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MANAGEMENT STRATEGY OF GEOTHERMAL EXPLORATION IN INDONESIA

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SUMMARY- Geothemal exploration in Indonesia was officialy started in 1972, although scientific drilling had been done as early as 1926 - 1928 in the Kamojang Geothermal prospect, West Java. During the last 20 years, more than 67 high enthalphy geothermal prospects have been discovered spreading along the islands of Sumatra, Java, Sulawesi and East Indonesia. In our geothermal exploration program, management strategy is important, because it affects further development. In order to minimize the cost, Pertamina has a standard procedure in approaching the decision whether or not a prospective area will be developed. Such procedure involves geoscientific surveys, laboratory works, scientific evaluation, engineering aspect study, and economical evaluation. The next step would be the explotation of selected prospects that can be done by a developer if a positive result is obtained from an environmental impact study and is approved by the government.

1. INTRODUCTION

The exploration stage of the geothermal development in Indonesia has been carried out by the Indonesia State Oil and Gas Company (Pertamina) since 1974. For more than 20 years geothermal resources in Indonesia were studied progressively and systematically using a cost effective approach of geothermal exploration program. The prospects identified so far are 28 in Sumatera, 21 in Java, one in Bali, 6 in Sulawesi and 8 in East Nusatenggara.

In Kamojang Pertamina and PLN (the State Electricity Company) have developed 140 MW power plant. Unocal Geothermal Ltd. and Amoseas Geothermal Ltd. installed a total of 165 MW capacity in Indonesia by the end of 1994. The Geothermal Development Plan issued by the Indonesian Government includes a total development of 309 MW by 1994 and 1,240 MW by the year 2006.

This paper reviews all activities that have been done by the Pertamina Geothermal Division for over 20 years.

2. EXPLORATION STAGE

The strategy for general fieldworks conducted by Pertamina for the geothermal exploration and development in 1970's to 1980's was reviewed by Ganda (1987). At present (1994) Pertamina still implements the same strategy, although there have been numerous refinement of evolutionary nature in both methodology and interpretative framework.

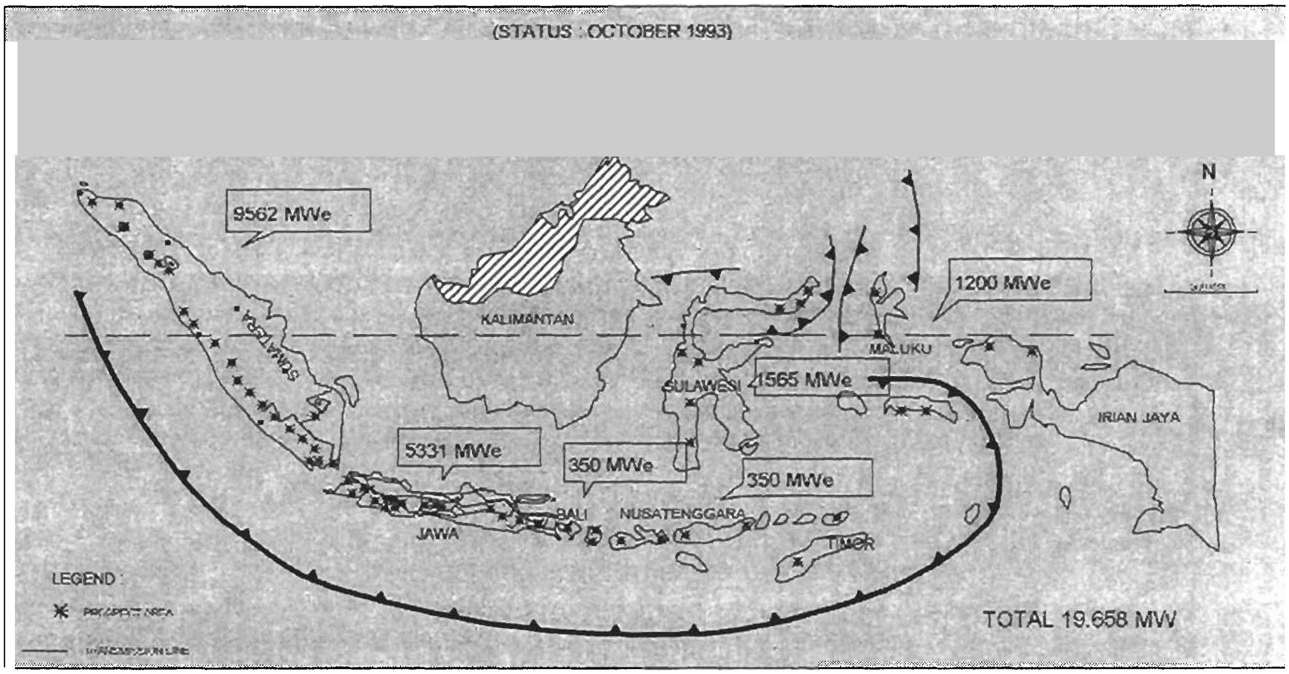
Pertamina's approach in geothermal exploration can be divided into 5 stages: 1). Geoscientific surveys, 2). Laboratory works, 3). Scientific evaluation, 4). Engineering aspect study, and 5). Economical evaluation.

