Presented at Short Course VII on Exploration for Geothermal Resources,
organized by UNU-GTP, GDC and KenGen, at Lake Bogoria and Lake Naivasha, Kenya, Oct. 27 – Nov. 18, 2012.

GEOTHERMAL ENERGY DEVELOPMENT & POTENTIAL, BIODIVERSITY CONSERVATION AND TOURISM DEVELOPMENT: EXAMPLES FROM KENYA

Gabriel N. Wetang'ula
Geothermal Development Company Ltd,
P.O. Box 17700-20100, Nakuru, Kenya
gwetangula@gdc.co.ke, gwetangula@gmail.com

ABSTRACT

Geothermal energy development in Kenya is associated with the African Rift Valley which intersects Djibouti, Eritrea, Ethiopia, Kenya, Tanzania Zambia, Malawi and northern Mozambique. There is a western segment that passes through Uganda, Rwanda and Burundi. All these countries have some geothermal potential. It is only in Kenya and Ethiopia that exploitation of geothermal energy for power generation has been attempted. Electricity generation from geothermal in Kenya started in 1981 with construction of Olkaria I station. The current output in Kenya is 209 MW which is about 16% of the country's effective capacity. There is a plan to increase the generation by an additional 5000 MW by 2030. The current geothermal capacity is located in Olkaria Geothermal field mainly within Hell's Gate National Park which is a nature/wildlife conservation area. Kenya has over the years gained experience in managing the environmental issues associated with geothermal development in nature conservation areas. This has proved that geothermal development can coexist with wildlife with maximum benefit from both resources. Kenya would like to replicate this success in other geothermal sites some of which are located in either National parks or Game Reserves.

1. INTRODUCTION

Most of the East African countries rely on biomass as the primary source of energy. Electricity accounts for between 10 and 30%. The electrical energy is predominantly from hydropower (70%), followed by fossil fuel thermal. With hydropower dominating the generation, Kenya and other East African Rift countries suffer from frequent rationing of power caused by drought and siltation in the dams and also experience high variations of prices caused by the world fuel markets. Geothermal development thus offers an excellent opportunity for saving foreign currency, cushion the supply variations and meet ever increasing power demand. Geothermal energy also offers renewable, indigenous and environmentally friendly alternative to more traditional sources.

Kenya has so far produced power from her geothermal resources. Kenya relies on three major sources of energy. These are biomass (68 %), petroleum (22 %) and Electricity (9 %). Hydropower (57 %) dominates the electricity sub-sector, followed by fossil- based thermal (32 %) and then geothermal (11 %). The other forms of renewable energy (wind, solar, biogas, micro hydro etc.) account for less than 1 %. Due to unreliable rain patterns, and the fact that Kenya depends highly on hydropower, the electricity supply has becoming unreliable especially during the dry seasons. Development of

geothermal energy, which is indigenous, low cost, environmentally benign and reliable, seems to be the long-term solution to this problem. Several recent least cost power development plans (KPLC, 2005) has considered geothermal energy as a least cost source of electrical power in Kenya.

The electrical power demand in Kenya has had an increasing trend over the last five years. This is expected to rise even more with the improvement of economy. With the commitment the government of Kenya has demonstrated to exploration and exploitation of geothermal energy, geothermal energy is expected to meet a large percentage of this demand. This paper presents geothermal development and nature conservation in selected geothermal fields and prospect areas.

2. GEOTHERMAL RESOURCES POTENTIAL IN KENYA

About fourteen geothermal prospects have been identified in the Kenyan Rift valley (Figure 1). Their geothermal potential is estimated to be in excess of 10,000 MWe. Wells have been drilled in only Olkaria, Eburru and Menengai but exploitation so far has only been done at Olkaria geothermal field.

