9602994	9603071
	Elevation (m)	-1250	-675	-790	-890	-990	-1090	-1190
Remarks		Banda Fault @1412 m	Banda Fault @779 m	Banda Fault @878 m	Banda Fault @988 m	Banda Fault @1113 m	Banda Fault @1248.9 m	Banda Fault @1384 m

		TLU-37R
Location	Easting (m)	424506
	Northing (m)	9602898
	Elevation (m)	58
Azimuth (deg. from true North)		64.53
KOP (m)		330
Build-up Rate (deg./10m)		1
Maximum Drift Angle (deg.)		35
Total Depth (m)		1650
Vertical Depth (m)		1453.22
Throw (m)		659.99
Target	Easting (m)	425032
	Northing (m)	9603149
	Elevation (m)	-1285
Remarks		Banda Fault @1516 m

IV.4 Plant Construction

In this section, the plant construction plan consisting of the overall location plan for the well pads and the power plant, and the plans for the geothermal Fluid Collection and Reinjection System (FCRS), the Geothermal Power Plant, and equipment transportation are studied.

IV.4.1 Overall Location Plan for Well Pads and Power Plant

In planning the overall location of the well pads and the power plant, the natural flow of the geothermal fluid is considered. The geothermal fluid naturally flows from higher to lower topographic elevations and from higher to lower energy levels as well. The geothermal fluid flows from a higher energy level to a lower energy level, or from the production wells to the geothermal power plant, and then finally to the reinjection wells. The production wells, the geothermal power plant and the reinjection wells need to be arranged from higher to lower topographic elevations, respectively. In particular, the brine in the reinjection pipeline is saturated hot water, and the transportation of saturated hot water from lower elevations to higher elevations should be avoided in order to prevent flash-over and water hammering in the pipeline.

The two-phase flow of geothermal fluid (a mixture of steam and hot water) from the production wells is fed to the separator(s) installed in the power plant. Then the separated steam will rotate the turbine-generator for power generation and the separated brine is transferred to the reinjection wells for return to the geothermal reservoir.

The location plan for the Production Well Pads (TLU-0, TLU-1 and TLU-2), the Reinjection Well Pad (TLU-3), the Power Plant, and the Transmission Line is shown in Fig. IV-4-1. The well pad currently being developed by PLN is Production Well Pad TLU-0 (from which the first exploration well, TLU-01, has been drilled), and Production Well Pads TLU-1 and TLU-2 will be located along the Banda Fault approximately 600 m and 1000m north-east of TLU-0, respectively. The Tulehu Geothermal Power Plant will be located adjacent to production well pad TLU-1. Reinjection Well Pad TLU-3 will be located approximately 1500 m northeast of the power plant. Accordingly, the production well pads will be located at an elevation of around 72 to 77 m above sea level, the geothermal power plant at around 72 m above sea level, and the reinjection well pad at around 58 m above sea level.

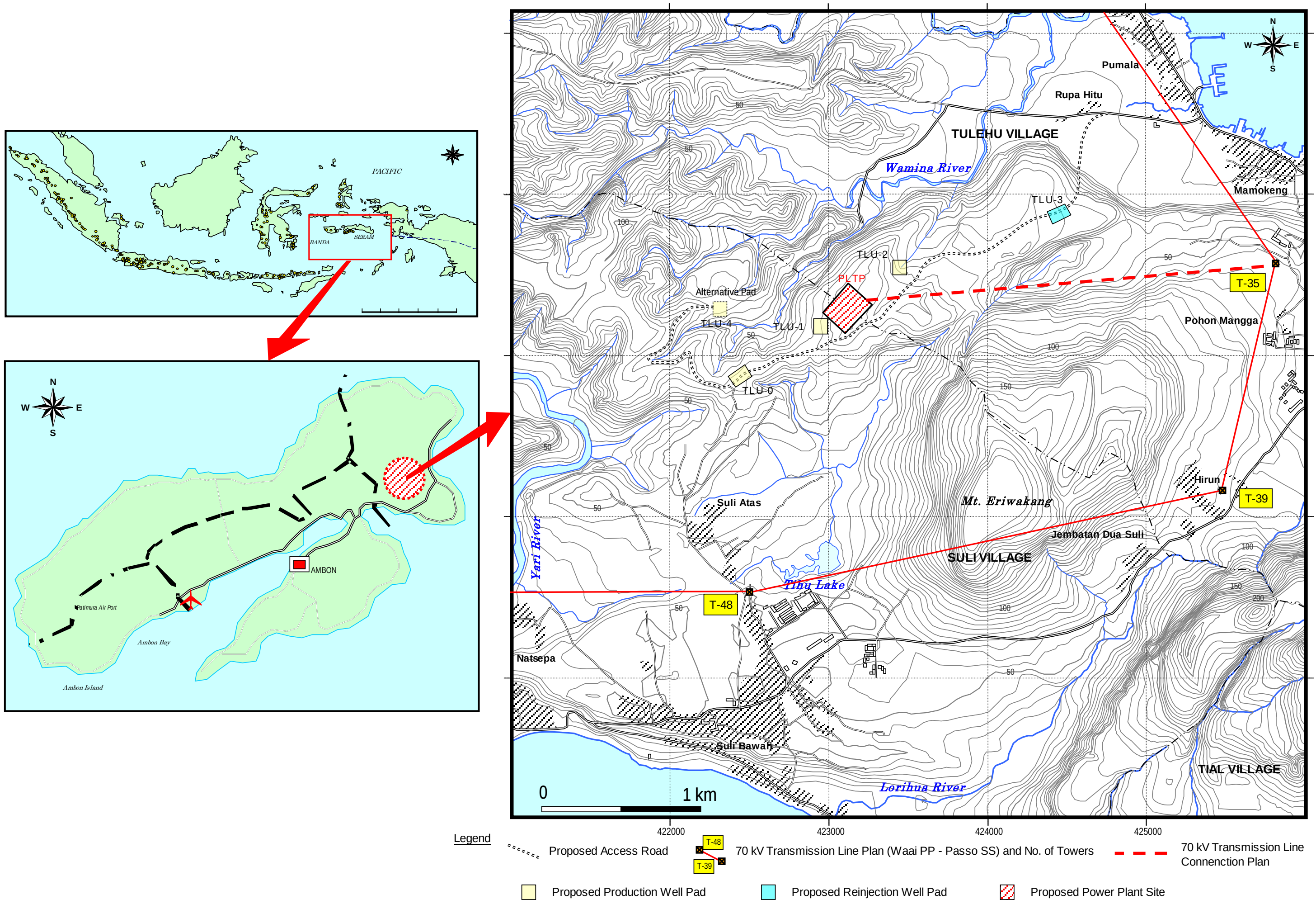


Fig. IV-4-1 Location Plan of Drilling Pads, Power Plant and Transmission Line

IV.4.2 FCRS Plan

The Fluid Collection and Reinjection System (FCRS) consists of the followings.

- Pipeline of steam and hot water mixture from the production wells to the separator(s),
- Separator(s),
- Steam pipeline from the separator(s) to the power plant,
- Brine pipeline from the separator(s) to the reinjection wells, and
- Condensate reinjection pipeline from the power plant to the reinjection pipeline.

For a double flash system, the flasher(s) will be additionally attached to the brine pipeline of the separator downstream. In the flasher(s), the brine temperature becomes lower (around 100°C), and the likelihood of a scaling problem increases. The scaling phenomenon will be carefully examined through geothermal fluid analysis in the production tests of the exploration wells in the near future, and the adequate flasher pressure will be determined. In addition, countermeasures against scaling problems will be taken, if necessary. The conceptual process flow diagrams are as follows for the following four types of FCRS.

Fig. IV-4-2	2 x 10 MW Single Flash System,
Fig. IV-4-3	1 x 20 MW Single Flash System,
Fig. IV-4-4	2 x 10 MW Double Flash System, and
Fig. IV-4-5	1 x 20 MW Double Flash System.

1. Geothermal Fluid Transportation Pipeline from Production Wells to Separator(s)

The geothermal fluid from the production wells will be transported to the separator(s) by pipeline as a two-phase flow (a mixture of steam and hot water). The two-phase flow pipelines from the production wells (TLU-0, TLU-1, and TLU-2) will be interconnected on the way to the separator(s) at the power plant compound. The two-phase pipeline will be arranged on the decline between the production wells and the separator(s).

A well-head separation system can be considered, in which the steam is separated at the well-head and the separated steam is transported to the power plant. In this case, a large size pipe will be necessary to transport the large amount of separated steam, and the construction cost for the pipe will be higher. Thus, for reasons of economy, a two-phase flow pipeline will be selected for the transportation of the geothermal fluid from the production wells to the separator(s).

2. Separator(s)/Flasher(s)

The separator(s) will be located in the power plant compound. The two-phase flow of geothermal fluid from the production wells will be separated into steam and brine. The separated steam will be supplied to the turbine(s) for power generation, and the separated brine will be transferred to the reinjection wells. For a double flash system, the flasher(s) will additionally be installed in the downstream portion of the separator brine line. In the flasher(s), additional secondary steam with a lower pressure will be produced, and the secondary steam will be used for power generation in the turbine(s).

In this scheme, the geothermal energy will be utilized more effectively for power generation.

3. Steam Supply Pipeline from Separator to Turbine

The steam separated in the separator(s) will be supplied to the steam turbine by the steam supply pipeline. Scrubber(s) and demister(s) will be provided to improve the quality of the turbine steam. A pressure relieving device and silencer will be installed on the pipeline for safety purposes. In the case of the double flash system, a secondary steam pipeline will be installed from the flasher(s) to the middle stage of the turbine(s).

4. Brine Pipelines from Separator(s) to Reinjection Wells

The brine separated in the separator(s) or flasher(s) will be transported to the reinjection wells and returned to the underground. The separated brine is saturated hot water, and the abnormal phenomena of flashing and water hammering in the pipeline can easily happen in a rising pipeline. To avoid such abnormal phenomena, it is best for the brine pipeline to be arranged so that it falls steadily toward the reinjection wells.

5. Power Plant Condensate Reinjection Pipeline

The steam, after working in the turbine, condenses by cooling down in the condenser, and the condensate is pumped up to the cooling tower and becomes re-circulating cooling water. Part of the re-circulating cooling water overflows at the cooling tower basin, and discharges out of the system. The overflow water (condensate) will be transported to the reinjection wells for return into the underground by a condensate reinjection pipeline connecting to the brine reinjection pipeline. The volume of condensate will be quite small compared to the hot brine mentioned above, and condensate admixture will have little cooling effect on the hot brine.

Conceptual Process Flow of Steamfield - Tulehu Geothermal Power Plant Project

2 x 10 MW Single Flash Cycle Case

Total steam flow:	200t/h
Total brine flow:	896t/h

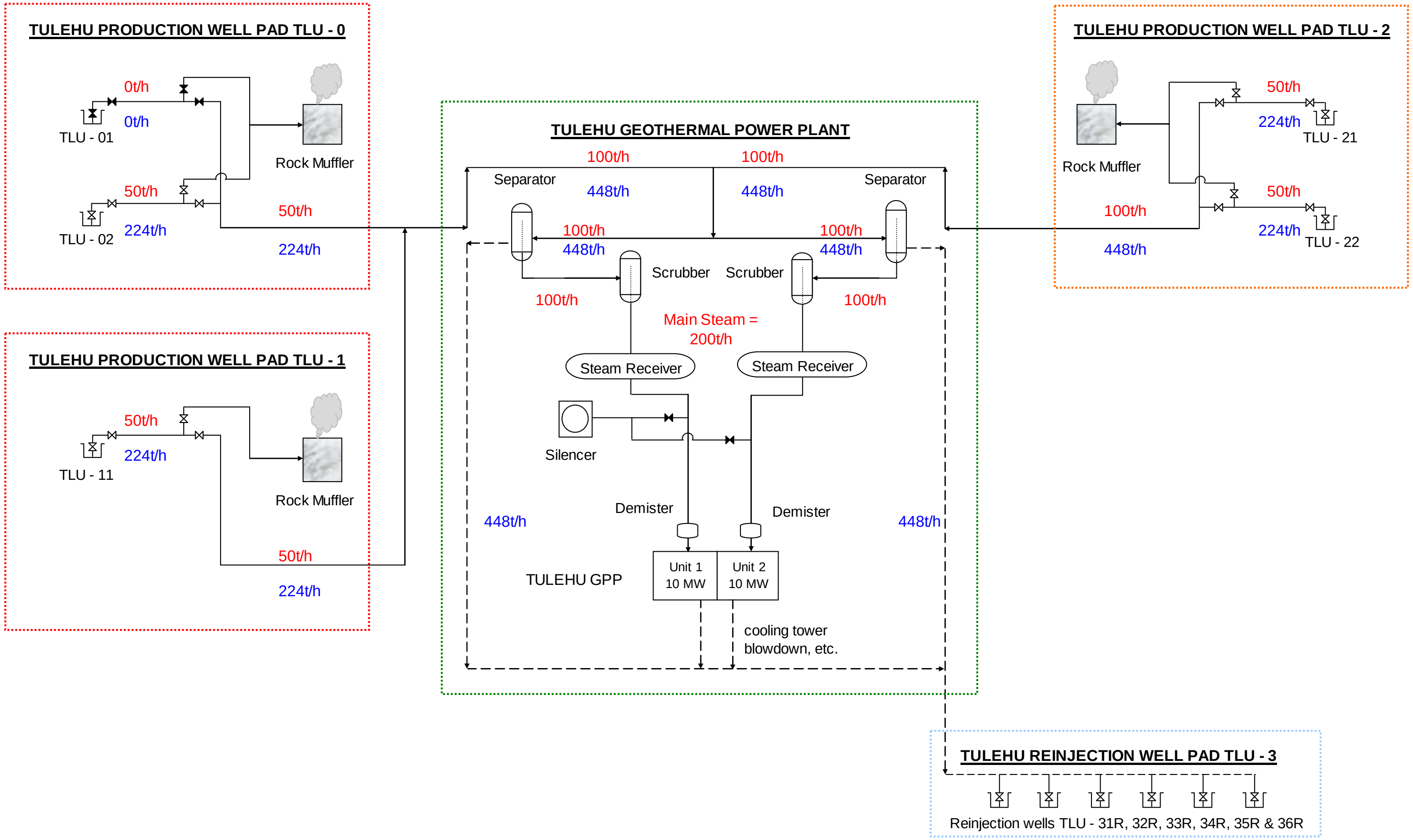


Fig. IV-4-2 2 x 10 MW Single Flash Cycle Case - Conceptual Process Flow of Steamfield of Tulehu Geothermal Power Plant Project

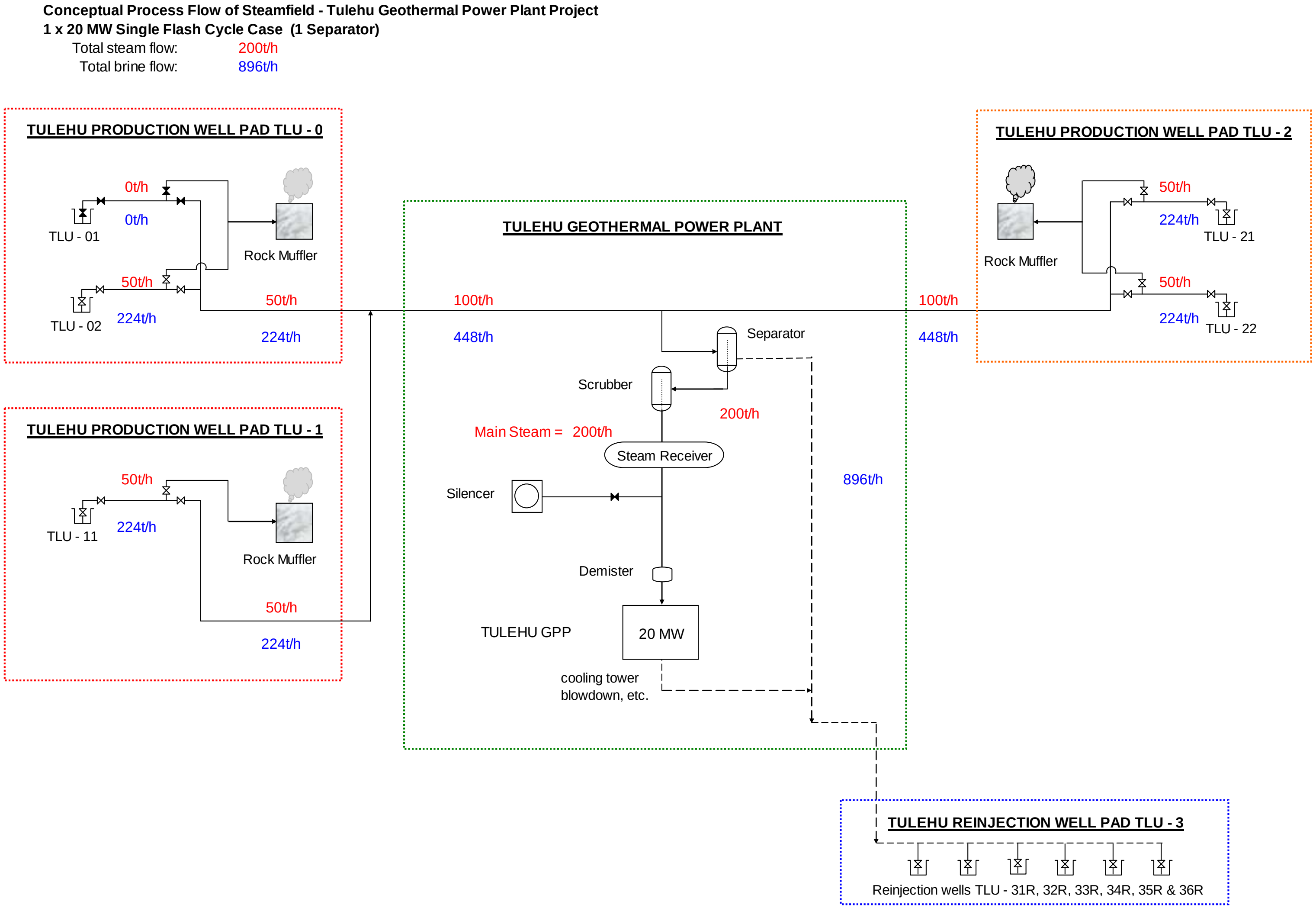


Fig. IV-4-3 1 x 20 MW Single Flash Cycle Case - Conceptual Process Flow of Steamfield of Tulehu Geothermal Power Plant Project

Conceptual Process Flow of Steamfield - Tulehu Geothermal Power Plant Project

2 x 10 MW Double Flash Cycle Case

Total steam flow:	150t/h / 44t/h	(Primary Steam / 2nd Flash Steam)
Total brine flow:	628t/h	

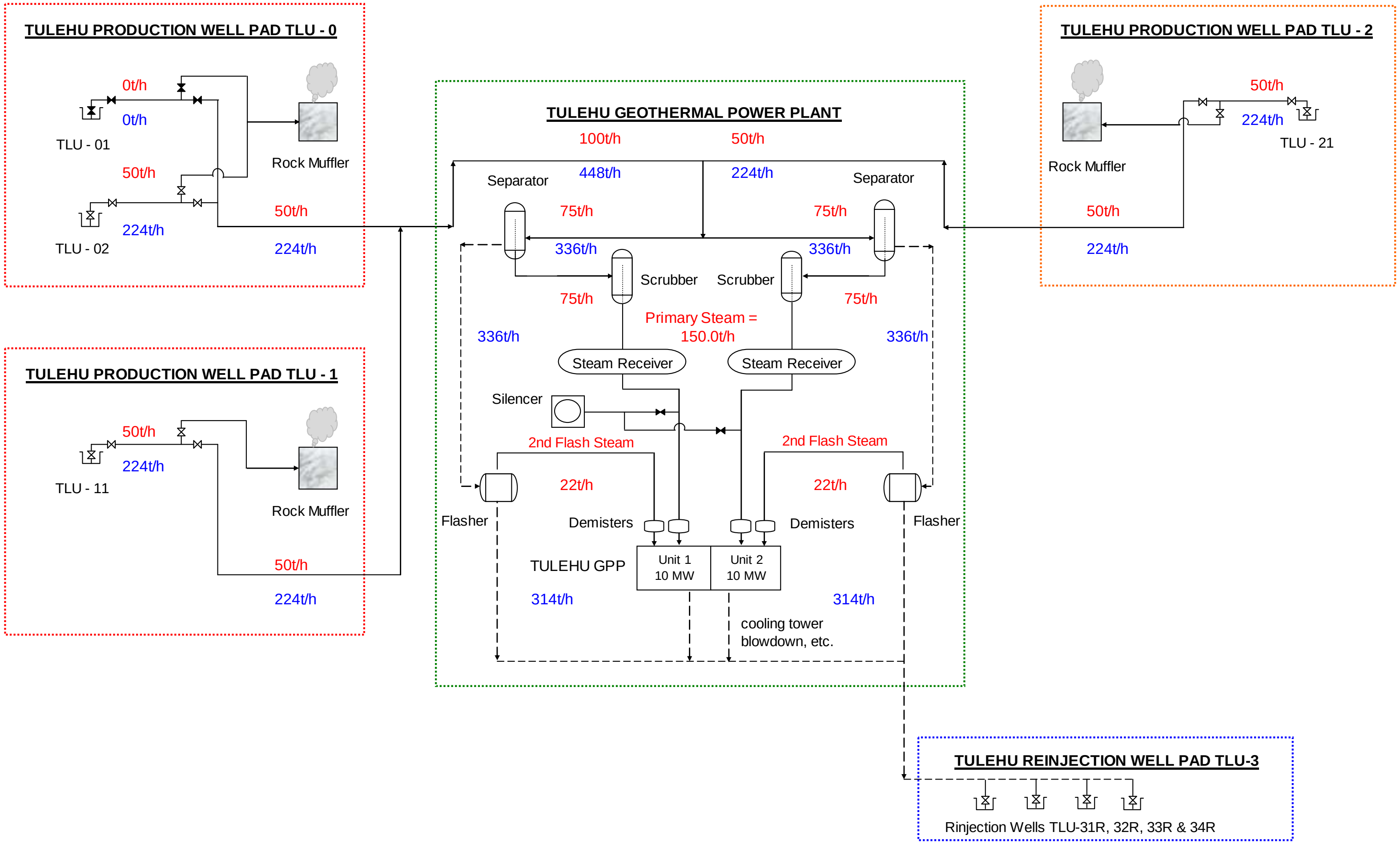


Fig. IV-4-4 2 x 10 MW Double Flash Cycle Case - Conceptual Process Flow of Steamfield of Tulehu Geothermal Power Plant Project

Conceptual Process Flow of Steamfield - Tulehu Geothermal Power Plant Project

1 x 20 MW Double Flash Cycle Case

Total steam flow: 150t/h / 44t/h (Primary Steam / 2nd Flash Steam)

Total brine flow: 628t/h

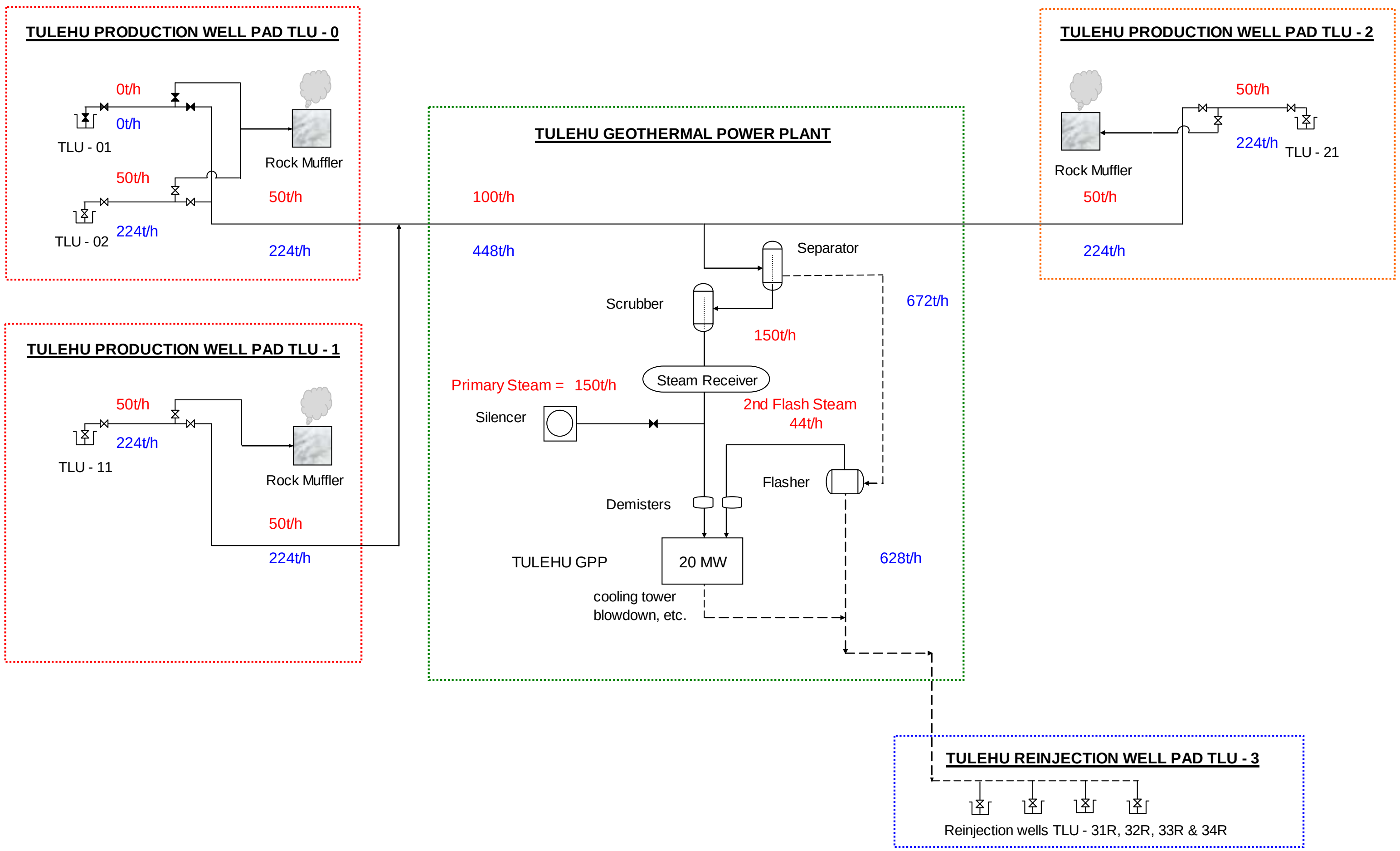


Fig.IV-4-5 1 x 20 MW Double Flash Cycle Case - Conceptual Process Flow of Steamfield of Tulehu Geothermal Power Plant Project

IV.4.3 Geothermal Power Plant Plan

Based on the geothermal resource study of the currently available data and the development plan explained in Chapter III and sections IV.1, 2, & 3, the following four (4) sets of plans for the four possible types of geothermal power plant are studied. As for the possible use of a geothermal binary system, this is considered only in general terms at this very initial stage of the project study.

- Single Flash System 2 x 10 MW
- Single Flash System 1 x 20 MW
- Double Flash System 2 x 10 MW
- Double Flash System 1 x 20 MW

The power plant systems (single flash system, double flash system, and binary system), the plant unit capacity, and the equipment and specifications for the mechanical, electrical, and instrumentation and control system of the power plant are studied in this section. The current outputs of geothermal resource study and its development plan are enhanced with some assumptions based on knowledge and experience, since the currently available data and information are limited. The geothermal resource evaluation should be re-examined in the light of additional data as more information on the drilling and testing of the further exploratory wells becomes available and in the light of meteorological observations at the project site. The geothermal resource development plan and the power plant plan will need to be reconsidered accordingly before starting project implementation.

1. Power Plant System

There are various types of geothermal power plant systems, such as the back-pressure system, the single flash condensing system, the double flash condensing system, and the binary system, as presented in Table IV-4-1. Based on the evaluation of the Tulehu geothermal resources, the single flash system and the double flash system, which are the most generally adopted systems for geothermal power plants, are studied in this feasibility study, and the features, merits and demerits of the both systems are compared in Table IV-4-2 to facilitate selection of the recommendable power plant system for Tulehu geothermal project.

The double flash system is more suitable for the Tulehu geothermal project than the single flash system because of the following technical and economic considerations. The double flash system is recommendable because of its effective utilization of the geothermal energy and because it results in a more economically viable geothermal power plant project, as explained hereinafter.

The pressure and temperature of the Tulehu geothermal fluid is not so high (around 3 bara / 133°C only), and the anticipated steam-hot water ratio will be approximately 1:4.5, meaning that a large volume of hot water will be contained in the fluid. In the case of the single flash system, the large volume of hot water separated as brine in the separator will be about 80 %wt of the total amount of the geothermal fluid. None of the separated brine will be utilized for power generation, but will be returned to the underground via reinjection wells. In the case of the double flash system, additional secondary steam will be extracted from the separator brine in the flasher, and this additional secondary steam will work to generate power, making the plant more efficient.

From the viewpoint of project costs, a single flash system project will cost approximately 40 % more (to drill the larger number of wells required) than a double flash system project. The single flash system project will need four (4) production wells and six (6) reinjection wells for operation of the 20 MW geothermal power plant, since there will be less usable steam and more brine to reinject. The double flash system project will require three (3) production wells and four (4) reinjection wells. It will require some additional investment, approximately a few per cent (%) increase, for the secondary steam facilities such as flasher(s), piping, valves, supports, etc., but this additional investment will be much lower than the cost of drilling additional wells for the single flash system project.

The chemical characteristics of the geothermal fluid are not available yet, and there could be a possibility of scaling problems arising in a low-temperature operation. Scaling problems would necessitate a limitation on the flashing pressure and temperature, which might restrict the double flash system to a limited utilization of the brine energy. The suitable geothermal power plant system should be re-studied in the next stage before implementation of the project on the basis of additional data, information, and the results of the further drilling of exploration wells, production tests, and chemical analysis of the geothermal fluid. If the geothermal fluid enthalpy proves to be lower than estimated and the hot water quantity is much greater than anticipated, the possibility of a binary system may be considered.

Geothermal Binary System:

Since the geothermal fluid of Tulehu is anticipated to be not so high in temperature and to comprise a large quantity of hot water, a geothermal binary system could also be an attractive choice. A geothermal binary system can effectively utilize the geothermal energy, and the number of wells to drill can be reduced, as with the double flash system compared to the single flash system. The unique feature of the binary system is that power generation is possible with a secondary medium of low boiling temperature, even when the available geothermal fluid is relatively low in temperature.

In a geothermal binary system, the geothermal fluid from the production wells is separated into steam and brine in the separator, and the geothermal energy of both the steam and the brine is transferred to a secondary medium in the heat exchangers. The steam heats and evaporates the pre-heated secondary medium in the evaporator, and the steam condensate meets the separated brine. The mixture of steam condensate and brine heats the secondary medium in the pre-heater, and the mixture of fluids is transferred to the reinjection wells for reinjection to the underground. The evaporated secondary medium rotates the turbine-generator for power generation, and it is cooled down and liquefied in the air-cooled condenser. The liquefied secondary medium is pumped into the pre-heater and it is heated again.

However, as in the case of the double flash system, a low limiting temperature due to the brine scaling problem will be a factor in geothermal fluid utilization. The in-house plant use of electric power with a geothermal binary system is as high as around 15 %, or double or triple the single flash and double flash system use of around 5 to 8 %. In order to secure the same net electric power generation as a single flash or double flash system, a larger gross generation capacity, approximately 10 % greater, will be required for a geothermal binary system. A geothermal binary system will also require a larger plant compound area to accommodate a number of air-cooled condensers.

In the technical study of a geothermal binary system, many design factors and conditions need to be clarified for secondary medium selection. Factors such as the pressure, temperature, and flow rate of the secondary medium, atmospheric design temperature, brine temperature, unit capacity, cooling methods, possible combination with a back-pressure steam turbine, and others need to be considered. Most of these factors and conditions cannot be confirmed at this stage in the feasibility study, and further consideration of a geothermal binary system is adjourned. It is recommended that further detailed studies of the geothermal binary system be resumed in the next engineering stage, when additional data and information on the characteristics of the geothermal fluid, steam, and brine will have been obtained through additional exploration well drilling and testing, and the atmospheric design conditions can be confirmed by meteorological observations at the project site.

Table IV-4-1 Geothermal Power Plant Systems

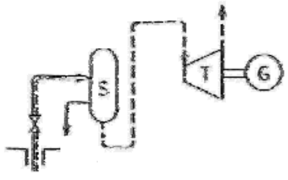
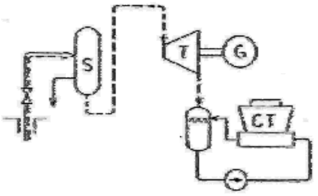
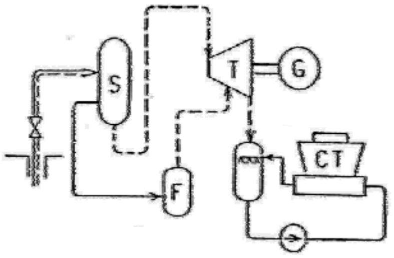
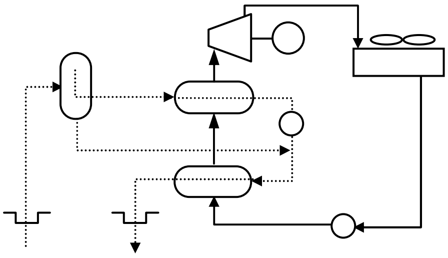
Type of Process	Features
1) Single Flash with Back Pressure System 	• Suitable for water-dominated resources. • Suitable for high NCG content. • Small capacity - Usually installed as a well-head generating pilot plant. • Lower efficiency compared to condensing steam turbine. • Low construction cost. • High exhaust noise level.
2) Single Flash with Condensing System 	• Suitable for water-dominated resources. • Wide range of capacity from small to large. • System in most general use. • Lower efficiency in utilizing geothermal energy for geothermal fluid of low specific enthalpy compared to double flash system.
3) Double Flash with Condensing System 	• Suitable for water-dominated resources • Wide range of capacity from small to large. • Main steam separated in separator and the additional steam separated in flasher. • Higher efficiency than single flash system. • Higher construction cost than for single flash. • Low-temperature brine from flasher would cause silica scale problem in reinjection line.
4) Two-phase (Biphase) Binary System 	• Suitable for water-dominated resources. • Suitable for resources of moderate to medium specific enthalpy. • Low-temperature brine from separator and heat exchanger would cause silica scale problem in reinjection line. • Unit capacity is small, up to around 10 MW. • Station power use is very large (approx. 15%).

Table IV-4-2 Case Study of Single Flash System and Double Flash System

Power Plant System	Single Flash System	Double Flash System
Current Study Results	Inferior	Superior
Turbine Inlet Steam Pressure	Primary steam: 3 bar-a Secondary steam: None	Primary steam: 3 bar-a Secondary steam: 1.2 bar-a
Number of Wells	**(+) 3 wells** Total: 10 wells Production: 4 wells Reinjection: 6 wells	**Base Case** Total: 7 wells Production: 3 wells Reinjection: 4 wells
Flasher & 2nd Steam System	Not Applicable	2 sets
Brine Reinjection Volume	Very great, Approx.: 896 t/h **Approx. (+) 268 t/h**	Less, Approx.: 628 t/h **Base Case**
Utilization of Geothermal Fluid Energy	*Lower utilization of geothermal fluid energy since all brine separated in separator is reinjected. * Ratio of the steam utilized for power generation and the total geothermal fluid supplied from production wells: Around 18% (weight)	*Higher utilization of geothermal fluid energy since additional steam is produced in a flasher from separator brine and is utilized for power generation. * Ratio of the steam utilized for power generation and the total geothermal fluid supplied from production wells: Around 23% (weight) (+) 5 points
Project Cost	**Higher Project Cost** *Higher investment for Production wells and Reinjection wells	**Base Case** *Lower investment for Production wells and Reinjection wells. *Additional investment for 2nd steam flash system, but the amount is much smaller than the cost for additional wells in a single flash system.
Necessary Power Plant Area	Approx. 100 m - 130 m x 150 m	Approx. 100 m - 130 m x 150 m *Extra space is necessary for 2nd steam flash facilities, but those facilities can be placed within the same area as in the Single Flash Case.
Construction Period	Standard schedule: 26 months	Standard schedule: 26 months (2nd steam flash facilities can be completed within the turbine construction period.)

2. Plant Unit Capacity

As mentioned in the geothermal resource study of chapter III, the development scale of the Tulehu geothermal field is 20 MW. The peak load demand of the Ambon electric power system will reach 110 MW in the near future. The Tulehu geothermal power plant will be operated as a base load power plant, and as large a unit capacity as practicable would be desirable. The unit generating capacity of the power plants will have an impact on the stable operation of the Ambon electric power system. A unit capacity of 10 to 20 MW for Tulehu geothermal power plant could be still tolerable, considering the future scale of the Ambon electric power system.

For reference, the unit capacity of the Waai coal-fired thermal power plant is 15 MW x 2 units. The Waai power plant is currently under construction in the eastern part of Ambon Island and will start supplying power to the Ambon electric power system in 2012 through a 70 kV transmission line. The peak load demand in 2013 of the Ambon electric power system is anticipated to be 52.9 MW.

The study of the two (2) cases of unit output capacity (2 x 10 MW and 1 x 20 MW) for the Tulehu geothermal power plant are summarized in the following Table IV-4-3.

Table IV-4-3 Case Study of Unit Output Capacity for Tulehu Geothermal Power Plant

Number of Units x Unit Output Capacity	2 units x 10 MW	1 unit x 20 MW
Current Study Results	Good	Good
Separator	2 sets	1 set
Flasher (Double Flash case)	2 sets	1 set
Turbine & Generator	2 sets	1 set
Cooling Tower	2 cells x 2 sets	3 cells x 1 set
Switchyard	5 Bays - 2 circuit Transmission Lines, - Bus Tie, - Unit-1 Main Transformer, - Unit-2 Main Transformer	4 Bays - 2 circuit Transmission Lines, - Bus Tie, - Main Transformer
Construction Period (EPC Contract – Taking Over)	26months - Unit 1: 23 months - Unit 2: 23 months (completed 3 months later)	23months
Unit Output Capacity against Ambon Power System	Unit capacity 10 MW: Within the allowable range of unit capacity for stable operation of Ambon power system (The predicted system peak load will be 72.9 MW at the initial commissioning of Tulehu GPP, and 110 MW a few years afterwards.) (Reference) 2 x 15 MW Waai coal-fired thermal power plant, currently under	Unit capacity 20 MW: Within the allowable range of unit capacity for stable operation of Ambon power system (The predicted system peak load will be 72.9 MW at the initial commissioning of Tulehu GPP, and 110 MW a few years afterwards.) (Reference) 2 x 15 MW Waai coal-fired thermal power plant, currently under

Number of Units x Unit Output Capacity	2 units x 10 MW	1 unit x 20 MW
Current Study Results	Good	Good
	construction, will start supplying power in 2012 to the Ambon Power System, in which peak demand will be 52.9 MW in 2013.	construction, will start supplying power in 2012 to the Ambon Power System, in which peak demand will be 52.9 MW in 2013.
Project Cost	Higher - Power Plant cost per kW is higher because of smaller unit capacity. - Higher investment for more cells and 2 sets for the cooling towers. - Higher investment for more bays for the switchyard.	**Base Case**
Necessary Power Plant Area	Approximately 1.95 ha (Approx. 130 m x 150 m) - Larger plant area for layout of 2 units of power generating facilities	**Base Case** Approximately 1.5 ha (Approx. 100 m x 150 m)
Purchase Marketability	- Many supply track records of 10 MW geothermal power units. - Lower competition of purchase marketability To be limited purchase competition by the manufacturers that entered the market of the geothermal power plant.	- Many supply track records of 20 MW geothermal power units. - Higher competition of purchase marketability To be good purchase competition by both of the advanced manufacturers and the manufacturers that entered the market of the geothermal power plant.

3. Specifications of Major Mechanical Equipment

The specifications of the major mechanical equipment for the Tulehu geothermal power plant are studied for the following four (4) cases of plant system and unit capacity: 2 x 10 MW Single Flash Condensing System, 1 x 20 MW Single Flash Condensing System, 2 x 10 MW Double Flash Condensing System, and 1 x 20 MW Double Flash Condensing System. The equipment and specifications mentioned hereunder should be reconsidered at the beginning of the project implementation stage in light of the test data from the additional exploration wells and the meteorological data observed at the project site.

For the above four (4) study cases, the typical layout plans of the power plants are shown in Figs. IV-4-6, IV-4-7, IV-4-8, and IV-4-9, and the overall flow diagrams of the power plants are shown in Figs. IV-4-10, IV-4-11, IV-4-12 and IV-4-13.

Major specifications of the power plant mechanical equipment are as follows.

Plant System & Unit Capacity	Single Flash, Condensing 2 x 10 MW	Single Flash, Condensing 1 x 20 MW	Double Flash, Condensing 2 x 10 MW	Double Flash, Condensing 1 x 20 MW
Turbine				
No. of units	1 set / unit x 2 units	1 set	1 set / unit x 2 units	1 set
Type	Single Casing, Single Flow, Impulse or Reaction, Condensing Type	Single Casing, Single Flow, Impulse or Reaction, Condensing Type	Single Casing, Single Flow, Impulse or Reaction, Condensing Type	Single Casing, Single Flow, Impulse or Reaction, Condensing Type
Rated output	10,000 kW / unit	20,000 kW	10,000 kW / unit	20,000 kW
Max. capacity	105% Rated output	105% Rated output	105% Rated output	105% Rated output
Speed	3,000 rpm	3,000 rpm	3,000 rpm	3,000 rpm
Steam press. / temp.	3.0 bar abs. / 133.5^{o}C *(Tentative)*	1st: 3.0 bar abs. / 133.5^{o}C 2nd: 1.14 bar abs. / 103.3^{o}C *(Tentative)*	3.0 bar abs. / 133.5^{o}C *(Tentative)*	1st: 3.0 bar abs. / 133.5^{o}C 2nd: 1.14 bar abs. / 103.3^{o}C *(Tentative)*
NCG content in steam	% in weight *(To be confirmed after well testing)*	% in weight *(To be confirmed after well testing)*	% in weight *(To be confirmed after well testing)*	% in weight *(To be confirmed after well testing)*
Steam rate at rated output	Approx. 125 t/h / unit *(Tentative)*	1st: Approx. 190 t/h 2nd: Approx. 54 t/h *(Tentative)*	Approx. 250 t/h *(Tentative)*	1st: Approx. 190 t/h 2nd: Approx. 54 t/h *(Tentative)*
Condenser				
No. of units	1 set / unit x 2 units	1 set	1 set / unit x 2 units	1 set
Type	Spray, Direct Contact type Condenser	Spray, Direct Contact type Condenser	Spray, Direct Contact type Condenser	Spray, Direct Contact type Condenser
Pressure	approx. 0.12 bar abs. *(Tentative)*	approx. 0.12 bar abs. *(Tentative)*	approx. 0.12 bar abs. *(Tentative)*	approx. 0.12 bar abs. *(Tentative)*
Gas Extractor				

No. of sets	2 sets / unit x 2 units	2 sets	2 sets / unit x 2 units	2 sets
Type	Two Stage Steam Jet Ejector	Two Stage Steam Jet Ejector	Two Stage Steam Jet Ejector	Two Stage Steam Jet Ejector
Capacity x Number of trains	1st stage: 100% x 2 2nd stage: 100% x 2	1st stage: 100% x 2 2nd stage: 100% x 2	1st stage: 100% x 2 2nd stage: 100% x 2	1st stage: 100% x 2 2nd stage: 100% x 2
Cooling Tower				
No. of units	1 set / unit x 2 units	1 set / unit	1 set / unit x 2 units	1 set / unit
Type	Counter or Cross flow, Mechanical Draft, Concrete Basin/Foundation and FRP structure	Counter or Cross flow, Mechanical Draft, Concrete Basin/Foundation and FRP structure	Counter or Cross flow, Mechanical Draft, Concrete Basin/Foundation and FRP structure	Counter or Cross flow, Mechanical Draft, Concrete Basin/Foundation and FRP structure
Number of cells	2 cells / set x 2 sets	3 cells / set x 1 set	2 cells / set x 2 sets	3 cells / set x 1 set
Hotwell Pump				
No. of units	2 sets / unit x 2 units	2 sets	2 sets / unit x 2 units	2 sets
Type	Vertical, centrifugal, double suction, single stage, canned pump	Vertical, centrifugal, double suction, single stage, canned pump	Vertical, centrifugal, double suction, single stage, canned pump	Vertical, centrifugal, double suction, single stage, canned pump
Capacity	50% /set	50% /set	50% /set	50% /set
Demister				
No. of units	1 set / unit x 2 units	1 set	1 set / unit x 2 units	1 set
Type	Vane or cyclone centrifugal type	Vane or cyclone centrifugal type	Vane or cyclone centrifugal type	Vane or cyclone centrifugal type
Steam dryness	At least 99.98% at outlet	At least 99.98% at outlet	At least 99.98% at outlet	At least 99.98% at outlet
Turbine Wash Water Pump				
No. of units	1 set / unit x 2 units	1 set	1 set / unit x 2 units	1 set
Type	Horizontal, centrifugal, to inject geothermal condensate (Hotwell pump discharge water) into main steam	Horizontal, centrifugal, to inject geothermal condensate (Hotwell pump discharge water) into main steam	Horizontal, centrifugal, to inject geothermal condensate (Hotwell pump discharge water) into main steam	Horizontal, centrifugal, to inject geothermal condensate (Hotwell pump discharge water) into main steam
Capacity	100% / set	100% / set	100% / set	100% / set
Primary Cooling Water Pump				

No. of units	2 sets / unit x 2 units	2 sets	2 sets / unit x 2 units	2 sets
Type	Horizontal, Single Stage, Centrifugal	Horizontal, Single Stage, Centrifugal	Horizontal, Single Stage, Centrifugal	Horizontal, Single Stage, Centrifugal
Capacity	100% / set	100% / set	100% / set	100% / set
Fluid	Geothermal condensate (Cooling Tower outlet)	Geothermal condensate (Cooling Tower outlet)	Geothermal condensate (Cooling Tower outlet)	Geothermal condensate (Cooling Tower outlet)
Water-water Heat exchanger				
No. of units	2 sets / unit x 2 units	2 sets	2 sets / unit x 2 units	2 sets
Type	Plate type or Shell & Tube type	Plate type or Shell & Tube type	Plate type or Shell & Tube type	Plate type or Shell & Tube type
Capacity	100% / set	100% / set	100% / set	100% / set
Fluid	Treated fresh water	Treated fresh water	Treated fresh water	Treated fresh water
Secondary Cooling Water Pump				
No. of units	2 sets / unit x 2 units	2 sets	2 sets / unit x 2 units	2 sets
Type	Horizontal, Single Stage, Centrifugal	Horizontal, Single Stage, Centrifugal	Horizontal, Single Stage, Centrifugal	Horizontal, Single Stage, Centrifugal
Capacity	100%/set	100%/set	100%/set	100%/set
Fluid	Treated fresh water	Treated fresh water	Treated fresh water	Treated fresh water
Main Oil Tank				
No. of units	1 set / unit x 2 units	1 set	1 set / unit x 2 units	1 set
Type	Rectangular steel tank	Rectangular steel tank	Rectangular steel tank	Rectangular steel tank
Capacity	100% / set	100% / set	100% / set	100% / set
Fluid	Turbine lubricant oil	Turbine lubricant oil	Turbine lubricant oil	Turbine lubricant oil
Oil Cooler				
No. of units	2 sets / unit x 2 units	2 sets	2 sets / unit x 2 units	2 sets
Type	Vertical shell and tube type, Two (2) pass	Vertical shell and tube type, Two (2) pass	Vertical shell and tube type, Two (2) pass	Vertical shell and tube type, Two (2) pass
Capacity	100 % /set	100 % /set	100 % /set	100 % /set
Fluid	Turbine oil / Treated fresh water	Turbine oil / Treated fresh water	Turbine oil / Treated fresh water	Turbine oil / Treated fresh water

