Presented at Short Course IV on Exploration for Geothermal Resources,
organized by UNU-GTP, KenGen and GDC, at Lake Naivasha, Kenya, November 1-22, 2009.

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GIS IN GEOTHERMAL RESOURCES DEVELOPMENT

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ABSTRACT

Geographic information system (GIS) is the most efficient technology for handling spatial data and information. KenGen uses GIS system for the data/information management of the geothermal resources development. Use of GIS for integrated data modelling for selecting best area of geothermal well sites for Menengai and L. Bogoria prospects was very successful. A model for data and information sharing for GIS for geothermal resources in the region is proposed and a tentative data infrastructure designed.

1. INTRODUCTION

1.1 What is GIS?

Geographic Information System (GIS) is a system for management, analyses and display of geographic information. Geographic information is any dataset and or information that can be used to model geography (i.e. features and activities on the earth's surface)

Basically, GIS systems are computer-based methods for solving real World problems. Data about real-world objects is stored in a database and dynamically linked to an onscreen map, which displays graphics representing real-world objects.

A GIS consists of five main components:

- *People*; experts trained in GIS
- *Data*; from which information will be derived. These may be organized in databases using generic GIS structures, commonly referred to as Geodatabases
- *Hardware*; equipment for data acquisition, data processing and storage, information display and result presentation. These include field devices like GPSs, computer systems, digitizers, plotters etc.
- *Software*; special computer programs for manipulating the data and carrying out spatial analyses essential in problem solving
- *Procedures*; systematic organization of process and workflow steps to be used in collection, collation, analyses of data, information extraction and dissemination of knowledge for useful problem solving.

1.2 Applications of GIS in geo-sciences.

Geographic Information System (GIS) technology represents the most modern methods of handling location-based data/information. Thus it has wide applications in geosciences from basic mapping to more complex activities like modelling of geological and geographic processes. GIS has been used in geological mapping, especially integration of remote sense data with ground collected data, hydrology, agriculture, urban planning, environmental planning and monitoring etc.

The ability to create *spatial databases* (geo-databases) that represent information in terms of GIS data models is a very important aspect for geological data management since most of geo-scientific data/information is comprised of Earth features and events, which have certain relationships. Another important aspect of the GIS technology is the ability to perform *geoprocessing*, which is the use of information transition tools (functions in the software programs) to derive new datasets from existing datasets. This includes use of analytical functions like statistical analyses etc. *Geo-visualization* is another very important functionality of GIS in which different maps views of underlying geographic information are constructed into sets of intelligent map that show various feature relationships. This is like creating a window to look into the database for querying and analyzing the data.

Every geographic information system should be capable of six fundamental operations in order to be useful for finding solutions to real-world problems. A GIS should be able to:

- Capture data
- Store data
- Query data
- Analyze data
- Display data
- Output data

2. WHY IS GIS FOR KENGEN?

In geothermal resources exploration and development, we normally deal with vast amounts of data/information from multiple sources. In all phases of geothermal resources development, exploration, resource appraisal, drilling, exploitation and management of steam/hot water fields, most of the resource data/information is location based (or geographic data), thus GIS comes out as the best option for handling the information. A lot of measurements, investigations and reporting going back to 1950s have been carried out in Kenya and East African Rift. However, this information is held by different institutions including, KenGen, Kenya Power & Lighting Company, Ministry of Energy, Mines and Geology department and other related research institutions like Universities both local and outside Kenya. All this information requires collating and synthesizing. This kind of data requires innovative information management solutions to ensure integrity, and fast access and accurate information extraction by the resource managers, decision makers and policy formulators.

At the Olkaria Geothermal project we have started a GIS unit with an objective of creating an integrated spatial database for geothermal resources and that can be used in resource development operations. In 2004, KenGen acquired and installed an 'enterprise' GIS system comprising the data acquisition hardware, high speed computer systems and soft-wares. We have quiet an ambitious program of developing KenGen-wide Geodatabases that can used to assist in decision making that are based upon spatial information. The pilot designing of the databases are being done using the geothermal projects data/information base because this is where vast amount of spatial data is generated and used in daily decision making.