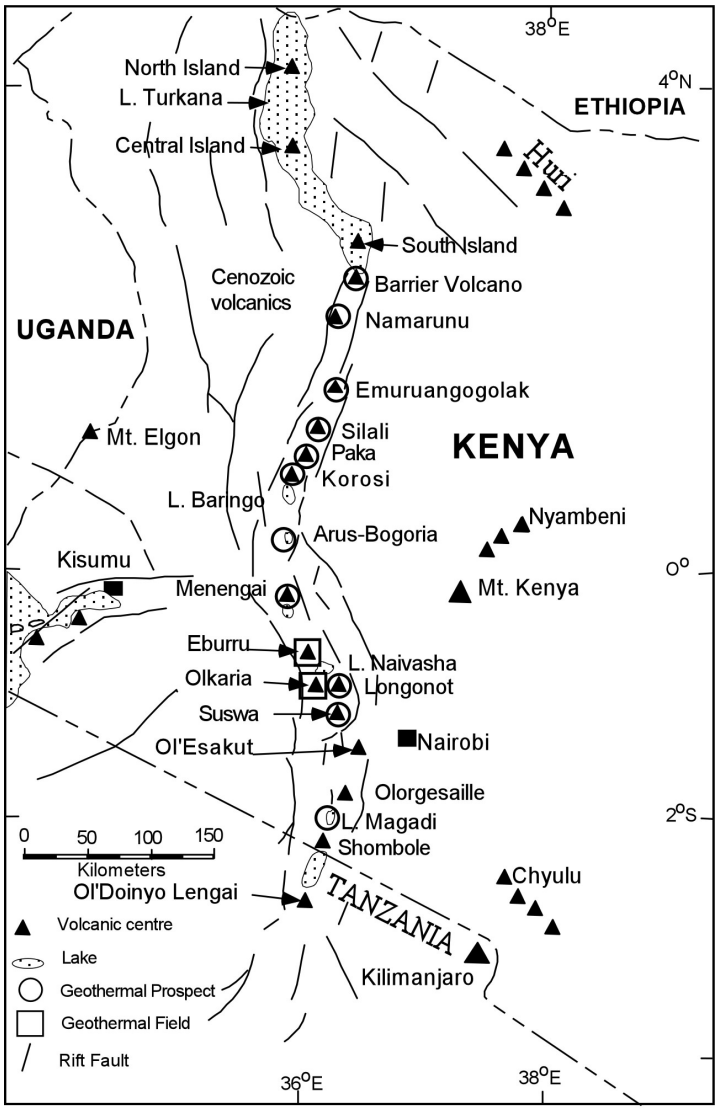

FIGURE 1: Geothermal prospects in the Kenya Rift Valley

For the sake of development, the Greater Olkaria geothermal area which is about 80 km2 has been divided into seven sectors namely Olkaria East, Olkaria West, Olkaria Northwest, Olkaria Northeast, Olkaria Central, Olkaria Domes and Olkaria Southwest. Currently, Olkaria East, and Olkaria Northeast Olkaria West and Olkaria Northwest fields are generating 209 MWe. In Olkaria Domes field, which is the fourth field targeted for development, exploration, appraisal and production wells have been drilled with 140 MWe of steam already proven with the planned construction of 140 MWe Olkaria IV geothermal power plant.

Detailed surface exploration was concluded in Suswa and Longonot, Menengai, Arus-Bogoria, Lake Baringo, Korosi-Chepchuk, Paka and Silali prospects and deep exploration wells have been sited. Exploration drilling is ongoing in Menengai field where four (4) wells have already been drilled by Geothermal Development Company.

3. GEOTHERMAL DEVELOPMENT AND UTILISATION

3.1 Electricity production

Currently, geothermal energy is being utilised in Olkaria field only. Three of the seven Olkaria sectors namely Olkaria East field, Olkaria West field and Olkaria Northeast field are generating a total of 209 MWe.

Olkaria I Power Plant: The Olkaria I power plant is owned by Kenya Electricity Generating Company Ltd (KenGen) has three turbo generating units each generating 15 MWe. The three units were commissioned in 1981, 1983 and 1985 respectively therefore the plant has been in operation over the last thirty (30) years.

Olkaria II Power Plant: Construction of 2 x 35 MW Olkaria II geothermal power station started in September 2000 was completed November 2003. An additional 35 MW Olkaria II 3rd Unit was commissioned in 2008 bring the total installed capacity of the plant to 105 MWe.

Olkaria III Power Plant: Olkaria III project is the first private geothermal power plant in Kenya. A 20 year Power Purchase Agreement (PPA) was awarded to Orpower 4 Inc. by Kenya Power and Lighting Company (KPLC) under a World Bank supervised international tender for the field development of up to 100 MWe. Currently, the plant has an installed capacity of 48 MWe in operation.

Oserian Plant: Oserian Flowers company has constructed a 5.0 MW binary plant Ormat OEC to utilise fluid from well OW-306 leased from KenGen. The plant provides electrical power for the farm's operations was commissioned in July, 2004.

3.2 Direct uses

3.2.1 Greenhouse heating

The only commercial application of geothermal energy for direct use in Kenya is at Oserian Development Company. The company grows cut flowers and other horticultural crops in greenhouses for sale in the European market. The company installed a greenhouse heating system in May 2003 using a 15 MWt well leased from KenGen. Heating the green houses increases the plants' growth rate, reduce humidity and consequently decrease diseases. The carbon dioxide from the well is also useful for the flower photosynthesis. The system is currently heating 30 hectares and there is a plan to expand the heating if more heat would be available. Oserian is therefore planning to lease more wells from KenGen for this purpose.

3.2.2 Swimming Pool heating

Hot springs have been used to heat spas in tourist hotels for example in Lake Bogoria Spa hotel which is located near the Lake Bogoria geothermal prospect.

3.2.3 Industrial Processing

The Local community at Eburru geothermal resource condenses the steam from fumarole and uses the water for domestic purposes. They also use geothermal to dry pyrethrum.

4. FUTURE DEVELOPMENTS

4.1 Electricity generation in Olkaria Fields

4.1.1 Olkaria I Units 4 and 5 power plant

The initial design of Olkaria I power plant and steamfield had proposed a life of 25 years. The units have been in operation for the last 30 years. Studies have shown that the plant and the reservoir are in good condition, and the reservoir is having more steam than is required to generate 45 MWe. An optimisation study conducted by KenGen revealed a possibility of increasing generation from this field hence a 140 MWe Olkaria I Unit 4 and 5 power is planned for this field. Additional production wells have already been drilled which have proven steam to support the plant.

4.1.2 Olkaria IV power plant

KenGen drilled three deep exploration wells in Domes field between September 1998 and May 1999. GDC has further drilled appraisal and production wells since 2008 which has proved steam equivalent of 140 MWe. This field is designated for construction of 140 MWe Olkaria IV geothermal power plant.