Main Oil Pump				
No. of units	1 set / unit x 2 units	1 set	1 set / unit x 2 units	1 set
Type	Main turbine driven, centrifugal type	Main turbine driven, centrifugal type	Main turbine driven, centrifugal type	Main turbine driven, centrifugal type
Capacity	100% / set	100% / set	100% / set	100% / set
Fluid	Turbine lubricant oil	Turbine lubricant oil	Turbine lubricant oil	Turbine lubricant oil
Auxiliary Oil Pump				
No. of units	1 set / unit x 2 units	1 set	1 set / unit x 2 units	1 set
Type	AC motor-driven, centrifugal type	AC motor-driven, centrifugal type	AC motor-driven, centrifugal type	AC motor-driven, centrifugal type
Capacity	100% / set	100% / set	100% / set	100% / set
Fluid	Turbine lubricant oil	Turbine lubricant oil	Turbine lubricant oil	Turbine lubricant oil
Emergency Oil Pump				
No. of units	1 set / unit x 2 units	1 set	1 set / unit x 2 units	1 set
Type	DC motor-driven, centrifugal type	DC motor-driven, centrifugal type	DC motor-driven, centrifugal type	DC motor-driven, centrifugal type
Capacity	100% / set	100% / set	100% / set	100% / set
Vapor Extractor				
No. of units	1 set / unit x 2 units	1 set	1 set / unit x 2 units	1 set
Type	Centrifugal type turbo-blower	Centrifugal type turbo-blower	Centrifugal type turbo-blower	Centrifugal type turbo-blower
Capacity	100%/set	100%/set	100%/set	100%/set
Oil Heater				
No. of units	1 set / unit x 2 units	1 set / unit	1 set / unit x 2 units	1 set / unit
Capacity	100%/set	100%/set	100%/set	100%/set
Oil Purifier				
No. of units	1 set / unit x 2units	1 set	1 set / unit x 2units	1 set
Type	Centrifugal type	Centrifugal type	Centrifugal type	Centrifugal type
Capacity	100% / set	100% / set	100% / set	100% / set
Fluid	Turbine lubricant oil	Turbine lubricant oil	Turbine lubricant oil	Turbine lubricant oil
Instrument Air Compressor				
No. of units	1 set each for	2 sets (1 set	1 set each for	2 sets (1 set

	units 1 & 2, and 1 set for common standby	standby)	units 1 & 2, and 1 set for common standby	standby)
Type	Oil free rotary screw or reciprocating	Oil free rotary screw or reciprocating	Oil free rotary screw or reciprocating	Oil free rotary screw or reciprocating
Pressure	7.5 bar	7.5 bar	7.5 bar	7.5 bar
Capacity	100% / set	100% / set	100% / set	100% / set
Service Air Compressor				
No. of units	1 set for common use for units 1 & 2	1 set	1 set for common use for units 1 & 2	1 set
Type	Oil free rotary screw or reciprocating	Oil free rotary screw or reciprocating	Oil free rotary screw or reciprocating	Oil free rotary screw or reciprocating
Pressure	7.5 bar	7.5 bar	7.5 bar	7.5 bar
Capacity	100%/set	100%/set	100%/set	100%/set
Chemical Dosing System				
No. of units	1 lot for common use for units 1 & 2	1 lot	1 lot for common use for units 1 & 2	1 lot
Type	Chemical storage and dosing system	Chemical storage and dosing system	Chemical storage and dosing system	Chemical storage and dosing system
Fire Fighting Equipment				
No. of units	1 set / unit x 2units	1 set	1 set / unit x 2units	1 set
No. of units	1 lot for common use for units 1 & 2	1 lot	1 lot for common use for units 1 & 2	1 lot
Type	Water storage, pumps, piping networks, hydrants, sprinklers, detectors, alarm, and fire extinguishers	Water storage, pumps, piping networks, hydrants, sprinklers, detectors, alarm, and fire extinguishers	Water storage, pumps, piping networks, hydrants, sprinklers, detectors, alarm, and fire extinguishers	Water storage, pumps, piping networks, hydrants, sprinklers, detectors, alarm, and fire extinguishers
Reinjection Pump				
No. of units	3 sets common for units 1 & 2	3 sets	3 sets common for units 1 & 2	3 sets
Type	Centrifugal	Centrifugal	Centrifugal	Centrifugal
Capacity	50 % / set	50 % / set	50 % / set	50 % / set
Reinjection Settling Basin				
No. of units	1 lot common for units 1 & 2	1 lot	1 lot common for units 1 & 2	1 lot
Type	Concrete pond	Concrete pond	Concrete pond	Concrete pond
Cranes & Lifting Devices (Turbine Hall, Hotwell Pump, Cooling Tower, Warehouse,				

Workshop)				
No. of units	1 lot common for units 1 & 2, 1 lot each for units 1 & 2 Cooling Towers	1 lot	1 lot common for units 1 & 2, 1 lot each for units 1 & 2 Cooling Towers	1 lot
Type	Overhead cranes, hoists	Overhead cranes, hoists	Overhead cranes, hoists	Overhead cranes, hoists
Workshop and Equipment				
No. of units	1 lot common for units 1 & 2	1 lot	1 lot common for units 1 & 2	1 lot
Laboratory Furnishings				
No. of units	1 lot common for units 1 & 2	1 lot	1 lot common for units 1 & 2	1 lot
Type	Chemical analysis laboratory, H_2S detection and protection system	Chemical analysis laboratory, H_2S detection and protection system	Chemical analysis laboratory, H_2S detection and protection system	Chemical analysis laboratory, H_2S detection and protection system
Warehouse				
No. of units	1 lot common for units 1 & 2	1 lot	1 lot common for units 1 & 2	1 lot
Ventilation and Air Conditioning System				
No. of units	1 lot common use for units 1 & 2	1 lot	1 lot common use for units 1 & 2	1 lot
Type	Ventilation fans, ductworks and Air conditioning with H_2S filters	Ventilation fans, ductworks and Air conditioning with H_2S filters	Ventilation fans, ductworks and Air conditioning with H_2S filters	Ventilation fans, ductworks and Air conditioning with H_2S filters
Service Water Supply System				
No. of units	1 lot common use for units 1 & 2	1 lot	1 lot common use for units 1 & 2	1 lot
Type	Raw water supply, water storage, filters, sterilizing, pumping, and distribution system	Raw water supply, water storage, filters, sterilizing, pumping, and distribution system	Raw water supply, water storage, filters, sterilizing, pumping, and distribution system	Raw water supply, water storage, filters, sterilizing, pumping, and distribution system
Waste Water Treatment System				
No. of units	1 lot common use for units 1 & 2	1 lot	1 lot common use for units 1 & 2	1 lot
Type	Oily water separator, settling pond, pH control system	Oily water separator, settling pond, pH control system	Oily water separator, settling pond, pH control system	Oily water separator, settling pond, pH control system

Powerhouse				
No. of units	1 lot common for units 1 & 2	1 lot	1 lot common for units 1 & 2	1 lot
Control & Electrical Building				
No. of units	1 lot common for units 1 & 2	1 lot	1 lot common for units 1 & 2	1 lot
Administration Building				
No. of units	1 lot common for units 1 & 2	1 lot	1 lot common for units 1 & 2	1 lot
Guard House				
No. of units	1 lot common for units 1 & 2	1 lot	1 lot common for units 1 & 2	1 lot

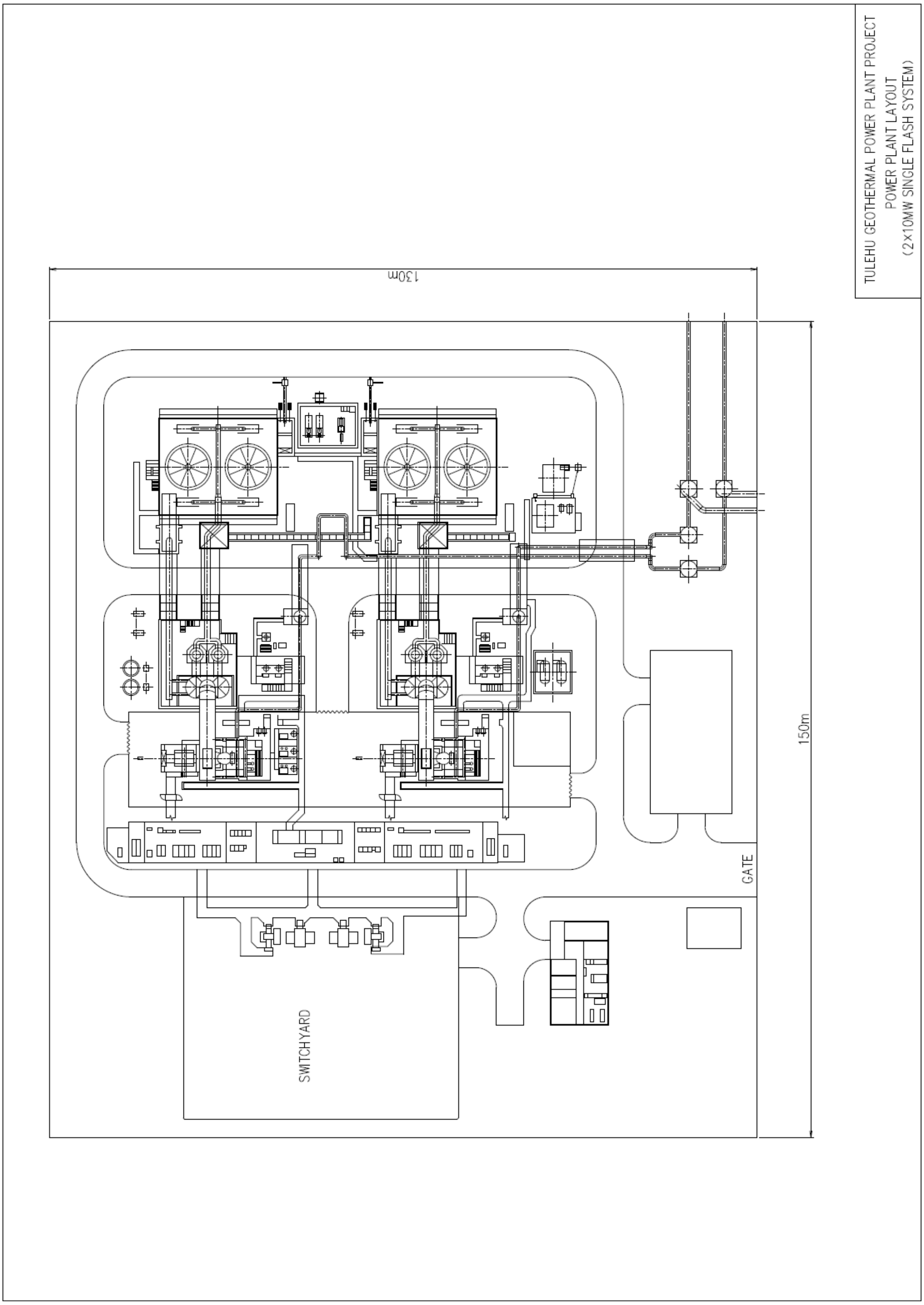


Fig. IV-4-6 Power Plant Layout (2 x 10 MW Single Flash System)

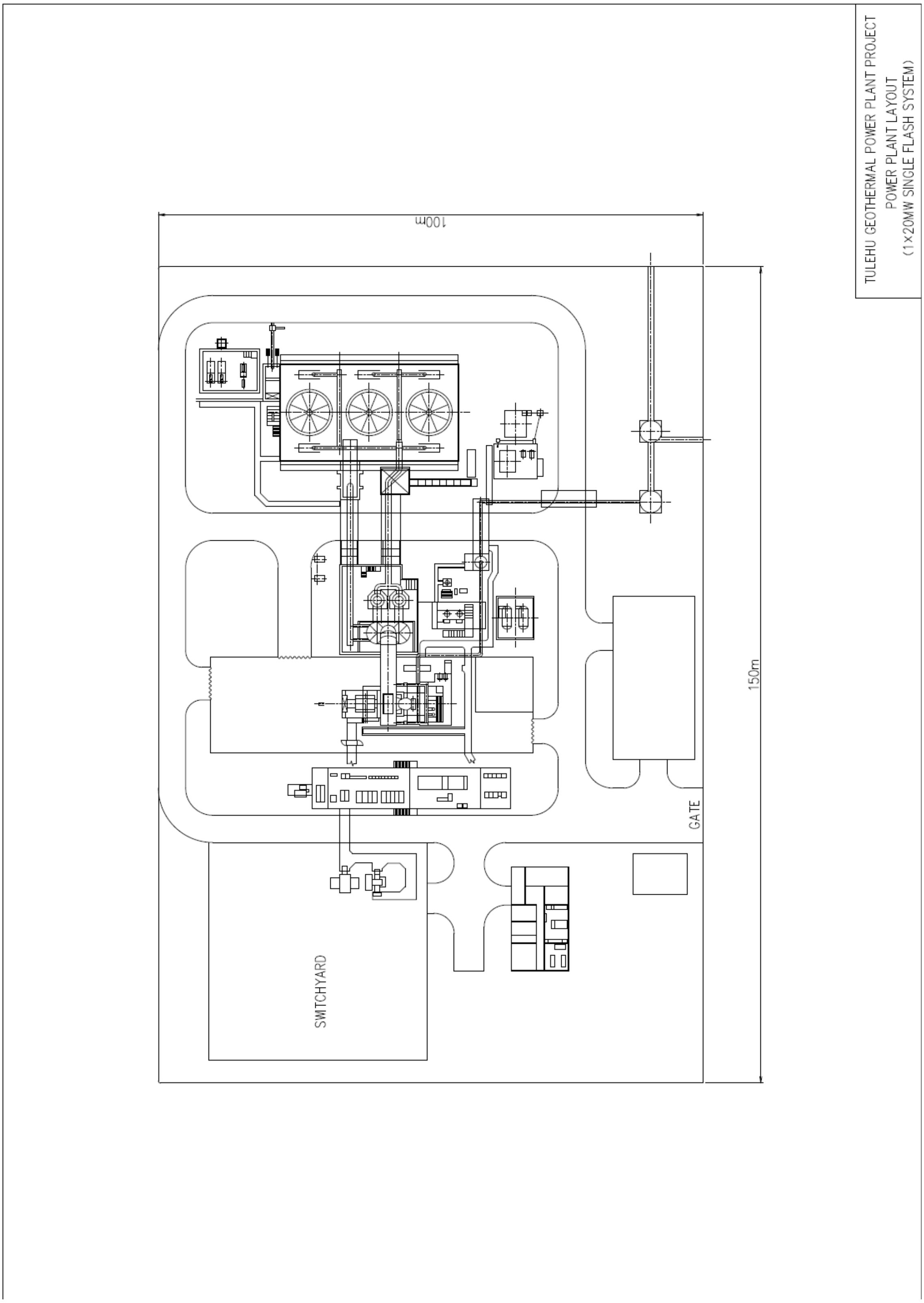


Fig. IV-4-7 Power Plant Layout (1 x 20 MW Single Flash System)

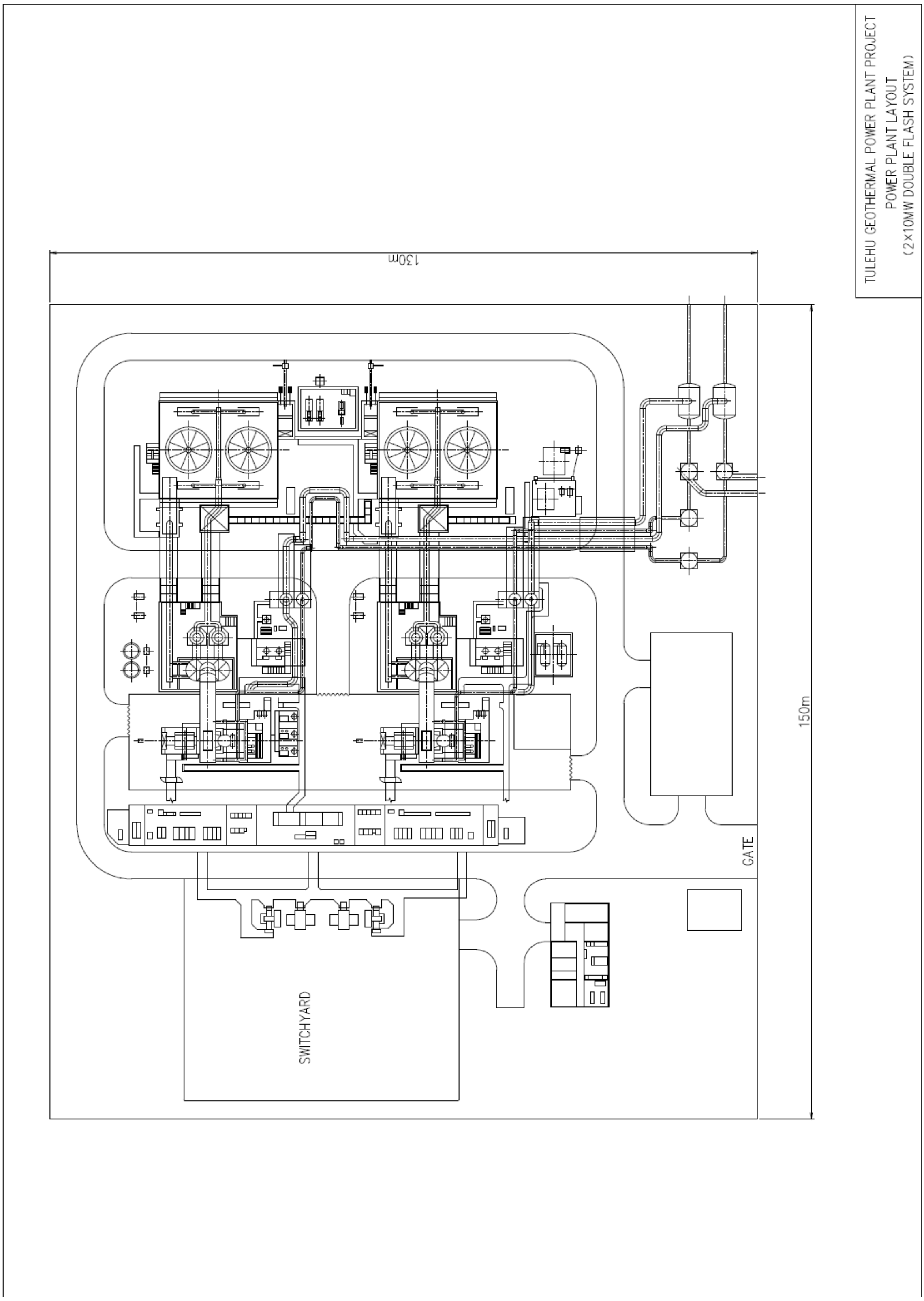


Fig. IV-4-8 Power Plant Layout (2 x 10 MW Double Flash System)

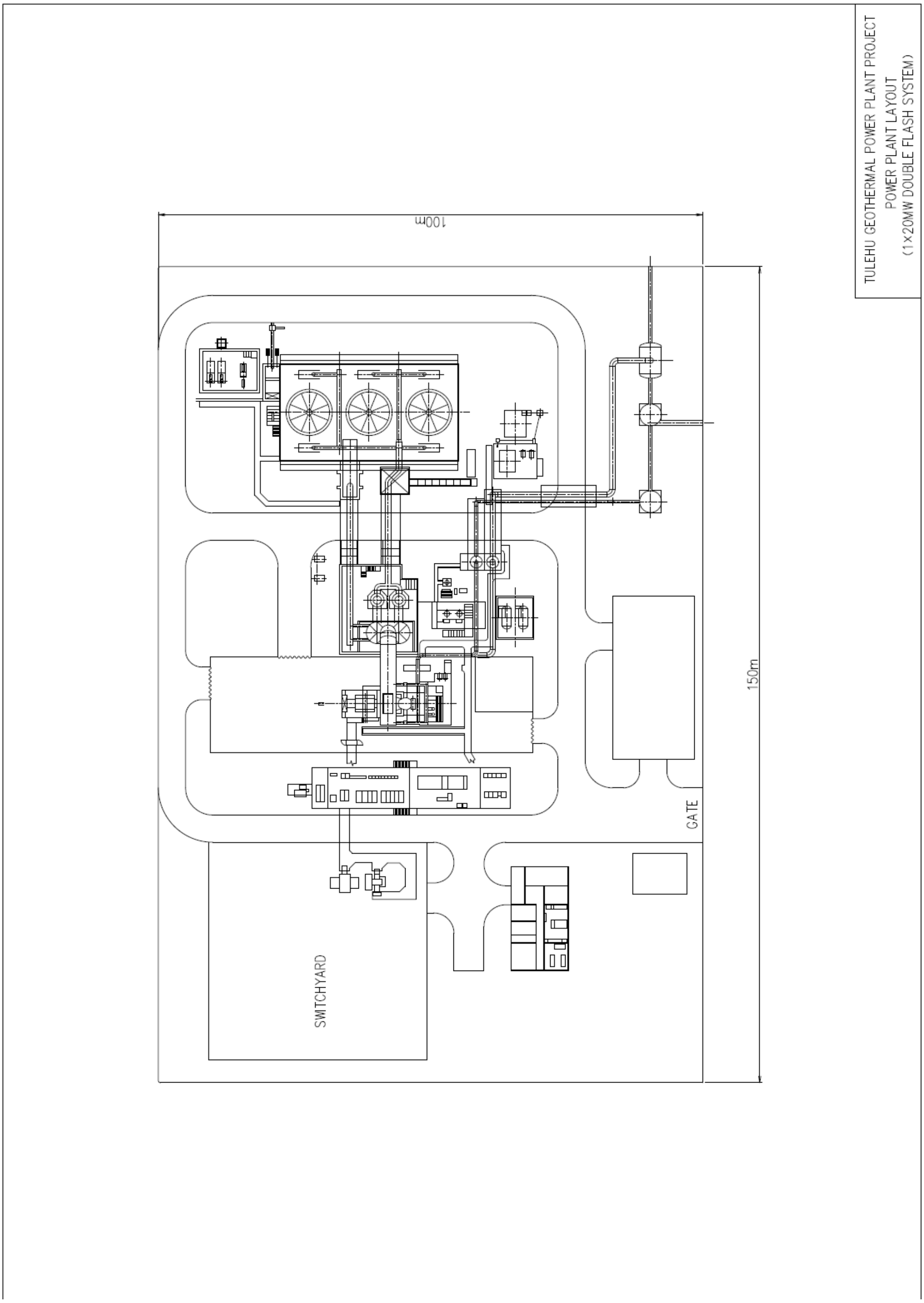


Fig. IV-4-9 Power Plant Layout (1 x 20 MW Double Flash System)

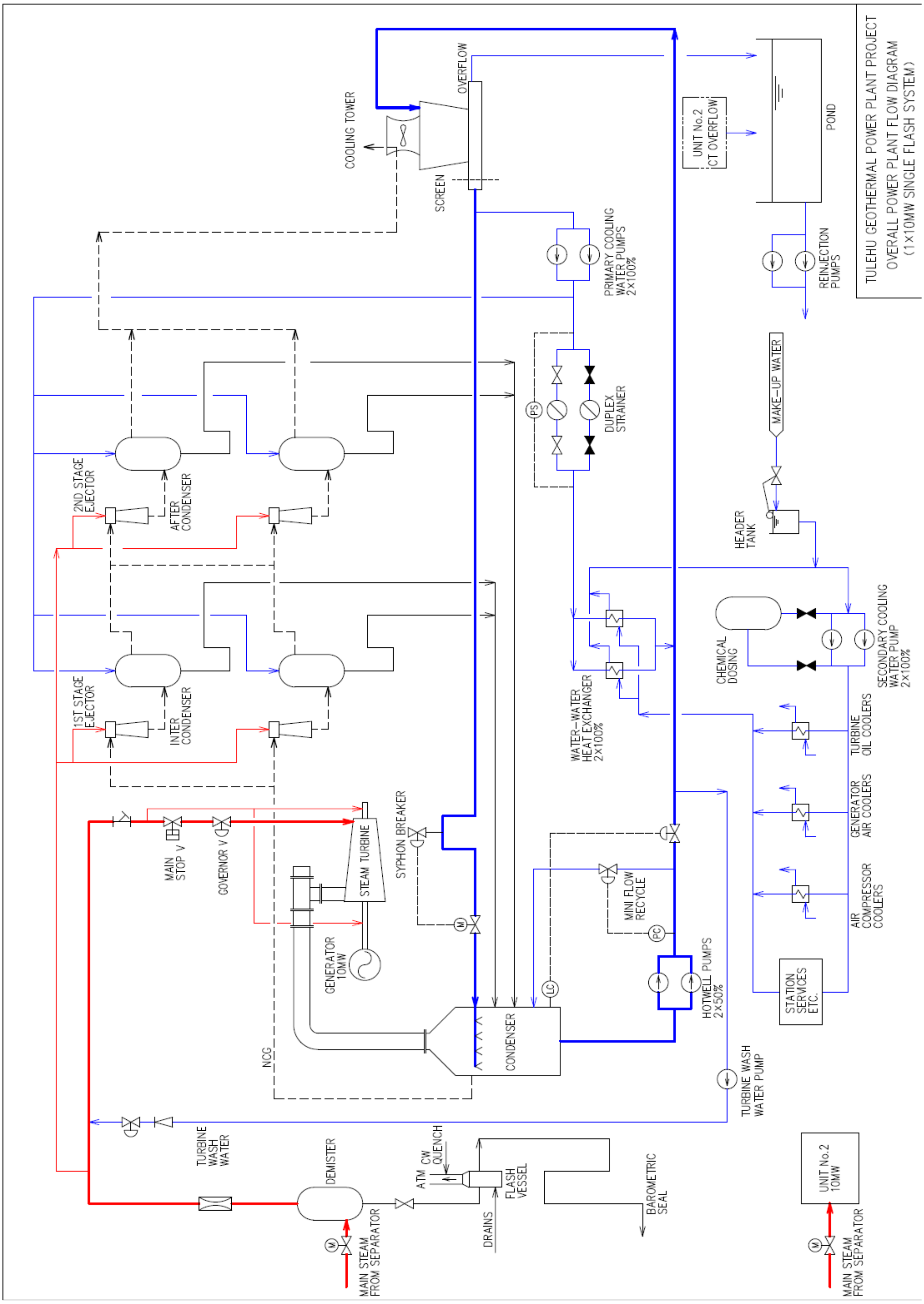


Fig. IV-4-10 Overall Power Plant Flow Diagram (2 x 10 MW Single Flash System)

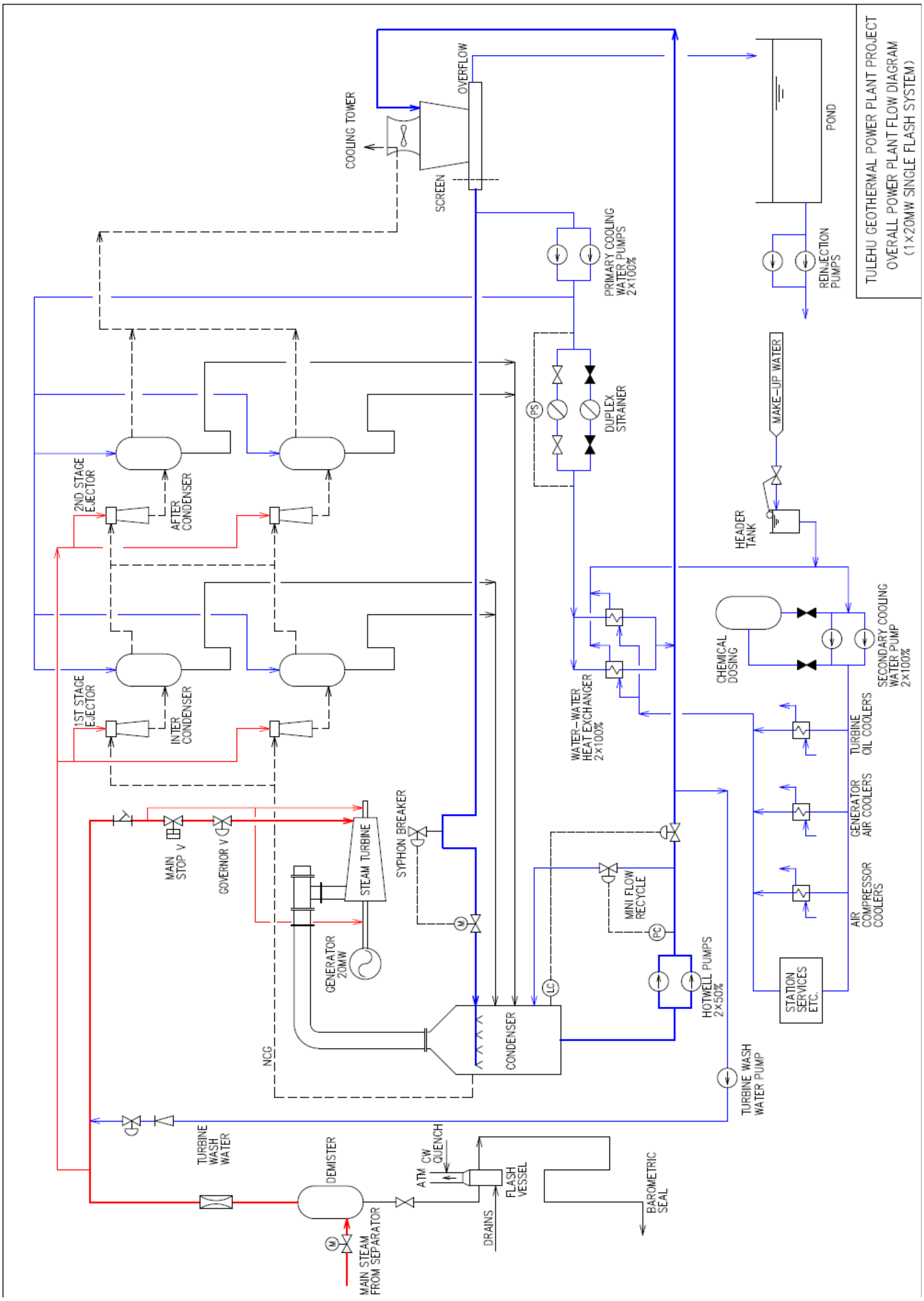


Fig. IV-4-11 Overall Power Plant Flow Diagram (1 x 20 MW Single Flash System)

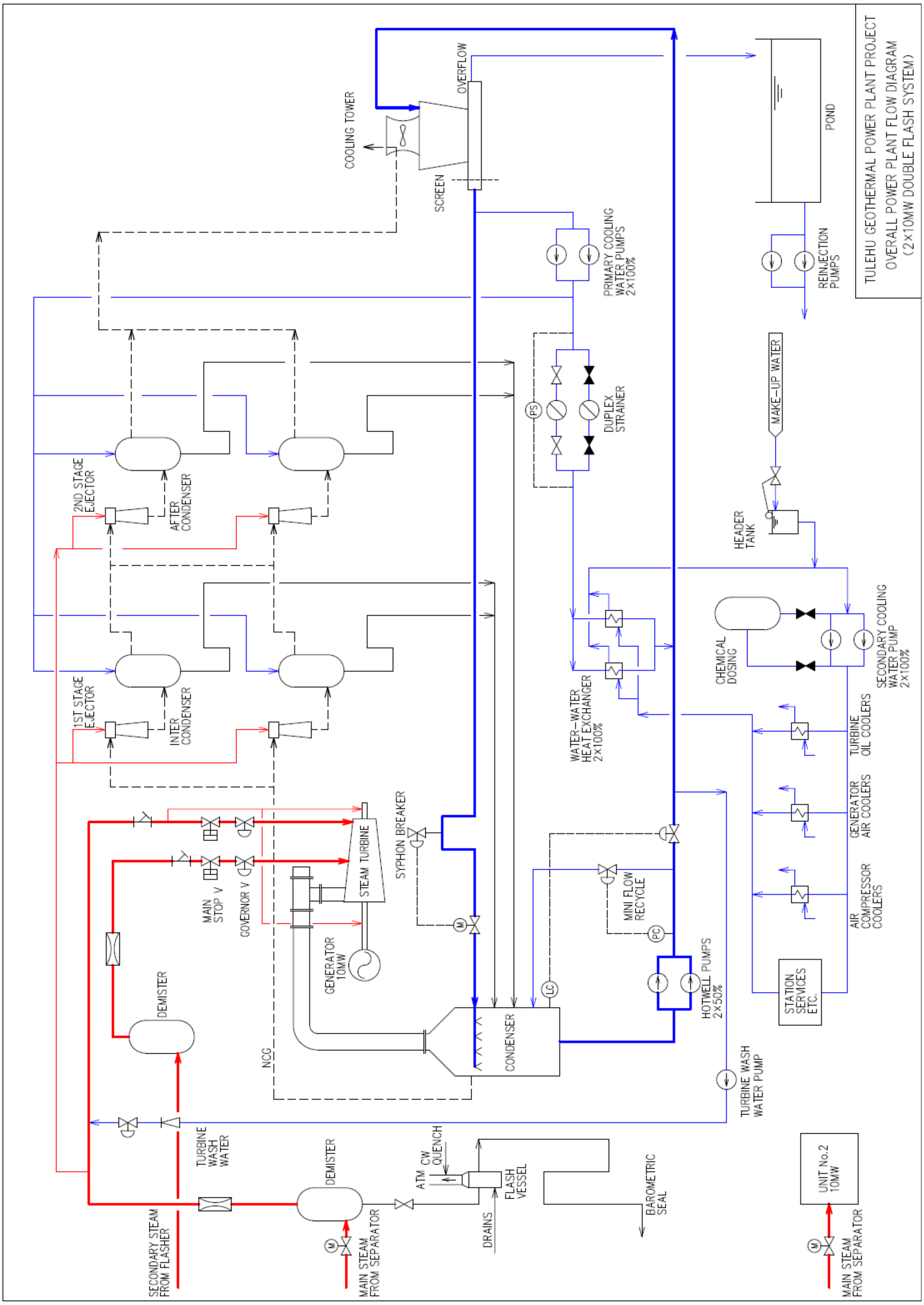


Fig. IV-4-12 Overall Power Plant Flow Diagram (2 x 10 MW Double Flash System)

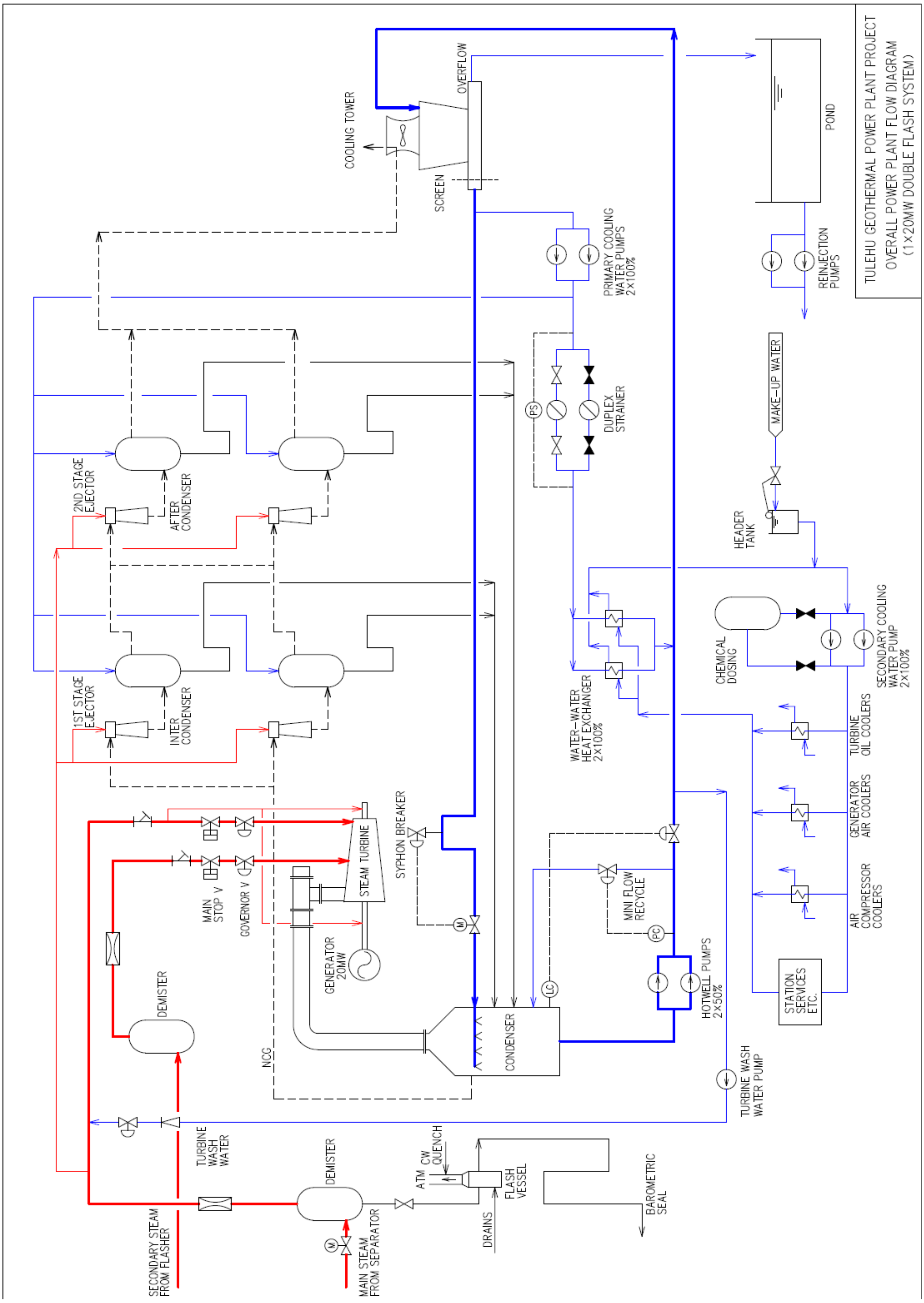


Fig. IV-4-13 Overall Power Plant Flow Diagram (1 x 20 MW Double Flash System)

4. Electrical Instrumentation and Control System

a. General

Since there is no specific difference between single flash and double flash in the electrical aspects of the project at the Feasibility study stage, only 2 cases (2 x 10 MW and 1 x 20 MW) are studied in this section. The voltage of the generator output is stepped up to 70 kV by the Main transformer(s) and connected to the 70 kV transmission line between Waai coal-fired thermal power plant and Passo substation through 70 kV switchgears in the power plant.

Power for the auxiliary equipment in the power plant is supplied through the Unit transformer(s) and an auxiliary circuit is formed in the power plant, as shown in the "Single Line Diagrams" of Fig. IV-4-14 and Fig. IV-4-15. Medium voltage (MV) equipment might be applied in order to reduce the large voltage drop on the low voltage bus. The voltage system configuration of auxiliary equipment in the power plant should be determined at the implementation stage.

The auxiliary power in the power plant will be supplied from the grid with the generator circuit breaker (CB) open at the time of start-up operation. As soon as the turbine is started, the generator is synchronized with the grid using the generator CB, and, from this point on, auxiliary power is derived from in-house generation. After the generator has reached its rated output, the start-up operation is complete. When the unit is shutdown, auxiliary power must be derived from the grid again with the generator CB open.

b. Generators

Air-cooled, three-phase synchronous generator(s) will be installed. They are easy to operate, require less maintenance and are well-proven in a geothermal environment. Corrosive gas like H_2S must be removed from the cooling air for the generator utilizing oxidized catalytic filters etc., since the atmosphere around the geothermal field contains highly corrosive H_2S gas. A brushless exciter system will be adopted.

The main specifications of the generators are as follows.

- Type : Cylindrical rotating field type, totally enclosed, air-cooled, three-phase synchronous generator(s)
- Rated Output : 2 x 10 MW or 1 x 20 MW
- Rated voltage : 11 kV (Manufacturer's standard)
- Frequency : 50 Hz
- Speed : 3,000 rpm
- Power Factor : 0.8 (Lagging)
- Neutral Grounding : Transformer

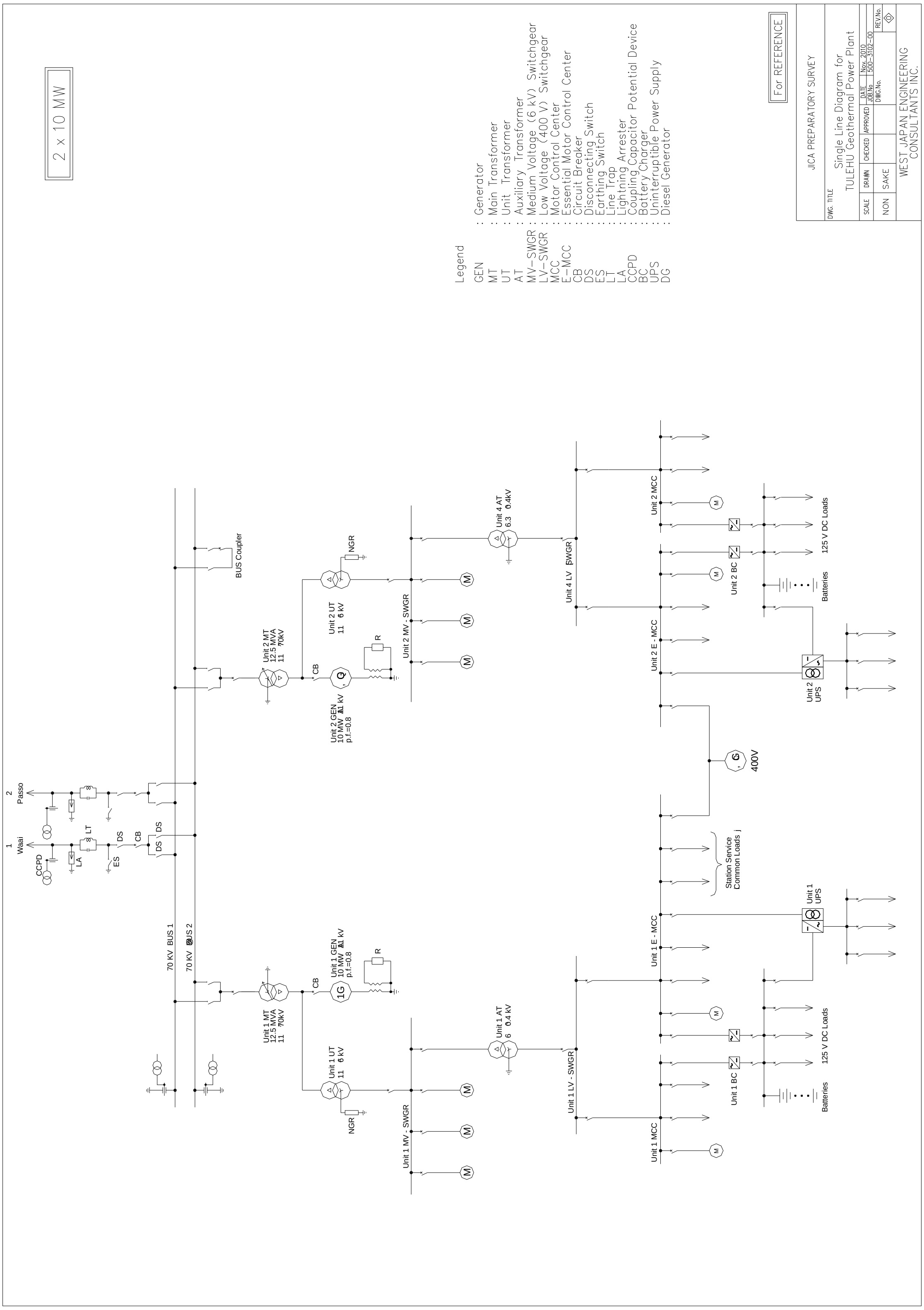


Fig. IV-4-14 Single Line Diagram (2 x 10 MW)

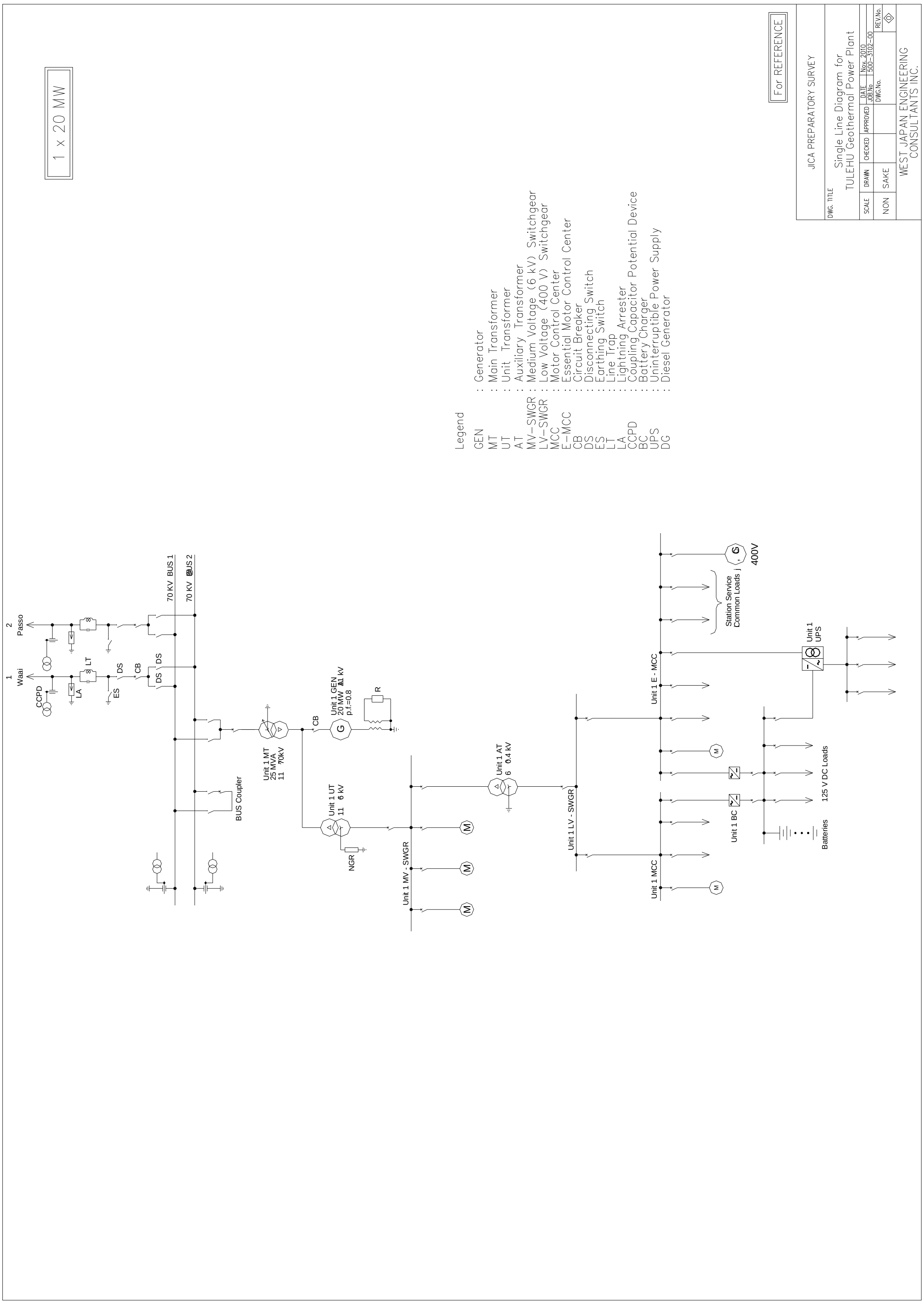


Fig. IV-4-15 Single Line Diagram (1 x 20 MW)

c. Sample Specifications of Major Electrical Equipment

Equipment	Sample Specification			
	Q'ty	2 x 10 MW	Q'ty	1 x 20 MW
a) Main Transformer (MR)	2	12.5 MVA, 11 kV / 70 kV +/- 10% (with On-load tap changer)	1	25 MVA, 11 kV / 70 kV +/-10 % (with On-load tap changer)
b) Unit Transformer (UT)	2	11 / 6 kV +/- 5% (with No-load tap changer, 5 taps) (Capacity to be changed by system)	1	Same as at left
c) Aux. Transformer (AT)	2	6 kV / 400 V +/-5 % (with No-load tap changer, 5 taps)	1	Same as at left
d) MV Metal-Clad Switchgear (M/C)	2 sets	6 kV, For aux. equipment of large capacity (The criteria to be defined)	1	Same as at left
e) 400 V Power Center (P/C)	2 sets	400 V, For aux. equipment of large capacity (The criteria should be defined later)		Same as at left
f) 400 V Motor Control Center (MCC)	1 lot	400 V, For aux. equipment of small capacity i) 1 x Common MCC For common use ii) 2 x Unit MCC For unit operation iii) 2 x Emergency MCC For essential loads at safety shut-down	1 lot	400 V, For aux. equipment of small capacity i) 1 x Common MCC For common use ii) 1 x Unit MCC For unit operation iii) 1 x Emergency MCC For essential loads at safety shut-down
g) Distribution Panels	2 sets	230 V / 110 V AC, For control, instrumentation, lighting and others	1 set	Same as at left
h) Control	1 lot	1 x Overall control system for power plant with Data acquisition system 2 x Auto. Voltage Regulator 2 x EHG Control 1 x Automatic synchronizing control All other control systems	1 lot	1 x Overall control system for power plant with Data acquisition system 1 x Auto. Voltage Regulator 1 x EHG Control 1 x Automatic synchronizing control All other control systems
i) Protection	1 lot	1 x Turbine protection 2 x Generator protection 2 x Main TR. protection 2 x Transmission line protection 1 x Event recorder All other protection panels	1 lot	1 x Turbine protection 1 x Generator protection 1 x Main TR. protection 2 x Transmission line protection 1 x Event recorder All other protection panels
j) DC Power supply system (125 V and 48 V DC)	2 sets	i) 125 V DC (for control and protection) - Batteries & Chargers - Distribution panels ii) 48 V DC (for communication) - Batteries & Chargers - Distribution panels	1 set	Same as at left
k) Uninterruptible power supply (UPS)	2 sets	230 V AC, Inverter panel, Distribution panels, for digital control, protection and instrumentation equipment	1 set	Same as at left
l) Emergency diesel generator	1 set	Diesel engine and 400 V Generator, fuel tank and other necessary materials	1 set	Same as at left

d. Control and Instrumentation Equipment

A micro-processor-based Distributed control system (DCS) will be installed to control the whole system and monitor various parameters of the geothermal power plant including the FCRS. The DCS contributes to the highly reliable, fail-safe operation and productivity of the power plant. The control systems in the geothermal power plant are mainly as follows.

