CONTRIBUTION OF GEO-INFORMATION SYSTEM FOR GEOTHERMAL POWER DEVELOPMENT IN INDONESIA

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ABSTRACT

Geothermal energy is characterized by geographic features due to its renewable and nun-exportable properties.
Hence, there are many geographic factors to be perceived, since the natural conditions should serve the technical requirements for power development.
The Geo-Information Systems offer considerable potential for contribution to Geothermal exploration due to their ability to automate and manipulate many geographic data simultaneously.
This paper describes an outline of Geo-Information Systems contribution for geothermal power development.

1. BACKGROUND

Geothermal resources are defined as rock heated hy volcanic or other heat sources, together with the associated fluids and minerals in the system.
Most occurences are associated with geologically recent volcanism and earthquake.
The Volcanological Survey of Indonesia has identified more than 200 geothermal prospects in Indonesia, where Kawah Kamojang in west Jawa is one system which has a substantial electrical generation of **140 MW**.
Geothermal systems are areas of abnormally shallow hot ruck through which ground water has percolated and heated. Usually they are imperfectly contained hy overlying caps and side constraints, hut leaks to the gruund surface cause hot springs and fumaroles (steam vents) which indicate the proximity of a geothermal reservoir, although they are not always located immediately above reservoir.

The power development can he done by extracting fluids from geothermal reservoir. When fluid is extracted, it flaws more easily through fissures than between small adjacent pores in the rock matrix. So well productivity depends on whether fractures are interested hy the well.
No two wells in any one field have exactly the same charcteristic, nor are any two fields exactly alike in their hehaviour.
It can be summarized that geothermal is **a non** exportable and geographically dependente resource. Hence, geo information is needed since preliminary identification until the constructionloperation stage will help the engineer, planner and designer to develop the geothermal resource.

2. APPLICATION OF GEO-INFORMATION FOR NATURAL RESOURCES DEVELOPMENT

The applied geosciences may he defined as the application of geo-information to the study of naturally occuring materials (ruck, soil, subsurface fluids etc), with the purpuse to ensure that all natural factors affecting the planning, design, construction, operation and maintenance of engineering structures and the development of natural resources are recognized, adequately interpreted and presented in engineering practice.

Hence, the requirement ofgeo-information is to provide the engineers, planners and designers with such information as will help them to create engineering structures and to develope the natural resources in the best possible harmony with the environment.

The required information of natural factors in this case could be outlined as follows (Figure 1) :

- **Material**

Its cover all naturally uccuring material in the project area including rock formations and soil. The information required here includs the physical and technical properties such as mineral composition. grain size, porosity/permeability, hearing capacity, chemical reactivity. Sometimes information about vegetation cover is also required for special purposes.
Related geosciences are mineralogy and soil mechanics.

Structure

The required structural information includes all relationships among the materials such as layering, fracture, fissures, crack/opening and any other existing discontinuities in the rock or soil.

The geosciences related to such structural information include can be mentioned here as structural geology, stratigraphy and geomorphology.

The task of the applied geo-scientist in this case is to provide such compilled information above, interpreted and presented in engineering practice. This part is called the information of applied geo-science. Some examples are; Engineering Geology for Civil Engineering ; Economic Geology fur mineral exploration ; Environmental Geology for regional planning ; and of course applied geological survey & methods for geothermal exploration.