4.2 Menengai field geothermal drilling project

Menengai Geothermal Project is located on the outskirts of Nakuru Town, about 180 Km west of Nairobi. The geothermal field will be developed in three phases of 400 MWe each. GDC has commenced drilling in the field using two rigs that will culminate in the production of steam for the power plants. Currently, already four (4) exploration wells have been successfully drilled. The objective of the project is to develop the field to a capacity of 400 MWe by 2016. Subsequently, an additional 200 Mwe capacity is anticipated to be on line by 2016 and a further 400 MWe by 2017. The total field capacity is estimated at over 1600 MWe.

4.3 Direct uses

Oserian Development Company, which is a flower growing company has realised the advantages of heating the greenhouses using geothermal brine in heat exchangers. Apart from enhancing growth, the heat reduces humidity in the houses and inhibits diseases that would otherwise be controlled using expensive pesticides. Also, the carbon dioxide gas from the wells enhances photosynthesis of the plants. Oserian is therefore planning to lease more geothermal wells from KenGen for this purpose. Other flower growing companies are also interested and the possibility of supplying them with brine is being evaluated.

4.4 Other geothermal prospects

A prefeasibility study for multiple use of geothermal for electricity generation and water production for agriculture and domestic use is being carried out at Eburru geothermal field by GDC. The first phase of this project, which is the construction of a 2.5 MW binary plant by KenGen is on-going and

is planned to be commissioned at the end of 2012. Detailed surface exploration work at Suswa, Longonot, Arus-Bogoria, Lake Baringo, Korosi-Chepchok, Paka and Silali prospects have been completed. Exploration drilling is planned to be done in Silali prospect by GDC in 2012 after acquisition of two more drilling rigs whose delivery is expected in early 2012.

5. GEOTHERMAL DEVELOPMENT IN NATURE CONSERVATION AREAS

The geothermal prospects that are located in nature conservation area (National Parks or Game Reserves) are Olkaria, Longonot, Lake Bogoria, and Lake Baringo. The rest of the prospects are in lands owned either by Government as forests (Eburru and Menengai), privately owned or in the hands of group communities.

As indicated, Olkaria, Eburru and Menengai fields are under development with Olkaria field being is the only field that is well developed so far in Kenya currently supporting three stations within Hell's Gate National Park, a wildlife conservation area. The planned 140 MWe Olkaria IV will be located in a private land. This paper will summarize the biodiversity conservation, tourism and geothermal power development in Olkaria, Longonot, Menengai, Lake Bogoria and Lake Baringo geothermal areas. A government institution known as Kenya Wildlife Service (KWS) manages National Parks whereas Game Reserves are owned and managed by Local Authorities and communities in which they are located.

5.1 Hell's Gate National Park in Olkaria Geothermal Field

Hell's gate National Park is situated within Olkaria geothermal area located on the southern side of Lake Naivasha, which is the lifeline of economic activities in the semi-arid region of Rift Valley Province of Kenya. The geothermal resource presently supports an existing 45 MWe power station (Olkaria I), which commenced construction in 1980. An important aspect in the environmental management of geothermal developments in this area has been the existence of Hell's Gate National Park, which was established in 1984 several years after the present Olkaria I Power Station was commissioned (The World Bank Group, 2001). The park covers an area of about 6825.7 ha (68.5 km^2) and encloses both the Olkaria I power station, Olkaria II power station under construction, Olkaria III power station operated by a private developer Orpower4 Inc in Olkaria Southwest and much of the geothermal resource. Major land uses in and around the park has been geothermal development, livestock ranching, cultivation of cut flowers for export market and conservation of wildlife. Wildlife conservation as an aspect of sound environmental management has been a key component in geothermal resource development.

5.1.1 Landscape and flora in Hells Gate National Park

Three major landscapes exist depending on terrain, vegetation and wildlife use (Kenya Wildlife Service, 1992). The plains are part of the Njorowa gorge that divides the park into two unequal parts with dominant plant species being *Cynodon dactylon, Digitaria scalarum, Tarchonanthus camphoratus* and *Acacia drepanolobium* (Kiringe, 1993). About 170 plant species have been recorded in HellsGate Park.The area holds substantial number of large herbivores due to its flat terrain and suitable food material (Kenya Wildlife Service, 1992; Simiyu, 2000).Hill and mountain encompasses the geothermal development area towards the Olkaria gate. Olkaria hill with an elevation of 2240 m.a.s.l is within this region. Dominant vegetation association are *Tarchonanthus/Acacia shrubland and Cymbopogon/ Themeda / Digitaria* which do not constitute important food source for the animals hence low concentration. Cliffs, main wall and towers consist of the main walls of the gorge and the Fischer's and central towers. The area is rocky with scanty vegetation. The cliffs form important breeding and nesting grounds for various bird species such as the verreaux's eagles, Ruppell's vulture and the rare lammergeyer (bearded vultures).

