THE SOCIO-ECONOMIC AND ENVIRONMENTAL IMPACT OF GEOTHERMAL ENERGY ON THE RURAL POOR IN KENYA

The Impact of a Geothermal Power Plant on a Poor Rural Community in Kenya

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AFREPREN in Brief

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Executive Summary

Kenya is the first country in Africa to tap geothermal resource for energy. The geothermal resource lies beneath the vast East African Rift Valley. The present production area of Olkaria covers 11 km^2 and has an estimated steam for 400MW years. A total of 53MWe of electricity is currently being generated from geothermal steam in the Olkaria area. This accounts for about 5.1% of the nation's electricity consumption. A total of 301MW is planned for generation by the year 2009.

The geothermal resource occurs in an area that has environmentally sensitive areas. The Olkaria field is in the middle of a game park and highly productive farms. Economic activities in this area have attracted a large human population. The exploration and exploitation of this resource should therefore be carried out with minimum negative impacts on the environment and the local communities. This study is designed to assess the socio-economic and environmental impacts brought about by the development of the Olkaria East geothermal plant, which has been in operation for the last 20 years.

The 15 years of the first power plant operation at Olkaria has shown that with proper management, geothermal energy production can go hand in hand with conservation. Analysis of geothermal hydrogen sulphide and carbon dioxide emissions shows that they are below the World Health Organisation harmful levels. Geothermal brine cation and anions concentrations from the present geothermal wells in Olkaria are not very high to warrant environmental risk. Heavy metal concentrations in potable water are below acceptable levels and therefore geothermal fluid may not be hazardous to the environment. Noise levels vary from 32-44dB(A) away from the station and 50-60dB(A) around the power station.

Attempts have been made not to fence off migration paths of animals by burying pipes underground or elevating them to allow free movement of animals. Sensitive habitats for animals and birds such as breeding, feeding and resting sites have also been preserved.

No adverse impacts by the project on the local communities have been reported. Proper operational management by the geothermal plant operators is in place to stem any possible conflict with the surrounding community. This includes fencing off the plant premises to prevent injury to the community and their animals, and the holding of regular meetings between the project management and the community. KenGen, the power utility has made some attempts to provide the community with infrastructures such as piped water, transport, shops and schools. In addition, there has been increased sale of souvenirs to tourists at the cultural centre, and creation of a market for their animal products.

However, there are a few concerns that have been raised by the Maasai community. Out of the 500 people employed at the plant, only seven (7) are from the local Maasai community. This is equivalent to 1.4% of the total workforce at the plant. These seven comprise of one copy typist, one clerk, one driver, one office messenger and three watchmen. The community felt that the project should have economically empowered them by providing more employment opportunities.

The study concludes with the following recommendations:

- Exploration, exploitation, environmental and cultural issues inherent in geothermal energy should be identified and evaluated in advance.

- Surface waters from well testing, disposal pipe; leakage and chemical stabilization ponds should be disposed by re-injection into appropriate deep reservoirs.

- The project should consider shifting more of its operations to the side of the game parks, initiate diagonal drilling, put up high hoops, paint the pipes green, and plant more indigenous trees as camouflage, in order to maintain the natural appearance and beauty of the park and its immediate surroundings.

- The findings of a study of the animal migratory routes should be taken into account in the design of the steam gathering system and power plant layout to avoid blocking key migratory routes. In addition, KenGen should pursue the option of burying pipes where routes are crossed.

- KenGen should, in collaboration with KWS and OrPower 4, establish a long-term park restoration endowment fund that will rehabilitate Hell's Gate Park after their operations come to an end.

- Above 85 dB of noise, the allowed exposure of workers should not exceed 8 continuous hours. This will require greater workers rotation on shifts, use of hearing protection and rest booths.

- Continuous monitoring program for noise and hydrogen sulphide emission levels should be maintained. In addition, the project needs to periodically contract an independent person or group of persons to evaluate their environmental management systems according to the ISO 14001 and 9001 certificate principles and guidelines.

- KenGen should find ways of assisting the neighbouring Maasai community acquire electricity.

- KenGen should provide more job opportunities to the local Maasai community.

- The power utilities involved should participate in community development activities such as infrastructure development to improve the community's standards of living. In addition, community members need to be educated on general safety measures.

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List of Acronyms and Abbreviations

BOC	Board of Consultants
EMS	Environment Management System
EPF	East Production Field
IPP	Independent Power Producer
ISO	International Standards Organization
KenGen	Kenya Electricity Generating Company
KWS	Kenya Wildlife Services
NEF	North East Field
ODC	Oserian Development Company
OWF	Olkaria West Field
UTM	Universal Transverse Mercator

List of Units

CH_4	Methane
CO_2	Carbon dioxide
dB	Decibels
H_2S	Hydrogen Sulphide
Km^2	Square kilometres
M^3/y	Meters cubed per year
MW	Megawatts
ppb	Parts per billion
ppm	Parts per million

List of Metals

B	Boron
Ca	Calcium
Cd	Cadium
Cl	Chlorine
Cu	Copper
F	Fluoride
K	Potassium
Li	Lithium
Mg	Magnesium
Pb	Lead
ZN	Zinc

1.0 Introduction

1.1 Background

Geothermal energy is the natural heat from the earth's interior stored in rocks and water within the earth's crust. This energy can be extracted by drilling wells to tap concentrations of steam at high pressures and at depths shallow enough to be economically justifiable. The steam is led through pipes to drive electricity-generating turbines. Geothermal fields are fairly widespread in the world and are exploited in Italy, the USA, New Zealand, Japan, Mexico, El Salvador, Iceland, the Philippines and Turkey.

Italy pioneered the use of geothermal energy for generating electricity in 1904 at Lardarello, near Pisa. However, the world showed little interest in geothermal development until the middle of the century when intensive exploration work was undertaken in New Zealand, Japan, and the United States. These exploration activities led to the commissioning of geothermal power stations in these countries in 1958, 1951 and 1960 respectively. Iceland joined the club in 1930.

A better appreciation of the benefits of geothermal energy occurred in 1970's after United Nations Conference on New Sources of Energy in 1961. This meeting helped to publicize the benefits and possibilities of using geothermal energy as a reliable source of electricity. Following the meeting, interest in geothermal development grew steadily especially from 1964 when a number of countries started preliminary investigation projects.

Kenya is the first African country to tap power from the crust of the earth for national development. This power is tapped at Olkaria East by the Kenya Electricity Generating Company (KenGen), while that of Olkaria West by OrPower 4. KenGen is a public utility while OrPower 4 is an independent power producer. Both companies use superheated water and steam to generate a total of 53 MWe of electricity.

Geothermal energy in Kenya lies beneath the vast, but environmentally and culturally sensitive East African Rift Valley. The exploration and exploitation of this resource should be done in a way that does not have negative impacts on the environment and human life. The present study is designed to assess the socio-economic impacts brought about by the development of the Olkaria East geothermal plant, which has been operated by KenGen for the last 20 years. OrPower 4's operations have been left out since they have been online for a period of less than 3 years. The studies included geothermal resource, land, and water use assessments prior to geothermal production.

1.2 Methodology

KenGen has a full time environmental management unit that deals with all environmental aspects pertaining to the development of geothermal energy. Discussions were held with this group to obtain background information as well as perusing through the literature at the Company’s Olkaria library. This was followed by direct field surveys, visiting the Maasai *manyattas,* and interviewing the residents. Elders as well as the administrative chief of the area were visited and discussions held. Of paramount importance was the identification of those Maasai who formerly lived in the park. All interviews were conducted with the assistance of a translator. An attitudinal survey of the Maasai community on people visiting the park and the power station was required. From this survey, the project development impact assessment was conducted. It is quite possible that the Maasai view the geothermal development in Olkaria as an attraction in its own right in their neighbourhood. This was to be determined during the attitudinal survey. Also, sought was information on whether they make any direct use of the waste geothermal waters for bathing and watering their animals.

The first step was to characterise the existing social and social economic environment of the area. An estimate of the impact was therefore expected to result from a comparison of this base-line data and effects during geothermal exploration, project construction or operation The Maasai population within 10 km radius of Olkaria power plant was studied and interviewed. Data was collected in order to assess all positive and negative impacts. This data was used to establish:

- Population size and growth rate.
- Provision of public services such as schools, water and hospitals.
- Improvement in infrastructure such as roads, water and power supply.
- Employment rate.
- Average size of families and educational achievement.
- Patterns and rate of migration.
- Effects of geothermal activity such as noise, hydrogen sulphide, cultural contamination, tourism and recreation.

The studies included:

- The beneficial impacts of the project such as employment, provision of water, and infrastructure.
- The negative impacts of the project, such as displacement and noise.
- Collection of adequate background information on the previous condition of the area and to collate the findings with the present situation from the time the Olkaria project was initiated.

Neighbouring the geothermal project, the Maasai run a cultural centre where tourists who visit the Hell's Gate National Park come for entertainment and purchase artefacts. Brief cultural studies were carried out. A large part of the Maasai community is still entrenched in their traditional way of living. Many of their traditional practices are largely intact and the cultural transformation has been slow. Change has occurred in those Maasai communities who have come into contact with other communities from other parts of the country, or schools, missionaries and development projects. Alteration or destruction of a cultural resource may impair its cultural value and consequently alter its role as a factor in the quality of the environment. Since cultural resources are unique and non-renewable, and therefore needing protection, a study was made to find out if and how the geothermal project has contributed towards the transformation of this community's way of life.

In summary, this study addresses the following research questions:

1. *Environmental*

    - To what extent did the development of the Olkaria Geothermal project adversely affect the land used by the local community?

2. *Operations*

    - Have gas emissions and waste brine contaminated the environment?
    - Have the domestic animals been affected by drinking waste brine?
    - Has the noise associated with the power station and drilling been a nuisance?
    - Has any member of the family or domestic animal been injured by anything related to the project?

3. *Social and Cultural Factors*

    - Was any provision made for housing or transport when families were displaced?
    - Has the project contributed in any way to their economy such as employment and business?
    - Has the project assisted them with infrastructure such as water, hospitals, roads and electricity, and if they actually use them?
    - Do they benefit from tourists visiting their cultural centre?

4. *Health Impacts*

    - Did the project create any health problem?
    - Has the project educated them on the dangers of geothermal wells?

5. *General Attitude*

    - What is the overall attitude/perception towards the project?
    - Are the regular meetings between the Maasai community and KenGen beneficial?
    - What were their reactions towards being relocated from the Park?
    - Will they oppose any future expansion of the project?

The Maasai homesteads are kilometres apart and there are very few motor-able roads. Data collection involved trekking long distances on foot. Data was collected using a questionnaire, an interview schedule, personal observation and a checklist for group discussions. In total, 48 respondents were interviewed; 43 people around Olkaria, and five from Suswa area for comparison.

2.0 Geothermal Resource Development

2.1 Resource Assessment

Before development options can be evaluated, it is necessary to complete an accurate and comprehensive resource assessment. This requires a staged program of continued exploration, surface investigation, drilling and well testing to delineate the total extent of the resource. This is followed by detailed evaluation to confirm production and exploitation potential. The quality of the data gathered and interpretations made during this assessment stage is critical. This is because they form the basis for decisions regarding further drilling and development plans that ultimately determine the success of the project.

The principle objectives of the resource assessment are to:

- Develop a conceptual model to characterise the geology, hydrology, chemistry and thermodynamics of the resource. This will enable estimates of the stored energy contained within the field to be made.

- Develop using this model a cost-effective strategy for continued exploration, delineation and assessment of the resource that will provide the depth and quality of the data needed for decisions regarding plans for further development at Olkaria.