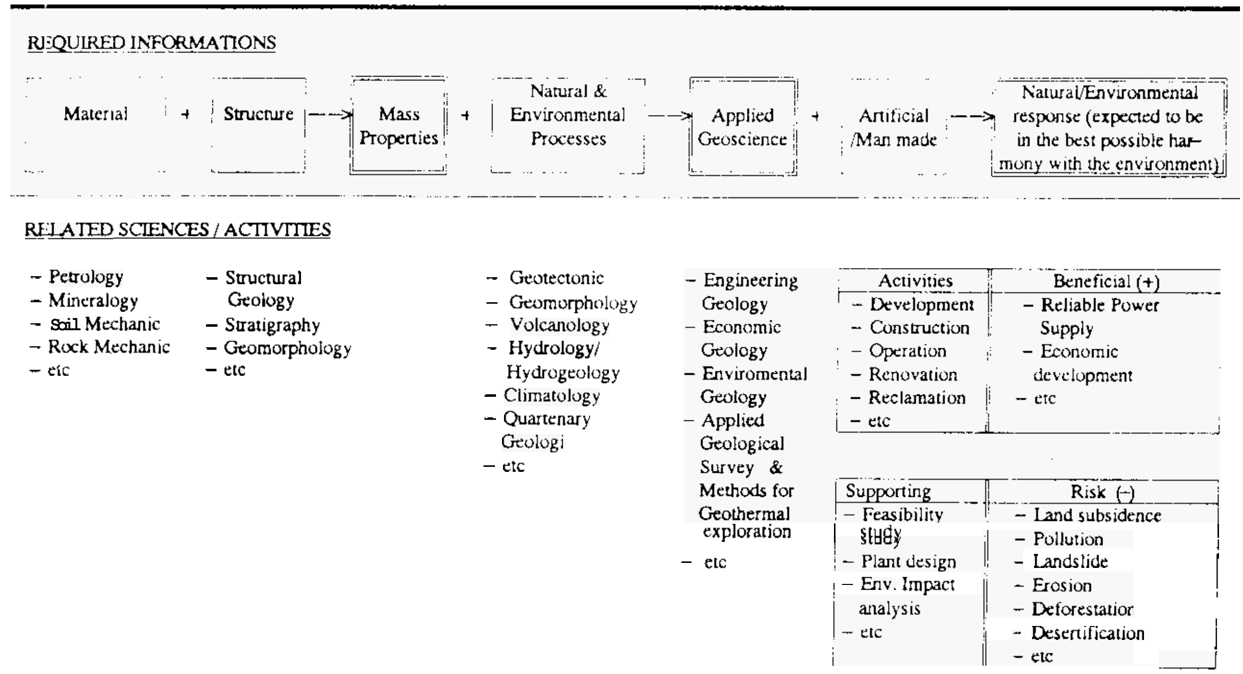

FIGURE 1 : OUTLINE OF GEO–INFORMATION CONTRIBUTION FOR NATURAL RESOURCES UTILIZATION

understanding both material and structural nformation then assists to the understanding of the mass properties of the project area.

Natural & Environmental processes

Information about natural and environmental processes whether in local or regional terms need to be identified. The information to he identified is not only the process itself, but includes all related leatures. The existence of natural springs, hot springs, and river course shifting, have to be notified because they may he related to on-going natural processes.

Natural and environmental processes information often indicate the potential or risks of the areas.

The natural geosciences which relate with such information are Geotectonic, Geomorphology, Hydrology / Hidrogeology, Climatology, Quartenary **Geology.**

The next stage involves the man made or artificial activities. This is the task of engineers, designers and planners to create and develop the natural resources, based on applied geo-information supplemented by geo- scientist.

Hence, the task of the geo-scientist is to provide the geo-information for them and it should he adequately interpreted and presented clearly in engineering practice.

The final target of such activities are the environmental response which are expected to be in the best possible harmony with the environment.

3. GEOLOGICAL STUDIES OF GEOTHERMAL PROSPECTS (Figure 2)

3.1 Preliminary Investigation and Reconnaissance

This very early stage of study is targetted to identify and catalogue known active, inactive an existing geothermal features, make a preliminary assessment of their significance, and recommend initial areas for investigation with regard tu actual or potential energy requirements.

The activity includes a compilation of data from local knowledge, maps, published and unpublished report and other literature

Preliminary assessment of data, requires a geologist experienced in geothermal studies to examine the existing data, inspect the existing maps, satelite images or aerial photographs whenever availahle, and inspect the location of thermal features in the field. Visiting selected areas to appraise local geological and hydrological features is required to prepare a report with recommendations.

Collection of water samples from thermal features for chemical analysis is sometimes necessary to suplement the report.

In the frame of geo-information, this stage aims aimed to recognize the natural and environmental processes which associate with geothermal potential areas.

3.2. Preliminary Exploration

The preliminary exploration is aimed to prepare a detailed geological map and report of a selected geothermal prospect and surrounding area, including detailed mapping ofgeothermal features in association with geochemical, geophysical and hydrological investigations, to recommend sites for exploratory wells.

The field geological survey is carried out to obtain an understanding of the geological structure and stratigraphy.

Petrological investigation is used to obtain a better understanding of reservoir characteristics and hidrothermal pmcesses.

In this stage the outline of applied geo-science information is expected to he obtained by compiling information of material (geological mapping & petrological investigation), structure (geological structure & stratigraphy) and natural/environmental processes (geochemistry & hydrothermal alteration).