Main steam supply

- Separator level control
- Steam supply control

Turbine and generator control

- Automatic start-up and shutdown of the turbine (from turbine start-up at cold condition to 100% load and vice versa)
- Automatic start-up of the turbine and load regulation in conjunction with digital electro-hydraulic governor (EHC)

Condenser level

- The hot water level in the condenser is controlled by the DCS to protect the Hotwell Pumps. The hot water level is detected by level switches, each of which is equipped with a transmitter. If the level falls below a pre-set level, the DCS gives a hot water low-level alarm as a level-low alert, and if the level falls further, the DCS finally triggers unit shutdown as an emergency trip.

Electrical equipment control

- Automatic synchronization to the grid
- Electrical equipment on/off control, and others

In addition to the control system, a plant interlock system must be provided to protect the power plant equipment. For equipment operation, the software interlock systems are included in the DCS. For emergency tripping of the major equipment, however, a hard-wired interlock system should be provided in order to protect valuable equipment. The operation of the plant can be carried out using operator work stations (OWS) with an LCD (Liquid Crystal Display) and keyboard, which are the man-machine interface between the DCS and operators in the control room. Power for the DCS should be supplied by an uninterruptible power supply system (UPS) so that power is available to the DCS even in case of emergencies like a black-out in the power plant.

e. Communication System

The power plant must have communication equipment to communicate with the Local control center for the Ambon system.

f. Switchyard Equipment

The configuration of the switchyard will be of 70 kV, outdoor, conventional type, with a Double busbar system, which is the standard system used by PLN. See the “Single line diagrams” in Figs. IV-4-14 and IV-4-15. In order to protect the switchyard equipment and transmission lines from corrosion due to H2S gas, the switchyard area will be located on the opposite side of the plant from the cooling tower facilities. The main specifications of the 70 kV switchgears are as follows.

- Switchyard type : Outdoor, conventional type
- Bus system : Double busbar system
- Rated voltage : 72.5 kV
- Rated current : 2,000 A
- Rated interrupting current : 25 kA or 31.5 kA (depending on the system)
- Rated insulation level
  - Lightning impulse withstand voltage : 325 kV
  - Power frequency withstand voltage : 140 kV
- Transmission line protection
  - Main protection : Impedance relay protection
  - Back-up protection : Directional earth fault protection and Overcurrent protection with Auto-reclose

Figs. IV-4-16, IV-4-17 and IV-4-18 show plan and side views of a typical 70 kV Switchyard.

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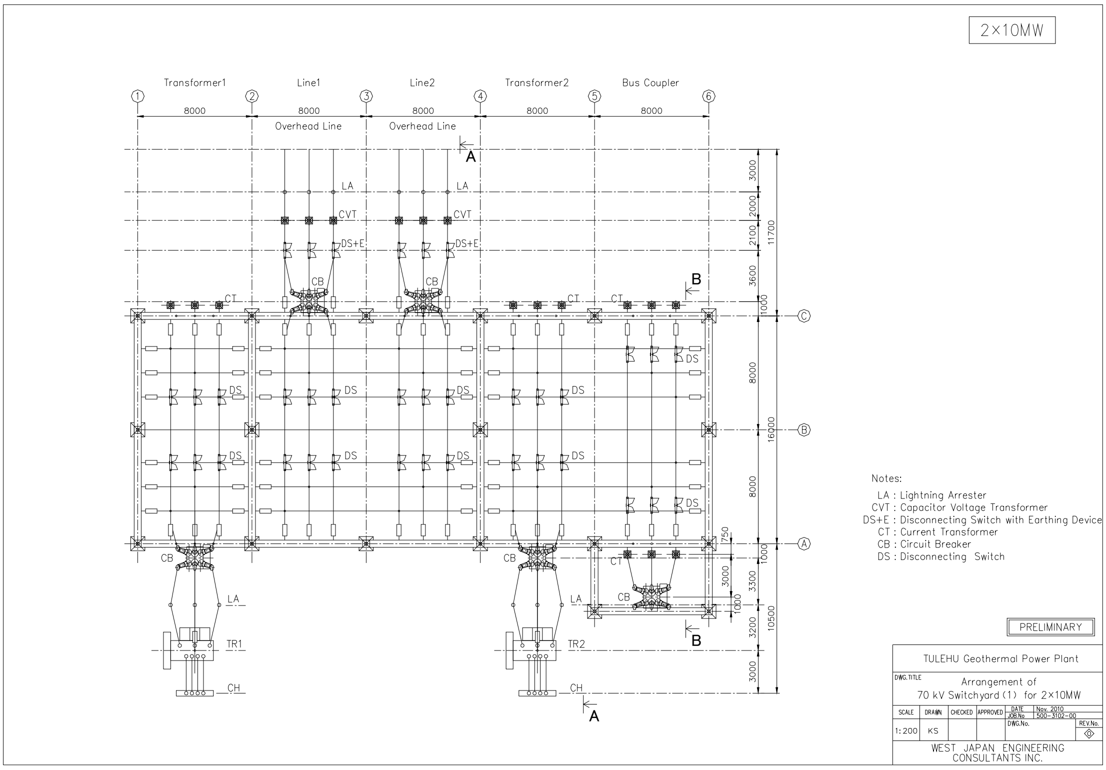


Fig. IV-4-16 Plan View of 70 kV Switchyard for 2 x 10 MW

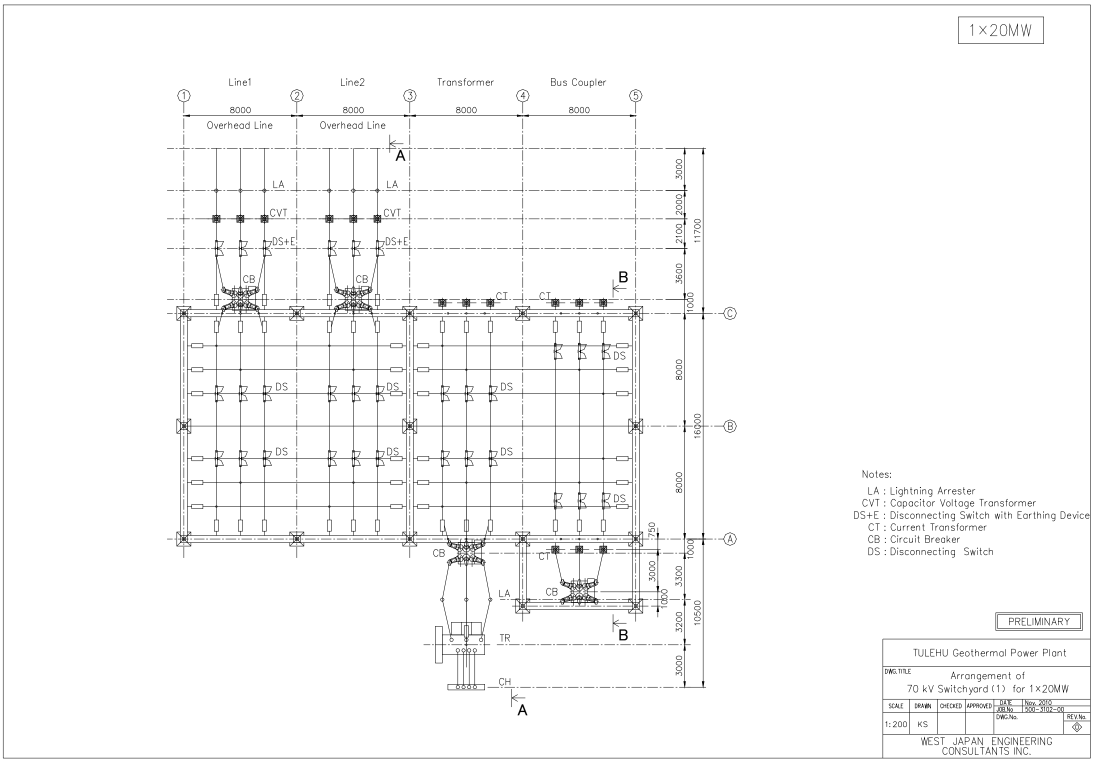


Fig. IV-4-17 Plan View of 70 kV Switchyard for 1 x 20 MW

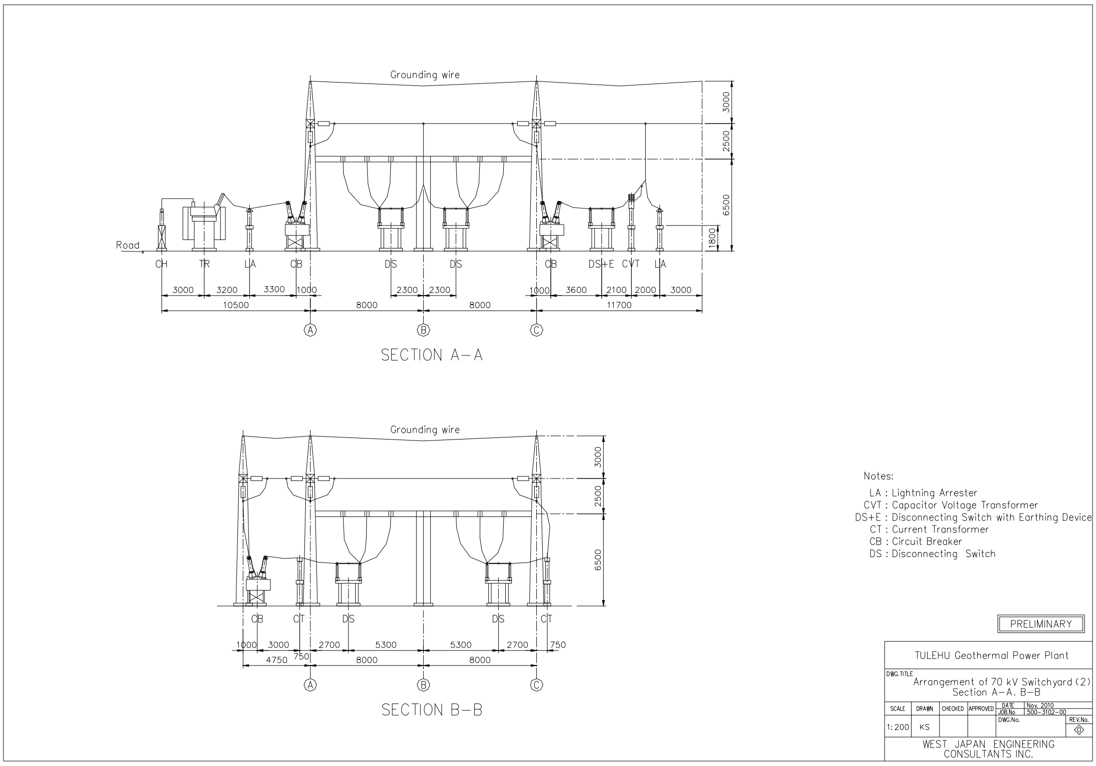


Fig. IV-4-18 Side View of Typical 70 kV Switchyard

IV.4.4 Equipment Transportation Plan

Ambon port is equipped with a wharf for large ships and unloading facilities. The wharf is large enough to accommodate a large ship transporting well-drilling and power plant equipment. The wharf unloading facility has a 32-ton lifting capacity and used especially for container handling. For the transportation and unloading of the power plant equipment for the project, it would be advisable to arrange for a ship equipped with its own lifting facilities.

The road from Ambon port up to the entrance of Rupa Hitu village is a well-paved national road, and there will be no difficulties transporting the necessary materials because of issues with road width, curves and slopes in the road, or bridges (either concrete or steel framework). Power lines, however, cross the national road at many places at a height of a few meters, and appropriate measures will need to be taken for the transportation of large size equipment. After Ambon port, the road passes through the center of Ambon city, which has heavy traffic. Therefore, special measures will need to be considered for moving heavy and large equipment, such as advance application for permits from the local government, nighttime transportation, etc.

An access road will be constructed from Rupa Hitu village to the production well pads and the power plant. This access road will be approximately 4 km long with a gradual slope. The following questions were also confirmed.

- Port of customs clearance in Indonesia: customs clearance is possible at Ambon port.

- Marine transportation within Indonesia: sea transportation is possible to Ambon port from Jakarta and other major cities in Indonesia.

Ambon Port Wharf – Anchored Ship and Loading Crane

IV.5 Transmission Lines

A double circuit 70 kV Transmission line will be constructed by PLN between the 70 kV switchyard in Tulehu geothermal power plant and the 70 kV transmission line which it is planned to construct for the new Waai thermal power plant. Fig. IV-5-1 shows a Single Line Diagram of the Ambon-Seram Interconnection system. (Source; PLN)

As shown in the Diagram, the double circuit transmission line from the plant will be cut in (Pi connection) to the one circuit 70 kV transmission line between PLTU Waai and GI Passo (Passo substation). According to a *document provided by Cabang Ambon, the T-35 tower is the most suitable tensional tower for the Pi connection of transmission lines (*Reference document; Survey Reconnaissance Jalur Transmisi 70 kV, PLTU Liang – Passo – Ambon, Augustus 2007). Please refer also to Fig. IV-4-1 “Location Plan of Drilling Pads, Power Plant and Transmission Line”. An appropriate design, taking into account both the physical connection and mechanical strength of the tower, should be elaborated for the tower (T-35 tower) so that it can accept a Pi connection of one line in the future, even when the other line is in operation. Fig. IV-5-2, a sample drawing for the provision of the necessary Pi connection, is provided for reference.

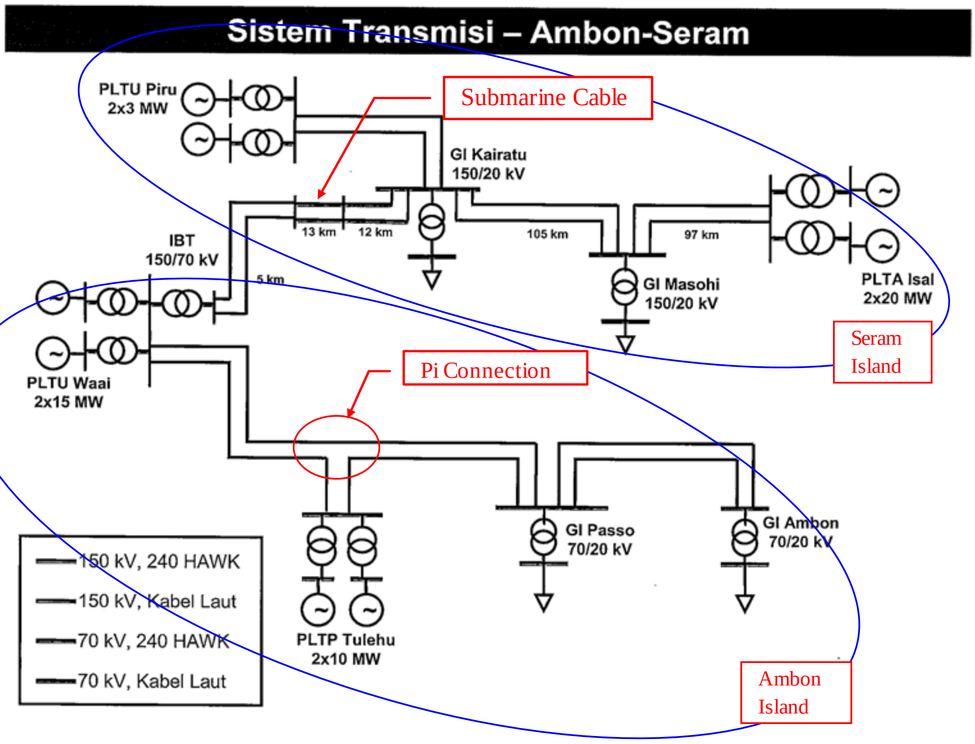


Fig. IV-5-1 Single Line Diagram of Ambon-Seram Interconnection System

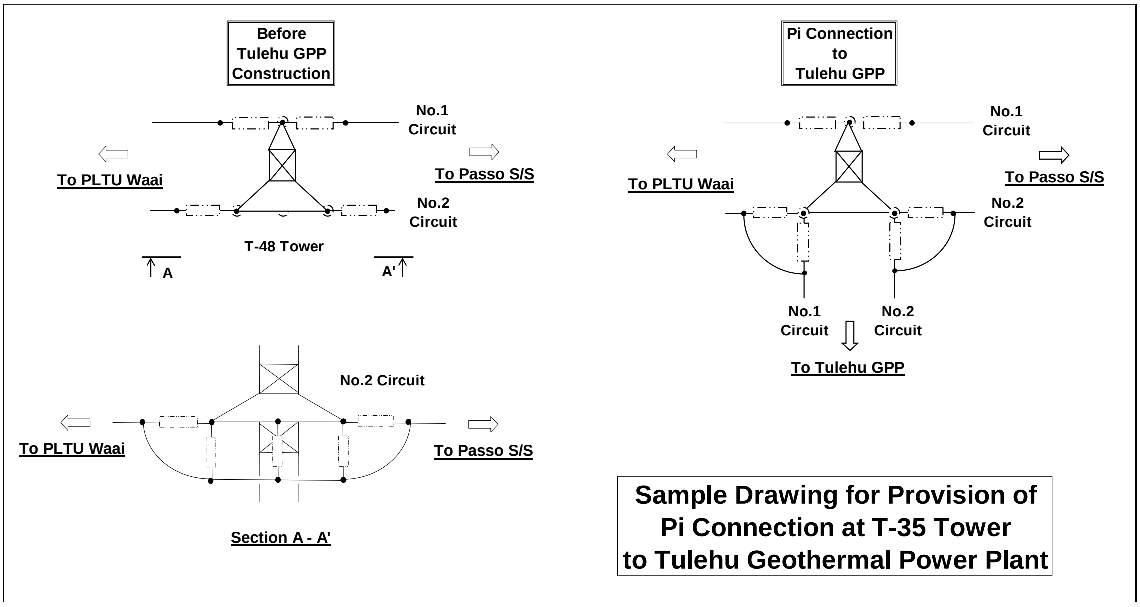


Fig. IV-5-2 Sample Drawing for Provision of Pi Connection

IV.6 Project Cost

IV.6.1 Resource Development Cost

The resource development cost is divided into two (2) categories; one will be the costs to PLN of carrying out and completing pre-construction work for the commencement of production drilling, and the other will be the costs for the construction stage including production and reinjection wells and power plant facilities. The work categories and cost estimates including land acquisition are shown below in Table IV-6-1. The necessary cost for each well is estimated based on recent market prices and shown in Table IV-6-2. The drilling costs and scheduling for the initial production and reinjection wells and for make-up wells are shown in Table IV-6-3. A construction cost estimate for well pads and access roads is shown in Table IV-6-4.

Table IV-6-1 Resource Development Cost

Work Category	Work Item	Cost Estimate (US$)
Single Flash		
Work done by PLN in preparation for the commencement of drilling work (Pre-construction Work)	Well Pad Construction (2 production and 1 reinjection)	1,320,000
	Access Road Construction (for new well pad)	360,000
	Water Line for Drilling	480,000
	Land Acquisition	373,800
	Sub-total	2,533,800
Construction Stage	Rig Mobilization/Demobilization	2,000,000
	Production Well Drilling including Testing (4 wells)	21,560,000
	Reinjection Well Drilling (6 wells)	23,100,000
	Sub-total	46,660,000
Grand Total		49,193,800
Double Flash		
Work done by PLN in preparation for the commencement of drilling work (Pre-construction Work)	Well Pad construction (2 production and 1 reinjection)	1,320,000
	Access road construction (for new well pad)	360,000
	Water Line for Drilling	480,000
	Land Acquisition	373,800
	Sub-total	2,533,800
Construction Stage	Rig Mobilization/Demobilization	2,000,000
	Production Well Drilling including Testing (3 wells)	16,170,000
	Reinjection Well Drilling (4 wells)	15,400,000
	Sub-total	33,570,000
Grand Total		36,103,800

Table IV-6-2 Drilling Cost Estimates

Item	**Production well** **Ave. Depth: 1,500m (Big hole)** **Ave. Drilling Days: 30**	**Reinjection well** **Ave. Depth: 1,500m (Standard hole)** **Ave. Drilling Days: 27**
1. Rig Hire		
a. Drilling cost		
***Rig Operation ($30,000/day)**	**1,080,000**	**972,000**
***Air drilling package**	**600,000**	**N/A**
b. Rig Move (On location)	**240,000**	**240,000**
Sub-total	**1,920,000**	**1,212,000**
2. Drilling Services		
a. Directional drilling service	**360,000**	**300,000**
b. Cementing services	**360,000**	**300,000**
c. Mud Log	**60,000**	**50,000**
d. Mud Engineering	**50,000**	**40,000**
e. Top drive	**360,000**	**300,000**
f. H2S Monitoring	**50,000**	**40,000**
g. Well logging	**90,000**	**60,000**
Sub-total	**1,330,000**	**1,090,000**
5. Drilling materials		
a. Bit and others	**160,000**	**120,000**
b. Casing and accessories	**700,000**	**500,000**
c. Well-head and valves	**240,000**	**180,000**
d. Mud materials	**90,000**	**75,000**
e. Cement and additives	**180,000**	**140,000**
f. Fuel and Oil supply	**360,000**	**300,000**
g. Drilling consumable-Foreign	**90,000**	**70,000**
h. Drilling consumable-Local	**20,000**	**18,000**
Sub-total	**1,840,000**	**1,403,000**
6. Drilling support		
a. Transport (on site)	**20,000**	**15,000**
b. Water supply	**40,000**	**30,000**
c. Others (Catering, etc.)	**60,000**	**50,000**
Sub-total	**120,000**	**95,000**
7. Well Testing	**180,000**	**50,000**
Grand Total for Drilling	**US$5,390,000/well**	**US$3,850,000/well**

Note: Excluding Rig Mob./Demob.

Table IV-6-3 Drilling Schedule and Costs

Single Flash

Drilling Schedule Drilling Unit Cost

						5.39	3.85	2.00	Mill US$
No.	Year	P-Well	R-Well	Rig Mob		P-Well	R-Well	Rig Mob	Total
-5	2010					0	0	0	0
-4	2011				JICA	0	0	0	0
-3	2012					0	0	0	0
-2	2013	4	1	1		21.56	3.85	2.00	27.41
-1	2014		5			0	19.25	0	19.25
Initial		4	6	1		21.56	23.1	2.00	46.66
1	2015					0	0	0	0
2	2016					0	0	0	0
3	2017					0	0	0	0
4	2018					0	0	0	0
5	2019					0	0	0	0
6	2020					0	0	0	0
7	2021					0	0	0	0
8	2022	1	1	1		5.39	3.85	2.00	11.24
9	2023					0	0	0	0
10	2024					0	0	0	0
11	2025					0	0	0	0
12	2026					0	0	0	0
13	2027					0	0	0	0
14	2028		1	1		0	3.85	2.00	5.85
15	2029					0	0	0	0
16	2030					0	0	0	0
17	2031	1		1		5.39	0	2.00	7.39
18	2032					0	0	0	0
19	2033					0	0	0	0
20	2034		1	1		0	3.85	2.00	5.85
21	2035					0	0	0	0
22	2036					0	0	0	0
23	2037					0	0	0	0
24	2038					0	0	0	0
25	2039					0	0	0	0
26	2040	1	1	1		5.39	3.85	2.00	11.24
27	2041					0	0	0	0
28	2042					0	0	0	0
29	2043					0	0	0	0
30	2044					0	0	0	0
Total		3	4	5		16.17	15.4	10.00	41.57
Grand Total		7							

Double Flash

Drilling Schedule Drilling Unit Cost

						5.39	3.85	2.00	Mill US$
No.	Year	P-Well	R-Well	Rig Mob		P-Well	R-Well	Rig Mob	Total
-5	2010					0	0	0	0
-4	2011				JICA	0	0	0	0
-3	2012					0	0	0	0
-2	2013	3	2	1		16.17	7.7	2.00	25.87
-1	2014		2			0	7.7	0	7.7
Initial		3	4	1		16.17	15.4	2.00	33.57
1	2015					0	0	0	0
2	2016					0	0	0	0
3	2017					0	0	0	0
4	2018					0	0	0	0
5	2019					0	0	0	0
6	2020					0	0	0	0
7	2021	1	1	1		5.39	3.85	2.00	11.24
8	2022					0	0	0	0
9	2023					0	0	0	0
10	2024					0	0	0	0
11	2025					0	0	0	0
12	2026					0	0	0	0
13	2027					0	0	0	0
14	2028					0	0	0	0
15	2029					0	0	0	0
16	2030					0	0	0	0
17	2031	1	1	1		5.39	3.85	2.00	11.24
18	2032					0	0	0	0
19	2033					0	0	0	0
20	2034					0	0	0	0
21	2035					0	0	0	0
22	2036					0	0	0	0
23	2037					0	0	0	0
24	2038					0	0	0	0
25	2039					0	0	0	0
26	2040	1	1	1		5.39	3.85	2.00	11.24
27	2041					0	0	0	0
28	2042					0	0	0	0
29	2043					0	0	0	0
30	2044					0	0	0	0
Total		3	3	3		16.17	11.55	6.00	33.72
Grand Total		6							

Table IV-6-4 Cost Estimates for Civil Work/Land Acquisition done by PLN

(Unit: MUS$)

ITEM		UNIT	QUANTITY	UNIT PRICE	PRICE	REMARKS
I	PRODUCTION WELL PAD	L.S.	1		740,000	
I-1	Production Pad No.1	m2	7,000	50	350,000	Size:70m x 100m
I-2	Production Pad No.2	m2	7,000	50	350,000	Size:70m x 100m
I-3	Cellar	nos	4	10,000	40,000	W2m x D3m x H2m x T0.3
II	REINJECTION WELL PAD	L.S.	1		580,000	
II-1	Reinjection Pad No.1	m2	10,400	50	520,000	Size:80m x 130m
II-3	Cellar	nos	6	10,000	60,000	W2m x D3m x H2m x T0.3
III	ACCESS ROAD	m	3,000	120	360,000	Width:5m, Unpaved
IV	WATER LINE	m	2,000	240	480,000	
V	LAND ACQUISITION	L.S.	1		373,800	
V-1	Well Pad	m2	29,400	7	205,800	(7,000 + 7,000 + 10,400) x 1.2
V-2	Access Road	m2	24,000	7	168,000	8m x 3,000m
GRAND TOTAL					**2,533,800**	I + II + III + IV + V

IV.6.2 Cost for Construction of Plant and Transmission Lines

1. Estimated Cost of Geothermal Power Plant

The costs for construction of plant and switchyards were estimated for four (4) cases (Single flash 2 x 10 MW, Single flash 1 x 20 MW, Double flash 2 x 10 MW, and Double flash 1 x 20 MW Systems). The details of the costs are shown in the following Tables. The construction costs of the Tulehu geothermal power plant including associated switchyard were estimated on the basis of the actual cost of the similar Lahendong-3 geothermal power plant project in North Sulawesi. The similarities between Lahendong-3 GPP and Tulehu GPP can be seen from the following: Lahendong-3 was a PLN geothermal power plant project carried out with a JICA ODA Loan. A 1-unit x 20 MW single flash plant was newly constructed in North Sulawesi, a remote, isolated, Indonesian island. The EPC contract was concluded in April 2007, and the project was completed in February 2009. The contracted project cost of Lahendong-3 GPP was approximately 1,900 US$/kW. Based on this recent contracted cost record, the construction cost for each of the four types of plant design being considered for Tulehu GPP was estimated, taking into consideration the wide variation in the US$ exchange rate, the increased cost factor for a double flash system and the cost disadvantage factor for a smaller capacity scale of 10 MW. The proportion of the foreign currency to the local currency was estimated in light of the actual contract details for Lahendon-3 GPP. The FCRS costs were estimated on the basis of the unit costs (US$/inch-m) estimated for the FCRS piping system in the 2010 feasibility study for a geothermal power plant project in Sumatra, Indonesia.

Table IV-6-5 Cost Estimate of Power Plant (4 cases)

Case-1: Single Flash 2 x 10 MW (MUS$)

	FC Percentage	LC Percentage	FC Portion	LC Portion	Total
FCRS:	56%	44%	4.69	3.69	8.38
Power Plant:	70%	30%	30.77	13.23	44.00
Turbine and Mechanical	94%	6%	19.49	1.24	20.73
Generator and Electrical	85%	15%	4.87	0.86	5.73
Control and Instrumentation	100%	0%	2.21	0.00	2.21
Balance of Plant	100%	0%	3.04	0.00	3.04
Civil Work	0%	100%	0	8.82	8.82
Others	38%	63%	1.34	2.19	3.53
FCRS + Power Plant	68%	32%	35.56	16.92	52.38

FC: Foreign Currency, LC: Local Currency

Case-2: Single Flash 1 x 20 MW (MUS$)

	FC Percentage	LC Percentage	FC Portion	LC Portion	Total
FCRS:	56%	44%	4.45	3.49	7.94
Power Plant:	70%	30%	29.4	12.60	42.00
Turbine and Mechanical	94%	6%	18.56	1.18	19.74
Generator and Electrical	85%	15%	4.64	0.82	5.46
Control and Instrumentation	100%	0%	2.10	0.00	2.10
Balance of Plant	100%	0%	2.94	0.00	2.94
Civil Work	0%	100%	0	8.40	8.4
Others	38%	63%	1.28	2.08	3.36
FCRS + Power Plant	68%	32%	33.85	16.09	49.94

FC: Foreign Currency, LC: Local Currency

Case-3: Double Flash 2 x 10 MW (MUS$)

	FC Percentage	LC Percentage	FC Portion	LC Portion	Total
FCRS:	56%	44%	3.71	2.91	6.62
Power Plant:	70%	30%	32.20	13.80	46.00
Turbine and Mechanical	94%	6%	20.32	1.30	21.62
Generator and Electrical	85%	15%	5.08	0.90	5.98
Control and Instrumentation	100%	0%	2.30	0.00	2.30
Balance of Plant	100%	0%	3.22	0.00	3.22
Civil Work	0%	100%	0	9.20	9.2
Others	38%	63%	1.40	2.28	3.68
FCRS + Power Plant	68%	32%	35.91	16.71	52.62

FC: Foreign Currency, LC: Local Currency

Case-4: Double Flash 1 x 20 MW (MUS$)

	FC Percentage	LC Percentage	FC Portion	LC Portion	Total
FCRS:	56%	44%	3.71	2.91	6.62
Power Plant:	70%	30%	30.66	13.14	43.80
Turbine and Mechanical	94%	6%	19.53	1.24	20.59
Generator and Electrical	85%	15%	4.84	0.85	5.69
Control and Instrumentation	100%	0%	2.19	0.00	2.19
Balance of Plant	100%	0%	3.07	0.00	3.07
Civil Work	0%	100%	0	8.76	8.76
Others	38%	63%	1.33	2.17	3.50
FCRS + Power Plant	68%	32%	34.37	16.05	50.42

FC: Foreign Currency, LC: Local Currency

2. Estimated Cost of Connecting Transmission Lines

The construction cost of the approximately 3 km transmission line connecting with the 70 kV transmission line is estimated at 0.3 Million US$. The study team confirmed that the connection work will be done with PLN's own financing, separate from the Yen Loan.

IV.7 Project Implementation Plan

IV.7.1 The Project

The Project is to construct a 20 MW geothermal power plant at Tulehu, on the Island of Ambon, Maluku, in accordance with the Geothermal Road Map of the Government and the President's 2nd 10,000 MW fast track program. The power generated by Tulehu geothermal power plant will be transmitted to the demand center of Ambon through a 70 kV transmission line which has been planned to accommodate the power generated by the 15 MW x 2 Waai IPP coal-fired power plant. These new power plants are expected to alleviate the tight demand-supply conditions for power in the Ambon power system, where so far diesel power has been the sole power source and PLN cannot fully satisfy demand due to aging and deteriorating equipment and facilities. Because PLN has had to turn down many requests for new electric power service, many commercial facilities have installed their own small, diesel-fueled, captive power plants. Power demand is increasing at an annual rate of about 10 percent, and PLN has coped with this increasing power demand by allowing IPPs to install diesel power plants. The project is also expected to reduce the need for government subsidies and expensive diesel fuel, as the geothermal power plant will be able to generate power much more cheaply than diesel plants.

IV.7.2 Project Executing Agency

The executing agency of the project is PLN (PT. PLN (Persero)).

IV.7.3 Project Implementation Plan

1. Project Implementation Organization

JICA pledged an Engineering Service (ES) Loan for this Project to the Government of Indonesia (GOI) in March 2011. JICA and GOI concluded an Exchange of Notes (E/N) on 18 August 2011 for a Geothermal Development Promotion Loan which includes the ES Loan and the Project Loan for Tulehu geothermal project. As soon as this Project feasibility study has been completed, JICA and GoI will proceed to the Loan Agreement (L/A) for the Engineering Service Yen Loan. PLN will start procurement of a Consultant who has an ample experience not only in the planning, design and construction of geothermal power plants but also in the procurement and supervision of geothermal well drilling and FCRS construction. With the consultant's assistance, PLN will implement the work of planning, design, contractor selection & contracting, supervision and management of contractors' work, and project acceptance. The following PLN divisions will play a major roles in the implementation of the Tulehu geothermal power plant project.

PLN Head Office	
Division of Alternative and Renewable Energy (Director of Planning and Technology)	Planning of Tulehu geothermal project
Division of Engineering Technology (Director of Planning and Technology)	Consultant procurement
Division of Procurement Management (Director of Strategic Procurement)	Contractor selection
Division of Construction & IPP for East Indonesia (Director of Operations for East Indonesia)	Overall Project construction control
PLN Project Management Office	
PLN Pikitring Sulmapa (at Makassar)	Project construction management
PLN Branch Office	
Wilayah Maluku & Maluku Utara at Ambon	
PLN Subsidiaries	
PT. PLN Geothermal	PLN's subsidiary company for geothermal business

2. Organization of Project Operation and Maintenance

The project operation and maintenance organization has not yet been clearly decided at PLN. The following operation organization can be anticipated from the operation organization of the Lahendong geothermal power plants which are in operation in North Sulawesi.

Steam Supply: PLN (PT PLN Geothermal)
Geothermal Power Generation: PLN (PT PLN Geothermal)
Transmission and Distribution: PLN (Wilayah Maluku & Maluku Utara at Ambon)

3. Project Composition and Procurement Plan

The Tulehu Geothermal Power Plant Project comprises the following work and services with financing from the sources indicated.

	Work & Services	Finance Source
1)	PLN Advance Work (land acquisition, well pad preparation, access road construction, meteorological observation at the Project site)	PLN's Own Funds
2)-1	Exploratory Well Drilling & Testing for Tulehu (3 production wells and 1 reinjection well)	JICA ES Loan
2)-2	Additional Well Drilling & Testing for Tulehu	JICA Project Loan
3)	Construction of FCRS	JICA Project Loan
4)	Construction of Geothermal Power Plant (including associated switchyard)	JICA Project Loan
5)	70 kV Transmission Line Connecting Work	PLN's Own Funds
6)	Engineering Consulting Services	JICA ES Loan
7)	Exploratory Well Drilling & Testing for future development site (2 production wells and 1 reinjection well)	JICA ES Loan

PLN will implement work item 1) PLN advance work and 5) 70 kV transmission line connection with its own funds. Work item 1) PLN advance work is very important initial work for ensuring the project implementation schedule. Work item 5) 70 kV transmission line connection should be incorporated into the design and planning of the ongoing 70 kV transmission line project between Waai coal-fired thermal power plant and the Passo substation. It is planned to connect the 70 kV transmission line from Tulehu geothermal power plant to the No.35 tower between Waai and Passo.

Utilizing the JICA ES Loan, PLN will first procure work item 2)-1 Tulehu exploratory well drilling, service item 6) engineering consulting services, and work item 7) exploratory well drilling in the future development site. Early execution of these first procurements, if possible even before the ES L/A is concluded, is desirable to ensure early project completion. PLN will conduct the procurement of the exploratory well drilling work for Tulehu and the future development site without consultant assistance, since the consultant selection will proceed at same time.

During the initial stage of the consulting services, additional data and information will be generated by work item 1) PLN advance work and work item 2)-1 the exploratory well drilling, such as meteorological data at the project site and the results of additional well drilling and testing. On the basis of such additional information and data, the consultant will review the previous studies evaluating the geothermal resource and determine the steam conditions, the drilling plan, the FCRS basic design, and the preliminary design of the geothermal power plant. The consultant will also upgrade and finalize the project implementation plan.

Based on the finalized project implementation plan, the JICA Project Loan will be concluded, and work items 2)-2 additional Tulehu well drilling, 3) FCRS construction, and 4) geothermal power plant construction will be implemented with the assistance of the consultant.

For project procurement and contracting, the project can be implemented generally according to the work packages mentioned in the above table. The FCRS and the geothermal power plant, however, will be procured as a single-package, full turnkey contract. The consultant's scope of services during the project implementation stage is as follows:

Resource Development

- Advisory services for supervision of exploratory well drilling at the Tulehu project site
- Advisory services for exploratory well testing at the Tulehu project site
- Geothermal resource evaluation of the results of exploratory well drilling and testing at the Tulehu project site
- PQ for drilling contractor for additional Tulehu production and reinjection wells
- Preparation of bidding documents for procurement of a drilling contractor for additional Tulehu production and reinjection wells
- Assistance to PLN in the bidding
- Evaluation of bids and assistance in contract negotiation and contracting of a drilling contractor for additional Tulehu production and reinjection wells
- Selection of drilling sites and targets for additional Tulehu production and reinjection wells
- Supervision of drilling work and hot water and steam analysis for additional Tulehu production and reinjection wells
- Resource assessment including reservoir simulation
- Training for transfer of technology
- Advisory services for supervision of exploratory well drilling at the future development site
- Advisory services for exploratory well testing at the future development site
- Geothermal resource evaluation of the results of exploratory well drilling and testing at the future development site

FCRS and Geothermal Power Plant Construction

- Review of previous project studies including FS based on the results of the geothermal resource evaluation mentioned above and meteorological data from the project site
- Basic Project design and engineering
- PQ for EPC contractor
- Preparation of bidding documents for procurement of EPC contractor
- Assistance to PLN in the bidding
- Evaluation of bids and assistance in contract negotiation and contracting for EPC

contractor

- Checking and review of EPC contractor’s design drawings and documents and witnessing factory tests
- Supervision of construction work and commissioning
- Evaluation of acceptance tests
- Training for transfer of technology

IV.7.4 Project Implementation Schedule

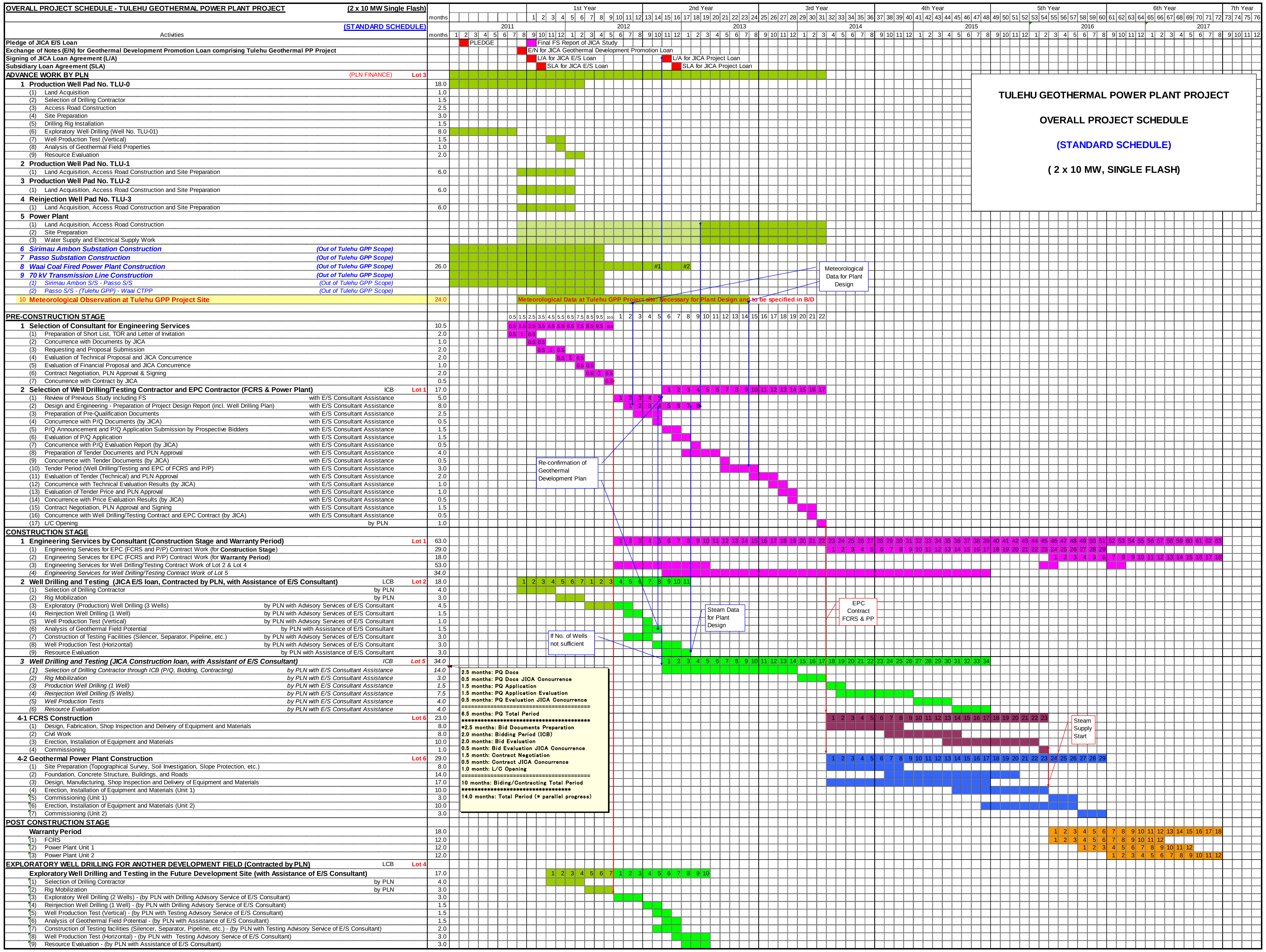
With due consideration of the JICA standard yen loan schedule, a tentative project implementation schedule has been prepared for the four (4) cases of the project: 2 x 10 MW Single Flash, 1 x 20 MW Single Flash, 2 x 10 MW Double Flash, and 1 x 20 MW Double Flash as shown in Figs. IV-7-1, IV-7-2, IV-7-3, and IV-7-4 respectively. The accelerated version of the project implementation schedules for the 2 x 10 MW and 1 x 20 MW Double Flash cases are studied as target schedules, in consideration of PLN’s strong intention to complete the project as early as possible. The major project activities and periods are summarized in Table IV-7-1 for each case.

The construction period is determined in consideration of the following work items and the tropical and isolated island conditions of the project site.