3. IDENTIFICATION OF PROSPECT AREAS

It was recognized that most of the 67 geothermal prospects identified in Indonesia are located along the major volcanic island arcs of Sumatra, Java-Bali, Sulawesi and the smaller island arc of Eastern Indonesia. Those prospects are estimated capable to provide a total electrical energy of about 19,660 MW (reserved and proven potential). Sumatra has the highest potential of about 9,560 MW and the second highest potential of 5,680 MW is in Java-Bali. Sulawesi is estimated to have 1,570 MW and the remaining potential is mostly located in many remote islands of Eastern Indonesia.

By early 1994 only 144.5 MW installed capacity was operating in Indonesia. As mentioned in the introduction, about 140 MW are generated in the Kamojang geothermal field, West Java. In addition, two pilot projects of 2 and 2.5 MW using non condensing and binary turbines are

Figure 1 : DISTRIBUTION AND POTENTIAL OF GEOTHERMAL RESOURCE IN INDONESIA



operating in Dieng (Central Java) and Lahendong (North Sulawesi), respectively. A further **110** MW power plant was then installed at Gunung **Salak** on August **1994** and Darajat has a unit of ***55*** MW by the end of **1994.**

4. GEOSCIENTIFIC SURVEYS

A number of geoscientific surveys (geological, geochemistry and geophysical; see figure 2) have been found to be a cost effective mean to provide significant information about most of the prospects. However, some prospects occur on steep volcanic terrain which imposes substantial constrains on surface exploration methods.

4.1. Geological survey

The ideal purposes of a geological survey are to identify prospect areas, to provide data to assess the prospects' significance, and to recommend more specific areas for further investigations. A geological survey involves preparation of a detailed geological map and production of a report on selected geothermal prospects, which also specifies the surrounding area. The survey also includes detailed mapping of geothermal features. The results, together with those obtained from geochemical and geophysical investigations are used to recommend sites for exploratory wells.

The main objective of the geological survey is to construct a volcano-geological model (e.g structure and stratigraphy) that includes description of thermal history of the prospective area. Such model will provide a useful guide for the subsequent multi-diciplinary evaluation.

In Indonesia, our experience with geological studies suggests that: **(1)** studies of petrology and hydrothermal alteration mineralogy are essential for the exploration and development of the prospect, and (2) volcano-geology and thermal history analyses can provide important information for hydrological models and structural analysis can help to identify initial permeability targets.