5.1.2 Fauna of Hells Gate National Park

Wildlife species in Hell's Gate National Park and adjoining area of Kedong Ranch, Kongoni Ranch and Akira Ranch are mainly plains game. They include Buffalo (*Syncerus cafer*), Zebra (*Equus burchellis*), Grant's gazelle (*Gazelle grantii*), Thomson's gazelle (*Gazelle thomsonii*), Coke's hartebeest (*Alcephalus buselaphus*), Maasai giraffe (*Giraffa reticulata*) among others. Avifauna is quite diverse due to its proximity to Lake Naivasha that has numerous bird species because of habitat heterogeneity (Kenya Wildlife Service, 1992). KWS/KenGen having been undertaking quarterly wildlife population in the Olkaria and adjacent areas to determine the population density and distribution (Figure 2).

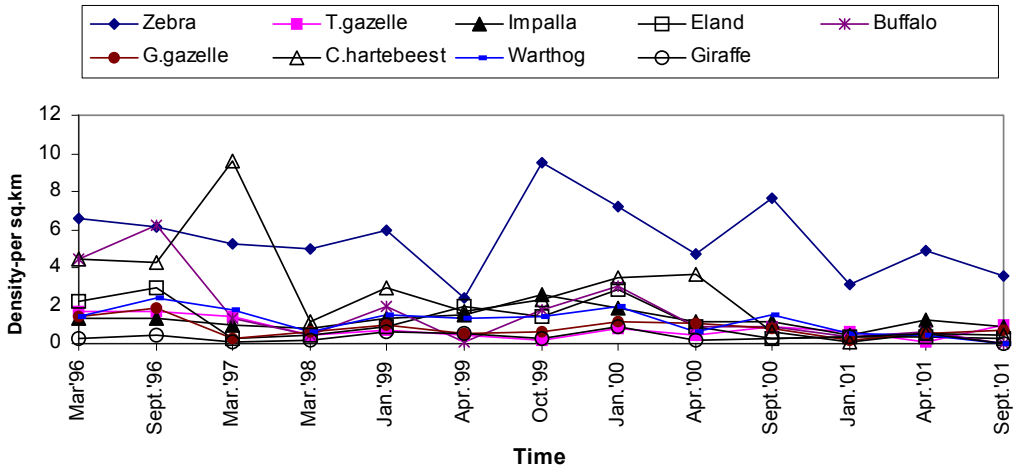

FIGURE 2: Wildlife population density Hell's Gate National Park, Olkaria (Wetangula, 2003)

5.1.3 Tourism in Hells Gate National Park

There is a marked increase in tourists visiting the Hell's Gate Park (Figure 3) some of whom are more interested in visiting the Olkaria I and II power stations rather than seeing the animals. The power stations have recorded about 2000 visitors a month on average. There are others that want to see both the animals and the power stations and even chose to camp nearby. In our view, the presence of the power stations is a major attraction to the tourists and consequently benefits the park.

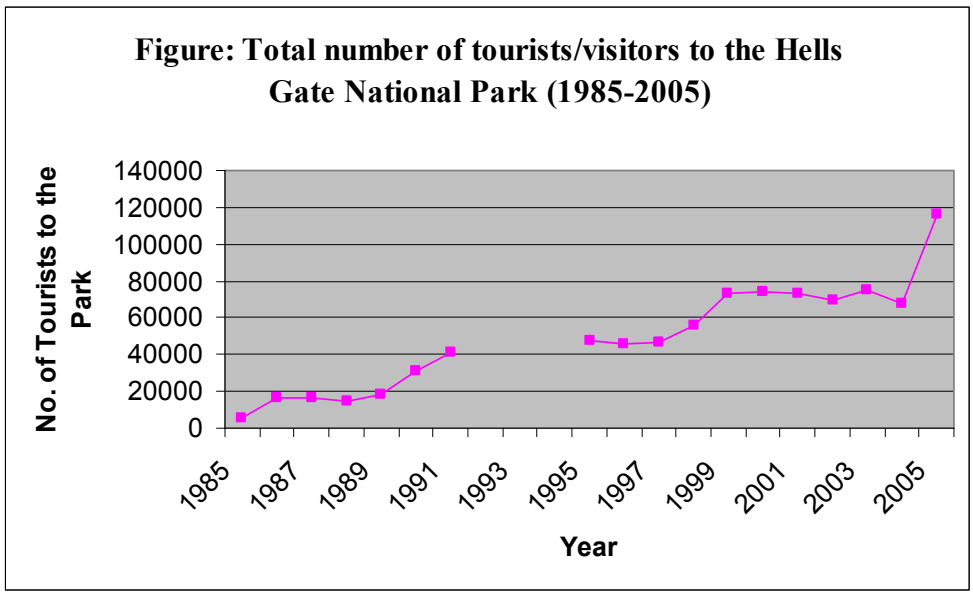

FIGURE 3: Tourists to Hells Gate National Park, Olkaria

5.2 Longonot Geothermal Prospect and National Park

Longonot National Park is Located to the east of Hell's Gate National Park about 85km North West of Nairobi. The park comprises of the Mount Longonot which is a central volcano with a crater at peak. The Longonot crater and caldera that hosts the Longonot Geothermal Prospect covers an area of about 35 km^2. KenGen carried out detailed surface surveys in this prospect between April and July 1998. Data analysis showed that Longonot Geothermal Prospect has positive indicators of a geothermal resource that can be commercially exploited. The geothermal potential of the area is associated with a large magma chamber under the caldera and summit crater on Mr. Longonot that also constitutes the heat source. The area around Longonot is marked by active manifestations that occur in the form of fumaroles, altered grounds, warm grounds, sulphur and silica depositions. Estimates deduced from gas geothermometry show that there exists a high temperature resource centred underneath the main summit crater with reservoir fluids temperatures in excess of 300ºC. Resistivity data indicates that the area starting from the Longonot crater and to the south define a low resistivity anomaly ($\leq 10\ \Omega m$) that extends over an area of 70 km^2.