Box 2.1 Development of a Geothermal Resource Testing Model

This involves a comprehensive review of all relevant collected geo-scientific (geology, geo-chemistry and geo-physics), well test and drilling data. This detailed evaluation of the data will lead to the development of a conceptual model of the field. Development of this model takes into consideration:

- **The inferred area extent (size) of the field.**
- **Its stratigraphic and structural framework.**
- **Geologic nature of the field boundaries.**
- **Postulated heat source.**
- **Temperature and pressure distribution (lateral and vertical).**
- **Hydrology of the reservoir fluids and their inter-relationship with adjacent hydrologic systems (recharge and discharge zones; surface manifestations).**

Other aspects incorporated into the model include:

- **Physical characteristics of the reservoir fluids and nature and distribution of the various phases present (vapour, 2-phase, water)**
- **Chemical composition and variation of reservoir fluid chemistries**
- **Geo-thermometry and permeability distribution within the field.**

2.2 Field Development Planning and Power Plant Design

In the field development task, information on the various study elements is integrated and analysed to identify the most realistic and economic strategy for further development of the geothermal field. This final analysis will lead to a comprehensive plan for continued exploration and resource confirmation, production drilling, field development and future power station construction and sequencing of capacity additions. However, scheduling and capacity additions are in part constrained by equipment and material supplies, complex field development, well performance and long-term reliability, and environmental and site factors. Such studies are required to identify a readily achievable steam-winning rate at reasonable risk so that the emphasis will be to maximise the rate of power development, consistent with production and least-cost of energy requirements.

Power plant designs are engineered to assess technical feasibility, cost, performance and comparative merits of various generation options. State-of-the-art power plant cycle and system design concepts are investigated with regard to their application and specific practical and economic merits in the context of the local conditions. Only commercially-proven reliable systems and items of equipment are considered.

The principal activities for the power generation aspects of these studies normally include the following:

- Evaluating site conditions, plant siting conditions, site access and environmental regulations.

- Analysing plant cycles, including single and double flash arrangements, and evaluate net benefits of differences in geothermal utilisation efficiency.

- Evaluating the use of both customer designed/constructed plant and packaged condensing turbine generator plant such as Mitsubishi and Toshiba.

- Developing technical designs for gas extraction, cooling systems, switchyard, electrical transmission lines, materials, equipment and support services.

- Developing cost estimates for major plant and facilities including for supporting infrastructure, electrical transmission facilities; operating and unit energy costs for the various options for a range of realistic capacity factors.

Studies for field development planning and power plant design are contracted out to a consultant.

2.3 Project Costs

In this section, the costs associated with exploration, field development (including the production well field, steam gathering lines and transmission line, power plant and auxiliary structures, field operation) are discussed in detail. Costs can be considered as a function of the following factors, both in absolute sense and relative to other prospects:

Prospect Accessibility:

- Necessity for road construction.
- Necessity to construct field camp.
- Additional time and cost of conducting surveys in difficult terrain.

Prior Investigation:

- The level of completeness and utility of prior investigations.
- Time and cost savings realised from use of prior work versus additional project risk (if any).
- Need to repeat surveys or augment prior work.

Proximity to Market and Transmission Lines:

- Available line capacity (if any); construction of additional lines.
- Possibility of local off-grid utilisation of electricity.

Resource Size:

- Economies of scale.
- Reward versus risk in large and small prospects
- Reserve capacity for contingencies.

Resource Characteristics:

- Required depth of drilling.
- Likely yield per well.
- Geologic complexity as a factor in determining success rates.
- Chemical or physical constrains on resource utilisation (scaling, corrosion, fluid enthalpy).
- Anticipated rate of pressure drawdown.

Power Plant:

- Generation mode as a function of resource characteristics and size.
- Fabrication and erection time as a function of generation mode and plant size.

Environment:

- Constrains on access, drilling, construction, water consumption, and waste disposal.
- Requirements for payment of compensation for damages.
- Possible interruption of projection activities.

Financing:

- Financing sources, terms and conditions.
- Availability of grants, soft loans and vendor credits.
- Project insurance.
- Terms of sale of electricity.
- Repatriation of hard currency.

The cost of field operation and maintenance consists of 4 major items:

- Drilling of make-up wells or replacement wells, or the re-drilling of existing wells. For Olkaria's case this involves one drilling operation every 3 years, at approximately US $1 million per drilling.

- Maintenance of existing wells and gathering lines. This involves labour, supplies and equipment to be used in testing, sampling, monitoring and routine maintenance operation.

- Office and warehouse operations: This includes labour, supplies and equipment to be used in maintenance of documentation, telecommunication, reporting, and re-supply.

- Miscellaneous: exploration for new resource areas; road maintenance; environmental or other remedial work; refurbishment of offices and equipment; purchase of vehicles and other equipment.

2.4 Impact on the Environment

Geothermal energy is energy from the depths of the earth, which is exploited after exploration, drilling, construction and operation. The latter three stages, namely drilling, construction and operation, have chemical environmental impacts.

2.4.1 Oil Spillage

Oil, grease and diesel are used extensively in the drilling rig. These substances pose serious environmental problems when they leak. It is difficult to predict the potential toxic effects of oil because of its very complex nature. Animals and plants may be affected by the physical properties of oil, which prevents respiration, photosynthesis or feeding. Higher vertebrates whose coats get covered in oil lose buoyancy and insulation, while the ingestion of oil often results in poisoning. Many water-soluble components of crude oil and refined products are toxic to organisms, their eggs and young stages being especially vulnerable.

2.4.2 Drilling Mud and Drilling Soap

Drilling mud (bentonite clay) is inert and this may not pose great risk to environment. However, it can smoothen leaves of plants and hence pollutes like oil. Where drilling mud lies, no plant can grow because it seals off air pathways to soil, thus there is no aeration of soil.

Drilling soap (alkyl benzene sulphonate) and detergents containing phosphate may pose a problem to the environment. Alkyl benzene sulphonate detergent may not be dangerous to the environment, since it forms foam with hard water. This may also create environmental pressure for water. Therefore, before drilling starts, estimates of water required should be calculated to avoid the problems.

2.4.3 Sewage Disposal

Where drilling is going on, people are bound to stay in one place for some time. Facilities such as pit latrines and portable toilets are necessary within the vicinity of drilling site. Proper sewage disposal measures should be done to avoid sewage pollution. Most of the polluting nutrients enter watercourses through effluents from sewage treatment works, untreated sewage or from farming activities.

2.4.4 Solid Waste

Drilling operations uses a lot of materials. Some will be broken and hence they have to be replaced. The solid wastes may include metals, asbestos insulators, plastics and rocks. All solid wastes from drilling operations must be disposed safely. Some solid wastes are hazardous to environment, like asbestos can cause cancer.

2.4.5 Impacts of Construction on the Environment

Construction of a steam-gathering system and power plant involves more than just erecting pipes and buildings. The production wells must be drilled and tested; drainage of wastewater must be completed; permanent offices and storage facilities built; access roads made; and finally erection of power plant made. Construction of buildings, pipeline and other related facilities involves excavation of land. Large-scale remoulding of soil has significant environmental impacts. Removal of vegetation and creation of large flat areas increases the susceptibility of soil particles to wind erosion, which act as airborne dust. Airborne dust will come with airborne transmitted diseases.

Large volumes of water are required during construction. This water may be obtained from the nearby lake or groundwater. The pressure for water may cause a shortage hence disturbing the environment. Disposal of domestic and industrial liquid and solid wastes used during construction may create environmental problems. These wastes may include lubricants, soaps, scrap metals, liquid and solid organic products. Their disposal may have an environmental impact on air and water. Some of the organic paints can pollute the air, especially oil emulsion type.

2.4.6 Impacts of Operation on the Environment

Operating a steam gathering geothermal system can produce large volumes of waste water and occasionally steam may be vented to the atmosphere when a turbine is over loaded or tripped, or repairs on pipes leading to power station. The well may not be shut for such a short time and instead the steam is released into the atmosphere.

Environmental effects associated with discharge of geothermal brine depend on the method of disposal. If the discharge is to the surface environment, the resulting pollution of fresh water depends upon the dilution capacity of the receiving water. If the discharge is to a shallow aquifer, (either through shallow re-injection or infiltration ponds), pollution impacts depend upon other uses of the aquifer, percolation rate into and groundwater movement within the aquifer, and the association between the aquifer and surroundings surface water. The most acceptable form of fluid disposal is by deep re-injection, although this may have environmental impact such as increase in micro-seismic activity.

The most immediate environmental concern associated with operating geothermal plants is the discharge of large volumes of hydrogen sulphide and carbon dioxide. Other gases include hydrogen, methane, nitrogen and oxygen.

A Geothermal reservoir gets recharged by groundwater, which may be connected to a nearby lake. Operating the geothermal power station has therefore introduced competition with other users of freshwater resource. Potable water supply is required for the staff. In addition, raw water for staff ablution facilities and irrigating the grounds, and make-up water for cooling towers is required.

3.0 Development of Geothermal Resource in Kenya

3.1 National and Historical Context

The drought over the last two years in Kenya has clearly demonstrated the dangers of relying too much on hydropower. Poor precipitation in the central Kenya region resulted in very low inflows into the River Tana where most of the hydropower plants are situated, leading to a reduction of hydropower production to about half. Load shedding and power rationing was inevitable. To keep the economy running, power had to be generated expensively on an emergency basis from hired diesel fired stations. During this time, the two geothermal power plants at Olkaria offered continuous base-load power with almost 100% availability, unaffected by the prevailing weather conditions. If more geothermal energy were available, the electricity supply would have been insulated from the power price fluctuations (referred to as Fuel Adjustment Levy). Table 3.1 summarises the installed capacity by KenGen.

Table 3.1 KenGen's Installed Electrical Capacity

Source	Installed Capacity (MWe)	Percentage (%)
Hydro	681.28	74.00
Thermal	197.8	21.00
Geothermal	45.00	5.00
Wind	0.35	0.04
TOTAL	*924.43*	*100.00*

Source: Kenya National Power Development Plan 1986-2006. Executive Summary. Report for the Ministry of Energy, pp12-13

Meanwhile, three IPPs contribute 87.5 MWe from thermal and 8 MWe from geothermal, bringing the total electrical power installed in the country to about 1,039.4 MWe. This figure excludes the small isolated diesel plants run by the Rural Electrification Program.

Continued reliance on fossil fuels, especial oil, causes air pollution, acid rain and damage to human health. Burning these oils also threatens us with global warming, potentially the most serious environmental crisis our planet has ever faced. Geothermal energy is generally regarded as a clean, secure and affordable energy. It is sustainably produced through out the year. The transition to this clean, renewable energy can be accomplished through a combination of the Government, business and industry initiatives that will encourage investment in these new options.

In this context, a Geothermal Resource Assessment Programme has been initiated by KenGen to explore and determine the various potential fields with adequate geothermal resources for exploitation. The total geothermal potential in the Kenya Rift is estimated to be around 2,000 MWe. It is expected that when fully utilised it will form the main resource for future power generation in Kenya. Future energy provision options are unlikely to include further hydropower generation on River Tana, which has hitherto been very much in the mind of Kenyan energy policy makers.

Geothermal energy is being tapped at Olkaria East by KenGen, and Olkaria West by OrPower 4. KenGen is a public utility while OrPower 4 is an IPP. Both companies use superheated water and steam to generate a total of 53 MWe of electricity. This currently meets about 5.1 % of the nation's electricity consumption. The first phase was connected to the national grid system in 1981, with KenGen initially supplying 15 MWe.