Petrology and hydrothermal alteration mineralogy studies in conjunction with other sources of data have been used to:

- identify the extent of alteration zone, hot spring precipitates, fluid compositions, and predict possible acid influx into the well and location of possible convective uplow;
- identify the permeable zones, predict reservoir temperature that might be encountered during drilling, and help to determine the depth of production casing;

- assist the construction of the geothermal model by defining the likely zones of upflow and outflow, cold ground water intrusions and high gas or near boiling condition ; and
- identify the likely problems for future development, in particular those affecting well management such as casing corrosion, which is associated with acid fluid and cold water intrusions, and the likely zones of potential scalling.

4.2. Geochemical survey

Geochemical studies involve sampling and analysis of hot springs, sublimates and gas from fumaroles and solfataras. The data obtained are essential for the determination of the geothermal system characteristics, and estimation of chemical constituent of fluid at depth, its source, temperature and other information useful for hydrological model.

The most important parts of the geochemical survey are analysis of chemical constituent, gas and isotope. Result from a combined gas and chemical contituent analyses can be used to identify the steam fraction and geothermometer. Isotope analysis can be used to clarify the origin and age of water. The methods have been used to define structures and up-flow zones at Dieng and Lumut Balai geothermal areas.

4.3. Geophysical survey

Geophysical methods can provide significant information about locality, size and probably the nature of the geothermal prospect through delineation of anomalies which reflect distribution of hot mineralized fluids and/or thermal alteration products. The geophysical exploration methods used by Pertamina are summarised in figure 2.

The Schlumberger dc-resistivity traversing (mapping) and vertical electrical sounding (VES) are the important geophysical exploration methods. The presence of a high electrical conductance (or low resistivity value) of subsurface rocks is significant in geothermal explorations as it may indicate hot mineralized fluids and clay alteration products.

5. LABORATORY WORKS

After finishing the scientific exploration fieldworks (geology, geochemistry and geophysics) and conducting preliminary analysis of the results, samples collected during the survey are sent to the laboratory for analysis. Fundamental parameters of interest are temperature, pressure, porosity, permeability, chemical composition of fluid and geothermal gas. Appropriate equipment are required to analyse these parameters. To speed up the works, all geoscientific laboratory works are done through contracts.

The accuracy of laboratory result is essential for a successful development of a geothermal prospect. The various physical properties related with geothermal system to be identified are summarised in figure 2. The geological laboratory work consists of petrology of country rocks, x-ray diffraction for clay study, fluid composition analysis (trace element analysis), age dating, and porosity and permeability assessment. The laboratory work for geochemistry includes analysis of samples from hot springs and seepages, fumarole emissions, gas discharges, and cold surface waters. Using results from these analyses, the geochemist may be able to predict the nature of the deeper system in terms of:

1. Composition range of hot fluid at depth.
2. Subsurface fluid temperature and pressure.
3. Subsurface rocks assosiated with hot fluid.
4. Origin of hot fluid, direction of flow through the area and residence times of water in the systems.
5. Geothermal gradient and the depth to the first boilling in the systems.
6. Mineral deposition potential of the fluid.
7. Zones of up flow and out flow.
8. The possibility to understand underground (deep) acidity which could cause difficulties during future exploitation.
9. Fluid constituents which could have cconomic value.

The physical properties measured in the laboratory for the geophysical investigation are electrical resistivity (Ωm), magnetic suceptibility, density (g/cm^3), seismic velocity (m/s) and thermal conductivity (W/m°C).

6. SCIENTIFIC EVALUATION

After finishing the laboratory works, an integrated interpretation of various geoscientific dicipline can be implemented. Results from different dicipline are macthed to construct the geothermal model (see figure 2).

Information contained in the model usually includes:

1. Area of the geothermal prospect.
2. The most feasible structural pattern facilitating upward movement of geothermal fluids.
3. Possible reservoir rocks and their likely physical characteristics.
4. Possible depth of reservoir.
5. Temperature of reservoir.
6. Characteristics of the geothennal system i.e. convective or conductive system.
7. Types of geothermal fluid.
8. Possible upflow and outflow zones.
9. Possible electric generation potential.
10. The best sites for exploratory wells.
11. Prediction of any future exploitation problems such as scalling problem, gas problem, geological hazard.