Longonot National Park (wildlife conservation area) was gazetted in 1984 together with Hell's Gate National Park as Hell's Gate/Longonot National Parks. Total area of the Park is 52km^2. The park can be zoned into three-zone categories namely special zone, semi wilderness and utility zone. The *Special Zone* encompasses the V-shaped valleys and steep slopes around the crater rims and their associated vegetation. According to the park management plan, it is recommended that no motorized drives should take place in this area unless it is very necessary and have to be kept to minimum. The three proposed sites for exploratory drilling are located within this zone. *Semi-wilderness Zone* has large tracts of relatively undisturbed but accessible for semi wilderness experience. Permitted developments in this area include walking trails, picnic sites and viewing sites. Some areas are motorable while others are non motorable. The *Utility Zone* provides sites for management and other developments where premises for tourism and general park management are situated.

5.2.1 Flora of Longonot

The most dominant vegetation in the area of interest is an association of Cymbopogon/ Themeda/Tarchonanthus/Acacia/Dwarf/Shrubland. This is the most dominant vegetation type and occurs in most higher areas. Dominant vegetation species include *Tarchonanthus camphoratus* (Mleleshwa), *Themeda triandra, Acacia drepanalopium and Cymbopogon* sp. The Park is quite open due to fire which sweeps across the mountain almost every year.

5.2.2 Fauna of Longonot

The wildlife species in Longonot National Park include, Reedbuck, Zebra, Eland, Lion, Cheetah and Buffalo. The Park has low wildlife numbers due to the nature of the vegetation and terrain. During the rainy season the animals are found in large numbers especially the Zebra. The numbers decline as the dry spell sets in due to reduced grazing materials. Zebra is the most abundant species in this ecosystem. No plant or animal has been identified as endemic in this Park.

5.2.3 Tourism

The largest tourist attraction of this park is climbing up to the crater and even circling it. Only the strong ones walk round the edge of the crater a distance of about 11 km.

5.3 Menengai caldera and forest reserve

Menengai caldera also attracts many visitors because of the beautiful scenery when at the top of Lion Hill View Point. School children and University students are the main visitors of this area because access to this crater is fairly easy. Tourists who visit Lake Nakuru Park also do visit this area. Part of

the caldera is gazetted as Menengai forest reserve and is under the management of Kenya Forest Service. The other part is trust land. Currently KFS is in the process of securing this area so as to earn revenue from the visitors by charging a fee for each visit. Already some organized groups have put up some tented camps for visitors.

5.3.1 Menengai forest and associated flora

Menengai Forest is at an altitude of 9910ft above sea level with total gazetted area of 7,315.3 ha including the crater. The forest vegetations resemble that of the "true savannah". The dominant natural vegetation: Leleshwa (*Tarconanthus camphorates), Rhus natalensis, Rhus vulgaris, Euclea divinorum, Acacia sp. (A. abysinnica & A. lahai), Cussonia sp. (C. spicata & C. simplifolia)*. Dying species due to illegal over explotation inside the crater include Cidar which are now too scattered and few to due illegal harvesting. There is a big portion of open glades of grass (grassland), which are susceptible to fires. Outside the caldera, on the hilly part of the forest are Black wattle (*Acacia mearsii*) and some planted *Eucalyptus sp.* (*E. maculata, E. saligna, E. globules & E. grandis*), which are however being destroyed by the locals. *Erytherina abbysinica* used to be wide spread within the forest but has been decimated by herbalists who have been digging/exploiting it for medicinal purposes, thus could become endangered if not controlled. Areas within the caldera floor are dominated by bushed grasslands comprised of species of *Tarconanthus camphoratus* and *Acacia drepanolobium* in association with *Chloris gayana*, *Digitaria abyssinica* , *Fimbristylis exilis* (geothermal grass)and *Boma Rhode* grasses. Parches of bushed woodland (*Tarconanthus camphoratus* (Leleshwa), *Acacia* and some *Euphorbia candelabra),* mixed bushland (*Acacia drepanolobium, Dodonea viogar* and *Tarconanthus camphorates)*, and open grasslands (*Themeda triandra*, *Cynodon dactylon*, *Chloris gayana* and *Digitaria abyssinica)* forming various associations are common both within and outside the Caldera floor.

5.3.2 Fauna of Menengai

The wild animal species documented in the Menengai geothermal the project area is given in Table 1. There are very few wild animal species as large parts of it are farmlands with no open grazing and dispersal areas. Leopards, Baboons, Wild pigs and Snakes are common within Menengai Caldera. Cases of Human - Wildlife conflicts mainly due to invasions of farms by the Baboons and Monkeys have been reported.