- Loan Agreement for JICA Engineering Service Loan (ES L/A)
- Sub-Loan Agreement between GoI and PLN for ES L/A
- Loan Agreement for JICA Project Loan (Project L/A)
- Sub-Loan Agreement between GoI and PLN for Project L/A
- PLN’s advance work for the project
- Employment of consultant
- Bidding, evaluation, and contracting of contractor for drilling of the exploration wells (3 production wells and 1 reinjection well)
- Exploration well (production and reinjection wells) drilling and tests
- Bidding, evaluation and contracting of contractors for additional well drilling, and the construction of the FCRS and geothermal power plant
- Detailed design of major equipment for the FCRS and geothermal power plant
- Manufacturing and factory inspection of major equipment for the FCRS and geothermal power plant
- Transportation to the project site
- Start of construction work at the project site
- Commissioning and Performance tests for acceptance
- Guarantee period after commissioning (12 months)
- Exploratory well drilling and testing at the future development site

Table IV-7-1 Major Project Activities and Periods

Major Project Activities and Periods		Standard Schedule				Accelerated Schedule	
		Single Flash		Double Flash		Double Flash	
		2 x 10 MW	1 x 20 MW	2 x 10 MW	1 x 20 MW	2 x 10 MW	1 x 20 MW
1	Employment of consultant	10.5	10.5	10.5	10.5	10.5	10.5
2	Bidding, evaluation, and contracting of contractor for drilling of the exploration wells (3 production wells and 1 reinjection well)	4	4	4	4	4	4
3	Exploration well (production and reinjection wells) drilling and tests	14	14	14	14	14	14
4	Bidding, evaluation and contracting of contractors for the additional well drilling	14	14	14	14	14	14
5	Additional well drilling and tests	17	17	15.5	15.5	15.5	15.5
6	Bidding, evaluation and contracting of contractors for the construction of the FCRS and geothermal power plant	22	22	22	22	18	18
7	FCRS design, procurement, manufacturing, transportation, installation, and commissioning	22	22	22	22	19	19
8	Geothermal PP design, procurement, manufacturing, transportation, installation, and commissioning	29	26	29	26	25	22
9	Project Total Period (Start – Plant Completion)	60 months	57 months	60 months	57 months	52 months	49 months
10	Warranty Period for the FCRS and Geothermal PP	12	12	12	12	12	12
11	Project Total Period (Start –Warranty Completion / Final Acceptance)	72 months	69 months	72 months	69 months	64 months	61 months



TULEHU GEOTHERMAL POWER PLANT PROJECT

OVERALL PROJECT SCHEDULE

(STANDARD SCHEDULE)

(2 x 10 MW, SINGLE FLASH)

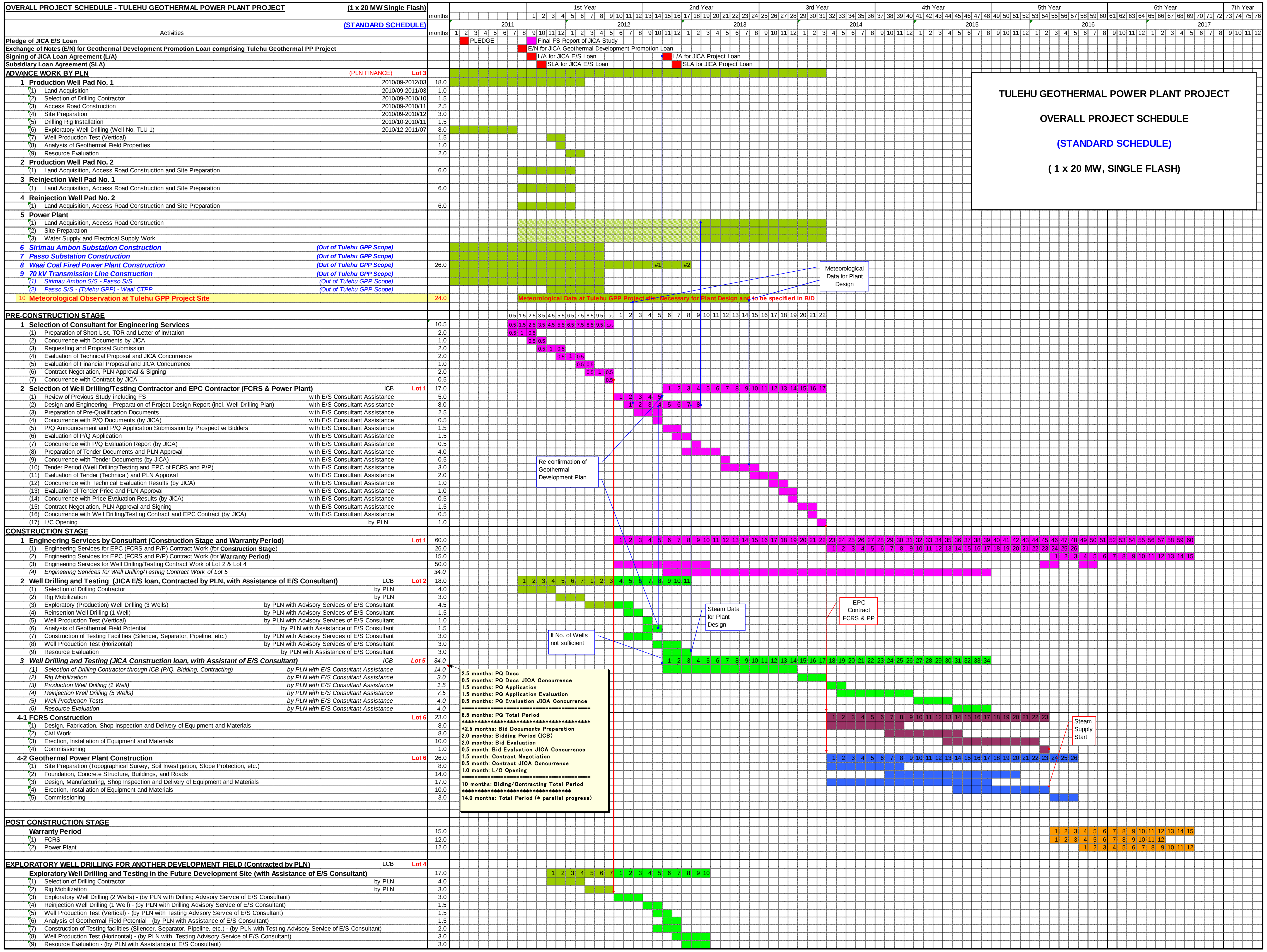
OVERALL PROJECT SCHEDULE - TULEHU GEOTHERMAL POWER PLANT PROJECT **(2 x 10 MW Single Flash)**

(STANDARD SCHEDULE)

Activities			months
Pledge of JICA E/S Loan			
Exchange of Notes (E/N) for Geothermal Development Promotion Loan comprising Tulehu Geothermal PP Project			
Signing of JICA Loan Agreement (L/A)			
Subsidiary Loan Agreement (SLA)			
ADVANCE WORK BY PLN	(PLN FINANCE)	Lot 3	
1 Production Well Pad No. TLU-0			18.0
(1) Land Acquisition			1.0
(2) Selection of Drilling Contractor			1.5
(3) Access Road Construction			2.5
(4) Site Preparation			3.0
(5) Drilling Rig Installation			1.5
(6) Exploratory Well Drilling (Well No. TLU-01)			8.0
(7) Well Production Test (Vertical)			1.5
(8) Analysis of Geothermal Field Properties			1.0
(9) Resource Evaluation			2.0
2 Production Well Pad No. TLU-1			
(1) Land Acquisition, Access Road Construction and Site Preparation			6.0
3 Production Well Pad No. TLU-2			
(1) Land Acquisition, Access Road Construction and Site Preparation			6.0
4 Reinjection Well Pad No. TLU-3			
(1) Land Acquisition, Access Road Construction and Site Preparation			6.0
5 Power Plant			
(1) Land Acquisition, Access Road Construction			
(2) Site Preparation			
(3) Water Supply and Electrical Supply Work			
6 Sirimau Ambon Substation Construction	*(Out of Tulehu GPP Scope)*		
7 Passo Substation Construction	*(Out of Tulehu GPP Scope)*		
8 Waai Coal Fired Power Plant Construction	*(Out of Tulehu GPP Scope)*		26.0
9 70 kV Transmission Line Construction	*(Out of Tulehu GPP Scope)*		
(1) Sirimau Ambon S/S - Passo S/S	*(Out of Tulehu GPP Scope)*		
(2) Passo S/S - (Tulehu GPP) - Waai CTPP	*(Out of Tulehu GPP Scope)*		
10 **Meteorological Observation at Tulehu GPP Project Site**			24.0
PRE-CONSTRUCTION STAGE			
1 Selection of Consultant for Engineering Services			10.5
(1) Preparation of Short List, TOR and Letter of Invitation			2.0
(2) Concurrence with Documents by JICA			1.0
(3) Requesting and Proposal Submission			2.0
(4) Evaluation of Technical Proposal and JICA Concurrence			2.0
(5) Evaluation of Financial Proposal and JICA Concurrence			1.0
(6) Contract Negotiation, PLN Approval & Signing			2.0
(7) Concurrence with Contract by JICA			0.5
2 Selection of Well Drilling/Testing Contractor and EPC Contractor (FCRS & Power Plant)	ICB	Lot 1	17.0
(1) Review of Previous Study including FS	with E/S Consultant Assistance		5.0
(2) Design and Engineering - Preparation of Project Design Report (incl. Well Drilling Plan)	with E/S Consultant Assistance		8.0
(3) Preparation of Pre-Qualification Documents	with E/S Consultant Assistance		2.5
(4) Concurrence with P/Q Documents (by JICA)	with E/S Consultant Assistance		0.5
(5) P/Q Announcement and P/Q Application Submission by Prospective Bidders	with E/S Consultant Assistance		1.5
(6) Evaluation of P/Q Application	with E/S Consultant Assistance		1.5
(7) Concurrence with P/Q Evaluation Report (by JICA)	with E/S Consultant Assistance		0.5
(8) Preparation of Tender Documents and PLN Approval	with E/S Consultant Assistance		4.0
(9) Concurrence with Tender Documents (by JICA)	with E/S Consultant Assistance		0.5
(10) Tender Period (Well Drilling/Testing and EPC of FCRS and P/P)	with E/S Consultant Assistance		3.0
(11) Evaluation of Tender (Technical) and PLN Approval	with E/S Consultant Assistance		2.0
(12) Concurrence with Technical Evaluation Results (by JICA)	with E/S Consultant Assistance		1.0
(13) Evaluation of Tender Price and PLN Approval	with E/S Consultant Assistance		1.0
(14) Concurrence with Price Evaluation Results (by JICA)	with E/S Consultant Assistance		0.5
(15) Contract Negotiation, PLN Approval and Signing	with E/S Consultant Assistance		1.5
(16) Concurrence with Well Drilling/Testing Contract and EPC Contract (by JICA)	with E/S Consultant Assistance		0.5
(17) L/C Opening	by PLN		1.0
CONSTRUCTION STAGE			
1 Engineering Services by Consultant (Construction Stage and Warranty Period)		Lot 1	63.0
(1) Engineering Services for EPC (FCRS and P/P) Contract Work (for **Construction Stage**)			29.0
(2) Engineering Services for EPC (FCRS and P/P) Contract Work (for **Warranty Period**)			18.0
(3) Engineering Services for Well Drilling/Testing Contract Work of Lot 2 & Lot 4			53.0
(4) Engineering Services for Well Drilling/Testing Contract Work of Lot 5			*34.0*
2 Well Drilling and Testing (JICA E/S loan, Contracted by PLN, with Assistance of E/S Consultant)	LCB	Lot 2	18.0
(1) Selection of Drilling Contractor	by PLN		4.0
(2) Rig Mobilization	by PLN		3.0
(3) Exploratory (Production) Well Drilling (3 Wells)	by PLN with Advisory Services of E/S Consultant		4.5
(4) Reinjection Well Drilling (1 Well)	by PLN with Advisory Services of E/S Consultant		1.5
(5) Well Production Test (Vertical)	by PLN with Advisory Services of E/S Consultant		1.0
(6) Analysis of Geothermal Field Potential	by PLN with Assistance of E/S Consultant		1.5
(7) Construction of Testing Facilities (Silencer, Separator, Pipeline, etc.)	by PLN with Advisory Services of E/S Consultant		3.0
(8) Well Production Test (Horizontal)	by PLN with Advisory Services of E/S Consultant		3.0
(9) Resource Evaluation	by PLN with Assistance of E/S Consultant		3.0
3 Well Drilling and Testing (JICA Construction loan, with Assistant of E/S Consultant)	*ICB*	*Lot 5*	*34.0*
(1) Selection of Drilling Contractor through ICB (P/Q, Bidding, Contracting)	*by PLN with E/S Consultant Assistance*		*14.0*
(2) Rig Mobilization	*by PLN with E/S Consultant Assistance*		*3.0*
(3) Production Well Drilling (1 Well)	*by PLN with E/S Consultant Assistance*		*1.5*
(4) Reinjection Well Drilling (5 Wells)	*by PLN with E/S Consultant Assistance*		*7.5*
(5) Well Production Tests	*by PLN with E/S Consultant Assistance*		*4.0*
(6) Resource Evaluation	*by PLN with E/S Consultant Assistance*		*4.0*
4-1 FCRS Construction		Lot 6	23.0
(1) Design, Fabrication, Shop Inspection and Delivery of Equipment and Materials			8.0
(2) Civil Work			8.0
(3) Erection, Installation of Equipment and Materials			10.0
(4) Commissioning			1.0
4-2 Geothermal Power Plant Construction		Lot 6	29.0
(1) Site Preparation (Topographical Survey, Soil Investigation, Slope Protection, etc.)			8.0
(2) Foundation, Concrete Structure, Buildings, and Roads			14.0
(3) Design, Manufacturing, Shop Inspection and Delivery of Equipment and Materials			17.0
(4) Erection, Installation of Equipment and Materials (Unit 1)			10.0
(5) Commissioning (Unit 1)			3.0
(6) Erection, Installation of Equipment and Materials (Unit 2)			10.0
(7) Commissioning (Unit 2)			3.0
POST CONSTRUCTION STAGE			
Warranty Period			18.0
(1) FCRS			12.0
(2) Power Plant Unit 1			12.0
(3) Power Plant Unit 2			12.0
EXPLORATORY WELL DRILLING FOR ANOTHER DEVELOPMENT FIELD (Contracted by PLN)	LCB	Lot 4	
Exploratory Well Drilling and Testing in the Future Development Site (with Assistance of E/S Consultant)			17.0
(1) Selection of Drilling Contractor	by PLN		4.0
(2) Rig Mobilization	by PLN		3.0
(3) Exploratory Well Drilling (2 Wells) - (by PLN with Drilling Advisory Service of E/S Consultant)			3.0
(4) Reinjection Well Drilling (1 Well) - (by PLN with Drilling Advisory Service of E/S Consultant)			1.5
(5) Well Production Test (Vertical) - (by PLN with Testing Advisory Service of E/S Consultant)			1.5
(6) Analysis of Geothermal Field Potential - (by PLN with Assistance of E/S Consultant)			1.5
(7) Construction of Testing facilities (Silencer, Separator, Pipeline, etc.) - (by PLN with Testing Advisory Service of E/S Consultant)			2.0
(8) Well Production Test (Horizontal) - (by PLN with Testing Advisory Service of E/S Consultant)			3.0
(9) Resource Evaluation - (by PLN with Assistance of E/S Consultant)			3.0

2.5 months: PQ Docs
0.5 months: PQ Docs JICA Concurrence
1.5 months: PQ Application
1.5 months: PQ Application Evaluation
0.5 months: PQ Evaluation JICA Concurrence
==
6.5 months: PQ Total Period
****
***2.5 months: Bid Documents Preparation**
2.0 months: Bidding Period (ICB)
2.0 months: Bid Evaluation
0.5 month: Bid Evaluation JICA Concurrence
1.5 month: Contract Negotiation
0.5 month: Contract JICA Concurrence
1.0 month: L/C Opening
==
10 months: Biding/Contracting Total Period
****
14.0 months: Total Period (* parallel progress)

Fig. IV-7-1 Tentative Project Implementation Schedule (2 x 10MW Single Flash System) – Standard Schedule



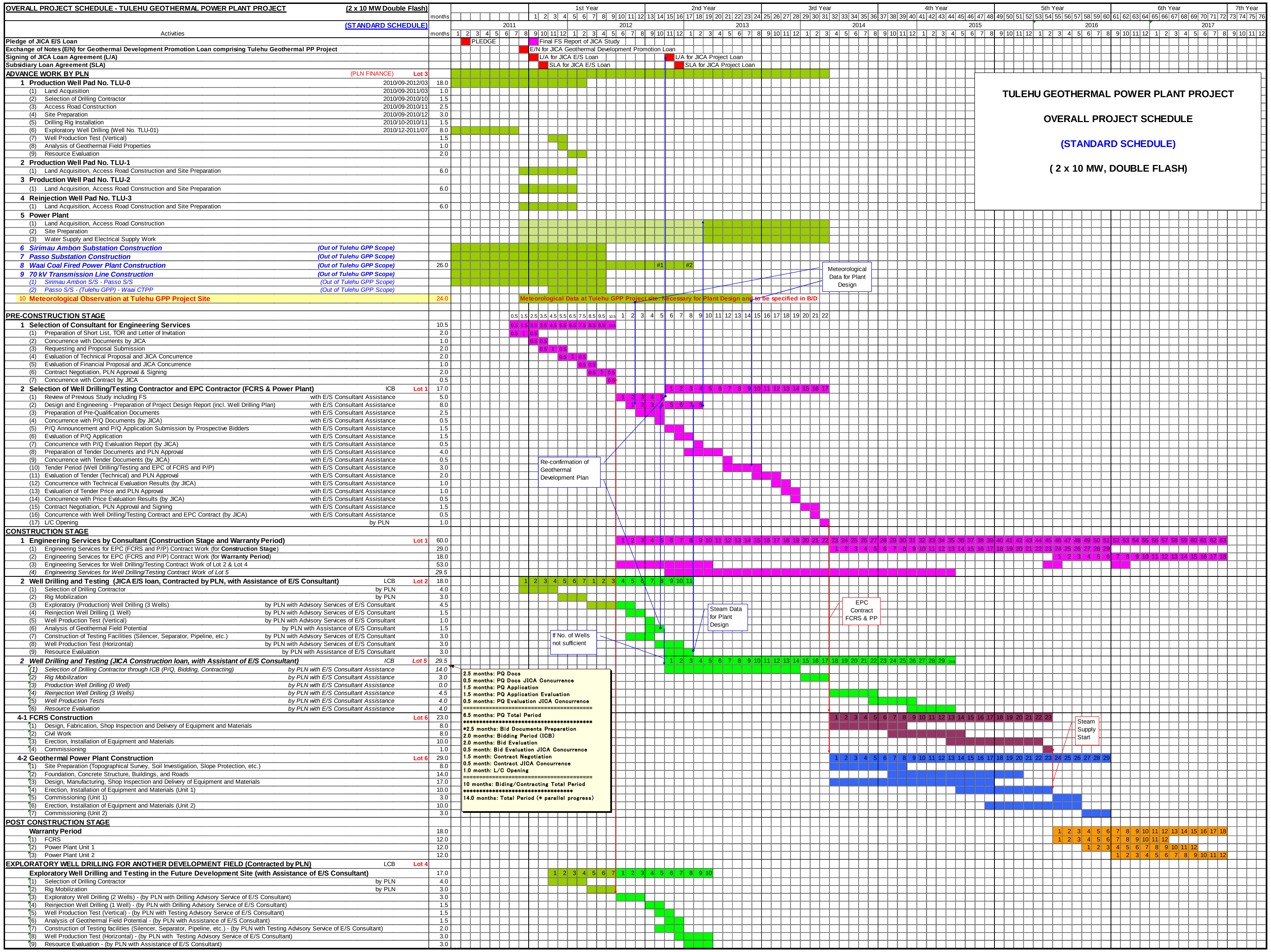
OVERALL PROJECT SCHEDULE - TULEHU GEOTHERMAL POWER PLANT PROJECT **(1 x 20 MW Single Flash)**

(STANDARD SCHEDULE)

Activities			months
Pledge of JICA E/S Loan			
Exchange of Notes (E/N) for Geothermal Development Promotion Loan comprising Tulehu Geothermal PP Project			
Signing of JICA Loan Agreement (L/A)			
Subsidiary Loan Agreement (SLA)			
ADVANCE WORK BY PLN	(PLN FINANCE)	Lot 3	
1 Production Well Pad No. 1	2010/09-2012/03		18.0
(1) Land Acquisition	2010/09-2011/03		1.0
(2) Selection of Drilling Contractor	2010/09-2010/10		1.5
(3) Access Road Construction	2010/09-2010/11		2.5
(4) Site Preparation	2010/09-2010/12		3.0
(5) Drilling Rig Installation	2010/10-2010/11		1.5
(6) Exploratory Well Drilling (Well No. TLU-1)	2010/12-2011/07		8.0
(7) Well Production Test (Vertical)			1.5
(8) Analysis of Geothermal Field Properties			1.0
(9) Resource Evaluation			2.0
2 Production Well Pad No. 2			
(1) Land Acquisition, Access Road Construction and Site Preparation			6.0
3 Reinjection Well Pad No. 1			
(1) Land Acquisition, Access Road Construction and Site Preparation			6.0
4 Reinjection Well Pad No. 2			
(1) Land Acquisition, Access Road Construction and Site Preparation			6.0
5 Power Plant			
(1) Land Acquisition, Access Road Construction			
(2) Site Preparation			
(3) Water Supply and Electrical Supply Work			
6 Sirimau Ambon Substation Construction	*(Out of Tulehu GPP Scope)*		
7 Passo Substation Construction	*(Out of Tulehu GPP Scope)*		
8 Waai Coal Fired Power Plant Construction	*(Out of Tulehu GPP Scope)*		26.0
9 70 kV Transmission Line Construction	*(Out of Tulehu GPP Scope)*		
(1) Sirimau Ambon S/S - Passo S/S	*(Out of Tulehu GPP Scope)*		
(2) Passo S/S - (Tulehu GPP) - Waai CTPP	*(Out of Tulehu GPP Scope)*		
10 **Meteorological Observation at Tulehu GPP Project Site**			24.0
PRE-CONSTRUCTION STAGE			
1 Selection of Consultant for Engineering Services			10.5
(1) Preparation of Short List, TOR and Letter of Invitation			2.0
(2) Concurrence with Documents by JICA			1.0
(3) Requesting and Proposal Submission			2.0
(4) Evaluation of Technical Proposal and JICA Concurrence			2.0
(5) Evaluation of Financial Proposal and JICA Concurrence			1.0
(6) Contract Negotiation, PLN Approval & Signing			2.0
(7) Concurrence with Contract by JICA			0.5
2 Selection of Well Drilling/Testing Contractor and EPC Contractor (FCRS & Power Plant)	ICB	Lot 1	17.0
(1) Review of Previous Study including FS	with E/S Consultant Assistance		5.0
(2) Design and Engineering - Preparation of Project Design Report (incl. Well Drilling Plan)	with E/S Consultant Assistance		8.0
(3) Preparation of Pre-Qualification Documents	with E/S Consultant Assistance		2.5
(4) Concurrence with P/Q Documents (by JICA)	with E/S Consultant Assistance		0.5
(5) P/Q Announcement and P/Q Application Submission by Prospective Bidders	with E/S Consultant Assistance		1.5
(6) Evaluation of P/Q Application	with E/S Consultant Assistance		1.5
(7) Concurrence with P/Q Evaluation Report (by JICA)	with E/S Consultant Assistance		0.5
(8) Preparation of Tender Documents and PLN Approval	with E/S Consultant Assistance		4.0
(9) Concurrence with Tender Documents (by JICA)	with E/S Consultant Assistance		0.5
(10) Tender Period (Well Drilling/Testing and EPC of FCRS and P/P)	with E/S Consultant Assistance		3.0
(11) Evaluation of Tender (Technical) and PLN Approval	with E/S Consultant Assistance		2.0
(12) Concurrence with Technical Evaluation Results (by JICA)	with E/S Consultant Assistance		1.0
(13) Evaluation of Tender Price and PLN Approval	with E/S Consultant Assistance		1.0
(14) Concurrence with Price Evaluation Results (by JICA)	with E/S Consultant Assistance		0.5
(15) Contract Negotiation, PLN Approval and Signing	with E/S Consultant Assistance		1.5
(16) Concurrence with Well Drilling/Testing Contract and EPC Contract (by JICA)	with E/S Consultant Assistance		0.5
(17) L/C Opening	by PLN		1.0
CONSTRUCTION STAGE			
1 Engineering Services by Consultant (Construction Stage and Warranty Period)		Lot 1	60.0
(1) Engineering Services for EPC (FCRS and P/P) Contract Work (for **Construction Stage**)			26.0
(2) Engineering Services for EPC (FCRS and P/P) Contract Work (for **Warranty Period**)			15.0
(3) Engineering Services for Well Drilling/Testing Contract Work of Lot 2 & Lot 4			50.0
(4) Engineering Services for Well Drilling/Testing Contract Work of Lot 5			*34.0*
2 Well Drilling and Testing (JICA E/S loan, Contracted by PLN, with Assistance of E/S Consultant)	LCB	Lot 2	18.0
(1) Selection of Drilling Contractor	by PLN		4.0
(2) Rig Mobilization	by PLN		3.0
(3) Exploratory (Production) Well Drilling (3 Wells)	by PLN with Advisory Services of E/S Consultant		4.5
(4) Reinsertion Well Drilling (1 Well)	by PLN with Advisory Services of E/S Consultant		1.5
(5) Well Production Test (Vertical)	by PLN with Advisory Services of E/S Consultant		1.0
(6) Analysis of Geothermal Field Potential	by PLN with Assistance of E/S Consultant		1.5
(7) Construction of Testing Facilities (Silencer, Separator, Pipeline, etc.)	by PLN with Advisory Services of E/S Consultant		3.0
(8) Well Production Test (Horizontal)	by PLN with Advisory Services of E/S Consultant		3.0
(9) Resource Evaluation	by PLN with Assistance of E/S Consultant		3.0
3 Well Drilling and Testing (JICA Construction loan, with Assistant of E/S Consultant)	*ICB*	Lot 5	*34.0*
(1) Selection of Drilling Contractor through ICB (P/Q, Bidding, Contracting)	*by PLN with E/S Consultant Assistance*		*14.0*
(2) Rig Mobilization	*by PLN with E/S Consultant Assistance*		*3.0*
(3) Production Well Drilling (1 Well)	*by PLN with E/S Consultant Assistance*		*1.5*
(4) Reinjection Well Drilling (5 Wells)	*by PLN with E/S Consultant Assistance*		*7.5*
(5) Well Production Tests	*by PLN with E/S Consultant Assistance*		*4.0*
(6) Resource Evaluation	*by PLN with E/S Consultant Assistance*		*4.0*
4-1 FCRS Construction		Lot 6	23.0
(1) Design, Fabrication, Shop Inspection and Delivery of Equipment and Materials			8.0
(2) Civil Work			8.0
(3) Erection, Installation of Equipment and Materials			10.0
(4) Commissioning			1.0
4-2 Geothermal Power Plant Construction		Lot 6	26.0
(1) Site Preparation (Topographical Survey, Soil Investigation, Slope Protection, etc.)			8.0
(2) Foundation, Concrete Structure, Buildings, and Roads			14.0
(3) Design, Manufacturing, Shop Inspection and Delivery of Equipment and Materials			17.0
(4) Erection, Installation of Equipment and Materials			10.0
(5) Commissioning			3.0
POST CONSTRUCTION STAGE			
Warranty Period			15.0
(1) FCRS			12.0
(2) Power Plant			12.0
EXPLORATORY WELL DRILLING FOR ANOTHER DEVELOPMENT FIELD (Contracted by PLN)	LCB	Lot 4	
Exploratory Well Drilling and Testing in the Future Development Site (with Assistance of E/S Consultant)			17.0
(1) Selection of Drilling Contractor	by PLN		4.0
(2) Rig Mobilization	by PLN		3.0
(3) Exploratory Well Drilling (2 Wells) - (by PLN with Drilling Advisory Service of E/S Consultant)			3.0
(4) Reinjection Well Drilling (1 Well) - (by PLN with Drilling Advisory Service of E/S Consultant)			1.5
(5) Well Production Test (Vertical) - (by PLN with Testing Advisory Service of E/S Consultant)			1.5
(6) Analysis of Geothermal Field Potential - (by PLN with Assistance of E/S Consultant)			1.5
(7) Construction of Testing facilities (Silencer, Separator, Pipeline, etc.) - (by PLN with Testing Advisory Service of E/S Consultant)			2.0
(8) Well Production Test (Horizontal) - (by PLN with Testing Advisory Service of E/S Consultant)			3.0
(9) Resource Evaluation - (by PLN with Assistance of E/S Consultant)			3.0

2.5 months: PQ Docs
0.5 months: PQ Docs JICA Concurrence
1.5 months: PQ Application
1.5 months: PQ Application Evaluation
0.5 months: PQ Evaluation JICA Concurrence
==
6.5 months: PQ Total Period
****
*2.5 months: Bid Documents Preparation
2.0 months: Bidding Period (ICB)
2.0 months: Bid Evaluation
0.5 month: Bid Evaluation JICA Concurrence
1.5 month: Contract Negotiation
0.5 month: Contract JICA Concurrence
1.0 month: L/C Opening
==
10 months: Biding/Contracting Total Period
****
14.0 months: Total Period (* parallel progress)

Fig. IV-7-2 Tentative Project Implementation Schedule (1 x 20MW Single Flash System) – Standard Schedule



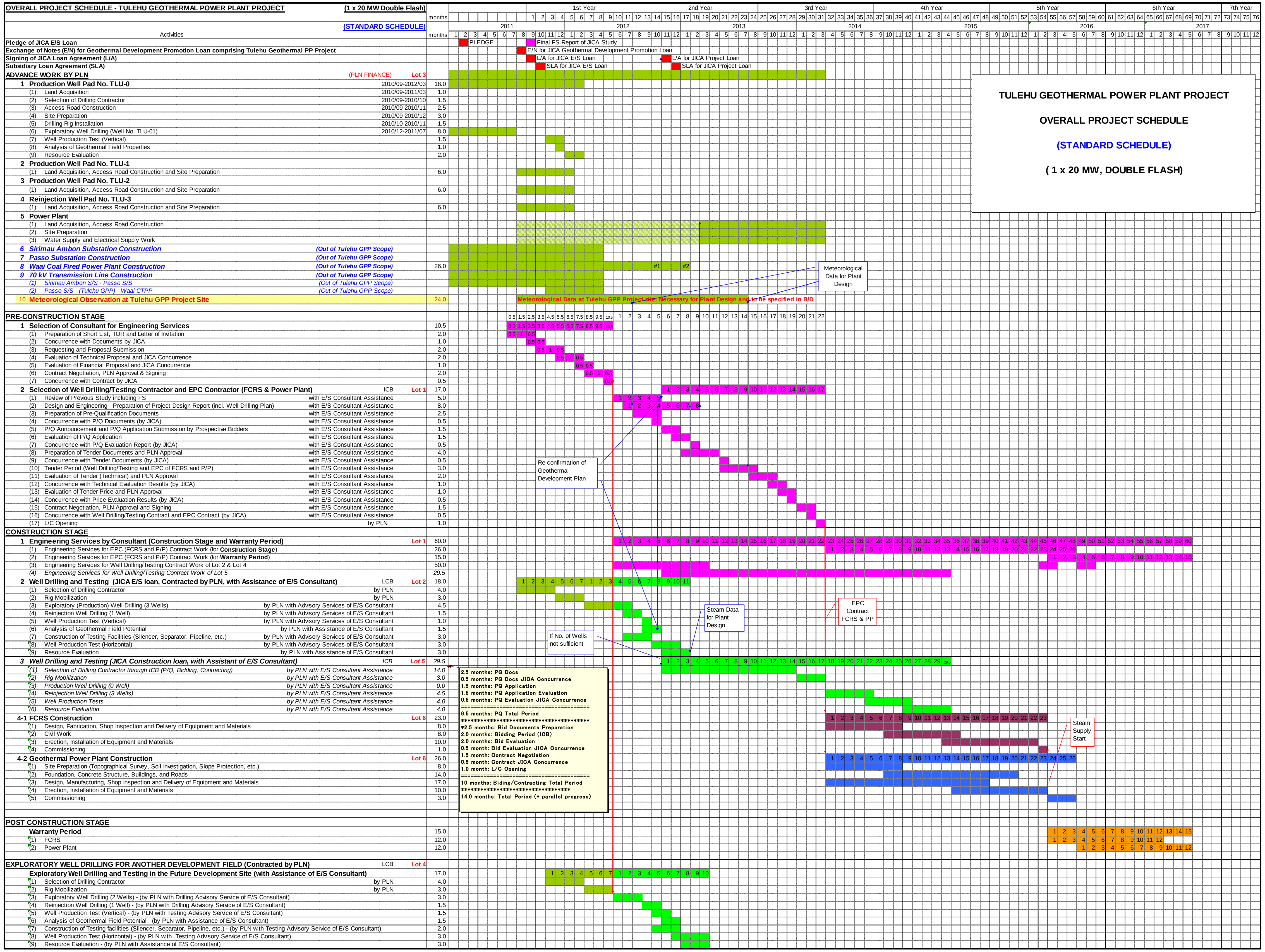
2.5 months: PQ Docs
0.5 months: PQ Docs JICA Concurrence
1.5 months: PQ Application
1.5 months: PQ Application Evaluation
0.5 months: PQ Evaluation JICA Concurrence
===
6.5 months: PQ Total Period
****
*2.5 months: Bid Documents Preparation
2.0 months: Bidding Period (ICB)
2.0 months: Bid Evaluation
0.5 month: Bid Evaluation JICA Concurrence
1.5 month: Contract Negotiation
0.5 month: Contract JICA Concurrence
1.0 month: L/C Opening
===
10 months: Biding/Contracting Total Period
****
14.0 months: Total Period (* parallel progress)

OVERALL PROJECT SCHEDULE - TULEHU GEOTHERMAL POWER PLANT PROJECT **(2 x 10 MW Double Flash)**

(STANDARD SCHEDULE)

Activities			months
Pledge of JICA E/S Loan			
Exchange of Notes (E/N) for Geothermal Development Promotion Loan comprising Tulehu Geothermal PP Project			
Signing of JICA Loan Agreement (L/A)			
Subsidiary Loan Agreement (SLA)			
ADVANCE WORK BY PLN	(PLN FINANCE)	Lot 3	
1 Production Well Pad No. TLU-0	2010/09-2012/03		18.0
(1) Land Acquisition	2010/09-2011/03		1.0
(2) Selection of Drilling Contractor	2010/09-2010/10		1.5
(3) Access Road Construction	2010/09-2010/11		2.5
(4) Site Preparation	2010/09-2010/12		3.0
(5) Drilling Rig Installation	2010/10-2010/11		1.5
(6) Exploratory Well Drilling (Well No. TLU-01)	2010/12-2011/07		8.0
(7) Well Production Test (Vertical)			1.5
(8) Analysis of Geothermal Field Properties			1.0
(9) Resource Evaluation			2.0
2 Production Well Pad No. TLU-1			
(1) Land Acquisition, Access Road Construction and Site Preparation			6.0
3 Production Well Pad No. TLU-2			
(1) Land Acquisition, Access Road Construction and Site Preparation			6.0
4 Reinjection Well Pad No. TLU-3			
(1) Land Acquisition, Access Road Construction and Site Preparation			6.0
5 Power Plant			
(1) Land Acquisition, Access Road Construction			
(2) Site Preparation			
(3) Water Supply and Electrical Supply Work			
6 Sirimau Ambon Substation Construction	***(Out of Tulehu GPP Scope)***		
7 Passo Substation Construction	***(Out of Tulehu GPP Scope)***		
8 Waai Coal Fired Power Plant Construction	***(Out of Tulehu GPP Scope)***		26.0
9 70 kV Transmission Line Construction	***(Out of Tulehu GPP Scope)***		
(1) Sirimau Ambon S/S - Passo S/S	*(Out of Tulehu GPP Scope)*		
(2) Passo S/S - (Tulehu GPP) - Waai CTPP	*(Out of Tulehu GPP Scope)*		
10 Meteorological Observation at Tulehu GPP Project Site			24.0
PRE-CONSTRUCTION STAGE			
1 Selection of Consultant for Engineering Services			10.5
(1) Preparation of Short List, TOR and Letter of Invitation			2.0
(2) Concurrence with Documents by JICA			1.0
(3) Requesting and Proposal Submission			2.0
(4) Evaluation of Technical Proposal and JICA Concurrence			2.0
(5) Evaluation of Financial Proposal and JICA Concurrence			1.0
(6) Contract Negotiation, PLN Approval & Signing			2.0
(7) Concurrence with Contract by JICA			0.5
2 Selection of Well Drilling/Testing Contractor and EPC Contractor (FCRS & Power Plant)	ICB	Lot 1	17.0
(1) Review of Previous Study including FS	with E/S Consultant Assistance		5.0
(2) Design and Engineering - Preparation of Project Design Report (incl. Well Drilling Plan)	with E/S Consultant Assistance		8.0
(3) Preparation of Pre-Qualification Documents	with E/S Consultant Assistance		2.5
(4) Concurrence with P/Q Documents (by JICA)	with E/S Consultant Assistance		0.5
(5) P/Q Announcement and P/Q Application Submission by Prospective Bidders	with E/S Consultant Assistance		1.5
(6) Evaluation of P/Q Application	with E/S Consultant Assistance		1.5
(7) Concurrence with P/Q Evaluation Report (by JICA)	with E/S Consultant Assistance		0.5
(8) Preparation of Tender Documents and PLN Approval	with E/S Consultant Assistance		4.0
(9) Concurrence with Tender Documents (by JICA)	with E/S Consultant Assistance		0.5
(10) Tender Period (Well Drilling/Testing and EPC of FCRS and P/P)	with E/S Consultant Assistance		3.0
(11) Evaluation of Tender (Technical) and PLN Approval	with E/S Consultant Assistance		2.0
(12) Concurrence with Technical Evaluation Results (by JICA)	with E/S Consultant Assistance		1.0
(13) Evaluation of Tender Price and PLN Approval	with E/S Consultant Assistance		1.0
(14) Concurrence with Price Evaluation Results (by JICA)	with E/S Consultant Assistance		0.5
(15) Contract Negotiation, PLN Approval and Signing	with E/S Consultant Assistance		1.5
(16) Concurrence with Well Drilling/Testing Contract and EPC Contract (by JICA)	with E/S Consultant Assistance		0.5
(17) L/C Opening	by PLN		1.0
CONSTRUCTION STAGE			
1 Engineering Services by Consultant (Construction Stage and Warranty Period)		Lot 1	60.0
(1) Engineering Services for EPC (FCRS and P/P) Contract Work (for **Construction Stage**)			29.0
(2) Engineering Services for EPC (FCRS and P/P) Contract Work (for **Warranty Period**)			18.0
(3) Engineering Services for Well Drilling/Testing Contract Work of Lot 2 & Lot 4			53.0
(4) Engineering Services for Well Drilling/Testing Contract Work of Lot 5			*29.5*
2 Well Drilling and Testing (JICA E/S loan, Contracted by PLN, with Assistance of E/S Consultant)	LCB	Lot 2	18.0
(1) Selection of Drilling Contractor	by PLN		4.0
(2) Rig Mobilization	by PLN		3.0
(3) Exploratory (Production) Well Drilling (3 Wells)	by PLN with Advisory Services of E/S Consultant		4.5
(4) Reinjection Well Drilling (1 Well)	by PLN with Advisory Services of E/S Consultant		1.5
(5) Well Production Test (Vertical)	by PLN with Advisory Services of E/S Consultant		1.0
(6) Analysis of Geothermal Field Potential	by PLN with Assistance of E/S Consultant		1.5
(7) Construction of Testing Facilities (Silencer, Separator, Pipeline, etc.)	by PLN with Advisory Services of E/S Consultant		3.0
(8) Well Production Test (Horizontal)	by PLN with Advisory Services of E/S Consultant		3.0
(9) Resource Evaluation	by PLN with Assistance of E/S Consultant		3.0
2 Well Drilling and Testing (JICA Construction loan, with Assistant of E/S Consultant)	*ICB*	*Lot 5*	*29.5*
(1) Selection of Drilling Contractor through ICB (P/Q, Bidding, Contracting)	*by PLN with E/S Consultant Assistance*		*14.0*
(2) Rig Mobilization	*by PLN with E/S Consultant Assistance*		*3.0*
(3) Production Well Drilling (0 Well)	*by PLN with E/S Consultant Assistance*		*0.0*
(4) Reinjection Well Drilling (3 Wells)	*by PLN with E/S Consultant Assistance*		*4.5*
(5) Well Production Tests	*by PLN with E/S Consultant Assistance*		*4.0*
(6) Resource Evaluation	*by PLN with E/S Consultant Assistance*		*4.0*
4-1 FCRS Construction		Lot 6	23.0
(1) Design, Fabrication, Shop Inspection and Delivery of Equipment and Materials			8.0
(2) Civil Work			8.0
(3) Erection, Installation of Equipment and Materials			10.0
(4) Commissioning			1.0
4-2 Geothermal Power Plant Construction		Lot 6	29.0
(1) Site Preparation (Topographical Survey, Soil Investigation, Slope Protection, etc.)			8.0
(2) Foundation, Concrete Structure, Buildings, and Roads			14.0
(3) Design, Manufacturing, Shop Inspection and Delivery of Equipment and Materials			17.0
(4) Erection, Installation of Equipment and Materials (Unit 1)			10.0
(5) Commissioning (Unit 1)			3.0
(6) Erection, Installation of Equipment and Materials (Unit 2)			10.0
(7) Commissioning (Unit 2)			3.0
POST CONSTRUCTION STAGE			
Warranty Period			18.0
(1) FCRS			12.0
(2) Power Plant Unit 1			12.0
(3) Power Plant Unit 2			12.0
EXPLORATORY WELL DRILLING FOR ANOTHER DEVELOPMENT FIELD (Contracted by PLN)	LCB	Lot 4	
Exploratory Well Drilling and Testing in the Future Development Site (with Assistance of E/S Consultant)			17.0
(1) Selection of Drilling Contractor	by PLN		4.0
(2) Rig Mobilization	by PLN		3.0
(3) Exploratory Well Drilling (2 Wells) - (by PLN with Drilling Advisory Service of E/S Consultant)			3.0
(4) Reinjection Well Drilling (1 Well) - (by PLN with Drilling Advisory Service of E/S Consultant)			1.5
(5) Well Production Test (Vertical) - (by PLN with Testing Advisory Service of E/S Consultant)			1.5
(6) Analysis of Geothermal Field Potential - (by PLN with Assistance of E/S Consultant)			1.5
(7) Construction of Testing facilities (Silencer, Separator, Pipeline, etc.) - (by PLN with Testing Advisory Service of E/S Consultant)			2.0
(8) Well Production Test (Horizontal) - (by PLN with Testing Advisory Service of E/S Consultant)			3.0
(9) Resource Evaluation - (by PLN with Assistance of E/S Consultant)			3.0

Fig. IV-7-3 Tentative Project Implementation Schedule (2 x 10 MW Double Flash System) – Standard Schedule



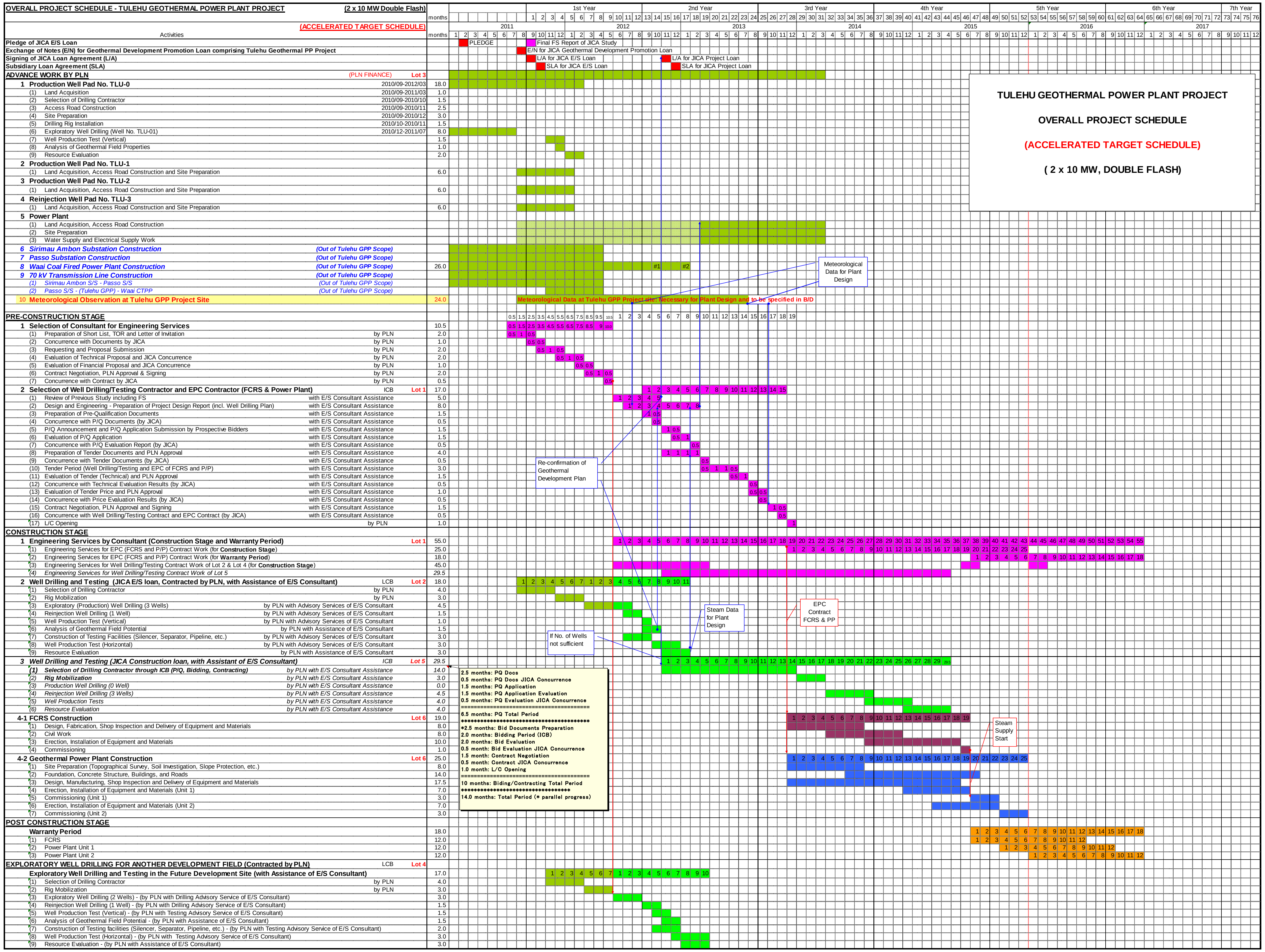
OVERALL PROJECT SCHEDULE - TULEHU GEOTHERMAL POWER PLANT PROJECT **(1 x 20 MW Double Flash)**

(STANDARD SCHEDULE)

Activities			months
Pledge of JICA E/S Loan			
Exchange of Notes (E/N) for Geothermal Development Promotion Loan comprising Tulehu Geothermal PP Project			
Signing of JICA Loan Agreement (L/A)			
Subsidiary Loan Agreement (SLA)			
ADVANCE WORK BY PLN	(PLN FINANCE)	Lot 3	
1 Production Well Pad No. TLU-0	2010/09-2012/03		18.0
(1) Land Acquisition	2010/09-2011/03		1.0
(2) Selection of Drilling Contractor	2010/09-2010/10		1.5
(3) Access Road Construction	2010/09-2010/11		2.5
(4) Site Preparation	2010/09-2010/12		3.0
(5) Drilling Rig Installation	2010/10-2010/11		1.5
(6) Exploratory Well Drilling (Well No. TLU-01)	2010/12-2011/07		8.0
(7) Well Production Test (Vertical)			1.5
(8) Analysis of Geothermal Field Properties			1.0
(9) Resource Evaluation			2.0
2 Production Well Pad No. TLU-1			
(1) Land Acquisition, Access Road Construction and Site Preparation			6.0
3 Production Well Pad No. TLU-2			
(1) Land Acquisition, Access Road Construction and Site Preparation			6.0
4 Reinjection Well Pad No. TLU-3			
(1) Land Acquisition, Access Road Construction and Site Preparation			6.0
5 Power Plant			
(1) Land Acquisition, Access Road Construction			
(2) Site Preparation			
(3) Water Supply and Electrical Supply Work			
6 Sirimau Ambon Substation Construction	***(Out of Tulehu GPP Scope)***		
7 Passo Substation Construction	***(Out of Tulehu GPP Scope)***		
8 Waai Coal Fired Power Plant Construction	***(Out of Tulehu GPP Scope)***		26.0
9 70 kV Transmission Line Construction	***(Out of Tulehu GPP Scope)***		
(1) Sirimau Ambon S/S - Passo S/S	*(Out of Tulehu GPP Scope)*		
(2) Passo S/S - (Tulehu GPP) - Waai CTPP	*(Out of Tulehu GPP Scope)*		
10 **Meteorological Observation at Tulehu GPP Project Site**			24.0
PRE-CONSTRUCTION STAGE			
1 Selection of Consultant for Engineering Services			10.5
(1) Preparation of Short List, TOR and Letter of Invitation			2.0
(2) Concurrence with Documents by JICA			1.0
(3) Requesting and Proposal Submission			2.0
(4) Evaluation of Technical Proposal and JICA Concurrence			2.0
(5) Evaluation of Financial Proposal and JICA Concurrence			1.0
(6) Contract Negotiation, PLN Approval & Signing			2.0
(7) Concurrence with Contract by JICA			0.5
2 Selection of Well Drilling/Testing Contractor and EPC Contractor (FCRS & Power Plant)	ICB	Lot 1	17.0
(1) Review of Previous Study including FS	with E/S Consultant Assistance		5.0
(2) Design and Engineering - Preparation of Project Design Report (incl. Well Drilling Plan)	with E/S Consultant Assistance		8.0
(3) Preparation of Pre-Qualification Documents	with E/S Consultant Assistance		2.5
(4) Concurrence with P/Q Documents (by JICA)	with E/S Consultant Assistance		0.5
(5) P/Q Announcement and P/Q Application Submission by Prospective Bidders	with E/S Consultant Assistance		1.5
(6) Evaluation of P/Q Application	with E/S Consultant Assistance		1.5
(7) Concurrence with P/Q Evaluation Report (by JICA)	with E/S Consultant Assistance		0.5
(8) Preparation of Tender Documents and PLN Approval	with E/S Consultant Assistance		4.0
(9) Concurrence with Tender Documents (by JICA)	with E/S Consultant Assistance		0.5
(10) Tender Period (Well Drilling/Testing and EPC of FCRS and P/P)	with E/S Consultant Assistance		3.0
(11) Evaluation of Tender (Technical) and PLN Approval	with E/S Consultant Assistance		2.0
(12) Concurrence with Technical Evaluation Results (by JICA)	with E/S Consultant Assistance		1.0
(13) Evaluation of Tender Price and PLN Approval	with E/S Consultant Assistance		1.0
(14) Concurrence with Price Evaluation Results (by JICA)	with E/S Consultant Assistance		0.5
(15) Contract Negotiation, PLN Approval and Signing	with E/S Consultant Assistance		1.5
(16) Concurrence with Well Drilling/Testing Contract and EPC Contract (by JICA)	with E/S Consultant Assistance		0.5
(17) L/C Opening	by PLN		1.0
CONSTRUCTION STAGE			
1 Engineering Services by Consultant (Construction Stage and Warranty Period)		Lot 1	60.0
(1) Engineering Services for EPC (FCRS and P/P) Contract Work (for **Construction Stage**)			26.0
(2) Engineering Services for EPC (FCRS and P/P) Contract Work (for **Warranty Period**)			15.0
(3) Engineering Services for Well Drilling/Testing Contract Work of Lot 2 & Lot 4			50.0
(4) Engineering Services for Well Drilling/Testing Contract Work of Lot 5			*29.5*
2 Well Drilling and Testing (JICA E/S loan, Contracted by PLN, with Assistance of E/S Consultant)	LCB	Lot 2	18.0
(1) Selection of Drilling Contractor	by PLN		4.0
(2) Rig Mobilization	by PLN		3.0
(3) Exploratory (Production) Well Drilling (3 Wells)	by PLN with Advisory Services of E/S Consultant		4.5
(4) Reinjection Well Drilling (1 Well)	by PLN with Advisory Services of E/S Consultant		1.5
(5) Well Production Test (Vertical)	by PLN with Advisory Services of E/S Consultant		1.0
(6) Analysis of Geothermal Field Potential	by PLN with Assistance of E/S Consultant		1.5
(7) Construction of Testing Facilities (Silencer, Separator, Pipeline, etc.)	by PLN with Advisory Services of E/S Consultant		3.0
(8) Well Production Test (Horizontal)	by PLN with Advisory Services of E/S Consultant		3.0
(9) Resource Evaluation	by PLN with Assistance of E/S Consultant		3.0
3 Well Drilling and Testing (JICA Construction loan, with Assistant of E/S Consultant)	*ICB*	Lot 5	*29.5*
(1) Selection of Drilling Contractor through ICB (P/Q, Bidding, Contracting)	*by PLN with E/S Consultant Assistance*		*14.0*
(2) Rig Mobilization	*by PLN with E/S Consultant Assistance*		*3.0*
(3) Production Well Drilling (0 Well)	*by PLN with E/S Consultant Assistance*		*0.0*
(4) Reinjection Well Drilling (3 Wells)	*by PLN with E/S Consultant Assistance*		*4.5*
(5) Well Production Tests	*by PLN with E/S Consultant Assistance*		*4.0*
(6) Resource Evaluation	*by PLN with E/S Consultant Assistance*		*4.0*
4-1 FCRS Construction		Lot 6	23.0
(1) Design, Fabrication, Shop Inspection and Delivery of Equipment and Materials			8.0
(2) Civil Work			8.0
(3) Erection, Installation of Equipment and Materials			10.0
(4) Commissioning			1.0
4-2 Geothermal Power Plant Construction		Lot 6	26.0
(1) Site Preparation (Topographical Survey, Soil Investigation, Slope Protection, etc.)			8.0
(2) Foundation, Concrete Structure, Buildings, and Roads			14.0
(3) Design, Manufacturing, Shop Inspection and Delivery of Equipment and Materials			17.0
(4) Erection, Installation of Equipment and Materials			10.0
(5) Commissioning			3.0
POST CONSTRUCTION STAGE			
Warranty Period			15.0
(1) FCRS			12.0
(2) Power Plant			12.0
EXPLORATORY WELL DRILLING FOR ANOTHER DEVELOPMENT FIELD (Contracted by PLN)	LCB	Lot 4	
Exploratory Well Drilling and Testing in the Future Development Site (with Assistance of E/S Consultant)			17.0
(1) Selection of Drilling Contractor	by PLN		4.0
(2) Rig Mobilization	by PLN		3.0
(3) Exploratory Well Drilling (2 Wells) - (by PLN with Drilling Advisory Service of E/S Consultant)			3.0
(4) Reinjection Well Drilling (1 Well) - (by PLN with Drilling Advisory Service of E/S Consultant)			1.5
(5) Well Production Test (Vertical) - (by PLN with Testing Advisory Service of E/S Consultant)			1.5
(6) Analysis of Geothermal Field Potential - (by PLN with Assistance of E/S Consultant)			1.5
(7) Construction of Testing facilities (Silencer, Separator, Pipeline, etc.) - (by PLN with Testing Advisory Service of E/S Consultant)			2.0
(8) Well Production Test (Horizontal) - (by PLN with Testing Advisory Service of E/S Consultant)			3.0
(9) Resource Evaluation - (by PLN with Assistance of E/S Consultant)			3.0