As shown in figure 3.1, Olkaria is an area located within the southern part of the Kenya Rift Valley from the Lake Naivasha in the north, to the Suswa volcano in the south. Extensive igneous and volcanic activity has occurred in this area in the recent geologic past (Clarke et al., 1987; Omenda, 1994; Muchemi 1994; Mungania, 1995). The area contains three large volcanic fields. These are the Longonot, Suswa and Olkaria, each with a significant caldera. Small basalt-trachyte-andesite cones characterize the intervening low areas. The exposed volcanic rocks on the rift floor include pyroclastics, tuffs, trachytes and rhyolites (Macdonald, 1994).

Figure 3.1 Simplified Geological Map Showing the Location of the Geothermal Areas in Kenya

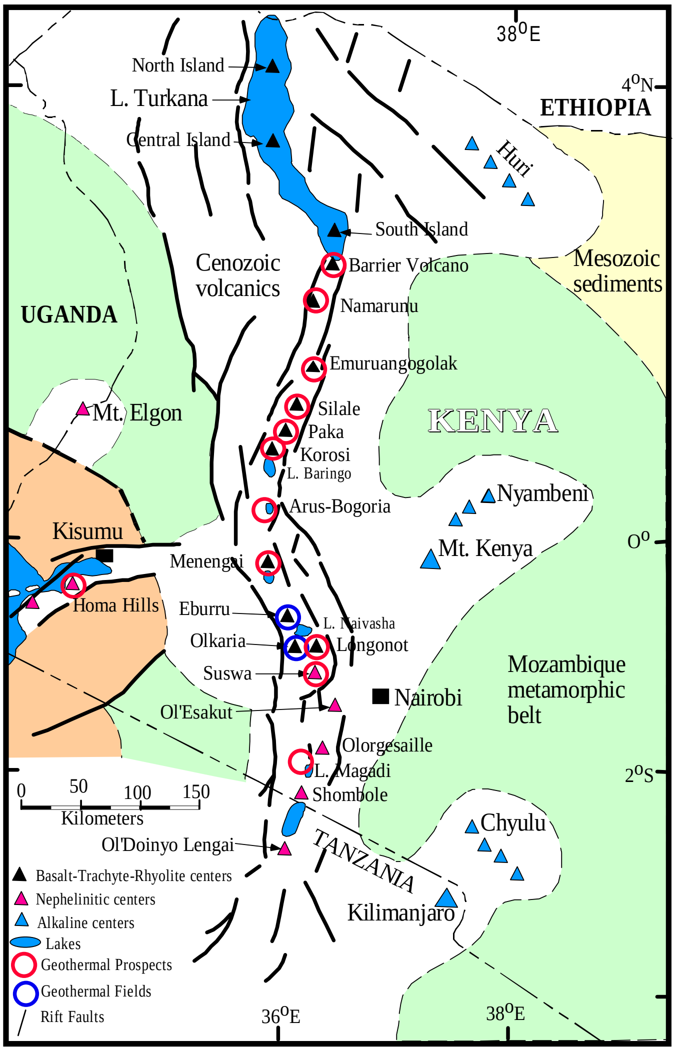

Fig. 1: Simplified Geological Map Showing the Location of the Geothermal areas in Kenya.

At Olkaria, geothermal investigations started as long ago as 1956 when exploratory drilling was undertaken by a consortium of companies, which included the then East Africa Power and Lighting Company Limited, and Balfour Beatty Company. Two wells were drilled without any marked success. It was not until the end of the next decade that interest in geothermal power revived.

A project was agreed upon and between 1970-72 investigations were undertaken at Olkaria, Lake Bogoria and in the Eburru area, north of Lake Naivasha. Further work that produced positive results was carried out on the two exploratory wells drilled at Olkaria in the fifties. On that basis, drilling started in earnest in 1973 and four more wells had been drilled in the area by 1975. A feasibility study was then undertaken to evaluate Olkaria's potential for generating electricity from geothermal steam. The study established that the Olkaria geothermal field covered some 80 km^2 and steam for 2,500 MW years. The present production area, which covers 11.9 km^2, was estimated to have steam for 400 MW years.

Presently, four potential areas have been identified within the Greater Olkaria Volcanic Area that is earmarked for separate development. As shown in figure 3.2, these are the East Production Field (EPF), the North East Field (NEF) and the Olkaria West Field (OWF). The EPF is generating 45 MWe. A second 64 MWe power station in the NEF to be managed by KenGen is now under construction and is expected to be working by the end of the year 2002. OrPower 4 is expected to increase its output from the current 12 MWe to 64 MWe in the next couple of years. This will bring the total power generated from Olkaria to 173 MWe. Additional geothermal stations of 64 MWe each will be in service in the years 2005 and 2006, thus bringing the total power generated from Olkaria by the year 2009 to 301 MWe.

Figure 3.2 Map of the Greater Olkaria Geothermal Area

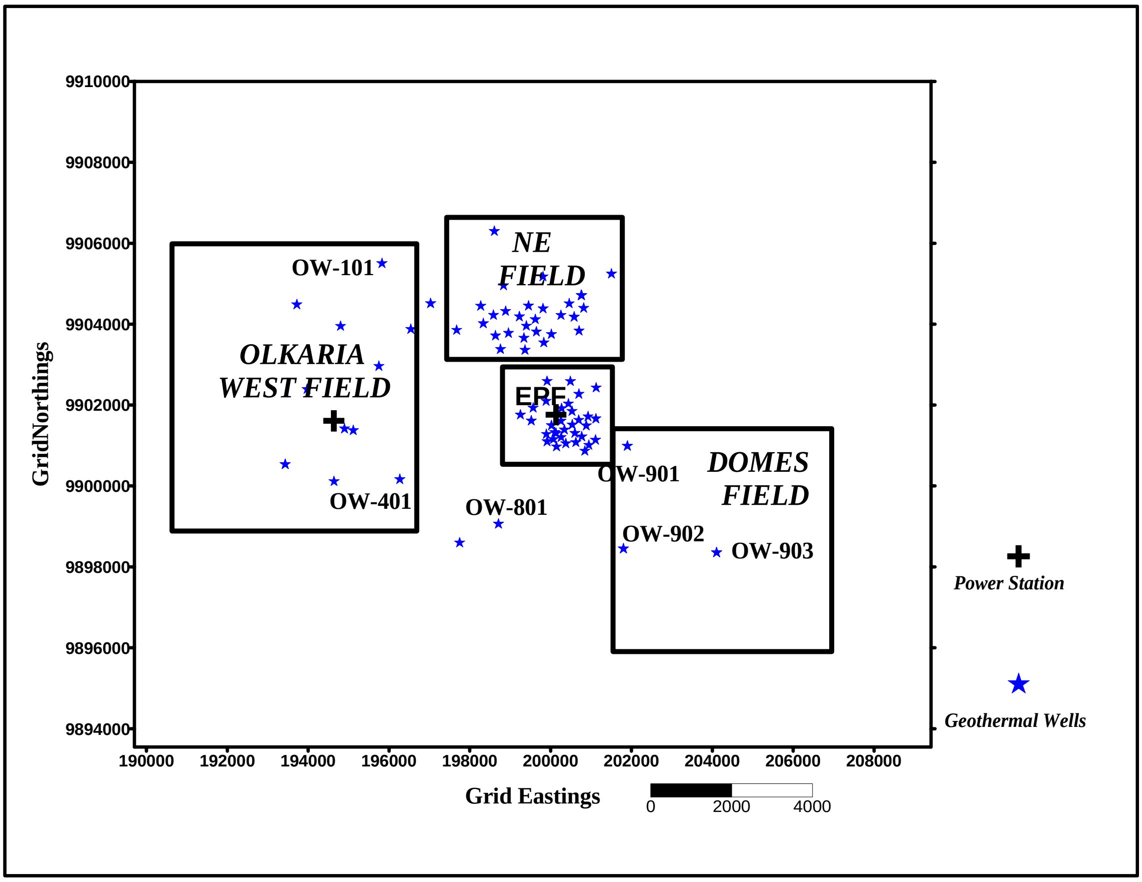

Fig. 2: Map of the Greater Olkaria Geothermal Area. Drilled wells are indicated by stars while the two power stations are shown as crosses. Orpower 4 is developing Olkaria West and KenGen operates both Olkaria East and Olkaria Northeast.

The national energy sector master plan has identified the generation of electricity from geothermal sources as the least cost source of energy and will therefore meet an increasingly larger proportion of the country's power needs in the years ahead. A total of 448 MWe of additional geothermal energy is envisioned up to the year 2015. This will represent about 36.9% of Kenya's power requirement. The development of this resource marks a significant step in Kenya technological and economic development.

3.2 Olkaria North East Geothermal Power Plant

The development of the Olkaria Northeast project is described in the feasibility studies prepared by Ewbank Preece Limited (1989). This section summarises information from this feasibility study to provide a description of the project for the purpose of determining its interactions with the environment. It provides a brief overview of the way in which a geothermal power station is developed, including a description of each phase of the project as well as costs.

3.2.1 Wells

The well field has been drilled and to date 27 production wells have been tested. These wells have been drilled vertically and their depths range from 1,744 to 2,497m below surface. This is down to 425 m above sea level to 341 m below sea level. Once the well is completed it is fitted with a valve and tested. The surrounding cleared land around the well can then undergo final rehabilitation with the naturally occurring grasses and shrubs. The area required around the well is approximately 20 m by 20 m.

3.2.2 Pipeline

The steam from the wells is led to the power station through pipes made up of high-pressure steel with thermal insulation. The outside temperature of these pipes is well below at which burning may occur if they are touched. The colour of the external cladding will be brown/green to reduce visual impacts. Pipelines that cross roads will be encased in concrete culverts. Further, following advice from the fauna consultant several additional crossing points will be provided to allow grazing animals greater freedom of movement within the well-field to minimise the interruption of daily migration routes.

3.2.3 Power Plant

The siting of the power plant takes into consideration both the engineering and environmental factors such as the requirement that it should be located in proximity to the wells and at an elevation which causes minimal loss of energy in transporting steam and hot water. Environmentally, the site should minimise the disturbance to existing land uses such as the grazing of wild animals.

The main structure of the power station includes the building housing the two turbines and two 32 MWe generators, pumps and condensers and two tanks of three cooling towers. The 32 kV substation is also located next to this building. The basic process by which the power station operate is through the use of high pressure from the well-field to drive two turbines, which in turn drive two 32 MWe generators.

The separated water from the steam is re-injected into designated wells as matter of an environmentally desirable disposal method. The non-condensable gases (mainly carbon dioxide, hydrogen sulphide, methane and nitrogen) are disposed off into the atmosphere via the cooling towers. The toxic component, H_2S is ultimately oxidised into sulphate and removed from the atmosphere by dry and wet disposition processes.

3.2.4 Cost Estimates

This section presents the consultant's estimated cost prepared in 1989 for constructing and operating the 2 X 32 geothermal units at Northeast Olkaria. The cost estimate was based on the project being undertaken on the basis of a number of contract packages. These packages include, civil, power plant construction, steam construction, electrical equipment and transmission lines. Recently, tenders were awarded and the power plant is now under construction and due for commissioning by late 2002.

The estimate shown in table 3.2 below includes allowances for physical contingencies at 15% and project engineering at 12%. The estimate has been split between foreign and local currency expenditures and was derived on the basis of budgetary estimates received from potential manufacturers and service providers. The total project cost at June 1989 prices was US $ 133,338 million. The present cost is much higher, taking into account inflation and the Kenya shilling depreciation of about 4 times. The exchange rate at that time was 1 US $ for 21 Kenya shillings.