3. CASE STUDIES

3.1 Introduction

Evaluation of geothermal resource prospects are major activities of the KenGen Geothermal Development Division. Geothermal resource assessment (GRA) is a Government of Kenya program under which all the geothermal areas in Kenya are systematically evaluated with aim of developing the same for electricity generation. KenGen executes the GRA programmes on behalf of Ministry of Energy (GoK). Correct decisions are possible only when a decision maker has good knowledge of the matter he/she is making decision of! Knowledge is based upon correct information, and information is derived from data through processing, analyses and interpretation. In most cases, the decision maker is neither the data collector nor the analyst. It therefore necessary to have in place an information system that ensures the decision maker has the knowledge/ and all information required to make the decision.

Initial surface geo-scientific measurements and data collection is done in order to determine the best area for direct probe by drilling for subsequent reservoir evaluations. The cost of drilling a typical geothermal well (2000 m deep) can vary from Kshs 150 M to Kshs 600 M. Determination of a suitable location for drilling a geothermal well is therefore critical issue and a major decision by resource managers.

Tabulated here below is a typical input data/information that is required from basic surface measurements and studies in order to decide the best location for a geothermal well:

Data type	***Derivative Parameter***
Geology	
Eruption centres:	Heat source
Structural setting:	Vertical permeability
Petrological analyses:	Geothermal fluids/permeabilities
Geochemistry	
Soil gas (CO2, Rn etc):	Leakages/heat source
Fluids chemistry:	Reservoir (physical & chemical) state
Geophysics	
Gravity:	Heat source
Resistivity:	Reservoir extent, permeability
Seismology:	Recharge, permeability
Others	
Civil data:	Access, source of bulk construction materials
Environmental data:	Environmental impacts

3.2 Well location suitability modelling for the Menengai and L. Baringo prospects.

Figure 1 shows a workflow process diagram of the various data input for determination of the most suitable locations of geothermal drill well in the Menengai and L. Baringo prospects. Much more data input may be required than summarized here. The data selection is dependent on the discipline expert and a criterion selected is therefore based on other interpretations. For instance, the consideration that areas with CO_2 leakages of > 3.5% of soil gas as 'preferred areas' is based upon the exploration Geochemist evaluation of the whole field data. Similarly the of selection areas bound by caldera collapse (Menengai) as a privileged zone is based upon the exploration Geologist's consideration of possible proximity to shallow hot magmatic bodies.

