ORPOWER 4 INC

ENVIRONMENTAL IMPACT ASSESSMENT

OLKARIA III GEOTHERMAL POWER PLANT

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0. EXECUTIVE SUMMARY

0.1 INTRODUCTION

Orpower4 Inc. proposes to develop, commission, and operate, an 8 Mwe geothermal power station at Olkaria (the Early Generation Facility), to generate electricity for sale to the Kenya Power and Lighting Company (KPLC) under the Power Purchase Agreement (PPA). Depending on the performance of the Early Generation Facility, and results from an ongoing test-drilling programme, there will be an option to build a Plant, as defined in the PPA to generate a total of 28 - 100 Mwe from the same concession area, which covers an area of approximately 11.9 km^2.

Approximately 20 housing units will be constructed for use by plant operators during the operation of the Early Generation Facility, and a total of 60 housing units for the main Plant. These houses are to be constructed at a 17.5 Ha site near the shores of Lake Naivasha.

An access road will be constructed within the National Park to facilitate access to the power station site.

This Environmental Impact Assessment Summary Report has been prepared for Orpower4 Inc. by Prof. Mwakio P. Tole and colleagues, to examine the possible impacts to the environment, likely to result from the construction and operation of both the Early Generation Facility, and the Plant of up to 100 Mwe power output. Impacts of auxiliary civil works are also considered.

At the time of conducting the study (April/May, 2000), construction of the Early Generation Facility was in progress, to draw geothermal fluid from wells drilled between 1983 and 1994 by the Kenya Electricity Generation Company (KenGen, then called the Kenya Power Company (KPC) Limited). Drilling was also in progress to prove steam for the main plant as was the construction of an access road. Construction of the workers' housing near Lake Naivasha was about to commence.

KenGen has operated, and still continues to operate, a 45 Mwe power plant, the first 15Mwe unit of which was commissioned in 1981, followed by another 15 Mwe unit in 1982, and a third unit in 1985. KenGen has plans to put up a new 64 Mwe power station at Olkaria North East, the Environmental Assessment Report for which concluded that, "…the proposed power station as set out in the feasibility study (Ewbank Preece, 1989) is an acceptable development from an environmental point of view." (Sinclair Knight and Partners (1994))

Despite this favourable assessment, it is necessary to evaluate the potential environmental impacts of each plant, in order to minimise adverse impacts peculiar to the plant site, and to maximise benefits to the local communities, and to the environment as a whole.

0.2. GEOGRAPHIC SETTING

The Olkaria field is located approximately 125 km to the north west of Nairobi south of Lake Naivasha (Figure 2). The Olkaria III concession area is within the southwest field, approximately 5 km south east of Lake Naivasha. It is one of 7 designated fields in the Greater Olkaria geothermal area, and covers an area of approximately 11.9 km^2. The other fields are Olkaria East (I); Olkaria Northeast (II); Olkaria Northwest; Olkaria Central; Olkaria Southeast; and Olkaria Domes. The Greater Olkaria geothermal area covers an area of 75 km^2, and has the potential to produce at least 300Mwe. The geothermal power potential of Kenya as a whole is estimated to be at least 2000Mwe, with some estimates putting the potential at between 6,882 and 18,680 MW.

The Olkaria III geothermal resource occurs partly within Hell's Gate National Park, and partly in Maella - Ngati and Kongoni farms. It falls within the zone gazetted as a geothermal resource area in 1971, with numerous fumaroles and hotsprings. The Hell's Gate National Park was gazetted in 1984. The geothermal field is in close proximity to Lake Naivasha and to flower-growing farms. These proximal locations have raised concerns about the impact of the geothermal operations on the Wildlife, Lake hydrology and on the flowers, in addition to impacts on the local Maasai community in terms of socio - economics and health.

0.3. BASELINE STUDIES

0.3.1 The Physical Environment

0.3.1.0 Geology

The Olkaria field is characterised by volcanic rocks of Pleistocene to Recent age. The last eruption in the area at Ololbutot is dated at approximately 200 years ago (Clarke, *et. al.*, 1990).

The Pleistocene Mau tuffs consisting of ignimbritic tuffs intercalated with rhyolitic lava flows, trachytes, and basalts form the reservoir rocks. Overlying this is a trachyte unit, followed by the uppermost rocks consisting of rhyolite intercalated with pyroclastics (Omenda, 2000). The rocks are blocky, and fractured at depth. Surface fumaroles and hotsprings abound in the area.

0.3.1.1 Climate

The nearest meteorological weather station to Olkaria West is situated at the KenGen Olkaria power station. Annual maximum temperature ranges from 21 to 29° C, and annual minimum temperature ranges from 11 to 15 ° C (Sinclair Knight and Partners, 1994). February is the warmest month, and June/July the coolest. Nighttime temperatures can occasionally be frosty, and mid afternoon temperatures very hot. Winds are generally southeasterly, except in February - April, when they tend to have a noticeable northeasterly component. Humidity ranges from a minimum of about 30% to a maximum above 90%. At the Olkaria III site, a meteorological weather station was operated for about two years. The records for 1996 (Appendix 1) give an annual total of 676mm, which closely approximates the annual averages for the Naivasha area of 625 to 697 mm. The pH of rainwater at Olkaria III site has been found to vary between 5.35 and 6.42 (Marani, 1995), and has no correlation with the sulphate concentration of the rainwater. Annual potential evaporation rates are in excess of 1700 mm/yr.

The minimum temperature around Olkaria West region is modified by the effect of Olkaria hill, which causes low-level inversions at the base of the mountain as a result of sinking air.

0.3.1.2 Soils

The soils at the Olkaria III field have high amounts of sand to silt sized particles, and are similar to those of Olkaria East, because the soil parent materials are predominantly volcanic in origin in both locations. The soils are generally porous, light grey to brown in colour, and are in general very poor in water retention capacity.

The most noticeable agent of erosion in Olkaria west area is rainwater. The erosion by water involves first the detachment of soil on any bare surface, and the actual transport of the detached soil. During heavy rains such as during the El Nino in 1998, small trees were also be uprooted.

Due to the erodable nature of the soils at the Olkaria III area, any surface left bare is very susceptible to erosion. The form of erosion, noticeable at the Olkaria west is gully erosion, with a few gullies cutting through the area.

The other form is erosion by mass movement. This was observed in a few areas around the SE of Olkaria hill. There is evidence of slumping and sliding of slopes and gully sides. The gullies observed are wide and vegetated on the floors by grasses and shrubs. They form resting-places for the animals.

Wind erosion can also be important in this area, especially where the soils are bare, such as along animal tracks, or along unpaved roads.

0.3.1.3 Hydrologic setting

The geothermal field is located in an arid area, where annual potential evapotranspiration exceeds annual precipitation. It has been postulated that groundwater recharge is predominantly from the Mau plateau to the west, with probably some contribution from Lake Naivasha (Arusei, 2000). Discharges at the surface are in the form of fumaroles, as well as hot and cold springs.

0.3.1.4 Noise

Background noise levels were measured for this study at various locations, and varied from 33 dB (A) 1 km south of Narasha gate on a warm and windy morning, to 68 dB (A) at the drilling site on a warm, windy and cloudy morning. At the power station site, the noise level was in the range 53 - 60 dB (A). It is therefore estimated that daytime background noise levels in this area are in the region of 30 - 40 dB (A).

Construction activities have added noise of temporary duration. In geothermal work, the noisiest activity is the testing of wells, where levels in excess of 100dB(A) are frequently recorded. The power station and cooling towers are also high noise environments, with noise levels of above 70 dB(A). Orpower is currently engaged in drilling and well testing, and operation of the power station will permanently introduce noise levels of about 70 dB(A) within 30 meters of the power station.

0.3.1.5 Aesthetics

The site is on a hill, with natural scrub vegetation. The power station, piping, and access roads will offer a visual intrusion into the natural landscape, and alter its appearance permanently.

0.3.1.6.Visuals

There is currently low density of traffic in the area from visitors to the Hell's Gate National Park. Transportation of construction workers for Olkaria III has resulted in increased levels of road traffic, and increased dust emissions from vehicles using unpaved roads (Plate 1). This causes obstruction of view to other motorists, and to animals. Plants close to the road are also coated in dust. These effects will decrease when construction is complete.

There are a few fumaroles in the Olkaria III area, but these are normally not obviously conspicuous, except on cool, humid days (Plate 2).

It is expected that the cooling towers of the power station will enhance production of plumes of vapour, especially during cold, humid days.

0.3.1.7 Land Subsidence

Soils are loose and fine-grained, which makes the area potentially hazardous if there is subterranean erosion. The power station site is being flattened and compacted to minimise subsidence. There are no data regarding subsidence in the presently operating KenGen Olkaria I power station, although land subsidence has been reported to be a problem in geothermal fields in New Zealand as a result of the withdrawal of geothermal fluids from the subsurface.

0.3.1.8 Earthquake Hazard

Seismic events in the Olkaria area are generally of magnitude 2 or less (Hamilton et al, 1973), and are located along faults east of Olkaria Hill (Simiyu and Keller 2000). In the Olkaria III area, seismic events are much fewer in frequency, occur as small and shallow events, and are localised in the center where the temperature is high. On the periphery of the field and outside it, events are larger and deeper (Simiyu, 1999).

0.3.1.9 Volcanic Eruption Hazards

There have been eruptions of lava from a postulated highly differentiated magma chamber at depth, the last of which occurred about 200 years ago. Simiyu (1999) interpreted S and P wave seismic data to mean that an attenuating body occurs beneath Olkaria hill, and extends to the west.

0.3.1.10 Electromagnetic Pollution

Currently, a 33 kV line to Narok town passes through the Hell's Gate national Park close to the Olkaria III station. The construction of an additional 230 kV transmission system will increase electromagnetic fields in the area. There is still controversy on the human health effects of electromagnetic radiation (especially its impacts on leukemia in children). This project is in the Park, and power lines will affect animals, particularly the navigation of birds.

0.3.2 The Biological Environment

Olkaria III is partly located within the Hell's Gate National Park. Lake Naivasha, a Ramsar Conservation site is located 5 km from the geothermal site. This calls for special care to preserve the sensitive environment. There is a seasonal wetland (the Narasha swamp, or Lake Odongo) that is used for pastures by the Maasai, located within 1 km of the Olkaria III geothermal site.

0.3.2.1 The Terrestrial Environment

0.3.2.1. Flora

The area falls into ecoclimatic zone 5, with bushland and bushed grassland. Sinclair Knight and

Partners (1994) noted the presence of unique species of pteridophytes and orchids in this area, associated with steam vents. This is confirmed by this study. Gorges and laggas also have associated unique plant species. In addition, Oserian Development Company is growing exotic flowers in the area, close to Olkaria III.

0.3.2.2 Fauna

Mammals found in the Hell's Gate National Park include Kongoni, Zebra, Thompson's gazelle, Grant's gazelle, Giraffe, Eland, Reedbuck, Warthog, Impala, Dik-dik, Steinbuck, Klipspringer, Buffalo, Wildebeest, and Waterbuck. Kongoni ranch also keeps a sizable population of the same animals found in Hell's Gate National Park. Recent population censuses show a decrease of animal populations in Hell's Gate National Park, between 1993 and 1998 as follows: - Kongoni from 479 to 81, Thompson's Gazelle (165 to 33), Grants gazelle (136 to 44), Giraffe (40 to 11), Eland (102 to 28), Reedbuck (32 to 13), Warthog (50 to 40), Impala (30 to 52), Dik-dik (25 to 0), Steinbuck (25 to 0), Klipspringer (10 to 0), Buffalo (105 to 28), Waterbuck (5 to 0). Only zebra show an increase in population within the Park (295 to 342).

Many species of birds and insects also occur in the Park, with more than 100 bird species having been recorded.

Most animals are found to the east of the Park, and less to the west where the Olkaria III project is located. The Narasha swamp at the foot of the hill where the power station is located is however an important area for both wild animals and Maasai livestock, although it is outside the Park and Olkaria III concession boundaries.

0.3.2.2 The Aquatic Environment

Lake Naivasha is host to numerous animal, plant, bird, insect, and fish species. The project will use water from the Lake for consumption in the work and home environments. Compared to what the flower growing Companies abstract for irrigation purposes, this will have a negligible impact on the hydrologic balance of the Lake. There is no evidence that exploitation of the geothermal system has any direct impact on the lake in terms of hydrology.

0.3.3 The Chemical Environment

0.3.3.1 Gaseous Pollution

The existing KenGen 45 Mwe plant at Olkaria I discharges uncondensable gases into the atmosphere. These include CO_2, H_2S, H_2, CH_4, N_2, and O_2. Tole (1990) estimated the annual emissions of gases from the KenGen Olkaria I geothermal station to be 22,000 tonnes CO_2, and 40 tonnes of CH_4. These are both greenhouse gases that promote global warming. Sinclair Knight and Partners (1994) estimate that 87,200 tonnes of CO_2 and 119 tonnes of CH_4 will be emitted from the combined KenGen 45 Mwe power plant, and the planned KenGen 64 Mwe power plant at Olkaria II (Olkaria Northeast). H_2S concentrations are also fairly high at Olkaria I, with maximum short term average H_2S levels rising to 11 ppm over periods of a few minutes at the power station site (Marani, 1995). Olkaria III has more CO_2 and less H_2S than Olkaria I. The design of the Olkaria III power station calls for 95% reinjection of the spent geothermal fluid for the Early Generation Facility, and about 60% brine reinjection for the Plant. There will be discharge of the non-condensable gases CO_2, H_2S, H_2, N_2, and CH_4 (4 - 5% by weight in the Early generation Facility, and 2 - 3% by weight for the Plant) into the atmosphere.

0.3.3.2 Radioactivity

Radon and thoron traverse surveys conducted in Olkaria west field by KenGen staff found that radon counts ranged between 0 and 25,000 counts per minute, and the average counts were 500 counts/minute. Clarke et al, (1990) recorded radon levels in the Olkaria area of 255 to 3000 counts per minute particularly near deep fault zones. Radioactive gases trapped inside buildings and other enclosed areas increase concentrations of the gases above values recorded in unenclosed sites.

0.3.3.3 Water Pollution

The salinity of the brines from Olkaria III is less than that in Olkaria I. The brine is mainly Na_2CO_3/$NaHCO_3$, with appreciable levels of SiO_2, K, Cl, and SO_4 (Appendix 2). As long as there is 60% fluid reinjection (all brine will be reinjected, with steam being recirculated), the brines will not be a hazard, especially if there is deep reinjection.

0.3.3.4 Solid Wastes

Wastes will arise during construction from vegetation clearing, earthworks during construction of well pads, roads, power station, piping, and drilling. These wastes need to be disposed of in a safe and sound manner.

Office and workers' household wastes should similarly be safely disposed of.

0.3.4 The Social Environment

Stake holders who will be impacted on by the project include, the local Maasai community, Orpower, KPLC, KenGEn and the Ministry of Energy (Electricity supply), Lake Naivasha Riparian Owners Association (Water availability for horticulture), Ministry of Water Resources and the Naivasha town Water Supply Department (Town water supply), Kenya Wildlife Service (Ecology of Lake Naivasha and the Hell's Gate National Park), and Kenyans in general (Electricity Supply).

Approximately 150 Maasai live in the vicinity of the project at Narasha village. The majority of the households interviewed did not have any form of formal education. The languages spoken by the Maasai community included the Maasai language and some English, Kiswahili and Kikuyu. The average family size of the community was 19individuals, which comprised of 3 wives and 6 children per woman on average. The majority of the population was in the 20-30-age bracket.

0.3.4.1 Land Ownership

The community members did 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 estimated at 100 acres per family.

0.3.4.2 Livelihoods

The predominant land use was pastoralism, which involved the keeping of cows, sheep, goats and donkeys. On average each family had about 70 cows, 200 Sheep and goats and 11 donkeys.

During the wet season (March to August) the men migrated to the highlands with the cows looking for pasture. The women were left behind with the children, to look after the home and also the remaining livestock. The men would then return during the dry season from August to February. Farming was practiced in the highland areas of Suswa and Maela and also in the lowland areas of Naivasha. The crops grown were maize, beans and potatoes, which were cultivated using hoes.

The community members sell their cows, sheep and goats at an average price of KSh. 7,000 and 1,500 respectively at market places. On average, 15 animals are sold per year. Milk is sold at an average price of KSh. 15 per litre. The community members also sell to tourists at the cultural center necklaces at KSh. 2,800, bracelets from between KSh. 300 – 600, KSh. 250 for shoes, cloth decorated with beads at KSh. 1,500 and, swords and knives at KSh. 3000 each.

A few of the community members are employed as watchmen and cleaners at KenGen. However, some of the community members are self-employed as carpenters and blacksmiths.

The community members have organized themselves into self-help groups, which include the women's group, the water development group, the cultural center group, the youth and church groups. The women group has 25 members, the cultural center group 67, the water development group 25 members and 12 members are in the KWS committee. One individual can be a member of more than one group. The membership charges for each group is based on each individual's ability to pay.

The houses lived in by the community members are temporary in nature with thatched roofs, wooden or mud walls with earth floors, which have to be repaired every year.

0.3.4.3 Health and Social Services

The facilities in the community include one primary school (Inkoriento primary school which is about 11km away) and one traditional healer. The health facilities visited by the community are the Naivasha district hospital and Maela health center, which are approximately 50 km away.

Some of the cultural activities involving the community members include circumcision, naming ceremonies, weddings, burials, religious ceremonies and sacred rituals. These activities are performed when the need arises. The community members also perform traditional songs and dances at the neighbouring cultural center.

Fuel wood and charcoal obtained from trees in the surrounding are the only sources of energy used for cooking and warming the houses.

The community members get their water from two water tanks provided to them by the Kenya electricity Generation Company (KenGen). Livestock are also watered at the Narasha wetland.

0.4. MITIGATION MEASURES

0.4.1 The Physical Environment

0.4.1.1 Climate

It is unlikely that operation of the Olkaria III power plant will have significant impacts on the local or regional climate, though wind flow locally will be modified by the plant structures. Humidity, temperatures, and rainfall may be affected locally by the steam condensate.

- A weather station should be established at Olkaria III to monitor weather parameters, including acidity of the rain.

0.4.1.2 Soils

In general the natural erosion hazard potential in the Olkaria west area is high, because of the loose soils, and the high relief. To minimise soil erosion hazard,

- Clearing of vegetation should be kept to a minimum during construction.
- There should be immediate revegetation of cleared areas, either for drilling, piping, or plant site.
- Star grass, which establishes quickly, should be planted on well pads.
- Dust reduction measures for all roads and the plant site is recommended to reduce wind

erosion.

- Speed limit signs and, where necessary, speed bumps should be erected.

0.4.1.3 Hydrology

Impacts on lake Naivasha due to withdrawal of geothermal fluid are unknown. The local hydrology is unlikely to be affected by deep reinjection of 60% of the geothermal fluid. The deep reinjection is also unlikely to affect the wetland south of the power plant. It is recommended that

- Tracer studies be conducted on breakthrough time for Lake Naivasha water to the geothermal wells, perhaps through a consultancy, using well tested and environmentally acceptable tracer materials.

- The wetland near the power station be monitored for water chemistry at least every six months.

- Water usage from Lake Naivasha be metered.

0.4.1.4 Noise

Drilling, construction of the power station, well testing, and road construction introduce noise, though temporarily. The actual operation of the power station is expected to have acceptable noise levels to the environment, though high noise levels will be expected near the turbines, pumps, and the cooling towers area. Therefore it is suggested that

- Workers in noisy areas (especially wells under test, and plant operators) should wear ear mufflers.

- Duration of work in noisy areas should be monitored, and kept to a minimum (e.g. by rotation).

- Silencers should be used when testing wells

0.4.1.5 Aesthetics

Physical structures should be made to blend with the natural environment by doing the following

- Piping should be painted either dull green or brown colours, to blend with the surroundings
- Structures should be kept as low as possible, so as not to conspicuously stand out
- Revegetation of cleared areas should be done so that structures are less conspicuous from a distance

At the time of the conduct of this study, these measures were already being implemented, though more care is needed to ensure that vegetation that is planted is watered until it is established, in this arid environment.

0.4.1.6 Visuals

There will be steam plume emissions during the plant operation phase. Dust from construction activities and road usage should, be minimised. Light from the drilling rig may disturb animals at night. The following recommendations are made to improve the situation

- Steam plume emissions will be a long-term impact in the area, adding to the natural fumarolic steam emissions that, for the time being, little can be done about under the present design. Use of air-cooled condensers, together with 100% fluid reinjection will eliminate this problem.
- Roads should be watered regularly to reduce dust emissions, and in the long run coated with dust reduction materials.
- Bare construction sites should be watered on dry days to reduce wind blown dust.
- Night time use of lights at the drilling rig should be kept to a minimum, and should be directed away from the animal habitats.

0.4.1.7 Land Subsidence

This may result from either subterranean erosion, or fluid withdrawal.

- Monitor land for possible subsidence

0.4.1.8 Earthquake Hazard

Reinjection of the fluids will minimise seismic hazard arising out of the project. However it is prudent to take precautions since the rift is a seismically active zone.

- Structures should be built to withstand at least a magnitude 4 seismic event
- Workers should be drilled on emergency shut down procedures in the event of an earthquake to prevent emission of fluids (especially pentane) to the environment
- Monitor seismicity of the area, either in collaboration with KenGen, or the National Seismic-monitoring network, or through a consultant, whichever option is deemed to be the best.

0.4.1.9 Volcanic Eruption Hazards

Operation of the geothermal power plant will reduce the volcanic hazard by extracting heat from the hot zone. Nevertheless, the rift is a volcanically active zone

- Workers should be trained on emergency shut down procedures in the event of a volcanic eruption
- Monitor magma chamber for activity when there is noticeable change in fluid chemistry, by using a suitable consultant.

0.4.1.10 Electromagnetic Pollution

This is normally accepted as an inevitable disadvantage of all electricity generation and transmission projects.

- Power transmission lines should take the shortest possible route, and avoid passing through sites documented to be sensitive for plants and/or animals.

0.4.2 The Biological Environment

0.4.2.1 The Terrestrial Environment

0.4.2.1.1 Flora

In order to conserve plant life, the following measures are recommended.

- Clearing of drilling pad sites, pipe ways, plant station, and access ways should be kept to a minimum.
- Replanting of indigenous species cleared during construction should be done immediately, to avoid invasion by opportunistic pioneer species.
- Exotic species should not be introduced into the area.
- Opportunistic pioneer species and any exotic species in the area should be immediately uprooted and destroyed.
- Plant species should be monitored every 2 years or so for changes in species composition and abundance.

There is already an agreement between Orpower 4 Inc. and KWS to implement these measures.

0.4.2.2 Fauna

The following measures are recommended to ensure the conservation of animal species.

- Sensitive habitats should be preserved, and avoided as sites of construction.
- Identified animal movement pathways should be kept open. Pipes should either be buried, or made with high loops at these locations.

- Pipes should be painted with natural camouflage colours so that they blend with the surroundings, in order not to scare away wild animals.
- Pipes should be insulated so as not to scald animals.
- Dust reduction measures on roads should be implemented to mitigate against dust, to prevent poor visibility that may cause animals to be hit by vehicles.
- Limit the speed of vehicles to 40 km/ hour within the park area.
- Limit noise, especially at night.
- Limit light shining away from the plant operations at night.
- Areas where animals can come into contact with drilling or geothermal fluids should be fenced off, while ensuring that fences do not enclose small animals. Fences should also not be placed in known migration paths of animals.
- Exotic animals should not be introduced into the area.
- Animal species composition and abundance should be monitored at least every two years.

An existing agreement between Orpower 4 Inc. and KWS to implement most of these recommendations is already in force (copy attached as Appendix 14).

0.4.2.2 The Aquatic Environment

- Staff houses should not be constructed too close to the water edge. The nearest constructed structure should be at least 100 meters away from the high water mark.
- No waste should be disposed of near the lake.
- Waste storage facilities should be designed to cope with periodic breakdown in municipal or private waste collection systems.
- Orpower should be an active member of the Lake Naivasha Riparian Association.

0.4.3 The Chemical Environment

0.4.3.1 Gaseous Pollution

There will be gaseous emissions of the non-condensable gases CO2, H2S, H2, N2, and CH4 into the atmosphere. Of these, CO2 and CH4 are greenhouse gases. CO2 could be tapped and sold off to companies manufacturing carbonated drinks. CH4 could be flared off. The levels of H2S from the Olkaria III plant will be low enough not to cause concerns over damage to human-, plant-, or animal- health. Pentane (motive fluid), should be handled with care. In cases of emergencies,

- Plant operators should be thoroughly drilled on emergency shut down procedures.

0.4.3.2 Radioactivity

This is naturally emitted in the area, and is not expected to increase due to plant operations. Radioactive gases may, however become trapped inside buildings. It is recommended that: -

- Buildings should be well ventilated to ensure radioactive gases are dispersed.
- Monitoring of radioactivity in indoor enclosed areas should be continuously carried out.
- If found to be exceeding recommended levels, appropriate worker protection measures should be implemented, such as limiting the number of hours workers can work in enclosed areas.

0.4.3.3 Water Pollution

Reinjection of geothermal fluid will not adversely affect the water systems in the area. As a precaution, however it is recommended that

- The chemistry of the Narasha seasonal wetland near the power station should be monitored at least twice a year.
- Wastewaters from offices and workers' houses should be properly disposed of.

0.4.3.4 Solid Wastes

- All solid wastes must be collected and properly disposed of.

0.4.4 The Social Environment

The following measures are recommended to foster good relations with, and maximise benefits to, communities in the vicinity of the power station.

- The project should involve the community members, through their recognised leaders, in the decision making process for activities that may have adverse impacts on the community. An environmental/public relations manager/consultant should be engaged by Orpower to smooth over relations with the local community.

- Environmental audits of the project should be carried out every 2 - 3 years, and these should include review of health records of the community members in the health centers that they visit.

- The project should participate in community development activities (e.g. periodic donations in cash or in kind to the self-help groups) in order for the community to identify with the project. This can be done in collaboration with KWS, Oserian Development Company, Lake Naivasha Riparian Association, and KenGen.

- Orpower 4 Inc., through the environment/public relations manager/consultant should educate Maasai community members on general safety measures required around the power plant so that they can to protect themselves and their livestock from dangers associated with the power plant.

- The project should have regular meetings with all the stakeholders concerned (particularly with KWS, KenGen, Lake Naivasha Riparian Association, and Oserian Development Company) in order to co-ordinate activities and reduce conflicts. This was already happening to some extent at the time of this study.

- The project should also collaborate in research with KenGen on matters relating to seismic/volcanic hazard monitoring, reservoir draw down conditions, groundwater status, and meteorological data collection.