TABLE 1: Distribution of wildlife species

Areas	**Common Wildlife Species**
Menengai Caldera	Antelopes, Dik dik, Gazelles, Monkeys (vevets, Columbus), Ant bears, Baboons, Leopards, Snakes (Puff udder), Birds (Quills, Guinea fowls, Cave spurrows, bats, weaver birds) and Wild pigs.
Solai	Leopards, Zebra, Velvet Monkeys, Baboons, Hyena, Tortoise and Snakes.
Kambi ya Moto	Porcupine, Zebra, Baboons and Impala.
Dundori	Columbus Monkey, Velvet Monkey, Wild-pigs and Baboons.
Bahati	Leopard, Mongoose, Porcupine, Baboons and Hyenas.

Source: Nakuru District KWS Warden's Office

5.3.3 Tourism in Menengai

The proposed project is within Menengai caldera, which is a tourist attraction, noted particularly for its scenic beauty (Figure 4). Some of the major tourist attraction sites like the Lake Nakuru National Park and Hyrax prehistoric sites are within proximity of the Menengai geothermal project. The tourism potential of the area has been enhanced by opening up more access roads into the caldera, which have previously been viewed as a place for bhang/marijuana growers and thieves' hideouts. Geothermal

drilling project in Menengai in itself is a tourist attraction feature which has witnessed a number of visitors to the project just like in Hells Gate National Park at Olkaria.

FIGURE 4: Wilderness of Menengai caldera as a tourist attraction feature in the area with Lion Hill viewpoint at background

5.4 Lake Baringo Geothermal Prospect and National Reserve

Lake Baringo Geothermal Prospect is one of the several important areas on the Kenya Rift floor that are associated with possible occurrence of geothermal resource. A surface exploration study encompassing geology, geochemistry, geophysics, heatflow were carried out by GDC between 16th February to 3rd March, 2011. This was a follow up to the infill work that had been carried out in July, 2010 (Figure 5). Previous survey was done by KenGen (Kenya Electricity Generation Company) in 2004. Hydrothermal activity in the Lake Baringo prospects is manifested by extensive occurrence of fumaroles, hot spring, altered grounds and thermally anomalous ground-water boreholes. One of these boreholes, the Chepkoiyo borehole, which was drilled in April 2004, self-discharged water at 98°C (local boiling point). The chemistry of the discharged fluids indicated possible input from a geothermal reservoir.

5.4.1 Fauna of Lake Baringo prospect area

Lake Baringo, fresh water lake in this geothermal prospect area that support a number of wildlife species lead to establishment of Lake Baringo Conservation Area. This conservation area was gazetted in 1994 and currently is managed by Baringo County Council. Wildlife in and around the Lake includes reptiles (crocodiles, snakes, tortoises), Hippopotamuses, over 480 bird species including ostriches, zebras and baboons) attracting many tourists, hence the area plays an important role in supporting the local and regional economy. The council in collaboration with the local community has also established a Reptile Park at Kampi Samaki. Though official information about wildlife does not exist, it is well known the lake is rich in hippopotamus and crocodiles. For example, Lake Baring Country Club estimated, by physical counting about 150 hippopotamuses and hundreds of crocodiles in 1999 though the population was higher before the 1993-94 drought (Sanyu Consultants Inc., 2001). The lake is famous worldwide for its ornithological sanctuary with more than 480 different species. Reported cases of human-wildlife conflicts are related to crocodiles attacking of children and livestock at lakeshores.

5.4.2 Tourism in Lake Baringo Prospect area

The lake has had many tourists both local and international due to the rich wildlife. Table 2 shows the visitors and revenue to Lake Baringo Conservation Area for the period 2003-2004. The number of visitors fluctuates very much according to season with the peak being in the months of July and October.