2.5 months: PQ Docs
0.5 months: PQ Docs JICA Concurrence
1.5 months: PQ Application
1.5 months: PQ Application Evaluation
0.5 months: PQ Evaluation JICA Concurrence
==
6.5 months: PQ Total Period
****
***2.5 months: Bid Documents Preparation**
2.0 months: Bidding Period (ICB)
2.0 months: Bid Evaluation
0.5 month: Bid Evaluation JICA Concurrence
1.5 month: Contract Negotiation
0.5 month: Contract JICA Concurrence
1.0 month: L/C Opening
==
10 months: Biding/Contracting Total Period
****
14.0 months: Total Period (* parallel progress)

Fig. IV-7-4 Tentative Project Implementation Schedule (1 x 20MW Double Flash System) – Standard Schedule



OVERALL PROJECT SCHEDULE - TULEHU GEOTHERMAL POWER PLANT PROJECT **(2 x 10 MW Double Flash)**

(ACCELERATED TARGET SCHEDULE)

Activities			months
Pledge of JICA E/S Loan			
Exchange of Notes (E/N) for Geothermal Development Promotion Loan comprising Tulehu Geothermal PP Project			
Signing of JICA Loan Agreement (L/A)			
Subsidiary Loan Agreement (SLA)			
ADVANCE WORK BY PLN	(PLN FINANCE)	Lot 3	
1 Production Well Pad No. TLU-0	2010/09-2012/03		18.0
(1) Land Acquisition	2010/09-2011/03		1.0
(2) Selection of Drilling Contractor	2010/09-2010/10		1.5
(3) Access Road Construction	2010/09-2010/11		2.5
(4) Site Preparation	2010/09-2010/12		3.0
(5) Drilling Rig Installation	2010/10-2010/11		1.5
(6) Exploratory Well Drilling (Well No. TLU-01)	2010/12-2011/07		8.0
(7) Well Production Test (Vertical)			1.5
(8) Analysis of Geothermal Field Properties			1.0
(9) Resource Evaluation			2.0
2 Production Well Pad No. TLU-1			
(1) Land Acquisition, Access Road Construction and Site Preparation			6.0
3 Production Well Pad No. TLU-2			
(1) Land Acquisition, Access Road Construction and Site Preparation			6.0
4 Reinjection Well Pad No. TLU-3			
(1) Land Acquisition, Access Road Construction and Site Preparation			6.0
5 Power Plant			
(1) Land Acquisition, Access Road Construction			
(2) Site Preparation			
(3) Water Supply and Electrical Supply Work			
6 Sirimau Ambon Substation Construction	***(Out of Tulehu GPP Scope)***		
7 Passo Substation Construction	***(Out of Tulehu GPP Scope)***		
8 Waai Coal Fired Power Plant Construction	***(Out of Tulehu GPP Scope)***		26.0
9 70 kV Transmission Line Construction	***(Out of Tulehu GPP Scope)***		
(1) Sirimau Ambon S/S - Passo S/S	*(Out of Tulehu GPP Scope)*		
(2) Passo S/S - (Tulehu GPP) - Waai CTPP	*(Out of Tulehu GPP Scope)*		
10 **Meteorological Observation at Tulehu GPP Project Site**			24.0
PRE-CONSTRUCTION STAGE			
1 Selection of Consultant for Engineering Services			10.5
(1) Preparation of Short List, TOR and Letter of Invitation	by PLN		2.0
(2) Concurrence with Documents by JICA	by PLN		1.0
(3) Requesting and Proposal Submission	by PLN		2.0
(4) Evaluation of Technical Proposal and JICA Concurrence	by PLN		2.0
(5) Evaluation of Financial Proposal and JICA Concurrence	by PLN		1.0
(6) Contract Negotiation, PLN Approval & Signing	by PLN		2.0
(7) Concurrence with Contract by JICA	by PLN		0.5
2 Selection of Well Drilling/Testing Contractor and EPC Contractor (FCRS & Power Plant)	ICB	Lot 1	17.0
(1) Review of Previous Study including FS	with E/S Consultant Assistance		5.0
(2) Design and Engineering - Preparation of Project Design Report (incl. Well Drilling Plan)	with E/S Consultant Assistance		8.0
(3) Preparation of Pre-Qualification Documents	with E/S Consultant Assistance		1.5
(4) Concurrence with P/Q Documents (by JICA)	with E/S Consultant Assistance		0.5
(5) P/Q Announcement and P/Q Application Submission by Prospective Bidders	with E/S Consultant Assistance		1.5
(6) Evaluation of P/Q Application	with E/S Consultant Assistance		1.5
(7) Concurrence with P/Q Evaluation Report (by JICA)	with E/S Consultant Assistance		0.5
(8) Preparation of Tender Documents and PLN Approval	with E/S Consultant Assistance		4.0
(9) Concurrence with Tender Documents (by JICA)	with E/S Consultant Assistance		0.5
(10) Tender Period (Well Drilling/Testing and EPC of FCRS and P/P)	with E/S Consultant Assistance		3.0
(11) Evaluation of Tender (Technical) and PLN Approval	with E/S Consultant Assistance		1.5
(12) Concurrence with Technical Evaluation Results (by JICA)	with E/S Consultant Assistance		0.5
(13) Evaluation of Tender Price and PLN Approval	with E/S Consultant Assistance		1.0
(14) Concurrence with Price Evaluation Results (by JICA)	with E/S Consultant Assistance		0.5
(15) Contract Negotiation, PLN Approval and Signing	with E/S Consultant Assistance		1.5
(16) Concurrence with Well Drilling/Testing Contract and EPC Contract (by JICA)	with E/S Consultant Assistance		0.5
(17) L/C Opening	by PLN		1.0
CONSTRUCTION STAGE			
1 Engineering Services by Consultant (Construction Stage and Warranty Period)		Lot 1	55.0
(1) Engineering Services for EPC (FCRS and P/P) Contract Work (for **Construction Stage**)			25.0
(2) Engineering Services for EPC (FCRS and P/P) Contract Work (for **Warranty Period**)			18.0
(3) Engineering Services for Well Drilling/Testing Contract Work of Lot 2 & Lot 4 (for **Construction Stage**)			45.0
(4) Engineering Services for Well Drilling/Testing Contract Work of Lot 5			*29.5*
2 Well Drilling and Testing (JICA E/S loan, Contracted by PLN, with Assistance of E/S Consultant)	LCB	Lot 2	18.0
(1) Selection of Drilling Contractor	by PLN		4.0
(2) Rig Mobilization	by PLN		3.0
(3) Exploratory (Production) Well Drilling (3 Wells)	by PLN with Advisory Services of E/S Consultant		4.5
(4) Reinjection Well Drilling (1 Well)	by PLN with Advisory Services of E/S Consultant		1.5
(5) Well Production Test (Vertical)	by PLN with Advisory Services of E/S Consultant		1.0
(6) Analysis of Geothermal Field Potential	by PLN with Assistance of E/S Consultant		1.5
(7) Construction of Testing Facilities (Silencer, Separator, Pipeline, etc.)	by PLN with Advisory Services of E/S Consultant		3.0
(8) Well Production Test (Horizontal)	by PLN with Advisory Services of E/S Consultant		3.0
(9) Resource Evaluation	by PLN with Assistance of E/S Consultant		3.0
3 Well Drilling and Testing (JICA Construction loan, with Assistant of E/S Consultant)	*ICB*	*Lot 5*	*29.5*
(1) Selection of Drilling Contractor through ICB (P/Q, Bidding, Contracting)	*by PLN with E/S Consultant Assistance*		*14.0*
(2) Rig Mobilization	*by PLN with E/S Consultant Assistance*		*3.0*
(3) Production Well Drilling (0 Well)	*by PLN with E/S Consultant Assistance*		*0.0*
(4) Reinjection Well Drilling (3 Wells)	*by PLN with E/S Consultant Assistance*		*4.5*
(5) Well Production Tests	*by PLN with E/S Consultant Assistance*		*4.0*
(6) Resource Evaluation	*by PLN with E/S Consultant Assistance*		*4.0*
4-1 FCRS Construction		Lot 6	19.0
(1) Design, Fabrication, Shop Inspection and Delivery of Equipment and Materials			8.0
(2) Civil Work			8.0
(3) Erection, Installation of Equipment and Materials			10.0
(4) Commissioning			1.0
4-2 Geothermal Power Plant Construction		Lot 6	25.0
(1) Site Preparation (Topographical Survey, Soil Investigation, Slope Protection, etc.)			8.0
(2) Foundation, Concrete Structure, Buildings, and Roads			14.0
(3) Design, Manufacturing, Shop Inspection and Delivery of Equipment and Materials			17.5
(4) Erection, Installation of Equipment and Materials (Unit 1)			7.0
(5) Commissioning (Unit 1)			3.0
(6) Erection, Installation of Equipment and Materials (Unit 2)			7.0
(7) Commissioning (Unit 2)			3.0
POST CONSTRUCTION STAGE			
Warranty Period			18.0
(1) FCRS			12.0
(2) Power Plant Unit 1			12.0
(3) Power Plant Unit 2			12.0
EXPLORATORY WELL DRILLING FOR ANOTHER DEVELOPMENT FIELD (Contracted by PLN)	LCB	Lot 4	
Exploratory Well Drilling and Testing in the Future Development Site (with Assistance of E/S Consultant)			17.0
(1) Selection of Drilling Contractor	by PLN		4.0
(2) Rig Mobilization	by PLN		3.0
(3) Exploratory Well Drilling (2 Wells) - (by PLN with Drilling Advisory Service of E/S Consultant)			3.0
(4) Reinjection Well Drilling (1 Well) - (by PLN with Drilling Advisory Service of E/S Consultant)			1.5
(5) Well Production Test (Vertical) - (by PLN with Testing Advisory Service of E/S Consultant)			1.5
(6) Analysis of Geothermal Field Potential - (by PLN with Assistance of E/S Consultant)			1.5
(7) Construction of Testing facilities (Silencer, Separator, Pipeline, etc.) - (by PLN with Testing Advisory Service of E/S Consultant)			2.0
(8) Well Production Test (Horizontal) - (by PLN with Testing Advisory Service of E/S Consultant)			3.0
(9) Resource Evaluation - (by PLN with Assistance of E/S Consultant)			3.0

2.5 months: PQ Docs
0.5 months: PQ Docs JICA Concurrence
1.5 months: PQ Application
1.5 months: PQ Application Evaluation
0.5 months: PQ Evaluation JICA Concurrence
===
6.5 months: PQ Total Period
****
*2.5 months: Bid Documents Preparation
2.0 months: Bidding Period (ICB)
2.0 months: Bid Evaluation
0.5 month: Bid Evaluation JICA Concurrence
1.5 month: Contract Negotiation
0.5 month: Contract JICA Concurrence
1.0 month: L/C Opening
===
10 months: Biding/Contracting Total Period
****
14.0 months: Total Period (* parallel progress)

Fig. IV-7-5 Tentative Project Implementation Schedule (2 x 10MW Double Flash System) – Accelerated Target Schedule

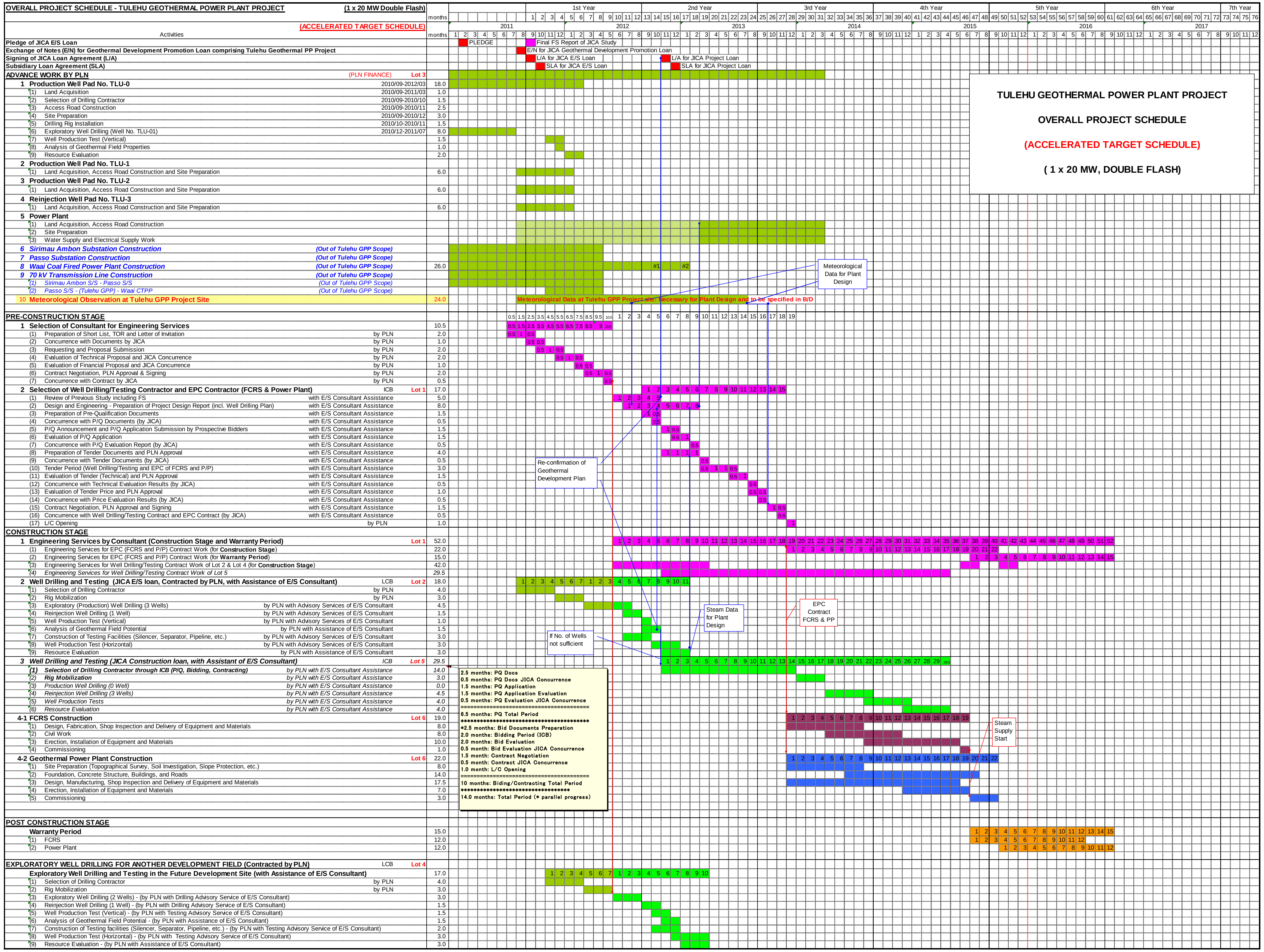


Fig. IV-7-6 Tentative Project Implementation Schedule (1 x 20MW Double Flash System) – Accelerated Target Sched

IV.8 Confirmation of Project Effects

IV.8.1 Finance Procurement

1. Finance

JICA will provide financing to PLN for less than 85% of the project cost aside from the consultant loan, and the remaining 15% or more of the cost will be covered from PLN's own equity. The loan conditions are summarized in the following table.

Table IV-8-1 Finance Conditions

	Project Loan	Consultant Loan	PLN Equity
Interest/ROR	0.3% per annum	0.01% per annum	12.00%
Grace Period	10 years	10 years	NA
Repayment	40 years	40 years	NA
Repayment Method	Principal equal installment	Principal equal installment	NA

(Source: JICA, Study Team)

Other terms and conditions of the Japanese ODA Loan are as follows:

- General untied (LCB for procurement of a drilling contractor)
- The upper limit on JICA finance is 85% of the total project cost, exclusive of land acquisition and the executing agency's administrative costs.
- The interest will be applied after the first disbursement
- A Commitment fee of 0.1% will be levied on the undisbursed amount of the loans 120 days after the signing of the L/A.
- The consultant will be procured according to the Guidelines for Employment of Consultants, and the project will be procured according to the Guidelines for Procurement under Japanese ODA Loans with optimized procurement to accommodate local procurement specified as Indonesian national policy.

2. Conditions for Financial and Economic Evaluations

The base cost will be estimated as of June 2011 with the following exchange rates. Cost estimates and the subsequent economic and financial evaluation are expressed in US$ollars. The final loan amounts for the project and consultant are expressed in Japanese Yen.

Yen/US$	US $ 1 =	79.5Yen
Rp/US$	US $ 1 =	8,558 Rp
Rp/Yen	Yen 1 =	0.00929 Rp

(Source: JICA)

The following escalation rates are used for price contingency:

Foreign portion	1.6% annually
Local portion	7.9% annually

(Source: JICA)

The physical contingency rate is 5% for all the services, construction and equipment.

3. Administration Cost

The project administration costs, 4% of the tangible cost, are appropriated in the project cost in consideration that this is the first geothermal power project involving resource development. The items and matters to be covered by this administration cost are not limited to but include the following:

Table IV-8-2 Administrative Work Items

1.Administrative matters	a. Administration of consultant and EPC contracting b. Insurance c. Regional and industrial relations d. Contract documentation e. Security
2.Construction management	g. Coordination between the government, consultant and EPC contractors h. Overall construction site management i. Construction-related documentation/applications to the government and financiers j. Construction safety and health program k. Construction site office/camp & utilities
3. Permits, rights-of-way and environmental management	l. Acquisition of permits and rights-of-way related to preparation, and construction of project-related facilities, and transportation of equipment to the site. m. Topographic or geological survey related the above n. Environmental assessment, impact and compliance certificate o. Environmental monitoring (some may be included in the project cost) p. Reporting to the authorities
4. Others	

IV.8.2 Project Operation Conditions

Under the Project, four (4) different geothermal units and configuration types are studied from the point of view of power demand conditions and assumed geothermal reservoir conditions: 1) 10 MW x 2 single flash, 2) 20 MW x 1 single flash, 3) 10 MW x 2 double flash and 4) 20 x1 double flash. The operating conditions for these units in addition to the Waai 15 MW x 2 coal-fired thermal power are assumed as follows.

Table IV-8-3 Project and Alternative Operating Conditions

Project

Unit Type		Unit	SF	SF	DS	DS
OPERATING CONDITIONS						
	Unit Capacity	MW	10	20	10	20
	No. of Unit	No.	2	1	2	1
	Total Capacity	MW	20	20	20	20
	Economic Life/Dep	Year	30	30	30	30
	Fuel Type		Geo	Geo	Geo	Geo
	Station Use	%	5.00%	5.00%	5.00%	5.00%
	System Losses	%	10.00%	10.00%	10.00%	10.00%
	Capacity Factor	%	85.00%	85.00%	85.00%	85%
	Annual Generation	GWh	148.9	148.9	148.9	148.9
	Salable energy at PP	GWh	141.5	141.5	141.5	141.5
	Fuel Consumption	Mil. lit./kg	0	0	0	0
	Salable Energy at SS	GWh	127.4	127.4	127.4	127.4
	Initial Production Well	No.	5		4	
	Initial Reinjection Well	No.	6		4	
	Make up Production Well	No.	3		3	
	Make up Reinj, Well	No.	4		3	

(Source: PLN and Study Team)

Alternative

Unit Type	Unit	Alt Coal	Diesel F Save	
OPERATING CONDITIONS				
Unit Capacity	MW	15	5	
No. of Unit	No.	2	5	
Total Capacity	MW	30	25	
Economic Life/Depreciation	Year	30	30	
Fuel Type		Coal	Diesel	
Plant efficiency	%	30.00%	35.00%	
Station Use	%	8.0%	7.0%	
System Losses	%	10.0%	10.0%	
Capacity Factor	%	58.53%	69.48%	
Annual Generation	GWh	153.0	151.0	
Salable energy at PP	GWh	**141.5**	**141.5**	
Salable Energy at SS	GWh	127.4	127.4	
Fule Cost		80 $/Ton	6122.6	Rp/Lit
Fuel Consumption	Mil. kg	104.43	41.31	Mil lit.
Annual Fuel Cost	M$	8.35	29.56	
Const. Cost	$/kW	1500.00	700.00	
Generating Cost at PP	USC/kWh	11.39	22.33	

(Source: PLN and Study Team)

Note: The table above shows that the generating cost at the power plant outlet will be 11.39 cent/kWh for coal-fired and 22.33 cent/kWh for diesel at the maximum continuous rating. These generating costs will be higher in actual operating modes due to load variations.

At present, power in the Ambon power system is totally supplied by its limited capacity of aging diesel generators. Though the power demand has been steadily increasing at 10% over the past three years, PLN cannot offer new electricity connections. As power demand increases and PLN fails to cope with this growing demand due to the limited nature of its installed capacity, the use of captive power generated by small-capacity diesel generators is increasing.

IV.8.3 Economic and Financial Evaluation

1. Project Cost Summary

With respect to the 4 types of power plant configuration, the respective project cost estimate is made on condition that financing will be available in the form of a JICA Yen Loan, and these estimates are summarized in Table IV-8-4, 5, 6 and 7 as follows.

Table IV-8-4 Cost Summary for 10 MW x 2 Single Flash

Project: Geothermal Power Plant 10 MW x 2, Single Flash

Unit: Million US$

	FC Ratio	LC Ratio	FC	LC	Total	Ratio
1 Project Up Stream Works						
1.1 Access Road/Civil Works (PLN portion)	0%	100%	0.00	2.53	2.53	
1.2 Well drilling (4 pro & 6 Reinj)	70%	30%	32.66	14.00	46.66	
Subtotal	0%	0%	32.66	16.53	49.19	36%
(Makeup well: 3 pro & 4 reinj)						
2 Project Down Stream Works						
2.1 Power Plant	70%	30%	30.80	13.20	44.00	
2.2 FCRS	56%	44%	4.69	3.69	8.38	
2.3 Connecting T/L (PLN Portion)	0%	100%	0.00	0.30	0.30	
Subtotal	0%	0%	35.49	17.19	52.68	38%
3 Total Project Cost			68.15	33.72	101.87	74%
4 Administration Cost	0%	100%	0.00	4.07	4.07	3%
5 Consulting Fee	75%	25%	7.88	2.63	10.51	8%
6 Contingencies						
6.1 Price Contingency (FC:1.6%, LC:7.9%)	27%	73%	3.99	10.72	14.71	
6.2 Physical Contingency	62%	38%	3.76	2.28	6.04	
Subtotal			7.75	13.00	20.75	15%
7 Grand Total			**83.78**	**53.42**	**137.20**	**100%**
8 Implementation						
9.1 PLN Equity	44%	56%	11.26	14.56	25.82	19%
9.2 JICA Project Loan, (less than 85%)	64%	36%	63.81	35.40	99.21	72%
9.3 JICA Consultant Loan, 100%	72%	28%	8.71	3.46	12.17	9%
Total	61%	39%	**83.78**	**53.42**	**137.20**	**100%**
Yen equivalent (Million Yen)						
9.1 PLN Equity			895	1,158	2,053	
9.2 JICA Project Loan, (less than 85%)			5,073	2,814	7,887	
9.3 JICA Consultant Loan, 100%			692	275	968	
Total			6,661	4,247	10,907	
9 IDC+Commitment Charge			1.19			

Table IV-8-5 Cost Summary for 20 MW x 1 Single Flash

Project: Geothermal Power Plant 20 MW x 1, Single Flash Unit: Million US$

	FC Ratio	**LC Ratio**	**FC**	**LC**	**Total**	**Ratio**
1 Project Up Stream Works						
1.1 Access Road/Civil Works (PLN portion)	0%	100%	0.00	2.53	2.53	
1.2 Well drilling (4 pro & 6 Reinj)	70%	30%	32.66	14.00	46.66	
Subtotal	0%	0%	32.66	16.53	49.19	37%
(Makeup well: 3 pro & 4 reinj)						
2 Project Down Stream Works						
2.1 Power Plant	70%	30%	29.40	12.60	42.00	
2.2 FCRS	56%	44%	4.45	3.49	7.94	
2.3 Connecting T/L (PLN Portion)	0%	100%	0.00	0.30	0.30	
Subtotal	0%	0%	33.85	16.39	50.24	37%
3 Total Project Cost			66.51	32.93	99.43	74%
4 Administration Cost	0%	100%	0.00	3.98	3.98	3%
5 Consulting Fee	75%	25%	7.88	2.63	10.51	8%
6 Contingencies						
6.1 Price Contingency (FC:1.6%, LC:7.9%)	27%	73%	3.89	10.48	14.37	
6.2 Physical Contingency	62%	38%	3.69	2.24	5.93	
Subtotal			7.58	12.72	20.30	15%
7 Grand Total			**81.97**	**52.25**	**134.22**	**100%**
8 Implementation						
9.1 PLN Equity	43%	57%	10.99	14.29	25.28	19%
9.2 JICA Project Loan, (less than 85%)	64%	36%	62.27	34.50	96.77	72%
9.3 JICA Consultant Loan, 100%	72%	28%	8.71	3.46	12.17	9%
Total	61%	39%	**81.97**	**52.25**	**134.22**	**100%**
Yen equivalent (Million Yen)						
9.1 PLN Equity			874	1,136	2,010	
9.2 JICA Project Loan, (less than 85%)			4,950	2,743	7,693	
9.3 JICA Consultant Loan, 100%			692	275	968	
Total			6,516	4,154	10,670	
9 IDC+Commitment Charge			1.16			

Table IV-8-6 Cost Summary for 10 MW x 2 Double Flash

Project: Geothermal Power Plant 10 MW x 2, Double Flash

Unit: Million US$

	FC Ratio	LC Ratio	FC	LC	Total	Ratio
1 Project Up Stream Works						
1.1 Access Road/Civil Works (PLN portion)	0%	100%	0.00	2.53	2.53	
1.2 Well drilling (3 pro & 4 Reinj)	70%	30%	23.50	10.07	33.57	
Subtotal	0%	0%	23.50	12.60	36.10	30%
(Makeup well: 3 pro & 3 reinj)						
2 Project Down Stream Works						
2.1 Power Plant	70%	30%	32.20	13.80	46.00	
2.2 FCRS	56%	44%	3.71	2.91	6.62	
2.3 Connecting T/L (PLN Portion)	0%	100%	0.00	0.30	0.30	
Subtotal	0%	0%	35.91	17.01	52.92	43%
3 Total Project Cost			59.41	29.62	89.02	73%
4 Administration Cost	0%	100%	0.00	3.56	3.56	3%
5 Consulting Fee	75%	25%	7.88	2.63	10.51	9%
6 Contingencies						
6.1 Price Contingency (FC:1.6%, LC:7.9%)	27%	73%	3.65	9.86	13.51	
6.2 Physical Contingency	62%	38%	3.36	2.03	5.39	
Subtotal			7.01	11.89	18.90	15%
7 Grand Total			**74.30**	**47.69**	**121.99**	**100%**
8 Implementation						
9.1 PLN Equity	43%	57%	9.84	13.12	22.96	19%
9.2 JICA Project Loan, (less than 85%)	64%	36%	55.75	31.11	86.86	71%
9.3 JICA Consultant Loan, 100%	72%	28%	8.71	3.46	12.17	10%
Total	61%	39%	**74.30**	**47.69**	**121.99**	**100%**
Yen equivalent (Million Yen)						
9.1 PLN Equity			782	1,043	1,825	
9.2 JICA Project Loan, (less than 85%)			4,432	2,473	6,905	
9.3 JICA Consultant Loan, 100%			692	275	968	
Total			5,907	3,792	9,698	
9 IDC+Commitment Charge			1.13			

Table IV-8-7 Cost Summary for 20 MW x 1 Double Flash

Project: Geothermal Power Plant 20 MW x 1, Double Flash Unit: Million US$

	FC Ratio	**LC Ratio**	**FC**	**LC**	**Total**	**Ratio**
1 Project Up Stream Works						
1.1 Access Road/Civil Works (PLN portion)	0%	100%	0.00	2.53	2.53	
1.2 Well drilling (3 pro & 4 Reinj)	70%	30%	23.50	10.07	33.57	
Subtotal	0%	0%	23.50	12.60	36.10	30%
(Makeup well: 3 pro & 3 reinj)						
2 Project Down Stream Works						
2.1 Power Plant	70%	30%	30.66	13.14	43.80	
2.2 FCRS	56%	44%	3.71	2.91	6.62	
2.3 Connecting T/L (PLN Portion)	0%	100%	0.00	0.30	0.30	
Subtotal	0%	0%	34.37	16.35	50.72	43%
3 Total Project Cost			57.87	28.96	86.82	73%
4 Administration Cost	0%	100%	0.00	3.47	3.47	3%
5 Consulting Fee	75%	25%	7.88	2.63	10.51	9%
6 Contingencies						
6.1 Price Contingency (FC:1.6%, LC:7.9%)	27%	73%	3.56	9.60	13.16	
6.2 Physical Contingency	62%	38%	3.27	1.99	5.26	
Subtotal			6.83	11.59	18.42	15%
7 Grand Total			**72.58**	**46.64**	**119.22**	**100%**
8 Implementation						
9.1 PLN Equity	43%	57%	9.58	12.87	22.45	19%
9.2 JICA Project Loan, (less than 85%)	64%	36%	54.29	30.31	84.60	71%
9.3 JICA Consultant Loan, 100%	72%	28%	8.71	3.46	12.17	10%
Total	61%	39%	**72.58**	**46.64**	**119.22**	**100%**
Yen equivalent (Million Yen)						
9.1 PLN Equity			762	1,023	1,785	
9.2 JICA Project Loan, (less than 85%)			4,316	2,410	6,725	
9.3 JICA Consultant Loan, 100%			692	275	968	
Total			5,770	3,708	9,478	
9 IDC+Commitment Charge			1.10			

<Reference> Lahendong No. 3 Unit, a 20 MW x 1 Single Flash unit identical in configuration to one of the considered in this report, was constructed with the financial assistance of JBIC, now JICA, with the L/A concluded in March 2004 (L/A amount: 5,866 Million Yen, STEP). The power plant cost estimated in the L/A was 4,160 Million Yen and the actual EPC contract cost in March 2007 for the power plant (excluding FCRS and resource development cost) was 38.15 Million US$ (or 3,815 Million Yen at the then-exchange rate of 100 yen/US$). This price is about 90% of the estimated PP cost this time, and so the estimated PP cost this time will be appropriate, considering that international competitive bidding was held for Lahendong No. 3 and the escalation of costs in the five intervening

years. The L/A estimated the consulting fee for Lahendong Project at 480 Million Yen. The consulting contract was concluded in May 2005, but the services are still continuing, and the final contract cost approximates to 480 Million Yen. This also indicates that the cost estimated in the L/A was right. (The consultant fee for the project this time includes services for resource development and FCRS design and supervision, so the estimated cost is about two (2) times that estimated for Lahendong.)

2. Economic Evaluation

a. Methodology

Diesel Fuel Oil Saving: Once the project is realized, the expensive use of diesel power may be avoided. Currently, diesel power is being generated at a net generating cost that is greater than the actual selling price, and the huge deficit has been covered by a government subsidy. So, first, the cost of fuel oil for power generation equal to that anticipated from the project will be compared with the cost of the Project, in order to calculate the Economic Internal Rate of Return (EIRR). Then, the obtained EIRR will be compared with the discount rate of 12%, which is generally used for power projects in Indonesia.

Government Power Tariff Subsidy Reduction: As shown in the table below, the high subsidy cost has become a serious issue for the government because the current generation cost in the Ambon System is much higher than the actual selling price. So, the cost of the Project (4 cases) will be compared with the anticipated reduction in the government subsidy. The obtained EIRR will be compared with the 12% hurdle rate.

Table IV-8-8 Subsidy Reduction (10 MW x 2 Double Flash Case)

a. Average actual generating cost in Ambon system*	2,758	Rp/kWh	0.3223	US$/kWh
b. Actual selling price at 678.58 Rp/kWh*			0.0793	US$/kWh
c. Current Subsidy c = a – b			0.2430	US$/kWh
d. LEC at sending end			0.1470	US$/kWh
e. Future subsidy e = d –b			0.0677	US$/kWh
f. Subsidy reduction f = c – e			0.1753	US$/kWh

Note: Statistik 2009, Ambon PLN

Least Cost Evaluation (Comparison with Coal-fired Power): At present, Waai IPP coal-fired thermal power plant with a 2 x 15 MW capacity is under construction. Coal-fired power as an alternative to the Project is compared with the Project.

Willingness-to-pay Evaluation: Because PLN cannot supply all power needed by the demanders due to its limited and aging installed capacity, the demanders, commercial and industrial users in particular, have installed their own diesel power. The study team surveyed the diesel power installation that some hotel owners have installed

(cf. photograph above) and found that its generation costs were about 2,500 Rp/kWh and that the generator is being operated every day for a limited time. This indicates that demanders in Ambon are prepared to buy power even at a cost of 2,500 Rp/kWh. Thus, the EIRR of the project is evaluated on the basis of a willingness to pay 2,500 Rp/kWh for the electricity. The sensitivity of the EIRR to the willingness-to-pay will be tested.

b. Results of Economic Evaluation

As compared with the cost of the Project, namely initial investment plus O&M costs including make-up wells for 30 years of operating life, the economic internal rates of return (EIRR) on the basis of diesel fuel saving, subsidy reduction and willingness-to-pay 2,500 Rp/kWh are calculated with the results summarized below.

Fuel Saving

Project	10 MW x 2 SF	20 MW x 1 SF	10 MW x 2 DF	20 MW x 1 DF
Fuel Saving	41.31 Million Liter/year			
Amount saved	29.56 Million US$/year			
EIRR	19.64%	19.98%	21.18%	22.57%

In each case, if the project avoids operation of an equivalent diesel plant, it results in the saving of the 41.31 Million liters of fuel consumed annually and worth about 30 Million US$. With this benefit, the project EIRRs well exceed the 12% economic hurdle rate. On the basis of the fuel cost saving, all cases of the project are judged to be economically feasible.

Subsidy Reduction

Project	10 MW x 2 SF	20 MW x 1 SF	10 MW x 2 DF	20 MW x 1 DF
Annual Reduction	19.97 Mill US$	20.34 Mill US$	22.33 Mill US$	22.66 Mill US$

EIRR	13.42%	13.96%	17.17%	17.76%

Similarly, the government subsidy reduction amounts to 20 to 22 million US$ annually in all cases. All the cases could exceed the 12% hurdle rate. In addition, the subsidy reduction can be evaluated together with the fuel cost reduction resulting from the avoidance of diesel power generation. The case of 20 MW x 1 Double Flash results in the maximum economic effect. The sum of annual savings from fuel and subsidy reductions amounts to about 50 million US$, which would recover the project investment costs in 3 years. From this point of view, the project is highly worth pursuing as a national project.

EIRR against 15 MW x 2 coal-fired power plant:

Project	10 MW x 2 SF	20 MW x 1 SF	10 MW x 2 DF	20 MW x 1 DF
EIRR	10.52%	10.94%	13.51%	14.06%

In the economic comparison with the 15 MW x 2 coal-fired thermal power plant, the coal-fired plant is superior economically to the single flash cases, as the investment costs for them are larger than those for the double flash systems. Thus, the economic viability of geothermal in the remote island when compared with small-scale, coal-fired thermal power will vary depending on the precise geothermal characteristics of the resource.

Willingness-to-pay at 2,500 Rp/kWh

Project	10 MW x 2 SF	20 MW x 1 SF	10 MW x 2 DF	20 MW x 1 DF
EIRR	17.47%	17.78%	19.61%	19.97%

In all cases, the project can exceed the 12% hurdle rate, and so the economic viability indicated by the evaluation of the willingness-to-pay in the Ambon power system is very high.

Sensitivity of Willingness-to-pay EIRR

The sensitivity of the EIRR to Willingness-to-pay was tested as shown below. If the willingness-to-pay is 2500 Rp/kWh, the EIRR can widely exceed the hurdle rate. The willingness-to-pay level at which the EIRR reaches 12% is 18.4 cent/kWh (or 1,570 Rp/kWh). So, if a majority of demanders in the Ambon power system should express their willingness to subscribe to electric service at 1,570 Rp/kWh, the project EIRR calculated by this method would be verified.

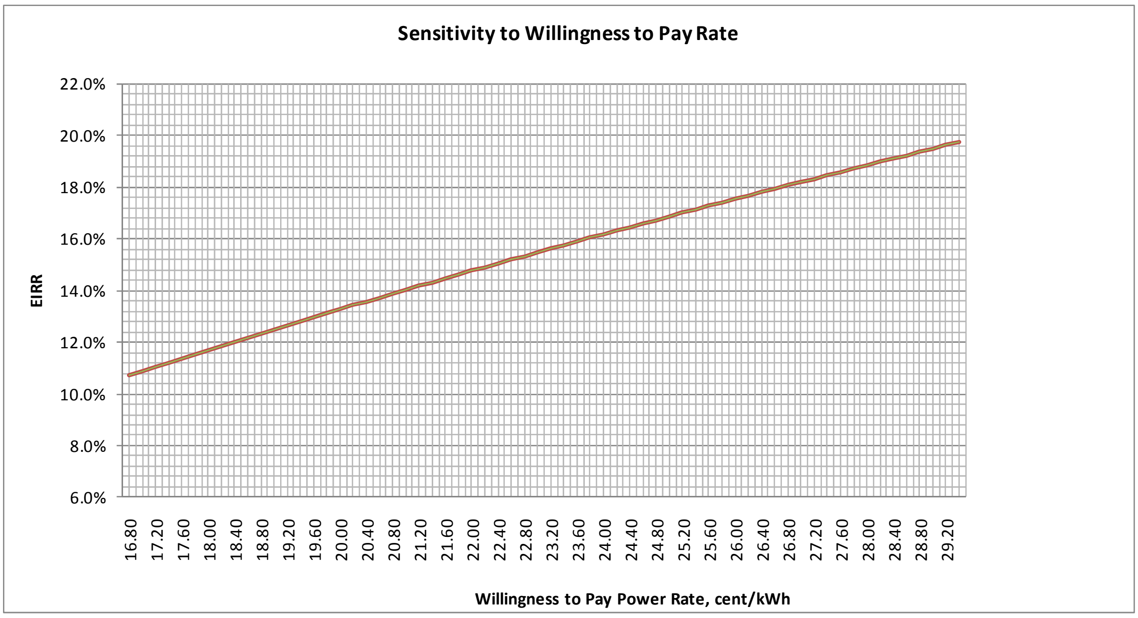


Fig. IV-8-1 Sensitivity of EIRR to Willingness-to-pay (10 MW x 2 DF)

Conclusion

Though the least-cost geothermal solution for the project could not compete with the coal-fired solution, the EIRR analysis revealed that the selection of geothermal will contribute greatly to the national economy, with fuel savings of 29.5 Million US$ and a subsidy reduction of 20 to 23 Million US$ annually. In terms of the national economy, this geothermal power project is worth pursuing. Among the four cases, the double flash system is most desirable for this geothermal field, as its selection is recommended from both the technical and economic viewpoint.

The EIRR calculation process for the Double Flash 10 MW x 2 case is presented in Table IV-8-9 for Fuel Saving and Subsidy, and in Table IV-8-10 for Willingness-to-pay.

Table IV-8-9 EIRR in terms of Fuel Saving and Subsidy Reduction

												Model: [Geo without LL & SS]					EIRR =	22.18%
		PROJECT							ALTERNATIVE :	[Fuel Save]								
Year	Year	Project Cost	Capacity	Capacity Factor	Annual Salable Energy	O&M Cost	Supple. Drilling Cost	Total Cost	Alt. Project Cost	Capacity	Capacity Factor	Annual Salable Energy	Effici–ency	Fuel Consump.	Fuel Cost (Fuel Save)	O&M Cost	Total Cost	Cost Balance
		MM$	MW	%	GWh	MM$	MM$	MM$	MM$	MW	%	GWh	%	Mil. Lit	MM$	MM$	MM$	MM$
-6	2010	0.00						-									-	0.00
-5	2011	0.00						-									-	0.00
-4	2012	14.52						14.52									-	-14.52
-3	2013	30.30						30.30									-	-30.30
-2	2014	23.16						23.16									-	-23.16
-1	2015	21.05						21.05									-	-21.05
1	2016	0.00	20	85.0%	127.40	1.93	-	1.93		25	69.85%	127.40	40.0%	41.31	29.56	-	29.56	27.63
2	2017		20	85.0%	127.40	1.93	-	1.93		25	69.85%	127.40	40.0%	41.31	29.56	-	29.56	27.63
3	2018		20	85.0%	127.40	1.93	-	1.93		25	69.85%	127.40	40.0%	41.31	29.56	-	29.56	27.63
4	2019		20	85.0%	127.40	1.93	-	1.93		25	69.85%	127.40	40.0%	41.31	29.56	-	29.56	27.63
5	2020		20	85.0%	127.40	1.93	-	1.93		25	69.85%	127.40	40.0%	41.31	29.56	-	29.56	27.63
6	2021		20	85.0%	127.40	1.93	-	1.93		25	69.85%	127.40	40.0%	41.31	29.56	-	29.56	27.63
7	2022		20	85.0%	127.40	1.93	11.24	13.17		25	69.85%	127.40	40.0%	41.31	29.56	-	29.56	16.39
8	2023		20	85.0%	127.40	1.93	-	1.93		25	69.85%	127.40	40.0%	41.31	29.56	-	29.56	27.63
9	2024		20	85.0%	127.40	1.93	-	1.93		25	69.85%	127.40	40.0%	41.31	29.56	-	29.56	27.63
10	2025		20	85.0%	127.40	1.93	-	1.93		25	69.85%	127.40	40.0%	41.31	29.56	-	29.56	27.63
11	2026		20	85.0%	127.40	1.93	-	1.93		25	69.85%	127.40	40.0%	41.31	29.56	-	29.56	27.63
12	2027		20	85.0%	127.40	1.93	-	1.93		25	69.85%	127.40	40.0%	41.31	29.56	-	29.56	27.63
13	2028		20	85.0%	127.40	1.93	-	1.93		25	69.85%	127.40	40.0%	41.31	29.56	-	29.56	27.63
14	2029		20	85.0%	127.40	1.93	-	1.93		25	69.85%	127.40	40.0%	41.31	29.56	-	29.56	27.63
15	2030		20	85.0%	127.40	1.93	-	1.93		25	69.85%	127.40	40.0%	41.31	29.56	-	29.56	27.63
16	2031		20	85.0%	127.40	1.93	-	1.93		25	69.85%	127.40	40.0%	41.31	29.56	-	29.56	27.63
17	2032		20	85.0%	127.40	1.93	11.24	13.17		25	69.85%	127.40	40.0%	41.31	29.56	-	29.56	16.39
18	2033		20	85.0%	127.40	1.93	-	1.93		25	69.85%	127.40	40.0%	41.31	29.56	-	29.56	27.63
19	2034		20	85.0%	127.40	1.93	-	1.93		25	69.85%	127.40	40.0%	41.31	29.56	-	29.56	27.63
20	2035		20	85.0%	127.40	1.93	-	1.93		25	69.85%	127.40	40.0%	41.31	29.56	-	29.56	27.63
21	2036		20	85.0%	127.40	1.93	-	1.93		25	69.85%	127.40	40.0%	41.31	29.56	-	29.56	27.63
22	2037		20	85.0%	127.40	1.93	-	1.93		25	69.85%	127.40	40.0%	41.31	29.56	-	29.56	27.63
23	2038		20	85.0%	127.40	1.93	-	1.93		25	69.85%	127.40	40.0%	41.31	29.56	-	29.56	27.63
24	2039		20	85.0%	127.40	1.93	-	1.93		25	69.85%	127.40	40.0%	41.31	29.56	-	29.56	27.63
25	2040		20	85.0%	127.40	1.93	-	1.93		25	69.85%	127.40	40.0%	41.31	29.56	-	29.56	27.63
26	2041		20	85.0%	127.40	1.93	11.24	13.17		25	69.85%	127.40	40.0%	41.31	29.56	-	29.56	16.39
27	2042		20	85.0%	127.40	1.93	-	1.93		25	69.85%	127.40	40.0%	41.31	29.56	-	29.56	27.63
28	2043		20	85.0%	127.40	1.93	-	1.93		25	69.85%	127.40	40.0%	41.31	29.56	-	29.56	27.63
29	2044		20	85.0%	127.40	1.93	-	1.93		25	69.85%	127.40	40.0%	41.31	29.56	-	29.56	27.63
30	2045		20	85.0%	127.40	1.93	-	1.93		25	69.85%	127.40	40.0%	41.31	29.56	-	29.56	27.63
31	2046																	
		89.02			3,822.00	57.78	33.72	180.52	-			3,822.00		1,239.41	886.70	-	886.70	706.18

		Model: [Geo without LL & SS			EIRR =	17.17%
		[Subsidy]				
Year	Year	Capacity Factor	Annual Salable Energy	Subsidy Reduction	Total Cost	Cost Balance
		%	GWh	MM$	MM$	MM$
-6	2010				-	0.00
-5	2011				-	0.00
-4	2012				-	-14.52
-3	2013				-	-30.30
-2	2014				-	-23.16
-1	2015				-	-21.05
1	2016	69.85%	127.40	22.33	22.33	20.40
2	2017	69.85%	127.40	22.33	22.33	20.40
3	2018	69.85%	127.40	22.33	22.33	20.40
4	2019	69.85%	127.40	22.33	22.33	20.40
5	2020	69.85%	127.40	22.33	22.33	20.40
6	2021	69.85%	127.40	22.33	22.33	20.40
7	2022	69.85%	127.40	22.33	22.33	9.16
8	2023	69.85%	127.40	22.33	22.33	20.40
9	2024	69.85%	127.40	22.33	22.33	20.40
10	2025	69.85%	127.40	22.33	22.33	20.40
11	2026	69.85%	127.40	22.33	22.33	20.40
12	2027	69.85%	127.40	22.33	22.33	20.40
13	2028	69.85%	127.40	22.33	22.33	20.40
14	2029	69.85%	127.40	22.33	22.33	20.40
15	2030	69.85%	127.40	22.33	22.33	20.40
16	2031	69.85%	127.40	22.33	22.33	20.40
17	2032	69.85%	127.40	22.33	22.33	9.16
18	2033	69.85%	127.40	22.33	22.33	20.40
19	2034	69.85%	127.40	22.33	22.33	20.40
20	2035	69.85%	127.40	22.33	22.33	20.40
21	2036	69.85%	127.40	22.33	22.33	20.40
22	2037	69.85%	127.40	22.33	22.33	20.40
23	2038	69.85%	127.40	22.33	22.33	20.40
24	2039	69.85%	127.40	22.33	22.33	20.40
25	2040	69.85%	127.40	22.33	22.33	20.40
26	2041	69.85%	127.40	22.33	22.33	9.16
27	2042	69.85%	127.40	22.33	22.33	20.40
28	2043	69.85%	127.40	22.33	22.33	20.40
29	2044	69.85%	127.40	22.33	22.33	20.40
30	2045	69.85%	127.40	22.33	22.33	20.40
31	2046					
			3,822.00		669.88	489.35