3.3. Exploratory Drilling

When all data have been collected from previous preliminary exploration, a decision will have to be made wether or not to pmceed with exploratory drilling.

This will depend on various factors, not necessarily all scientific.

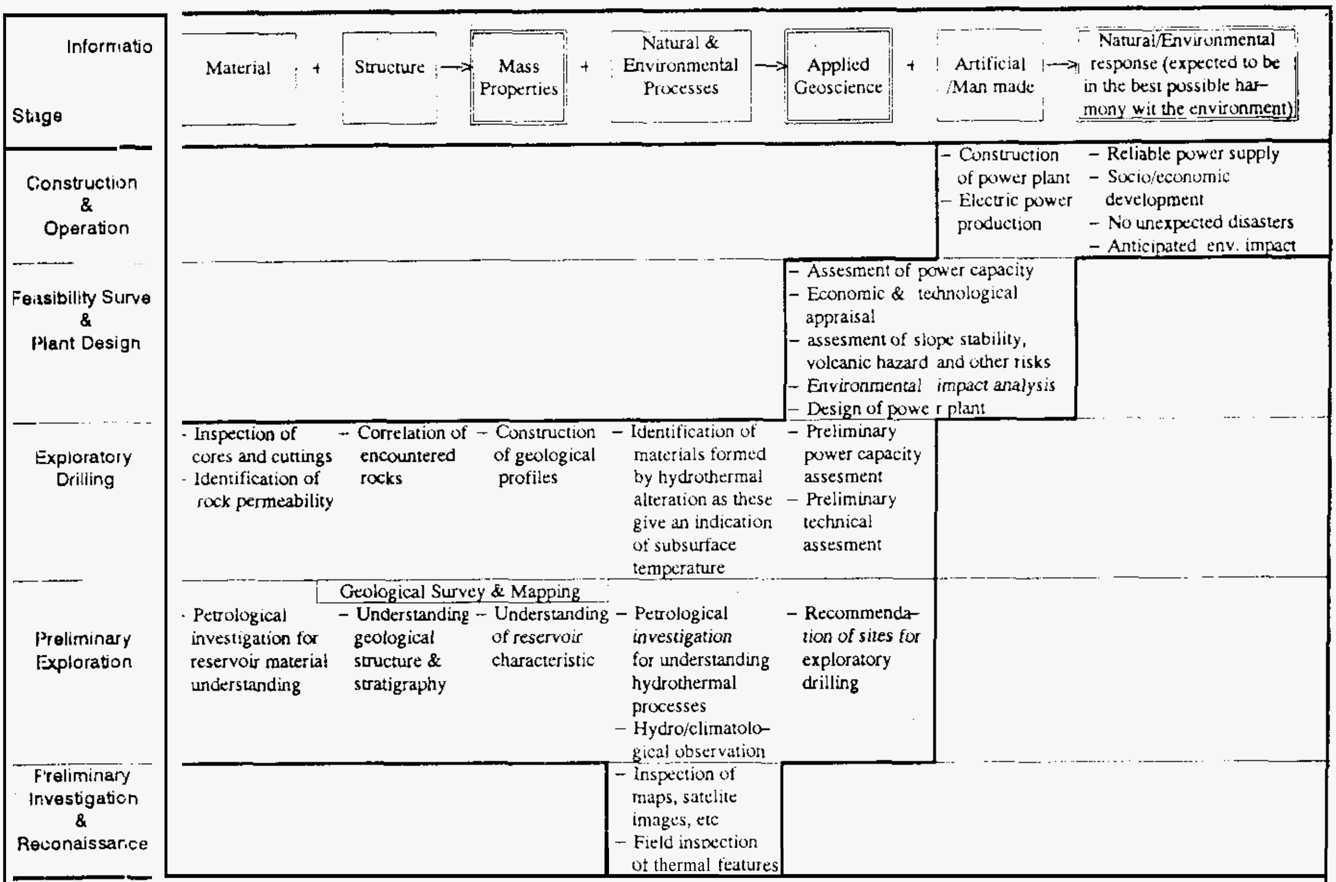

FIGURE 2 : CONTRIBUTION OF GEO–INFORMATION IN GEOTHERMAL EXPLORATION

The exploratory drilling is aimed to obtain geological informalion in depth about the field, and establish the relationship of temperature and permeability lo the geological structure and the surrounding area.
The drilling includes inspection of cores and cuttings, as drilling proceeds, for identification and corellation of ruck encountered, and for the identification of minerals formed by hydrothermal alteration, as these give an indication of subsurface temperature and permeability.
Geological profiles through the field and surrounding area are constructed and based on the interpretation of the data, additional exploration wells are sited.
Further detailed applied eeo-science information could he obtained in this stage. It could he used for preliminary technical assessment and for further exploratory or development and production drilling.