- The project should periodically contract an independent person or group of persons to evaluate their environmental management systems to gauge compliance to the ISO 14001 and 9001 certificate principles and guidelines, to operational directive 4.01 of the World Bank, and to the Kenya National Environmental Management Bill.
- The project should regularly monitor daily water consumption through metered readings for drilling, construction and general operations in order to use water efficiently.
- The project, jointly with KWS and KenGen, should set up a park restoration fund that will rehabilitate Hell’s Gate National Park when their operations cease. Alternatively, an environmental insurance scheme should be set up to cater for decommissioning of the plant at the end of its useful life.
- The project should do directional drilling, put up high loops, paint the pipes dull green or brown, and plant indigenous trees to camouflage structures, and maintain the natural appearance and beauty of the park and its immediate surroundings.
- The project should set an example of how a geothermal power plant can sustainably co-exist with nature.
- The project, in partnership with KWS, KenGen and tour operators should develop a better road network system with bumps and speed limits of 40km/hr, to link Hells gate and Longonot parks, and to avoid speeding in the parks.
- There should be an arrangement for sharing of environment friendly technologies among KenGen, Orpower 4 Inc., KWS, and Lake Naivasha Riparian Association for the improvement of the environment.

0.5. CONCLUSION

The Orpower 4 Inc. Olkaria III geothermal project, located partly in the Hell's Gate National Park will have some environmental impacts, mostly on the animals in the Park, especially during construction. Impacts will be less during operation of the power station. The negative impacts can be kept to a minimum by adopting the mitigation measures recommended in this report, and by KWS. Most of these mitigation measures are already being implemented.

Similarly, physical and chemical impacts are minimal, and can be kept to acceptable levels. Monitoring for earthquakes, volcanic hazards, radioactivity, and water bodies in the area is recommended to allow for early precautions to be taken to avoid adverse impacts.

The project is expected to have positive social and economic impacts to the local Maasai community, and to Kenya's economy when it provides electricity. The project should actively seek to create good relations with the local community to enhance acceptability of the project, and improve the social status of the Maasai in the area. In collaboration with KWS, Oserian Development Company, Lake Naivasha Riparian Association, and KenGen, Orpower 4 Inc. should support community projects in the area (provision of water, electricity, roads, schools, and health facilities).

1.0 INTRODUCTION

This Environmental Impact Assessment Study Report has been prepared for Orpower4 Inc. by Prof. Mwakio P. Tole and colleagues.

Orpower 4 Inc intends to build, own and operate an 8 Mwe geothermal Early Generation Facility, and a Plant of up to 100 Mwe net electrical power output at the Olkaria III geothermal field, which falls partly within the Hell's Gate National Park. This study examines the possible impacts to the environment, likely to result from the construction and operation of a plant of up to 100 Mwe Plant. Impacts of auxiliary civil works are also considered.

World Bank guidelines for preparation of Environmental Assessments have been followed, to provide the following structure and information.

0.0 Executive Summary

1.0 Introduction

2.0 Policy, Legal and Administrative Framework

3.0 Description of the Proposed Project

4.0 Baseline Data

5.0 Significant Environmental Impacts

6.0 Assessment of Alternatives

7.0 Mitigation Measures

8.0 Conclusions and Recommendations

9.0 References

10.0 Appendices

2.0 POLICY, LEGAL AND ADMINISTRATIVE FRAMEWORK

2.1 Policy

The government of Kenya is committed to facilitating development of geothermal resources in Kenya to meet growing demand for energy in the country. All geothermal resources are vested in the Government (Geothermal Resources Act).

The Government is equally committed to conservation of wildlife and other natural resources (Environmental Management Bill, Wildlife Conservation and Management Act, Forest Act). The control of all wildlife conservation areas is vested in the Kenya Wildlife Service (KWS).

2.2 Legal and Administrative Framework

The project is located in Nakuru district of Rift Valley Province, partly within the Hell's Gate National Park, which was gazetted as a National Park in 1984. Prior to that, the land had been declared a Geothermal Resource area in 1971, and KPC (now KenGen) have operated a geothermal Power Station in the area since 1981.

The Geothermal Resources Act (1982) vests all geothermal resources in the Government, and the minister in charge of energy affairs can declare any area a geothermal resources area through a gazette notice. The minister also authorises the search for geothermal resources (prospecting license renewable annually), and also grants a geothermal resources license for a maximum period of thirty years for exploitation of geothermal resources. Such license is subject to the Water Act (Cap 372), so that exploitation of geothermal resources should not pollute surface or ground waters.

A by-product of geothermal exploitation may be recovered by modifying the geothermal license to include provisions of the Mining Act (Cap 306). The Geothermal Resources Act also provides for supervision of activities, so that there is no harm done either to the environment or to the workers in a geothermal license area, and for compensation for land owners and for injury/ damage to land. The Geothermal Resources Regulations (1990) prohibit entry into an area declared to be a National Park under the Wildlife (Conservation and Management) Act, Cap 376, except by the express authority of the competent authority (Kenya Wildlife Service in this case). It is the responsibility of the Minister in charge of energy matters to seek and secure such authority. The Olkaria III area was declared a geothermal resources area under legal notice No. 16 dated 4th February, 1999.

The Electric Power Act (1997) opened the generation of electricity to the private sector, under the Electricity Regulatory Board. Subsequently, the Kenya Power Company Limited (KPC) was separated from the Kenya Power and Lighting Company Limited (KPLC), with the former being responsible for generation, and the later responsible for distribution of electricity. The Kenya Power Company Limited assumed a new name and identity, as the Kenya Electricity Generating Company Limited (KenGen), and entered into a Power Purchasing Agreement (PPA) with KPLC.

The Environmental Management Act (2000) provides for the creation of an authority to manage all matters dealing with the Environment in Kenya, including the conduct of Environmental Impact Assessments for project deemed to have potential adverse impacts on the environment. Currently, the National Environment Secretariat (NES), created in 1972, is still in charge of the coordination of environmental activities in Kenya. However, the Authority is yet to be put in place at the time of conducting this Environmental Impact Study.

A Memorandum of Understanding (MOU) between KPC and KWS has guided geothermal operations at the Olkaria geothermal field, so that exploitation of the geothermal resource is carried out under conditions that protect the wildlife. Orpower 4 Inc. has also been guided by the terms of the MOU between KPC and KWS. In addition to the Wildlife (Management and Conservation) Act, the Geothermal Resources Act, the Electric Power Act, and the Environmental Management Act, other relevant Acts include the Water Act, the Mining Act, the Forest Act, the Agriculture Act, the Factories Act, the Public Roads and Roads of Access Act, the Land Acquisition Act, and the Public Health Act.

3.0 DESCRIPTION OF THE PROPOSED PROJECT

3.1 The Need for the Project

At the time of conducting this study (April/May, 2000), electricity was being rationed as a result of generation being less than demand. This is due primarily to two factors:

1. Failure of rains over three consecutive seasons (April-May, 1999; September - November, 1999; and April - May, 2000) meant that hydroelectric dam levels were low. It became necessary to ration power from September 1999, and the hours of rationing were increased in May, 2000.

2. Discontinuation of credit facilities to Kenya by multilateral agencies since 1992 put on hold power development projects that were supposed to have been implemented to meet rising demand for electricity in Kenya.

Ewbank Preece Limited (1989) revised the power requirement forecasts for Kenya made by Acres International (1985). Peak demand for 1999/2000 was projected to be between 806 and 1014 Mwe, and to rise to between 1008 and 1407 Mwe by 2004/2005. The actual peak demand in 2000 is about 745 Mwe, as against an installed generation capacity of 846 Mwe. However, as pointed out above, most of the installed capacity in the hydropower schemes cannot be utilised fully due to unfavourable weather conditions.

Kenya depends on Hydro electric power sources (584 Mwe installed capacity); Thermal (177 Mwe installed); Geothermal (45 Mwe installed); and imports from Uganda (30 Mwe). Wind- and solar- generated electricity are also used on a small scale.

In Kenya, geothermal energy potential is high along the Rift Valley, and in a few sites outside the Rift (figure 1). Most of Kenya's hydroelectric power potential has already been tapped, so that geothermal energy is set to play a more significant role in the country's electrical energy mix. Geothermal energy potential has conservatively been estimated at at least 2000 Mwe; other estimates put the potential at between 6,882 MW and 18680 MW (Crane and O'Connel, 1983). The Olkaria area alone is estimated to have potential of generating at least 300 Mwe.

In looking at the electrical energy situation in Kenya, therefore, it is most likely that geothermal energy will play an increasingly important role, because: -

a. Kenya is currently generating less electricity than required to meet consumer demand

b. Kenya is close to reaching the limit of exploitation of large scale hydro electric sources

c. There are large reserves of geothermal energy along the Rift Valley (and at a few locations outside the Rift - Figure 1)

d. Geothermal energy is not as susceptible to weather fluctuations as is hydroelectric energy

e. Geothermal energy is cheaper than other sources in Kenya

f. The costs of oil fired thermal sources is extremely high for Kenya, making it a secondary, last resort option

g. The costs of geothermal electricity can be reduced even further, if, with proper planning, Industrial plants and factories that can buy waste heat from power producers are set up around the geothermal power stations

h. Geothermal resource is an indigenous and relatively clean source of power.

3.2 Geographic setting

The Olkaria field is found approximately 125 km to the north west of Nairobi, south of Lake Naivasha (Figure 2). The Olkaria III concession comprises the southwest field, located approximately 5 km south east of Lake Naivasha, in an area with fumaroles and hot springs. It is one of 7 designated fields in the Greater Olkaria geothermal area, and covers an area of approximately 11.9 km^2. The other fields are Olkaria East (I); Olkaria Northeast (II); Olkaria Northwest; Olkaria Central; Olkaria Southeast; and Olkaria Domes. The Olkaria geothermal area covers an area of 75 km^2, and has the potential to produce at least 300Mwe.

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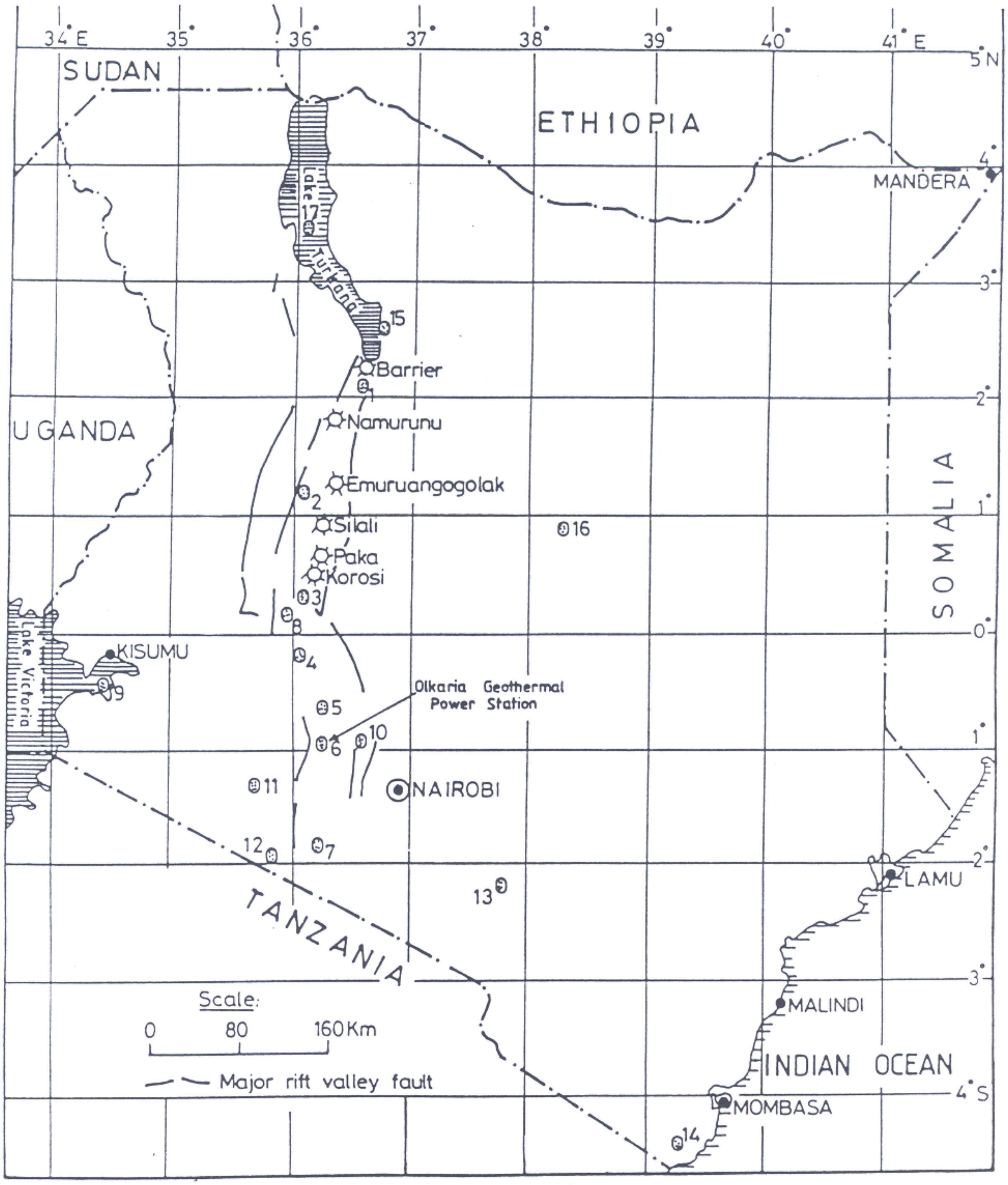

Figure 1. Location of the hot springs in Kenya. 1: Hot springs and geysers at the morthern end of the Suguta Valley; 2: hot springs at Kapedo, 48 km north of Lake Baringo; 3: hot springs and geysers around Lake Bogoria; 4: hot springs, gas jets and hot water boreholes in the area of Solai and Nakuru, including the Menengai crater; 5: the Eburru steam jets; 6: the Olkaria-Njorowa Gorge steam jets, including Mount Suswa; 7: hot springs around Lake Magadi; 8: hot springs at Arus and Kureswa, near the Eldama ravine; 9: Homa Bay hot springs; 10: hot springs and hot water boreholes around Kijabe; 11: hot springs at Majimoto, 34 km southwest of Narok town; 12: hot springs at Narosura, east of the Loita Hills; 13: Masamukye hot springs, south of Nguu, near Kiboko; 14: hot springs ar Mwananyamala, northeast of the Jombo Hill intrusion; 15: Loyangalani hot springs; 16: hotsprings west of the Merti Plateau; 17: hot springs at Central Island; ☆ *volcanic centre.* (Tole, 1996)

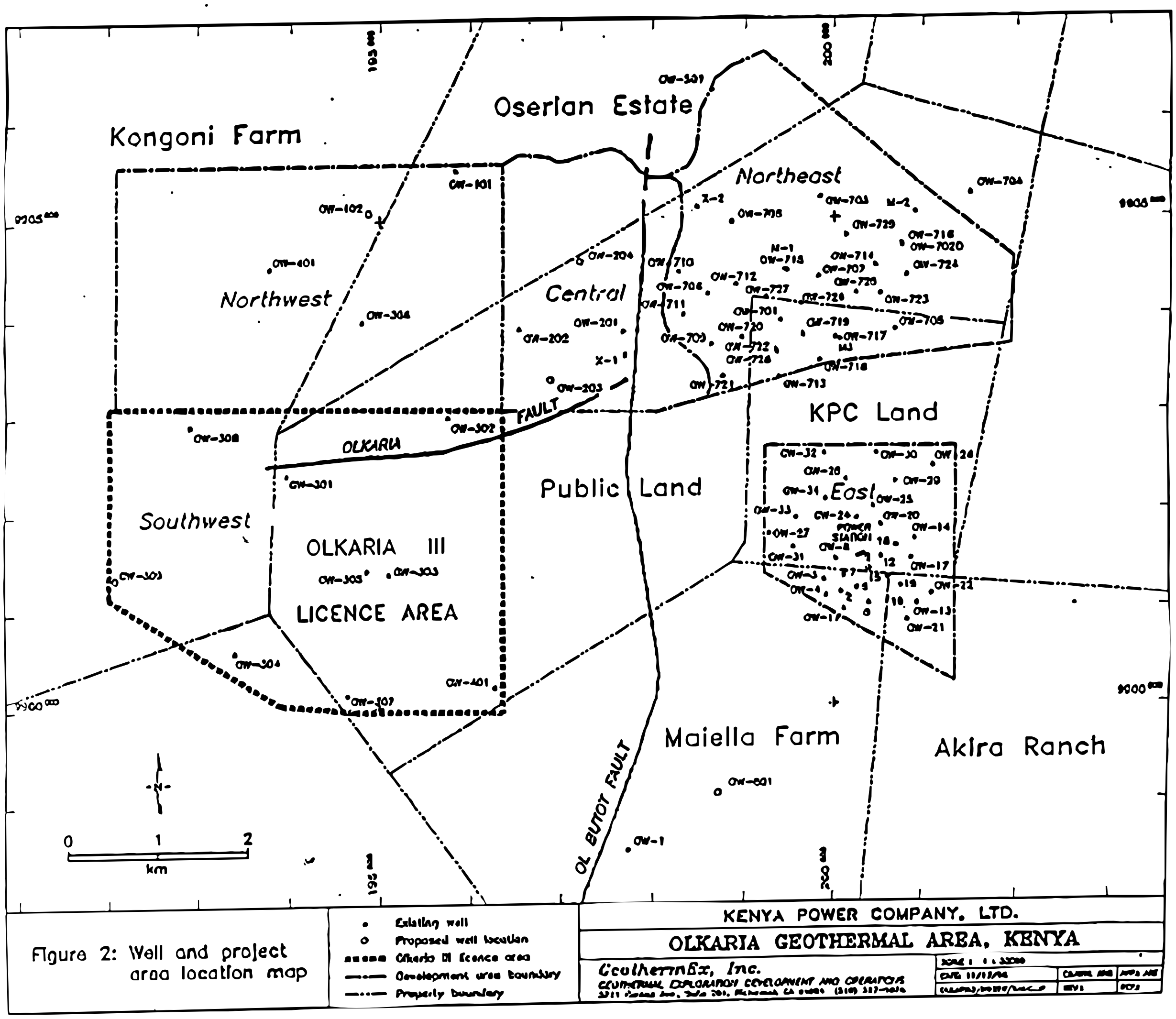

Figure 2. Location of the Olkaria geothermal field (Kenya Power Company Ltd.).

KenGen has operated a 45 Mwe power plant at Olkaria, the first 15Mwe unit of which was commissioned in 1981, followed by another 15 Mwe unit in 1982 and a third unit in 1985.

The Olkaria III geothermal resource area occurs includes parts of the Hell's Gate National Park, Maiella - Ngati and Kongoni farms, within the zone gazetted as a geothermal resource area in 1971. The geothermal field is in close proximity to Lake Naivasha and to flower-growing farms, a fact which has raised concerns about the impact of the geothermal operations on the Wildlife, Lake hydrology and on the flowers.

Olkaria geothermal complex is located between northings 9900000 and 9905000 and eastings 195000 and 202500. It is situated in south west of Lake Naivasha and west Ol Njorowa Gorge. Olkaria west field in located near Olkaria hill, which is the highest feature around the area. Like Olkaria east and northeast field, land use in Olkaria west 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.

3.3 Scope of the EIA study

The project occurs partly within the Hell's Gate National Park, but the workers' housing will be located further to the north of the project site, on the shores of Lake Naivasha. Impacts of the project on the wildlife, and the surrounding indigenous communities, as well as on the flower- and wildlife ranch- farmers, and on the Lake Naivasha Riparian Association are critically examined. The objective was to make recommendations on how to mitigate adverse impacts, so that the project can accrue benefits to the surrounding communities, and to the national economy, without causing undue damage to the environment.

This report is prepared on the basis of field and literature surveys. At the time of conducting the study, construction of the 8Mwe Early Generation facility station to draw steam from wells previously drilled by KenGen was in progress, as was construction of an access road. Drilling for steam for the plant and connection of production and reinjection wells to the station were also in progress. Construction of workers' housing had not yet started, although a site on the shores of

Lake Naivasha had already been identified. The study relied on previous studies in the area (Virkir/Mertz and McLellan, 1977; Tole, 1990; Clarke et al, 1990; Sinclair Knight and Partners, 1994; Marani, 1995; Simiyu, 1995; KenGen, 1999) for baseline information. Where possible, the information was checked for verification during the study.

KenGen has operated, and is still operating, a 45Mwe geothermal power station at Olkaria since 1984, and has plans to put up a new 64 Mwe power station at Olkaria North East. In the Environmental Assessment Report for the Olkaria North East Project, Sinclair Knight and Partners (1994) concluded that, "…the proposed power station as set out in the feasibility study (Ewbank Preece, 1989) is an acceptable development from an environmental point of view."

Despite this favourable assessment, it is necessary to evaluate the potential environmental impacts of each plant, in order to minimise adverse impacts peculiar to the plant site, and to maximise benefits to the local communities, and to the environment in general.

3.4 Technical Description

Geothermal energy is energy from the depths of the earth, in the form of heat. The heat reaches the surface of the earth either naturally as surface manifestations of deep hydrothermal systems, or artificially through hot dry rock projects, where heat is extracted by injection of cold water through hot fractured rocks. Natural hydrothermal systems occur at plate tectonic boundaries (subduction zones, passive plate margins, and rift zones), while hot dry rock systems occur where granites have high heat content from high levels of radioactivity. Hydrothermal systems therefore occur in unstable parts of the earth, characterised by earthquakes and/or volcanic eruptions, while hot dry rock systems occur in more stable parts of the earth.

In either case, heat from the earth heats water to generate steam, either naturally, or by artificial introduction of cold water into the hot dry rocks. (The vapor of a suitable fluid may also be generated). The pressurised steam, or other vapour in the case of binary generating facilities, is used to drive turbines coupled to a generator for electricity generation.

The details of the technical aspects of the Olkaria III geothermal project are contained in "Functional Specification of the Project" document by Orpower 4 Inc. (April 2000).

Orpower4 Inc. proposes to build, own, and operate (BOO), an 8 Mwe geothermal power station at Olkaria, the "Early Generation Facility", to generate electricity for sale to the Kenya Power and Lighting Company (KPLC), under the Power Purchase Agreement (PPA) between the two companies. Depending on the performance of the pilot plant, and results from an ongoing test-drilling programme, there will be an option to build a Plant, as defined in the PPA, to generate a total of 28 - 100 Mwe from the same concession area, which covers an area of approximately 11.9 km^2.

The Early Generation Facility will consist of one generator coupled to two turbines driven by pentane as the motive fluid in a closed Rankine cycle (Figure 3). Steam from the wells will be separated at the wellhead, with the brine being used to preheat the motive fluid, and the steam being used to drive a backpressure steam turbine. Both the spent steam (steam condensate) and the geothermal brine will be reinjected in well OW307. It is estimated that over 95% reinjection will be achieved. Total fluid flow rate at this stage is estimated at 180 - 230 tonnes/hour, with a 4 - 5% non- condensable gas fraction by weight. The non-condensable gases will be discharged into the atmosphere. Figure 3 shows the design schematics of the Early Generation Facility.

The second stage Plant will use conventional condensing steam turbines, though the brine will be used to vapourise the motive fluid to drive the Early Generation Facility. In this stage, only 60% reinjection (of brine and some condensate) will be achieved. Total fluid flow rate (steam and brine) in this phase is estimated at 600 - 1400 tonnes/hour. The non-condensable gas fraction will constitute 2 - 3% by weight, and will be discharged to the atmosphere. Figure 4 shows the design schematics of the second phase plant.

An access road is being constructed within the National Park to facilitate easier access to the power station site (Figure 5).

Orpower 4 Inc. will construct approximately 20 housing units for use by plant operators during the operation of the Early Generation Facility, and a total of 60 housing units for the second phase plant. These houses are to be constructed at a 17.5 Ha site near the shores of Lake Naivasha (Figure 2).

At the time of conducting the study, construction of the Early Generation Facility power station

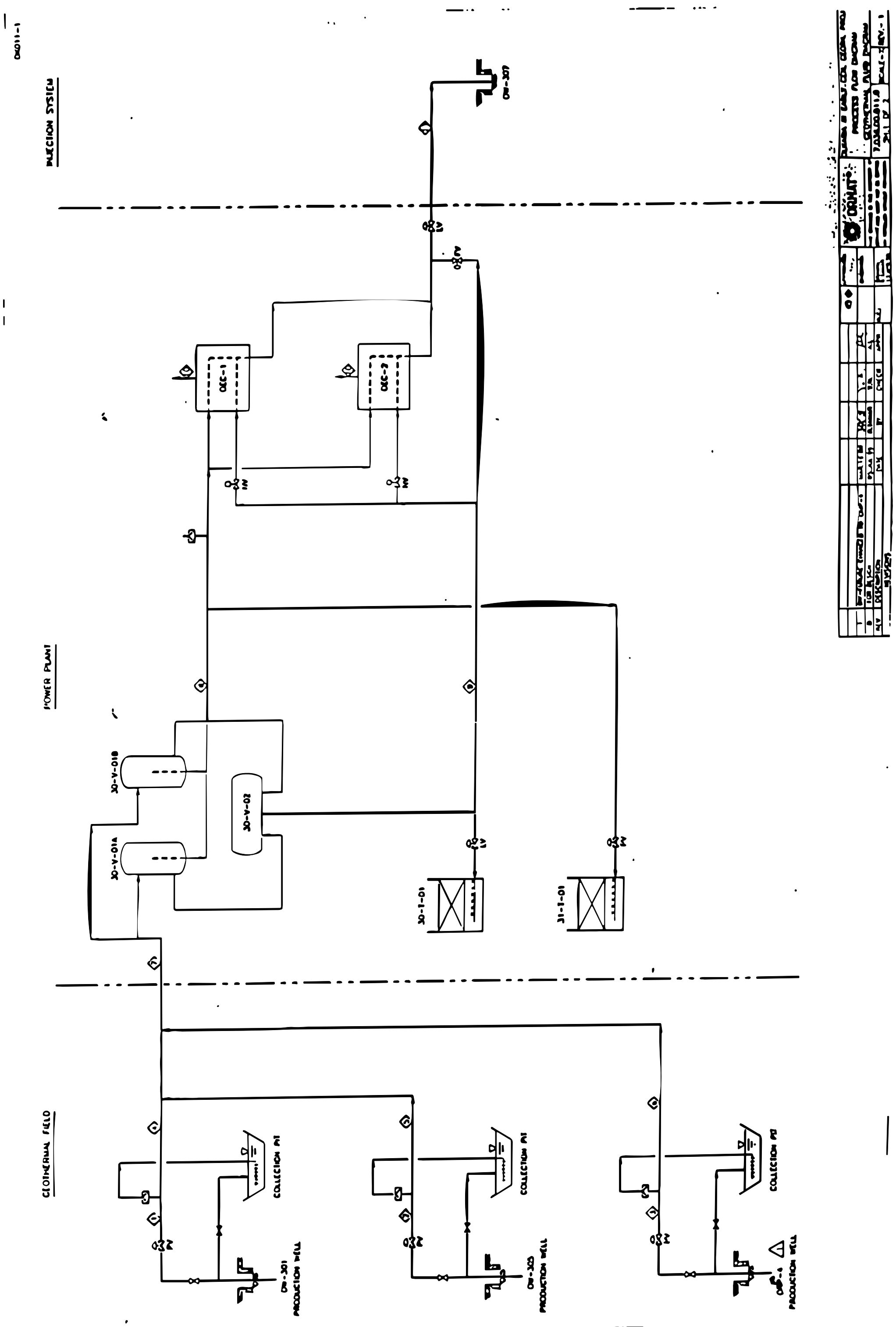

Figure 3. Design schematics for the Early Generation Facility (Orpower 4 Inc.).