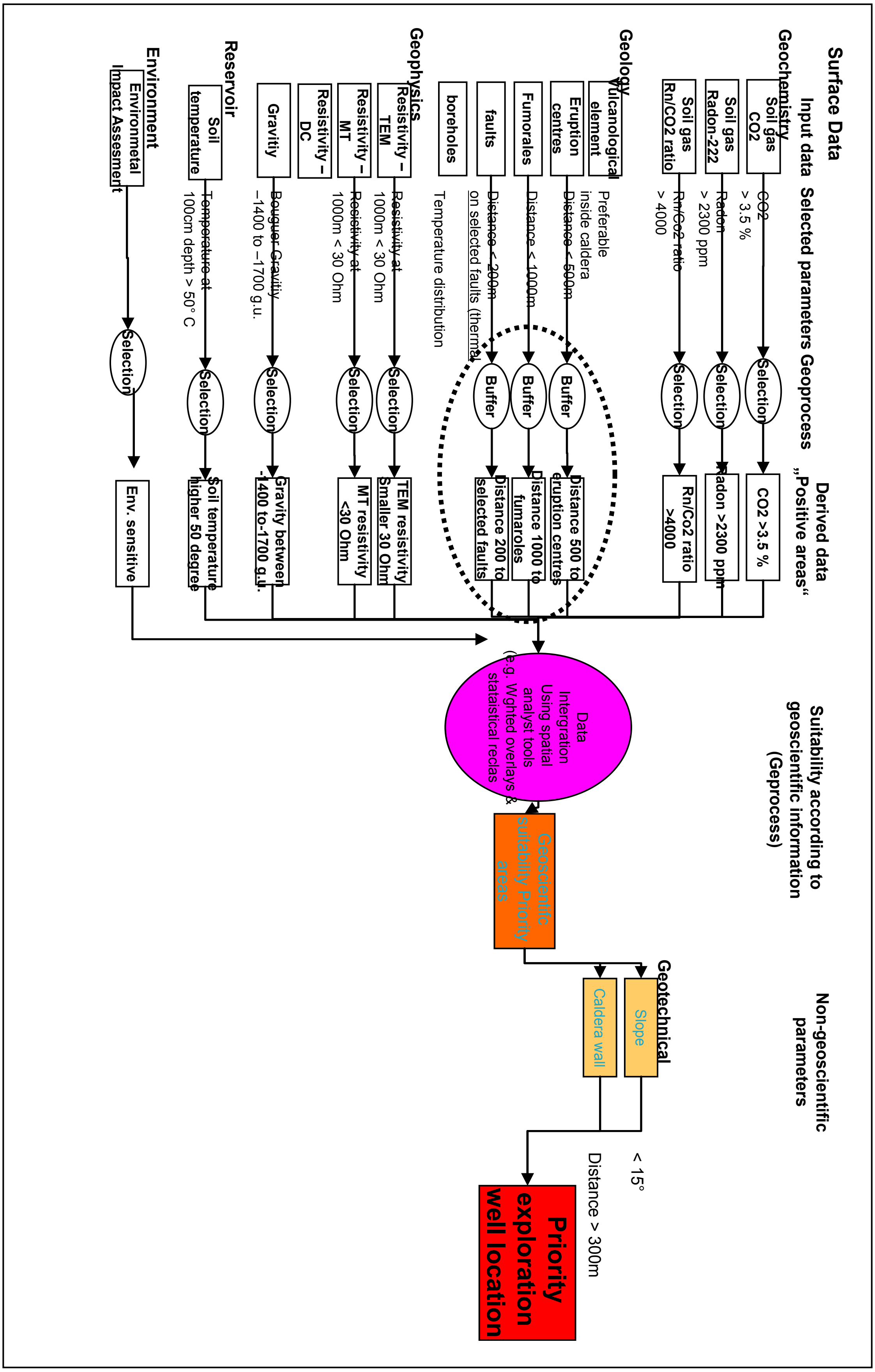

FIGURE 1: Work flow diagram: data processing schema

3.3 Geoprocessing

Using simple spatial analyst tools 'positive' are derived based upon criterion of a given discipline. Derivation of the single intermediate product requires creation of a geoprocessing model using the system's inbuilt tools referred to as 'model builder'. Figure 2 shows an example of geoprocessing model used to process some of the geology input data. It is important to note that very detailed