Table IV-8-10 EIRR in comparison with 15 MW x 2 Coal-Fired Power Plant

													Model: [DF20MW x 1]				EIRR =	13.51%
		PROJECT							ALTERNATIVE :	[Coal Fired]								
Year	Year	Project Cost	Capacity	Capacity Factor	Annual Salable Energy	O&M Cost	Supple. Drilling Cost	Total Cost	Alt. Project Cost	Capacity	Capacity Factor	Annual Salable Energy	Effici–ency	Fuel Consump.	Fuel Cost	O&M Cost	Total Cost	Cost Balance
		MM$	MW	%	GWh	MM$	MM$	MM$	MM$	MW	%	GWh	%	Mil. Kg	MM$	MM$	MM$	MM$
-6	2010	0.00						-	0.00								-	0.00
-5	2011	0.00						-	0.00								-	0.00
-4	2012	14.52						14.52	2.25								2.25	-12.27
-3	2013	30.30						30.30	11.25								11.25	-19.05
-2	2014	23.16						23.16	18.00								18.00	-5.16
-1	2015	21.05						21.05	13.50								13.50	-7.55
1	2016	0.00	20	85.0%	127.40	1.93	-	1.93		30	58.53%	127.40	30.0%	104.43	8.35	2.17	10.52	8.60
2	2017		20	85.0%	127.40	1.93	-	1.93		30	58.53%	127.40	30.0%	104.43	8.35	2.17	10.52	8.60
3	2018		20	85.0%	127.40	1.93	-	1.93		30	58.53%	127.40	30.0%	104.43	8.35	2.17	10.52	8.60
4	2019		20	85.0%	127.40	1.93	-	1.93		30	58.53%	127.40	30.0%	104.43	8.35	2.17	10.52	8.60
5	2020		20	85.0%	127.40	1.93	-	1.93		30	58.53%	127.40	30.0%	104.43	8.35	2.17	10.52	8.60
6	2021		20	85.0%	127.40	1.93	-	1.93		30	58.53%	127.40	30.0%	104.43	8.35	2.17	10.52	8.60
7	2022		20	85.0%	127.40	1.93	11.24	13.17		30	58.53%	127.40	30.0%	104.43	8.35	2.17	10.52	-2.64
8	2023		20	85.0%	127.40	1.93	-	1.93		30	58.53%	127.40	30.0%	104.43	8.35	2.17	10.52	8.60
9	2024		20	85.0%	127.40	1.93	-	1.93		30	58.53%	127.40	30.0%	104.43	8.35	2.17	10.52	8.60
10	2025		20	85.0%	127.40	1.93	-	1.93		30	58.53%	127.40	30.0%	104.43	8.35	2.17	10.52	8.60
11	2026		20	85.0%	127.40	1.93	-	1.93		30	58.53%	127.40	30.0%	104.43	8.35	2.17	10.52	8.60
12	2027		20	85.0%	127.40	1.93	-	1.93		30	58.53%	127.40	30.0%	104.43	8.35	2.17	10.52	8.60
13	2028		20	85.0%	127.40	1.93	-	1.93		30	58.53%	127.40	30.0%	104.43	8.35	2.17	10.52	8.60
14	2029		20	85.0%	127.40	1.93	-	1.93		30	58.53%	127.40	30.0%	104.43	8.35	2.17	10.52	8.60
15	2030		20	85.0%	127.40	1.93	-	1.93		30	58.53%	127.40	30.0%	104.43	8.35	2.17	10.52	8.60
16	2031		20	85.0%	127.40	1.93	-	1.93		30	58.53%	127.40	30.0%	104.43	8.35	2.17	10.52	8.60
17	2032		20	85.0%	127.40	1.93	11.24	13.17		30	58.53%	127.40	30.0%	104.43	8.35	2.17	10.52	-2.64
18	2033		20	85.0%	127.40	1.93	-	1.93		30	58.53%	127.40	30.0%	104.43	8.35	2.17	10.52	8.60
19	2034		20	85.0%	127.40	1.93	-	1.93		30	58.53%	127.40	30.0%	104.43	8.35	2.17	10.52	8.60
20	2035		20	85.0%	127.40	1.93	-	1.93		30	58.53%	127.40	30.0%	104.43	8.35	2.17	10.52	8.60
21	2036		20	85.0%	127.40	1.93	-	1.93		30	58.53%	127.40	30.0%	104.43	8.35	2.17	10.52	8.60
22	2037		20	85.0%	127.40	1.93	-	1.93		30	58.53%	127.40	30.0%	104.43	8.35	2.17	10.52	8.60
23	2038		20	85.0%	127.40	1.93	-	1.93		30	58.53%	127.40	30.0%	104.43	8.35	2.17	10.52	8.60
24	2039		20	85.0%	127.40	1.93	-	1.93		30	58.53%	127.40	30.0%	104.43	8.35	2.17	10.52	8.60
25	2040		20	85.0%	127.40	1.93	-	1.93		30	58.53%	127.40	30.0%	104.43	8.35	2.17	10.52	8.60
26	2041		20	85.0%	127.40	1.93	11.24	13.17		30	58.53%	127.40	30.0%	104.43	8.35	2.17	10.52	-2.64
27	2042		20	85.0%	127.40	1.93	-	1.93		30	58.53%	127.40	30.0%	104.43	8.35	2.17	10.52	8.60
28	2043		20	85.0%	127.40	1.93	-	1.93		30	58.53%	127.40	30.0%	104.43	8.35	2.17	10.52	8.60
29	2044		20	85.0%	127.40	1.93	-	1.93		30	58.53%	127.40	30.0%	104.43	8.35	2.17	10.52	8.60
30	2045		20	85.0%	127.40	1.93	-	1.93		30	58.53%	127.40	30.0%	104.43	8.35	2.17	10.52	8.60
31	2046																	
		89.02			3,822.00	57.78	33.72	180.52	45.00			3,822.00		3,132.90	250.63	65.10	360.73	180.21

Table IV-8-11 Willingness-To-Pay EIRR

model: PLN Tulehu Geothermal Project, Double Flash 10 MW x 2 [MM $]

		OUTPUT	SALES	INVESTMENT						REVENUE	COSTS								NET INCOME		NET INCOME	CASH FLOW
No.	YEAR	MW	GWH SALE Total	INITIAL INV. (w/o IDC) Total	Fm Loan	Equity	No. of Supplem. Wells	SUPPLM. INVEST.	TOTAL INVEST.	TOTAL REVENUE	OPER COST		DEPRECIATION Total	Well	T/L	Others	SUP. WELL DEPN.	TOTAL EXPENSES	NET INCOME	Tax	[After Tax]	FREE CASH FLOW
			1	2	2.1	2.2		3	4 [2+3]	5	6		7	7.1	7.2	7.3	8	9 [6+7+8]	10 [5-9]	11	12 [10-11]	13 [-4+7+8+12]
			[GWh]					[M$/well]												[34%]		
-6	2009																					0.00
-5	2010								0.00													0.00
-4	2011			21.23	16.54	4.69			21.23													-21.23
-3	2012			40.18	32.57	7.61			40.18													-40.18
-2	2013			32.07	26.09	5.98			32.07													-32.07
-1	2014			28.52	23.83	4.68			28.52													-28.52
1	2015	20	127.40							37.22	1.93		6.11	3.36	0.01	2.74		8.03	29.18	3.64	25.55	31.65
2	2016	20	127.40							37.22	1.93		6.11	3.36	0.01	2.74		8.03	29.18	3.53	25.66	31.76
3	2017	20	127.40							37.22	1.93		6.11	3.36	0.01	2.74		8.03	29.18	3.53	25.66	31.76
4	2018	20	127.40							37.22	1.93		6.11	3.36	0.01	2.74		8.03	29.18	3.53	25.66	31.76
5	2019	20	127.40							37.22	1.93		6.11	3.36	0.01	2.74		8.03	29.18	3.53	25.66	31.76
6	2020	20	127.40							37.22	1.93		6.11	3.36	0.01	2.74		8.03	29.18	3.53	25.66	31.76
7	2021	20	127.40				2	11.24	11.24	37.22	1.93		6.11	3.36	0.01	2.74	1.12	9.15	28.06	3.15	24.92	20.90
8	2022	20	127.40							37.22	1.93		6.11	3.36	0.01	2.74	1.12	9.15	28.06	1.91	26.16	33.38
9	2023	20	127.40							37.22	1.93		6.11	3.36	0.01	2.74	1.12	9.15	28.06	0.79	27.28	34.50
10	2024	20	127.40							37.22	1.93		6.11	3.36	0.01	2.74	1.12	9.15	28.06		28.06	35.29
11	2025	20	127.40							37.22	1.93		2.75		0.01	2.74	1.12	5.80	31.42	0.38	31.04	34.91
12	2026	20	127.40							37.22	1.93		2.75		0.01	2.74	1.12	5.80	31.42	0.60	30.82	34.69
13	2027	20	127.40							37.22	1.93		2.75		0.01	2.74	1.12	5.80	31.42	0.82	30.60	34.47
14	2028	20	127.40							37.22	1.93		2.75		0.01	2.74	1.12	5.80	31.42	1.04	30.38	34.25
15	2029	20	127.40							37.22	1.93		2.75		0.01	2.74	1.12	5.80	31.42	1.26	30.17	34.04
16	2030	20	127.40							37.22	1.93		2.75		0.01	2.74	1.12	5.80	31.42	1.48	29.95	33.81
17	2031	20	127.40				2	11.24	11.24	37.22	1.93		2.75		0.01	2.74	1.12	5.80	31.42	1.69	29.73	22.36
18	2032	20	127.40							37.22	1.93		2.75		0.01	2.74	1.12	5.80	31.42	1.92	29.51	33.38
19	2033	20	127.40							37.22	1.93		2.75		0.01	2.74	1.12	5.80	31.42	2.13	29.29	33.16
20	2034	20	127.40							37.22	1.93		2.75		0.01	2.74	1.12	5.80	31.42	2.35	29.07	32.94
21	2035	20	127.40							37.22	1.93		2.75		0.01	2.74	1.12	5.80	31.42	2.57	28.85	32.72
22	2036	20	127.40							37.22	1.93		2.75		0.01	2.74	1.12	5.80	31.42	2.79	28.63	32.50
23	2037	20	127.40							37.22	1.93		2.75		0.01	2.74	1.12	5.80	31.42	3.01	28.41	32.28
24	2038	20	127.40							37.22	1.93		2.75		0.01	2.74	1.12	5.80	31.42	3.22	28.20	32.07
25	2039	20	127.40							37.22	1.93		2.75		0.01	2.74	1.12	5.80	31.42	3.45	27.98	31.85
26	2040	20	127.40				2	11.24	11.24	37.22	1.93		2.75		0.01	2.74	2.24	6.92	30.30	3.28	27.02	20.77
27	2041	20	127.40							37.22	1.93		2.75		0.01	2.74	1.12	5.80	31.42	3.88	27.54	31.41
28	2042	20	127.40							37.22	1.93		2.75		0.01	2.74	1.12	5.80	31.42	4.10	27.32	31.19
29	2043	20	127.40							37.22	1.93		2.75		0.01	2.74	1.12	5.80	31.42	4.26	27.16	31.03
30	2044	20	127.40							37.22	1.93		2.75		0.01	2.74	1.12	5.80	31.42	4.35	27.07	30.94
	Total		3,822.00	121.99	99.03	22.96	6	33.72	155.71	1,116.50	57.78		116.04	33.57		82.25	28.00	201.82	914.68	75.69	838.98	827.32

Willingness to Pay 29.21 （¢/kWh） 2500 Rp/kWh

Project E.I.R.R. **19.61%**

3. Financial Evaluation

a. Methodology

To check the financial conditions of the Project for PLN, the financial internal rate of return is calculated for each project configuration case, and compared with the WACC (weighted average cost of capital) at 2.56%. Two different selling prices were studied; one is the levelized energy cost (LEC) and the other is the actual average PLN selling price of 7.93 cent/kWh. The LEC is calculated with the annualized value of the net generating cost at the discount rate of 12%, including the make-up well costs for a life of 30 years.

WACC (Opportunity Cost of Capital)	2.56%

b. Results of FIRR

The results of the FIRR evaluation are summarized in the following tables:

10 MW x 2 Single Flash

Financial Evaluation

1 Levelized Energy Cost at PP outlet (House service ratio at 5%)		14.89	cent/kWh
2 Levelized Energy Cost at Sending end (System loss at 10%)		16.55	cent/kWh
3 WACC		2.56%	
4 FIRR at actual selling price at	7.93 cent/kWh	2.35%	<2.56%
5 Project FIRR at LEC at sending end		8.90%	>2.56%
6 Equity FIRR at LEC at sending end		30.46%	>12%

20 MW x 1 Single Flash

Financial Evaluation

1 Levelized Energy Cost at PP outlet (House service ratio at 5%)		14.63	cent/kWh
2 Levelized Energy Cost at Sending end (System loss at 10%)		16.26	cent/kWh
3 WACC		2.56%	
4 FIRR at actual selling price at	7.93 cent/kWh	2.48%	<2.56%
5 Project FIRR at LEC at sending end		8.90%	>2.56%
6 Equity FIRR at LEC at sending end		30.43%	>12%

10 MW x 2 Double Flash

Financial Evaluation

1 Levelized Energy Cost at PP outlet (House service ratio at 5%)		13.23	cent/kWh
2 Levelized Energy Cost at Sending end (System loss at 10%)		14.70	cent/kWh
3 WACC		2.56%	
4 FIRR at actual selling price at	7.93 cent/kWh	3.27%	>2.56%
5 Project FIRR at LEC at sending end		8.85%	>2.56%
6 Equity FIRR at LEC at sending end		29.55%	>12%

20 MW x 1 Double Flash

Financial Evaluation

1 Levelized Energy Cost at PP outlet (House service ratio at 5%)		12.99	cent/kWh
2 Levelized Energy Cost at Sending end (System loss at 10%)		14.44	cent/kWh
3 WACC		2.56%	
4 FIRR at actual selling price at	7.93 cent/kWh	3.41%	>2.56%
5 Project FIRR at LEC at sending end		8.86%	>2.56%
6 Equity FIRR at LEC at sending end		29.53%	>12%

As shown above, the LEC for each case is much higher than the actual selling rate of 7.93 cent/kWh, but much cheaper than the actual average generating cost of 30.5 cent/kWh. Except for the 10 MW x 2 Single Flash case, the FIRR of all the other cases exceeds the WACC and the project is judged to be financially feasible. If the selling price is set equal to the LEC, the FIRR is much higher than the WACC. The project is expected with a high degree of confidence to improve the financial condition of PLN Ambon. The financial viabilities of the four cases are, in descending order: 20 MW x 1 DF, 10 MW x 2 DF, 20 MW x 1 SF, and 10 MW x 2 SF. So on the basis of the presently available data, the 10 MW x 2 DF plant will be the most suitable selection, considering future operation and maintenance. The 10 MW x 2 Double Flash case is the configuration planned by PLN. The repayment schedule, FIRR calculation, and cash flow statement for this case are shown in Tables IV-8-12, -13 and 14.

c. Sensitivity Analysis

(1) Levelized Energy Cost

LEC at sending end			
Dis Rate	LEC,$	ProjFIRR	Eqty FIRR
12.00%	**0.147**	**8.85%**	**29.55%**
3.00%	0.073	2.5%	#DIV/0!
4.00%	0.080	3.3%	#DIV/0!
5.00%	0.087	4.1%	#DIV/0!
6.00%	0.095	4.9%	#DIV/0!
7.00%	0.103	5.6%	13.5%
8.00%	0.111	6.3%	19.3%
9.00%	0.120	7.0%	22.6%
10.00%	0.129	7.7%	25.3%
11.00%	0.138	8.3%	27.5%
12.00%	0.147	8.9%	29.6%
13.00%	0.156	9.4%	31.4%
14.00%	0.166	10.0%	33.2%
15.00%	0.176	10.5%	34.9%
16.00%	0.185	11.1%	36.5%

LEC at PP outlet			
Dis Rate	LEC, $	ProjFIRR	Eqty FIRR
12.00%	**0.132**	**8.85%**	**29.55%**
3.00%	0.065	2.5%	#DIV/0!
4.00%	0.072	3.3%	#DIV/0!
5.00%	0.078	4.1%	#DIV/0!
6.00%	0.085	4.9%	#DIV/0!
7.00%	0.092	5.6%	13.5%
8.00%	0.100	6.3%	19.3%
9.00%	0.108	7.0%	22.6%
10.00%	0.116	7.7%	25.3%
11.00%	0.124	8.3%	27.5%
12.00%	0.132	8.9%	29.6%
13.00%	0.141	9.4%	31.4%
14.00%	0.149	10.0%	33.2%
15.00%	0.158	10.5%	34.9%
16.00%	0.167	11.1%	36.5%

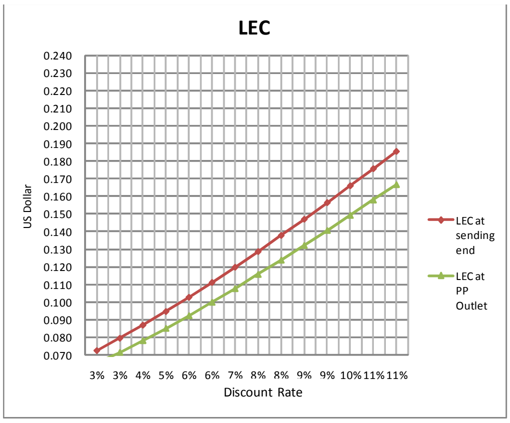


Fig. IV-8-2 Levelized Energy Cost (10 MW x 2 Double Flash)

Though the discount rate used for the LEC calculation is 12%, if the WACC of about 2.56% is the opportunity cost and discount rate, the generating cost at the power plant is 6.2 cent/kWh and that at the sending end (selling unit rate) is 7.0 cent/kWh., which less than the actual selling rate of 7.93 cent/kWh.

(2) Sensitivity to Power Selling Rates

If the real selling rate of 7.93 cent/kWh is applied, the FIRR is as low as 2.81%, as against the WACC at 2.56%. In order to ensure the finance soundness of the project (ensuring that there be no additional expenses when make-up wells are drilled over the project life of 30 years), a selling rate of about 10 cent/kWh would be desirable so that the obtained FIRR would be 6% and roughly double the WACC.

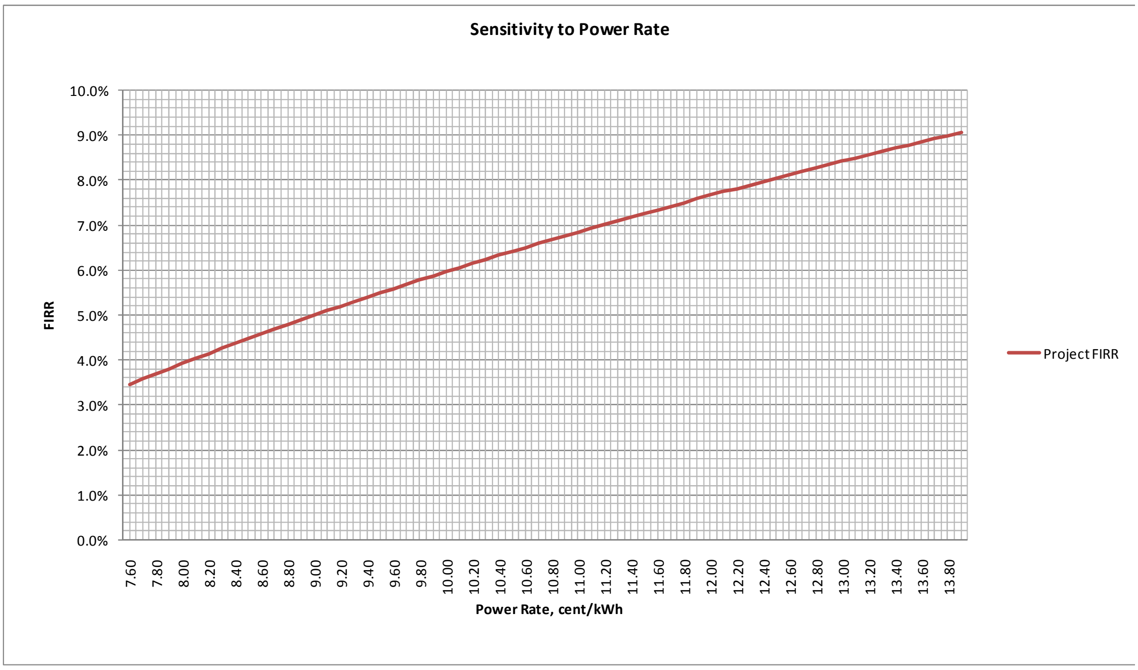
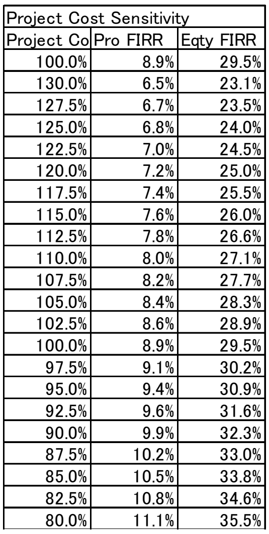


Fig. IV-8-3 Sensitivity to Power Selling Rates

(3) Sensitivity to Project Costs

The FIRR of the base case for a 10 MW x 2 Double Flash System is recorded at 8.9%. Even if the project cost should be 30% higher than the base case, the FIRR is still 6.5% and exceeds the 2.56% WACC.



Project Cost Sensitivity		
Project Co	Pro FIRR	Eqty FIRR
100.0%	8.9%	29.5%
130.0%	6.5%	23.1%
127.5%	6.7%	23.5%
125.0%	6.8%	24.0%
122.5%	7.0%	24.5%
120.0%	7.2%	25.0%
117.5%	7.4%	25.5%
115.0%	7.6%	26.0%
112.5%	7.8%	26.6%
110.0%	8.0%	27.1%
107.5%	8.2%	27.7%
105.0%	8.4%	28.3%
102.5%	8.6%	28.9%
100.0%	8.9%	29.5%
97.5%	9.1%	30.2%
95.0%	9.4%	30.9%
92.5%	9.6%	31.6%
90.0%	9.9%	32.3%
87.5%	10.2%	33.0%
85.0%	10.5%	33.8%
82.5%	10.8%	34.6%
80.0%	11.1%	35.5%

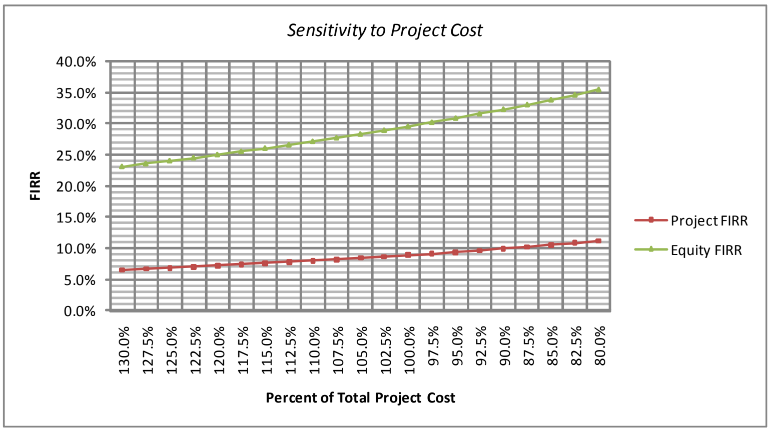


Fig. IV-8-4 Sensitivity to Project Costs (10 MW x 2 Double Flash)

If the Project should be completed without any expenses for contingencies (103.1 Million US$ as against the base of 122.0 Million US$, or about 85% of the base), the project financial conditions would be as follows:

Financial Evaluation		With Contingencies		Without Contingencies	
1 Levelized Energy Cost at PP outlet (House service ratio at 5%)		12.99	cent/kWh	11.58	cent/kWh
2 Levelized Energy Cost at Sending end (System loss at 10%)		14.44	cent/kWh	12.87	cent/kWh
3 WACC		2.56%		3.01%	
4 FIRR at actual selling price at	7.93 cent/kWh	3.41%	>2.98%	3.90%	>3.01%
5 Project FIRR at LEC at sending end		8.86%	>2.98%	9.10%	>3.01%
6 Equity FIRR at LEC at sending end		29.53%	>12%	29.05%	>12%

4. CDM Effects

a. CO_2 Reduction Calculation and Annual CER Revenue

The CO_2 emissions reduction resulting from this project is calculated with the 0.8 ton/MWh CO_2 emission coefficient of diesel power, as the Ambon Power System is now totally reliant on diesel power. Thus, the CO_2 reduction will be obtained with the following formula.

20 MW x 8,760 hr x 85% (capacity factor) x 0.8 = 119,136 tons/year

Since the steam in this field includes non-condensable gases containing CO_2 at 98 vol% (or 0.87 wt%) as shown in Section III-2, the certified value of the CO_2 reduction should deduct the amount of CO_2 produced in the operation of the geothermal power plant:

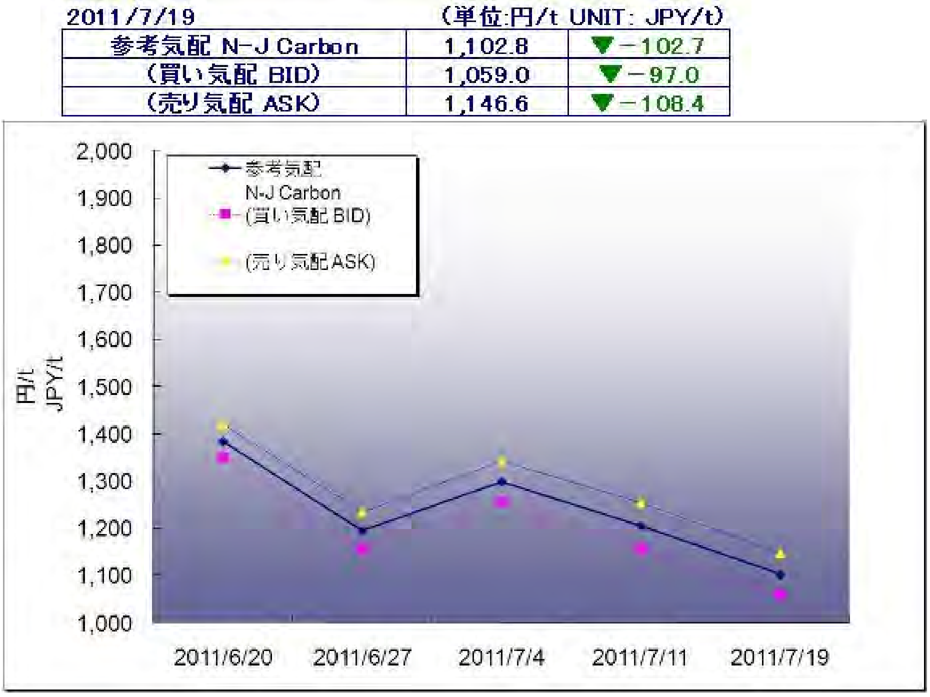
20 MW x 8,760 hr x 85% x 10 t/MWh (consumption) x 0.87CO_2wt%/100 =12,956 tons/year.

Thus, the annual CER CO_2 volume associated with this geothermal power project will be

119,136 – 12,956 = 106,180 tons/year.

b. CER Value

According to the Nikkei-JBIC carbon quotation index shown below, CO_2 is currently transacted at a unit cost of 1,100 yen/t, or13.7 US$/t. If the CO_2 reduction from this project should be transacted, the annual CER value will be approximately 1.0 Million US$. It is said that the preparation by an independent consultant of the Project Design Documents (PDD) necessary for CER approval costs around 300,000 US$/site, so the annual revenue increase of 1.0 Million US$ is worth pursuing even given the high consulting fee.



2011/7/19 (単位:円/t UNIT: JPY/t)

参考気配 N-J Carbon	1,102.8	▼−102.7
(買い気配 BID)	1,059.0	▼−97.0
(売り気配 ASK)	1,146.6	▼−108.4

Fig IV-8-5 Nikkei-JBIC Carbon Quotation Index

Table IV-8-12 Repayment Schedule (10 MW x 2 Double Flash)

PLN Tulehu Geothermal Project, Double Flash 10 MW x 2

Loan					Total Repayent				
No	Year	Loan	Equity	Total	Principal	Interest During Construction	Interest	Repay-ment	Outstand-ing Balance
-6	2010	0.00	0.00	0.00	-	0.00			
-5	2011	0.00	0.00	0.00	-	0.01			
-4	2012	33.69	4.69	38.38	-	0.11			38.75
-3	2013	32.57	7.61	40.18	-	0.18	-	-	68.29
-2	2014	26.09	5.98	32.07	-	0.23	-	-	92.62
-1	2015	23.83	4.68	28.52	-	0.27	-	-	116.70
0	2016	0.00	0.00	0.00	-	0.32		-	117.03
1	2017				-		0.32	-	117.35
2	2018				-		0.32	-	117.67
3	2019				-		0.32	-	117.99
4	2020				-		0.32	-	118.31
5	2021				-		0.32	-	118.63
6	2022				-		0.32	-	118.95
7	2023				1.73		3.96	5.46	117.45
8	2024				3.40		7.26	10.52	114.19
9	2025				4.74		9.67	14.34	109.52
10	2026				5.97		11.81	17.78	103.55
11	2027				5.97		11.17	17.14	97.58
12	2028				5.97		10.52	16.49	91.61
13	2029				5.97		9.87	15.84	85.64
14	2030				5.97		9.24	15.21	79.67
15	2031				5.97		8.59	14.56	73.70
16	2032				5.97		7.95	13.92	67.73
17	2033				5.97		7.30	13.27	61.76
18	2034				5.97		6.66	12.63	55.79
19	2035				5.97		6.01	11.98	49.82
20	2036				5.97		5.38	11.35	43.85
21	2037				5.97		4.73	10.70	37.88
22	2038				5.97		4.08	10.05	31.91
23	2039				5.97		3.45	9.42	25.94
24	2040				5.97		2.80	8.77	19.97
25	2041				5.97		2.16	8.13	14.00
26	2042				5.97		1.52	7.49	8.03
27	2043				4.24		0.87	5.11	3.79
28	2044				2.57		0.41	2.98	1.23
29	2045				1.23		0.14	1.37	0.00
30	2046				0.00		0.00	0.00	0.00
					-		-		
Total		82.49	18.27	100.77	119.40	1.13	137.49	254.52	

Note: IDC include 0.1% of commitment charge

Table IV-8-13 FIRR Calculation (10 MW x 2 Double Flash)

model: PLN Tulehu Geothermal Project, Double Flash 10 MW x 2 [MM $]

		OUTPUT	SALES	INVESTMENT						REVENUE	COSTS								NET INCOME		NET INCOME	CASH FLOW
No.	YEAR	MW	GWH SALE Total	INITIAL INV. (w/o IDC) Total	Fm Loan	Equity	No. of Supplem. Wells	SUPPLM. INVEST.	TOTAL INVEST.	TOTAL REVENUE	OPER COST		DEPRECIATION Total	Well	T/L	Others	SUP. WELL DEPN.	TOTAL EXPENSES	NET INCOME	Tax	[After Tax]	FREE CASH FLOW
			1 [GWh]	2	2.1	2.2		3 [M$/well]	4 [2+3]	5	6		7	7.1	7.2	7.3	8	9 [6+7+8]	10 [5-9]	11 [34%]	12 [10-11]	13 [-4+7+8+12]
																						0.00
-5	2010								0.00													0.00
-4	2011			21.23	16.54	4.69			21.23													-21.23
-3	2012			40.18	32.57	7.61			40.18													-40.18
-2	2013			32.07	26.09	5.98			32.07													-32.07
-1	2014			28.52	23.83	4.68			28.52													-28.52
1	2015	20	127.40							18.73	1.93		6.11	3.36	0.01	2.74		8.03	10.70	3.64	7.06	13.17
2	2016	20	127.40							18.73	1.93		6.11	3.36	0.01	2.74		8.03	10.70	3.53	7.17	13.27
3	2017	20	127.40							18.73	1.93		6.11	3.36	0.01	2.74		8.03	10.70	3.53	7.17	13.27
4	2018	20	127.40							18.73	1.93		6.11	3.36	0.01	2.74		8.03	10.70	3.53	7.17	13.27
5	2019	20	127.40							18.73	1.93		6.11	3.36	0.01	2.74		8.03	10.70	3.53	7.17	13.27
6	2020	20	127.40							18.73	1.93		6.11	3.36	0.01	2.74		8.03	10.70	3.53	7.17	13.27
7	2021	20	127.40				2	11.24	11.24	18.73	1.93		6.11	3.36	0.01	2.74	1.12	9.15	9.58	3.15	6.43	2.42
8	2022	20	127.40							18.73	1.93		6.11	3.36	0.01	2.74	1.12	9.15	9.58	1.91	7.67	14.89
9	2023	20	127.40							18.73	1.93		6.11	3.36	0.01	2.74	1.12	9.15	9.58	0.79	8.79	16.02
10	2024	20	127.40							18.73	1.93		6.11	3.36	0.01	2.74	1.12	9.15	9.58		9.58	16.80
11	2025	20	127.40							18.73	1.93		2.75		0.01	2.74	1.12	5.80	12.93	0.38	12.55	16.42
12	2026	20	127.40							18.73	1.93		2.75		0.01	2.74	1.12	5.80	12.93	0.60	12.33	16.20
13	2027	20	127.40							18.73	1.93		2.75		0.01	2.74	1.12	5.80	12.93	0.82	12.11	15.98
14	2028	20	127.40							18.73	1.93		2.75		0.01	2.74	1.12	5.80	12.93	1.04	11.89	15.76
15	2029	20	127.40							18.73	1.93		2.75		0.01	2.74	1.12	5.80	12.93	1.26	11.68	15.55
16	2030	20	127.40							18.73	1.93		2.75		0.01	2.74	1.12	5.80	12.93	1.48	11.46	15.33
17	2031	20	127.40				2	11.24	11.24	18.73	1.93		2.75		0.01	2.74	1.12	5.80	12.93	1.69	11.24	3.87
18	2032	20	127.40							18.73	1.93		2.75		0.01	2.74	1.12	5.80	12.93	1.92	11.02	14.89
19	2033	20	127.40							18.73	1.93		2.75		0.01	2.74	1.12	5.80	12.93	2.13	10.80	14.67
20	2034	20	127.40							18.73	1.93		2.75		0.01	2.74	1.12	5.80	12.93	2.35	10.58	14.45
21	2035	20	127.40							18.73	1.93		2.75		0.01	2.74	1.12	5.80	12.93	2.57	10.37	14.23
22	2036	20	127.40							18.73	1.93		2.75		0.01	2.74	1.12	5.80	12.93	2.79	10.14	14.01
23	2037	20	127.40							18.73	1.93		2.75		0.01	2.74	1.12	5.80	12.93	3.01	9.92	13.79
24	2038	20	127.40							18.73	1.93		2.75		0.01	2.74	1.12	5.80	12.93	3.22	9.71	13.58
25	2039	20	127.40							18.73	1.93		2.75		0.01	2.74	1.12	5.80	12.93	3.45	9.49	13.36
26	2040	20	127.40				2	11.24	11.24	18.73	1.93		2.75		0.01	2.74	2.24	6.92	11.81	3.28	8.53	2.28
27	2041	20	127.40							18.73	1.93		2.75		0.01	2.74	1.12	5.80	12.93	3.88	9.05	12.92
28	2042	20	127.40							18.73	1.93		2.75		0.01	2.74	1.12	5.80	12.93	4.10	8.83	12.70
29	2043	20	127.40							18.73	1.93		2.75		0.01	2.74	1.12	5.80	12.93	4.26	8.68	12.54
30	2044	20	127.40							18.73	1.93		2.75		0.01	2.74	1.12	5.80	12.93	4.35	8.58	12.45
	Total		3,822.00	121.99	99.03	22.96	6	33.72	155.71	561.85	57.78		116.04	33.57		82.25	28.00	201.82	360.03	75.69	284.33	272.66

Electricity Price (at sending end) **14.70** (¢ /kWh)

WACC of Project: **2.56%**

Equity FIRR **29.55%**

Project F.I.R.R. **8.85%**

Table IV-8-14 Cash Flow Statement (10 MW x 2 Double Flash)

Model: PLN Tulehu Geothermal Project, Double F [MM $]

No.	Year	Cash Inflow									Cash					Balance	
		Borrowing (w/o IDC)	Equity	Cash Flow from Operating Activities				Depreciation		Total	Initial		Additional Investment	Repayment Capital	Total	Per Year	Accumulate
				EBIT	Interest	Tax	Profit	Initial Inv.	Add'nal Inv.		Investment	Equity					
		1		2	3	4 [34%]	5 [2−3−4]	6	7	8 [1+5+6+7]	9		10	11	12 [9+10+11]	13 [8-12]	14
-6	2009																
-5	2010																
-4	2011	16.54	4.69							21.23	16.54	4.69			21.23		
-3	2012	32.57	7.61							40.18	32.57	7.61			40.18		
-2	2013	26.09	5.98							32.07	26.09	5.98			32.07		
-1	2014	23.83	4.68							28.52	23.83	4.68			28.52		
1	2015			10.70		3.64	7.06	6.11		13.17						13.17	13.17
2	2016			10.70	0.32	3.53	6.85	6.11		12.95						12.95	26.12
3	2017			10.70	0.32	3.53	6.85	6.11		12.95						12.95	39.07
4	2018			10.70	0.32	3.53	6.85	6.11		12.95						12.95	52.03
5	2019			10.70	0.32	3.53	6.85	6.11		12.95						12.95	64.98
6	2020			10.70	0.32	3.53	6.85	6.11		12.95						12.95	77.93
7	2021			9.58	0.32	3.15	6.11	6.11	1.12	13.33			11.24		11.24	2.09	80.03
8	2022			9.58	3.96	1.91	3.71	6.11	1.12	10.93				1.73	1.73	9.20	89.23
9	2023			9.58	7.26	0.79	1.53	6.11	1.12	8.75				3.40	3.40	5.35	94.58
10	2024			9.58	9.67		-0.09	6.11	1.12	7.13				4.74	4.74	2.39	96.97
11	2025			12.93	11.81	0.38	0.74	2.75	1.12	4.61				5.97	5.97	-1.36	95.61
12	2026			12.93	11.17	0.60	1.16	2.75	1.12	5.03				5.97	5.97	-0.94	94.67
13	2027			12.93	10.52	0.82	1.59	2.75	1.12	5.46				5.97	5.97	-0.51	94.16
14	2028			12.93	9.87	1.04	2.02	2.75	1.12	5.89				5.97	5.97	-0.08	94.08
15	2029			12.93	9.24	1.26	2.44	2.75	1.12	6.31				5.97	5.97	0.34	94.42
16	2030			12.93	8.59	1.48	2.87	2.75	1.12	6.74				5.97	5.97	0.77	95.18
17	2031			12.93	7.95	1.69	3.29	2.75	1.12	7.16			11.24	5.97	17.21	-10.05	85.13
18	2032			12.93	7.30	1.92	3.72	2.75	1.12	7.59				5.97	5.97	1.62	86.75
19	2033			12.93	6.66	2.13	4.14	2.75	1.12	8.01				5.97	5.97	2.04	88.79
20	2034			12.93	6.01	2.35	4.57	2.75	1.12	8.44				5.97	5.97	2.47	91.26
21	2035			12.93	5.38	2.57	4.98	2.75	1.12	8.85				5.97	5.97	2.88	94.14
22	2036			12.93	4.73	2.79	5.41	2.75	1.12	9.28				5.97	5.97	3.31	97.45
23	2037			12.93	4.08	3.01	5.84	2.75	1.12	9.71				5.97	5.97	3.74	101.19
24	2038			12.93	3.45	3.22	6.26	2.75	1.12	10.13				5.97	5.97	4.16	105.35
25	2039			12.93	2.80	3.45	6.69	2.75	1.12	10.56				5.97	5.97	4.59	109.94
26	2040			11.81	2.16	3.28	6.37	2.75	2.24	11.36			11.24	5.97	17.21	-5.85	104.09
27	2041			12.93	1.52	3.88	7.53	2.75	1.12	11.40				5.97	5.97	5.43	109.52
28	2042			12.93	0.87	4.10	7.96	2.75	1.12	11.83				4.24	4.24	7.59	117.11
29	2043			12.93	0.41	4.26	8.27	2.75	1.12	12.13				2.57	2.57	9.57	126.68
30	2044			12.93	0.14	4.35	8.44	2.75	1.12	12.31				1.23	1.23	11.09	137.77
		99.03	22.96	360.03	137.49	75.69	146.84	116.04	28.00	412.87	99.03		33.72	119.40	275.11	137.77	

CHAPTER V

V ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

V.1 Environmental Impact Assessment And The Project Category

V.1.1 Environmental Impact Assessment

Indonesian law (No ordinance. 17/2001) specifies that geothermal power plants with a less than 55 MW do not require an AMDAL (environmental impact assessment). This project capacity is 20 MW (less than 55 MW) is not required the AMDAL. However, as stipulated by the Decree of the Minister of Environment No. 86 (2002), a UKL and UPL need to be submitted. UKL and UPL for this project have been prepared in Mach 2010.

V.1.2 The Project Category

The Tulehu Geothermal Power Plant Project is classified as Category “A” in accordance with the JICA’s Guideline for Environmental and Social Considerations (issued in April 2002) listed in the thermal power generation (including geothermal power) sectors.

V.2 Environmental Baseline of The Study Area

V.2.1 Natural Environment

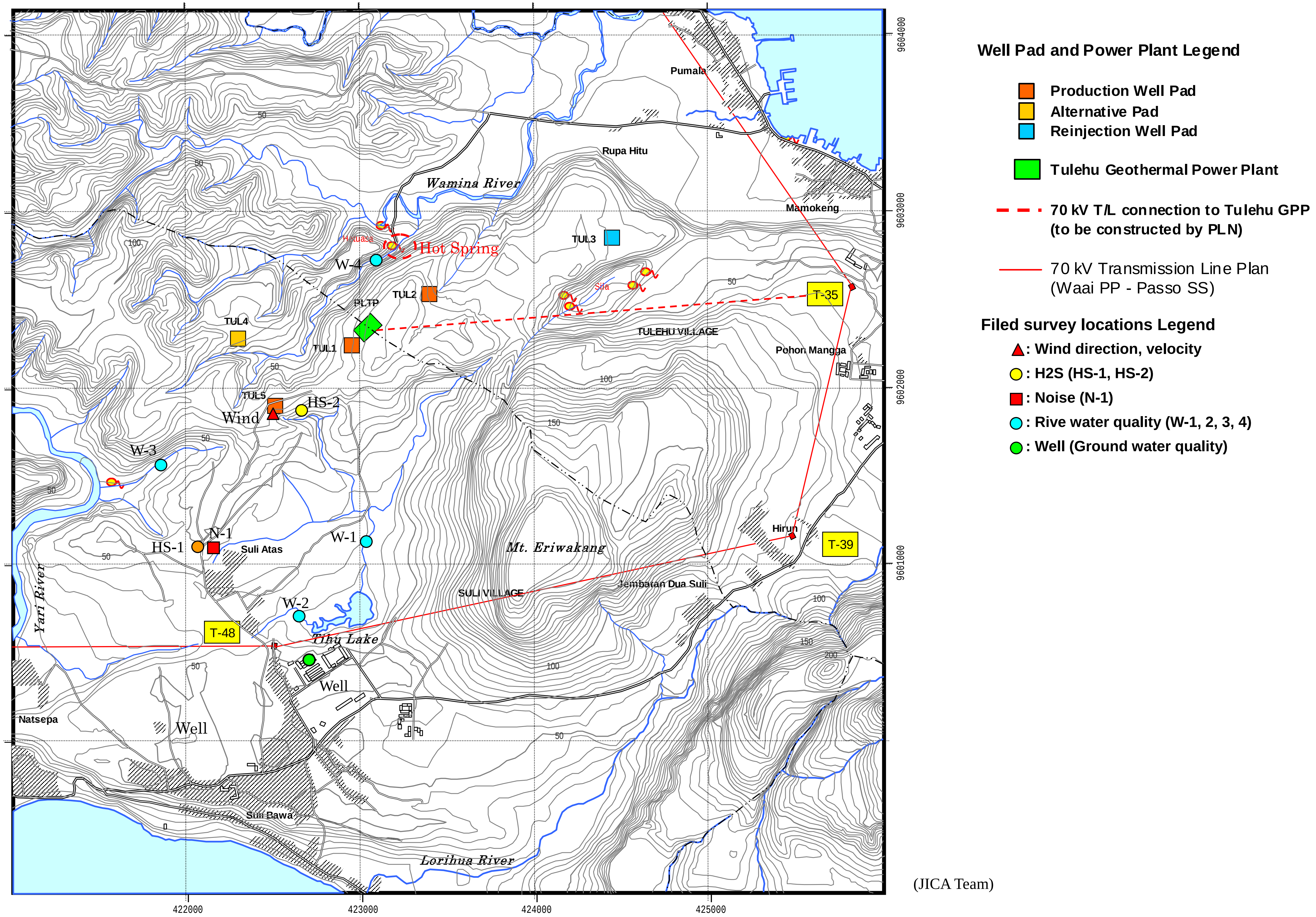
1. Data Collection and Field Survey

a. Data Collection

Weather data for the last 5 years (2005 to 2009) was obtained from the Meteorology and Geophysics Board (BMKG) Climatology Station at Pattimura Airport (Ambon City, Maluku Province). The data covers air temperature, humidity, rainfall , and wind direction and velocity. It is about 40 km from the Pattimura airport Climatology Station to the planned project site.

b. Field Survey

A field survey of wind direction and velocity, H_2S, noise and water quality was carried out to grasp the environmental situation of the study area. The locations of measurement points for wind direction and velocity, H_2S, noise and water quality are shown in Fig. V-2-1.



(JICA Team)

Fig. V-2-1 Location of sampling points for field survey

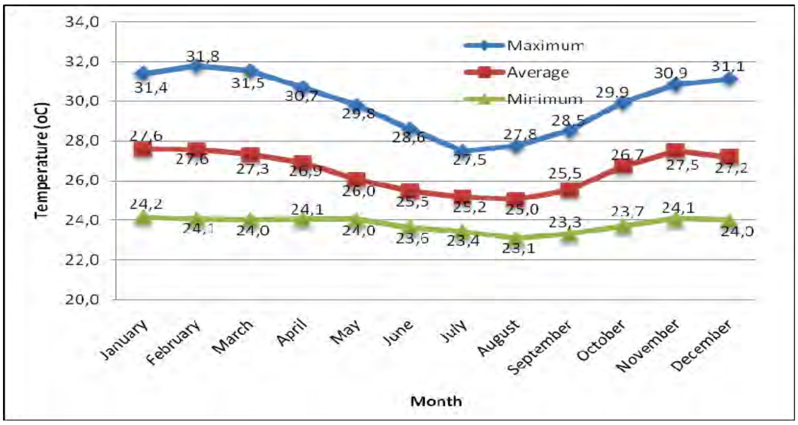
2. Climate

a. Overview

As with other areas in Indonesia, the city of Ambon, Maluku also knows only two seasons, a dry season and a rainy season. This situation is closely related to the prevailing winds blowing in Indonesia. From June to September, the wind comes from Australia and does not contain much moisture, resulting in a dry season in Indonesia. Conversely, from December to March, the wind comes from Asia and the Pacific Ocean and contains water vapor. In these months the rainy season usually occurs. This situation changes every six months, mediated through a transitional period in April-May and October-November.

b. Air Temperature

Based on BMKG data, the average air temperature during the period from 2005 to 2009 ranged from 25.0ºC to 27.6°C, while the highest maximum temperatures occurred in February (31.8ºC) and the lowest maximums occurred in July (27.5°C). The highest average temperature and the highest minimum occurred in January (27.6°C and 24.2°C, respectively) and the lowest average and minimum occurred in August (25.0ºC and 23.1°C, respectively), as shown in Fig. V-2-2. The figure also shows the pattern of temperature change as the west monsoon reaches a maximum and then continues to decline through transitional season I (April-May) and the east monsoon, and then rises again in transitional season II (October-November).

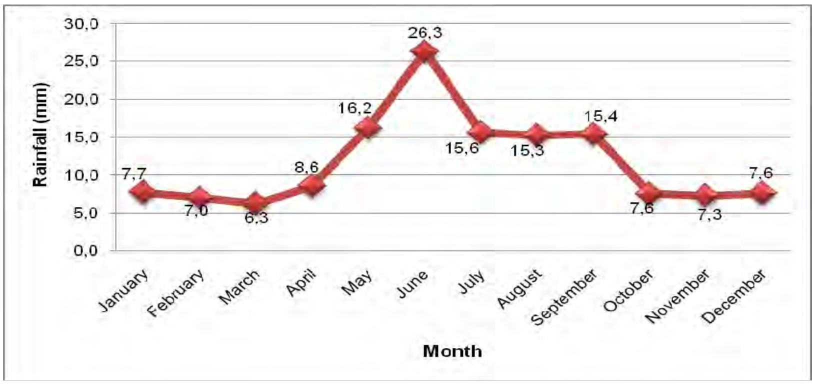


(Source: BMKG)

Fig. V-2-2 Graph of Temperature during the 2005 – 2009 Period

c. Rainfall

Rainfall conditions in the area of Ambon, Maluku are somewhat different from the western region of Indonesia in that in this region the highest average rainfall occurs in June (26.3 mm) and it is lowest in March (6.3 mm), as shown in Fig. V-2-3. The figure also shows a pattern of increasing rain in transitional season I and the beginning of the summer monsoon, with decreasing rainfall in the latter part of the summer monsoon and transitional season II.

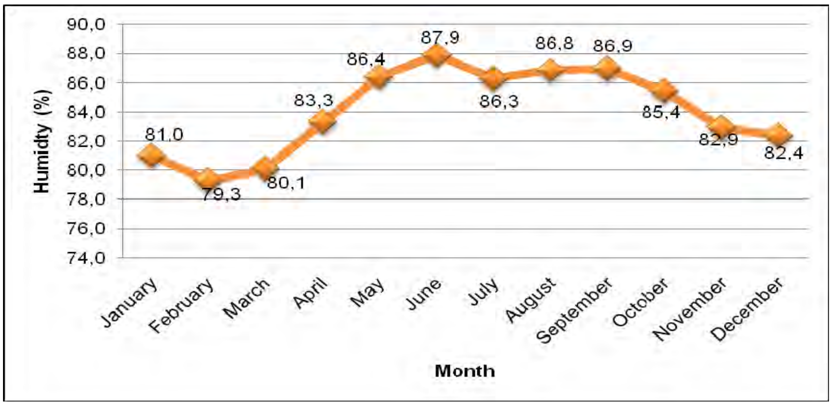


(Source : BMKG)

Fig. V-2-3 Graph of Average Rainfall (mm) during the 2005 – 2009 Period

d. Humidity

In the tropics, the relatively high air humidity ranges from 43% to 99%, with an average of 79.3% to 87.9% during the period from 2005 to 2009, as shown in Fig. V-2-4. The figure shows that in the winter monsoon (February) humidity reached a minimum, followed by a maximum in the summer monsoon (in June). Also the average humidity patterns in the winter monsoon season first declined and then rose through transitional season I to a maximum in the summer monsoon, only to decrease again in transitional season II.