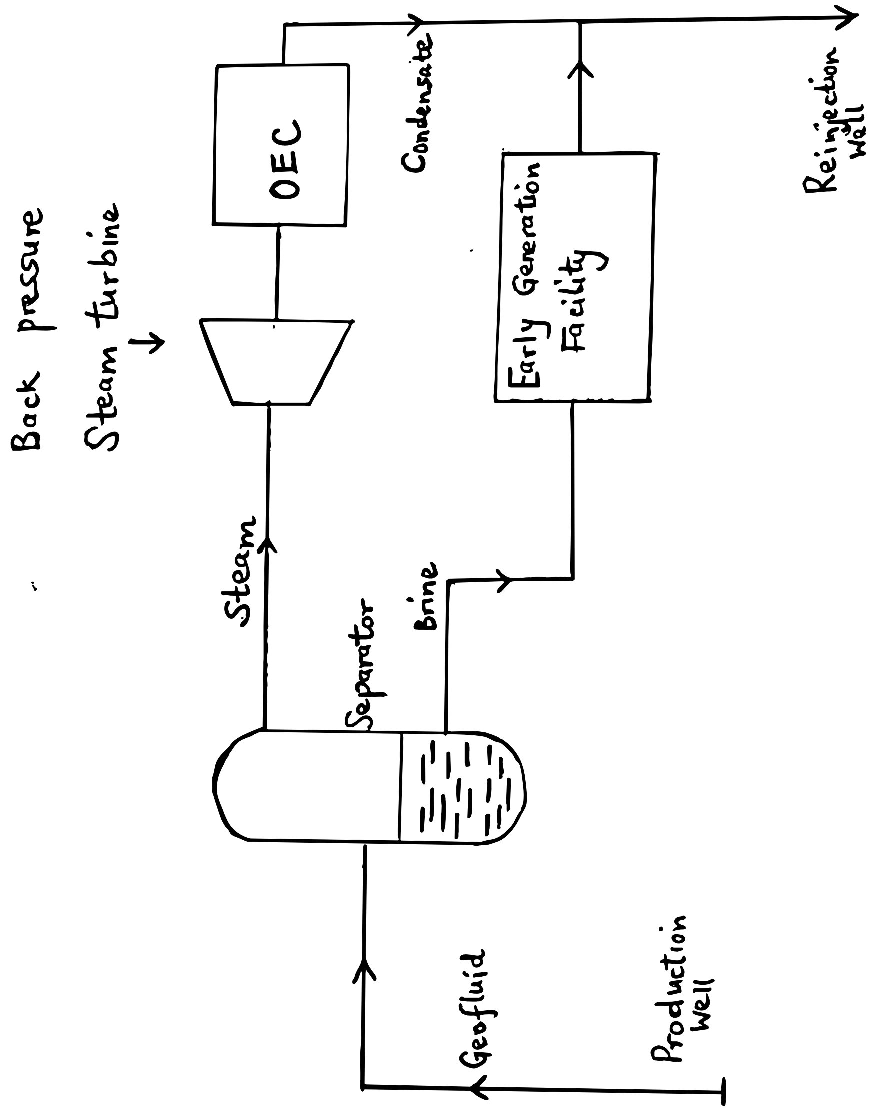

Figure 4. Design Schematics for the Plant (Orpower 4 Inc.).

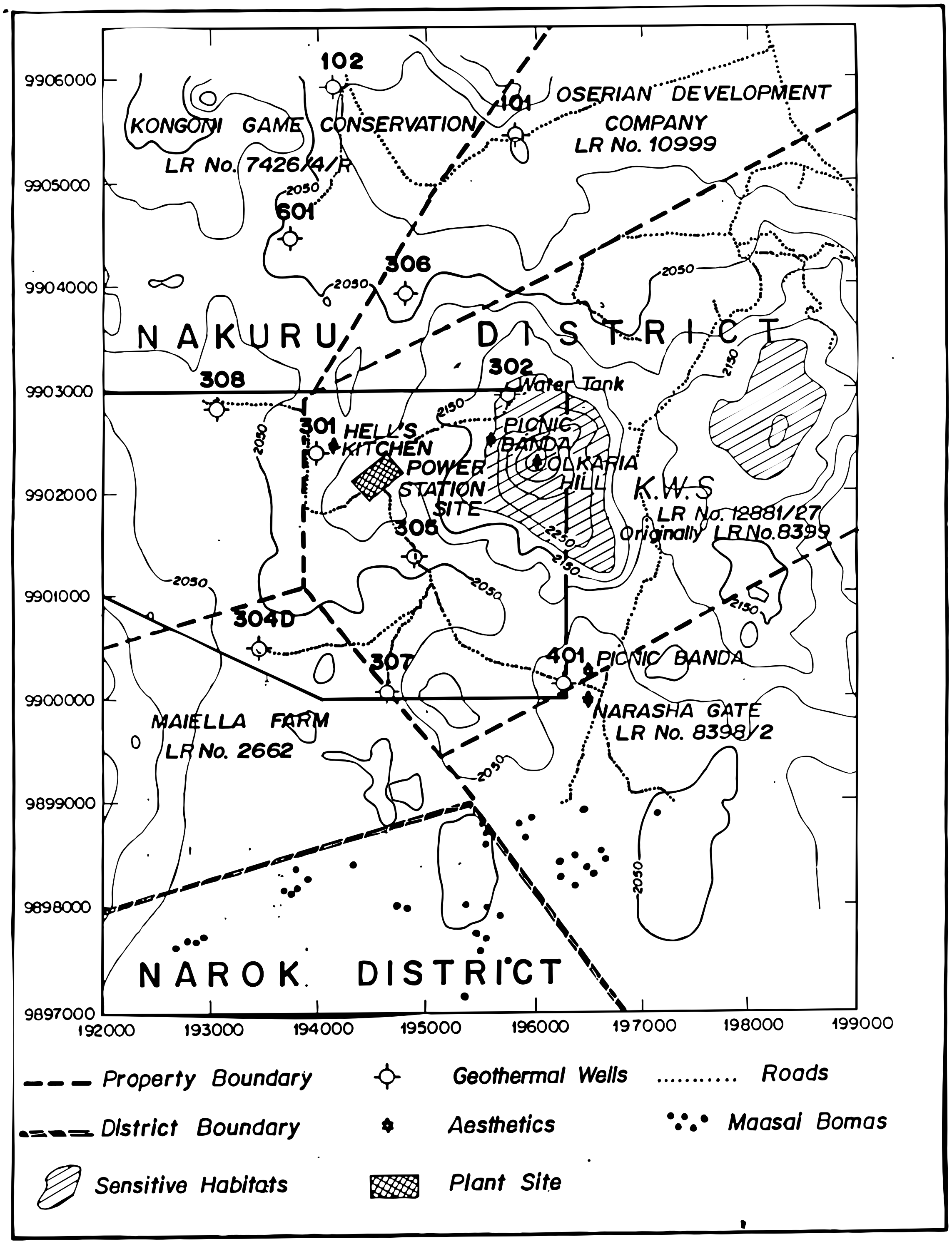

Fig. 5 Map of Olkaria III Area showing Environmental features (After KenGen, 1999)

and steam-gathering system was in progress, to draw geothermal fluid from wells drilled between 1983 and 1994 by KenGen (then Kenya Power Company Limited) was in progress. Drilling was also continuing to prove steam for the main plant. Construction of the access road bypassing the Narasha wetland was also in progress, while the construction of workers' housing was about to commence.

4.0 BASELINE DATA (EXISTING ENVIRONMENT)

4.1 THE PHYSICAL ENVIRONMENT

4.1.0 Geology

The Olkaria field is characterised by volcanic rocks of Pleistocene to Recent age. The last eruption in the area at Ololbutot is dated at approximately 200 years ago (Clarke, *et. al.*, 1990).

The Pleistocene Mau tuffs consisting of ignimbritic tuffs intercalated with rhyolitic lava flows, trachytes, and basalts form the reservoir rocks. Overlying this is a trachyte unit, followed by the uppermost rocks consisting of rhyolite intercalated with pyroclastics (Figure 7, Omenda, 2000). The rocks are blocky, and fractured at depth. Fumaroles and hotsprings abound in the area.

4.1.1 Hydrogeology

The hydrogeology of Olkaria West area is strongly controlled by western rift flank faults, fractures, rift floor faults, the rock types and the tectono volcanic axes. Fluids are recharged from the northern side along the major and minor volcanic axes that trend southwards.

The regional NE and NW faults such as Olkaria fracture and Suswa lineament that cut across the rift from the margins are conduits for cold-water recharge into the geothermal systems. The younger NS trending grid faults such as Olkaria fracture control the hydrogeology within the field.

The reservoir rocks consist of acid lavas, tuffs and agglomerates; the lava flows are of the order of 50 m thick. Producing horizons occur mostly at contacts between strata but fractures in the lavas are also important. The main capping to the system is tuffs that range between 1600-800 masl.

The numerous faults/fractures in the area create a good secondary permeability especially along reactivated faults. Most of the fumaroles in the region occur along the near N-S faults, and the Olkaria fault zone. This indicates that these faults have recently been activated and that they are

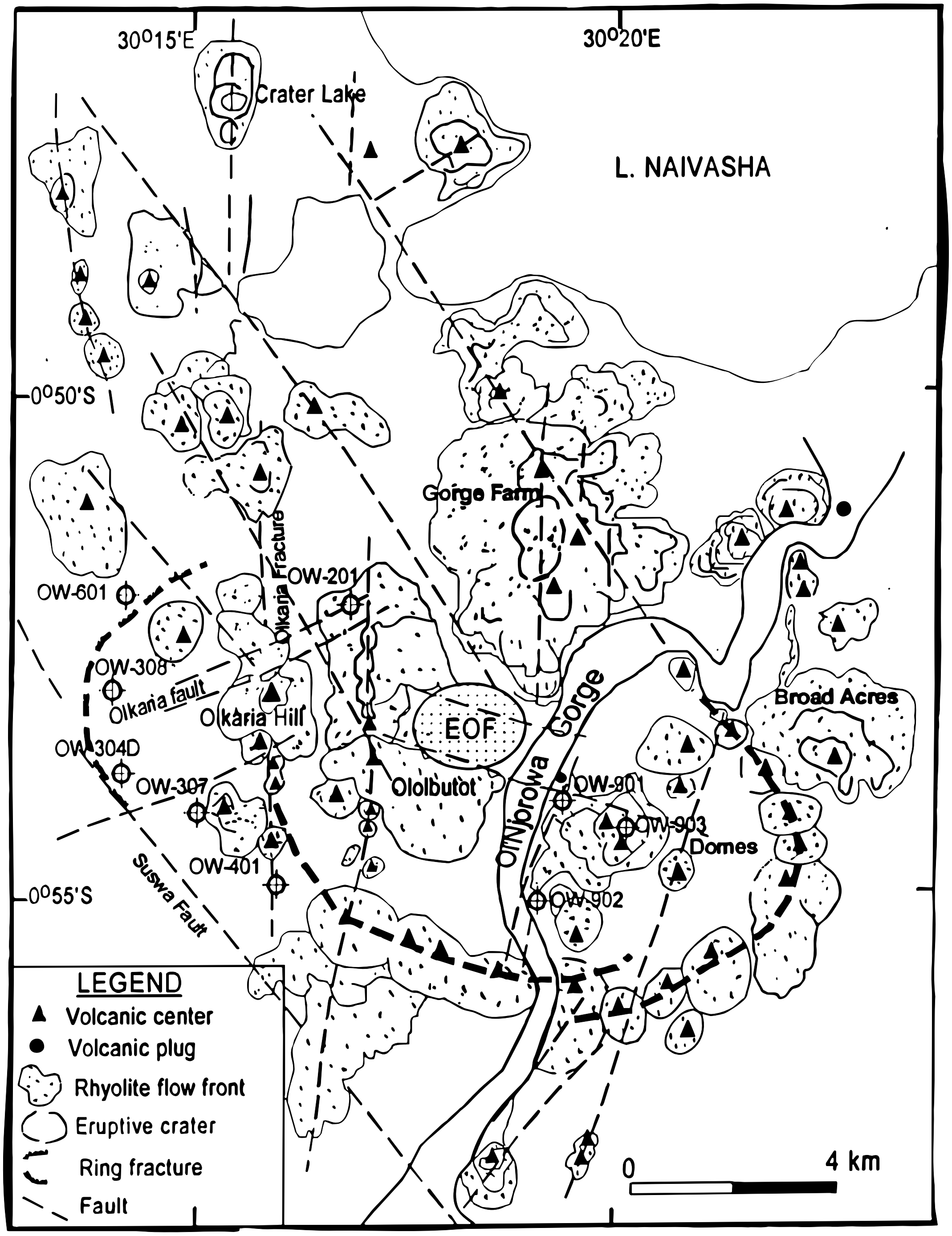

Figure 6. Geological structural map of the Olkaria III area (KenGen, 1999).

still open to fluid movement. The resistivity profile indicates that there is a strong structural control of fluids along the N-S, NW and NE trending faults. The seismic data also indicates that there is still movement along these faults.

These faults are also pathways for cold fluid flow in addition to the two inflows from the NE and NW rift scarps. Isotope data (Ojiambo, 1984) indicate similarities an Oxygen -18 shift of the water of this area with respect to precipitation in the rift valley escarpment areas. This was interpreted to mean that the Olkaria water represents rainfall from the escarpment areas that has been enriched with the heavy oxygen isotope ^{18}O through reactions with the sub-surface rocks. This is an indication that there is water recharge coming from the rift valley flanks into the geothermal system. To be able to confirm accurately the recharge source to the system, further isotope geochemistry is necessary.

Well flow tests have indicated permeability - thickness product of 1-4 Darcy-meter (Bodvarsson and Pruess, 1981) and on average about 3.0 Darcy-meter but range to over 10 Darcy-meter in OW-301 (Haukwa, 1985).

The discharge fluid flows west, east and south from the upflow center. The fluid flow to the east is restricted by the Olkaria fracture, which appears to be a conduit for cold fluids that flow across the field from north to south. The cold fluid mixes with the limited recharge of hot fluid from the upflow center and the combined flow discharges to the south in a corridor east of the Olkaria fracture. This is also supported by the regional southward hydrological gradient observed in the piezometric map of the area.

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, (McCann, 1974; Allen et al., 1981; Arusei, 1991, Thompson and Dodson, 1963; Glover, 1973). Recent work done by Arusei, (2000) shows that the lake water is discharged southwards only and not northwards. 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. McCann (1974) estimated outflow of Lake Naivasha to be 39 x 10^6 m^3/y; Allen, et al, (1981) estimated 45 x 10^6 m^3/y; while Arusei (2000) estimated between 50 and 60 x 10^6 m^3/y. 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 Knight and partners, 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 have adverse hydrological or chemical impacts on the Lake.

4.1.2 Rainfall and Climate

Sinclair and Knight (1994) have presented climate data for the Naivasha region. Since Olkaria West area falls within the same Eco-climatic area like Naivasha, the area rainfall around Naivasha is representative of the general rainfall at Olkaria West. The mean annual rainfall as measured at the Naivasha Water Supply Department from 1965 to 1988 is 696.6 mm; at Naivasha District Office from 1910 to 1988 is 625.4mm; while at Kongoni Farm, from 1968 to 1988, it is 672.8mm.

The nearest meteorological station to Olkaria West is situated at Olkaria power station with an annual maximum temperature range of 21 to 29 ^oC and annual minimum temperature range of 11 to 15 ^oC (Sinclair Knight and Partners, 1994).

The minimum temperature around Olkaria West region is modified by the effect of Olkaria hill, which causes low-level inversions at the base of the mountain as a result of sinking air.

At the present site of power plant under construction, a meteorological station was operated for about two years. The records for 1996 are given in Appendix 3.

The total rainfall for 1996 (676.3 mm) closely approximates the annual averages for Naivasha. More data are needed to obtain a reliable annual average for the Olkaria III project area.

4.1.3 Soils and soil erosion

The erosion hazard is mainly due to the nature of the soils. The soils at the Olkaria west are similar to those of Olkaria East, as the soil parent materials are predominantly volcanic in origin with high amounts of silt and sand. These soils are light grey to brown in colour, and their high porosity means that their capacity to retain water is very low.

Erosion by water involves the detachment of soil on any bare surface that is devoid of vegetation, followed by the actual transport of the detached soil. The most vulnerable areas to soil erosion are the slopes around Olkaria hill. The site for Olkaria III project exhibits a low vulnerability to erosion by water due to good vegetation cover and cohesive, relatively stable ground. However, erosion is still facilitated along access roads, particularly on steep slopes.

Due to the nature of the soils at Olkaria west, all surfaces left bare are highly susceptible to erosion. The form of erosion most noticeable at Olkaria west is gully erosion, and there are numerous gullies cutting through the area. The gullies are wide and vegetated on their floors by grasses and shrubs. They form resting - places for the animals.

The other form is erosion by mass movement. This was observed in a few areas to the SE of Olkaria hill. There is evidence of slumping and sliding of slopes and gully sides. In the event of heavy rainstorms, there will be erosion problems in areas with steep slopes such as toward OW-301 to the NW, OW-305 and OW-304 to the SW. During heavy rains such as during the El Nino in 1998, small trees can also be uprooted.

Wild animals also play a significant role in soil loss, as this can be evidenced as one climbs the road towards Maiella escarpment near the Narasha wetland (Lake Odongo).

Wind erosion is of minimal importance because the area is fairly well vegetated.

Soil erosion will become a serious problem in Olkaria west if the ground cover is removed or run-off patterns are disturbed as a result of development activities and fires.

4.1.4 Volcanic and seismic hazards

4.1.4.1. Volcanic hazards

The occurrence of acid volcanic rocks (rhyolite and pyroclastics) from the surface to about 1400 masl indicates that there existed a large highly differentiated magma chamber at depth (Omenda, 2000). Repeated eruption and intrusion of lava from this chamber has produced large quantities of pyroclastics and tuffs. Subsequent extrusions of magma along a N-S trend, and along the ring structure have produced highly siliceous alkaline rocks, indicating continued differentiation of the magma chamber. A plot of Nb versus Zr (Clarke et al., 1990) shows that there is great compositional variation within the Olkaria volcanic rocks. Analysis done by LeBas (1987) indicates that Olkaria lavas vary considerably in the Nb/Zr content. They are divided into four units, depending on the degree of fractionation. The increasing totals of incompatible elements indicate more highly evolved compositions. The plot of the Zr/Nb ratio on different linear trends indicates that the lavas could be tapping from different parched magma chambers. This, together with the fact that the youngest lava is of a different chemistry indicates that there exist separate parched magma chambers that have evolved separately. Subsequent eruptions along the N-S faults and the caldera ring structure have resulted in intrusion of magma nearer the surface. Thus, the shallow heat source is expected to be along these structures. From the variation of maximum Zr contents in Olkaria volcanics it was observed that higher incompatible trace element content characterize the Olkaria hill volcanic center.

Most of the fumaroles in the region occur along the N-S faults, the ring structure, and the Olkaria fault zone, indicating the recent re-activation of the faults, so they are still open to fluid movement.

4.1.4.2 Seismic hazards

The earliest seismic investigation in the Olkaria area involved passive and active source seismic studies that concentrated on the Olkaria, Eburru and Lake Bogoria geothermal fields. These were carried out by the United States Geological Survey (Hamilton et al., 1973) using an eight-station network that was deployed in each field for 2 months. They located events of magnitude 2 and less that were restricted mainly within the fields along fault zones.

Regional stress analysis in the southern Kenya rift (Strecker and Bosworth, 1991) and seismic studies (Fairhead and Stuart, 1982) suggest that stress along the rift floor is released by a high intensity of micro-seismic activities in geothermal areas but by a few large earthquake sequences along the rift boundary faults. In many cases, the location of a geothermal system coincides with an area where regional stress is being released at a different rate to the surrounding areas (Foulger et al., 1989, 1997). Seismicity in the Olkaria west is more intense in the center of the field where temperature is high, with smaller and shallower events (Simiyu, 1999). On the periphery and outside the field, where drill holes show low temperatures, events are larger and deeper.

Temperatures lower than 450^o C are required for an earthquake to occur in crustal rocks (Chen and Molnar, 1981). The Olkaria west field shows an increase in seismic events to a maximum depth of 4-5 km, which is the depth of the brittle-ductile transition zone for this area (Simiyu, 1999). Outside the geothermal field, earthquakes deepen to the west, northwest, north and northeast, away from the geothermal field. Seismicity gaps mapped within the Olkaria West field mark zones of hot magma intrusions that have raised the temperature above 450^oC. The size and depth of the shallow possible magmatic bodies and relationship to the geothermal heat sources were mapped by locating areas of anomalously low S-wave amplitudes beneath the young volcanics of the geothermal field (Simiyu, 1999). Back projection of relative S and P wave amplitudes to the position of their anomalies show an attenuating body beneath the Olkaria hill extending to the west that is also associated with a seismicity gap.

Numerous studies show that recent intrusions are associated with high levels of earthquake activity (for example Mt. St. Helen, Nevado del Ruiz - Lees and Crosson, 1989; Zollweg, 1989; Fehler, 1983; Krafla, Iceland - Foulger, 1983; Stromboli, Italy - Ntepe and Dorel, 1990; Mammoth - Stroujkova & Malin, 1999). These studies show that prior to the eruptions, the level of seismicity increases by more than 5 times above background. Spectral analyses of these individual events show that they are characterized by unique, low frequency source mechanisms. The events are often emergent, lack clear phases, and contain several characteristic frequencies. These events gave information on the dimensions of their associated magmatic and hydrothermal systems, all of which control the amount of geothermal energy that is available at a given field.

At Olkaria west, three types of events have been identified (Simiyu, 2000):

Type 1: Signals with well defined P and S phases and spectra that are characterized by one corner frequency. They have a monochromatic character starting with a weak emergent phase followed by a phase of greater amplitude but at about the same frequency. A strong dominant frequency is observed at 2 Hz and smaller frequency peak is noticeable at 4 Hz. These types of signals are from deep events and are probably related to volcano-tectonic activity (Ward and Bjornson 1971; Ward, 1972).). A few events were deep, emergent, lacked clear phases, and occurred below the ductile transition zone. These events could be associated with magmatic activity.

Type 2: These are signals with characteristics between Types 1 and 3, and have a more complicated shape with two phases. The first phase is a low frequency signal followed by a second phase, which is more enriched in high frequencies. The dominant frequency is 2 Hz for the first phase and secondary frequency peaks occur at about 5 and 8 Hz for the second phase. It is presently not possible to infer a process for the generation of these events.

Type 3: Events of the third type lack clear phases after the first arrival and have spectra characterized by one dominant frequency. These events have higher frequencies than Type 1 and 2 events and the onset of the signals is relatively sharp with a dominant frequency at 5.5 Hz. These events have relatively shallow hypocenters and are possibly related to fluid movement within the reservoir.

4.1.5 Noise

Background noise levels were measured at various locations within the surroundings of Olkaria West area. The results are shown in table 1 below.

Noise levels were found to vary from 32 - 44 dB (A) away from the station, to 50 - 60 dB (A) around the power station construction site base and on top of the crater. Noise levels increase as one approaches the drilling area, reaching maximum level of 68 dB (A). Higher noise levels are found closer to the road, as a result of the vehicle movement, and towards the top of the Olkaria hill due to winds. In the park, the noise level is low when there are calm wind conditions.

Table 1. Noise levels at selected areas around Olkaria West (this study).

Day	Time	Location	Noise Levels dB (A)	Weather
Day -1	10.10 am	1.2 km south of Station	32-37	Calm and cloudy
	11.20 am	Narasha swamp (L. Odongo)	38-44	Windy and cloudy
	12.15 pm	Next to Olkaria hill	44-58	Windy and cloudy
	1.40 pm	Power station site	56-60	Windy and warm
	2.05 pm	Narasha Gate	35-37	Windy and cloudy
Day -2	9.10 am	Base of Olkaria hill	44	Calm
	9.20 am	0.5 km West of Narasha gate	55	Windy and cloudy
	9.50 am	0.2 km east of Narasha gate	43	Windy, cloudy and warm
	10.04 am	1 km south of Narasha gate	33	Windy and warm
	11.05 am	Drilling rig site	68	Windy, cloudy and warm
	11.50 am	Power station site	53	Windy and warm
	12.30 pm	0.7 km SW of power station	54	Windy, cloudy and warm

	1.20 pm	OW -307	55	Windy, cloudy and warm
	1.30 pm	OW -301	37	Windy, cloudy and warm
	2.40 pm	OW -302	69	Windy, cloudy and warm
Day -3	10.30 am	OW -305	36	Cloudy and calm
Day -4	4.00 pm	OW -401	41	Warm and partly cloudy
	2.12 pm	0.5 km W. of the power station	47	Warm and partly cloudy
	3.00 pm	1 km south of Power station	32	Warm and cloudy
	3.08 pm	OW -304	35	Warm and partly cloudy
	3.09 pm	1 km east of Olkaria hill	55	Warm and partly cloudy
	3.30 pm	Along road at OW -305	75	Warm and partly cloudy
	4.10 pm	Along road at Narasha Gate	70	Warm and partly cloudy

4.2.0 THE CHEMICAL ENVIRONMENT

4.2.1 Air Quality

Gas emission from the existing KenGen Olkaria East power station predominantly consists of carbon dioxide (95.1%) and hydrogen sulphide (4.4%). 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 forms about 2% of geothermal effluent (Sinclair Knight and partners, 1994). This is discharged to the atmosphere.

4.2.1.1 CO_2 and CH_4.

Carbon dioxide and methane are greenhouse gases that have global climate impacts. Apart from being a greenhouse gas, 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.

Normal precipitation has pH values between 5.6 and 5.65 due to the presence of carbon dioxide in the atmosphere.

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 at al, 1999), as summarized on the table 2 below:

Annual carbon dioxide emission from the present 45 Mwe is estimated to be 21,850 tonnes, compared to a coal-fired power plant of the same rating which releases 140,200 tonnes of the gas to the atmosphere (Tole, 1990). Therefore, carbon dioxide emission from geothermal plant in Olkaria east field is approximately seven times less than produced by coal-fired power station of the same power rating.

4.2.1.2 Hydrogen Sulphide

Hydrogen sulphide is a colourless flammable gas, which is denser than air and liquefies at -60° C. Because of its chemical properties, it is soluble to both polar (water) and non-polar (organic) solvents. It is a very reactive gas and hence oxidizes rapidly in air and solution. It reacts readily

Table 2. Effects of CO_2 on Human Health (after Kubo et al, 1999).

Concentrations (ppm)	**Effects**
50,000	Shortness of breath, dizziness mental confusion, headache and possible loss of consciousness.
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 behavioral change.
100,000	Normally, one losses consciousness and eventually death if no action is taken

with most metals causing corrosion on them. Because of its density, hydrogen sulphide settles at the lowest points. Thus, 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 well head or sump within the power station.

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

Non-condensable gases from the present geothermal power station contain about 5% hydrogen sulphide and 95% 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 hydrogen sulphide emitted from the gas ejectors does not preferentially settle out from the plume any more than other gases in air. The only time hydrogen sulphide settles down more preferentially than other gases in the air, is in enclosed area, where there is no wind.