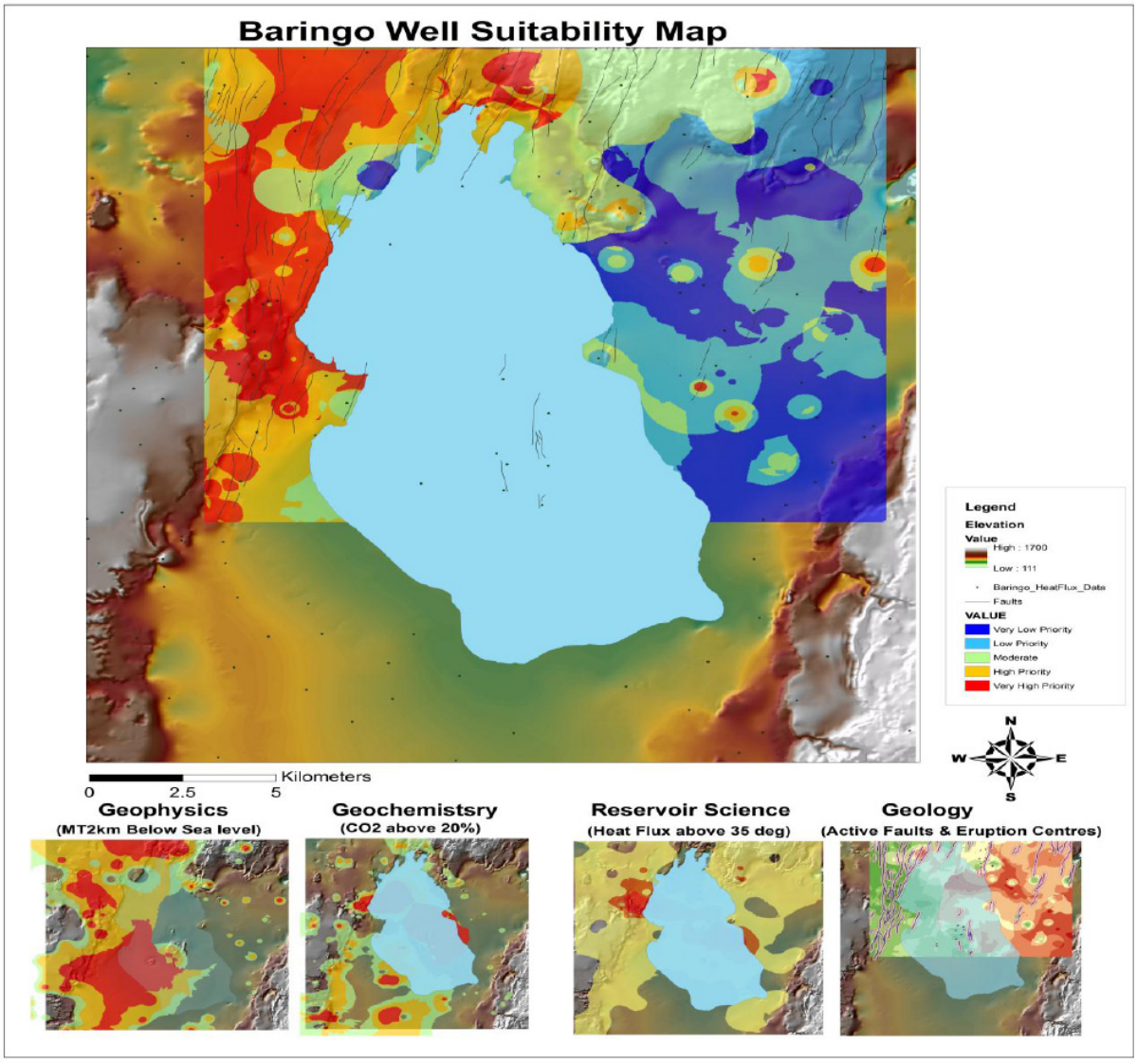

FIGURE 5: Lake Baringo prospect geothermal suitability map

TABLE 2: Visitors numbers and revenue for Lake Baringo Conservation Area

Month/Year	No. of paying Visitors	No. of non paying Visitors	No. of paying Vehicles	Total Revenue KShs. @79.30 US$
June 2003	703	167	71	60,410
July 2003	1196	261	158	155,440
August 2003	1546	319	169	147,250
September 2003	677	527	59	58,360
October 2003	1530	1098	99	89,330
November 2003	1221	134	67	56,540
December 2003	2106	149	182	139,060
January 2004	674	68	125	80,030
February 2004	603	73	128	89,520
March 2004	663	643	104	68,990
April 2004	903	533	76	61,800
May 2004	385	91	46	26,930
June				

Source: Lake Baringo Statistical Information and Conservation Centre

5.4.3 Flora of Lake Baringo prospect area

The prospect area is characterized by bush acacias especially *Acacia reficiens, Acacia mellifera, Acacia nubica* and *Acacia tortilis* dominating the landscape. Vegetation on escarpment includes evergreen bushland, abundant species of which are *Croton dichogamus, Maytenus sp., Euclea sp*. Evergreen wooded grassland can be found at the Arabal valley. The area is dominated by mainly *Balanites aegyptiaca*, *Acacia gerardii*, and *Cynodon dactylon* grass. Semi-deciduous woodland dominates the lower part of this area especially along rivers, northern part of which is called Njemps flat. Major vegetation species are *Acacia tortilis* and *Acacia elatior*. Deciduous bushland dominates western part of Lake Baringo where *Acacia mellifera*, *Acacia reficiens* and *Acacia nilotica*, *Acacia commiphora.*Grasses in the area include *Eragrostis sp*., *Tribulus terrestis*, *Heliotropium sp*., *Cynodon dactylon*, *Cynodon plectostachyus* and *Echinocloa haplocada*.

5.5 Lake Bogoria Geothermal Prospect Area and National Reserve

Lake Bogoria and part of its catchment area is rich in fauna hence has been protected as 'Lake Bogoria National Reserve' (LBNR) and covers an area of 107 km^2. It was gazetted in 1973 and is currently managed by Baringo and Koibatek County Councils. Recently the LBNR was designated as a third Ramsar site after Lake Nakuru and Naivasha. The lake is saline and covers an area of 34 km^2. It is rich in biodiversity, hosting about half of the world's population of lesser flamingos (*Phoeniconaias minor*). It is also a habitat to other bird species including greater flamingos (*Phoeniconaias rubber*), black-necked grebe (*Podiceps nigricollis*), ostriches, fish eagles and several migratory species. Due to its avifauna richness, it has been designated as an Important Bird Area (IBA). The mammalian fauna in LBNR include zebras, gazelles, buffaloes, several primates and the only relatively accessible population of greater kudus. In addition to its rich biodiversity, Lake Bogoria has numerous hot springs.