Table 3.2 Northeast Project Capital Cost Estimate as of June 1989 (000 US$)

Description	Foreign Cost	Local cost	Total Cost
Geo-technical Investigation	-	48	48
Bore-hole field Development	30,000	0	30,000
Consultancy Services	250	40	290
Site Development	0	383	383
Main Civil Works and Foundations	700	6,350	7,050
Turbine Generators & Auxiliaries	23,413	3,992	27,405
Cooling System	3,040	1,423	4,463
Plant Services (workshop, water treatment, fire-fighting etc)	2,314	448	2,762
Transmission links to Nairobi	12,132	1,992	14,124
Steam-line development	8,262	9,989	18,251
TOTAL	***80,111***	***24,665***	***104,776***

Source: Update of Least Cost Power Development Plan 6. Report for the Ministry of Energy

A detailed estimate of annual project operating and maintenance costs including the provision of make-up wells is shown in table 3.3. The estimate is US $ 2,988,000 per year, although this excludes a sum for KenGen's own scientific support services that were not available to the author.

Table 3.3 Northeast Project Estimated Annual Running Costs (000 US$)

Description	Foreign Cost	Local Cost	Total Cost
Make-up well drilling	535	296	831
Connection Cost	125	125	250
Steam-field O & M	25	300	325
Power Station O & M	535	535	1,070
Caustic Dosing	122	0	122
KenGen Scientific Support Services	0	?	?
Sub Total	***1,342***	***1,256***	***2,598***
Contingency @ 15%	201	188	390
TOTAL	**1,543**	**1,444**	**2,988**

Source: Update of Least Cost Power Development Plan 6. Report for the Ministry of Energy

3.3 Olkaria Geothermal Power Projects Human Resources Development

At the Olkaria Geothermal Project, the technical aspects of geothermal resource development are shared out between Projects and Generation Divisions. Table.3.4 shows the existing number of professionals and how they are distributed. The organisation is mainly for administrative reasons and the progression of the activities, continuous, and may in some cases overlap. Staff from both divisions jointly carry out the tasks.

At the start of geothermal resource investigations in Kenya in the 1960s, foreign companies contracted by the company carried out the work. These companies would then establish offices locally and recruit expatriates to manage the geothermal program in all areas. The hiring of contractors and resident consultants to carry out programs such as exploration and development was found to be an expensive option, which contributed significantly to geothermal power development costs. Consultants in these categories cost about US$ 500-700 per day per consultant. These figures are conservative and do not include commissions paid to the contracted organization, administrative, and local costs.

In the 1970s, the Company started hiring engineers and scientists from the local market, to work with the expatriates in a scheme that was designed for technology transfer. During this period, the Company started a geothermal section to coordinate geothermal development. In the 1980s, when the geothermal training institutes were fully established, the Company initiated a comprehensive training program and started sending employees for training. It is during this period that the Company started generating power from geothermal steam. Recruitment of scientists and engineers was intensified with a view to strengthening the geothermal section. Local professionals are now managing exploration, field development, and power plant operation and maintenance as shown in table 3.4.

The role of expatriates was reduced and consisted mainly of consultancy work. By the early 1990s, the local capacity was found to be adequate to manage most phases of geothermal development and all resident consultant contracts were replaced with a Board of Consultants (BOC). The BOC meets twice a year for a period of one week for each meeting depending on the geothermal program. The role of the BOC is to review recommendations made by the Project staff and report to KenGen management and the World Bank. The meetings of the Board are convened only when there is enough data to be discussed.

Table 3.4 Distribution of Professionals at Olkaria 1 Geothermal Project

Section	Profession	Available	Trained
Scientific	Geologists	4	4
	Geophysicists	3	3
	Geochemists	4	4
	Reservoir Engineers	6	6
	Environmental Scientists	4	3
Drilling	Drilling Engineers	5	5
	Maintenance Engineers	3	2
Power Station	Power Station Engineers	7	4
	TOTAL	***36***	***31***

Source: GG Muchemi, 1999: KenGen Internal Report

Development and exploitation of geothermal resources require the involvement of professionals who are skilled in earth sciences, drilling technology, reservoir management, power station operation and maintenance and environment management. Table 3.5 shows the phases of geothermal resource development and exploitation, and the roles played by various professionals.

The Kenya Electricity Generating Company recruits scientists and engineers from the local market. These cadres are from local universities where geothermal technology is not offered at degree level. The employees are inducted into the system through various internal courses for a period of one to two years. They are then taken to overseas institutes for specialized training in geothermal technology. Over the years, the Company has developed enough capacity in most areas to manage its geothermal facility without hiring resident consultants. Consultants are currently hired for specific services such as simulation studies, feasibility studies, plant design, and construction where capacity is yet to be developed.

Currently, the professionals in the Olkaria Geothermal Project manage all phases of geothermal exploration, development, production and generation without the use of resident consultants. The areas that are not adequately provided with qualified personnel include:

- Steam gathering system design.
- Simulation studies.
- Power station design.

Future training should target these areas. Because of the magnitude of the work required in power station design and construction, this area is better left to organisations specialising in these services. However, the consultant work can gradually be transferred to the local professionals through formal training and attachment during design and construction.

Table 3.5 Required Professionals in Different Phases of Geothermal Resource Development

Phase	Activity	Required Professional
Exploration	Reconnaissance Surveys	Geologists Geophysicists Geochemists, Environmentalists
	Detailed Investigation	Geologists Geophysicists Geochemists, Environmentalists
	Exploration Drilling	Drilling Engineers Reservoir Engineers Geologists Geochemists, Environmentalists
Appraisal	Appraisal Drilling	Drilling Engineers Reservoir Engineers Geologists Geochemists, Environmentalists
	Reservoir Evaluation	Reservoir Engineers Geochemists Geophysicists Geologists
	Feasibility Study	Engineers, Environmentalists
Steam Field Development	Production Drilling	Drilling Engineers Reservoir Engineers Geologists Geochemists, Environmentalists
	Well Testing	Reservoir Engineers, Environmentalists
	Preliminary Design	Engineers, Environmentalists
Power Plant Construction	Detailed Design	Engineers, Environmentalists
	Construction	Engineers, Environmentalists
	Commissioning	Engineers
Resource Utilization	Operation	Engineers
	Plant Maintenance	Engineers
	Reservoir Management	Reservoir Engineers Geochemists Geophysicists Environmentalists

Source: G.G Muchemi, 1999: KenGen Internal Report

Table 3.6 shows the management of the various phases of geothermal energy development versus the trained capacity. Table 3.7 identifies the components that can be sourced locally and those that can only be obtained from outside the country. It is clear that some activities do not have trained personnel and as such the work is still carried out by contractors and consultants. Materials such as drilling fluids and power plant components have to be imported. In practice some jobs like power plant will always be contracted. However, it is possible to train personnel to manage most areas where there is need for consultants. It is worth noting that, M/s OrPower 4 Inc., the IPP and competitor in power generation, have on several occasions contracted KenGen to provide services including consultancy.

Table 3.6 Management of Phases of Geothermal Resource Development and Utilization

Phase	Activity	Trained Capacity
Exploration	Reconnaissance Surveys	Adequate
	Detailed Investigation	Adequate
	Exploration Drilling	Adequate
Appraisal	Appraisal Drilling	Adequate
	Reservoir Evaluation and Modelling	Partly Adequate
	Feasibility Study	Partly Adequate
Steam Field Development	Production Drilling	Adequate
	Well Testing	Adequate
	Preliminary Design	None
Power Plant Construction	Detailed Design	None
	Construction	None
	Commissioning	Adequate
Resource Utilization	Operation	Adequate
	Plant Maintenance	Adequate
	Reservoir Management	Partly Adequate

Source: G.G Muchemi, 1999: KenGen Internal Report

Table 3.7 Sources of Materials and Personnel During the Various Phases of Geothermal Resource Development and Utilization

Phase	Activity	Source Of	
		Materials	Personnel
Exploration	Reconnaissance Surveys	Local	Local
	Detailed Investigation	Local	Local
	Exploration Drilling	Local+ Foreign	Local
Appraisal	Appraisal Drilling	Local+ Foreign	Local
	Reservoir Evaluation	Local	Local
	Feasibility Study	Local	Local
Steam Field Development	Production Drilling	Local+ Foreign	Local
	Well Testing	Local	Local
	Preliminary Design	Local+ Foreign	Local+ Foreign
Power Plant Construction	Detailed Design	Local+ Foreign	Local+ Foreign
	Construction	Local+ Foreign	Local+ Foreign
	Commissioning	Local+ Foreign	Local+ Foreign
Resource Utilization	Operation	Local	Local
	Plant Maintenance	Local+ Foreign	Local
	Reservoir Management	Local+ Foreign	Local

Source: G.G Muchemi, 1999: KenGen Internal Report

4.0 Socio-Economic and Physical Settings around Olkaria Area

Olkaria geothermal complex is located between UTM northings 9900000 and 9905000 and eastings 195000 and 202500. It is situated in south west of Lake Naivasha and west Ol Njorowa Gorge. Land use in Olkaria field is predominantly conserved for wildlife, grazing by Maasai herds, and flower farming. Most of Maasai homesteads are found to the south and southeast of the field while flower farming is found to the northern parts. Private residence and tourists accommodations are mainly located to the north of the field along the shores of Lake Naivasha.

4.1 Socio-economic Background

The Maasai inhabits the area around the Olkaria geothermal project. The Maasai are mainly a pastoralist community that keeps cows, goats, sheep and donkeys. The findings of this study revealed that the total population of the Maasai in the vicinity of the project was approximately 2,000. Many respondents regarded the present location of residence as their permanent home, though they sometimes migrated to some other places for a while in search of pasture.

The community members do not have title deeds to the land in which a large majority had been born in, but only had numbers and sketch maps. The average land size held by the community members was 100 acres per family. Farming is practised in the highland areas of Suswa and Maela and also in the lowland areas of Naivasha. The crops grown are maize, beans and potatoes, which are cultivated using hoes. Some respondents had large farms of up to 300 acres on which they planted wheat as a cash crop.

The majority of the households interviewed did not have any form of formal education; though 5 respondents said they had secondary school education. The facilities found in the community include one primary school (Inkorienito primary school which was about 15km away). No High School or college exits in our area of observation. The health centres visited by the community were the Naivasha and Maela district hospitals, which were approximately 50 km away.

A few of the community members were employed as watchmen, cleaners, drivers, and office messengers at either KenGen or OrPower 4 Inc. They complained that the two companies had not done enough in terms of employment. However, some of the community members were self-employed as carpenters and blacksmiths. The community members sold or bought their cows, sheep and goats at an average price of Ksh. 7,000 and 1,500 respectively mainly at Suswa market. An average of 15 animals were sold per year. The community members also sold to tourists at the cultural centre necklaces, bracelets, shoes, cloth decorated with beads, swords and knives. Daily household requirements were bought at either Inkorionito market or KenGen employee shops. The average monthly income of the community members was Ksh. 4,000.

About half of the families visited had one or two houses with mud walls and corrugated aluminium sheets. The other houses were the traditional *Manyatta* type, which they revealed had to be redone every year. Two families had brick/stone walled houses. Five families have vehicles and all of them are pick-ups. Over 90% off the community members got their water from two water tanks provided to them by KenGen.

There are no telephone facilities nearby except those at KenGen premises. Five of the respondents said they had made calls using the public telephone facility at the KenGen Co. Ltd. The type of road infrastructure found in the community included both tarmacked and all weather roads which were built by KenGen and Kenya wildlife services (KWS). No public transport was available near their homesteads. The community members have to walk for about 10 to 15 km to the nearest public transport point. Once in a while, they got lifts on KenGen or KWS vehicles.