3.4. Feasihility Survey and Plant Design

Analysis of all field information is carried out during feasibility survey stage, for an economic and technological appraisal of the resources prior to ordering plant. Site investigations, assessment of slope stability, volcanic risk and geologic hazards will need lo he made. Environmental impact analysis is required as well.

The prepared final report may include requests for wells for monitoring purposes, and recommendations for future developments.
This stage will he lead mostly by the designer and economist in coordination with the field engineers. However, the contributions of geo-scientist are still required as well.

3.5. Construction and Operation

This stage is lead by the designer.
The geo-scientist especially geologist is still involved during this stage, because he/she should be aware of changes occuring in the field under development, and possible geological factors influencing these.
The petrologist may need to identify mineral scale deposits or well ejecta as in the exploratory drilling stage.

4. DEVELOPMENT OF KAWAH KAMOJANG GEOTHERMAL FIELD (Figure 3)

The Kawah Kamojang Geothermal field has Indonesia's first Geothermal Power Plant of 140 MW installed capacity. It is situated in the east of Bandung, the capital city of West Jawa province, at the elevation between 1500 - 1900 m above sea level.

The development of such geothermal fields was suggested as early as 1918.
However it was not until 1926 - 1928 that five shallow exploration wells were drilled. One of these wells is still discharging steam with a temperature of 140° C and pressure of 3,5 to 4 bars absolute.

In 1972, afterjoint reconaissance programme between the New Zealand and Indonesian Government involving a number of geothermal fields on Jawa, Bali,' Sulawesi, Sumatera and elsewhere, Kawah Kamojang was accorded the highest priority for further scientific investigation.