5.5.1 Flora of Lake Bogoria Prospect area

The vegetation is mainly thorny bushland dominated by the species of *Acacia*, *Balanites* and *Commiphora* with patches of riverine woodland containing *Ficus capensis*, *Acacia xanthophloea* and *Acacia tortilis*. In the lower slopes of the Siricho Escarpment, *Combretum* and *Grewia* thickets dominate.

5.5.2 Fauna and Avifauna of Lake Bogoria Prospect area

Lake Bogoria is internationally important as a main feeding ground for a large percentage of the world's population of the lesser flamingo (*Phoeniconaias minor*). The high productivity of the blue-green algae, *Spirulina platensis*, coupled with the presence of freshwater at several places results in a concentration of the lesser flamingo in large numbers, at times over two million, to give the appearance of large shimmering pink sheets across the lake. Kenya holds between a third and a quarter of the total world population of the lesser flamingo. There are no mammals inside Lake Bogoria but a small variety of animals exist in the adjacent areas. They include the rare Greater Kudu (*Tragelaphus strepsiceros*) and many other antelopes such as gazelles and impala. Other mammals found in LBNR are zebras and buffaloes. The Greater Kudu population is reported to be on the decline, as a result of the demand on their horns, which are used by the locals for ritual purposes. The zebra population is reported to have increased tremendously in the recent past.

5.5.3 Tourism in Lake Bogoria geothermal area

Tourists and visitors to the Reserve are stakeholders, in search of recreation, education and research. They include both local, national, and international tourists and visitors. According to records in the Lake Bogoria recording station, over 50,000 school children visit Lake Bogoria annually to understand and appreciate the unique physical geography of the Rift Valley, an important topic in the geography syllabus in Kenyan schools. Researchers who come to seek knowledge are among this group. The

number of visitors to LBNR fluctuates very much according to season with the peak being between the months of July and September (Figure 6).

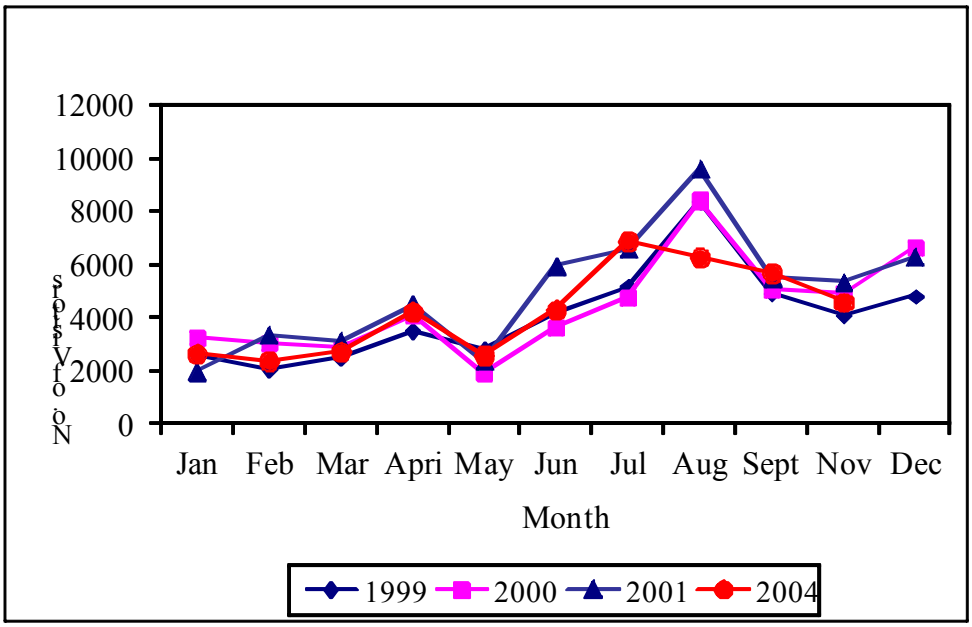

FIGURE 6: Visitors to Lake Bogoria National Reserve

6. CONCLUSION

The success achieved in the development of geothermal energy resource in nature conservation areas/ National park demonstrates that geothermal energy development, wildlife conservation and tourism development can coexist by carefully using sound environmental management systems and monitoring as have been the case in Olkaria geothermal field and Menengai geothermal field. Geothermal power Plants have been successfully developed in Olkaria field within Hell's Gate National Park while geothermal drilling is successfully ongoing in Menengai. With sound environmental management systems, properly designed operation systems can be used to mitigate most of the envisaged impacts. The developments of the geothermal projects do enhance the attraction of these nature /wildlife conservation areas and increase revenues. They are also offering many other socio-economic benefits to the communities in which they are located.

REFERENCES

GDC, 2011: *Lake Baringo geothermal prospect. Investigation for its geothermal resource potential. A geothermal resource assessment*. Draft report. Compiled by Cleophas Simiyu

Sanyu Consultants Inc., 2001: *The study on the Integrated Rural Development Project in the Baringo Semi Arid Land Area (Marigat and Mukutani Divisions) in The Republic of Kenya*. Draft Final Report prepared for Japan International Cooperation Agency (JICA) and Ministry of Agriculture and Rural Development (MOARD).

KPLC, 2005: *Least Cost Power Development Update*. A report for the Government of Kenya.