An experienced scientific evaluator is required to comprehend many aspects in the framework above to obtain the maximum result.

7. ENGINEERING ASPECT STUDY

Engineering aspect study tend to be emphasized after exploration drillings finished. It involves well testing to evaluate reservoir parameters such as pressure, temperature, permeablity and porosity of reservoir rocks, likely thickness of reservoir, types of geothermal fluid and characteristics of the geothermal system.

After reservoir properties have been evaluated, prediction of well performance for various campletion sizes can be made by using a two phase wellbore simulation programme (the Wellsim programme, developed by GNZL). To illustrate this point, a case study example of the Sibayak geothermal prospect (Pujiastuti *et al.*,1994) is described below and summarised in Table 1.

Matching analysis using production data of SBY-1 well suggest an increase of 56% when a big hole completion is used. Low permeability and low temperature wells (PI=2.32 and 3.1, T=240°C) results in a capacity improvement of 59% on average. Low permeability and high temperature wells (PI=1.55, 2.32 and 3.1, T=260°C) results in an improvement of 40% on average. For an intermediate permeability wells with low and high temperature (PI=7.75, T=240°C and 260°C) there will be an improvement of 77% when a big hole completion is applied. The improvement for high permeability wells of low and high temperature (PI= 15.5, T=240°C and 260°C) ranges from 96% to 99%.

Table 1

Summary of the result from matching reservoir parameters using initial production data SBY-1

	Standard Hole Completion steam Rate* (tonhour)	Big Hole Completion steam Rate* (ton/hour)
Case 1 (PI=1.55)		
Tr=240°C	9.19	14.28
Tr=250°C	13.83	19.09
Tr=260°C	18.26	22.78
Case 2 (PI=2.32)		
Tr=240°C	12.01	19.08
Tr=250°C	17.78	26.50
Tr=260°C	23.53	32.57
Case 3 (PI=3.1)		
Tr=240°C	14.42	22.90
Tr=250°C	20.74	32.26
Tr=260°C	27.49	40.67
Case 4 (PI=7.75)		
Tr=240°C	21.91	38.87
Tr=250°C	31.27	54.31
Tr=260°C	39.54	69.66
Case 5 (PI=15.5)		
Tr=240°C	26.57	53.01
Tr=250°C	37.86	74.06
Tr=260°C	47.07	92.26

* Wellhead Pressure=10 kscg, Separator Pressure=8 kscg

8. ECONOMIC EVALUATION

Economic evaluation is based on several factors, such as the potential of geothermal recourses, plan for development, market share and electricity transmission line. The apparatus for the economic evaluation is a sensitivity analysis for electricity price, rate of return, pay out time, annual revenue, rate of investment, net present value and profitability index. These items are analysed based upon three main assumptions: (1) 100% equity, (2) 34% tax of the net operating income (the Presidential Decree No 49/1991), and (3) 30 year long-life turbine. We found that a small scale geothermal plan is the first priority for development, e.g 1 x 10 MW, 2 x 5 MW, 2 x 5 MW or 4 x 2.5 MW. Based on the cost model shown in table 2 and time schedule presented in figure 3, a sensitivity analyses was made and shown in figure 4.