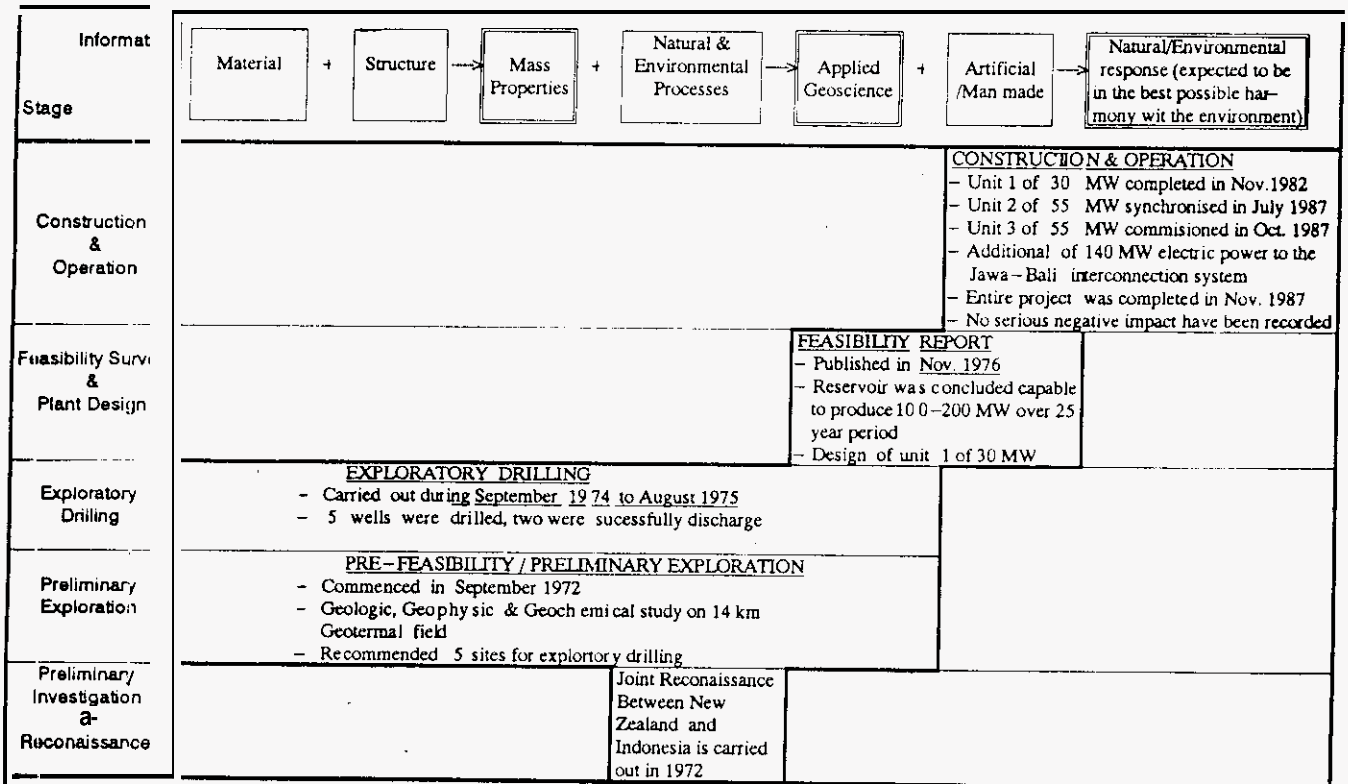

FIGURE 3 : DEVELOPMENT OF KAWAH KAMOJANG GEOTHERMAL FIELD IN THE FRAME OF GEO–INFORMATION

A pre-feasibility or preliminary exploration of the Kawah Kamojang was commenced in September **1972.** The detailed geophysical, geological and geochemical studies carried out, delineated a geothermal field of about **14** km^2 in area.
Following such pre-feasibility study, an exploratory drilling programme of five small diameter, medium depth wells were carried out in the period from September **1974** to August **1975.** Two of the five wells successfully discharged and all gave positive temperature indications.

The results of these preliminary investigations were summarized in feasibility report published in November 1976, which concluded that the reservoir was capable of supporting between **100** to **200** MW of electric power over a **25** year period, certainly enough to justify a programme of drilling and development aimed at the instalation of a 30 MW power station as the first stage of a much larger future development.

In September **1976** the first production well was spuded in, while the design of power station began. By August **1979,** production drilling was essentially completed and the single unit **30** MW station (unit 1) was commissioned in November **1982.**
Result obtained from wells drilled after the completion of unit **1 soon** confirmed earlier indications that there was obviously potential for a substantial extension to the installed electrical generation capacity at Kamojang.
And the unit **2** was synchronised in July 1987 and following sucessful commisioning of unit 3 two months later, the entire project was completed in November **1987.**

5. THE *NEW* DEVELOPED GEO-INFORMATION SYSTEM (GIS)

The newly developed Geo-Information Systems (or GIS) are tools for storing and manipulating various geographical based information (or maps) in a computer. Once maps are in the computer, we **can** ask questions of the data base and manipulate, analyze, and display geographic information with a speed and a set of functions.

Conceptually, a map is a kind of information system, since it is a collection of stored and analyzed data. Hence,GIS is a high order map stored in a computer, where it must be able to convey information in a clear, unambiguous fashion to its intended users.
The advantages of computerized new developed Geo-Information System are the systematic storing of many giagraphic data and attributes in a databank, and its ability to automate, analyze and manipulate such giagraphic data simultaneously and quickly, to be displayed as thematic geographical based information as intended **by** various users.

A lot of sophisticated GIS softwares has been developed in the last decade. **Some** is able to process and analyze satelite and other remote sensing data whether in digital form or in printed images.
Various geographical based information or maps are stored in a computer and can be organized into layers, such as geology, topography, land use areas, road and transportation lines, etc (Figure 4)
The mayor advantage of a **GIS** is that it allows **us** lo identify the spatial relationship between map features by overlaying layers. Essentially, a GIS is able lo create new relationships, to associate **new** attributes to map features, and then store these in the attribute table. **In** other words, a GIS is able to manipulate several maps **by** overlaying to produce a new intended thematic map.