The energy demands and supply for the Maasai around Olkaria was found to be similar to that of other communities in Kenya. Fuel wood and charcoal were the main sources of energy used for cooking and warming the house, which they got from nearby bushes.

As shown in table 4.1, fuel wood contributes almost all the energy requirements of the interviewees. There is concern, however, that over-reliance on fuel wood will impact negatively on the environment resulting is deforestation. This is a serious problem as Olkaria is located in a semi-arid area with a mean annual rainfall of less 1,000mm, reducing chances of timely rejuvenation of the bushes once they have been cleared for fuel-wood in order to ensure a sustainable supply. Table 4.1 shows a break down of the types of primary energy supply and the percentage of users. The total number of respondents was 48.

Table 4.1 Primary Energy Supply and Usage

Type of Usage	Source of Energy	Respondents	%Usage
Cooking and Warmth	Wood	48	100.0
	Paraffin	6	12.5
	Gas	2	4.2
Lighting	Paraffin	48	100.0
	Solar	2	4.2
	Gas	0	0.0

Source: Data collected by author for current report

Though electrical supply is gradually reaching rural areas in Kenya through the Government's Rural Electrification Program, the number of households already connected is dismally low. The community around Olkaria is yet to enjoy this facility in spite of the fact that the Olkaria Power station is just next door. This is mainly attributed to the high costs of rural electrification and politics.

4.2 Physical Settings

The Olkaria region can mainly be classified as a semi arid region with moderate rainfall. Since Olkaria area falls within the same Eco-climatic area as Naivasha, the area rainfall around Naivasha is representative of the general rainfall at Olkaria. The average annual rainfall figures for the Naivasha Water Supply Department from 1965 to 1988 was 696.6 mm, at the Naivasha District Office was 625.4mm from 1910 to 1988, and 672.8mm at Kongoni Farm, from 1968 to 1988. The annual maximum temperature ranges from 21 to 29^{o}C and annual minimum temperature range of 11 to 15^{o}C (Sinclair Knight and Partners, 1994). Table 4.2 shows the rainfall monthly variation for the year 2000.

Table 4.2 Mean Monthly Rainfall for Olkaria Area for the Year 2000.

Month	Rainfall
January	62.1
February	40.2
March	65.8
April	47.5
May	43.2
June	76.1
July	56.0
August	101.1
September	38.1
October	25.6
November	90.4
December	20.3
Total	**676.3**

Source: Geothermal Energy Development. KenGen Report No. Geo/8/009b

The total average for 2000 closely approximates the annual averages for Naivasha. However, the records for one year alone cannot be taken to be representative of the annual average of an area.

To a large extent, the severity of drought depends upon the level of resources exploitation in the area. If exploitation is excessive, the land may be unable to recover even when the rains come, and it becomes unproductive. The fact that such droughts are prolonged or intensified because of desertification in neighbouring countries further compounds the problem. Soil erosion is generally severe unless the land is carefully managed. In over-grazed rangelands, soils are easily washed away by rainwater. Wild animals also play a significant role in soil erosion.

The most noticeable agent of soil erosion in Olkaria area is erosion by rainwater. Wind erosion is of minimal importance in this area because the area is fairly vegetated. The erosion by water involve first the detachment of soil on any bare surface, devoid of vegetation and the actual transport of the detached soil. During heavy rains such as during the El Nino in 1998, small trees are also uprooted.

Due to the nature of the soils at Olkaria, any surface left bare is very susceptible to erosion. In general the natural erosion hazard in Olkaria area is low, because the area is well vegetated. The high erosion hazard is observed at the hills. Soil erosion will become a serious problem in Olkaria only when the ground cover is removed or run-off patterns disturbed as a result of development activities and fires.

The most vulnerable areas are the water catchment zones that include the slopes around the hills. Erosion is facilitated along the motorable access roads. As previously mentioned, the conditions of the soil and the rains contribute to the susceptibility of the erosive processes that can lead to small gullies that become bigger with every subsequent rain. During strong rains, there are erosion problems in the areas with strong slopes.

4.3 Natural Vegetation

The Olkaria area is representative of some of the vegetation types found in arid areas of Kenya, classified under Eco-climate zone 5. This characteristic vegetation is unique in that it develops in volcanic soil of recent origin. The bush land and bushed grassland is also a characteristic vegetation type found in other areas of the Rift valley. The presence of steam vents creates some unique features in soil and geological formations, which dictate the type of vegetation that develops in association with this phenomenon. Notably, several species of pteridophytes and orchids, which would normally be lacking in this eco-climatic zone, are associated with the steam vents. Several are epiphytic plants on woody plants, occurring near the steam vents, where humidity is high. Oserian Development Company (ODC) has flower plantations of *Ferore, Rony and Bonita* Carnations, white and purple *Stattice, Arabicum* and Roses for export.

4.4 Animal Species

Table 4.3 shows the mammals found in Hell's Gate National Park.

Table 4.3 Mean Estimates of Mammal Population Size and Density in Hell's Gate National Park March 2000.

Species	Population Size	Density/km^2 of total park	Density/km^2 of utilised area
Kongoni	479	6.95	29.37
Zebra	295	4.33	18.43
Thompson's Gazelle	165	2.43	10.31
Grants Gazelle	136	2.00	8.50
Giraffe	40	0.58	2.50
Eland	102	1.50	6.37
Reedbuck	32	0.47	2.00
Warthog	50	0.74	3.12
Impala	30	0.44	1.87
Dik-dik	25	0.36	1.56
Steinbuck	24	0.35	1.50
Klipspringer	10	0.15	6.25
Buffalo	105	1.54	6.70
Waterbuck	5	0.07	3.12
Wildebeest	-	-	-

Source: Kenya Wildlife Services, Olkaria

103 species of birds have been recorded in the park. The survey revealed 65 species of birds were recorded. During the survey the rare *Lammergeyer* of Bearded vulture, which has been recorded previously, was not recorded. However it was worthwhile noting that this species has not been seen in the park for decades and was probably never a common bird in the park. No attempt was made to estimate population size of the avifauna.

The avifauna is diverse because of habitat heterogeneity and also because of proximity to Lake Naivasha. The cliffs and gorges are important breeding grounds for vultures, swifts and other species. The vultures move in from far places while the swifts engage in displays, nesting and mating during the rainy season.

The maintenance of natural habitat of these breeding grounds is a concern that should be given special focus. Dusts, gases, and destruction of vegetation all have the potential to affect the bird life.

5.0 Socio-Economic and Environmental Impacts

5.1 Impacts on the Neighbouring Community

Five families who were interviewed said that they used to stay in the area now occupied by the geothermal project and National Park. They said they were simply asked to move without any compensation. They also do no understand why they are prohibited from grazing within the game park. However, they appreciated the permission to use some of KenGen facilities such as transport, schools, and shops. They were especially grateful to KenGen for providing them with piped water, which has reduced cases of water borne diseases like cholera and typhoid. Some claimed that bathing in the KenGen effluent waters has assisted them in managing some skin ailments. Most said that the noise or gas emissions did not discomfort them in any way. Neither as far as they know have any of their animals been hurt by the project facilities.

On whether the project has had any impact on their lives many mentioned the positives of water, shops and the school. They strongly felt that the project would have economically empowered them if many of their members were employed there. Other concerns raised included:

- The increasing dust levels and smells the project could bring if it expands towards their homesteads.
- A rise in respiratory diseases (asthma), eye problems, colds and flu's.
- Displacement/ resettlement from their present homes.
- The reduction in land size(s) as the project expands.
- The reduction in grazing land for their livestock.
- A reduction in family size due to the gradual decrease in land sizes.
- An increase in miscarriages or children being born with deformities or retarded if the projects expand.
- Their cultural values being eroded by outsiders.

Table 5.1 summarises the socio-economic impacts on the Maasai as a result of the Olkaria Geothermal Project. It is evident that the greatest benefits of the project have been the provision of shopping centres, water and sale of souvenirs to tourists at the cultural centre. This has resulted in increased income levels and subsequent rise in living standards and quality of life. The company employees do provide some market for sale of animal products.

Table 5.1 Socio-Economic Impact Resulting from the Presence of the Geothermal Project

Facility	Respondents who enjoy facility	
	Number	Percent
Entertainment centres	9	18.75
Cultural centres	17	34.40
Health centre	4	8.30
Water pipeline	41	85.40
Employment at Power Project	4	8.30
Telephone	10	20.80
Tourism	19	39.60
Small shops	43	90.00
Small businesses (sale of milk/animal products)	14	29.10
KenGen. Co. Ltd Schools	3	7.00

Source: Data collected by author for current report

In terms of employment, the impact is negligible. Table 5.2 shows the human resource distribution in the project. The Olkaria 1 Geothermal Project employs about 500 people.

Table 5.2 Olkaria 1 Geothermal Power Project Human Resource Distribution

Profession	Number
Scientists	15
Engineers	21
Technicians	82
Artisans/Craftsmen	175
Support staff (clerks, drivers, mechanics, cleaners and security personnel	200
Total	***493***

Source: Data collected by author for current report

It should be noted however, that, of these 500 only 7 come from the Maasai community. They comprise of one copy typist, one clerk, one driver, one office messenger and 3 watchmen. Only 1.4% of the work force at Olkaria East is Maasai, three of them are from Narok District. This poor representation is due to several factors. The main one being the general low level of education of the Maasai community and the other is their hitherto nomadic way of life.

5.2 Impact on the Environment

5.2.1 Noise

Background noise levels at various locations within the surroundings of Olkaria area are shown in Table 5.3 (Sinclair Knight and Partners, 1994). Noise levels varied from 32 - 44 dB (A) away from the station, and 50 - 60 dB (A) around the power station. Levels increased as one approached the drilling activity area, reaching maximum level of 68 dB (A). Higher noise levels were also found closer to the road, as a result of vehicular movements. Deeper inside the park, there were lower noise levels because of calm wind conditions. The winds increased as one approached the top of the Olkaria hill. They also cause the whizzing sound, and thus higher sound levels.

Table 5.3 Noise level at selected areas around Olkaria

Day	Time	Location	Noise Levels dB (A)	Weather
Day 1	10.10	1.2 km south of station	32-37	Calm and cloudy
	11.20	Lake Odongo	38-44	Windy and cloudy
	12.15	Next to Olkaria Hill	44-58	Windy and cloudy
	13.40	Power station site	56-68	Windy and cloudy
	14.05	Narasha Gate	35-37	Windy and cloudy
Day 2	9.10	Base of Olkaria Hill	44	Calm
	9.20	0.5 km of Narasha gate	55	Windy and cloudy
	9.50	0.2 km of Narasha gate	43	Windy, cloudy and warm
	10.04	1 km south of Narasha gate	33	Windy and warm
	11.05	Drilling rig site	68	Windy, cloudy and warm
	11.50	Power stations site	53	Windy and warm
	12.30	0.7 km of SW of power station	54	Windy, cloudy and warm
	13.20	OW-307	55	Windy, cloudy and warm
	13.30	OW- 301	37	Windy, cloudy and warm
	14.40	OW-302	69	Windy, cloudy and warm
Day 3	10.30	OW-305	36	Cloudy and calm
Day 4	16.00	OW-401	41	Warm and cloudy
	14.12	0.5 km west of power station	47	Warm and partly cloudy
	15.00	1 km south of power station	32	Warm and cloudy
	15.08	OW-304	35	Warm and partly cloudy
	15.09	1 km east of Olkaria Hill	55	Warm and partly cloudy
	15.30	Along road at OW-305	75	Warm and partly cloudy
	16.10	Along road at Narasha gate	70	Warm and partly cloudy

Source: Geothermal Energy Development. KenGen Report No. Geo/8/009b

5.2.2 Air Quality

Gas emissions from the existing power station are predominantly carbon dioxide (80%) and hydrogen sulphide (9.5%). The other gases, which include hydrogen, methane, nitrogen and oxygen, form 0.5% (wt/wt) of the total non-condensable gas fraction. Total geo-gas from existing geothermal station forms about 2% of geothermal effluent (Sinclair and Knight, 1994).