The toxic effects of hydrogen sulphide human and animals very according to dosage and these are summarized in table 3 below.

The toxic effects of hydrogen sulphide have been classified into three categories, acute, sub-acute and chronic. Acute intoxication refers to effects of a single exposure to a massive dose of hydrogen sulphide of the order of 1000 ppm and above. At this concentration, hydrogen sulphide exerts an effect on the whole nervous system by inhibiting the enzyme cytochrome oxidase, which is involved in the aerobic metabolic pathway (Sinclair Knight and partners, 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 that may spontaneously reverse if the depletion has not gone too far. However, if breathing does not

Table 3. Effects of H_2S on Human Health (Sinclair Knight and partners, 1994).

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.
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 – 1000	Causes immediate unconsciousness. Death or permanent brain damage may result unless rescued promptly.
1000 – 2000	Immediate collapse with respiratory failure.

spontaneously recommence and artificial respiration is not given, death from suffocation occurs. At concentration above 1000ppm 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. Hydrogen sulphide is very rapidly oxidized in blood and is not considered a cumulative poison.

Sub-acute intoxication refers to the effects of continuous exposure to mid-level concentrations of hydrogen sulphide in the range 100 - 600 ppm. At these concentrations irritation of the mucous membranes of the eyes and the respiratory tract occur. While eye irritation is by far the most common mode of sub-acute poisoning, irritations of the respiratory tract can sometimes lead to severe and even fatal complications such as pulmonary oedema (Sinclair Knight and partners, 1994).

Chronic intoxication is defined as the effects of intermittent exposure to low or intermediate concentrations (50-100 ppm) of hydrogen sulphide. These are characterized by 'lingering' largely subjective manifestations of illness. There is no universal agreement in the literature about this category as being clinically distinct from repeated episodes of sub-acute intoxication (Sinclair Knight and partners, 1994).

The effects of hydrogen sulphide on vegetation are not well documented largely because, in contrast to animals, there appear to be a wide variation in response across species (Sinclair and Knight, 1994). Sulphide taken up by plants is primarily metabolized to sulphate; or incorporated into plant proteins and as in the case of sulphur dioxide, low concentrations may have a growth stimulation or fertilizing effect. At higher concentrations, hydrogen sulphide can cause leaf lesions, defoliation and reduced growth, with young plants being the most susceptible.

The effects of hydrogen sulphide on aquatic animals have been evaluated by Axtmann (1971), who recommended that concentrations in water of less than 0.006 ppm were safe.

Hydrogen sulphide is a very strong oxidizing agent and corrodes metals including copper, silver, and even gold which is not easily oxidized by normal oxidizing agents. It reacts with lead-based paints to produce discolouration. This corrosion can cause malfunctioning in electronic equipment, which have been exposed to the gas.

Oxidation of H2S in the atmosphere results in the formation of SO2, which forms acid precipitation in the presence of moisture. Acid rain is defined as precipitation with the pH values of less than 5.8.

Acid rain causes a deficiency of nutrients in terrestrial ecosystems due to change of soil pH. Most cations are released into solution under low pH, so that they can be leached below the root zone of several vegetation types, rendering them unavailable to the plants.

Acidification of lakes reduces lower phytoplankton biomass, which forms fish food. Thus acidification of lake waters depletes stock of fish, which depend on phytoplankton for food. Change of soil pH may decompose microorganisms in the soil, which are responsible for nitrogen fixing. The removal of such microorganisms in the soil may retard growth in plants due to deficiency of nitrates. The damage on crops may vary from extensive foliage damage to reduction in crop yield.

Results of intensive monitoring of hydrogen sulphide by KenGen staff three times a week for several locations around and away from the power station indicate the highest short-term concentrations that occur from the present power station. Measurements were taken at least three times a week for stations near power stations and at least once a week for those further away. The concentrations of hydrogen sulphide at various stations are shown in Appendix 5. Marani (1995) also monitored H2S concentrations in the Olkaria East and Northeast areas.

Highest hydrogen sulphide concentrations were recorded at power station (4.4 ppm). This was in accordance to the basic Gaussian plume equation. The frequency of various concentrations at different stations were computed as in the table 4 below.

The distribution of H2S in the area is shown in Appendix 12.

Table 4. H2S concentration Frequencies around the Olkaria I field (Kubo et al, 1999).

(a) Power station

Conc. (ppm)	Frequency	Percentage Freq.	Cum. Percentile
0.0	96	27	27
0.23	81	23	50
0.46	60	17	67
0.69	18	5	72
0.93	25	7	80
1.16	10	3	82
1.39	16	5	87
1.62	15	4	91
1.85	8	2	93
2.08	6	2	95
2.32	4	1	96
2.55	3	1	97
2.78	4	1	98
3.01	2	1	99
3.94	1	0	99
4.40	3	1	100

(b) Seal Pit Station.

Conc. (ppm)	Frequency	Percentage Freq.	Cum. Percentile
0.0	130	62	61
0.15	30	14	76
0.29	13	6	82
0.44	8	4	86
0.59	1	0	86
0.74	1	0	87
0.88	6	3	90
1.03	8	4	93
1.18	4	2	95
1.33	5	2	98
1.47	1	0	98
2.51	3	1	100
2.80	1	0	100

(c) Administration Block

Conc.(ppm)	Frequency	Percentage Freq.	Cum. Percentile

0.0	250	79	79
0.14	40	13	91
0.21	10	3	95
0.34	4	1	96
0.41	5	2	97
0.55	1	0	98
0.62	3	1	99
0.82	1	0	99
0.96	1	0	99
1.03	1	0	100
1.3	1	0	100

(d) Store Station

Conc. (ppm)	Frequency	Percentage Freq.	Cum. Percentile
0.0	33	60	56
0.1	7	12	68
0.2	3	5	73
0.3	3	5	78

0.4	2	3	81
0.5	2	3	85
0.8	2	3	89
0.9	3	5	93
1.6	2	3	97
1.9	2	3	100

(e) Workshop Station.

Conc. (ppm)	Frequency	Percentage Freq.	Cum. Percentile
0.0	27	40	40
0.13	25	37	76
0.21	10	15	91
0.34	2	3	94
0.42	2	3	97
0.8	2	3	100

station was 0.4 ppm, seal pit, administration block, workshop were 0.1 ppm, and Store, the value was below detection limit. Although Gaussian plume model predicts higher concentrations in all the stations, the most probable concentrations were the ones shown by the graphs. Plume model predicts the worst scenarios of environmental risks.

4.2.2 Geothermal Brines.

Geothermal brine from the present geothermal wells in Olkaria would have the following mean concentrations of cations and anions:

The heavy metals 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 metal in potable water is shown in table below.

Most of these elements were below maximum permissible levels, and therefore geothermal fluid from Olkaria may not be hazardous to environment. 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 summarized in table 7 below:

Other chemical constituents, which may be harmful at high concentrations, are chloride and fluoride. Acceptable levels for these elements are Cl- (250 ppm) and F- (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 mottling and disfiguration of teeth and further related problems.

Table 5. Mean Concentrations of Brine in Olkaria III Field (after KenGen, 1999)

(All concentrations in ppm)

Chemical	**OW-301**	**OW-302**	**OW-305**	**OW-307**	**OW-308**	**OW-401**
Na	1340	570	525	684	534	811
K	195	104	116	57	63.4	101
Ca	0.021	0.020	0.020	0	0.09	0
Mg	0.084	0.021	0.019	0	0	0.6
Li	3.25	314	4.21	2	1.42	1.7
B	6.82	307	8.01	2	-	3.5
SiO_2	605	730	516	33	105	424
CO_2	2437	520	87.1	1028	4062	362
SO_4	110	65	16	158	43.5	98
H_2S	3.44	3.4	3.05	0.15	0.12	10.5
Cl	231	436	986	34	26.5	789
F	112	75	50.8	-	22.9	178

Table 6. Permissible levels of some metals in drinking water (WHO, 1984)

Pb	Cu	Zn	Cd	B
0.1	1.0	5.0	4.0	20

Table 7. Biological impacts of selected metals on human health (Mason, 1991).

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 to 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 are 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 1ppm presents no problems for aquatic life especially for fish.

4.2.3 Radioactive Gases.

4.2.3.1 Radon -222A and Thoron –220 distribution.

Radon 222 and thoron 220 are responsible for the α -activity in the soil gas. They are the decay products of radium 236 (itself a daughter product of uranium 238 and radium 236). Because half-lives of these gases are short, (3.82 days for radon 222), their detection on the surface depends on the permeability of the soil. High permeability especially at faults and other fractures allows the gases to reach the surface easily and facilitates their detection. When the permeability is low, these gases decay out before reaching the surface. A high radon anomaly is therefore indicative of high permeability in the rocks and soils.

4.2.3.2 Radon and Thoron emission

It is generally assumed that there is no threshold limit for radiation damage and that the amount of damage caused is roughly proportional to the total amount of radiation absorbed. Therefore it is essential to restrict man-made emissions of radiation to the environment. Table 7 below shows the proportions of radiation from different sources received by an average Briton (Mason, 1991). 88% of radiation received by human beings is from natural origin, over which we have no control (Mason, 1991).

It is clear from the above that most of human radiation comes from radon and thoron gases. These gases produce α particles. Alpha particles consist of two protons and two neutrons, which have very little penetrating power and lose energy in a short distance. If, however they do penetrate living tissue by inhalation or ingestion, they can do considerable damage because they are strongly ionizing.

Radon and thoron traverse survey was conducted in Olkaria west field by KenGen staff to reveal the much-predicted Suswa fault. It was found that radon count per minute ranged between 0 and 25,000 and the average counts were 500 counts/minute.

Table 8. Radiation Exposure Sources in Britain (Mason, 1991)

Sources	**%**
Cosmic rays from outer space	10
Terrestrial gamma rays from rocks and soils	14
Radon and thoron gas inside buildings	52
Food and drink accumulated within tissues	12
Medical, mainly from x-rays	11.4
Miscellaneous	0.6
Nuclear industry	0.004

4.2.4 Fresh water quality and management.

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. Near Olkaria west field the Narasha wetland (Lake Odongo). It collects rainwater and sometimes it can be quite extensive. During long dry seasons, the wetland dries up. The water quality parameters for the Narasha wetland and Lake Naivasha are presented in table 8 below.

From the results above, Lake Naivasha is not very good for human consumption before treatment because of high concentrations of fluoride, lead, mercury, and arsenic which all exceed the recommended limits for drinking water.

As noted in the section on hydrology above, Lake Naivasha is unlikely to be affected by brine reinjection since the Olkaria II field is to the south of the Lake, and water from the Lake flows southwards. Deep reinjection into well OW307 at a depth of 1997 meters (bottom elevation 49 meters above sea level, compared to Narasha swamp elevation of 2007 meters above sea level) will not affect the chemistry of the wetland.

Table 9. The Chemical composition of Lake Naivasha waters compared to maximum limits.

	Health limits (mg/l)	Average conc. of Lake water (mg/l)
Na	200	37.5
NO_3	10	0.3
NH_4	-	0.140
P	-	0.514
S	-	0.311
B	30	0.027
F	1.4 - 2.4	1.728
Pb	0.05	0.088
Hg	0.001	0.055
Ca	-	15.62
As	0.05	0.908
Mg	-	5.87
Al	0.2	0.05
Si	-	5.11
Cl	250	6.75

K	-	19.66
Mn	0.1	0.042
Fe	0.3	0.127
Ni	-	0.005
Zn	5.0	0.089
Cu	1.0	0.010

Partly after Sinclair Knight and Partners, (1994)

4.2.5 Suspended particulate matter (Dust).

Suspended particulate matter or dust, include particles of solids or liquids ranging in size from those which are visible (dust, smoke and soot) to those which are invisible. Such small particles can remain suspended for a long time and can be carried away to greater distance by wind. The main sources of particulates are combustion in power plants, especially in coal fired ones, and dust generated from transport vehicles on earth roads. Dust can cause problems to the environment in many ways. The adverse health effects of particulates depend not only on their amounts, but also on their chemical and physical properties. Particle size determines whether the particles reach the lungs or not. Those that reach the lungs via the mouth are usually less than 15µm and those through the nose are less than 10µm. Fine aerosol particles of 2µm or smaller, ultimately reach the lungs fine structures, the individual alveoli. The effects produced depends on their chemical properties, toxicity, acidity, solubility and physical structures. The larger particles have few health effects, but many cause soiling and deterioration of materials and damage to some agricultural crops.

4.3.0 THE BIOLOGICAL ENVIRONMENT

The Olkaria III area is partly located within the Hell’s Gate National Park. The park has some sensitive habitats, significant natural sites, and some unique and rare species of plants, wildlife and a variety of birds. Lake Naivasha, a Ramsar Conservation site is located 5 km from the geothermal site. This call for special attention to preserve and protect the sensitive environment. The Narasha seasonal wetland, used as pasture by the Maasai, is located within 1 km of the proposed site.

4.3.1 The Terrestrial Environment

4.3.1.1 The Flora

The floral checklist in the vicinity of Olkaria III Geothermal Power Plant at the onset of the wet season in May 2000 is shown in Appendix 6. The area falls into Agro-Ecological Zone 5, with heterogeneous open bushland and bushed grassland vegetation dominated, in most places, by *Tarchonanthus comphoratus* (Leleshwa) thickets. This is the characteristic unique vegetation type found, often on stony hills, in volcanic soils of recent origins. The vegetation type is found in a variety of habitats in the arid and semi-arid districts of the Kenyan Rift Valley, including Nakuru, Baringo, Laikipia and Kajiado.

4.3.1.1.1 The Plant Associations

From photographs and ground reconnaissance of the area in the vicinity of the proposed Olkaria III Geothermal Power Plant, the following distinct floral associations can be discerned:

A. Open Shrubland

B. Bushed Shrubland

C. Bushland

D. Bushed Grassland

E. Sensitive Unique Floral Habitats: Drainage gorge forests, Rock Outcrop and Barren Land and Steam Vents

The associations merge into one another with boundaries dictated either by change in topography, soil type, drainage patterns, rock structure, occurrence of steam vents, or burned bare rocks.

A. The Open Shrubland

This association is typical of the disturbed cleared sites for the construction of roads, drilling camps and power plant. Members of the Solanaceae family including *Datura stramonium, Nicotiana glauca, Solanum incanum and S. nigrum* dominate the open shrubland. Other common plant species of the disturbed areas *are Achyranthes aspera, A. aspera varisicula, Amaranthus hybridus, Tagetes minuta, Ricinus communis, Portulaca oleracea, Calotropis procera, Rumex usambarensis and Urtica massaica.* This plant community mainly consists of opportunistic weed species, which take advantage of the cleared disturbed areas with the potential to become a nuisance. *Datura stramonium, Calotropis procera* and *Nicotiana* glauca are very poisonous plants and unpalatable to both domestic and wild animals. Kikuyu grass*, Penisetum clandestimum (= P. kikuyorum)* and *Cyperus rotundus* are the main types of grass covering the open ground following rainfall.

B. Bushed Shrubland

This plant community is characteristic of recently burned fertile Leleshwa (*Tarchonanthus comphoratus*) bushlands and cleared Maasai cattle *bomas*. *Urtica massaica* (stinging plant) is the dominant vegetation in the bushed shrubland. Other plant species associated with this vegetation type include *Galinsoga parviflora,Tagetes minuta, Vernonia laesiopus, Amaranthus hybridus, Fuerstia africana, Commelina benghalensis, Datura stramonium, Calotropis procera, Nicotiana glauca, Cucumis ficifolius, Zebrina scabra* and young shoots of *Tarchonanthus comphoratus.*

C. Bushed grassland/Bushland

Tarchonanthus comphoratus and *Hyperrhenia hirta* with scattered *Acacia drepanolobium* dominate the Leleshwa bushland plant community. The association occurs on hill slopes of the proposed site between the bushed shrubland and the drainage gorge forests. This vegetation occupies the largest area around the Olkaria III Geothermal Power Plant. Other plant species associated with this community are *Hypoestes aristata, Euphorbia crotonoides, E. prostrata, Aspilia massambicensis, Achyranthes aspera varisicula, Asparagus africanus, Gloriosa superba, Onithogalum gracillimum, Ocimum gratissimum, Crotolaria laburnifolia,C. balbi, Indigofera arrecta* and a few grass stands of *Hyperrhenia hirta, Rhynchelytrum repens, Themeda triandra*, in open parts the bushes. *Acacia xanthophleoa* occurs in the lower wetter parts of this vegetation type

D. Sensitive Unique Floral Habitats

Steam vents and the drainage areas, gorges and luggas, are unique habitats with rare plant associations not normally found Agro-Ecological Zone 5 of Kenya. Steam vents create peculiar geological soil and rock formations, very high temperatures and sauna-like high humidity conditions, which impose several species of pteridophytes and orchids that normally are not associated with this ecological zone. Also unusual is the occurrence of woody plants (*Ficus* and

Syzigium species) and pteridophytes (e.g. *Lycopodium cernuum*) on rocky/soil formations surrounding the outlets of the underground steam in the area. A sedge, *Fimbrisylis exilis* (Family: Cyperaceae) grows in the steam vents, and is a good indicator of the presence of steam vents. Other unique species that are common to this area include the pteridophytes, *Dissotis senegambiensis, Ophioglossum rubellum, Dicranopteris linaeris* and *Pleopeltis macrocarpa.*

Other rare and peculiar plants associated with the steam vents in the area are the orchids species (Family: Orchidaceae), *Angraecum humile*, *Ansellia gigantea* and *Pteroglossaspis ruwenzoriensis*. These are very highly valued plants by the florists. Because they are over-exploited, some of the species of orchids are threatened with extinction and therefore the plants and their unique habitats need to be protected. Sinclair Knight and Partners (1994) made similar observations in their earlier environmental assessment studies in the area.

Gorges and luggas (drainage areas) in the vicinity of the proposed Olkaria III Geothermal Power Plant have plant species peculiar to the ecoclimatic zone 5. The species associated with the seasonal streams forest areas include *Dombeya burgessia*, *Maerua triphylla*, *Olea africana (=O. europoea*), *Grewia similis* and *Ficus* spp. A fern, *Cheilanthes multifida*, occurs in a gorge extending only 50 m from the hot volcanic Hell’s Kitchen near the powerful well 301. These unique sensitive habitats and significant natural sites in the area need to be conserved.

4.3.1.2 Fauna

Hell’s Gate National Park, within which the Olkaria III Geothermal Power Plant is located, is a home to a variety of wildlife and many species of birds and insects. The cliffs in the park are nesting/roosting sites for many birds of prey including the rare Lammergeyer, Griffon vulture, and the magnificent Verreaux Black eagle. Lammergeyer or Bearded Vulture (*Gypaetus barbatus*) were known to be breeding in the park as early as 1914, but were last seen in 1984 (Hell’s Gate National Park Management Committee).

The Hell's Gate National Park mammal and birds checklists are given in and Appendices 2.3.1.2 and 2.3.1.2 respectively. Wildlife censuses carried out recently show decreases in the populations of most animal species in Hell's Gate National Park. Between 1993 and 1998 the following changes were recorded: Kongoni from 479 to 81; Thompson Gazelle from 165 to 33; Grants Gazelle from 136 to 44; Giraffe from 40 to 11; Eland from 102 to 28; Mountain Reedbuck from 32 to 13; Warthog from 50 to 40; Dik Dik from 25 to 0; Steibuck from 25 to 0; Klipspringer from 10 to 0; Buffalo from 105 to 28; and Waterbuck from 5 to 0. Only zebras and impalas show an increase in their population in the park over the same period, from 295 to 342, and from 30 to 52 respectively. Table 2.3.1.2 shows the species, number, and sex of mammals found Hell's Gate of the latest census carried out in January 2000. It is worth noting that in the private game ranches, on the other hand, animal populations have increased over the same period, some quite dramatically. There are no wildlife movements between the park and Kongoni Ranch, which has now an electric fence. On the other hand, there are a lot of movements between Kedong Ranch and the park.

The wildlife population in the park exhibit seasonal variations (Figure 7), which are probably due to migrations and/or mortality due to droughts frequently experienced in the area. The effects of differing and changing demographic parameters commonly manifest themselves in the fluctuations inherent in natural populations (Delany, 1982).

In the period between 1996-2000, the mean population of animals in the park has been fluctuating around 1150 (Figure 8). This value can, therefore, be taken as a sensible wildlife baseline average upon which impacts of future geothermal developments in the park can be evaluated and monitored.

According to the Kenya Wildlife Service (KWS), the construction of roads and laying of pipelines for the KenGen Olkaria Geothermal Plant, has isolated a group of Maasai giraffes, buffaloes and the rare Chanler's mountain reedbuck from the rest of the park. The animals now move between Hobbley Volcano and the proposed power plant site. Though, little evidence has been mustered in support of the premise that subdivision of wildlife habitat to small units

Table 10. Mammal Census at the Hell's Gate National Park, January 2000 carried out by the Kenya Wildlife Service, Naivasha-Kenya.

MAMMAL	MALE	FEMALE	YOUNG	TOTAL
Zebra	151	318	24	493
Thomson Gazelle	23	32	1	56
Grant Gazelle	19	62	-	81
Impala	33	45	48	126
Eland	52	144	-	196
Buffalo	81	126	-	207
Kongoni	101	127	9	237
Waterbuck	4	3	-	7
Warthog	45	90	-	135
Giraffe	31	32	-	63
Rock Hyrax	19	14	-	33
Lion	-	-	-	-
Leopard	2	-	-	2
Cheetah	-	-	-	-
Jackal	1	1	-	2
Hyena	-	-	-	-
Serval Cat	2	2	-	4
Dik Dik	4	5	-	9
Duicker	-	4	-	4
Bushbuck	-	-	-	-
Reedbuck	12	15	-	27
Steinbuck	1	-	-	1
Klipspringer	5	10	-	15
Baboon	3	4	8	15
African Hare	1	1	-	2
Bat-eared Fox	-	-	-	-
Mountain Reedbuck*				12
Silver-backed Jackal	-	-	-	-
Total				**1704**

- * = 12 Mountain reedbucks spotted during this study on a hill at the Hobbley Volcano
- - = Not observed

automatically increases rates of extinction of the affected animals, rates of extinction can be unacceptably high in very tiny isolated reserves (Gilbert, 1980; Boecklen and Gotelli, 1984, Boecklen and Simberloff, 1987).

During the study, obviously frightened and isolated 12 mountain reedbucks were spotted on a hill at Hobbley's Volcano. Wildlife censuses in the park by KWS show that the population of this rare buck has remained between 13 and 15 for a long time now. It is speculated that the mountain reedbuck has a low fecundity and the survival rate of the juveniles is poor.

2.3.1.3.1 Sensitive Habitats

The Hobbley Volcano, the Olkaria Hill and the Hell's Kitchen, in the vicinity of the proposed geothermal power plant site, are sensitive habitats and important natural sites hosting some rare or endangered wildlife species. The area is covered with young volcanic rocks, from recent volcanic activity of the Olkaria, with sparse vegetation dominated by *Erica arborea,* which forms an ideal camouflage background for the Chanler's mountain reedbuck (*Renduca redunca*). A rare leafhopper insect (*Platypleura sp*., Family: Cicadoidea) with a high pitched-cricket sound is found in association with the Leleshwa bushes near the Hell's Kitchen only 100 m from well 301 of the Orpower Geothermal Power Plant.

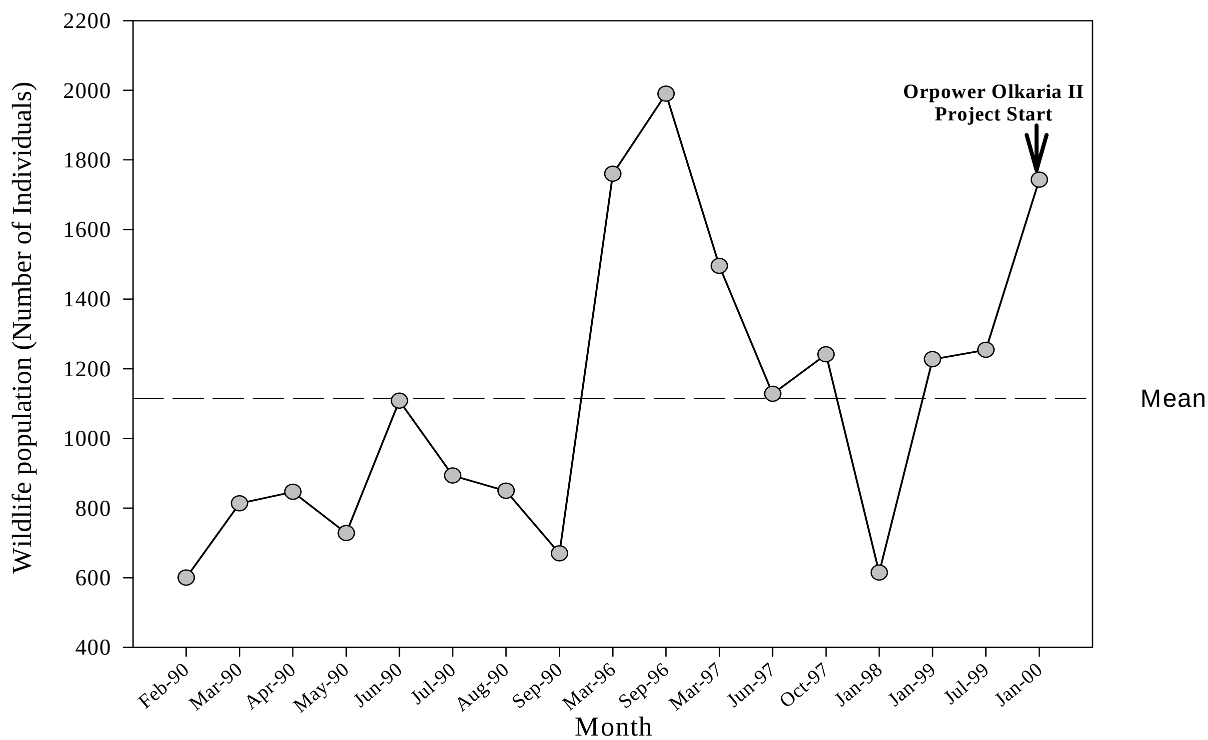

Fig. 2.3.1.2. Hell's Gate National Park Wildlife census between 1996 and 2000.
(Wildlife census data courtecy of the Kenya Wildlife Services, Hell's Gate National Park, Naivasha)

Figure 7. Variation in mammal populations in Hell's Gate National Park (data from KWS).

4.4 THE SOCIO-ECONOMIC ENVIRONMENT

Communities in the immediate vicinity of the project are most likely to be directly impacted on by the project. The Maasai community at Narasha, KWS, KenGen, Oserian Development Company, Kongoni Game Conservation Ranch, and the Lake Naivasha Riparian Association were selected for the socioeconomic survey, as well as government officials in Naivasha. For the survey a questionnaire and an interview schedule were used (Appendices 9 and 10). The following summarises the findings of the survey.

4.4.1 The Maasai Community

4.4.1.1 Historical background: The Narasha Maasai community (including their in laws) has occupied the Hell's gate area since the early 18th century. They were displaced from the Olkaria east area in the 1980s and relocated to the south. The land use pattern of the Maasai had changed over the years, from pure pastoralism to sedentary farming and ranching. Pastoral activities have given way to mixed farming and land subdivisions.