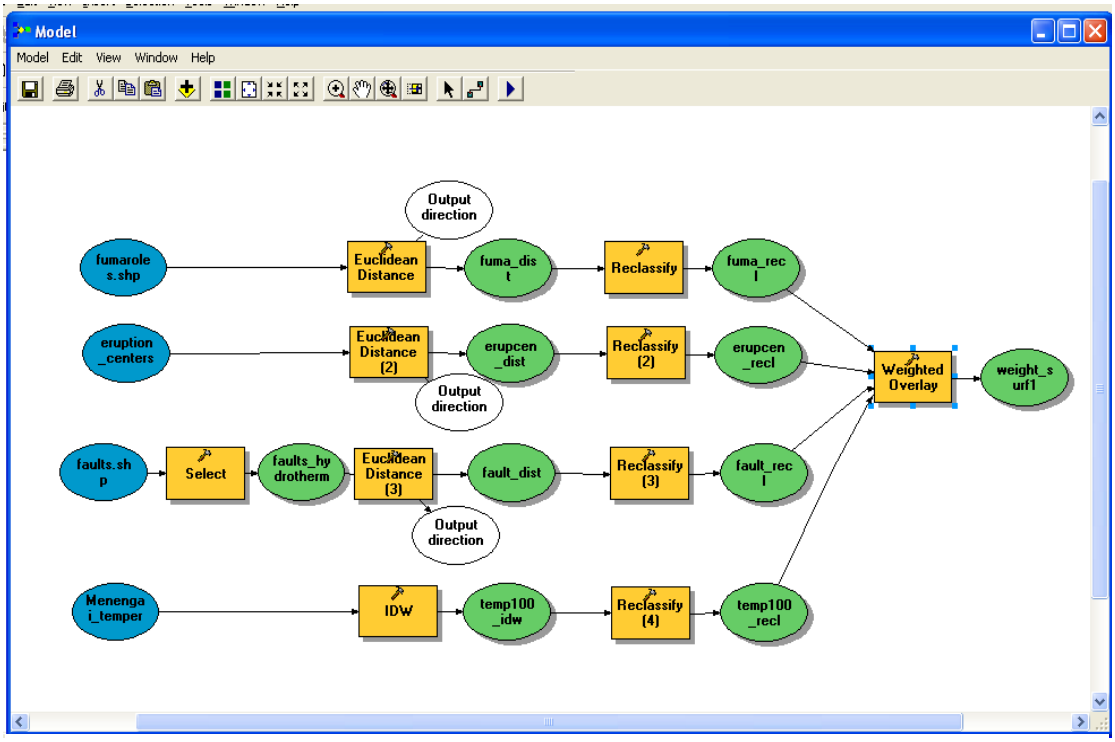

FIGURE 2: Model for geoprocessing geology data

measurements aspects have been brought into consideration e.g. distances from mapped fumarolic activities, classification of faults into hydrothermal active/inactive, distances from fault/fracture because of subsurface permeability distribution etc. This is to ensure the final product with which the decision makers would be referring to will have taken into account all measurements. The intermediate products are shown on Figure 3.

The intermediate products are then integrated into a single suitability map. The procedure for data integration involves use of statistical tools to combine all information of positive areas. A measurement from a given method may be giving a higher confident on interpretation of a geothermal system than another. For instance, ground resistivity at 2 km depth measured using TM tells more about the hydrothermal activity at the subsurface than fumarole temperature measured at the Earth's surface. The derived data 'positive areas' are put through weighted overlays and a reclassification process.

The statistical weighting applied to the various data depends on the target depth and type of well. For instance, for a very shallow well <500 m, data derived from some methods will have different weightings from that of wells targeting 1500~2000 m depth. Table 1 shows a table with statistical weighting that was applied to data for the Lake Baringo prospect. The intermediate and final suitability maps for Menengai and Lake Bogoria prospects are shown on Figures 4 and 5, respectively.