Carbon Dioxide and Methane

Carbon dioxide and methane are greenhouse gases and may have some global impact. Apart from being a greenhouse gas, carbon dioxide can also cause acid rain. Carbon dioxide combines with moisture in the air to form carbonic acid, which is a weak acid. Depending on the amount of the acid formed, pH values of rainwater may be lowered. The low concentration of carbon dioxide from the present power station makes it less hazardous to the environment. Acid rain is defined as precipitation with the pH values of less than 5.8. Normal precipitation has pH values between 5.6 and 5.65. This mild acid is caused by the presence of carbon dioxide in the atmosphere, which on precipitation forms carbonic acid.

According to Tole (1996), annual carbon dioxide emission from the present 45 MWe is estimated to be 21,850 tonnes and a coal-fired power plant of the same rating releases 349,143 tonnes of the gas to the atmosphere. Therefore, carbon dioxide emission from geothermal plant is not high compared to one from coal-fired plant. The carbon dioxide produced by the present power station is approximately seven times less than the ones produced by coal-power station.

Carbon dioxide is not the only gas that causes acid rain. Large quantities of oxides resulting from combustion of fossil fuels and industrial processes are converted into strong acids (sulphuric and nitric acids). Fortunately, geothermal power plant at Olkaria does not produce the above oxides, and therefore if there is any increase in acid rain, it must be due to carbon dioxide and hydrogen sulphide gases. The damage on crops may vary from extensive foliage damage to reduction in crop yield.

Long exposure of high concentration of carbon dioxide has serious impact on human beings. Studies have shown that exposure of various concentrations of carbon dioxide have effects on human breathing (Kubo et al, 1999), as summarised on table 5.4.

Table 5.4 Effects of Exposure to Carbon Dioxide

Concentrations (ppm)	Effects
10,000 - 20,000	Long-term exposure to such levels can cause increased calcium depositions in the body tissues and may cause mild stress and behavioural change.
50,000	Shortness of breath, dizziness, mental confusion, headache and possible loss of consciousness
100,000	Normally, one losses consciousness and eventually death if no action is taken

Source: Geothermal Energy Development. KenGen Report No. Geo/8/009b

Hydrogen Sulphide (H_2S)

Although geothermal power plants are environmentally active because of their renewable energy status, they pose an environmental threat because of hydrogen sulphide gas that is contained in most geothermal steam sources. If not correctly disposed of, this gas can cause health and safety problems.

Hydrogen sulphide is a dangerous gas and standard quality varies from country to country. Air quality criteria, has been formulated by regulatory bodies in other countries to maintain acceptable environmental quality. Hydrogen sulphide is a noxious and potentially poisonous gas with odour of rotten eggs. About 90% of global emissions are estimated to be from natural occurrences, the remaining 10% is from industrial wastes, which include sewage treatment plants petroleum refineries and Kraft paper mills (Sinclair and Knight, 1994).

The gas is colourless and flammable. It is denser than air and liquefies at negative 60°C. It is soluble to both polar (water) and non-polar (organic) solvents because of its chemical properties. It is a very reactive gas and hence oxidises rapidly in air and solution. It reacts readily with most metals causing corrosion on them. Its density makes it settle at the lowest points. Thus, a slow leak of the non-condensable fraction of cooled geothermal gas emitted into an enclosed environment, such as gullies and valley, can allow a build up of dangerous concentration of hydrogen sulphides. However, such concentrations may occur in cellars that are part of the wellhead or sump within the power station.

Non-condensable gases from the present geothermal power station contain about 9.5% H_2S and 80% carbon dioxide. When they are ejected into the atmosphere, these gases are at higher temperature than ambient air. Hot non-condensable fumes are lighter than normal air, and this helps the gases to mix rapidly with ambient air. Therefore H_2S emitted from the gas ejectors does not preferentially settle out from the plume any more than other gases in air. The only time that H_2S settles down more preferentially than other gases in the air is in an enclosed area, where there is no wind. The toxic effects of H_2S to human and animals vary according to dosage and these are summarised in table 5.5.

Table 5.5 Effects of H_2S on Human Beings and Animals

Concentrations (ppm)	Effects
Below 1	Offensive odour
1 – 10	Occupational exposure limit. Breathing apparatus required
10 – 20	Ceiling of occupation exposure limit. Worker must wear breathing apparatus
20 – 100	Loss of sense of smell in 2 - 15 minutes. May burn throat and chest. Causes headache and nausea, coughing and skin irritation
100 – 200	Sense of smell lost rapidly, burns eyes, and throat
200 – 500	Loss of reasoning and balance. Respiratory disturbance in 2 - 5 minutes. Prompt resuscitation required
500 – 700	Immediate unconsciousness with one sniff. Causes seizures, loss of control of bowel and bladder. Breathing will stop and death will result if no resuscitation is done.
700 – 1,000	Causes immediate unconsciousness. Death or permanent brain damage may result unless rescued promptly
1,000 – 2,000	Immediate collapse with respiratory failure

Source: Geothermal Energy Development. KenGen Report No. Geo/8/009b

Toxic effects of H_2S have been classified into three categories, namely:

- Acute
- Sub-acute
- Chronic.

Acute intoxication refers to effects of a single exposure, to a massive dose of hydrogen sulphide of the order of 1000 ppm. At this concentration, hydrogen sulphide exerts an effect on the whole nervous system by inhibiting the enzymes cytochrome oxidise, which is involved in the aerobic metabolic pathway (Sinclair and Knight 1994). The symptoms are an initial stimulation of respiration resulting in very rapid breathing and subsequent depletion of carbon dioxide in the blood. This leads to respiratory inactivity than may spontaneously reverse if the depletion has not gone too far. However, if breathing does not spontaneously recommence and artificial respiration is not given, death from suffocation occurs.

At concentration above 1,000-ppm hydrogen sulphide may have a direct paralysing effect on the nervous system. In this case, if no stimulation of breathing occurs, immediate respiratory failure occurs. However, the heart does not stop beating immediately and artificial respiration can be given until the levels of hydrogen sulphide in the bloodstream drop sufficiently to allow breathing to resume. H_2S is very rapidly oxidised in blood and is not considered a cumulative poison.

The effects of H_2S on vegetation are not well documented. Contrast to animals, there appears to be a wide variation in response across species. Sulphide taken up by plants is primarily metabolised to sulphate; or incorporated into plant proteins and as in the case of sulphur dioxide, low concentrations may have a growth stimulation or fertilising effect. At higher concentrations, hydrogen sulphide can cause leaf lesions, defoliation and reduced growth, with young plants being the most susceptible.

KenGen staff carry out an intensive monitoring of H_2S three times a week for most locations around and away from the power station. The dispersions of hydrogen sulphide at various stations are shown in table 5.6 below. Concentrations are in ppm.

Table 5.6 Hydrogen Sulphide Dispersion at Various Locations at Olkaria

Location	Average	Maximum	Minimum	Median
Workshop	0.020	0.80	0.00	0.00
Power station	0.500	4.40	0.00	0.00
Administration	0.050	1.30	0.00	0.00
Spit 1	0.160	2.80	0.00	0.00
Spit 2	0.190	3.40	0.00	0.00
WO	0.093	1.30	0.00	0.00
WO2	0.060	1.00	0.00	0.00
KWS	0.020	0.20	0.00	0.00
L. View	0.000	0.10	0.00	0.00
L. Site	0.000	0.00	0.00	0.00
Store	0.120	1.00	0.00	0.00
OW-709	0.040	0.20	0.00	0.00

Source: Kubo, 1999

Highest H_2S concentrations were recorded at the power station (4.4 ppm). This was in accordance to the basic Gaussian plume equation. The frequency of various concentrations at two of the stations was computed as shown in table 5.7 below.

Table 5.7 Frequency of Various H_2S Concentrations at Two of the Stations

(a) Power Station

Conc. (ppm)	Frequency	Cum. Frequency	Cum. Percentile
0.0	96	96	27
0.23	81	177	50
0.46	60	237	67
0.69	18	255	72
0.93	25	280	80
1.16	10	290	82
1.39	16	306	87
1.62	15	321	91
1.85	8	329	93
2.08	6	335	95
2.32	4	339	96
2.55	3	342	97
2.78	4	346	98
3.01	2	348	99
3.94	1	349	99
4.40	3	352	100

(b) Workshop Station.

Conc. (ppm)	Frequency	Cum. Frequency	Cum. Percentile
0.00	27	27	40
0.13	25	52	76
0.21	10	62	91
0.34	2	64	94
0.42	2	66	97
0.80	2	68	100

Source: Kubo, 1999

As indicated in the tables, most probable concentrations of hydrogen sulphide at these stations were below detection limit. Although Gaussian plume model predicts higher concentrations in all the stations, the most probable concentrations were the ones shown. Plume model predicts the worst scenarios of environmental risks.

5.2.3 Geothermal Brines

Table 5.8 shows geothermal brine cations and anions concentrations from the present geothermal wells in Olkaria East.

Table 5.8 Average Concentrations of Cations and Anions from Olkaria Geothermal Wells (ppm)

Na	K	Mg	Ca	Li	Cl	SO_4	SiO2	Zn	Cu	Pb	Cd	B
800	50	0	0	2	700	80	900	0.016	0.007	0.032	0.008	3

Source: Kubo, 1999

These concentrations are not very high to warrant any environmental risk. The only chemical constituents that might have negative environmental impacts are the heavy metals, which are toxic to both plants and animals. Where sufficient accumulation occurs along the food chain, there is usually an increasing risk to both animals and humans. Permissible levels for heavy metals in potable water are shown in table 5.9. Most of these elements were below acceptable levels, and therefore geothermal fluid from Olkaria may not be hazardous to the environment.

Table 5.9 Permissible Levels for Heavy Metal in Potable Water

Metal	Permissible Levels
Pb	0.05 ppm
Cu	1.00 ppm
Zn	5.00 ppm
Cd	4.00 ppb
B	20.00 ppb

Source: Kubo, 1999

Disposal of geothermal water might cause some concern due to precipitation of silica on the surface thus blocking infiltration of water into the soil. However, this will depend on the method of disposal. If the discharge is to the surface environment, the resulting pollution of fresh water depends upon the dilution capacity of receiving water. If the discharge is to a shallow aquifer, pollution impacts will depend on other uses of the aquifer, percolation rate into and groundwater movement within the aquifer, and the association between the aquifer and surrounding surface water. The most acceptable form of fluid disposal is by deep re-injection, although this may also have environmental impacts such as increase in micro-seismic activity. Biological impacts of these heavy metals on humans are summarised in table 5.10.