4.4.1.2 Location: The Maasai community surveyed resided in Narasha village, which is in the vicinity of the project. The village has an area of approximately 13 km^2.

4.4.1.3 Population characteristics: The findings of this study revealed that there were 15 homesteads in Narasha village. Each homestead has an average family size of about 15 people (1 man, 2-3 women and 11 children). The total population of the Maasai community was 225 members. The population growth rate is approximately 2.5% per year. The ratio of boys to girls is about 3: 5. The population density of the Maasai community in the Narasha village is 17 people per sq. km. The mortality rate of the population was 1/15 (1 at 2.5 years).

On average the girls get married at 13 years, while the boys get married at 16 years. The average life expectancy rate of the community members is around 43 years. The majority of the population is between the 7-15 age group. The languages spoken by the Maasai community include the Maasai language and some English, Kiswahili and Kikuyu.

4.4.1.4 Clans: The Maasai community is grouped into two major clans: the Odomongi (the largest clan) and Orok Kiteng. The Odomongi clan is divided into sub-clans that included the

Ilmolelian, Ilmakesen, Ilkerin inkishu and the Iltaar losero. The Orok Kiteng clan was subdivided into the Ilaiser and Ilukumae sub-clans.

4.4.1.5 Land ownership and size: The community members do not have title deeds, but only land or plot numbers and sketch maps. The average land size held by per family is around 20 acres in the Narasha village and 50 acres in the Suswa area.

4.4.1.6 Land use system: The predominant land use is pastoralism, which involves the keeping of cows, sheep, goats and donkeys. On average each family has 40 cows, 50 sheep and goats and 7 donkeys. During the wet season (March to August) the men migrate to Suswa with the cows looking for pasture. The women are left behind with the children, to look after the home and also the remaining livestock. The men then return during the dry season from August to February.

Farming is practiced predominantly in the highland areas of Suswa (30 km away), and at a small scale in the lowland areas of Narasha. The crops grown are maize, beans, potatoes, wheat and vegetables (sukuma wiki, tomatoes and onions) all cultivated using hoes. The Maasai also rent their farms to Kikuyu and Luhyia community members. The average yield per acre for maize, beans and wheat is 3, ½ and 20 bags respectively.

4.4.1.7 Social organization: The community members have organized themselves into self-help groups, which include the women's group, the water development group, the cultural center group, the youth and church groups. The women group has 25 members, the cultural center group 67, the water development group 25 members and 12 members are in the KWS committee. Membership is not restricted to only one group. The membership fee of each group is based on each individual's ability to pay.

4.4.1.8 Shelter: The houses of the community members are temporary in nature, and are made with tree posts plastered with mud and cow dung for the walls, thatched roofs, and earth floors. They have to be repaired every year. The community members also build pit latrines. On average each homestead has 5 huts (1 for the head of the household, 1 for each of the 2 wives, 1 for the girls and also 1 for the boys). The married son lives outside the fencing of the homestead with his family. An enclosure of thorny tree bushes for livestock is also found within the fenced homestead.

4.4.1.9 Social facilities: The facilities found in the community include one primary school (Inkoriento primary school (11km away) with only 2 children out of the 300 coming from the Narasha community. It was also revealed that there was only one traditional healer. The children would go to high schools in Narok, Kajiado, Nakuru and Naivasha. The total amount of school fees per year is KSh. 2000. The public health facilities used by the community include the Naivasha district hospital and Maela health center, which are approximately 50 km away. The treatment fee is approximately KSh. 2000 per visit on average.

4.4.1.10 Cultural activities: Some of the cultural activities of the community members include circumcision, naming ceremonies, weddings, burials, religious ceremonies and sacred rituals. These activities are performed when the need arises. The community members also perform traditional songs and dances at the nearby cultural center.

4.4.1.11 Sources of energy: Fuel wood and charcoal, obtained from trees in the surroundings, are the sources of energy used for cooking (maize, beans, potatoes, vegetables and boiling milk) and also for warming the house.

4.4.1.12 Sources of water: The majority of the community members get their water from one water tank (with four watering points) provided to them by the Kenya electricity generation company (KenGen). A few community members also get their water for domestic and livestock from the Narasha wetland (Lake Odongo), a seasonal wetland, covering an area of about 90,000m^2. During prolonged dry weather, the wetland dries up, leaving an evergreen flat area that is popular with livestock and wild animals.

4.4.1.13 Employment: A few of the community members are employed as watchmen and cleaners at KenGen. However, some of the community members are self-employed as carpenters and blacksmiths.

4.4.1.14 Income generating activities: The community members sell their cows, sheep and goats at an average price of KSh. 7,000 and 1500 respectively at market places when the need arises. On average, 10 animals are sold yearly per family. Milk is sold daily at an average price of KSh. 15 per litre. Maize is sold at KSh. 1500 per bag, beans at KSh. 3,500 and wheat at KSh. 4,200 per bag after the annual harvest. The community members also sell to tourists at the cultural center necklaces at KSh. 2,800, bracelets for between KSh. 300 and KSh. 600, shoes for KSh. 250, cloth decorated with beads at KSh. 1,500, and swords and knives at KSh. 3000 each.

4.4.1.15 **Infrastructure:** The type of infrastructure found in the community include both tarmaced and all weather roads, which were built by KenGen and Kenya wildlife Service (KWS).

4.4.1.16 **Telecommunication services:** The community does not have any telecommunication services like telephone booths.

4.4.1.17 **Income:** The average monthly income of the community members is KSh. 70,000. The survey revealed that this amount is not adequate to meet all family needs.

4.4.1.18 **Market centers:** The main trading centers used by the community members are Naivasha and Maela, both approximately 50km away. The community members also use the shopping facilities of KenGen, as well as Oserian and Sulmac markets.

4.4.1.19 **Living standards and quality of life:** The study of the community members revealed that their living standards and quality of life are very low. Their diet consists mainly of milk, blood, meat, maize, beans, potatoes, and vegetables. There were no cases of malnutrition noted among the Maasai, and it was assumed that they are able to meet daily nutritional requirements. Clothing for the men consisted, on average, of 2 pairs of "shukas" and 1 pair of sandals made from rubber/hides and skins. The women have on average 3 pairs of "shukas" and 1 pair of sandals made from rubber/hides and skins. The children had 1 pair of "shukas" and 1 pair of sandals made from rubber/hides and skins. 3 of the youth had on average 2 pairs of formal trousers and shirts.

4.4.1.20 **Social problems:** The social problems include violence against women, beating, poverty, early marriages, drought, malnutrition, child exploitation, diseases (malaria, colds, flu, typhoid and cholera), drunkenness, erosion of cultural values and high illiteracy levels.

4.4.1.21 **Gender roles:** The role of the men includes making all the necessary decisions pertaining to the homestead and the buying and selling of livestock when necessary. The women's role includes the building of houses, the fetching of water and firewood, the raising of children, the cooking of food, the selling of milk, and farming. The predominant role of the young boys and girls (7-15 years) is the herding of livestock, and farming and household chores respectively.

4.4.1.22 Law and Order: The Maasai community largely uses chiefs and sub-chiefs to settle disputes. They also occasionally use the Kongoni police station near Kongoni Ranch and the Olkaria police station near the Olkaria east power station when the need arises.

4.4.2 Other Stakeholders

4.4.2.1 The Lake Naivasha Riparian Association (LNRA): The LNRA is a voluntary organization, relying on contributions from members and well wishers to carry on its work. It was founded in 1929 by the landowners surrounding the lake. The main objective of the association was to ensure sound environmental management of the lake's resources. It advocates good practice and establishes mechanisms to implement environmental policy, legislation and regulations with each individual member, group of members, and the relevant government and NGO sectors.

The associations' members are drawn from a wide variety of backgrounds: they include tour operators, the Kenya Power Company, ranch owners, flower growers, small farmers, cooperatives and the local Municipal Council- anyone who owns land on the shore of the lake. Thus the membership of about 140 represents a large number of individual stakeholders from a diversity of economic activities. Although the shoreline is almost entirely in private hands, the lake itself is a national asset: the LNRA members are its custodians, charged with a moral responsibility for ensuring its survival for future generations.

The LNRA has put in place a management plan to control those forces that threaten the lake's quality and beauty. Official implementation of the plan began in 1997. A hydrological study of the lake and its catchment area is being carried out; the horticultural growers are currently using drip feed irrigation, water meters and controlled use of pesticides; a code of conduct for the horticultural, power generation, fisheries, tourism and livestock industries has been written. The Municipal Council's sewage treatment plant is currently being restored.

The study findings reveal that the area of the lake varies between the dry and wet periods, from 102 km^2 during dry cycles to 150 km^2 during wet cycles (Lake Naivasha Management plan, 1999). The lake is shallow, deepening towards its southwestern part to a maximum of 8m in depth, though the deepest part of the lake is at 16m off Crescent Island. The volume of the lake had varied between $50x10^6$ m^3 and $600x10^6$ m^3 in recent times (Lake Naivasha Management plan, 1999). The lake water budget is summarized in appendix 3. The following ca be deduced from the water budget in appendix 3:

- The surplus water during mean conditions is mainly from surface runoff or flash floods from rivers and ungauged areas of the watershed;
- In prolonged dry conditions the lake is acutely threatened by present levels of abstractions;
- Increased abstraction or expansion of present activities cannot be sustained if several dry years follow each other.

Lake Naivasha is a natural beauty and has features which have attracted tourists and tourist infrastructure. The tourist attractions include more than 350 species of birds, and 34 mammals, including the African waterfowl.

4.4.2.2 KWS: Hells Gate Park is situated in the eastern Rift Valley in Kenya at a mean altitude of 1885m above sea level. It is located at latitude 00^0 46'S and longitude 36^0 22'E in Nakuru district, about 100 km Northwest of Nairobi. The park was declared a national park in 1984. The park has three gates Elsa, Olkaria, and Narasha gate.

The study findings revealed that between 1985 and 1992, the number of visitors to Hell's gate national park had increased by more than 600% (Lake Naivasha management plan, 1999). In 1994 a total of 41,000 visitors entered the park, and by 1997 there were 47,311 visitors (Lake Naivasha management plan, 1999). The number of visitors entering through the Narasha gate which is close to the project is on average 20 foreign visitors per day in the high season (October-March) and 5 local visitors per day during the low season (April-September). On average, 10,000 students per month also pass through the Narasha gate.

The park charges are Ksh.100 for adults, KSh. 50 for students and US$ 5 for tourists. Tourist attractions found in the park include viewing of game (Zebra, Buffalo, Hartesbeete, Thomson and Grant gazelles), a cultural center, rock climbing and walks at the Obsidian caves and nature trails, the viewing of cliffs, volcanic sites (Fisher and Central tower), Njorowa gorge, hot and cold waterfalls, and Maasai manyattas. There was also camping at (Naiburta, Endachata, Ol Dubai, Narasha gate and Olkaria) and picnics sites. Natural streams and swamps are also found in the park. Some local visitors, particularly school parties, come specifically to view the geothermal development project, and not the wild life.

4.4.2.3 KenGen: The KenGen project started at Olkaria in 1970. The first exploration work was completed in 1978, with 6 wells. In 1981, the first electricity-generating unit of 15 Mwe was commissioned. In 1985, 45 Mw of electricity were being produced. In addition to the present 45 Mw power plant, KenGen is scheduled to construct the Olkaria II power plant of 64 Mw in the northeast field, to be commissioned in 2003/4.

The study findings revealed that KenGen has about 5 geothermal fields; the east, northeast, northwest, central and Domes. The north east wells (28 wells drilled, but only 19 are productive) which will produce between 64 - 78.4 Mw of electricity; the eastern wells (3 wells drilled, with each producing 15 Mw to produce a total of 45 Mw); the north west well (produced 1.5Mw); and the south west wells which are however not productive; the wells in the Domes (2 productive and one not very hot at 235^0 C). There are also 5 wells in the central field. The total area taken up the Domes and the eastern geothermal field each is 6 km^2, while the northeastern field takes up 4 km^2.

The study findings reveal that KenGen has also been involved in a number of social programmes such as the provision of water tanks, free medical services, a primary school, transport, employment opportunities, the buying of books for the community members, and also the donation of 3000 tree seedlings to the local community. It is also a member of KWS park management and LNRA.

4.4.2.4 Fisheries: The fisheries sector involves commercial fishermen, sport fishermen, fish wardens and researchers, who are given licenses where necessary to carry out their activities. Commercial fishermen have designated landing beaches/stations for fish display and sale and also to count fish for bio-statistical data. The commercial fishermen are permitted to use a maximum of ten gill- nets (maximum total length – 100m) with a minimum mesh size of four inches. Juvenile fish (less than 18 cm for tilapia) are returned to the water. The sport fishermen-individuals, from clubs, marinas or hotels, do sport fishing strictly for leisure purposes only. The fishing practices used by sport fishermen include the use of a rod and line with which to catch fish.

Fishing is only allowed in open Lake water, away from lagoons and bays at distances of more than 100m from papyrus fringes or shoreline. Fish in breeding grounds are not to be disturbed. Fishing is allowed during the day only. Illegal fishing or fishing without a license or permit is a criminal offence.

In 1998 the fishing industry supported 3300 people. An average catch of 126 metric tonnes with a value of KSh. 4.7 million was realised. At present an average of 1000 fishermen have licenses. Lake Naivasha has an average of 378 metric tones of fish in its waters. Most of the fish (black bass and tilapia) is consumed in Naivasha. The rest is sold in Nairobi, Nakuru (the major consumer), Eldoret and Kisii.

4.4.2.5 Oserian Development Company: The Oserian Development Company is currently one of Kenya’s largest growers and exporters of fresh cut flowers. The flower plantations include the Ferore, Rony and Bonita Carnations, white and purple Stattice, Arabicum and Roses.

4.0 SIGNIFICANT ENVIRONMENTAL IMPACTS

Below are outlined some of the changes to the environment that are expected to occur as a result of the Building and operation of the Olkaria III geothermal power station.

5.1 PHYSICAL IMPACTS

5.1.1 Impacts on soil erosion

5.1.1.1 Preparation of Well Pads

Some excavation will be required in the Olkaria III area for the well pads. This will promote soil erosion, unless proper measures are put in place immediately to stabilize all bare surfaces.

5.1.1.2 The Discharge of Waste Water

Wastewater discharged from well pads during drilling and well testing phases, if disposed of on the surface can lead to gully erosion. Once gullies develop, they are very difficult to control, as is evident for the gulley before Narasha Gate.

5.1.1.3 Roads

Run-off from roads has the potential to cause erosion either in the drainages that run parallel to the roads, or where concentrated run-off is discharged from culverts.

Traffic on the Olkaria West road has increased due to heavy commercial vehicles supplying construction materials at the power station site (table 11). A total of 36 vehicles passed the Narasha Gate within 2 hours on 3rd May, 2000. During the station operation, there will be fewer heavy vehicles. The scenario is likely to change if the road is improved, so that it facilitates easier access to Suswa and Narok. This will increase the number of commercial and tour vehicles. Removal of vegetation during road construction will lead to soil erosion.

5.1.1.4 Laying of Pipes

Clearing of vegetation for the purpose of lying of pipelines will also contribute to soil erosion.

Table 11. Traffic on Olkaria West–KWS road (3rd, May 2000) (This study).

Time	No. of heavy vehicles	No. of light vehicles
11.40 am - 12.40 PM	8	17
12.41 PM - 1.41 PM	3	8
Total after 2 hours	11	25

5.1.2a Predicted noise impacts from the Olkaria III power plant

We have developed a contour model (Appendix 11) of the predicted noise levels in the Olkaria West fields and around the power station during the production stage. The model is based on the measured levels around the Olkaria I production plant in the Olkaria East field, prevailing wind direction and speed and the existing topography. We started with the measured levels at Olkaria I cooling tower complex and gas injectors and then we input the physical conditions at Olkaria III. The modeling and analysis procedure are similar to those used in the Olkaria II power plant EIA and are discussed in details by Sinclair Knight and Partners (1994). During this study, the Olkaria III area was divided into 500 m square grids that covered a total area of 6 x 6 km. The model takes into account the changes in noise levels due to distance, natural barriers such as topography, wind speed and direction and relative humidity (Harris, 1979). Thus the level and distance affected depends on the source level with frequency, geometry of barriers and the prevailing atmospheric conditions. Although the Olkaria I power plant has an installed capacity of 45 MWe compared to the planned 28-100 MWe plant for Olkaria III. It is expected that with the design of Olkaria III, the noise levels will not be much higher than Olkaria I.

As seen from, the model, the level of Noise will be highest within and around the power plant decreasing with distance away from the plant. The prevailing wind direction from SE to NW and the presence of Olkaria hill will have a modifying effect on the noise levels as it affects the wind speed and direction. The area extending to the northeast up to the Kongoni farm boundary will experience noise levels above 40 dB. The southern parts including Narasha Gate and Lake Odongo will not experience noise levels above the measured background. The northern parts will experience moderate levels 60-40 dB, while the area to the east behind Olkaria high is unlikely to experience any power plant induced noise. In general the KWS national park areas used by visitors will not experience noise levels above background.

5.1.2 Seismic impacts

A cumulative magnitude frequency distribution was plotted for the whole area. Earthquakes within the center of the network with accurate picks (quality 0 & 1) were chosen and checked to ensure that they were not clipped. The magnitude-frequency relation was plotted for these earthquakes. The magnitude-frequency relation in a particular area obeys the following relation

$$\text{Log}_{10}\ \text{N}=a-bM_c$$

Where,

N =the number of earthquakes with a magnitude at least M_c,

a = is related to the length of time under consideration, normalized to 1 year.

The relationship becomes non-linear below M_c =0.1 and above M_c =2.4 with a change in slope at M_c =0.8 and M_c =1.4. The M_c =0.1 value reflect the lower limit for earthquakes registered within the network and the slope change at M_c =0.8 has not been explained.

The slope change at M_c =1.4 indicate a magnitude threshold for this area. It should also be noted that most of the earthquakes with magnitude 1.4 and more are on the periphery of the geothermal field and outside. This implies that stresses within the geothermal field are being released at a different rate to the surrounding areas. This is consistent with the regional stress analysis studies (Sass and Morgan, 1987), which suggest that the stress along the rift floor is released by micro-seismic activities in geothermal areas but by larger earthquake sequences along the rift boundary faults. Fault zones within a high temperature area tend to move by creep and the energy available for elastic rebound is therefore less. Also induced seismicity by fluid injection and extraction along faults is a stress relaxation mechanism. Outside the high temperature zone, elastic energy is not released by these mechanisms, so it tends to build up and then be released by large earthquakes. This means that the crust in the geothermal area has been weakened by the physical-chemical effects of high temperature and geothermal activities.

The value of ‘b’ parameter in the relation is relatively high at around 1.05. This implies that the reservoir rocks are in a low stress state with less likelihood of a large earthquake occurring within this volume of the rocks within the field than outside. This value is within the limits usually found within geothermal fields (McEvilly, 1985). The high value implies that there is high heat flow and stress is being released through a high frequency of small magnitude earthquakes. The corresponding ‘a’ value is 3.3 that give a magnitude-frequency expression below,

$\text{Log}_{10}\ N=3.3-1.05M_c$.

Based on the above expression, there is very little risk of a potentially destructive magnitude $M_c>5$ earthquake occurring within the geothermal field in a period of less than one century. The calculated predictions are given below;

$M_c > 3$	1 event every 1 year	not felt	not destructive
$M_c > 4$	1 event every 8 years	slightly felt,	not destructive
$M_c > 5$	1 event every 1 century	felt	destructive
$M_c > 6$	1 event every 10 centuries	strongly felt	Very destructive
$M_c > 7$	1 event every 112 centuries	extreme	disastrous

5.2 CHEMICAL IMPACTS

The wells that were considered in this report are OW-301, OW-302, OW-305, OW-307, OW-308 and OW-401, and their locations are shown figure 9 below. Average concentrations of geothermal fluids are summarized in the table 10 below.

Well OW-301 discharges water which is predominantly sodium bicarbonate type with low mean chloride concentration of 241 ppm, whereas OW- 302 and OW-401 discharge a mixture of sodium bicarbonate and sodium chloride type of water, with a mean chloride concentrations of 514 ppm and 510 ppm respectively. Well OW-305 discharges water which is predominantly sodium chloride. OW-307 discharges hot geothermal water with no steam and it will be used as a re-injection well. The highest measured temperatures of well reservoirs were, OW-301, 306 ^{0}C, OW-302, 294 ^{0}C, OW-305, 321^{0}C, OW-307, 179 ^{0}C, OW-308, 231^0 C and OW-401, 227 ^{0}C.

The early generation facility is designed to utilize geothermal brine and steam from OW-301, OW-305, and an additional well that has been drilled by Orpower 4 Inc., to generate 8 Mwe using two Ormat Energy Converter (OEC) units. In the OEC unit, power is generated by one common generator coupled to two turbines, which are driven by a motive fluid, operating in a closed Rankine cycle. The heat source for the motive fluid cycle involves pre-heating by using the mixed stream of steam condensate and brine, followed by vaporization of motive fluid by the total steam flow.

The plant phase will use condensing steam turbines to produce at least 64 Mwe.

Gathering of geothermal fluid is done by metallic pipes, which direct the fluid into a separator. In the separator, steam and water are separated. Dry steam from the separator is directed to turn the first turbine and then heat up the motive fluid in the evaporator. Geothermal brine is directed to a pre-heater, where the motive fluid is heated up and channeled to an evaporator. Then the two fluids meet and are directed to the re-injection well.

Non condensable gases will be released to the atmosphere. The fluids (both geothermal and pentane motive fluid require precautions in case of an accident or a shut down of the station

5.2.2 Air Quality

The impact of the release of non-condensable gases into the environment is assessed. Concentrations of major gases were recorded and the fraction of total non-condensable gases calculated. The data is summarized in the table 10 below.

In the early generation phase, total fluid flow (steam + brine) is expected to be 230 tonnes per hour, consisting of 5% non-condensable gases, of which 99.5% is CO_2. If the geo-fluid will come predominantly from wells similar to well 301, then a total of 11.5 tonnes of CO_2 will be released every hour, and in a year, 100,809 tonnes of CO_2 will be released. This is a large amount of CO_2 from one plant, in view of its green house effects.

Table 12. Expected releases of Non-condensable gases into the atmosphere (this study).

Well No.	CO_2 Conc.	H_2S Conc.	% CO_2	% H_2S	Water T/hr	Steam T/hr	CO_2 T/hr	H_2S T/hr
301	7670	10.8	99.5	0.04	43.4	40	7.8	0.008
302	587	3.4	98.5	0.36	34.2	17.6	0.014	0.001
305	320	13.6	95.1	0.84	7.3	14.8	0.12	0.004
308	2.743×10^4	0.439	99.8	0.002	9.2	13.3	8.9	0.000
401	519	1.6	99.6	0.19	46.4	10.9	1.4	0.003
							18.4	0.016

Concentrations of gas are in millimoles/100 moles of steam

Most wells in the Olkaria III field have more carbon dioxide than wells in the KenGen Olkaria northeast and Olkaria east fields. Non-condensable gases in the KenGen power station constitute about 2% of geothermal effluents, while at the Olkaria III field, they will form about 7.1%. Carbon dioxide in Olkaria east is about 95% and in Olkaria west field it is about 98% of all non-condensable gases. Carbon dioxide is found to be abundant in OW-301 and OW-308. The two wells can produce 16.7 tonnes/hour of carbon dioxide into the atmosphere. This is equivalent to 146,292 tonnes/year of carbon dioxide. This amount is seven times the amount of carbon dioxide produced by all the production wells in Olkaria east field. This amount of gas released to the atmosphere will definitely affect the environment, and will increase Kenya's share of CO_2 emissions under the Kyoto protocol.

5.2.2.1 H2S Dispersion Modeling

Hydrogen sulfide in this field is less than in Olkaria east field. Total hydrogen sulphide produced by Olkaria east field was estimated to be 890 tonnes per year, (Tole, 1990), while the estimates of the gas produced at the Olkaria west field will be 146 tonnes per year, six times less. The model AUSPLUME (Sinclair Knight and Partners, 1994) could not be run during this study. An empirical model was used to predict the concentrations of H2S likely to result from the operation of the Olkaria III power station. Mean 24 hourly H2S concentrations were modeled.

Olkaria III H2S emissions will be 1/6th those of the Olkaria East power station when the plant is in full operation. This means that the mean 24 hourly H2S concentrations around the power station will be 0.33 ppm (compared to 2 ppm at the Olkaria East power station). Empirical data by Marani (1995) show decreases of H2S concentrations down wind of between a factor of 16 per km in the first kilometer, and about 30 per km over the next 12 km. These decay factors were used to calculate H2S concentrations at I km distances downwind of the power station, and using the south east as the dominant wind direction. The results are shown in Appendix 12. These results indicate that no inhabited areas (Narasha Maasai community, KWS Narasha Gate) will experience H2S concentrations above 0.004 ppm due to operation of this plant. No adverse impacts to human health is thus foreseen. Enhanced corrosion of metals close to the power station may need to be monitored.

5.2.3 Geothermal Brine

The concentrations of chemicals in geothermal brines from the Olkaria III field are less than those in the KenGen Olkaria east field. Boron and fluoride concentrations are, however, higher in the Olkaria III field than in the Olkaria east field. The average boron concentration in the brines in this field is 3.05 ppm, while for fluoride it is 60 ppm.

Boron is required by the plants for normal growth, but is toxic at high concentrations. Fluoride affects human teeth when the concentration is higher than 2.0 ppm. Boron and fluoride are both well above acceptable levels, and therefore care has to be taken in disposing the brine. All geothermal brine should be re-injected. If the reinjection wells fail, any infiltration ponds where the fluid may be temporarily stored should be fenced off to ensure wild animals and cattle do not use the wastewater. Vegetation around such ponds should be regularly harvested, and disposed of in such manner that livestock and wild animals do not feed on it. Silica precipitation problems are not foreseen, since the concentration of silica in brines of this field is relatively low.

5.2.4 Motive Fluid

Binary power plants use motive fluid to turn the turbine to produce electricity. The motive fluid is n-pentane, C_5H_{12}. This substance is highly flammable, with a high risk of vapour ignition at normal handling temperatures. There are risks of generating electrostatic charges during handling. When inhaled or ingested, vomiting and serious lung damage may result. It may cause frost burn due low boiling point. Long term health hazards for this compound are not known.

In case this substance leaks to atmosphere and is inhaled by the workers, the victim should be removed to fresh air, and artificial respiration done on the victim. If it is ingested, vomiting should not be induced, but the victim should taken to hospital quickly. If it comes in contact with the skin, it should be washed with a lot of water. Because of being flammable, fire extinguishers should be kept in the station. Cigarette smoking should be discouraged inside the power station.

5.3.0 BIOLOGICAL IMPACTS

The development of Orpower Geothermal Plant has a number of impacts on the biological environment. Construction of the power plant site, the road, accommodation camps for workers,

Table 13. Concentrations of H_2S in wells at Olkaria III (KenGen, 1999).