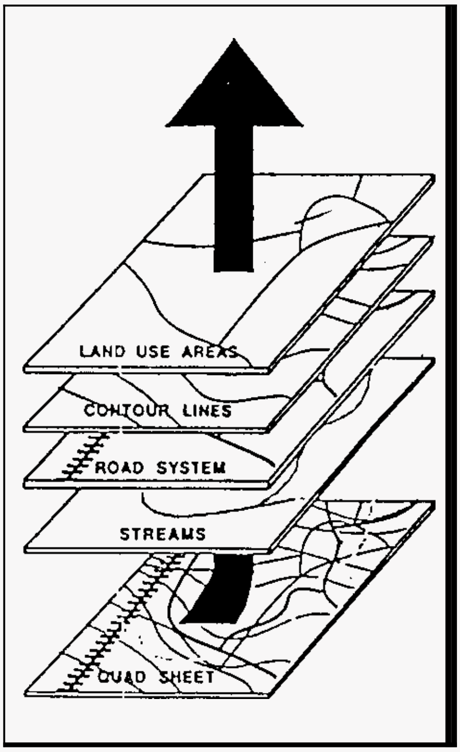

FIGURE 4 : ORGANIZING *MAP* DATA IN GIS

The result of these analytical operations adds **new** descriptive data about features to the feature attribute table for a area. Once these relationships are recorded, arithmetic and logical operations can be performed **on** the tabular attributes. With tabular analyses, it can he determined, for example, the suitability of various sites for development, evaluate environmental impact, identify the best location for several facilities and **so on.**
Example layers in a geographic database for general natural resource application is presented in figure **5.**
For such **reasons** above, it **can** be summarized that GIS is very helpfull for all activities which work with maps or geographical based informations.

Geothermal exploration is une example where various maps are analyzed and manipulated to pmduce new applicable thematic maps. Hence GIS a offer very usefull contribution for such exploration.

During preliminary investigation or reconaissance, informatiun about thermal features could he stored in geographic hased computer (or **GIS**) and compilled with other stored geographic informations (maps, satelite images etc) to delinate some geothermal prospective areas for futher investigation (preliminary exploration).
Other related information collected during preliminary exploration such as materials, structures and natural processes, are stored. Hence, computerized geographic information (or GIS) is able to compille, analyze and manipulate it. Very useful conclusions can he drawn to support recommendations for futher investigation (exploratory drilling).
Cxploratory drilling result will pmvide more detailed informatiun, which again can he stored tu update geographic attributes in the computer.
Finally, econumic and technological appraisal, including all other natural/environmental assesment can be supported considerably hy GIS for geothermal power development.
However, its GIS databank system will still he necessary and helpfull during construction, and the existing stored information still possible to be improved and up-dated easily during operatiunal phase fur evaluation.

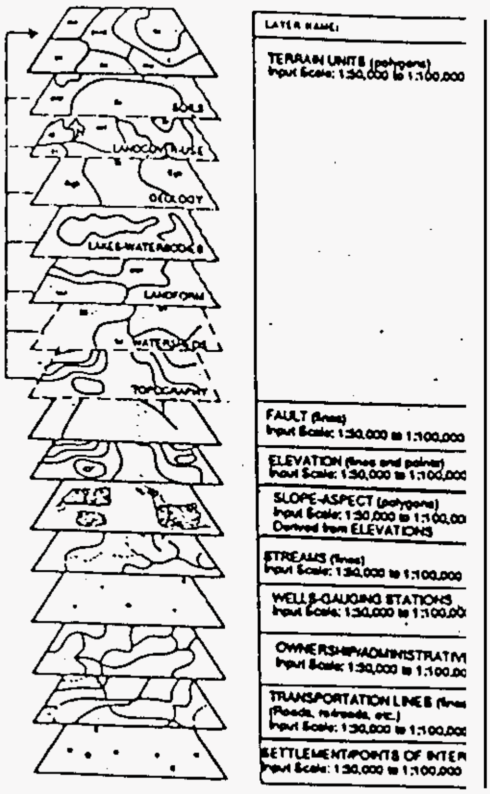

FIGURE 5 :
EXAMPLE **MAP LAYERS IN** A GEOGRAPHIC **DATABASE FOR NATURAL** RESOURCES **APPLICATIONS**

6. CONCLUDING REMARK

Computerized geo-information system (GIS) may he defined as a management information system that is designed to work with data referenced by spatial or geographic coordinates (or maps). Hence, GIS could he applied for geothermal exploration since it is characterized by a stmngly geographic dependence.
The function of GIS in this case is as a tool to accelerate the analysis procedure.
All collected geo-information are classified and stored systematically in computer. It could be retrieved at any time for updating, manipulating and analysis.
However, its effectivity depends fully on the people who use it.

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