Table 5.10 Possible Biological Impacts of Heavy Metals

Element	Effects
Lithium (Li)	No adverse effects on human or aquatic life. Severe toxicity on plants especially citrus fruits
Boron (B)	Long-term exposure leads to gastro-intestinal irritations in human as B is rapidly and almost completely absorbed by intestinal track. This is through food intake rather than through drinking water. B is essential for normal plant growth, but can be toxic when present in excess of the required concentration.
Zinc (Zn)	From the physiological view, and without regard to toxicity, the tolerable amounts of Zn in water limited by unpleasant taste of Zn (5-10 ppm) Zn is toxic for aquatic life, the toxicity depends on the mineralisation of water and species in question. The metal is toxic to fish at a concentration higher than a few ppm. Agriculture plants may wither if Zn levels are higher than 5.0 ppm in water or soils
Copper (Cu)	The toxicity of Cu salts is relatively low therefore higher concentrations could be specified as Cu is ingested everyday with food. However, at Cu concentrations of 4 - 5 ppm or above, water acquires a metallic stringent flavour. Aquatic life may be disturbed by lower dose, but the condition of toxicity depends on the species and the composition of water CO_2 temperature, Ca, Mg etc.
Cadmium Cd)	It is relatively high toxicity in kidneys troubles and enzymatic anomalies, which may impede the transport of iron. Cadmium levels below 1 ppm presents no problems for aquatic life especially for fish

Source: Kubo, 1999

The other chemical constituents, which may be harmful in high concentration, are chloride and fluoride. Acceptable levels for these elements are chloride (250 ppm), and fluoride (1.3 ppm) in drinking water. Fluoride is beneficial in small concentration for the structure and resistance to the delay of children's teeth. Higher concentrations would cause pronounced smoothing and disfiguration of teeth and other related problems.

5.3 Impact on Water Quantity and Quality

Water quality and quantity are important issues at Olkaria geothermal filed, because of semi-arid climate and proximity of Lake Naivasha. Lake Naivasha is an important water body to many interested parties, which include farmers, tourists, local inhabitants, fishermen, geothermal community and possibly geothermal reservoir and general groundwater regime around it.

The chemical environmental assessment for Olkaria west is not concerned with the quality of Lake Naivasha water, but quality of geothermal effluents that may make lake water more polluted with unacceptable chemical substances. Lake Water is used in drilling and domestic use by KenGen and OrPower 4 employees.

The hydrology of Lake Naivasha is complex, however studies have shown that the lake may be having outflows to the north and south of the lake. Recent work done by Arusei (pers. comm.) showed that the lake water is discharged southwards only and not northwards as has hitherto postulated. The northern boreholes within drainage divide of Lake Naivasha may be recharging the lake. If this is true, then all the present and future Lake Naivasha water abstractors should be encouraged to sink their boreholes on the outflow direction, to utilize outflow water. Arusei, (pers. comm) estimated between 50 and 60 x 10^6 m^3/y of outflow water. The estimated water consumption of ten highest water abstractors from Lake Naivasha based on electric power consumption was about 60 x 10^6 m^3/y (Sinclair and Knight, 1994). That means if the consumption remains constant, then all water abstractors can be satisfied by outflow water. Therefore direct pumping from the lake should be discouraged.

If the movement of groundwater in the south of the lake is southwards, then geothermal brine re-injected into the ground will not come in contact with lake water, and thus will not be affected.

5.4 Impacts on Animal Movements and Migration Corridors

Animals concentrate more in the park during the dry season. This is because of the provision of water holes, or wastewater from human settlements. During the wet season, the animals are widespread both within and outside the park in areas that offer suitable feeding areas. During the dry season, the herbivores gradually shift from open grassland and open bushed grassland feeding areas to more bushed areas. They do so to shelter themselves from the heat of the day. The routes (trails), which the animal use in the course of these movements are permanent and have been used for a very long time. Geothermal development may affect wildlife by blocking animal movement and destroying their habitats. At Olkaria, attempts have been made not to fence off migration paths of animals. This is done by burying pipes underground or elevating them to allow free movement of animals and preserving sensitive habitats for animals and birds such as breeding, feeding and resting sites.

5.5 Other Stakeholders

Lake Naivasha Riparian Association

The findings revealed that there was concern over increased abstraction of 30,000m^3 per month or more, as the project expands during prolonged dry conditions. There was also concern that large volumes of wastewater re-injected underground could affect the interrelationship between the surface and underground aquifers.

Kenya Wildlife Services

There was concern over the future state of the park and it's surrounding 20 years after the project is abandoned. There was also concern over the interference of nature trails, camping and picnic sites and compensation, tourist safety, the speeding of vehicles and also the location of the park.

Oserian Development Company

There was general concern over the natural beauty of the Kongoni wildlife sanctuary as the project expands. It was revealed that the company had worries on possible effects of Hydrogen Sulphide on its farming activity.

Fisheries

There was general concern over siltation of the aquatic ecosystem from the construction of roads and drill pads, and the laying of pipe. Others include rainfall runoff, wastewater from wells and burst water, fuel and oil pipes. There was also concern of long-term acidic precipitation on aquatic life.

Municipal Council

The main concern was the break down of waste disposal systems due to over use and pollution of the lake and surrounding environments.

Tour Operators

There was concern over increased traffic and commercialisation of the park. There was also concern over the design of the expanding road network. However, it was revealed that the project would benefit from the expanding road networks.

Forestry Department

There was concern over the increased destruction of vegetation to make way for roads, drilling pads and buildings, and the displacement of existing useful tree species that could provide food sources for the local fauna. It was revealed that the project would benefit from increasing its donations of indigenous tree seedlings.

6.0 Conclusions

Preliminary analysis of the data indicates that the general environment of the community around Olkaria has not been affected much by the power project. Proper operational management by the geothermal plant operators is in place to stem any possible conflict with the surrounding community. This includes the fencing off the plant premises to prevent injury to the community and their animals and the holding of regular meetings between the project management and Maasai elders.

The study shows that although the area surveyed has very low rainfall, loose soils and high ground slope, it is well preserved by a light vegetative cover. Drilling activities have the potential to degrade the quality of the environment if not properly handled. Care has had to be taken during road construction, drill-site preparation and effluent disposal to avoid soil erosion. The results show that the project, if properly executed, will not adversely affect wildlife and human life, either directly or indirectly. All the possible environmental impacts evaluated can be mitigated. Contamination of groundwater is unlikely since the water table is very deep and the wastewater being re-injected. Care will therefore need to be taken during road construction, further drill-site preparation and effluent disposal to avoid soil erosion.

The Olkaria geothermal project to some extent has improved the living standards of the Maasai community. The project can become a good example of a large-scale power project impacting positively on the welfare of the local community. To a large extent the project has opened up this community "to the outside world" by the construction of infrastructure such as roads and telecommunication, making access to markets and other facilities possible. It was noted that a good number of visitors to the power plant do call at the Maasai Cultural Centre to admire and possibly buy Maasai artefacts and watch traditional dances, bring in revenue.

None of the Maasai interviewed complained of health problems relating to either the noise or the H_2S gas or the geothermal wastewaters. This is most likely due the favourable separation distance of the homesteads from the power plants and the general wind directions.

While many of the respondents had favourable comments about the project and were specifically appreciative of the provision of water, shopping facilities and occasional hikes in company vehicles, many felt that the project could do more to the local community. Job opportunities for them could be much higher than they currently are. There was a general feeling that the project employees, many of whom are from other parts of the country, never make any effort to socialise with the local Maasai community.

Many of the interviewees also wondered why the company, and for that matter the Government, could not provide them with electricity now that it is being produced from what they consider their former lands. However, they would rather have more of their people employed at the power plants than have electricity. When asked what their reaction would be if the power plants were trans-located elsewhere, they said they would use any possible means to block the move. It would therefore appear that despite the complaints from the local community around the Olkaria Geothermal Power Plant the project is nevertheless viewed as beneficial.

7.0 Recommendations

7.1 Utilities Institutional and Management Issues

KenGen's geothermal staff and management have continued to make notable progress in recent years in almost all aspects of the geothermal program. The company is considered fully competent to conduct geothermal exploration, drilling and development activities, and in the operation and management of a geothermal power plant and field station, as well as having adequate capability in environmental protection and community relation activities.

New challenges include the following:

- Satisfying the requirement of the National Power Development Plan for 576 MWe of geothermal power by 2016.

- Operating as a commercial entity in an energy sector that is increasingly transparent and open to private competitors.

- Taking the initiative in such matters as the design and the supervision of construction of well connections, separator stations and water disposal lines.

- Relying less on outside consultants and contractors in environmental monitoring and assessments, numerical simulation of reserves, and the interpretation of injection data.

- Taking the initiative in discussions with engineering consultants and power plant designers in order to maximise the power yield from a give quantity of geothermal fluid, while minimising the cost of design and construction.

KenGen will continue to face challenges in obtaining financing for geothermal projects. To accomplish this, KenGen staff must continue to improve performance, reduce costs and time delays, and make geothermal power truly least-cost power generation. The geothermal staff must also avoid "empire-building" and will need to learn to work cooperatively with private power developers for mutual benefit. For example, the IPP, OrPower 4, is expected to supply 64 MWe in next couple of years. If this company cannot achieve this level of production, KenGen will have to identify and assess additional geothermal prospects to make up the difference.

Secondly, whenever there are two operators in a contiguous area, there will be issues of concern to be resolved to mutual satisfaction. These may include, but not limited to, water supply for drilling and power plant operations, road construction and land access, environmental issues and agreements, community relations, joint monitoring operations, sharing of exploration and well test data, joint procurement activities, sharing of work facilities, and/or rental or sale of equipment and supplies. There may additionally be a need for a mechanism for settling agreements or claims of damages.

There is need for the project to also cost share in research activities with OrPower 4 on the geothermal reservoir particularly on issues concerning the output of wells, the chemical composition of the discharge fluids, the temperature and pressure profiles of the wells and also on the direction and angle of deviated wells.

7.2 The Local Community

The Maasai community has lived in the Kenya Rift for many years, well before Europeans moved in and occupied most of it. Modern Maasai still live in game parks and the geothermal areas where they graze their livestock. They believe that land is a resource meant to support the human race and one cannot therefore claim ownership to it, have titles or sell it. During the first half of this century, colonialist took their land, sub-divided it and issued titles among themselves thus systematically marginalized them.

The Maasai, in spite of their nomadic life, lived harmoniously with wildlife. The open areas that remained at independence, on which they now live and graze cattle, were declared government land. This land was initially reserved for wildlife and game parks that include Olkaria (Hell's Gate) and Longonot. This was done without considering the needs of the Maasai who were living on it. Thus, in effect, the Maasai ended up living illegally on land, which was actually theirs by history. Over the years, this reserved land was used by the Government as a fall back for other development purposes, thus reducing the size of available grazing land. At present, the available grazing area for the Maasai and wildlife is too small to sustain both. There is, therefore, a direct conflict between the Maasai people, geothermal development, and wildlife conservation. It is therefore necessary to develop ways of extracting the geothermal resources without placing more pressure on the remaining land.

The National Resources Development Act gives express powers to utilities to explore the natural resources and if viable, develop them and compensate titleholders. In the past, some of the people compensated with money have ended up on the streets because they had not been trained in the use of money and given guidance or counselling on the expected lifestyle changes. Assessment of the level of such cultural impacts that the project expansion will have in potential areas should be made in advance of development. Programs have to be drawn that can be used to educate the target community on the expected changes in lifestyle, the cash economy, and the possibility of exotic diseases and cultural erosion.

Although socio-economic impacts are inevitable in any development of geothermal power, they can be minimised by holding consultations with the affected residents and taking their interests, fears and concerns into consideration. For example, Tole (1997) has shown that long-term monitoring of the welfare of displaced residents is effective. He has also suggested that for the residents that remain in the vicinity of a project, it is essential for them to be provided with social amenities so that they can identify with the project. This is important because the land on which the projects stand was their only ancestral inheritance.

For Olkaria's case, ways have to be found to assist the neighbouring Maasai acquire electrical power. Emphasis should be placed on integration of electricity power use for income generation into the overall project planning and implementation. As far as funding is concerned, a Fund could be set up based on experiences gained within and outside Kenya through which funds are mobilised and channelled for such a community based project, involving community members, NGOs and of course the Government whose role should be only that of a regulator.