	Conc. H_2S (mmol/100mol.)	% H_2S in non-condensable Gas
OW-301	22.6	0.3
OW-302	21.99	2.7
OW-305	23.06	7.5
OW-308	3.87	0.02
OW-401	3.67	0.8

site for storage of equipment, drilling pad sites, and pipe ways have resulted in clearing of vegetation in virgin areas of Hell's Gate National Park. Wildlife can no longer be able to use most of these sites for feeding and breeding, due to the power plant operations. Test drilling in promising areas normally require an access road for a drilling rig, and clearance of about 1000 m^2 for each drilling (El-Hinnawi, 1981). In addition, lighting, noise, airborne effluents (e.g. dust, hydrogen sulphide, carbon dioxide, sulphur dioxide etc.), liquid effluents, thermal discharges and power transmission lines will change the environment in the vicinity of the power plant.

Hydrogen sulphide (H_2S) is the main airborne effluent of real concern in the Olkaria geothermal fields at the present. Although H_2S is a poisonous gas at high concentrations, the main problem in geothermal development is simply its objectionable smell. Sub-ppm levels do not appear to present a health problem, and communities in New Zealand are known to have lived for generations with local air containing 0.01 - 0.1 ppm (El-Hinnawi, 1981). As H_2S is a heavy gas, it tends to concentrate around geothermal plants in enclosed areas. It becomes a health hazard at concentrations over 10 ppm. Since Orpower Geothermal Plant is sited on a hill, this problem is likely not to occur, as the H_2S will likely have been oxidised to SO_3 by the time it reaches ground level at the bottom of the hill (see Appendix 12).

Pipe line and power line right-of way will have impacts on wildlife habitats. Shear clearing through the characteristic Leleshwa bushland around power plant is not consistent with good forestry and wildlife management practices.

3.3.1 Impacts on Flora

As the intensive development of the power plant in Olkaria III is associated with clearance of land of soft hydrothermally altered rocks, some plant associations have changed. There has been a conversion from Leleshwa bushland to open shrubland and bushed shrubland dominated by opportunistic weeds typical of cultivated and disturbed fields. The significant impacts accruing from the development of the geothermal power plant on the flora in the area include:

- Replacement of Leleshwa bushlands with open shrubland and bushland shrubland. This could lead to a loss of some plant species typical of the bushland vegetation.

- Invasion of the cleared construction sites and road sides with opportunistic weed plants e.g. *Datura stramonium, Nicotiana glauca, Solanum incanum, Tagetes minuta, Ricinus communis, Portulaca oleracea, Calotropis procera* etc. This is likely to change the physiognomic characteristics of the vegetation in the vicinity of the geothermal plant.
- Dust from the construction sites and roads settle on plants and interfere with their photosynthetic capacity, thus lowering their productivity with the likelihood of stunting their growth.
- Sites for the construction of the access roads, drilling pads, drilling camp, steam pipe and power lines right-of-way and areas for the storage of pipes require a large area of land which has to be cleared of vegetation.
- Likely loss of biodiversity, especially the rare and unusual floral species unique to the ecoclimatic zone 5, for example species of orchids, woody plants, pteridophytes, ferns and sedges.
- Depending on the quantities produced and weather conditions, gaseous effluents such as hydrogen sulphide (H_2S), sulphur dioxide (SO_2), ammonia (NH_3) and carbon dioxide (CO_2) released in escaping steam are likely to have some impacts on the vegetation of the area in the long term. Work by Thompson and Kats (1978) showed that constant exposure to H_2S concentrations of 0.3 ppm or over affected the foliage and growth of California buckeye, lettuce, alfalfa, sugar beet, grapes, ponderosa pine and Douglas fir. However, low concentrations of H_2S at 0.1 and 0.03 ppm had little effect, and actually stimulated the growth of the field crops. A number of studies (EPA, 1977; El-Hinnawi, 1981) indicate that some plant species show significant tolerance to foliar concentrations of most of the gaseous effluents associated with geothermal power production. Studies done at the KenGen Olkaria east area on the impacts of H_2S on flowers showed no deleterious impacts. The long-term effects of sustained exposure to the current levels of H_2S, SO_2, NH_3 and CO_2 on the local natural vegetation, and on the possibility of formation of acid rains near the Orpower Geothermal Plant needs further investigation. Marani (1995), however showed that there was no acid rain induced by H_2S emissions from the current KenGen power plant at Olkaria east.

- Loss of unique sensitive habitats and scenic natural sites, along with their associated unique flora, for example parts of the Olkaria Hill and the Hell's Kitchen and rocky/soil formations surrounding the outlets of the underground steam vents.

3.3.1 Impacts on Fauna

The development of Orpower Geothermal Plant in Hell's Gate National Park has many potential impacts on the wildlife in the park. Foremost among them is the loss of their natural habitat and migration route areas which have been used for the construction of the access roads, drilling pads, camp sites, pipe lines, power transmission lines and sites for storage of construction material. It is possible that some important wildlife feeding and breeding/nesting sites have been disturbed. It is worthwhile noting that the development of the power plant, KenGen Power Plant and the fencing of the Kongoni Ranch, has led to isolation of a group of giraffes, buffaloes and the rare mountain reedbuck from the rest of the wildlife population in the park. Furthermore, recent censuses show a decline in wildlife population in the park. In summary the likely impact of the geothermal power plant development on fauna include:

- Loss of some habitats of some rare wildlife species (e.g. the mountain reedbuck) might put them in danger of becoming extinct.
- Noise during construction, testing of the wells and the operation phase of the project is likely to have adverse effects on wildlife. Currently the mountain reedbucks are found in the Hobbley Volcano area instead of their normal home on the Olkaria Hill.
- Transmission power lines and steam pipes are likely to interfere with wildlife migration routes and/or isolate some populations in the park. This could interfere with breeding patterns of some wildlife and the roosting/homing behaviour of some important birds prey e.g. the Ruppel's Griffon Vultures, which travel long distances to feed during the day, but return in the evening to their nests on the Vulture Cliffs in the park.
- High-voltage transmission lines are likely to have adverse effects on wildlife and human beings in the area. There is some evidence to indicate that behavioural modification may occur among waterfowls when crossing a wetland area (El-Hinnawi, 1981). This could result in the absence of birds covering an area of 1 km of the transmission lines. The swaying of the lines in the wind, their reflective properties and the humming of the lines probably scare

away the birds. Transmission lines can have an effect on migratory birds using magnetic homing. According to Janes (1977), electric fields associated with transmission lines can produce a charge on animals or human beings within the range of its influence.

- Gaseous effluents e.g. H_2S, SO_2 and NH_3 which are to cause or exacerbate certain diseases in human beings, are likely to have similar effects on wildlife around the power plant.
- Loss of unique sensitive habitats and scenic natural sites, along with their associated unique fauna (e.g. the leafhopper insect, mountain reedbuck), for example parts of the Olkaria Hill and the Hell's Kitchen near the Orpower Plant. This would further endanger the survival of the already threatened species.
- The geothermal plant will reduce the aesthetic and natural value of the landscape and this is likely to scare away the wildlife. It is noticeable that mountain reedbucks have moved from their normal home on the Olkaria Hill, near the plant, to the Hobbley Volcano area.

3.3.2 Impacts on Lake Naivasha

- Abstraction of water from Lake Naivasha catchment as steam and for cooling or condensing steam is likely to have an effect on the hydrology of the area over the long term as the number of companies producing geothermal power increase.

The construction of staff houses near the lakeshore could have adverse pollution effects on the lake.

5.4.0 SOCIO – ECONOMIC IMPACTS

The project will enhance cash economy activities in an area of traditional economic activity. Demand for livestock products (especially meat and milk) by the plant construction crew will be high during the construction phase, but less after construction is complete. Benefits and Costs of the project to the stakeholders are considered below.

5.4.1 The Maasai Community

5.4.1.1 Social benefits: The Maasai community members felt that they would benefit from:

- The expansion of the road network
- Additional nearby health centers and schools that would be built for workers
- The nearby water tanks and watering points that would be built for project operations
- The telecommunication facilities that would be put in place like telephone booths
- The increased employment opportunities that the project could bring for about 20 Maasai (including 2 of the graduates students)
- Reduced cases of water borne diseases like cholera and typhoid
- The shopping centers built for the workers
- Vehicles giving lifts, to and from the park
- Increased collaboration with the self help groups
- Increased demand for livestock and livestock products by plant workers
- Increased security due to the project's security arrangements on equipment and storage yards.

5.4.1.2 Social costs: The community members were concerned about:

- The increased noise levels that the project would bring due to the drilling and testing of new wells (80 dB for 8 hrs per day or more) and also from construction and general operations
- The increased noise levels that would be brought from speeding vehicles
- The increased dust levels and smells (hydrogen sulphide) the project would bring as it expands
- A rise in incidences of respiratory diseases such as asthma, eye problems, colds and flu. The residents also expressed fears that the nausea-inducing H_2S would affect pregnant

women and their unborn children. No impacts on unborn children are reported in the literature, but it is important to explain this to the community for them to accept the project.

- Displacement/ resettlement from their present homes due to wells, pipes, the power plant and transmission lines (residents would be required to live about 100 away from the power lines)
- The reduction in land size(s) as the project expands to a total area of 8 km^2
- The reduction in dry grazing land for the Narasha and Suswa pastoralists
- Their identity and cultural values being eroded by outsiders
- Increased traffic in the park from workers and visitors
- A lack of privacy to carry out their sacred rituals like circumcision and prayer sacrifices
- Increased injuries to community members and the livestock due to steam and power transmission lines and leaking water
- The possibility of Narasha wetland (Lake Odongo) being polluted with drilling and waste fluid effluents. However, this is unlikely, as explained earlier.

5.4.1.3 Living standards and quality of life: The extent of realisation of these benefits and costs will depend on the efforts made by the community members to interact with the project, and by the project to reach out to the local community. The Maasai have proved over the years to be extremely resistant to change and influence from out side cultural and economic forces. Only the small numbers who go beyond High School in education are likely to adopt a westernised life style. It is expected therefore, that for the majority of the Narasha Maasai community members, their diet, clothing, and housing will not be greatly changed by the project.

5.4.2 Other Stakeholders

5.4.2.1 LNRA: The findings indicate that the project would provide benefits from reduced rationing of electricity and unscheduled blackouts.

The findings however revealed that there was concern over increased abstraction of over 4.2 million gallons of water (30,000m^3 per month mainly for drilling), especially during these prolonged dry conditions. There was also concern on the long and short- term effects of drilling and re-injection on the interrelationship between surface and underground aquifers. There was also concern on the possible hydraulic-link from the lake to the geothermal field, which could result in the lowering of Lake Levels. There were also concerns over the safe and harmless disposal of potentially harmful wastewater (containing high fluoride, arsenic and mercury levels).

5.4.2.2 KWS: The findings indicate that the project would provide benefits from the electricity generated, and the expanded road network. There was however concern over the future state of the park and it's surrounding after the project lease ends in about 40 years' time, the increase of power lines from Olkaria's 132kv to Ormat's proposed 220kv power line. There was also the fear that more independent power producers would come into the park. There was also concern over the interference of nature trails and picnic sites, lights and noise during night camping and lack of compensations for loss of revenue, tourist safety and enjoyment, the speeding of vehicles and also the location of the park on Olkaria hill. KWS was also concerned about the disposal of waste (cigarettes, paper, used pipes, plastics and human waste), which could affect the health of the wildlife.

5.4.2.3 Oserian Development Company: The study revealed that Oserian Development Company felt that the project would provide benefits due to the increased electricity supply to the national grid. There was however general concern over the spoilage of the natural beauty of the Kongoni wildlife sanctuary as the project expands.

5.4.2.4 Fisheries: There was general concern over siltation of the aquatic ecosystems from increased erosion due to the construction of roads and drill pads, the laying of pipes, and also from runoff from waste water from wells and from burst pipes. There was also concern of long-term acidic precipitation on aquatic life. It was also revealed that the project would provide benefits due to increased electricity supply.

5.4.2.5 Municipal council: There was concern over the break down of waste disposal systems due to over use, and pollution of the lake and surrounding environments. It was revealed that the project could provide benefits if there was sharing of technical information on waste disposal systems.

5.4.2.6 KenGen: There was general concern over the possible interferences of the various reservoirs, resulting in wells producing at lower rated capacities/levels. There was also concern on power price charges, which could affect the purchase price for KenGen generated power. KenGen also revealed that they might benefit from offering consultancy services to the independent power producers.

5.4.2.7 Tour operators: There was concern over increased traffic and commercialization of the park. There was also concern over the design of the expanding road network. The tour operators felt that the project would provide benefits due to the expanded road networks.

5.4.2.8 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. The Forest department felt that the project would provide benefits if they donated indigenous tree seedlings from any nurseries they may establish.

5.4.2.9 District environmental protection officer: There was concern over waste that could not be readily combustible and also on the aesthetically appropriate location of landfills. Perceived benefits from the project were increased energy supply.

5.4.2.10 Lake Naivasha growers group: There was general concern over the improper storage of oil and grease products in the warehouses, which could pollute the soil over a long period of time.

5.4.2.11 District officer: There was general concern over responsible and safe geothermal exploitation practices, with due regard to the interests of the community and the environment.

5.4.2.12 Ministry of land and settlement: There was general concern over displacement of the affected residents/families.

6.0 ASSESSMENT OF ALTERNATIVES

6.1 ASSESSMENT OF ALTERNATIVE ENERGY SOURCES

This project is aimed at producing electricity from geothermal energy. The electricity produced will be fed into the national grid, to meet a shortfall in generation capacity for electricity in Kenya.

Acres International (1987) and Ewbank Preece Ltd. (1989) discussed Kenya's electrical power needs and alternative methods of meeting these needs.

The alternatives include (a) doing nothing, which means that growing demand will remain unmet, (b) import power from Uganda, (c) develop further hydro projects, (d) develop coal - fired, oil - fired, or gas turbine plants, (e) develop wind or solar power systems, (f) conserve energy, or manage demand. To these may be added (g) generate from municipal and agricultural wastes and (h) use nuclear energy.

The do nothing alternative is economically, and politically untenable, since it results in unacceptably high costs in lost economic and social activity. Imports from Uganda have been unreliable, since, although an agreement for importation of 30 Mwe has been in force since 1954, the available supply has been only about 10 Mwe. It is estimated that large scale (>1 Mwe) hydro potential in Kenya is 841 Mwe, out of which 598.5 Mwe has already been harnessed. There is therefore little prospect of satisfying national requirements using hydro in the long run, especially after the development of the Sondu Miriu in Western Kenya, currently under construction. The use of fossil fuels may be necessary to meet emergency shortfalls in electricity supply in Kenya. However, fossil fuels have high environmental and economic costs. The energy resources have to be imported, since Kenya does not have proven reserves of fossil fuels, and emissions of CO_2, SO_x, and NO_x will be much higher than for a geothermal power station. Wind and solar energy potential in Kenya is very high, but reliability, technological, and cost considerations preclude their use as serious sources of electrical energy on a large-scale national level. They also have environmental impacts that need to be examined when they are given serious consideration. Energy conservation is always a desirable and even economically beneficial measure. But it alone cannot make up for national energy shortfalls in an economy that is developing. Use of municipal wastes is also an attractive option, both from an economic and environmental viewpoint. It needs to be explored for supplementation of national electricity requirements, and also to alleviate the problems of waste disposal. It is not considered an immediate option in the crisis that Kenya finds itself in. Similarly, nuclear energy has environmental costs that are not acceptable, especially at this stage of Kenya's development, where safety regulations may not be strictly enforced.

This means that geothermal energy is the most viable option for the immediate future in Kenya. It is an indigenous resource that is found in large quantities in the Rift Valley of Kenya.

Since geothermal energy must be utilised or converted in the immediate vicinity of the resource to prevent excessive heat loss, the entire fuel cycle, from extraction to transmission, is located at one site. This offers environmental advantages in terms of land area requirements, and in terms of effluent disposal. As such its impact on the biological environment (flora and fauna) is minimal. Furthermore, because geothermal power plants can use recycled condensed steam for cooling, the plants do not necessarily require external water sources. This helps in the conservation of surface freshwater in aquatic ecosystems. However, geothermal energy development has a number of negative environmental impacts on flora and fauna as discussed under impacts above. It is, however, apparent that geothermal energy development offers several significant advantages over hydropower, fossil and nuclear energy projects. Below is a brief outline of impacts of alternative energy sources.

6.1.1 Hydro-Power Production

Hydro-electricity generation has a number of impacts on the physical, social, and biological environments. The building of a dam converts a predominantly terrestrial environment into an aquatic environment, and completely changes the hydrological regime of the area. This can set in motion a series of drastic impacts on biological systems. The flooding of the area has immediate significant impact on the flora and fauna, and sensitive and important natural habitats, which are inundated.

The construction of a dam and the creation of the associated reservoir/man-made lake have the following impacts on the terrestrial flora and fauna:

1. The disappearance of terrestrial and riverine environments along with most of their biodiversity.
2. If hydropower was to be developed in the Hell's Gate National Park instead of geothermal, a very large area of the park would have to be flooded with water and this would have more damaging impacts on the plants and wildlife.
3. Increase of incidences of water-borne diseases e.g. malaria and bilharzia (schistosomiasis).
4. Impoundment or damming of rapid-flowing rivers reduces the incidence of the river blindness (Onchocerciasis).
5. The impacts of high-voltage power transmission lines are similar to those of the geothermal power production.

6.1.2 Solar Energy

Though the costs of initial installation of solar panels can be a hindrance to its development, the use and development of solar energy is more environmentally friendly that most of the other energy sources. Decentralised small units (e.g. water heaters, solar dryers, cooker, solar refrigeration etc.) do not only reduce the demand geothermal energy leading to conservation of such renewable energy sources, but also lead to the reduction of the bulk of the pollutants emitted from the geothermal plant. The main setback of solar power plants is the extensive land requirements. The development of solar energy plant in the Hell's Gate National Park could have the following impacts on the biological environment of the area:

1. A large area would be cleared for the setting up of the plant.
2. A lot of wildlife would be displaced.
3. Many floral and faunal habitats would be destroyed.
4. Aside from the land requirements, however, the production of solar power would have less

impact on the biodiversity of the area because solar plants do not emit gaseous, liquid or solid wastes, as do geothermal power plants.

6.1.3 Wind Energy

Since the ground area requirements are small and the land surrounding the windmills can be used with few restrictions, the use of wind energy has far less impact on plants and wildlife that the geothermal energy. However, the windmills might interfere with the migration routes of wildlife, especially the birds. Otherwise, development and production of wind energy is more environmentally friendly than geothermal energy.

6.2 ASSESSMENT OF ALTERNATIVE SITES

Analysis of sites for geothermal energy development in the Kenyan Rift Valley have concluded that the Greater Olkaria area has the best prospects for development due to its location close to existing infrastructure, and the high energy potential (Glover, 1972; Sweco/Virkir, 1976; KPLC, 1980; KRTA, 1985; Acres International, 1986). Seven fields, Olkaria East (I); Olkaria Northeast (II); Olkaria West (III); Olkaria Northwest; Olkaria Central; Olkaria Southeast; and Olkaria Domes have been delineated on the basis of geological, geophysical, and geochemical modeling of the field.

The Greater Olkaria geothermal area falls within the Hell's Gate National Park and surroundings, in an otherwise sparsely populated area that for a long time was traditionally used for pastures by the Maasai. KenGen has developed the Olkaria East field for generation of 45 Mwe, and is awaiting funds to further develop a 64 Mwe at Olkaria Northeast. It is likely that given the current and continued power deficit in Kenya, the other fields will also be developed over time. This calls for the development of a management plan by KWS and the Ministry of Energy for the Greater Olkaria area, so that power development is done in the most environmentally friendly manner. One option would be to site the power stations outside the National Park, and do directional drilling into the geothermal fields. Cost analyses of these options, however, need to be carried out well in advance.

The present location of the Orpower Olkaria III station has the disadvantage of being located on high ground, so that it is a visual intrusion into the surrounding natural environment, and landscaping has resulted in movement of large volumes of soils. As against this, the location allows for easier dispersion of the non-condensable gases than would be the case if the power station were located at the foot of the hill. Distances of transport of geothermal fluid are also reduced, since the power station is close to the production wells. Siting the station at Narasha seasonal wetland would also have resulted in greater damage to the ecological functions of the wetland. Under the circumstances, the present location of the Olkaria III power station is considered optimal, provided that environmental precautions outlined below are adhered to.

Siting of the plant outside the Hell’s Gate National Park is likely to have fewer impacts on the wildlife but would still affect the vegetation and human settlements.

7.0 MITIGATION MEASURES

7.1 MITIGATION OF PHYSICAL IMPACT

7.1.1 Soil Erosion

It will be necessary to make the drill site ground smooth to a uniform slope and plant grass on it. Star grass that has been planted at Olkaria East pads has been found to spread rapidly covering the bare area quickly.

Studies show that fluid re-injection is the only way the wastewater can be disposed because of its technical, economic, and environmental viability and acceptability. Where re-injection is not possible, ponds will have to be dug to confine the wastewaters so that they do not cause soil erosion, or go to watercourses where animals and plants will come into contact with them. Such ponds must be properly fenced to keep the animals away. In summary,

- All bare surfaces like the well pads should be graveled or re-vegetated with plant species that spread rapidly like the star grass and Rhodes grass that can cover the ground quickly.

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

- All run-offs from stabilized roads (murram or tarmac) through culverts should be handled in the best way to avoid gulley erosion. New run-off can be diverted at regular intervals before it accumulates to problem levels.

7.1.2 Volcanic and seismic hazards mitigation

It has been argued that the evolved nature of the most recent volcanics at Olkaria West indicates that an active magma chamber still exists and the last eruption occurred ~200 years ago. There are risks in terms of emission of poisonous gases, ashes and surface deformation. It is therefore necessary at the earliest to assess the depth to this magma chamber, status of the melt and any changes in chemistry. This can be achieved by monitoring for changes in the concentrations of magmatic gases such as CO_2, H_2S, NH_3, CH_4 and N_2 of a few identified fumaroles on a regular basis (once a month).

A permanent micro-seismic monitoring network is another useful way of monitoring volcanic activities. While micro-seismic activities in a volcanic area such as Olkaria is invaluable in giving information on fluid movement within the reservoir, it is also useful for monitoring the magmatic activities that might occur before a volcanic eruption. Collection of such data also brings about concilence between geothermal power development, geological hazard identification, and environmental impacts, because earthquakes are indicators of both geothermal fluids and subsurface stress conditions. As opposed to tectonically derived seismicity, volcano-seismic events manifest themselves as a series of sequences of events with high intensity above background that occurs before the eruption. These are as a result of magmatic injection and expansion of high-pressure fluids as it enters crustal rocks thus causing fracturing. This is also accompanied by subterraneous noises that can be detected by micro-seismic equipment. It will be necessary to establish a multi purpose micro-seismic monitoring network to be used not only for the volcano-seismic hazard monitoring but also for monitoring;

1. The changes in geothermal reservoir phases (water/steam) during exploitation.
2. Seismicity caused by movement of injected fluids.
3. Seismicity induced by exploitation.
4. Fault mapping and activation of fault systems
5. Aiding location of best drilling targets at fault intersections

Early installation of a network is important for continuous resource evaluation and risk monitoring. Monitoring the magma activities of this volcano will form a basis for an early warning system. This can be carried out by analyzing seismic waves for attenuation, reflected arrivals, delayed arrivals and changes in intensity and focal depths that may be related to upsurge of magma bodies beneath the volcano.

7.1.3 Mitigation of noise impacts

Although there is no power plant in operation right now in the Olkaria III field, it is anticipated that when it becomes operational, there will be noise above the permitted dB levels, especially in the power plant area. This will be a problem especially to the personnel working in the powerhouse. Noise control measures 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 vibrations control within the original design of the equipment in order to avoid generation and structural transmission. Where noise control cannot be mitigated in the original design, acoustic barriers and silencers must be used.
- It is recommended that exposure to workers should not exceed 8 continuous hours for noise levels of 85 dB (A) and above. This will mean use of hearing protection and rest booths, and rotating shifts for workers.

7.2 MITIGATION OF CHEMICAL IMPACTS

7.2.1 Air Quality.

7.2.1.1 Hydrogen Sulphide

The most dangerous gas produced in the geothermal system is hydrogen sulphide. From the data presented, this gas is not high enough to pose health risks. The gas concentration is less than Olkaria Northeast field, where it has not been giving any problem. However, new wells must be monitored for H_2S content. Metallic structures should be painted to protect them from corrosion.

7.2.1.2 Carbon dioxide

To reduce the effects of high concentrations of carbon dioxide on the environment, re-injection of all geo-fluid into the ground will help. Another alternative is to trap and bottle the gas for selling to Carbacid Ltd. or to BOC Gases Ltd. who mine it in other locations in Kenya and sell it for the manufacture of carbonated drinks. The gas can also be reacted with sodium hydroxide, readily available from Magadi Soda and purifying and selling the resulting sodium carbonate as a laboratory reagent. Another option is to deep case all the wells in this field, because sodium carbonate waters seem to be coming into the wells at shallow depths. Deep casing will seal off inflow of high CO_2 water.

7.2.1.3 Geothermal brine

The only hazardous chemicals in the geothermal brine are fluoride and boron. If most of the geothermal water is going to be re-ejected into the ground, then the effect of these substances will be minimized. In the event of malfunction of reinjection wells, all water should be drained into an infiltration pond that has a perimeter fence, to keep off domestic and wild animals from using the water. Plants that grow around surface ponds must be regularly harvested and disposed of in a way that livestock and wild animals will not feed on it.

7.2.2 Suspended particulate matter (Dust).

Some of the ways of removing dust is by filtering, washing, centrifugal separation and electronic precipitation, which are difficult and costly. Dust from moving vehicles on earth roads, can be reduced by watering, applying gravel, or road tarmacing and reducing vehicle traffic on the road.

7.3 MITIGATION OF BIOLOGICAL IMPACTS

Given that the siting of the Orpower Geothermal Power plant is partially in the Hell’s Gate National Park, it is very important to put in place measures to mitigate and monitor significant impacts of the development of the plant on the biological environment. This is to ensure the co-existence of the power plant and the game park.

The combination of a national park and a geothermal power station enhances tourism in the area, since some tourists come specifically to view the geothermal power station. The following mitigation measures are recommended to ameliorate adverse biological impacts.

- Significant and unique natural sites e.g. the Hobbley Volcano and the Hell's Kitchen need to be gazetted as "Protected Areas of National Importance".
- Kenya Wildlife Service should urgently undertake and Environmental Impact Assessment to map out important breeding and nesting sites for rare and important migration routes for wildlife in all of the Hell's Gate National Park. This will minimise the conflicts between wildlife conservation and development of geothermal power plants in the area now and in the future.
- Monitoring of the significant impacts predicted in this and other studies should be carried out on a long-term basis, to ensure that the right mitigation measures are put in place to minimise the negative effects on the environment.
- Frequent meetings between all stakeholders – KWS, KenGen, Lake Naivasha Riparian Association and the local Maasai communities should be encouraged.
- To conserve the beautiful natural landscape in the park, the Orpower Company should attempt planting the Fever Tree (*Acacia xanthophloea*) around the plant, especially in areas where the groundwater table is high. This is a large, tall indigenous tree reaching 25 m or more. The tree is fast growing, and attractive as an ornamental and could be a good camouflage for the geothermal power station.