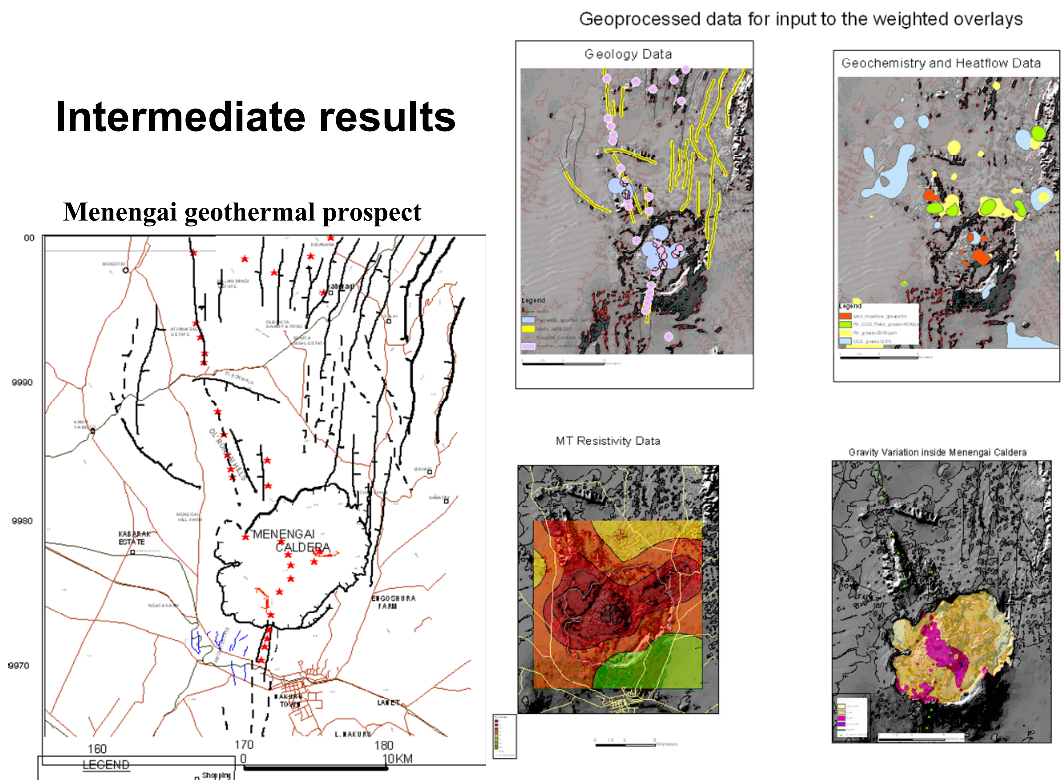

FIGURE 3: Derived positive areas

TABLE 1: Weighted overlay statistical table

Weighted overlay table

Raster	% Influence	Field	Scale Value
Rcl_TEM700	10	Value	
		1	1
		5	5
		7	7
		9	8
		10	9
		126	NODATA
		NODATA	NODATA
Recl_faults	25	Value	
		1	1
		4	4
		7	5
		9	8
		10	9
		NODATA	NODATA
Rcl_CO2	5	Value	
		1	1
		4	2
		8	4
		10	9
		NODATA	NODATA
rcl_r220	5	Value	
		1	1
		2	2
		7	3
		9	6
		10	9
		NODATA	NODATA
rcl_gravity	2	Value	
		1	1
		5	3
		7	5
		9	8
		10	9
		NODATA	NODATA
rcl_mtkrig	35	Value	
		1	1
		3	3
		7	7
		10	9
		NODATA	NODATA
recl_erupt	10	Value	
		1	1
		4	4
		6	6
		8	7
		10	9
		NODATA	NODATA
recl_t100	8	Value	

It can be observed that the final products show that the highest priority areas lie along zone of geological and tectonic significance. Therefore, this procedure can be scientifically relied upon. Since data integration process is quiet automated, human bias is minimized. The final priority map would normally be used by decision maker; therefore the decision maker would be making decision based upon all available information and data.