When we used an estimated electricity price within the range of US $70 to 75/MWh, ROR values of 11.2 - 12%, 12 - 12,8 % and 12.5 - 13,4% we can expect good economic value from the combinations of **4** x **2.5, 2** x **5** and **1** x **10** MW. It can be seen that the three combinations are favorable eventhough the ROR values are not classified as high. The project using **1** x **10** MW **has** the highest ROR value which is above the acceptable price range, but there is a disadvantage of using this scheme, **i.e.** the whole electricity production would have to be cut off when it is necessary to repair the turbine (Hermanses *et al.*, **1993).**

Table **2**

Investment Comparison of Total Project (1 X 10, 2 X 5 and 4 X 2.5 MW)

Activity	cost US $ Millions 1 X 10 MW	 2 X 5 MW	 4 X 2.5 MW
UP STREAM			
- Road & Loc.	1.350	1.350	1.350
- Drilling	7.450	7.450	7.450
- Prod. Facilities	2.300	2.300	2.300
- Miscelaneous	1.825	1.825	1.825
Sub Total	12.925	12.925	12.925
DOWN STREAM			
- Power Plant	11.748	12.500	14.000
- Transmission	3.668	3.668	3.668
Sub Total	15.668	16.168	17.668
TOTAL (%)	28.341	29.093	30.568
	(100%)	(103%)	(108%)

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REFERENCES

Ganda, S., **1987:** Planning and Operational activity Geothermal Laboratory Subsection. ***Unpublished Report, Pertamina Geothermal Division.***

Ganda *S.*, Sunaryo, D., Hantono, D .and Tampubolon, T., **1992:** Exploration Progress of High Enthalpy Geothermal Prospect in Indonesia. ***Geothermal Resources Council Transactions,*** Vol **16,** p **83 -** 88.

Ganda, S., Hantono, D., **1992:** Alteration Mineralogy of the Wayang Windu Geothermal Fields, West Java, Indonesia. ***Proceedings of the 7th International Symposium on Water Rock Interaction, USA***, vol 2, p **1405 - 1409.**

Hermanses, A., et.all., **1993:** Small Scale Geothermal Development in Indonesia. ***Published in Repso Seminar, Jakarta.***

Pertamina, **1994:** Scientific Model of the BT.LUMUT-BALAI Geothermal System, South Sumatra, ***Unpublished Report, PT. Geoservices (LTD).***

Pertamina, **1994:** Plan of Development Total Project Sibayak, Sumatra Utara **(1** x **2** MW and **2** x **11** MW). ***Unpublished Report, Geothermal Division.***

Pudyastuti, K., et.all., **1993:** Optimization of Completion Size For Sibayak Geothermal Field. ***International Symposium on Reservoir Management***, IATMI, Yogyakarta, Indonesia., **p 331 - 334.**

Sunaryo, Hantono, D., Ganda, S. and Nugroho. **1993:** Exploration Results of the Ulubelu Geothermal Prospect, South Sumatra, Indonesia. ***Preceedings 15th NZ Geothermal Workshop,*** p **103 - 106**