7.3.1 Flora

- Areas with endemic and/or rare plant species e.g. some selected steam vents/ fumaroles need to be set aside as "Protected Areas" where development of geothermal power plants should not be allowed.
- Clearing of drilling pad sites, pipe ways, plant station, and access ways should be kept to a minimum.
- The areas cleared for the drilling campsite and storage of pipes should be rehabilitated after the drilling by removing the camp structures and replanting the area with Leleshwa bushland vegetation.
- Replanting of the indigenous species that were cleared should be done immediately, to avoid invasion by opportunistic pioneer species.

- Exotic species should not be introduced into the area.
- Opportunistic pioneer species e.g. *Datura stramonium, Nicotiana glauca, Solanum incanum, Tagetes minuta*, *Ricinus communis* etc. and any exotic species in that area should be immediately uprooted and destroyed by incineration.
- Floral species should be investigated every 2 years to monitor any changes in species composition and abundance of vegetation in the area.
- Investigation of the long-term effects of consistent exposure of the local natural vegetation to the gaseous effluents e.g. H_2S, SO_2, NH_3 and CO_2, and the possibility of formation of acid rain near the Orpower Geothermal Plant should be started immediately.

Both Orpower 4 Inc. and KWS concur that these measures should be implemented for their mutual coexistence in the area.

7.3.2 Fauna

- Sensitive habitats e.g. Hell's Kitchen and the Olkaria Hill should be preserved and avoided as sites for construction. This will protect the endangered wildlife species (e.g. the leafhopper insect and the mountain reedbuck).
- Identified animal movement/migration pathways should be kept open. Steam/water pipes should either be buried, or made with high loops at these locations.
- Overhead power transmission lines should be well coordinated and planned so as not to disturb the natural scenery of the park and not to interfere with movements of birds.
- Pipes should be painted with natural camouflage colours so that they blend with the surrounding.
- Pipes should be insulated so as not to scald animals.
- Power transmission line routing should be planned in such a way as to reduce their impact on the wildlife migratory routes. For example, the lines should not impinge on areas valued as routes for migratory birds, nesting/breading sites, or important historic or touristic sites. The

routing of the lines should be planned in such a way as to cover a minimum distance within the park. The Orpower high-voltage transmission line should be linked immediately to that of the KenGen before joining the national grid. KWS should be consulted in the planning of routes for the lines.

- Dust reduction measures on roads should be implemented to mitigate against dust, which causes poor visibility, and may result in animals being knocked down by vehicles.
- Limit the speed of vehicles to 40 km/hour within the park area.
- Limit noise, especially at night.
- Limit light shining away from the plant operations at night.
- Areas where animals can be exposed to drilling or geothermal fluids should be fenced, while ensuring that fences do not enclose small animals. Fences should also not be placed in known migration routes of animals.
- Exotic animals should not be introduced into the area.
- Animal species composition and abundance should be monitored at least every two years.

Both Orpower 4 Inc. and KWS concur that these measures should be implemented for their mutual coexistence in the area.

7.3.3 The Aquatic Environment

- Staff houses should not be constructed too close to the water edge.
- No waste should be disposed of near the lake.
- Waste storage facilities should be designed to cope with periodic breakdown in municipal or private waste collection systems.
- Orpower should be an active member of the Lake Naivasha Riparian Association.

7.4 MITIGATION OF SOCIAL IMPACTS

In order for the local communities to view the project positively and minimise hostility and conflict, the following measures are recommended.

7.4.1 The Maasai Community

1. The project should involve the community members, through their recognized leaders, in the decision making process for activities that may have adverse impacts on the community like displacement and resettlement.

2. The project should give financial compensation for any community land that may be acquired and used for infrastructural development (roads, wells, pipes and power lines).

3. The project should regularly monitor the health and welfare of the community members.

4. The project should participate in community development activities (e.g. regular donations in cash or in kind to the self-help groups), in order for the community to identify with and benefit from the project.

5. Efforts should be made to supply the community with electricity that is generated from their ancestral land.

6. The community members should be educated on general safety measures in order for them to protect themselves against any harmful incidences.

7.4.2 Other Stakeholders

1. The project should have regular meetings and legally binding agreements with all the stakeholders concerned (particularly with KWS, KenGen, and Oserian Development Company) in order to co-ordinate activities and reduce conflicts. A public relations/ environmental officer should be appointed to participate in the enhancement of the project's activities and image in the area.

2. The project should cost share with KenGen and KWS in the construction of community- based projects like: schools, health centers, roads and water tanks, and also participate in the establishment of tree nurseries.

3. The project should also cost share in research activities with KenGen 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.

4. The project should periodically contract an independent person or group of persons to evaluate conformity of their environmental management systems with the ISO 14001 and 9001 certificate principles and guidelines, and also with the Operational Directive 4.01 of the World Bank and Kenyan legislation

5. The project should regularly monitor daily water consumption through metered readings for drilling, construction and general operations in order to use water efficiently.

6. The project should cost share with KWS and KenGen a park restoration fund that could rehabilitate Hell’s gate park after their operations.

7. The project should maintain the natural appearance and beauty of the park and its immediate surroundings.

8. The project should set an example of how a geothermal power plant can sustainably co-exist with nature.

9. The project should, in partnership with KWS, KenGen, and tour operators, develop a better road network system to link Hells gate, Suswa, Mai Mahiu (this will reduce distance to Nairobi by 20-30 km), and Longonot.

10. The proposed power line of 220 kV should be centralized into one collection point.

8.0 CONCLUSIONS AND RECOMMENDATIONS

The Orpower 4 Inc. geothermal project at Olkaria III, located inside Hell's Gate National Park will have some environmental impacts, mostly on the animals in the Park, especially during construction. Impacts will be less during operation of the power station. The negative impacts can be kept to a minimum by adopting the mitigation measures recommended in this report, and by KWS. Most of these mitigation measures are already being implemented.

Similarly, physical and chemical impacts are minimal, and can be kept to acceptable levels. Monitoring for earthquakes, volcanic hazards, radioactivity, and water bodies in the area is recommended to allow for early precautions to be taken to avoid adverse impacts.

The project is expected to have positive social and economic impacts to the local Maasai community, and to Kenya's economy when it provides electricity. The project should actively seek to create good relations with the local community to enhance acceptability of the project, and improve the socio-economic status of the Maasai in the area. In collaboration with KWS, Oserian Development Company, and KenGen, the project should support community projects in the area (provision of water, electricity, roads, schools, and health facilities).

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10.0 APPENDICES

Appendix 1a: Terms of Reference for the EIA Study

The environmental impact study will consist of:

(i) Preliminary activities: Discussions leading to agreements on Terms of Reference.

(ii) Setting up the team to conduct the EIA

(iii) Impact identification (Scoping)

(iv) Baseline studies, including Physical status (climate, hydrology, soils, and earthquake/volcanic eruption hazards), Biological status (existing plant and animal species), Chemical environment status (air, water, soil pollution), and socioeconomic status (livelihoods, lifestyles, and income levels).

(v) Impact Evaluation (Quantification) of the likely impacts on the Physical, Biological, Chemical, and Socio-economic milieu as documented in (iv) above.

(vi) Mitigation measures to conserve, or improve on the milieu in (iv) above to maximise project benefits to the environment.

(vii) Assessment (Comparison of Alternatives)

(viii) Documentation (production of the final EIA report, including assessment of alternatives)

At all stages, consultations with all stakeholders will be made in so far as is possible (Local communities, Environmental Advocacy groups in the area, including the Lake Naivasha Riparian Owners Association, Relevant Government ministries and departments, NGOs, and CBOs).

Appendix 1b: List of Environmental Impact Assessment Study Personnel

Coordinator of Study	Prof. Mwakio P. Tole, PhD Professor of Environmental Geochemistry, School of Environmental Studies, Moi University
Biological Impacts	Dr. William Aino Shivoga, PhD Lecturer in Biological Sciences, Department of Environmental Sciences, Egerton University
Physical Impacts	Dr. Silas Simiyu, PhD Geophysicist, KenGen, Olkaria Geothermal Power Station
Chemical Impacts	Mr. Musa Arusei, B.Sc., M.Sc., PhD candidate, and Lecturer in Chemistry, Department of Chemistry, Moi University
Socio-economic Impacts	Ms. Charity Konana, B.A.., M.Phil. (Candidate), Moi University, School of Environmental Studies.

Appendix 2: List of Interviewees

All interviews were conducted between 26th April, 2000 and 20th May, 2000. Interviewees included:

1. Maasai Cultural Center Group
2. Residents of Narasha village
3. Orpower 4 Inc. Staff
4. KenGen Staff
5. KWS warden at Hell's Gate National Park
6. Lake Naivasha Riparian Association staff
7. Oserian Development Company Staff
8. Fisheries Officer, Naivasha
9. District Officer, Naivasha
10. Tour operators
11. Forestry Officer, Naivasha
12. Farmers, Lake Naivasha area
13. Lands Officer, Naivasha

Appendix 3: Monthly rainfall for Olkaria West area (1996).

MONTH	***RAINFALL IN MM***
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	**666.4**

Appendix 4: Preliminary annual water budget (in millions of cubic meters of water) for Lake Naivasha. Source: Lake Naivasha Management Plan (1999)

Inputs	**Wet Conditions**	**Mean Conditions**	**Dry Conditions**
Direct rainfall over the lake	140.8	72.9	45.0
Malewa river	378	153	53
Gilgil river	74	24	3.2
Karati river	6.5	2.1	0.28
ungauged area of the watershed	117.8	77.9	34.2
Seepage-in	54	54	32
TOTAL INPUTS	**771.1**	**383.9**	**167.7**
Outputs	**Wet Conditions**	**Mean Conditions**	**Dry Conditions**
Loss due to Evapotranspiration	38.5	26.7	21.9
Evaporation loss	229	183.5	177.8
Seepage-out	54	54	32
Abstraction (estimated)	33.8	44.6	53.2
TOTAL OUTPUTS	**355.3**	**308.8**	**284.9**
BALANCE	**415.8**	**75.1**	**-117.2**

Appendix 5: Concentrations of H2S measured at various sites around Olkaria I area

	W shop	Power St.	Adm.	Spit 1	Spit 2	W1	W2	KWS	L. View	L. Site	Store	OW-709
Av.	0.02	0.50	0.05	0.16	0.19	0.093	0.06	0.02	0.00	0.00	0.12	0.04
Max.	0.80	4.40	1.30	2.80	3.40	1.30	1.00	0.20	0.10	0..00	1.00	0.2
Min.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Median	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

From (Kubo et al., 1999)

Key: W shop - Workshop; W1- Workshop 1; W2 -Workshop 2

Appendix 6: Floral Checklist in the Vicinity of Olkaria III area at theOnset of the Wet Season, May 2000

Taxa	Remarks
ACANTHACEAE	
Hypoestes aristata (Vohl.) Roem. & Schultes	-Common in dry grassland and bushes
Thunbergia alata Sims.	-Trailing or climbing in *Tarchonanthus* bushes
AMARANTHACEAE	
Achyranthes aspera L.	-Grows at bush edges
	-Scrambler on bush thicket
A. aspera varisicula L.	-Weed of cleared disturbed/ construction sites
Amaranthus hybridus L.	-Open, cleared ground
Alternanthera pungens Kunth.	
AMARYLLIDACEAE	
Crinum macowanii Bak.	-Fairly common in open grassland
ANACARDACEAE	
Rhus natalensis Krus.	-Seasonal streams edges, browsed by animals
APIACEAE	
Heteromorpha trifoliata Chum. & Schldl.	- Along seasonal streams/drainage gorges
ARALIACEAE	
	-Edges of seasonal streams

Cussonia spicata Thunb.

ASCLEPIADACEAE

Calotropis procera	-Poisonous plant, common on the road sites
Sacostema viminale R.Br.	-Stem exudes latex, along seasonal streams

ASTERACEA

Artemisia afra Willd.	-Leaves sweet scented, common under the bush -Common in bush and on roadsides
Aspilia massambicensis (Oliv.) Willd.	-Occurring in grassland along roadside
Athroisma psyllioides (Oliv.) Matlf,	-Dry grassland
Felicia muricata (Thunb.) Nees.	-Grows in cultivated and disturbed ground
Galinsoga parviflora Cav.	-Rocky eroded poor grassland
Guternbergia cordifolia Oliv.	-Common on edges of seasonal streams
Senecio petitianus *A.Rich.*	-Abundant, troublesome weed
Tagetes minuta L.	-Dominant vegetation in the Olkaria III Geothermal Plant area
Tarchonanthus comphoratus L.	-Disturbed sites with *Urtica massaica*

Vernonia laesiopus O.Hoffm.

BORAGINACEAE

Cynoglossum coeruleum A.DC.	-Nutlets of the plant usually spring all over

CAESALPINACEAE

Chamaecrista mimosoide L.	-Near steam vents

CAMPANULACEAE

Wahlenbergia abyssinica (A.Rich.) Thulin.

CAPPARACEAE

Maerua triphylla Forssk. -Gorges and luggas/seasonal streams

COMMELINACEAE

Aneilema sp. -Near steam vents

Commelina africana L. -Yellow flowers

C. benghalensis L. -Blue flowers

C. imberbis Hassk. -Near steam vents

CONVOLVULACEAE

Ipomea wightii (Wall.) Choisy. -Browsed by animals

CRASSULACEAE

Crassula volkensii Engl. -Associated with mosses near steam vents

Kalanchoe densiflora Rolfe. -Found in bushes and disturbed places

CRUCIFEREAE

Erucastrum arabicum Fisch. & Mey. -Wild vegetable

CUCURBITACEAE

Cucumis ficifolius A.Rich.

Zebrina scabra (Lin.f.) Sond. -Common on bush thickets

CYPERACEAE

Cyperus giolii Chiov.	-Found in wooded grassland
C. rotundus	-Common on wet ground
Fimbrisylis exilis (H.B.N.) Roem. & Schult.	-Associated with the presence of steam vents

ERICACEAE

Erica arborea L.	-Very common on volcanic rocks and cliff edges at Hell’s Kitchen and Hobbley Volcano

EUPHORBIACEAE

Acalpha volkensii Pax.	-Fertile ground in association with *Urtica massaica*
Clutia abyssinica Jaub. & Spach.	-Associated with *Tarchonanthus* undisturbed bushes
Euphorbia crotonoides Boiss.	-Contains milky latex, browsed by wild animals
E. prostrata Ait.	-Has milky latex
Ricinus communis L.	-Wild weed on any open ground

GLEICHENIACEAE

Dicranopteris linaeris (Burm.f.)	-Steam vents

LABIATAE

Ocimum gratissimum L.	-Found in association with *Tarchonanthus* bushes/disturbed sites
Fuerstia africana T.C.E.Fr.	-Leaves with orange dye when squeezed
Prectranthus laxiflorus Benth.	-Common on edges of seasonal streams
P. silvestris	-Near steam vents

P. tenuiflorus (Vatke.) Agnew.	-Found in rocky places
Satureia biflora (CD.Don.) Benth.	-Common in dry grassland
LILIACEAE	
Asparagus africanus Lam.	-Occur in open vegetation forming low bushes
Gloriosa superba L.	-Brilliant red flowers
Onithogalum gracillimum R.E.Fries	-Forms a bulb in the ground
LYCOPODIACEAE	
Lycopodium cernuum L.	-Steam vents
MALVACEAE	
Abutilon mauritianum (Jacq.) Medic. Miller.	-Common on wet dumpy ground
A. longiscupe Hochst. Miller.	-Seasonal stream edge
Hibiscus fuscus Garcke	-Common on disturbed ground
H. vitifolius	-Common on disturbed ground
Sida cuneifolia Roxb.	-Found in Grassland bush
MELASTOMATACEAE	
Dissotis senegambiensis (Guill. & Perr.9 Triana.	-Gorges near steam vents
MENISPERMACEAE	
Cissampels pareira L.	-Common in fertile bush
MORACEAE	

Ficus ingens Miq.	-On rocky cliff edges near steam vents
Ficus spp.	-On rocky cliff edges near steam vents
MIMOSACEAE	
Acacia drepanolobium Harms	-Common on dry rocky hill side in association with *Tarchonanthus* bushes
A. xanthophloea Benth.	-Not common, found near dams, gorges and luggas/seasonal streams
MYRATACEAE	
Syzigium sp.	-Near steam vents on rocky cliffs
OLEACEAE	
Olea africana (=*O. europoea*) L.ssp.	-Gorges and Luggas/seasonal streams
OPHIOGLOSACEAE	
Ophioglossum rubellum A.Br.	-Steam vents
ORCHIDACEAE	
Angraecum humile	-Associated with humid, hot steam vents
Ansellia gigantea	-Associated with humid, hot steam vents
Pteroglossaspis ruwenzoriensis	-Associated with humid, hot steam vents
PAPILIONACEAE	
Crotolaria laburnifolia L.	-Widespread in bush-land and grassland -Found in cleared places and bush-land -Near steam vents
C. balbi Chiov.	-Grassland and bush
C. chrysochlora Harms	-Bushland and at the dam

Indigofera arrecta A.Rich.	-Grassland in association with *Penisetum clandestimum (= P. kikuyorum)*
Rhynchosia elegans A.Rich.	
Trifolium stedneri Schweinf.	
PHYTOLACCACEAE	
Phytolacca dodecandra L'Herit.	-Poisonous to sheep and cattle
P. octandra L.	-Fruits exude purple colour when squeezed
POACEAE (GRAMINAE)	
Chloris gayana Kunth.	-Seen on road sides and cleared ground
Hyperrhenia hirta (L.) Stapf.	-Common and doing well on cleared sites
Penisetum clandestimum (= P. kikuyorum) Hochst. ex Chiov.	-Common in cleared/sites
Rhynchelytrum repens	-Common in cleared sites and bushland
Themeda triandra	-Common in the bushland in association with *Hyperrhenia hirta*
POLYPODIACEAE	
Pleopeltis macrocarpa (Willd.) Kaulf.	-Steam vents
POLYGONACEAE	
Polygonum pulchrum Blume.	-Near a dam
Rumex usambarensis (Dommer) Dommer	-Invades newly cleared *Tarchonanthus* bushes
PORTULACACEAE	
Portulaca oleracea L.	-Common on sandy and loamy soils

PTERIDOPHYTES	
Cheilanthes multifida (Sw.) Sw.	-Near steam vents
PROTEACEAE	
Faurea saligna	-On cliff edges near steam vents
RANUNCULACEAE	
Clematis brachiata L.	-Wooded grassland/ disturbed ground in association with *Urtica massaica*
RUBIACEAE	
Galium spurium L.	-Common under fertile bushes
Pentas lanceolata (Forsk.) Deflers.	-Common in *Tarchonanthus* bushes
Rubia cordifolia L.	-Roots contain orange dye
SAPINDACEAE	
Dodonaea viscosa (L.) Jacq.	-Found in drainage gorges near steam vents
SCROPHULARIACEAE	
Cycnium tubulosum (L.f.) Engl.	-Near steam vents
SOLANACEAE	
Datura stramonium L.	-A prolific weed, takes advantage of cleared grounds -Exotic, opportunistic plant, common on disturbed, excavated sites -Found along road sides where soil has been scrapped
Nicotiana glauca R. Grah.	-Weed in cleared/cultivated fields
Solanum incanum L.	-One plant spotted on disturbed ground
S. nigrum L.	

Withania somnifera L.	
STERCULIACEAE	
Dombeya burgessiae Gerradex.Harvey.	-While flowers massed in umbels, found in gorges and luggas/seasonal streams
TILIACEAE	
Grewia similis L.	-Gorges and luggas/seasonal streams
URTICACEAE	
Urtica massaica Mildbr.	-Prolific, stinging herb, invades burned/cleared *Tarchonanthus* bushes
VERBENACEAE	
Lantana trifolia L.	-Bush edges and on roadsides -Browsed by goats
Lippia javanica (Burm.f.) Spreng.	

Appendix 7: Mammal Checklist of the Hell's Gate National Park

HERBIVORES

Buffalo	*Syncerus caffer*
Burchell's Zebra	*Equus burchelli*
Chanler's Mountain Reedbuck **	*Rendunca renduca*
Grant Gazelle	*Gazella grantii*
Thompson's Gazelle	*Gazella thomsonii*
Maasai Giraffe	*Giraffa cemelopardalis*
Kongoni (Coke's Hartebeest)	*Alcephalus buselaphus coki*
Eland	*Taurotraqus oryx*
Impala	*Apyceros melampus*
Warthog	*Phacochoerus aethiopicus*
Dafassa Waterbuck	*Kobus defassa*
Klipspringer	*Oreotragus oreotragus*
Steinbok	*Rhaphicerus campestris*
Kirk's Dik Dik	*Rhynchotragus kirkii*
African Hare	*Lepus sp.*
Spring Hare	*Pedetes capensis*
Squirrel	*Finisciurus sp.*
Mole Rat	*Tachyorectes plendens*

CARNIVORES

Lion	*Panthera leo*
Leopard	*Panthera pardus*

Cheetah	
Golden Jackal	*Canis sp*
Silver-backed Jackal	*Canis sp*
Bat-eared Fox	.
Spotted Hyena	

OTHER MAMMALS

Olive Baboon	*Papio anubis*
Rock Hyrax	*Heterophyrax brucei*
Aardvark	*Orycteropus afer*
Hedgehog	*Erinaceus albiventris*

**Threatened/Endangered species

Appendix 8: Birds Checklist of the Hell’s Gate National Park

COMMON NAME	SCIENTIFIC NAME
Maasai Ostrich	*Struthio cemlus*
Secretary Bird	*Saggtarius serpentarius*
Ruppel’s Griffon Vulture	*Gyps ruppellii*
White-backed Vulture	*Gyps bengalensis*
Nubian Vulture	*Torgos tracheliotus*
Egyptian Vulture	*Neophron percnopterus*
Lammergeyer**	*Gypaetus barbaus*
Augur Buzzard	*Buteo rufofuscus*
Cocqui Francolin	*Francolinus coqui*
Scaly Francolin	*Francolinus squamatus*
Hilderbrandt Guinea Fowl	*Francolinus hildebranti*
Helmeted Guinea Fowl	*Numida melaegris*
Speckled Pigeon	*Columba guinea*
Laughing Dove	*Steptopelia senegalensis*
Red-eyed Dove	*Steptopelia semitorquata*
Ring-necked Dove	*Steptopeliacapicola*
White-fronted Bee Eater	*Merops bullockoides*
African Hoopoe	*Upupa epops*
Harrier Hawk	*Polybariodes radiatus*
Batleur	*Terathopius ecaudatus*
African Hawk Eagle	*Hieraaetus spilogaster*
African Fish Eagle	*Haliaeetus vocifer*

Long-crested Eagle	*Lophaetus occipitalis*
Tawny Eagle	*Aquila rapax*
Verreaux's Eagle	*Aquila verrauxii*
Whalberg's Eagle	*Aquila wahlbergi*
Lanner	*Falco biarmicus*
Peregrine	*Falco peregrius*
African Hobby	*Falco cuvieri*
Fox Kestrel	*Falco alopex*
Wattled Starling	*Spreo sp.*
Blue-eared Glossy Starling	*Lamprotornis chalybaeus*
Red-winged Starling	*Onychognathus morio*
Superb Starling	*Spreo Susperbus*
Oxpeckers	*Buphagus erythrorhynchus*
Rufous Sparrow	*Passer motitensis*
Speke's Weaver	*Ploceus sp.*
Schalow's Wheatear	*Oenanthe lugubris*
Yellow Bishop	*Euplectus capensis*
Purple Grenadier	*Uraeginthus ianthinogaster*
Willow Warbler	*Phylloscopus trochilus*
Rattling Cisticola	*Cisticola chiniana*
Tawny-Flanked prinia	*Prinia sublava*
Black-Breasted Apalis	*Apalis flavida*
Red-Faced Apalis	*Apalis rufifrons*
Buff-bellied Warbler	*Phyllolis pulcheella*
Grey- Blacked Camaroptera	*Camaroptera brevicaudata*
Crombec	*Sylvietta brachyura*

Dusky Flycatcher	*Alsenax adustus*
White-eyed Slaty Flycatcher	*Dioptornis fischeri*
Grey Flycatcher	*Bradornis microrhynchus*
Chin-Sport Flycatcher	*Batis molitor*
Hunter's Sunbird	*Nectarina hunteri*
Scarlet Chested Sunbird	*Nectarinia senegalensis*
Variable Sunbird	*Necterinia venusta*
Bronze Sunbird	*Nectarinia kilimensis*
Golden-Breasted Bunting	*Emberiza flaviventris*
Cinnamon-breasted Rock Bunting	*Emberiza tahapis*
Yellow-rumped Seed Eater	*Serinus atrogularis*
Brimstone Canary	*Serinus sulphuratus*
Crimson-rumped Waxbill	*Estrilda rhodopyga*
Common Waxbill	*Estrida astrilda*
Purple Grenadier	*Uraeginthus ianthinogaster*
Pin-tailed Whydah	*Vidua macroura*
Ricenow's Weaver	*Ploceus baglafeht*
Vitteline Masked Weaver	*Ploceus velautus*
Yellow bishop	*Euplectes capensis*
Rufous Sparrow	*Passer motiensis*
Gey-headed Sparrow	*Passer griseus*
Redwing Startling	*Onychognathus morio*
Blue-eared Glossy Startling	*Lamprotornis chalybaeus*
Superb Startlig	*Spereo superbus*
Red-billed Oxpecker	*Buphagus erythrorhynchus*
Black-headed Oriole	*Oriolus larvatus*

Diongo	*Dicurus adsimilis*
Black-lored Babbler	*Turdoides melanops*
Wood Warbler	*Phylloscopus sibilatrix*
Brown Woodland Warbler	*Phylloscopus umbrovirens*
Yellow-rumped Seedeater	*Serinus atrogularis*
Anteater Chat	*Myrmecocichla aethiops*
Fiscal Shrike	*Lanius collaris*
Richard’s Pipit	*Anhus novaeseelandiae*
Rufous-naped Lark	*Mirafra africana*
Redwing Bush Lark	*Mirafra hypermetra*
African Rock Martin	*Hirundo fuligula*
European Swallow	*Hirundo rustica*
Grey-rumped Swallow	*Hirundo griseopyga*
Gey Wagtail	*Motacilla clara*
African Pied Wagtail	*Moticilla aguimp*
Yellow-vented Bulbul	*Pycnonotus barbatus*
Horus Swift	*Apus horus*
Little Swift	*Apus affinis*
Mottled Swift	*Apus aequatorialis*
Nyanza Swift	*Apus niansae*
Nightjar	*Caprimulqus sp.*
Drdric Cuckoo	*Chrysococcyx caprius*
Klaas’s Cuckoo	*Chrysococcyx klaas*
Red-chested Cuckoo	*Cuculus solitarius*
Spotted Eagle Owl	*Bubo africanus*
Kori Bustard	*Ardeotis kori*

Crowned Plover	*Vanelus coronatus*
Crowned Sandpiper	*Tringa hypoleucos*
Temminck's Courser	*Cursorius temminckii*
Speckled Mousebird	*Colius striatus*
Abyssinian Scimitarbill	*Phoeniculus minor*
Gold-tailed Woodpecker	*Campethera cacillautii*
Bearded Woodpecker	*Thripias namaquus*
Plain-backed Pipit	*Anthus leucophrys*
Black- Backed Puff back	*Dryoscopus cubla*
Brown- headed Tchagra	*Tchagra austalia*
Tropical Boubou	*Laniarius ferruineus*
Fiscal Shrike	*Lanius collaris*
Grey- backed Fiscal Shrike	*Lanius excubitorius*
Stone Chart	*Saxicola torquata*
Schalow's Wheatear	*Oenanthe lugubris*
Anteater Chat	*Mymecocichla aethiops*
Robin Chat	*Cossypha caffra*
White-browed Robin Chat	*Coccypha heuglini*

**Threatened/Endangered species

Appendix 9: Questionnaire

Household Number ………..