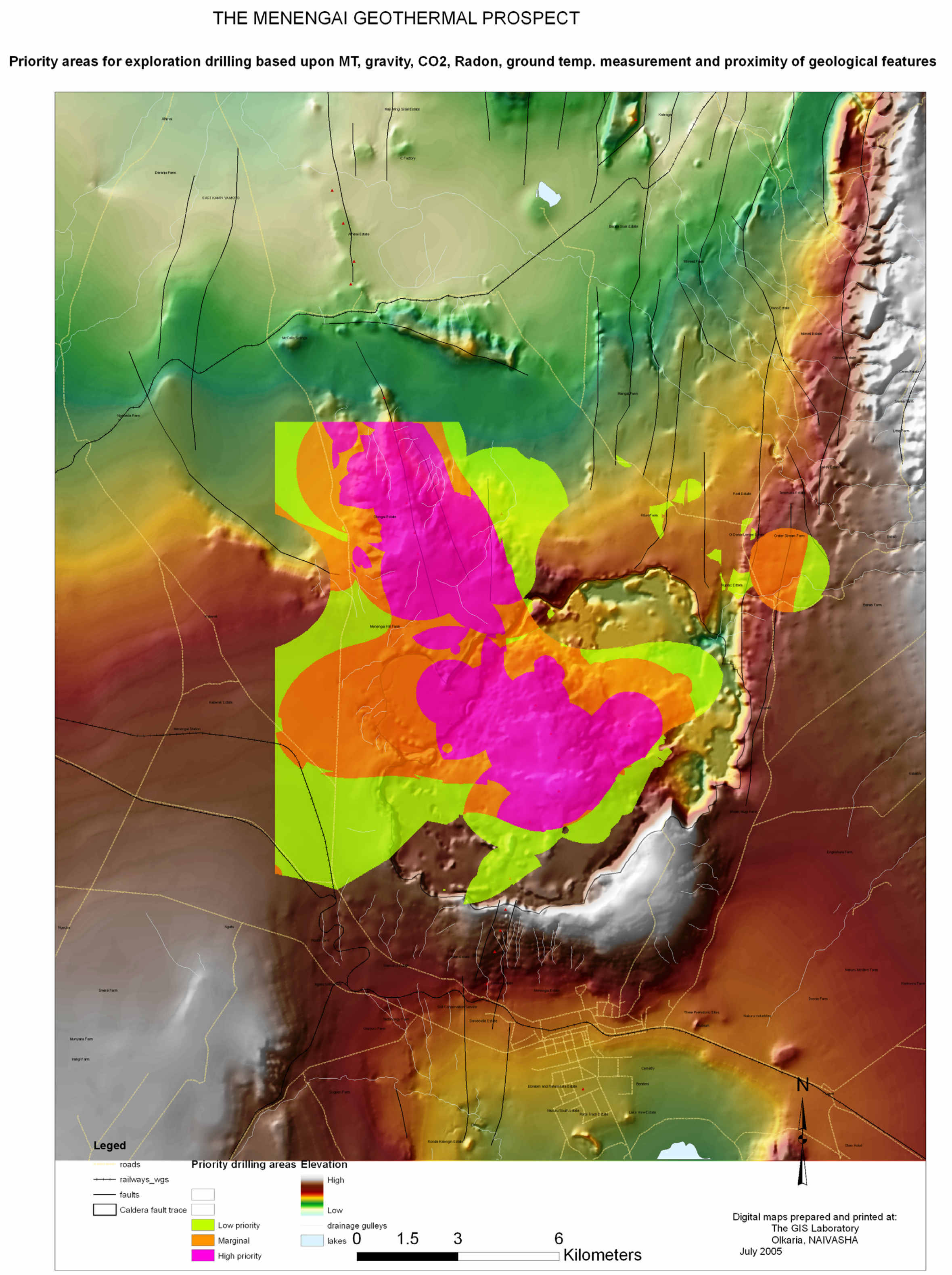

FIGURE 4**:** Priority areas for geothermal well sites

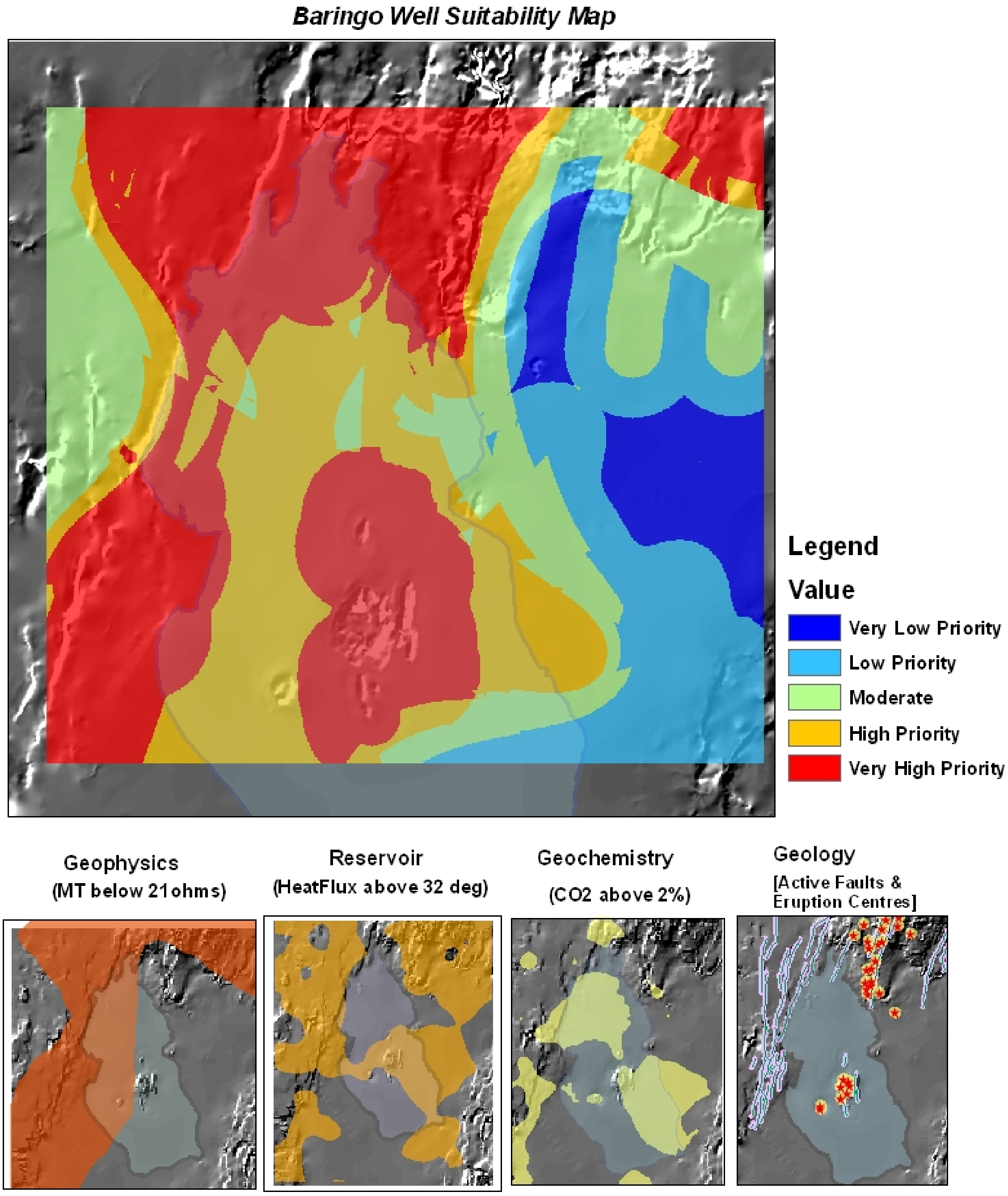

FIGURE 5: Suitability analysis map for L. Baringo prospect

4. DISCUSSION

4.1 Challenges

After realizing the importance of using the GIS technology in enhancing the overall efficiency of in geothermal resources development activities, KenGen invested in GIS hand-ware and software facilities. The various departments (like geology, geophysics, drilling, environmental etc.) involving in the geothermal resources development have independent systems and of handling their data and data management soft-wares, thus several stages of data reduction and or reformatting before importing into the GIS databases is a major challenge. Some of the information is in hard copies (e.g. hard copy reports, maps, hand written tables, scale-less diagrams etc) that require digitizing, georeferencing and extensive field ground truthing. The procedures are time consuming and well trained GIS experts to produce good results are required.

4.2 Proposed data/information sharing model of GIS for geothermal resources.

Lack of data sharing culture among professionals, institutions and Government departments has been and still is the biggest stumbling block of benefiting from vast amount of innovative work by many great minds. Most of us scientists, engineers and other good researchers believe that the value of data and information we may be having depends on how few people knows about it. In fact, this is a cheap theoretical reasoning good for economists/journalists etc based upon capitalistic ways of conning the World of the existing wealth and never creating new wealth at all! African herbalist may be the best example of holder of information and knowledge that is of little consequence because of lack of 'information sharing' culture in their profession! University professors, local industries, Government departments are known to be locking piles of sheets and tables of data in the name of 'classified and confidential'. Any **data** is only as good as the **information** that can be derived from it. The information itself is not important unless it is shared among many to be common **knowledge**. Decision makers' sanction for actions based upon what they know**. *If you would like your data /information to be used in decision making, it is upon you to share it as soon as you get it!***

TABLE 2: Proposed data/info sharing model for GIS for geothermal

Data Theme	**Scale/level of user**					**Data properties**
	Nation/ state	Local Auth	Private Dev	Educ/ Res Univ	Env. planng.	