FIGURE 2

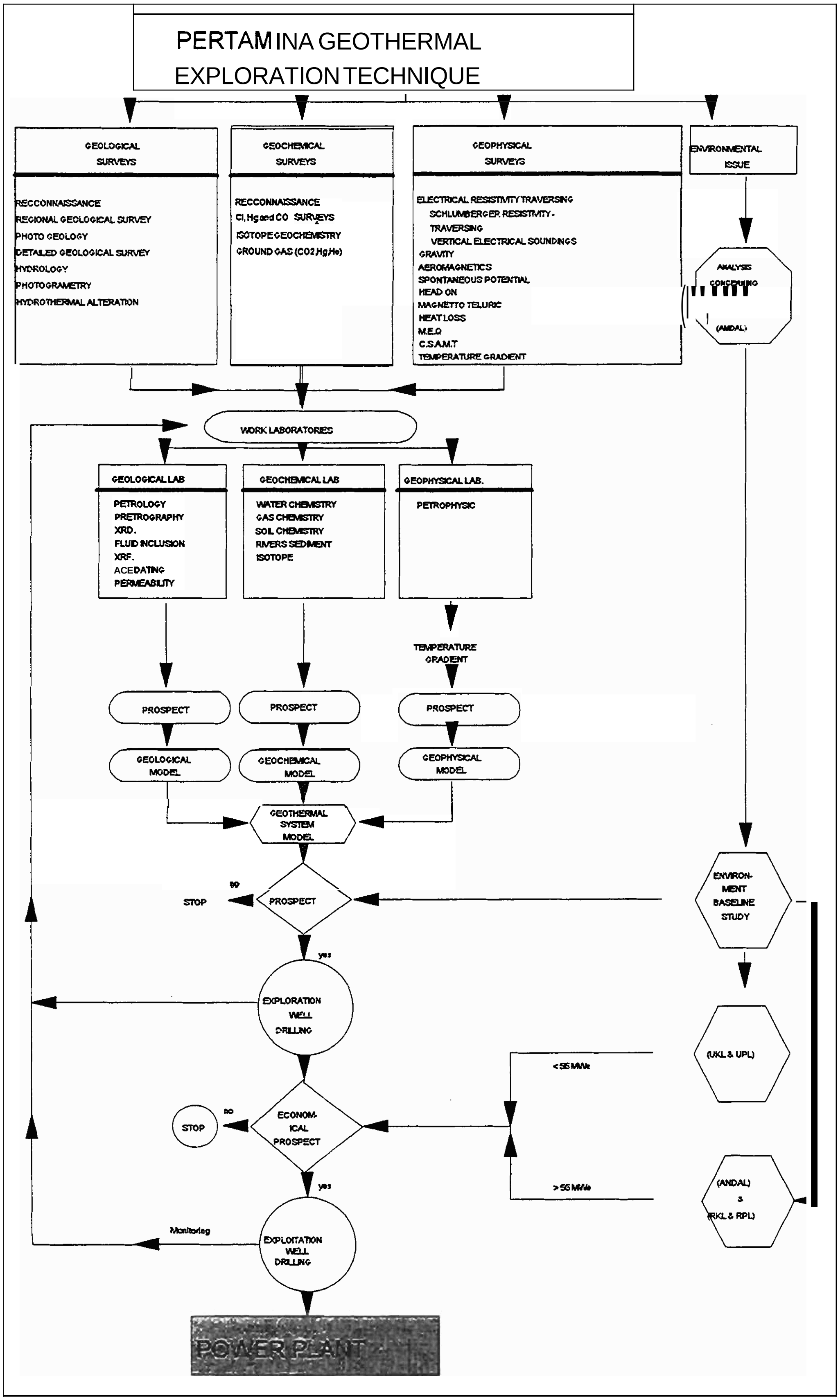
PERTAMINA GEOTHERMAL
EXPLORATION TECHNIQUE
GEOLOGICAL SURVEYS
RECCONNAISSANCE
REGIONAL GEOLOGICAL SURVEY
PHOTO GEOLOGY
DETAILED GEOLOGICAL SURVEY
HYDROLOGY
PHOTOGRAMETRY
HYDROTHERMAL ALTERATION
GEOCHEMICAL SURVEYS
RECCONNAISSANCE
Cl, Hg and CO2 SURVEYS
ISOTOPE GEOCHEMISTRY
GROUND GAS (CO2,Hg,He)
GEOPHYSICAL SURVEYS
ELECTRICAL RESISTIVITY TRAVERSING
SCHLUMBERGER RESISTIVITY-TRAVERSING
VERTICAL ELECTRICAL SOUNDINGS
GRAVITY
AEROMAGNETICS
SPONTANEOUS POTENTIAL
HEAD ON
MAGNETTO TELURIC
HEAT LOSS
M.E.Q
C.S.A.M.T
TEMPERATURE GRADIENT
ENVIRONMENTAL ISSUE
ANALYSIS CONCERNING (AMDAL)
WORK LABORATORIES
GEOLOGICAL LAB
PETROLOGY
PRETROGRAPHY
XRD.
FLUID INCLUSION
XRF.
ACE DATING
PERMEABILITY
GEOCHEMICAL LAB
WATER CHEMISTRY
GAS CHEMISTRY
SOIL CHEMISTRY
RIVERS SEDIMENT
ISOTOPE
GEOPHYSICAL LAB.
PETROPHYSIC
TEMPERATURE GRADIENT
PROSPECT
PROSPECT
PROSPECT
GEOLOGICAL MODEL
GEOCHEMICAL MODEL
GEOPHYSICAL MODEL
GEOTHERMAL SYSTEM MODEL
no
STOP
PROSPECT
yes
ENVIRONMENT BASELINE STUDY
EXPLORATION WELL DRILLING
(UKL & UPL)
< 55 MWe
STOP
no
ECONOMICAL PROSPECT
> 55 MWe
yes
(ANDAL) & (RKL & RPL)
Monitoring
EXPLOITATION WELL DRILLING
POWER PLANT