(Source : BMKG)

Fig. V-2-4 Graph of Average Humidity (%) during the 2005 – 2009 Period

e. Wind Direction and Velocity

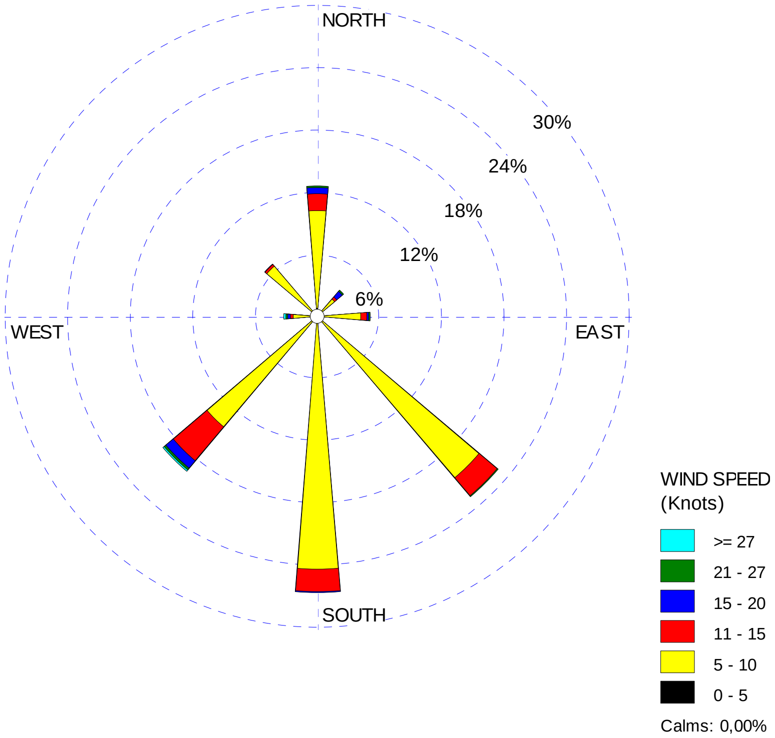
Daily maximum wind data from BMKG for the Ambon region was analyzed to determine the frequency and percentage of wind velocity as shown in Table V-2-1. Fig. V-2-5 is a wind rose based on the data in Table V-2-1. The figure and table show a prevailing daily wind direction mostly from the south (26.6%) or from the southeast (22.8%) and a minimum of wind from the northeast and west, 3.3% and 3.4% respectively. The most common daily wind velocities fell in the interval of 5-10 knots (80.8%).

Table V-2-1 Frequency and Percentage of Maximum Wind during 2005 – 2009

Wind Direction	0 – 5 knot		5 – 10 knot		10 – 15 knot		15 – 20 knot		20 – 27 knot		≥ 27 knot		Total	
	F	%	F	%	F	%	F	%	F	%	F	%	F	%
N	16	0.9	174	9.4	30	1.6	11	0.6	3	0.2	-	-	234	12.6
NE	2	0.1	40	2.2	5	0.3	13	0.7	3	0.2	-	-	63	3.4
E	2	0.1	77	4.1	11	0.6	3	0.2	3	0.2	-	-	96	5.2
SE	10	0.5	369	19.9	42	2.3	-	-	2	0.1	-	-	423	22.8
S	13	0.7	439	23.6	40	2.2	2	0.1	-	-	-	-	494	26.6
SW	4	0.2	255	13.7	79	4.3	17	0.9	4	0.2	3	0.2	362	19.5
W	3	0.2	41	2.2	5	0.3	5	0.3	3	0.2	4	0.2	61	3.3
NW	14	0.8	105	5.7	4	0.2	1	0.1	-	-	-	-	124	6.7
Total	64	3.4	1500	80.8	216	11.6	52	2.8	18	1.0	7	0.4	1857	100

*F: Frequency

(Source: BMKG)



(Source: BMKG)

Fig. V-2-5 Wind rose for the 2005 – 2009 period

f. Wind Direction and Velocity at Site

Wind data was obtained for 7 days from 7 October to 13 October every 5 minutes from a measurement device installed 10 m above ground level at the TLU-0 drilling pad in Suli Village (coordinates: S: 040 10’ 22.8" E: 1030 38' 40.0”, see Fig. V-2-1). Anemometer wind velocity was obtained from the south as much as 20.49% of the time (413 events), from the north, 18.90% of the time (381 events), and under calm conditions 54.6% of the time (1100 events). Velocities of 1-2 m / s were most common (30.21%), whereas the maximum wind velocity of ≥ 5 m/s occurred only once (0.05%). The data obtained show an average velocity of 0.92 m/s. The largest wind velocity generally occurs during the daytime.

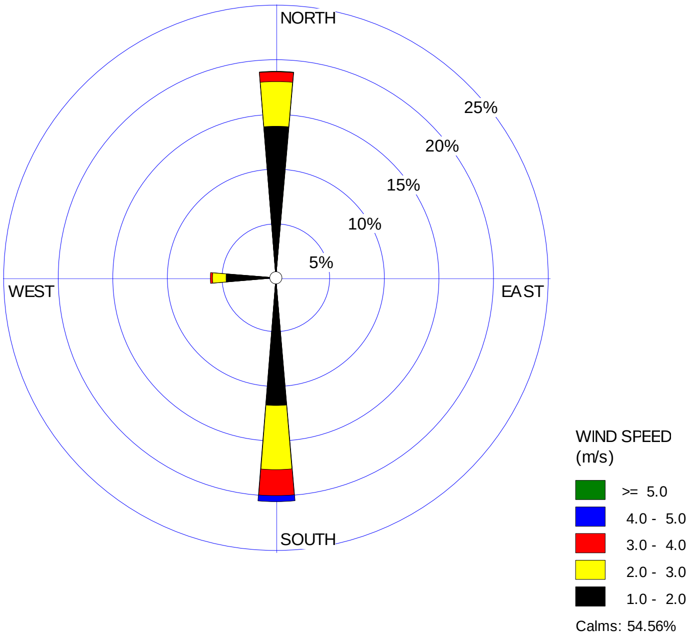
Measured data of wind velocity are shown in Table V-2-2 and Figure V-2-6, 7.

Table V-2-2 Frequency and Percentage of Wind every Five Minutes during October 7 - 13, 2010

Wind Direction	1 – 2 m/s		2 - 3 m/s		3 - 4 m/s		4 - 5 m/s		≥ 5 m/s		Total	
	F*	%	F	%	F	%	F	%	F	%	F	%
N	280	13.89	82	4.07	18	0.89	-	-	1	0.05	381	18.90
NE	-	-	-	-	-	-	-	-	-	-	-	-
E	-	-	-	-	-	-	-	-	-	-	-	-
SE	-	-	-	-	-	-	-	-	-	-	-	-
S	236	11.71	118	5.85	48	2.38	11	0.55	-	-	413	20.49
SW	-	-	-	-	-	-	-	-	-	-	-	-
W	93	4.61	25	1.24	4	0.20	-	-	-	-	122	6.05
NW	-	-	-	-	-	-	-	-	-	-	-	-
Subtotal	609	30.21	255	11.16	70	3.47	11	0.55	1	0.05	916	45.44
Calms											1100	54.6
Total											2016	100

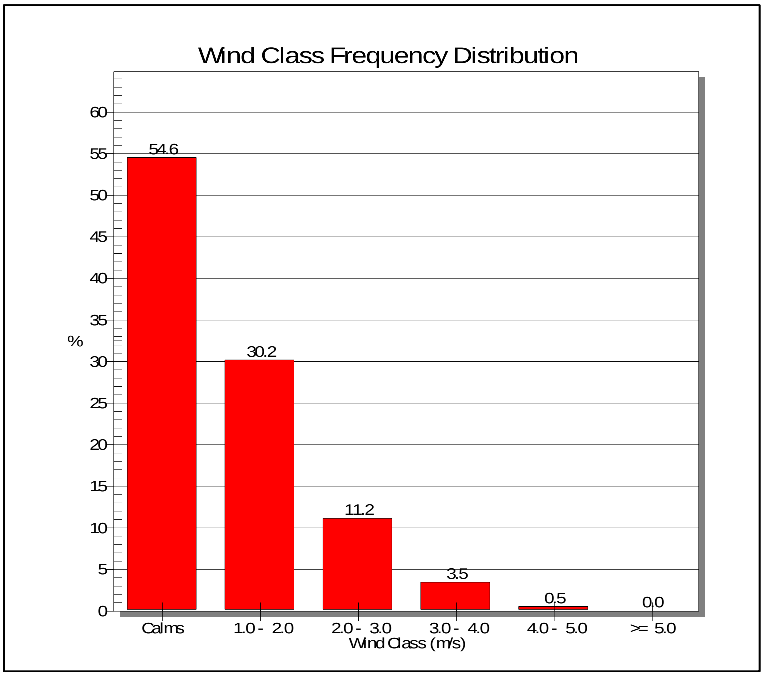
*F：Frequency

(JICA Team)



(JICA Team)

Fig.V-2-6 Wind Rose for October 7 –13, 2010 at the Project Site



(JICA Team)

Fig.V-2-7 Distribution of Wind Class Frequency for October 7 –13 at the Project Site

3. Hydrology

a. Surface Water

In the study area, there are three main rivers and one lake in the village of Suli, namely Waetatiri, Waelorihua, and Waeyari Rivers and Tihu Lake, and two main rivers in the village of Tulehu, namely Waerutung and Wae Mareta Rivers (Table V-2-3).

Table V-2-3 Total River and Lake in the Study Area

Village	Name of River	Lake
Suli	Yari river tributary：Waiyari, Waetatiri Lorihua river (Waelorihua)	Tihu Lake
Tulehu	Wamina river tributary：Waerutung, Wae Mareta	-

(JICA Team)

b. Spring Water

In the study area there are two springs that are at the same coordinates (S3 35.603 E128 18.506).

c. Water Utilization

Ground water is the main source of water for the local people. A few use dug wells and some use water tanks provided by the local government. According to PLN Geothermal, well drilling for TLU-01 will use water from Tihu Lake (see Fig. V-2-1), for which permission has already been obtained from the the village head . Tihu Lake and its waters are not used by local residents. In addition, PLN is scheduled to investigate where water can be sourced for other drilling and for operation of the power plant, and the specific necessary water volume needed for of the plant and the specific location of the well drilling will beexamined to determine the exact location of the river intake and intake point later.

4. Air Quality (H_2S: Hydrogen Sulphide))

The H_2S measurement locations are shown in Fig. V-2-1 as HS-1 and HS-2. The concentration of H_2S measured is <0.005 ppm (Table V-2-4). The level of odor and the concentration of H_2S around the survey location is not over the required quality standard of 0.02 ppm specified in Decree of Minister of Environment Number: Kep/50/MENLH/11/1989.

Table V-2-4 Results of H_2S Measurements

PARAMETER	QUALITY STANDARD*)	UNIT	RESULTS	
			HS-1	HS-2
Hydrogen Sulfide (H_2S)	0,02	Ppm	<0,005	<0,005

Source: JICA Team (Results of laboratory analysis, 2010)

Remarks: *) = KEP.50/MENLH/XI/1996 on Odor Level Standard

HS-1 = Settlement Boundary (Triple Roads position S : 03° 36' 31.8" E :128° 17' 54.9")

HS-2 = Near the Project Site (Near Fumaroles with position S : 03° 36' 10.2" E : 128° 18' 13.2")

5. Noise

The noise measurement location is shown in Figure V-2-1 as N-1. The level of noise in the measurement location ranges between 39 and 48 dB (Table V-2-5). The source of noise is mainly from the activity of motor vehicles and residents. The quality standard for residential areas that is specified in Decree of Ministry of Environment Number Kep 48/MENLH/11/1996 is 55 dBA. The measurement results at the location meet the quality standard for noise level.

Table V-2-5 Result of Noise Measurement (Measurements for 24 hours)

NO.	LOCATION	RESULTS *)			QUALITY STANDARD
		L_SdB(A)	L_MdB(A)	L_{SM}dB(A)	
N-1	Northern Suli Village	48	39	47	55

Source: JICA Team (Results of laboratory analysis, 2010)

*: Leq = Equivalent continuous sound pressure level

L_S = Value of Leq in daylight (16 hours)

L_M = Value of Leq in night (8 hours)

L_{SM} = Value of Leq in all day (24 hours)

***: Noise level of quality standards in accordance with the decision of the Ministry of Environment No. Kep.48/MenLH/11/1996

6. Water Quality

a. Lake and River Water Quality

To determine the quality of surface water in the vicinity of the study area, water sampling was carried out in four locations, W1 = upstream of Tihu Lake, W2 =

downstream of Tihu Lake, W3 = Waiyari River, W4 = hot spring (see Fig. V-2-1 for measurement location.). The river water quality standard is based on Government Regulation No. 82 year 2001 on Water Quality Management and Control of Water Pollution Class IV. Results of laboratory analysis of the samples are presented in Table V-2-6.

The table shows that the overall water quality can be categorized as good, as evidenced by the fact that most of the chemical physical parameter values are still well below the environmental quality standards. But there are some parameters whose values exceed environmental quality standards, namely BOD, COD, phosphate, copper, coliform and fecal coliform.

In the Waiyari River and Tihu Lake, water temperatures between 26.0ºC and 26.70ºC were recorded. The Tulehu River, of which the source is hot spring Hatuhasa, recorded a water temperature of 34.0ºC

The Sampling point of Tulehu River is anaerobic, causing a bad smell in the water. Results of analysis of BOD and CODrecorded 10.5 mg/L and 31.5 mg/L, while the environmental quality standards for BOD are 3 mg/L and COD are 25 mg/L. The high value of BOD in rivers is considered to be caused by a large amount of organic substances contained in the water that come from housesaround the rivers.

Measured values for coliform and fecal coliform at all locations exceed the required quality standard. So this water could not be used as a source of drinking water without mitigation of the coliform bacteria.

Table V-2-6 Results of River Water Quality Analysis

No	Parameter	Unit	Measurement Result				Max Concentration Allowed
			W1	W2	W3	W4	
A. PHYSICS							
1	Temperature	^{O}C	26	26.7	26	34	Temperature ± 3^{o}C
B. CHEMICALS							
1	pH	–	6.8	6.8	6.0	7.0	6 -9
2	BOD	mg/l	2.3	3.0	1.2	10.5	3
3	COD	mg/l	8.1	12.0	6.2	31.5	25
4	DO	mg/l	7.2	4.3	6.9	4.9	> 4
5	Total Phosphate	mg/l	0.2678	0.0120	0.293	0.293	0.2
6	Nitrate	mg/l	< 0.003	< 0.003	< 0.003	< 0.003	10
7	Nitrite	mg/l	< 0.002	< 0.002	< 0.002	< 0.002	0.06
8	Cadmium	mg/l	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.01
9	Chromium (VI)	mg/l	< 0.004	< 0.004	< 0.004	< 0.004	0.05
10	Copper (Cu)	mg/l	0.15	0.28	0.14	0.14	0.02

No	Parameter	Unit	Measurement Result				Max Concentration Allowed
			W1	W2	W3	W4	
11	Lead (Pb)*	mg/l	< 0.0040	< 0.0040	< 0.0040	< 0.0040	0.03
12	Sulphate (SO4)	mg/l	118	50	116	137	400
13	Zinc	mg/l	< 0.0078	< 0.0078	< 0.0078	< 0.0078	0.05
14	Cyanide	mg/l	< 0.001	0.005	< 0.001	0.007	0.02
15	Iron (Fe)	mg/l	< 0.0041	0.2631	< 0.0041	< 0.0041	1.0
16	Manganese (Mn)	mg/l	< 0.049	< 0.049	< 0.049	< 0.049	0.5
17	Ammonia (NH3)	mg/l	0.17	0.43	0.110	0.39	1.5
18	HydrogenSulfide (H2S)	mg/l	< 0.001	0.06	< 0.001	< 0.001	0.002
19	Fluoride	mg/l	0.21	0.54	0.36	0.49	1.5
20	Chloride	mg/l	19	9	18	250	600
C. ORGANIC CHEMICALS							
1	Detergent (MBAS)	ug/L	< 0.003	< 0.003	< 0.003	< 0.003	200
2	Phenolic Compounds	ug/L	< 0.002	< 0.002	< 0.002	< 0,002	1
D. MICROBIOLOGY							
1	Coliform	MPN/100 ml	59 x10^{2}	52 .x 10^{2}	95 x. 10^{2}	50 .x 10^{2}	5000
2	Fecal Coliform	MPN/100 ml	39 .x10^{2}	12 .x 10^{2}	33. x10^{2}	10 .x 10^{2}	1000

Source: JICA Team (Results of laboratory analysis, 2010)

b. Ground Water Quality

Some residents in Suli Village use groundwater to meet their needs for domesticclean water. Examples of the quality of ground water drawn from wells owned by residents located in Banda Baru – Suli Village are shown in Table V-2-7. Environmental quality standards of Water Quality are specified in Regulation of the Minister of Health of Indonesia No. 416/ MenKes./Per/IX /1990 (Limited Parameters).

Based on the Microbiology parameters, this ground water does not meet clean water requirements. Values higher than 1,600 coliform MPN/100ml were recorded, while environmental quality standards for clean water not carried in pipes specify a maximum of 50 coliform MPN/100 ml. The high ground water on site and residents dug wells thought to be caused by the pervasiveness of water from the lake or river water levels coliform cleaner

Table V-2-7 Ground Water Quality

No	Parameter	Unit	Measurement Result	Max Concentration Allowed
A. PHYSICS				
1	Color	PtCo	< 1	50
2	TDS	mg/l	–	1500
3	Turbidity	NTU	1.43	25
4	Taste	-	No taste	No taste
5	Odor	-	No smell	No smell
6	Temperature	°C	26.8	Temperature ± 3°C
B. CHEMICALS				
1	Mercury (Hg)*	mg/l	< 0.0010	0.001
2	Arsenic (As)*	mg/l	–	0.05
3	Iron (Fe)	mg/l	< 0.0041	1.0
4	Detergent	mg/l	< 0.001	0.5
5	Fluoride (F)	mg/l	0.63	1.5
6	Cadmium (Cd)*	mg/l	< 0.0010	0.005
7	Chromium.Val ^{6} (Cr^{+6})*	mg/l	< 0.004	0.05
8	Calcium Carbonate/$CaCO_3$	mg/l	45.991	500
9	Chloride (Cl^{2-})	mg/l	35	600
10	Manganese (Mn)	mg/l	< 0.049	0.5
11	Nitrate (NO_3)	mg/l	< 0.003	10
12	Nitrite (NO_2)	mg/l	< 0.002	1.0
13	pH	–	5.5	6.5 - 9.0
14	Selenium (Se)*	mg/l	–	0.01
15	Zinc (Zn)	mg/l	0.0079	15
16	Cyanide (CN)*	mg/l	0.005	0.1
17	Sulfate(SO^-_4)	mg/l	< 1	400
18	Lead (Pb)*	mg/l	< 0.0040	0.05
19	Chlorine	mg/l	–	Not regulated
20	Phenol	mg/l	< 0.002	0.01
21	$KMnO_4$	mg/l	0.002	10
C. MICROBIOLOGY				
1	Coliform	MPN/100 ml	≥ 1600	Piping = 10 W/o piping = 50
2	Fecal Coliform	MPN/100 ml	≥ 1600	Not required

Source: JICA Team (Results of laboratory analysis. 2010)

7. Fauna and Flora

a. Protected Fauna and Flora

According to the UKL, UPL and local environmental bureau (Mr. Yunan Tan, Vice-Coordinator), there are no precious species living or growing in the planned area. The study area consists of low trees and grass with groves of sago palm. With obvious human intervention already in place, the environment presents little in the way of untouched nature, and the likelihood of precious species of fauna and flora being present is very slight.

b. Flora

Various types of existing vegetation in the study area were observed and distinguished according to the nature of the ecosystem, namely secondary forest, swamp forest, cultivated vegetation or shrubs. The main species in the secondary forest are Clove (*Syzigium aromaticum*), Albizia (*Albizia falcataria*), Hibiscus (*Hibiscus macrophyllus*), Bechwood (*G melina arborea*), and White cheesewood (*Alstonia spp*). In addition to secondary forest ecosystems, there are a few swamp forests that are dominated by Polynesian ivory palm (*Metroxylon sp*) and in which are found some Polynesian chestnut (*Inocarpus fagiferus*), Sea mango (*Cerbera manghas*), Fernns (*Hymenophyllum sp*) and Elephant-ear (*Colocasia sp.*). The bush ecosystem, on the other hand, is dominated by Blady grass (*Imperata cylindrica*), Siam weed (*Eupatorium odoratum*) and Lantana (*Lantana camara*).

c. Fauna

Those existing animals were confirmed based on interviews with local people during the survey this time are listed below:

Mammals: Wild boar (*Sus scrofa*), Southern pig-tailed macaque (*Macaca spp*), Lesser mousedeer (*Tragulus javanicus*), Common barking deer (*Muntiacus muntjak*).

Birds: Junglefowl *(Gallus gallus*), Cattle egret (*Ebubulcus ibis*), Greater coucal (*Centropus sinensis*), Pin-striped tit-babbler (*Macronus gularis*), Slender-billed crow (*Corvus enca*), Whiskered treeswift (*Hemiprocne comata*), Sooty-headed bulbul (*Pygnonotus aurigaster*), and White-rumped shama (Copsychus malabaricus).

Reptiles and Amphibians: Lizards (*Bungarus fasciatus*), Monitor lizard k (*Varanus salvator*), and Asian pit viper (*Trimeresurus sp*).

8. Land Use

Geographically, the project site plan area is in the western part of the Regency of Central Maluku on the Island of Ambon, which is rather dry and hilly. The land uses in the village of Bandabaru were listed in a 2008 monograph as being cultivation/plantation (62.27%), settlement/building (28.04%) roads (3.36%), cemetery

(0.67%), hot water sources (0.67%), office/public facility (3.30%), and recreational places (1.69%).

Based on the land use map shown in Fig. V-2-8, the pattern of land cover in the Regency of Central Maluku can be classified into natural forest, secondary forest, bush, dry land farming, mixed farming and rice. The planned development activities of a geothermal power plant are located in dry land farming areas and adjacent to mixed farming. A preserved forest spreads out at about 2km west of the project area. It is quite unlikely that the development of the power plant will cause environmental impact onto the forest since the distance between the forest and the plant location is sufficiently separated.

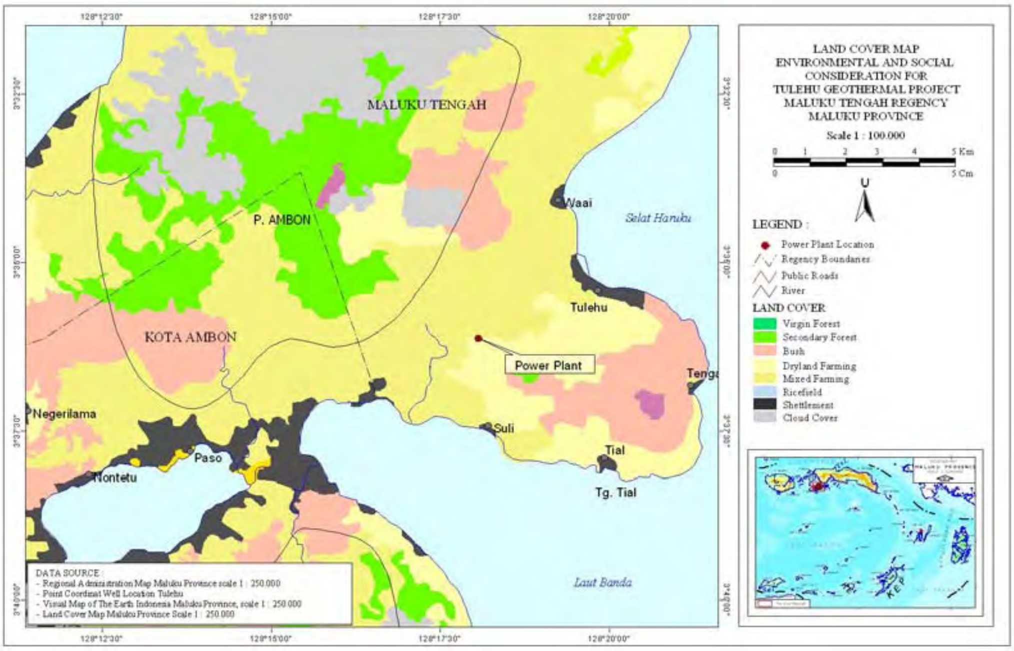


Fig. V-2-8 Land Use Map

V.2.2 Social Environment

1. Overview

The planned Tulehu Geothermal Power Development will be located in Suli and Tulehu villages and surrounded by Tial village, Salahutu District, Regency of Central Maluku. The Social Environment study area covers the villages of Suli, Tulehu and some parts of Tial (Fig. V-2-9).

Data on the social economy and social culture was obtained from the Statistics Book of Salahutu district and Central Maluku District 2009, issued by the Statistical Bureau of Central Maluku District. Data analysis was carried out with a view to elaborating a description of the following components: Demography, Economy, Culture and

Environmental Sanitation.

2. Population

Salahutu district is the second most populated in Central Maluku Regency. Data from Central Maluku *in Figures 2008* shows the population of this district as 44,603 persons. With a total land area of 151.82 square kilometers, the population density of Salahutu district is 294 persons per square kilometer.

Among the villages in Salahutu District, Tulehu village has the largest population, with 15,852 persons, and the least populated is Tial village with a population of 2,362 persons (Salahutu District in figures 2008). The population in this area is tabulated in Table V-2-8.

The average Tulehu village family consists of five people, whereas the average for the village of Suli and Tial is four people. Thus, each family consists of parents and two or three children only.

Table V-2-8 Size of Population

Village	Male	Female	Total	Households	Density	Population per Household
Suli	4,419	4,447	8,896	2,186	137	4
Tulehu	7,835	8,017	15,852	3,457	514	5
Tial	1,145	17	2,362	556	100	4
Total	13,399	12,481	27,110	6,199		4.3

(Source: Salahutu in Figures 2008)

3. Education

According to Salahutu District in Figures 2008, education facilities in this district are adequate. At the kindergarten level each of the villages has one or two schools, and at the Elementary school level all of villages have two or more schools. Suli has five schools, Tial has two and Tulehu has 12. At the Junior high school level each village has one or two schools, but Senior High School is only available in Suli and Tulehu (Table V-2-9).

Table V-2-9 The number of School Facilities

Village	Kindergarten	Elementary	Junior high school	Senior High school
Suli	1	5	1	1
Tial	1	2	1	-
Tulehu	2	12	2	4
Total	4	19	4	5

(Source: Salahutu in Figures 2008)

4. Health

Health facilities in Salahutu Subdistrict up to 2008 consisted of one hospital located in Tulehu Village, and three public health centres in Suli Village and 1 in Tial Village. The state of the public health service in the region is also indicated by the availability of health workers who serve the community. Salahutu District has 10 medical staff, while there are 4 in Suli Village, and three in Tulehu and other villages. There were 35 paramedical workers in total, 15 in Suli, one in Tial, 13 in Tulehu, and 6 in other villages. There are also 20 medical centre midwives, 7 in Suli, 1 in Tial, 3 in Tulehu, and 9 in other villages. There are in addition village midwives in each village in numbers varying from 2 to 15. The availability of Health workers in the study area villages is tabulated in Table V-2-10. The most common illnesses suffered by population in the study area are ranked in Table V-2-11.

Table V-2-10 Health Workers

Village	Medical Doctor	Para Medic	Medical Centre Midwives	Village Midwives	Others
Suli	4	15	7	12	10
Tial	-	1	1	2	1
Tulehu	3	13	3	15	14
Total	7	29	11	29	25

(Source: Salahutu in Figures 2008)

Table V-2-11 Most Common Diseases in the Study Area

Name of Disease	No. of Cases	%
ARI (acute respiratory infection)	1982	28,5
Diarrhea	339	4,9
Malaria	748	10,8
Mouth cavity disease	357	5,1
Muscle tissue and connective tissue disease	281	4,0
Skin infection	279	4,0
Tuberculosis (TBC)	250	3,6
Other diseases	900	13

(Source : Salahutu in Figures 2008)

5. Social Economy and Livelihoods

The agriculture sector provides the main income of people in Central Maluku Regency including Salahutu District. Available data from the Central Bureau of Statistics is tabulated in Table V-2-12, giving us information about the number and sex of workers aged 15 years and over in the various economic sectors of Central Maluku Regency. In this table we can see that agriculture, forestry, plantations, fishery and the livestock sector absorb more than 58% of the labor force. The main food commodities produced are corn, cassava, yams and peanuts. The plantation crops are cloves and coconuts. The second most significant source of income for the labor force is the trade, hotel and restaurant sector, which accounts for more than 15% of employment.

Table V-2-12 Number and Sex of Workers Aged 15 Years and Over in Each Sector

No	Main Sector	Male	Female	Total
1	Agriculture, forestry, plantations, fishery and livestock	48,339	17,708	66,047 (58%)
2	Manufacturing	3,265	2,403	5,668 (5%)
3	Trade, hotels and restaurants	6,037	11,172	17,209 (15%)
4	Public service	6,537	4,787	11,324 (10%)
5	Others: mining and quarrying, electricity, gas and water supply, construction, transportation, finance, etc.	12,349	1,041	13,390 (12%)
	Total	76,527	37,111	113,638 (100%)

(Source: Central Maluku in Figures, 2009)

6. Ethnic Composition and Religion

Residents living in the capital district of Central Maluku district and the city are relatively heterogeneous, but the people who live in the villages are of Moluccan ethnic origin. Residents living around the study area from the Banda tribe have been displaced since 2001. Islam and Christianity are widely practiced among the general population in the district of Salahutu, with most of the population in the village of Tulehu being Moslem, while most of population in the village of Suli are Christian. In the village of Suli there are 12 mosques, 21 Mushollas (Islamic prayer rooms) and 33 churches. In the village of Tial, there are 9 mosques, 17 mushollas and 2 churches, while in Tulehu there are 57 mosques, 47 mushollas and 15 churches. This religious infrastructure is tabulated in the following Table V-2-13.

Table V-2-13 Religious Facilities in the Study Area

Village	Mosques	Mushollas (prayer rooms)	Churches
Suli	12	21	33
Tial	9	17	2
Tulehu	57	47	15
Total	78	85	50

(Source: Salahutu in Figures 2008)

7. Land acquisition Plan

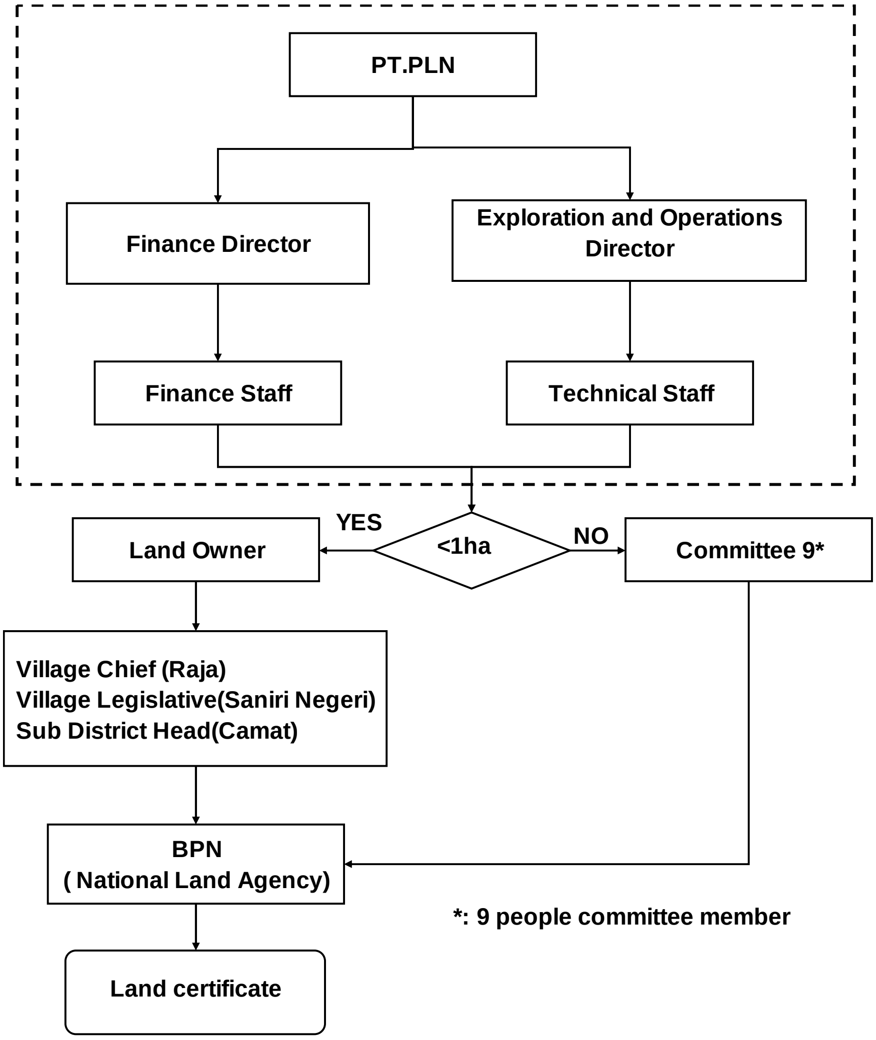
a. Legal Framework for Land Acquisition

In Indonesia, land acquisition of a nationa development project was processed base on the Presidential Regulation No. 36 of 2005, which was then refined by Presidential Decree No. 65 of 2006 and implemented accoding to the regulation of the National Land Agency No. 3 of 2007. The main process of the land acquisition by PLN is as follows.

- For total area less than 1 (one) hectare land acquisitions, PT. PLN as state owned company directly negotiates with the land owners regarding the price. After payment, the land registration certificate will be changed to the name of PT. PLN.
- For total area more than 1 (one) hectare land acquisition, PT.PLN as state owned company cannot directly negotiate with the owner or owners and should raise the matter for consultation with a commitee consisting representatves of some goverment institutions to negosiate with the land owner or owners. The committee consists of the maximum of 9 persons.
- After having agreed with the price for transaction, PLN will pay the agreed price and the land registration certificate will be changed to the name of PLN.

b. Implementation Structure for the Land Acquisition

The flow of land acquisition process is shown in Fig. V-2-9.



(Source : PLN)

Fig.V-2-9 Flow of the Land Acquisition Process

c. Implementation Schedule of Land Acquisition

The implementation schedule of land acquisition is shown in Fig. V-2-10.

LAND ACQUISITION SCHEDULE

Activites / Month / Weeks	Oct-11				Nov-11				Dec-11				Jan-12			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Coordination with local office, establishing committee 9			🟧	🟧	🟧	🟧										
Process of land acquisition by committee 9							🟧	🟧	🟧	🟧	🟧					
Measurement by local office of National Land Agency (Badan											🟧	🟧	🟧			
Clarification by BPN														🟧		
Payment															🟧	

Fig. V-2-10 Implementation Schedule of Land Acquisition

d. Land Planning

According to the UKL and UPL, the present project requires a total of approximately 7 hectares of land. PT.PLN has stated in response to questions from the study team that all land in and around the planned project site is the private property of twelve owners and this land consists of unused cultivable lands (Table V-2-14).

Table V-2-13 Area of Land Acquisition and Characteristics

Status of Land				
Legal Status of the ownership	Area of land acquisition (ha)	Number of households whose land or assets will be affected	Number of households who have to be resettled	Number of shops, factories, business facilities to be affected
Legal	App. 7 ha	12 families	-	-
Illegal	-	-	-	-
Others	-	-	-	-
Total	-	12 families	-	-

Type and Area of Land to be Acquired (Unit: ha)			
Residential Land	Cultivated Land	Public Land	Total
-	App. 7 ha	-	App. 7 ha

Note: This is a preliminary assumption

(Source: PLN)

The land has been freed up and compensation paid through the involvement of the village head and community leaders. In interviews with the head of Suli village, the village head has observed that land prices have been agreed by all owners and the compensation process has been going well. Thus, there are no problems in terms of land acquisition.

V.2.3 Socioeconomic Survey

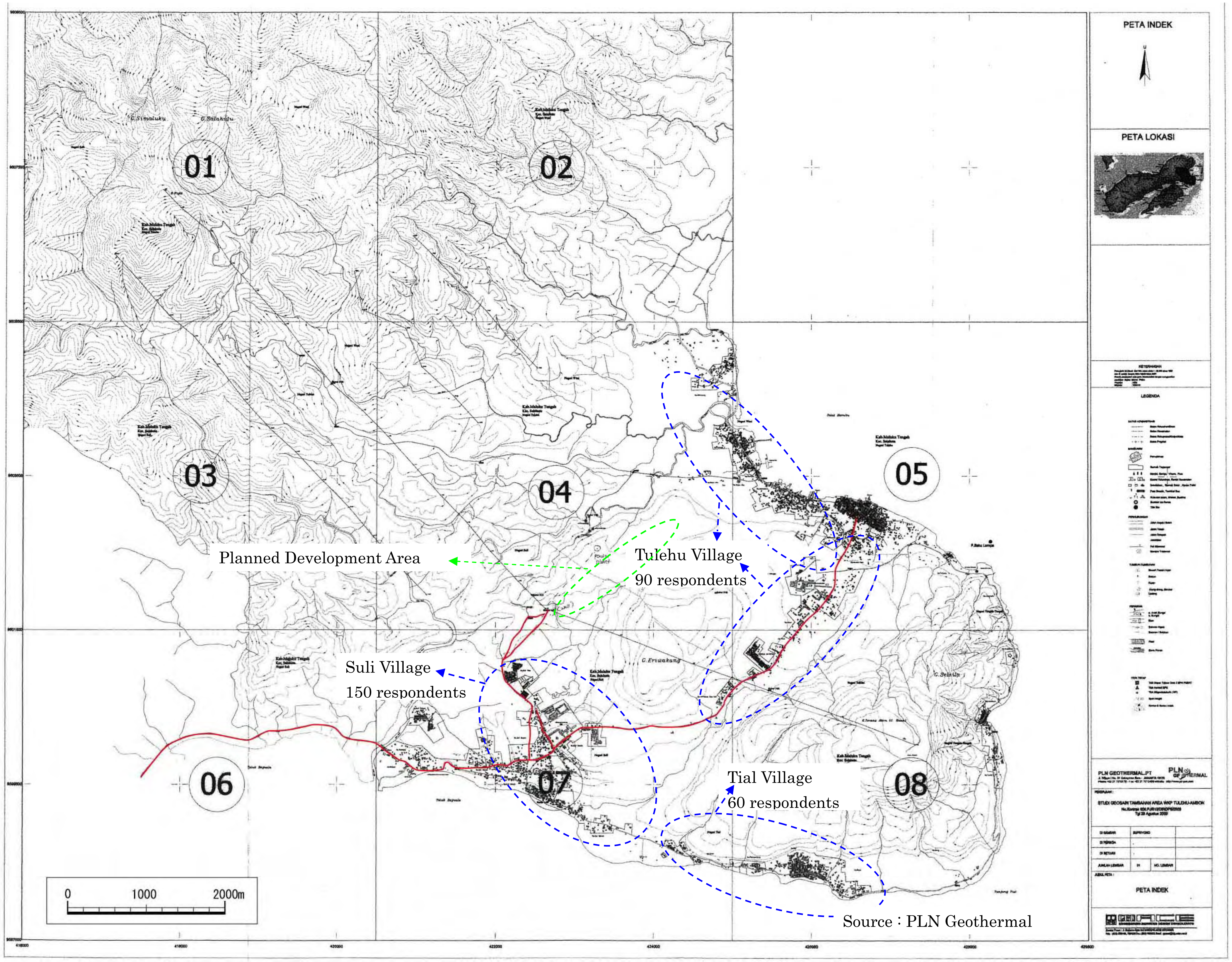
1. Survey Method

A socioeconomic survey of the study area using a questionnaire and field observations was conducted from October 2 to 7, 2010. In total 300 responses were received, consisting of 150 responses from Suli village, 90 responses from Tulehu Village and 60 responses from Tial Village (Fig. V-2-11). Suli village is the village where the powerplant will be located, while Tulehu and Tial are two nearby villages where impacts will be felt. Purposive method sampling was used for the survey, with the target group being households, so that each household is a respondent.

2. Identification of Respondents

Respondents consisted of 216 men and 84 women, 160 of them Moslem and 140 Christian. Most of respondents (> 70%) had lived in this village continuously for 10 – 40 years, while only 13% - 18% of respondents had lived there for more than 40 years. Family sizes varied as follows:

- 30% - 35% of respondents had families consisting of 1 to 2 people;
- 50% - 60% of families had 3-5 members and
- 18% of respondents had a family consisting of more than 6 people.



Source：PLN Geothermal

Fig. V-2-11 Location of Socioeconomic Survey Villages

3. Survey Results

a. Education

The education level of the respondents showed that 99.5% of the respondents in Suli Village are literate, with only 0.5% illiteracy, while all the respondents in Tulehu and Tial Village are literate. 46 to 56% of respondents had completed senior high school ; 23 - 34% had completed junior high school; 7 to 10% had graduated from primary school and 6% had graduated from college. Most respondents studied in the public schools (70 - 80%), while the other 20 – 30% studied in private schools or religious schools (called Madrasahs or Church schools).

b. Economic Conditions

In Salahutu Subdistrict most of the people are farmers, especially cassava farmers, coconut farmers, clove and nutmeg farmers. The main plantation food crops are cassava and sweet potatoes; there are no rice fields in this area. In line with this, the main source of income for 80 to 90% of the respondentsis from farming activities (as farmers), while the rest work as private employees or civil servants. Only 3 - 4% of them had no steady job or were looking for work. Some respondents earn additional income from collecting eucalyptus leaves that grow abundantly in the jungle-forest around settlements. In a day, each family can collect 40-50 kg of eucalyptus leaves, which are then sold at a price of Rp. 500/kg.

92 - 98% of respondents stated that the heads of household (fathers) make the largest contribution to family income, with only 2 - 8% saying that the biggest contribution comes from the mother's income. Families who declare income from the mother are mostly single-parent families consisting of a widow and her children. In general, respondents felt that economic conditions for their families are better this year than in the previous year. However, 15 to 25% of respondents reported that the family economic situation is worse this year than it was last year. Only 10 to 15% of the respondents stated that economic conditions this year are similar to those prevailing last year. Some respondents complained that the government did not care about them, that some roads are in poor repair, and that the price of food has risen sharply, making it difficult for them to have enough food for their family.

Moreover, the number of respondents declaring that they feel better about life this year than last year varies from village to village. 80% of respondents in Suli Village said that economic conditions for their families were better than last year, while only 40% of respondents in Tulehu Village and Tial Village said conditions were better than in the previous year. Similarly, the Tulehu and Tial villagers felt national economic conditions have not changed much from the previous year. The respondents in Suli Village are more optimistic: more than 70% of them said that the economic situation of the people is better compared to last year. 48% of respondents in Tulehu Village and 40 % in Tial Village felt that economic conditions are worse now than they were last year.

c. Land and House Occupation

Most respondents (73 to 82%) occupied houses on their own land, with only 7 to 8% stating that they occupied a rented house, and 13 to 20% saying that their house was not built on their own land, but they paid no rental fees because it belonged to a relative. 2 to 8% stated that they were only staying in the area temporarily. The houses which 58 to 69% occupy are simple 1 or 2-room wooden houses without bedrooms, 22 to 32% occupied homes with 3 to 4 rooms (1 to 2 bedrooms), while only 7 to 8% have a house with 5 to 6 rooms (3 to 4 bedrooms).

Most families own relatively little land, especially for respondents in Suli Village. More than 70% of the respondents said that they have less than 0.5 ha of land; 15% declared that they have 0.5 to 1 ha, and 12 - 16% stated that their land was larger than 1 ha. Residents who have little land of their own cultivate other people's land with permission, but free of charge. The main of commodities cultivated are : cassava, corn, groundnuts, bananas, and some fruit and vegetables.

d. Access to Clean Water

90% of the respondents in Suli Village entirely stated their source of water for domestic uses, especially for drinking and for cooking, comes from shallow wells (surface water) and, when there is a long dry season, they take water from the rivers. In Tulehu and Tial Villages, 88% of respondents take water for domestic use from the river, and 12% use water wells.

e. Perception of the Project

40 to 55% of the respondents who live in Suli village stated that they had received information about the project plan, and 45 to 60% claimed they did not know about the project. More than 70% of respondents who live in Tulehu and Tial Villages did not know about the project development. 45 – 60% of respondents who knew about the project said that they received project development information from stakeholder meetings held in the office of the Raja (village head) by PLN Geothermal. Other respondents learned about the project from consultants during their preparation of the Geothermal plant generation feasibility study. Respondents who knew about the existence of the project plan, declared that the development plans of PLTP in their village were satisfactory, because they realize they need electricity to improve their living standards, and they also need jobs.

In line with this, the community wished to see the project give some development assistance to their village or increase their income. 54 to 82% of respondents suggested developing water piping and road infrastructure and creating job opportunities.

Other respondents (About 35 – 55 %) also expect they will have free or cheap electricity, if PLTP develops a power plant in their village. Another 25 - 32% hope they will have a job working on the project. 74 - 82% of respondents are opposed to the project using labor from outside, especially in positions that can be filled by local hiring.

Many of the respondents were not satisfied with the information that they received either casually or through the attending the stakeholders' meeting. 75 - 80% of respondents felt that information regarding PLTP provided by the speakers was incomplete, and that there was only very limited time. The community insisted that they want to know more, particularly about waste from the Geothermal plant, about water use, and about the benefits of the project for the surrounding communities.

A number of respondents who were absent from the stakeholders' meeting argue that they they were not invited or did not receive information regarding the meeting. This is perhaps due to the fact that the invitations to the stakeholders' meeting were not distributed until just a few days before the event.

V.3 Environmental Impact Assessment and Mitigation Measures

V.3.1 Selection of Items for Environmental Impact Assessment

Based on the results of field reconnaissance, confirmation of the UKL and UPL prepared by PLN, as well as the characteristics of the area and the project, the environmental items that may be affected by implementation of the present project and descriptions of the possible impacts are listed in Table V-3-1. For items on the list where the impact might be significant (those with an A rating), impact analysis and mitigation measures are presented in the next section.

Table V-3-1 Selected Items in the Environmental Impact Forecasts and mitigation measures

Environmental Item	Rating	Impact Analysis	Mitigation Measures
Air quality （H_2S）	A	The H_2S in the emissions from the cooling tower of the power plant may affect the environment in the villages around the planned project site. Although a predicted value for H_2S emissions is included in the UKL and UPL, the basis for the data used in the predictive calculation is unknown. It will therefore be necessary to reexamine the impact of H_2S after the final project plan has been confirmed.	To be studied in the next section.
Water quality	A	There are rivers and ponds near the planned site. Muddy water generated during well drilling, as well as wastewater generated during the operation of the power plant, may affect the water of the rivers and ponds.	To be studied in the next section.
Noise	A	There are villages and a hot spring around the planned site that may be affected by the noise of the geothermal fluid being ejected during the exploration stage, and by noise generated by construction machinery. However, since this noise will be temporary, the impact on the environment is considered to be insignificant. During the operation period, noise from power plant facilities such as the cooling tower, steam turbine and generator may affect the environment in the nearby villages.	To be studied in the next section
Soil contamination	B	In the exploration stage, when the reinjection facilities have not yet been completed, geothermal	The geothermal hot water will be temporarily stored

		hot water may leak out around the exploration well and contaminate the soil.	in an impermeable reservoir. After the reinjection facilities have been completed, the water will be reinjected underground through the reinjection wells.
Waste	A	Industrial waste (excavation sludge and waste materials) will be generated during construction. Civil engineering work will generate spoil, for which methods to reduce the volume and for appropriate disposal to the spoil bank need to be studied.	To be studied in the next section.
Water use	B	The use of water for well drilling and civil engineering work, as well as for water intake for power plant operation during the in-service period, may affect the river discharge and pond water levels.	Water resources (ponds, rivers and groundwater) will be monitored, and water intake will be limited to a level that will not cause significant changes in the river discharge or pond water levels.
Fauna, Flora and ecosystem	B	The existence of protected species, such as rare or indigenous species, has not been confirmed around the planned project site. The scheduled site is surrounded by fields with low trees and grass, and by groves of sago palm. With obvious human intervention already in place, the environment presents little in the way of unaltered nature. The effect of implementation of the project on the fauna, flora and ecosystem is considered to be insignificant. Construction will involve almost no modification of the aquatic environment, and implementation of water quality maintenance measures will minimize the effect of effluents on the water areas. Therefore, impact on organisms in the water areas is expected to be insignificant.	Special considerations are unlikely to be called for. However, if conditions that may be affected by the project are found, care will be taken to conserve the habitat of fauna and flora when implementing the construction work.
Forests and natural reserves	D	In the study area, there are no forests or natural reserves where development is restricted.	—
Involuntary resettlement	D	Implementation of the project will not involve resettlement of residents.	—

Land acquisition	B	1) According to the UKL and UPL, the present project requires a total of approx. 7 hectares of land. 2) All lands at and around the planned project site are the private property of twelve owners. 3) All these lands are unused cultivable lands. 4) PLN has already acquired one hectare and borrowed another one hectare of the land for the project. In the future additional pieces of land will be purchased gradually as needed. 5) The land owners have no particular objection to the present project. 6) Since all of the land needed for the planned site is unused and some owners of the land live outside the project region, the effect of land acquisition on the lives of local residents is considered to be insignificant.	For anyone affected by the land acquisition, efforts will be made to help them secure their livelihood through such measures as preparation of alternative land or, as needed, preferential employment on the project.
Minorities and indigenous peoples	D	No minorities or indigenous peoples live in the study area.	—

Ratings:
A: Serious impact is expected,
B: Some impact is expected,
C: Extent of impact is unknown,
D (or No Mark): No impact is expected. IEE/EIA is not necessary.

(Source: JICA Team)

V.3.2 Study of Pollution Control Measures

1. Environmental Impacts and Mitigation in the Exploration and Drilling Work Phase

a. Air Pollution and Mitigation

(1) H_2S

The volume and components of gas and steam produced from the drilled wells vary depending on the location, pressure of the reservoir, brine temperature conditions, and other such factors. Monitoring and measuring of the geothermal discharge is necessary to evaluate the volume, temperature and other such data concerning the steam that can be collected from the geothermal reservoir. During this testing period, H_2S contained in the geothermal fluid is likely to affect the surrounding environment. Some temporary impact will be considered to the surroundings of H_2S contained in the gaseous discharge during the test wells.