Geothermal Res. inventory	i		i	i	i	Resource dist. Maps, classifications (Prob, poss,proven), Geol. Ass, rankings Ref. for other documentations
GRA status (expl & Res assesmnt data)	i		i	?	i ?	Explo –geology, geochem, geophy etc results, records etc. reserv asses, explo drilling, Res characteristics, estimated potential. Baseline env data
Individual fields data/info	i	i	i ?		i ?	Total field Doc. Proven, exploited potential, capacities, Steamfield/pstn info. Onewrship. Dev status. Future plans. Full EIA study results and reports
Directory of res. Dev facilities in the region	i		i	i	i ?	Location, desc.,details of consultants, professional, Lab, eqpt, contractors traning centres and service providers of geothermal industry.

In the effort of creating a GIS for geothermal resources it is recognized that the resource potential extent covers the Eastern Africa Rift system. Thus a number of countries in the region are direct stake holders to resource (and therefore information about the resource). Table 2 shows the proposed data and information sharing model for GIS for geothermal resources up to national level. The data will be grouped into various categories (themes) that are expected to have certain scope (data properties). The stake-holders or data users are grouped into various levels because the kind of information that they may be looking for from the system differs with purpose. Similarly the type of data and information they would contribute into the system vary with their activities. For instance, a local authority will require some information if they have to license some exploitation activity for a geothermal resource within their county. This kind of information may be categorized as information of the individual fields. Thus, documentation of a field in terms of potential, revenue expected, capacity of reservoir, optimized developments and EIA reports may be the necessary information required by a local authority to calculate the local taxation and approve licensing. On the hand University researcher may want information about investigation methodologies, testing procedures, results and the scientific associated with the various geothermal resource sites that are included in this information system.

5. SUMMARY

- The GIS is the most efficient information system for geothermal resources
- The two case studies carried out by KenGen shows the GIS technology can be used to model for the best exploration sites in geothermal prospects
- The challenges that face creation of a GIS for geothermal resources will be overcome by professional embracing ‘data & information sharing culture’
- We all need to strive to convert data we have into information, and information to knowledge that decisions and actions may be based upon