Figure 3 : TIME SCHEDULE OF TOTAL PROJECT DEVELOPMENT

(1 x 10, 2 x 5 AND 4 x 2.5 MW)

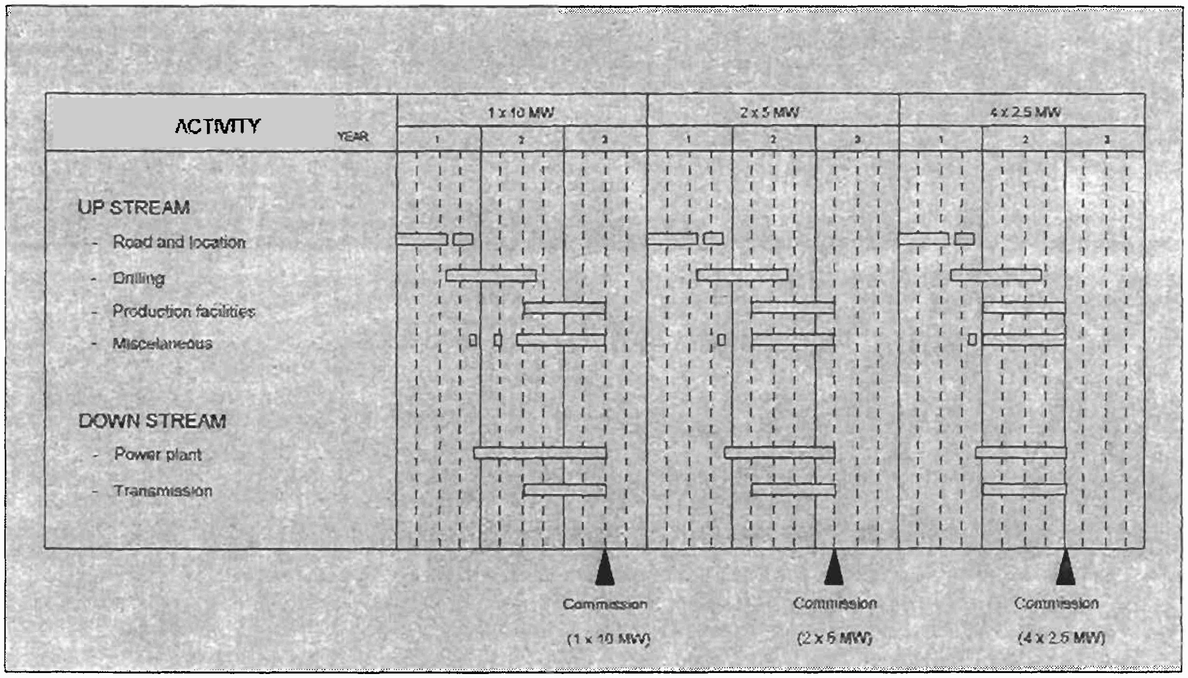

Figure 4 : ECONOMIC SENSITIVITY ANALYSIS OF TOTAL PROJECT