PART 1: EXISTING CONDITIONS

SECTION A: DEMOGRAPHIC DATA

1. Name ………………………………..
2. Age …………………………………..
3. Sex …………………………………..
4. Level of education ……………………
5. Number of wives ……………………..
6. Number of children …………………...

SECTION B: LAND USE SYSTEM

1. When did you come here? …………….
2. Type and number of animals kept

Type	Number
………..	………..
………..	………..
………..	………..
………..	………..

3. Where do you get your water? ……….

   ………………………………………..

4. Do you practice farming? Yes ……….

   No ……….

   If yes, where? …………………………

SECTION C: ECONOMIC ACTIVITIES

1. What income generating activities are you involved in?

   ………………………………………..

   ………………………………………..

2. What is your total monthly income?

   …………………………………………

SECTION D: SOCIO-CULTURAL ACTIVITIES

1. What socio-cultural activities are you involved in?

   …………………………………………

2. What schools do your children go to?

   …………………………………………

3. Which hospitals do you go to?

   …………………………………………

4. Where do you your shopping?

   …………………………………………

PART 2: SOCIO-ECONOMIC IMPACT

1. How will drilling and construction affect your life?

   ……………………………………….

   ……………………………………….

2. How will the expanding road network impact on your life?

   ………………………………………..

   ………………………………………..

3. How will the proposed project affect your livelihood in terms of

   a. Water availability and quality

      ……………………………………

      ……………………………………

   b. Livestock numbers and forage

      …………………………………….

      …………………………………….

   c. Health issues ………………………

   d. Social interactions …………………

   e. Where they live and for how long

      ……………………………………...

   f. Access to hospitals and schools

      ………………………………………

g. Job opportunities/employment

………………………………………

h. The number of children and wives

………………………………………

i. Income levels ……………………….

j. General living standards …………….

PART 3: MITIGATION

1. What do you recommend as solutions to the above problem (s)

   ………………………………………………..

   ………………………………………………..

2. Who do you think should be involved in solving the above problems and to what extent?

   ………………………………………………..

   ………………………………………………..

Appendix 10: Interview Schedule

1. Name of the organization ………………………..
2. Type of business …………………………………
3. In your opinion, what the probable environmental and social economic impacts of the project on
    a. The surrounding community and environment

       ……………………………………………….

       ……………………………………………….

       ……………………………………………….

    b. Your operations?

……………………………………………….

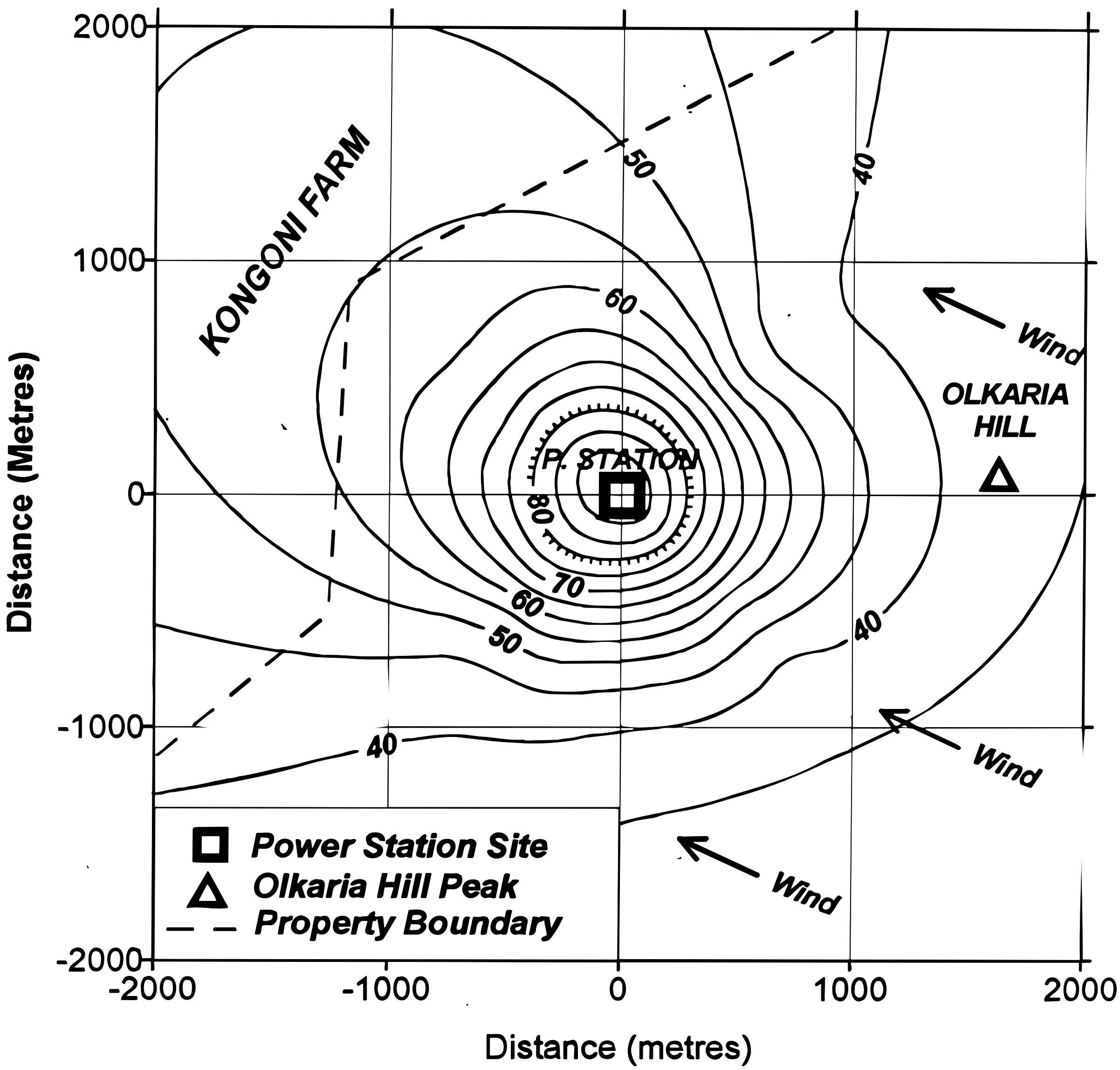
……………………………………………….

4. What are the solutions you propose and why?

…………………………………………………

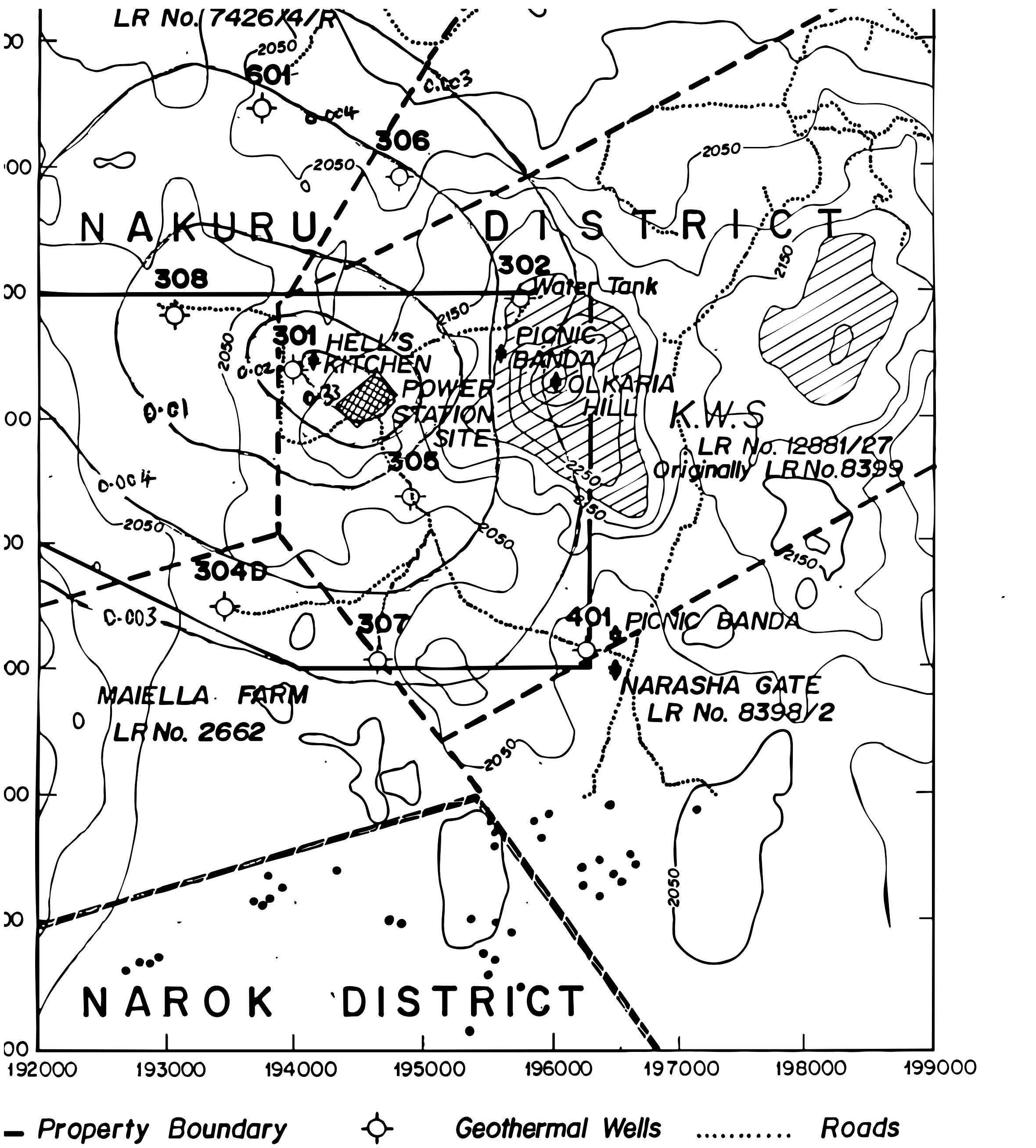
…………………………………………………

Appendix 11: Model describing project - induced noise levels



A model of the expected Olkaria III plant induced noise levels (dB) during full capacity operation.

Appendix 12: Dispersion model for H2S emissions (mean 24 hour concentrations)



Appendix 13: Letter Demonstrating Orpower 4 Inc.'s Concern for Erosion Hazard Due to Road Works

Our Ref: MO/sw/B-4.1
Your Ref:

19th October 1999.

The Director
Kenya Wildlife Services
P. O. Box 40241
NAIROBI

Dear Sir

RE: **ACCESS ROUTE TO OLKARIA III POWER STATION AREA**

Orpower4, Inc. kindly requests your advice and help to obtain an access road to the Olkaria III Power station area. The company has looked at four(4) possible routes and established the following problems for each route shown on the attached map.

1. **ROUTE A:** This is the shortest route parallel to the KenGen water pipeline along the Oserian boundary with the National Park and up the Olkaria Hill slopes to well OW-302 proposed camp site. However the slope from OW-202 point to OW-302 is very high and would involve too much cutting into the hill slope Because of the unstable soil conditions of the area, too much cutting is considered not acceptable environmentally. This route is not recommended.

2. **ROUTE B:** This is the longest route through the National Park and crosses gulleys and the Naivasha swamp both of which cannot be used by vehicles during rains. This route is impassable during most the year and therefore it cannot be selected.

3. **ROUTE C:** This route around the southern edge of Olkaria Hill will have to be cut and because it is in the Park and will have to cross gulleys from the hill slopes, it is also dis-recommended because it will create soil erosion and would also be problematic during the rainy season.

ORPOWER 4, INC.
P. O. Box 76188 • Telephone (254)2 449454 • Facsimile (254) 2 449455
Riverside Drive, SDA Building Nairobi Kenya
980 Greg Street, Sparks, NV 89431 - 6039 • Telephone (775) 356-9029 • Facsimile (775) 356-9039

4. **ROUTE D:** The route fall along the road that has been used in the past by KPC (KenGen) when working in Olkaria West. The road is stable and can be easily maintained to allow for all weather use by all types of vehicles.

However, the problem is that it crosses into Oserian farm and runs along the Oserian Farm and Kongoni conservancy boundary. Therefore to use the route, there must be an agreement between the Oserian Development Company, Kenya wildlife Services and Orpower4, Inc. that takes care of the interest of all stakeholders.

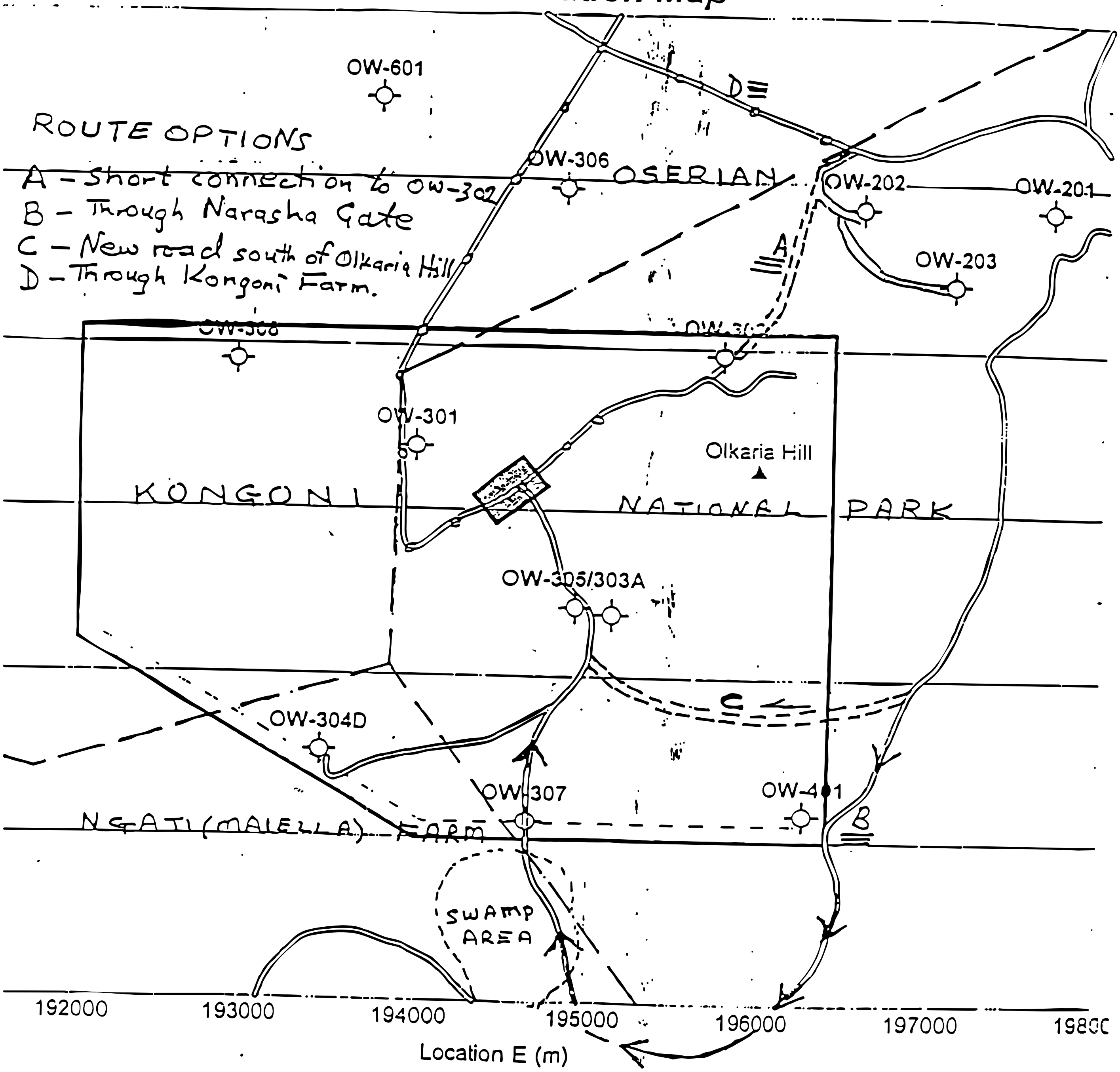
Therefore, Orpower, 4, Inc. re-emphasizes their interest to go into some sort of negotiation to enable the company to use ROUT4 as their access road to the working area. Please help.

Yours sincerely
For: **ORPOWER4, INC.**

Mr. RUEVEN SHMUCHER
PROJECT MANAGER

CC: Mr. Francis Ole Nkako

Olkaria III Location Map



Appendix 14: Draft Agreement Between KWS and Orpower 4 Inc.

AGREEMENT

BETWEEN

KENYA WILDLIFE SERVICE

AND

OR POWER 4 INC

FOR

GEOTHERMAL DEVELOPMENT
IN
HELL'S GATE NATIONAL PARK

AGREEMENT
BETWEEN
KENYA WILDLIFE SERVICE
AND
OR POWER 4 INC
FOR
GEOTHERMAL DEVELOPMENT
IN
HELL'S GATE NATIONAL PARK

THIS AGREEMENT (hereinafter referred to as "the Agreement") is made on the .... Day of .... 2000, between **KENYA WILDLIFE SERVICE**, a body corporate established under the provisions of the Wildlife (Conservation and Management) Act (Cap 376 of the Laws of Kenya) and of Post Office Box Number 40241, Nairobi in the Republic of Kenya(hereinafter referred to as **"The Service"**) of the one part **and ORPOWER 4 INC** (hereinafter referred to as **'The Company"**) a limited liability company through its Kenya Branch and whose address is Post Office Box number 1566 Naivasha on the other part.

PREAMBLE

WHEREAS the Service is mandated, under the Wildlife (Conservation and Management) Act (Cap 376 of the Laws of Kenya) to conserve and manage all forms of wild fauna and flora in Kenya to hold in trust, for now and future, the responsibility for the protection and conservation of Kenya's extraordinary natural wealth as represented by it fauna, flora and natural beauty;

A. The Service is legally entrusted with the management of Hell's Gate National Park and the conservation of all types of Fauna and Flora found therein as well as environmental protection, management and conservation ;

B. The Company has signed with Kenya Power and Light (KPLC) a Power Purchase Agreement (the "PPA"), and for that purpose has been granted by the Government Of Kenya the access and rights to the exploration and production of geothermal power within the environs of Hell's Gate National Park; and have obtained the necessary licenses and leases for the said activities.

C. The Service requires the Company's compliance with the conditions set out herein below, through out the period that the Company is engaged in the exploration and production of geothermal power/energy within the said National Park.

NOW THIS AGREEMENT WITNESSETH AS FOLLOWS: -

1. PARK MANAGEMENT

FLORA

(a) Company shall not remove any natural vegetation without the consultation with the Service and its consent given thereof when it is absolutely essential for example in the construction of sites, pipelines, roads, infrastructure or propagation therein in which event such physical removal shall be kept to the minimum.

(b) Removal of vegetation shall be restricted and shall not exceed[M2 **need explanation**] per well.

(c) The Company shall at all times in collaboration with the Service ensure that all-opportunistic plant species that may have been introduced in the process of earthworks shall be uprooted and burned at designated areas so as to control the spread of the species. Such species would include <u>datura strammonium</u> and any other species classified by the Service for destruction by the company.

(d) The Company shall in collaboration the Service's herbarium, immediately rehabilitate all areas cleared of flora by planting appropriate indigenous plant species. Such species shall include "Mleleshwa" (Tarchonanthus camphoratus) and any other species classified as appropriate by the Service, and the Company has a written notification from the service of such species, and shall be planted by the Company in the cleared areas.

(e) The Company shall give to the Service a schedule for any rehabilitation of cleared areas and will place signs to indicate such areas that will be undergoing the said rehabilitation.

(f) The Service and the Company shall jointly endeavor to continuously monitor the Abundance and diversity of natural vegetation.

(g) The Company shall not introduce into the park any exotic species of flora.

(h) The Company shall not consume or harvest any wood, timber or wood products originating from the park.

FAUNA

(h) The Service and the Company shall only fence such areas, as both parties shall have identified as dangerous or appropriate for the protection of staff. Such fences shall not enclose small animals.

(i) The Company shall ensure that pipelines and any other earthworks that obstruct identified animal movement paths are placed at a reasonable depth under the ground, or as alternative high above ground providing sufficient clearance. The Company shall also remove all derelict pipes and low lying and unused power cables. The cost of such activity shall be borne by the Company.

(j) The Company shall effect a ban on introduction of exotic animals such as dogs or cats by its workforce.

(k) The Service shall regularly educate the staff of the Company on the national park rules and regulations particularly with regard to their interaction with wild animals, proper disposal of litter and proper handling of park visitors by the Company's staff at the barriers.

SOIL

(l) The Company will minimize cutting slopes in its areas of operation and fill earthworks.

(m) Both parties will monitor the effectiveness of erosion control measures by making regular visual inspections at construction sites and annually in operation phases. If the erosion control measures are not found to be sufficient, the Company shall take the necessary remedial action to implement more effective measures to the satisfaction of the Service.

(n) The Company shall nominate an officer to monitor and control soil conservation operations whose costs shall be borne by the Company and the officer shall have sufficient authority in matters regarding soil conservation.

(o) Both parties shall exchange information on research on soil erosion control and research on soil conservation generally in the parks.

2. ENVIRONMENTAL PROTECTION, CONSERVATION AND MANAGEMENT

AIR

(a) Before commissioning the plant in accordance with the PPA terms, the Company shall provide for meteorological monitoring at identified sites agreed upon by both parties and utilize any data collected to increase the quality of air in and around the park. The Company shall regularly avail to the Service details of efforts to minimize air pollution resulting form geothermal explorations.

(b) The Company shall procure hydrogen sulphide monitors and regularly monitor hydrogen sulphide in an endeavor to verify the prediction made by dispersion modeling and such model must be fine-tuned so that the Company may have an improved tool to assess the impacts and to provide further data for other environmental monitoring programmes such as vegetation monitoring. The Company shall avail such data to at reasonable and regular intervals.

(c) Environmental auditors will be consulted from time to time with a view to establishing, monitoring, regularizing and controlling air quality within the park.

(d) There shall be established an environmental audit fund to which parties shall contribute.

NOISE

(e) The Company shall regularly monitor noise levels in its site lease area and in particular in areas settled by its staff such as the power plant site

(f) Wells shall not be dug within park housing areas, picnic and campsites whereby the noise levels will be hazardous to the residents and or users of the areas thereof.

(g) The Company shall not construct any wells or stations near, the Service's staff quarters where noise and pollution levels are unbearable for long periods.

(h) During the construction period the Service and the Company shall prepare detailed and exhaustive information on noise levels in the park and fore warn park visitors of the excessive noise emitted by the wells under test. The information will generally be transmitted through s' outlets in form of brochures and guide books. Costs of such exercise shall be borne by the Company.

WASTE DISPOSAL

(i) The Company shall deep re-inject waste water and brine in power stations both existing and future as well as production fields to avoid potential toxic effect on flora.

(j) The Company shall reduce vertical discharge and well testing periods to the lowest minimum possible.

ROADS

(k) The Company will gravel top cover and maintain all roads associated with the power station and wells.

(l) The Company shall not endeavor to create its own infrastructure within the park and shall be guided at all times by the Service on all matter pertaining to infrastructure within the park.

(m) The Company shall not construct any additional roads within the parks without the approval and consent of the Service which approvals and consents shall be in writing, and shall not be unreasonably withheld.

RESTORATION OF THE PARK

(n) At the conclusion of its operations the Company shall restore the park to condition and in accordance with standards as commonly used in similar places for similar projects. Said conditions and standards shall be detailed in a mutually agreed Agreement.

FIRE

(n) The Company shall ensure at all times that proper and adequate measures are taken for the prevention, detection, and extinguishing of fire and that proper insurance policies are taken details of which shall be provided for in the Lease Agreement referred to herein below.

3. TOURISM PLANNING AND AESTHETICS

(a) The Company and the Service shall from time to time hold joint meetings to discuss and agree on plans for expansion of exploration and prospecting as well as tourism planning and development. In this regard each party shall have one of its members co-opted in the other party's planning committees at all times during the existence of this agreement.

(b) The Company undertakes to plant suitable trees in order to minimize the views of power stations and enhance the natural features within the park.

(c) There shall be no staff housing for the Company's employees within the park at all times, but for a temporary drilling man-camp (for the drilling period), which its site and location shall be approved by the Service.

(d) The Company undertakes to instruct all its contractors, as a condition precedent to the award of any contract within the park's areas, to house all their workers outside the National Park.

(e) The Company shall be responsible for enhancing security in the park for visitors and their staff.

(f) The Company shall in consultation with the Service, paint or construct future steam gathering systems with materials blending with the environment.

(g) Subject to the Services 's consent, the Company may present its proposals on road designs and construction for the purpose of harmonizing the transport network within Hell's Gate National Park.

TRAFFIC

(h) The Company shall ensure that pipelines and any other earthworks that obstruct identified animal movement paths are placed at a reasonable depth under the ground, or as alternative above ground, providing sufficient clearance. The Company shall also remove all derelict pipes and low lying and unused power cables. The cost of such activity shall be borne by the Company.

(i) The Company and The Service shall erect speed bumps and other reasonable barriers on road sections identified by to have animal paths for the purpose of eliminating the danger caused to animals by over-speeding motor vehicles

(k) The Company shall observe speed limit of 40 Kilometers per hour which is the speed limit within all parks and shall always give the animals right of way.

5. EFFECTIVE DATE

This Agreement shall come into operation on a date appointed and agreed by the parties. The duration shall be for the term of the validity of the PPA agreement.

6. REVIEWS

(a) There will be joint reviews of this Agreement by the parties annually. Any amendments to the Agreement, after a joint review or any other time shall be made in writing by mutual agreement between and the parties hereto.

7. CONFLICT RESOLUTION

Every effort shall be made by both parties to settle amicably any dispute or difference arising between the parties as to the interpretation of this Agreement on the rights, duties or obligations of either party hereunder or any matter arising out of or concerning this Agreement. If such disputes or differences are not settled amicably, they shall be dealt with in accordance with the provisions of the Arbitration Act Chapter 49 of the Laws of Kenya.

IN WITNESS WHEREOF the parties hereto have executed this Memorandum the day and year first herein above written.

Signed for and on behalf of)
KENYA WILDLIFE SERVICE)
)
) ______________________
) DIRECTOR

In the presence of:)
Signature:)
Name:)
Address:)

Signed for and on behalf of	)	
OEPOWER 4 INC	)	
	)	
	)	______________________
	)	MANAGING DIRECTOR

In the presence of:	)
Signature:	)
Name:	)
Address:	)

June-00

ORMAT

OLKARIA III - EARLY GENERATION GEOTHERMAL POWER PROJECT

Naivasha, Kenya (East Africa)