Findings of our present study also agree with those of Sinclair Knight (1992), who carried out an interview with the local community around the power plant seeking the community’s attitude towards the geothermal project. Our survey found out that, the interviewees exhibited a generally favourable and positive attitude to wards the project. Even those members of the community who were relocated to areas that are outside the national park without any compensation being advanced to them were not bitter. Their presence in the project area had been seen as an environmental threat in terms of outstripping the ecological capacity of the area coupled with the region's soils which are highly susceptible to erosion (Omondi, 1987).

The Maasai community now resides outside the park, mostly on the land between the southern boundary of Hell's Gate National Park and Suswa. It is our view that this good will could be reciprocated by offering appropriate jobs to some of the local Maasai. This is especially true for those with secondary education. The current number of members from the local community who work at the two power plants does not represent a fair deal to them. Out of the 500 people employed at the plant, only seven (7) are from the local Maasai community. This is equivalent to 1.4% of the total workforce at the plant. These seven comprise of one copy typist, one clerk, one driver, one office messenger and three watchmen.

Occasionally, the project does involve the community members, through their recognised leaders to address some conflicts of interest. However, if there is need to involve them more in the decision making process for activities that may have adverse impacts on the community. We recommend that the project participate in community development activities (e.g. regular donations in cash or in kind) to local self-help groups in order for the community to identify with the project. And, finally, the community members need to be educated on general safety measures to protect themselves.

7.3 Animal Movement and Migration Corridors

The geothermal resource occurs in an area that has environmentally sensitive sites. The animal sanctuaries in this area keep some of the world's most endangered species such as the rhino. It is therefore imperative to maintain development that allows for such conservation. Studies in Olkaria show that animals maintain uniform migratory routes and any above surface steam gathering pipelines across these routes will impair their movement (Tole, 1996). Thus, a prior study of the animal migratory routes must be an input into the steam gathering system and power plant design to avoid blocking them. Another alternative is to bury the pipes where the routes are crossed. Studies by Marani et al (1995) show that, at times, there could be visual impairment to animals by steam condensation. High humidity on cold and wet day's results in a white plume of condensing steam around the power plant and wellhead steam separators.

Most of the rift geothermal fields are in semi-arid areas; therefore the animals are drawn to any surface waters from well testing, disposal pipe leakage, and chemical stabilisation ponds. Green vegetation that is attractive to animals tends to grow around these waters and animals can feed on them. Toxicity monitoring of the soils and plants around the stabilisation ponds by Simiyu and Tole (1995) show accumulation of toxic constituents and therefore the water and plants around the ponds are not fit for animal consumption. At the same time, if these waters are not disposed by injecting into the deep reservoir, it can get into the shallow water table that is already being used for human consumption.

7.4 Noise and Emissions Control

It is anticipated that when Olkaria II becomes operational, there will be noise above the permitted dB level especially near the power plants. The noise control measure that should be taken include the following:

- The control room and general powerhouse design should be made in a way that reduces the emission and propagation of noise as part of the noise control program. These should include vibration control within the original design of the equipment in order to avoid generation and structural transmission. Where it cannot be incorporated in the original design, then acoustic barriers and silencers can be used.

- It is recommended that starting from 85 dB, the allowed exposure to workers should not exceed 8 continuous hours. This will mean workers rotation on shifts, use of hearing protection and rest booths.

- We see the need for KenGen to adopt safety standards as secondary reference point. While the results of air monitoring indicate compliance with occupational standards, there are secondary standards on the length and peak of exposure to H_2S emissions. It is also worthwhile to check the sensitivity of the automatic H_2S equipment to low concentrations, because the equipment might have the capability to measure ambient H_2S with accuracy, resulting in misleading zero values.

For the last four decades, Kenya has been one of the leading tourist destinations in the world. The main attractions are the wildlife, lakes, and vegetation within the rift valley where the flora and fauna has been preserved because there had been very little human social-economic activity. The last 10 years have seen this region of Kenya emerge as one of the leading cut flow exporting regions of the world. Flower farming has done well in the rift valley due to volcanic soils around the volcanic centres. This is also where the geothermal resources are. One of the flower farms (Oserian) now uses the geothermal steam and water from a well leased from KenGen for soil fumigation and greenhouse heating.

Analysis of H_2S and CO_2 geothermal emissions at Olkaria show, that they are below the World Health Organization harmful levels (Sinclair Knight and Partners, 1994). KenGen together with the Oserian Development Company (ODC) that owns the nearby flower farms carried out a study on the effect of these gases on the performance of flower growing. They found that flowers that were exposed to geothermal emissions did better than those that were not (Muna, 1998). Scientific reasons have to be found out for this observation as well as determine if this phenomenon is long lasting or temporary. It is noteworthy that KenGen has a continuous monitoring program of noise and H_2S emissions. This needs to be maintained.

7.5 Landscaping

The floor of the rift valley in this area is composed of loose volcanic soils that are susceptible to wind and water erosion. Where there are steep slopes, gully and sheet erosion is common, often having been initiated by any disturbance such as, construction, road building and even tracks caused by off-road vehicles. Geothermal development involves a lot of earth movement to make roads and drilling pads that can affect the soil stability.

Micro-gravity and precise levelling at the Olkaria production field carried out since 1983 show mass withdrawal and ground subsidence (Mariita et al., 1998). This has had the effect of triggering landslides and accelerating soil erosion; unless the ground slope is stabilized by planting vegetation, building terraces and reinforcement. It also has the effect of affecting buildings thus reducing their lifetime and increasing vulnerability to collapse during earth tremors. To reduce the mass withdrawal and subsidence, an injection program was instituted with a hope of keeping a balancing a balance between the mass drawn as steam and recharge. Later, it was realized that there was excessive injection when cooling and condensation started to occur in the reservoir. This was because there was no monitoring concurrent with injection. This omission needs to be rectified.

There is need for KenGen to cost share with KWS and OrPower 4 a park restoration fund that could rehabilitate Hell's gate park after their operations. The project need to consider doing its operations at the side of the park, do diagonal drilling, put up high hoops, paint the pipes green, and plant more indigenous trees as camouflage, in order to maintain the natural appearance and beauty of the park and its immediate surroundings. KenGen should in partnership with KWS, OrPower 4 and tour operators, develop a better road network system with bumps and speed limits of 40km/hr, to link Hells gate and Longonot park and also to avoid speeding in the park respectively.

7.6 Coordination with other Stakeholders

The active participation of KenGen and OrPower 4 in the activities of some of its concerned stakeholders (particularly with KWS, and Oserian Development Company) has resulted in improved relations with the project petitioners. Co-ordination work showed transparency on the part of KenGen, provided a forum to provide correct information to these groups, and created goodwill. A public relations environmental officer should be appointed to participate in the enhancement of the project activities and image in its vicinity.

Since the flower farming, geothermal, wheat farming, dairy, tourism and wildlife conservation, all use water pumped directly from the Lake Naivasha or wells drilled within the Lake Naivasha groundwater basin, co-ordination is necessary. This enclosed lake has only one small river flowing into it and the lake level has been going down over the last 20 years (Njenga, 1994). At the moment, irrigation farming in this arid region has the largest impact on the water level. Most of the irrigation water evaporates and very little of it gets back into the ground water system. Although all these activities depend on water from the lake and basin, the amount of pumping from the Lake and drill holes has not been evaluated and is not controlled. This needs to be implemented. Flower farming and geothermal production are the fastest expanding industries putting pressure on the lake water. At the current rate of expansion, the lake environment might not be able to sustain a reasonable water level for balanced future development.

Joint flower experiments between KenGen and Oserian Development Company (ODC) were completed in 1995. There is need to get a formal document on the closure of the flower plantation contamination issue. It has been suggested by KenGen's consultants that there is need to get ODC confirmation through its acceptance of the final report or co-authorship of the flower experiment report. We further recommend the publication of the study.

7.7 Environment Management System

The project need periodically to contract an independent person or group of persons to evaluate their environmental management systems according to the ISO 14001 and 9001 certificate principles and guidelines. The 4.01 operational directives of World Bank funded projects need to be followed in order to ensure that there is proper management of the immediate and surrounding environment. We recommend that the geothermal project first focus its efforts and resources on the installation/formalisation of an Environmental Management System (EMS). The EMS is expected to protect the companies from liabilities from environmental risks, and to assist in sustaining project operations through environmentally sound and socially acceptable practices. Once the EMS is installed, the ISO 1400 accreditation can be easily attained.

Surface disposal of waste waters which are discharged from well pads during drilling and well testing phases should be avoided as much as possible because this can also lead to gully erosion. Once gullies develop they are very hard to control. The best disposal method is to re-inject all the wastewater in to the deeper reservoir so that it does not get into shallow water aquifer.

All run-offs from stabilised roads (murram or tarmac) through culverts should be handled in the best way to avoid gully erosion. New run-off can be diverted at regular intervals before it accumulates to problem levels. The prevalent form of erosion is water whose erosion potentials are evidently great. This can be attributed to the loose physical nature of the soils that consists mainly of volcanic ash. The area falls in a semi-arid zone classified as Eco-climatic zone 5. Erosion by water only occurs during rainy seasons and affects almost the entire prospect area to varying degrees.

Bush fires regularly occur in Olkaria. A fire Control Plan is recommended, possibly in conjunction with the Kenya Wildlife Service, to minimise recurrence of these events. The plan has not yet been prepared, due to the concentration of the KenGen Environmental staff on the Environmental Assessment and Monitoring Programs. Considering the small size of the environmental crew, the programs put together with co-ordination with stakeholders and participation in policy/regulation meetings take up the entire time. That is why the streamlining and downsizing of the monitoring workload are recommended by the author, so that other equally important concerns, such as fire-control plan, can be attended to.

7.8 Integrated and Sustainable Policies

Olkaria has the energy producing wells inside a wildlife sanctuary and a flower farm. The 15 years of operation of the first power plant at Olkaria has shown that with proper management, geothermal energy production can go hand in hand with conservation. Given the speed and direction geothermal development is moving in Kenya, we believe it is critical to complete studies as soon as possible so that what has been glimpsed at Olkaria can be continued without slowing development essential to Kenya's future. These studies should be geared towards developing an integrated policy for sustainable, ecological, and culturally balanced geothermal development. Geothermal development with minimum environment and cultural impact can be achieved through exploration and exploitation programs that have integrated environmental monitoring and socio-economic-balance components.

A baseline and map for sustainable environmentally responsible geothermal exploitation ahead of financial investment need to be developed. At Olkaria east, the 45 MWe power plant is currently being supplied steam by 28 wells producing an average of 1.6 MWe per well (Ouma, 1998). Drilling of each well cost about 1 Million US$ (Sinclair Knight and Partners, 1994). Scattering many wells has very high environmental impact because drill pads, roads, and steam gathering and disposal pipelines have to be made for each well. We recommend a method be developed that enables drilling of fewer high producer wells, thus cutting down on cost and adverse environmental impacts.

To reach this goal, the exploration, exploitation, environmental and cultural issues inherent in geothermal energy should be identified and evaluated in advance. It will then be possible to develop programs that monitor and address anticipated problems and leave space for the unanticipated ones. Achieving these goals will benefit investors, the environment, and the public in the following ways:

- Maximizing knowledge of reservoir characteristics in advance of decisions on drilling, steam gathering, water availability and disposal, injection systems, and turbine types.

- Advance knowledge of the environment and cultural issues to be addressed, with anticipatory and clear guidelines on how to address issues as they arise, including the equitable use of water.

- Limited interruption of ways of life of the people living on their ancestral lands and public use of resources while preserving globally important environments and cultures.

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