(2) Recommendation Mitigation

The test well will be connected with the facilities immediately upon completion of testing and will not be left open.

b. Noise and Mitigation

(1) Noise

Noise to be considered includes that emitted from the operation of well-drilling machinery (generators, mud-water discharge pumps, compressors, etc.) and material/equipment transporting vehicles, and when steam is discharged from the well into the atmosphere.

(2) Recommendation Mitigation

For steam discharging into the atmosphere from the well, a silencer will be installed to reduce noise emissions and also to prevent hot brine dispersion.

c. Water Pollution and Mitigation

(1) Effluents Discharge

A small amount of muddy wastewater and hot water separated from the well will be generated during drilling work. There will also be sewage water including human waste generated during drilling work.

(2) Recommended Mitigation

Muddy wastewater produced during the drilling work period will be stored in a sludge pond, lined so that it is impermeable, to allow for evaporation or discharge of the upper clear portion. In addition, hot water separated from the wells will be temporarily collected in an impermeable reservoir and returned deep underground through reinjection wells. However, sewage water should be no problem since the amount will be small and it will be properly treated at the site.

d. Solid Waste and Mitigation

(1) Drilling Mud

Well drilling will generate mud waste, which experience suggests will be around 200 to 300 cubic meters per well.

(2) Recommended Mitigation

The mud waste produced by excavation will be collected in the sludge dam, which is lined for impermeability, to allow for evaporation. Thereafter, the sludge will be disposed of properly in accordance with applicable regulations (Government Regulation Number 74 Year 2001 concerning Hazardous and Toxic Material Waste Management).

2. Environmental Impacts and Mitigation during the Construction Work Phase

a. Noise and Mitigation

(1) Noise

Noise to be considered during construction is that emitted from construction machinery and material/equipment transporting vehicles.

(2) Recommended Mitigation

Efforts should be made to minimize noise by such means as selecting low-noise types of construction machinery as far as possible and avoiding a concentration of noise-emitting work.

b. Water Pollution and Mitigation

(1) Effluent Discharge

In the construction stage, there may be construction effluents, and muddy water may flow when it rains. There will also be sewage water including human waste generated during the plant construction period.

(2) Recommended Mitigation

Muddy water during construction is collected in a settling pond to settle the mud, and then discharged. However, a septic tank should be installed during the construction period to deal with the sewage water.

c. Solid Waste and Mitigation

(1) Solid Waste and Waste Soil

Scrap materials, excavation soil and other solid waste will be produced during the construction work phase.

(2) Recommended Mitigation

At the construction site, scrap materials and construction waste will be sorted by category and placed in designated containers. Recyclers will then collect metals such as pipes, wires, and hardware. Non-metal scrap materials and waste including plastic, vinyl, and glass will be disposed of according to the applicable regulations (Government Regulation No. 74, 2001). Such construction debris as concrete and bricks will be collected in a spoil bank set up at the site and then properly disposed of. Excavated soil will be used within the premises for backfilling the foundation work, construction of related facilities, ground preparation for plants and trees, and other such purposes. Effective recycling and utilization of materials should be promoted to reduce waste in general.

3. Environmental Iimpacts and Mmitigation in the Ooperation Pphase

a. Air Pollution and Mitigation

(1) H_2S

The substance that may cause atmospheric contamination and a foul odor during geothermal power plant operation is hydrogen sulfide (H_2S). No data indicating H_2S concentration levels in the geothermal fluid are presently available. Therefore, it is necessary to forecast and evaluate the impact the project may have on the surrounding environment based on the H_2S concentration levels in geothermal fluid to be identified in future investigation and detailed specification of the geothermal power plant by simulation of a H_2S dipersion model or wind tunnel experiment.

(2) Recommended Mitigation

Hydrogen sulfide (H_2S) in the geothermal steam will be extracted from the condensers using the gas extractor, sent to the cooling tower and discharged into the atmosphere from the top of the tower where it is diluted and dispersed. This type of treatment is standard practice in geothermal power plants around the world, and in most cases can sufficiently reduce the H_2S concentration at ground level. However, a detailed evaluation should be carried out based on the maximum ground concentration of H_2S calculated through diffusion simulation (the H_2S simulation is implemented by project executing agency, PLN in the ES).

Comparisons with other geothermal power plant in Japan for the volume of H_2S emission and the maximum ground concentration level i made by a wind tunnel experiment are given in Table V-3-2 for reference.

(3) Other

In Indonesia, the environmental standards for H_2S odor levels are stipulated under Ministry decree KEP-50/MENLH/11/1996. In addition, the standard value for H_2S emissions from stationary sources is set forth in Ministry decree KEP-13/MENLH/3/1995, and the H_2S concentration level in emissions from geothermal power plants is regulated (Table V-3-3). The odor level standards will apply even to areas with no housing and to geothermal manifestation areas such as hot springs, as the decree does not designate particular areas where the standards should apply. However, these areas are exempt from such standards in most other countries where environmental standards for odor levels have been established.

There will be a serious problem that the Ministry Decree does not specify the evaluation time for the standard. Generally, it is considered that odor should be evaluated at a moment (of a few seconds) concentration but if the said standard should be applied, the evaluation period becomes uncertain. According to “Air Quality Guidelines, Second Edition of WHO, a H_2S impact to a human body should be less than 150μg/m^3 in average of 24 hours. Thus, it is desirable to evaluate H_2S impact to the surroundings according to the WHO guidelines.

Table V-3-2 Wind Tunnel Experiments of H_2S Emission and Maximum Concentration of H_2S from Individual Geothermal Power Plants: 55 MW x 2

Output of Power Plant (MW)	H_2S concentration at cooling tower outlet (ppm)	Tunnel experiments		
		Volume of H_2S emission(m^3N/h)	Distance of appearance of max. H_2S con.(m)	Max. H_2S concentration at ground level (ppm)
A (27.5)	Approx.62 (summer) Approx. 120 (winter)	Approx. 58	100~500	0.030~0.060
B (50)	Approx. 14 (summer) Approx. 120 (winter)	Approx. 140	100	0.006~0.008
C (65)	Approx.49 (summer) Approx. 110 (winter)	Approx. 720~730	300~800	0.141~0.193
D (55 × 2)	Unit-1: 8.0~10.3 Unit-2: 6.1~7.3	Unit-1: 65 Unit-2: 63	100~300	0.0063~0.0066 (110 MW)
E (30)	Approx. 21(summer) Approx. 20 (winter)	Approx 83	~240	N.D~0.0006
F (50 & 30)	Unit-1: 2.9~11.6 Unit-2: 2.7~7.0	Unit-1: Approx 41 Unit-2: Approx 23	120	0.091~0.009 (80 MW)

Source: Haraguchi, “Chinetsu”, Vol.32 No.1 (Ser.No.136), p57-69, 1995

Table V-3-3 Hydrogen Sulfide Standard in Indonesia

Item	Unit	Hydrogen sulfide (H_2S)
Gas Exhaust Standard1) (Total Reduced Sulfur)	mg/ m^3	35
Odor level Standard2)	ppm	0.02
WHO Air Quality Guideline3)	ug/m^3	150

Source : 1) Decree of the State Minister for Environment concerning Emission Standards for Stationary Sources (KEP-13/MENLH/3/1995))

2) Decree of the State Minister for Environment concerning Offensive Odor Level Standards (KEP-50/MENLH/11/1996)

3) The World Health Organization air quality for Europe (second edition) 2000.

b. Noise

(1) Prediction of Noise

There are villages and hot spring facilities around the planned site for this project, and the impact of noise from the power plant needs to be confirmed（Fig V-3-1）. Among the geothermal power plant’s power generating equipment and facilities, the main sources of noise include the steam turbines, generators, condensers, cooling towers and cooling tower fans. Measurements of noise at existing geothermal power plants indicate that the cooling tower emits the highest noise levels of these possible noise sources.

An impact prediction for noise from operation of the geothermal power plant to be constructed in the present project was performed at the nearest private home and nearest village. The prediction sites and conditions are shown in Table V-3-4. For this prediction, the project cooling tower was chosen as the noise source. This choice was based on reviews of noise levels from major sources in existing 20 MW geothermal power plants with capacities identical to the planned power plant. The measured levels from these existing 20 MW geothermal power plants were used for the predictions. The predicted level of noise from operation of the power plant was 52 dB at the hot spring site, and 48 dB at Suli village.

(2) Assessment

Compared with the survey results concerning current noise levels 47 dB(24hr), the predicted level is 5dB higher at the hot spring site and the predicted level is 1dB higher at the Suli village site, and meets the environmental standard (< 55 dB) for residential areas in Indonesia. Therefore, noise from the operation of the power plant to be constructed is likely to have only a minor impact on the nearest private homes and villages.

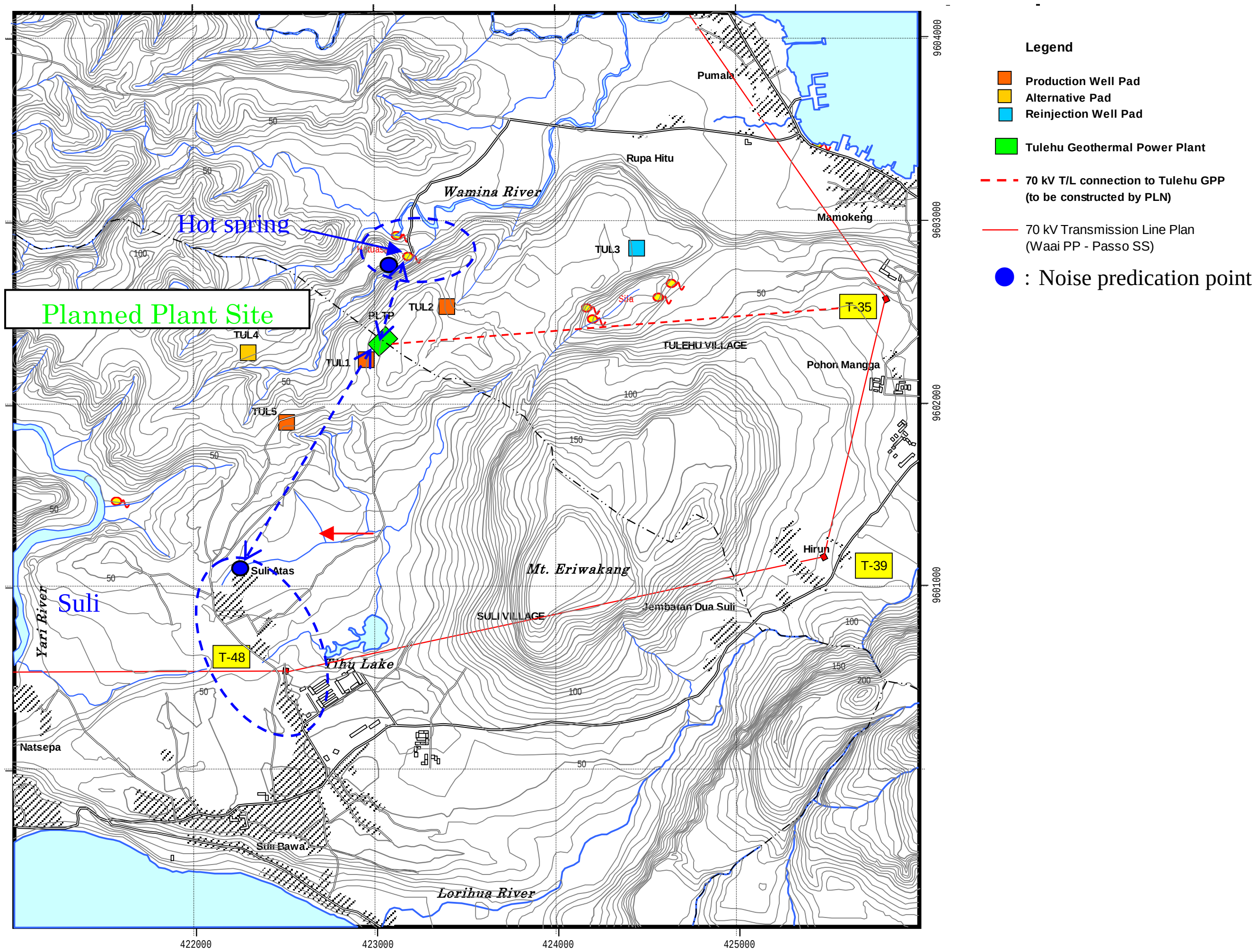


Fig. V-3-1 Noise Prediction Points

Table V-3-4 Prediction points and conditions

Item		Contents
Prediction points		Hot spring and Suli Village
Distance from the Site		Hot spring：About 700m Suli Village：About 1,300m
Sound source		Planned Geothermal power plant site
Prediction condition		Consideration only of the distance decrease and atmospheric absorption
Existing Environmental noise		47dB（24hr）
Predicted level	Suli Village	48dB
	Hot spring	52dB
Environmental standard*		55dB(Residential and Settlement)

*: Noise level of quality standards in accordance with the decision of the Ministry of Environment. No. Kep.48/MenLH/11/1996.

(Source: JICA Team)

c. Water Pollution

(1) Effluent Discharge

Liquid effluents to be discharged from geothermal power plants are hot water separated by a steam-water separator, cooling water effluent from cooling towers, and general wastewater. The separated hot water will be returned underground through reinjection wells.

(2) Recommended Mitigation

The cooling tower overflow (geothermal steam condensate) does not contain impurities. and therefore, its reuse is recommended. If it is not reused, it will be returned underground through reinjection wells as is done for separated hot water. Wastewater containing oil or other substances will be collected in the sump pit, and after the oil is separated or appropriately treated by other means, will either be reused or returned underground as is done for separated hot water.

d. Waste and Mitigation

(1) Waste

Waste generated in the course of plant maintenance and management includes general waste, cooling tower sludge, and waste oil. Consideration must be given to the treatment and disposal of such waste so as not to adversely affect the surrounding environment.

(2) Recommended Mitigation

i- General Waste

In the same manner as during the aforementioned construction phase, the general waste will be separated by material category, collected, and properly disposed of by recycling agents. Otherwise, wastes line concrete, brick, etc. will be collected in a spoil dump set up at the site in accordance with the applicable regulations (Government Regulation Number 74 Year 2001）.

ii- Cooling Tower Sludge

After drying up the sludge from water content, those cooling tower sludge will be collected in the sludge damp site, which has been lined for anti-infiltration, set up at the site in accordance with the applicable regulations（Government Regulation Number 74 Year 2001） and will never be left untreated.

iii- Waste oil

Turbine oil and lubricant oil will be stored in a drum and handed over to a professional company regularly in accordance with the applicable regulations （Government Regulation Number 74 Year 2001）.

V.4 Study of Alternative Plans

V.4.1 Alternative Plans

There are single flash and double flash system plans for the project, as described below. This section examines the environmental impact of these plans.

- 2 x 10 MW Single Flash System
- 1 x 20 MW Single Flash System
- 1 x 20 MW and 2 x 10 MW Double Flash System

The results of studies of the alternative plans are summarized in Table V-4-1.

Table V-4-1 Results of Studies of the Impact of Alternative Plans

Environment Impact Items	2 x 10 MW Single Flash System	1 x 20 MW Single Flash System	1 x 20 MW and 2 x 10 Double Flash System
	Current PLN Plan	FS Plan	FS Plan
Air Pollution(H_2S)	A	A	B
Noise	A	B	B
Water Pollution	B	B	B
Waste	A	A	B
Natural Environment	A	A	B
Involuntary Resettlement	C	C	C
Land acquisition	A	B	B
Local Economy, such as Employment and Livelihood, etc	B	B	B

Note : The double flash systems are treated in one category as the impacts are considered identical

A: Serious impact is expected

B: Some impact is expected

C: No impact is expected

(Source : JICA Team)

V.4.2 Comparison between the Zero Option and Implementation of the Present Project

In the present project region, the major power source is diesel power generation, and the existing diesel power plants have been the cause of serious environmental problems. The present project will construct a geothermal power plant as a supply source to replace some of the existing diesel power plants. If the present project is not implemented, the following can be predicted:

- Environmental pollution will worsen, as the variety of environmental problems attributable to diesel power plants cannot be remedied.
- Due to a shortage of electric power, coal-fired thermal power plants are under planning and additional diesel power plants may be constructed, which will increase the environmental loads in many parts of the region, and negatively impact (dusts, SPM, NOx Sox and other thermal discharge) the residents' living environment.
- Diesel power generation will continue, causing increased CO_2 emissions and above mentioned harmful substances.

Table V-4-2 uses a matrix to compare the predicted results of not implementing the project with the predicted results of replacing some diesel power generation by implementation of the project plan.

Table V-4-2 Comparison between the Zero Option and Present Project Implementation

Environment Impact Items		Zero option	Implementation of the plan
Air Pollution	NOx, Sox	--	++
	H_2S	0	--
Noise		--	-
Water Pollution		--	-
Natural Environment		0	--
Land Use and Utilization of Local Resources		--	++
Involuntary Resettlement		0	0
Local Economy such as Employment and Livelihood, etc		0	++
Waste		--	-
Global Warming		--	++
Cost		--	++

When the diesel power and alternative geothermal power are respectively compared with the current environmental conditions:

-- worse ++: better -: insignificantly worse +: insignificantly better 0: no change

(Source : JICA Team)

V.5 Transmission Lines

V.5.1 Items Having Environmental Impacts

A 70-kv transmission line is scheduled to run from the planned project site and be directly connected to the transmission tower to be constructed at point T-35 (See Fig.V-2-1). The laws of Indonesia require a UKL and UPL for transmission line construction, and PLN plans to prepare them. In general, the major items having an environmental impact associated with the construction and operation of a transmission line are the following four items:

- Resettlement of residents living on the planned route
- Effect on fauna and flora during the construction stage (civil engineering work, tower construction work, etc.)
- Effect on water quality during the construction stage (civil engineering work)
- Effect on fauna (birds) during the in-service period of the power plant (operation)

V.5.2 Current Environmental Conditions

Although a final plan has not been formulated for the transmission line route, it is known that there is no forest or protected natural reserve near the tentatively planned route. According to the local environmental bureau there are no protective species living or growing in the planned area. As with the planned plant site, fields of low trees and grass with groves of sago palm are seen in the area around the planned transmission line route. With obvious human intervention already in place, the environment presents little in the way of untouched nature, and the likelihood of precious species of fauna and flora is very slight. There are no houses on the planned transmission line route, and no rice paddies or other farmlands are seen around it.

V.5.3 Prediction and Assessment

Predictions and assessments of environmental impacts that the transmission lines may have are shown in Table V-5-1.

Table V-5-1 Prediction and Assessment of T/L Environmental Impacts

Items	Construction stage	Operation
Resettlement	Construction of the transmission line does not involve resettlement of residents, as there are no houses on the planned route.	—
Fauna and Flora	There are no precious species living or growing around the planned route, and the area of land modified by the construction of a 70-kv transmission tower will be only about 20 m x 20 m. Therefore, the effect of transmission line construction on fauna and flora is considered to be small.	There is no large-bird habitat around the planned transmission line route, and the area is not confirmed to be on the migratory routes of large birds. The existence of a transmission line is thus not expected to affect birds.
Water Pollution	In the construction stage, there may be construction effluent, and muddy water may flow when it rains. However, special consideration will be unnecessary because the impact will be temporary, with only a small area of land being modified and a small amount of construction effluent.	—

(Source :JICA Team)

The environmental items and possible impacts that are considered to be important in association with the construction and operation of the transmission line are stated in this section. However, when the final transmission line plan is settled, each of these items should be reconsidered in the UKL and UPL.

V.6 Explanation to the Local Stakeholders

The Stakeholders' Meeting was held on Saturday, October 2, 2010 at the office of Suli village Head. The consultation was chaired by Head of Suli Village, and attended by indigenous leaders (called "Saniri") of Suli village and community representatives, a representative of PLN headquarters (dispatched from Jakarta), a representative of PLN Maluku Region, and consultants from West JEC and Amythas Experts and Associates, PT. The total number of participants was approximately 55.

In the opening speech of the stakeholders' meeting, Head of Suli village delivered some direction. He urged that that the development of the geothermal power plants which will be located in the area of the village of Suli is very important both for society and also for the Province of Ambon as a whole. He explained that in the morning traditional ceremonies had been held, and that now the stakeholders' meeting followed. He reiterated the view that the project will bring much benefit to communities but also have some negative impacts, especially from construction, mobilization of heavy equipment etc. At this time he invited positive support from all of the communities, and requested the participants to listen to the information to be delivered by PLN headquarters regarding the project.

After the opening speech, PLN Geothermal briefed the meeting regarding the overall project. In his briefing, he said that research into the geothermal potential in this region has been carried out since 1990 and that a project named Project Geothermal Tulehu was finally green lighted by a presidential directive (IMPRES). He said that people who live along the entrance road to the project as well as people in Banda Baru will experience negative impacts during the construction (drilling) and mobilization phase. Now we are in exploration phase, he said. If the results of exploration are encouraging, then we will continue to the exploitation of geothermal to utilize in power plants. Therefore, he asked the community for support.

During the period of activity, he explained, negative impacts such as noise, increased dust, and road damage would certainly occur. PLN will seek to minimize these impacts by mobilizing heavy equipment at night and will repair the road after the activity ends, he said. After his briefing, the chairman asked participants to give any comments or ask any questions they might have. Four participants had the following questions or suggestions:

In addition, it will be necessary to hold a stakeholders' meeting in Tulehu village for residents around the project site regarding power plant construction and the drilling of wells. After determining the project's specific plan before the construction, PLN Geothermal plans to hold a stakeholders' meeting in Tulehu village.

1) The head of RT 08 (RT: a group usually consisting of 30 or 40 houses in a village)
   He supports the development of a geothermal power plant in Suli, and requested that the project's name be changed from Tulehu to Suli, because the activity is not in Tulehu. He urged that mobilization be carried out at night, because during the day it is likely to cause traffic accidents. In addition he asked who would be responsible, if there is a negative impact.
2) Community Representative
   He requested that the project name be changed to Suli, and asked how much was being invested in the project.
3) A Banda Baru resident
   He requested that the project recruit employees from Banda Baru Village where the project is located.
4) Community Representative
   He expects that the project can be of benefit to the poor in Suli Village, and worried about the negative impact like the incident in Sidoarjo Lapindo.

In answering these questions, PLN Geothermal said in addition:

1) The problem is that it is not simple to change the name of project, because of its implications for continued financing and construction and operating permits. Therefore he asked that this problem be left unresolved during exploration, but said that, if the project proceeds to exploitation, then the name of the project will be tailored to the will of the community. In this connection, he asked the communities to begin to consider the name they would prefer for the project.
2) In regard to who will be held responsible if there is a negative impact, he said that, in general, PLN will responsible, but it will be necessary to consider why the impact occurred and as a result of what activity. If the impact is caused by contractor negligence, then it would be the contractor who is held responsible.
3) Regarding labor, he said that local labor meeting the necessary criteria and having the necessary skills for the project will be hired where possible.
4) There will certainly be benefits to Suli Village in the form of employment for those with the necessary skills and in the form of an indirect boost to the regional economy with the opening of business opportunities.
5) In regard to the development for project, he said that the development of geothermal power requires huge investments. Therefore he asked for the all the residents to support these activities which could bring great benefits to the people of Maluku.

V.7 Environmental Management Plan

Table V-7-1 shows the environmental management plan

Table V-7-1 Environmental Management Plan

Construction phase			
Items	Management Content	Recommend Frequency	Responsibility
Hydrology	・ For all new abstractions. identify any local users immediately downstream	Within a month	Project manager (Executing Agency: EA) and Contractor
	・ Choose abstraction rate and timing to minimize impacts on water course ・ Record quantity of water abstracted and timing of abstractions	Daily (Abstraction Period)	
Surface water	・ Ensure adequate capacity of treatment ponds to safely manage quantities of waste water arising. ・ Ensure integrity of the pond lining and maintain treatment system.	Daily (Abstraction Period)	Project Manager(EA), Contractor, and Environmental, Consultant
	・ Monitor water quality.	Quarterly	
Air Quality	・ Set and implement speed limit. ・ Traffic management plan, adapt route and operating hours	Ongoing during construction	Project Manager(EA), and Contractor
	・ Water spraying if required	If required based on monitoring	
	・ Minimize/avoid vertical tests. Plan and inform the community. ・ Minimize duration of horizontal tests. Locate atmospheric flash tanks away from receptors	Prior well testing.	

Noise	• The construction contractor will demonstrate best practicable means based on site layout, selection of plant, working practices and limiting working hours in accordance with Government requirements. • If required to use silencers and / or acoustic barriers if noise levels exceed the limits for prevention of nuisance. • Local community to be notified in advance of any particularly noisy activities. • Schedule road traffic movements to avoid noise sensitive periods (e.g. Night-time). • Route traffic away from noise sensitive receptors.	Throughout drilling / construction phase	Project Manager(EA), Contractor, Environmental Consultant
	• Noise monitoring and mitigation measures will be implemented to demonstrate compliance with relevant standards and guidelines.	Monthly	
Waste	• Develop a Waste Management Plan which specifically identifies measures for minimisation of waste and safe disposal of construction wastes. • Monitor, segregate, collect, store and dispose of all solid waste generated. • Segregate, inventory and recommend disposal methods for waste generated during plant operation. • Test for their chemical characteristics and toxicity to determine disposal means.	Throughout drilling / construction phase	PLN-GE to communicate framework WMP, Contractors to develop and implement
Power Plant Operation			
Items	Management Content	Frequency	Responsibility
Water Quality	• Monitor power plant discharge water. • Manage processed waste water septic tank • Monitor river water quality.	Once two months	Project Manager(EA), Environmental Consultant
Air Quality Impairment	• Monitor H2S to houses and village site	Quarterly	Project Manager(EA),
	• Assess cumulative impacts of H2S	Once a week for	

	emissions • Measure and monitor NCGs.	cumulative measurements and NCGs.	Environmental Consultant
Noise	• Continue noise level monitoring of the site boundary compliance with PT.PLN standards	Once/two months	PLN-GE, Environmental Consultant Project Manager(EA); Contractor.
	• Provide and enforce use of PPE	Random	
Waste	• Segregate, inventory and recommend disposal methods for waste generated during plant operation. • Test for their chemical characteristics and toxicity to determine disposal means. • Deploy drip trays while maintaining power plant equipment. • Maintain oil interceptors.	Monthly.	PLN-GE

V.8 Environmental Monitoring Plan

The UKL and UPL prepared by PLN for the present project contain no plans for the monitoring of water wells in Suli village near the project site, or at hot springs around the site. Table V-8-1 shows the environmental items for which monitoring is considered to be important during construction (including the well-drilling phase and ejection testing phase), as well as during the facility in-service period.

The Environmental monitoring is implemented by project executing agency, PLN. Environmental monitoring must be reported every 6 months to Office of Environmental Control of Central Maluku Regency and the related agencies.

Table V-8-1 Schematic List of Monitoring Items and Points of Attention

Environmental Impact Items		During Construction (include well operation)	During Operation
Air quality	Survey Item	H_2S emissions (during Geothermal drilling operations)	H_2S emissions
	Frequency	When appropriate	Twice a year
	Survey Points	Around the drilling fields and settled areas (Suli and Tulehu Village)	Around power plant sites and settled areas (Suli and Tulehu Village)
Noise	Survey Item	Noise Level at designated sites and settled areas	Monitoring noise emissions at designated sites
	Frequency	When appropriate	Twice a year
	Survey Points	Designated sites and settled areas (Suli and Tulehu Village)	Designated sites and settled areas (Suli and Tulehu Village)
Water pollution	Survey Item	Water quality and effluent quality of standard items	Water quality and effluent quality of standard items.
	Frequency	When appropriate	Twice a year
	Survey Points	Drilling effluent quality and settling ponds effluent quality Water quality of surface water (Waiyari rive , Waetatiri rive and Wamina rive: Upstream and downstream)	Effluent quality of cooling tower overflow and septic tank effluent Water quality of surface water Waiyari rive , Waetatiri rive and Wamina rive: Upstream and downstream)
Subsi-dence	Survey Item	Ground elevation, with monitoring from before inception of power plant operation.	
	Frequency	Early plant operation: once; During plant operation: annually	
	Survey Points	Around the power plant area (several points determined by the distribution situation of production wells TUL1, 2, 4 and 5),	
Hot spring	Survey Item	Amount of hot spring discharge, temperature and water quality	Amount of hot spring discharge, temperature and water quality
	Frequency	When appropriate	During early plant operation: twice During plant operation: twice a year

	Survey Points	Hot spring of Tulehu village (See Fig.V4-2-1)	ot spring of Tulehu village (See Fig.V4-2-1)
Ground-water	Survey Item	Ground water levels and water quality	Ground water levels and water quality
	Frequency	When appropriate	During early plant operation: twice During plant operation: twice a year
	Survey Points	Suli village wells (1 place) and Tolehu village wells (1 place)	Suli village wells (1 place) and Tolehu village wells (1 place)

(Source : JICA Team)

V.9 Environmental Checklist

The environmental checklist for Tulehu project is as follows.

Environmental Check List

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
1 Permits and Explanation	(1) EIA and Environmental Permits	(a) Have EIA reports been already prepared in official process? (b) Have EIA reports been approved by authorities of the host country's government? (c) Have EIA reports been unconditionally approved? If conditions are imposed on the approval of EIA reports, are the conditions satisfied? (d) In addition to the above approvals, have other required environmental permits been obtained from the appropriate regulatory authorities of the host country's government?	(a) Y (b) Y (c) N (d)	(a)UKL/UPL has been prepared. (b)UKL/UPL has been approved by Government of Central Maluku Regency (Approval letter No.660.21/PLH-III/2010, 12 March 2010). (c) The were 8 conditions on UKL/UPL approval letter. PT. PLN GE will take responsibility to follow these conditions (d)No other environmental permissions are required for this project.
	(2) Explanation to the Local Stakeholders	(a) Have contents of the project and the potential impacts been adequately explained to the Local stakeholders based on appropriate procedures, including information disclosure? Is understanding obtained from the Local stakeholders? (b) Have the comments from the stakeholders (such as local residents) been reflected to the project design?	(a) Y (b) Y	(a)A project briefing session for the local residents was held at the SULI village office on October 1, 2010, with the village head acting as the mediator. The main points of the project and predicted environmental impact during construction were explained, and the understanding and cooperation of the residents was obtained. (b)The residents' opinions will be closely considered, and will be reflected in the project as much as possible.
	(3) Examination of Alternatives	(a) Have alternative plans of the project been examined with social and environmental considerations?	(a) N	At the first stage we did not consider the other alternative such as the geothermal potential at Haruku Island located 7 km in front of Tulehu. Tulehu is the closest location from the load center (demand area, Ambon City) and the resource, and the project site of Tulehu was indicated, also there will be no significant negative impact of environmental and social there.
2 Pollution Control	(1) Air Quality	(a) Do air pollutants, such as hydrogen sulfide (H2S) emitted from geothermal power plants comply with the country's standards? Is there a possibility that the emitted hydrogen sulfide will have an impact on the surrounding areas, including vegetation? Are any mitigating measures taken? (b) Do air pollutants emitted from the other project facilities comply with the country's emission standards?	(a) Y (b)	(a)There is no data available. The project activity is still in the exploration stage (drilling activities, exploitation same as the above. 1) H_2S in the geothermal steam will be extracted from the condensers using a gas extractor, sent to the cooling tower and discharged into the atmosphere from the top where it is diluted and dispersed. This type of treatment method is a standard practice employed in geothermal power plants around the world, and in most cases can sufficiently reduce the H_2S concentration at ground level. However, a detailed evaluation should be carried out based on the maximum ground concentration of H_2S calculated through diffusion simulation. 2) Although H_2S level predictions were included in the UKL and UPL, the basis of the data used for the predictions is unknown. 3) In terms of H_2S, existing geothermal power plants meet the environmental standards with almost no impact on the environment around the plants. Therefore, although H_2S emission data for the present project is not available, H_2S is considered to be no particular problem as long as its emissions are within the levels of existing geothermal plants. (b)None of the geothermal power plant facilities output any air pollutant other than H_2S.
	(2) Water Quality	(a) Do effluents (including thermal effluent) from the project facilities, such as power generation facilities comply with the country's effluent standards? Is there any possibility that the effluents from the project will cause any areas not to comply with the country's ambient water quality standards? (b) In the case of geothermal power plants, is there any possibility that geothermal utilization will cause water pollution by toxicants, such as Arsenic (As) and Mercury (Hg) contained in geothermal fluids? If the water pollution is anticipated, are adequate measures considered? (c) Do leachates from the waste disposal sites comply with the country's effluent standards and ambient water quality standards? Are adequate measures taken to prevent contamination of soil, groundwater, and seawater by leachates? (d) Is there any possibility that effluent from well excavation would cause water contamination? If water pollution is anticipated, are adequate measures considered?	(a) Y (b) N (c) N (d) N	(a)Domestic sewage from the power plant facilities will be treated in a septic tank to be provided, while wastewater containing oil will be collected in a drainage tank to separate the oil from the water before draining. With these measures, the effluent standards can be met. (b) Geothermal hot water will not generate water pollution as it will be reinjected underground through reinjection wells. (c)There are no plans for a waste repository for the present project. (d)Effluent from well drilling will be stored in a reservoir provided with permeation prevention measures, and the effluent will be recycled for reuse.

Environmental Check List (Continued)

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
2 Pollution Control	(3) Wastes	(a) Are wastes generated by the plant operations properly treated and disposed of in accordance with the country's regulations? (b) Are wastes generated by the effluents from well-excavation properly treated and disposed of in accordance with the country's standards?	(a) Y (b) Y	(a)Sludge from the cooling tower and waste oil will be appropriately treated and disposed of in accordance with Government Regulation Number 74 Year 2001 concerning Hazardous and Toxic Material Waste Management. (b)Sludge generated by well drilling will be stored in a reservoir provided with permeation prevention measures, and will be appropriately treated and disposed of in accordance with Government Regulation Number 74 Year 2001 concerning Hazardous and Toxic Material Waste Management.
	(4) Noise and Vibration	(a) Do noise and vibrations comply with the country's standards?	(a) Y	(a)Monitoring of existing geothermal power plants of a scale (20 MW) identical to the present project indicates that the noise levels at neighboring villages meet the environmental standards. The predicted level of noise from operation of the power plant was 45 dB at the nearest village (Suli), and meets the environmental standards (Kep.48/MenLH/11/1996).
	(5) Subsidence	(a) Is there any possibility that the extraction of steam will cause subsidence?	(a)	(a)No ground subsidence has been reported in relation to existing geothermal power plants, though the impact of these plants on the ground is unknown. In order not to affect the shallow groundwater that could cause ground deformation, steel pipe (impervious tube) will be inserted deep underground in the production well and the gap between the pipe and the well wall will be cemented。 Consideration has been given to preventing ground deformation, and includes plans to reinject geothermal hot water deep underground via the reinjection wells.
	(6) Other	(a) Are there any odor sources such as H2S, and any anticipated effects? Are adequate odor control measures taken?	(a) Y	(a) See air quality (b)
3 Natural Environment	(1) Protected Areas	(a) Is the project site located in protected areas designated by the country's laws or international treaties and conventions? Is there a possibility that the project will affect the protected areas?	(a) N	(a)The project areas are not located in protected areas designated by the country's laws or international treaties and conventions.
	(2) Ecosystem	(a) Does the project site encompass primeval forests, tropical rain forests, ecologically valuable habitats (e.g., coral reefs, mangroves, or tidal flats)? (b) Does the project site encompass the protected habitats of endangered species designated by the country's laws or international treaties and conventions? (c) Is there a possibility that the project will adversely affect downstream aquatic organisms, animals, plants, and ecosystems? Are adequate protection measures taken to reduce the impacts on the ecosystem?	(a) N (b) N (c) N	(a)The project area is located in a traditional cultivated area that is privately owned. (b)We observed that there are no rare and endangered species defined by the Indonesian Laws and the International Union for Conservation of Nature and Natural Resources (IUCN's) Red List in or around the project area. (c)The mitigation of negative impacts on flora and fauna caused by the project will be done by minimizing the number of trees to be cut.There is no regulation governing trees after cutting in that area.
	(3) Topography and Geology	(a) Is there any possibility that the project will cause a large-scale alteration of the topographic features and geologic structures in the surrounding areas?	(a)	(a)The project will not cause large-scale alteration of topographic features and geologic structures.

Environmental Check List (Continued)

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
4 Social Environment	(1) Resettlement	(a) Is involuntary resettlement caused by project implementation? If involuntary resettlement is caused, are efforts made to minimize the impacts caused by the resettlement? (b) Is adequate explanation of compensation and resettlement assistance given to affected people prior to resettlement? (c) Is the resettlement plan, including compensation with full replacement costs, restoration of livelihoods and living standards developed based on socioeconomic studies on resettlement? (d) Is the compensation going to be paid prior to the resettlement? (e) Are the compensation policies prepared in document form? (f) Does the resettlement plan pay particular attention to vulnerable groups or people, including women, children, the elderly, people below the poverty line, ethnic minorities, and indigenous peoples? (g) Are agreements with the affected people obtained prior to resettlement? (h) Is the organizational framework established to properly implement resettlement? Are the capacity and budget secured to implement the plan? (i) Are any plans developed to monitor the impacts of resettlement? (j) Is a grievance redress mechanism established?	(a) N (b) N (c) N (d) N (e) N (f) N (g) N (h) N (i) N (j) N	No involuntary resettlement is expected due to the project, as the project is located in a cultivated area. (a) (b) (c) (d) (e) (f) (g) (h) (i) (j)
	(2) Living and Livelihood	(a) Is there a possibility that the project will adversely affect the living conditions of inhabitants? Are adequate measures considered to reduce the impacts, if necessary? (b) Is there a possibility that the amount of water (e.g., surface water, groundwater) used and the discharge of effluents by the project will adversely affect the existing water uses and water area uses?	(a) Y (b) Y	(a)the livelihood of the local residents will be affected adversely due to the construction and operation of the project. Compensation plans will follow the government regulations. Additionally, a Community Development Program of PLN (as part of the Corporate Social Responsibility/ CSR program of PLN) will be considered in our compensation plans in order to smooth the land acquisition process. (b)The project will not use much surface water in the operation stage compared with the construction stage. The amount of water used during operation by PLN GE will be in accordance with the standards. So there should not be a severe
	(3) Heritage	(a) Is there a possibility that the project will damage the local archeological, historical, cultural, and religious heritage? Are adequate measures considered to protect these sites in accordance with the country's laws?	(a) N	(a)There are no local instances of archeological, historical, cultural, and religious heritage that would be at risk.
	(4) Landscape	(a) Is there a possibility that the project will adversely affect the local landscape? Are necessary measures taken?	(a) N	(a)There are not any special landscapes, touristic places or scenic spots in or around the project site
	(5) Ethnic Minorities and Indigenous Peoples	(a) Are considerations given to reducing impacts on the culture and lifestyle of ethnic minorities and indigenous peoples? (b) Are all of the rights of ethnic minorities and indigenous peoples in relation to land and resources respected?	(a) N (b) N	There are no indigenous people or minorites in the project area. (a) (b)

Environmental Check List (Conitnued)

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
4 Social Environment	(6) Working Conditions	(a) Is the project proponent respecting any laws and ordinances associated with the working conditions of the country which the project proponent should observe in the project? (b) Are tangible safety considerations in place for individuals involved in the project, such as the installation of safety equipment which prevents industrial accidents, and the management of hazardous materials? (c) Are intangible measures being planned and implemented for individuals involved in the project, such as the establishment of a safety and health program, and safety training (including traffic safety and public health) for workers etc.? (d) Are appropriate measures taken to ensure that security guards involved in the project do not threaten the safety of other individuals involved, or local residents?	(a) Y (b) Y (c) Y (d) Y	(a)In the Bid Documents, PLN GE plans to include requirements for the contractors to comply with all laws and regulations on working conditions, and to present a compliance plan to this end. (b)The installation of safety facilities will be added to the design after the final plans for the project have been decided. (c)The requirements in the Bid Documents will include the formulation of safety and health plans and implementation of safety education for the workers and other people involved in the project. (d)The requirements in the Bid Documents will also include compliance with public morality and the maintenance of good community relations. In addition, PLN GE means to instruct the contractors to take appropriate measures toward these ends.
5 Others	(1) Impacts during Construction	(a) Are adequate measures considered to reduce impacts during construction (e.g., noise, vibration, turbid water, dust, exhaust gases, and wastes)? (b) If construction activities adversely affect the natural environment (ecosystem), are adequate measures considered to reduce the impacts? (c) If construction activities adversely affect the social environment, are adequate measures considered to reduce the impacts?	(a) Y (b) Y (c) Y	(a)The main impact during construction is air pollution, especially construction dust, and damage to roads due to heavy equipment transportation. Another impact is river water turbidity caused by soil erosion. All of the impacts can be reduced by several mitigation measures (based on UKL/UPL). (b)The project area is located in a traditional cultivated area where there are no rare and endangered species. No important effects on the ecosystem are anticipated. (c)The main impact during construction will be in the form of jobs and business opportunities and disappearance of calm environment. All of the impacts can be reduced by several mitigation measures (based on UKL/UPL).
	(2) Accident Prevention Measures	(a) Does the project have any accident prevention equipment and scheme to store, emit and transport toxic and hazardous materials? Are any measures taken to prevent the pollution of drinking water, for example when the facilities discharge liquid wastes into the rivers in an emergency?	(a) Y	(a)The requirements in the Bid Documents will include the establishment of accident prevention measures. It is common practice in geothermal power plants for kerosene (for use in the emergency generators) and chemicals such as NaOH and H_2SO_4 to be placed at designated locations. In transporting and storing the kerosene and chemicals, measures to prevent accidents will be required, including such means as using appropriate transport routes and the provision of dikes, in
	(3) Monitoring	(a) Does the proponent develop and implement a monitoring program for the environmental items that are considered to suffer potential impacts? (b) What are the items, methods and frequencies of the monitoring program? (c) Does the proponent establish an adequate monitoring framework (organization, personnel, equipment, and adequate budget to sustain the monitoring framework)? (d) Are any regulatory requirements pertaining to the monitoring report system identified, such as the format and frequency of reports from the proponent to the regulatory authorities?	(a) Y (b) Y (c) Y (d) Y	(a) PLN GE has developed a monitoring program (UPL). The program requires additional monitoring of the nearby hot spring and residential wells. (b)In the monitoring program, monitoring is conducted periodically in each phase. For example, water monitoring is done quarterly, air monitoring biannually etc. (c) A HSE team is stationed in the project area, under a supervision of HSE manager who is supported with adequate budget and personnels. The HSE team is in charge of monitoring safety controls and implementing mitigation measures when the results of monitoring exceed the standard. (d)PT PLN Geothermal will conduct monitoring and report every six (6) months to the Environmental Protection Office of Central Maluku Regency, as mentioned in the approval of the UKL-UPL Report.
6 Note	Reference to Checklist of Other Sectors	(a) Where necessary, pertinent items described in the Power Transmission and Distribution Lines checklist should also be checked (e.g., projects including installation of electric transmission lines and/or electric distribution facilities).	(a)	(a)Construction of the transmission line does not involve resettlement of residents, as there are no houses on the planned route. There is no large-bird habitat around the planned transmission line route, and the area is not confirmed to be on the migratory routes of large birds. The existence of a transmission line is thus not expected to affect birds.
	Note on Using Environmental Checklist	(a) If necessary, the impacts to transboundary or global issues should be confirmed (e.g., the project includes factors that may cause problems, such as transboundary waste treatment, acid rain, destruction of the ozone layer, or global warming).	(a) N	(a) Not Necessary

1) Regarding the term “Country's Standards” mentioned in the above table, in the event that environmental standards in the country where the project is located diverge significantly from international standards, appropriate environmental considerations are required to be taken.
In cases where local environmental regulations are yet to be established in some areas, measures should be taken based on comparisons with appropriate standards of other countries (including Japan's experience).
2) The environmental checklist provides general environmental items to be checked. It may be necessary to add or delete an item taking into account the characteristics of the project and the particular circumstances of the country and locality in which it is located.

CHAPTER VI

VI CONCLUSIONS AND RECOMMENDATIONS

VI.1 Summary of Study Results

A feasibility study of the construction of a 20 MW geothermal power plant in Tulehu geothermal field has been conducted. The results of the current study can be summarized as follows.

- The geothermal resource potential in Tulehu area is sufficient for development of a 20 MW geothermal power plant.
- Banda-Hatuasa fault, Banda fault, and R2 fault are promising development targets.
- The drilling results from TLU-01 confirmed the existence of a high-permeability reservoir. In addition, many data indicate that the reservoir temperature exceeds 200°C from relatively shallow regions to deep regions.
- It was confirmed that the bottom depth of the cap rock layer is approximately -300m above sea level in the vicinity of the TLU-01 drilling site.
- The number of wells necessary for generation of 20 MW of power was estimated, and the results are shown in the following table.

Power Generation Type	Initial Wells (Production)	Initial Wells (Reinjection)	Make-up Wells (Production)	Make-up Wells (Reinjection)
Single Flash	4 (+ 1backup)	6	3	4
Double Flash	3 (+ 1backup)	4	3	3

- Based on the study of the currently available geothermal resource data and the development plan, four (4) sets of plans for the four possible types of geothermal power plant are considered: 2 x 10 MW Single Flash Condensing System, 1 x 20 MW Single Flash Condensing System, 2 x 10 MW Double Flash Condensing System, and 1 x 20 MW Double Flash Condensing System.
- As for the possible use of a geothermal binary system, this is considered only in general terms at this very initial stage of the project study. Most of the factors and conditions that are relevant for the detailed study of a geothermal binary system cannot be confirmed at this stage in the feasibility study, and further consideration of a geothermal binary system is postponed until the next Engineering Service stage.
- The double flash system and binary system are more suitable for the Tulehu geothermal project than the single flash system because of their effective utilization of the geothermal energy in the Tulehu geothermal fluid, which is anticipated to contain a large volume of hot water (anticipated steam-hot water ratio 1:4.5).
- A unit capacity of 10 to 20 MW for Tulehu geothermal power plant should be appropriate considering the future scale of the Ambon electric power system.

- The current results of geothermal resource study and the development plan have been enhanced with some assumptions based on knowledge and experience, since the currently available data and information are limited. The geothermal resource evaluation should be re-examined in the light of additional data, as more information on the drilling and testing of the further exploratory wells becomes available and in the light of meteorological observations at the project site. The geothermal resource development plan and the power plant plan will need to be reconsidered accordingly before starting project implementation.
- The project costs were estimated for the four cases of power plant design, and each case was examined through economic and financial evaluation. The results indicate that a double flash system would be advantageous for the generation of 20 MW of power in Tulehu field. For the unit capacity of the power plant, the results indicated that both 2 x 10 MW and 1 x 20MW should be feasible. However, a comprehensive investigation suggested that the 1 x 20MW configuration was most advantageous for the project.

VI.2 Recommendations

The issues yet to be clarified in the current study are summarized in what follows.

- The intrinsic reservoir temperature of TLU-01 is uncertain due to the remarkable cooling effect of the drilling mud.
- TLU-01 encountered major lost circulation zones around depths of 703 m and of 900 m. These zones are regarded to be the reservoir along the Banda fault, but the depths are much shallower than the initially planned drilling depth of 1,500m. It is likely that TLU-01 tapped just the upper portion of the reservoir. Consequently, the reservoir characteristics in the deep portion of Banda fault are not clearly delineated.
- Due to the lack of production tests, the necessary data for delineating the characteristics of the steam/brine in the vicinity of the Banda fault are unavailable.
- The natural water level of TLU-01 was approximately 70m below its well head. If the water level in the (future) reinjection area is the same, reinjection strategies must be carefully studied in order to maintain the necessary reinjection capacity.

To clarify the issues listed above, the Study team recommends conducting the following investigations in the near future.

- An exploratory well approximately 1,500m deep should be drilled (preferably from a drilling pad which is different from the TLU-0 pad), and a production test using TLU-01 and the newly drilled well should be conducted.
- In the production test, the chemical composition of the geothermal fluid and the concentration of non-condensable gas should be clarified.
- Static temperature loggings in TLU-01 should be run once a month in order to monitor its temperature recovery. The temperature recovery data can be utilized in assessing the possibility of spontaneous fluid production in TLU-01.

- Through the additional exploration well drilling and production testing recommended above, the steam conditions (pressure, temperature, and NCG volume and composition), hot water quantity, and the scaling characteristics of the geothermal fluid will need to be clarified for the basic planning of the power plant and design of the project implementation.
- Meteorological observation at the project site should be commenced immediately and continue for two (2) years, and the meteorological conditions (temperature, atmospheric pressure, wet bulb temperature, wind direction, wind speed, rainfall, etc,) for the project design should be determined.
- The geothermal power plant plan will need to be reconsidered in light of the abovementioned steam conditions, geothermal fluid characteristics, and meteorological conditions, and the optimum choice of power plant system (double flash, single flash or binary) and unit generation capacity should be determined in the process of the basic planning and design of the geothermal power plant before starting project implementation.
- The environmental impacts of H_2S gas should be evaluated by conducting a diffusion simulation or wind tunnel experiments based on the H_2S concentrations and the power plant design.