Expansion of Geothermal Development in Environmentally Significant Areas: The Case of Olkaria Geothermal Project in Hell's Gate National Park, Kenya

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ABSTRACT

Due to a growing national demand for electricity, the Kenya Electricity Generating Company Limited (KenGen) developed plans to increase production of geothermal energy within the Greater Olkaria Geothermal Area. The plans call for the establishment of additional power plants and enhancement of the existing capacity in the Olkaria I power generating station. But these plans come at a cost: the proposed location of the additional plants is home to a variety of wildlife and vegetation species. This paper describes the environmental management plans put in place by KenGen to promote environmental and wildlife conservation, in cooperation with the Kenya Wildlife Service (KWS), to mitigate the anticipated adverse impacts arising from the introduction of additional power plants within the Hell's Gate National Park.

1. INTRODUCTION

1.1 Background

The Kenya Electricity Generating Company Limited (KenGen) is a State Corporation that supplies bulk power - about 80% - to the national electricity grid. The Company's power generation mix comprises of hydro, thermal, geothermal and wind resources (KenGen, 2010). Currently, KenGen operates two geothermal power stations and a wellhead power generator that are located within Hell's Gate National Park in Naivasha District. An additional wellhead generator is situated in Eburru Location of Gilgil District. The Olkaria I (commissioned between 1981 and 1985) and Olkaria II (commissioned in 2003 and 2010) power stations generate 45 MW and 105 MW of electricity respectively. The Eburru Wellhead (EW) 1 and Olkaria Wellhead (OW) 37 generators produce 2.3 MW and 5 MW of electricity respectively. The Olkaria III geothermal power station, which generates 48 MW of electricity, belongs to an independent power producer (IPP), Orpower 4 Limited, and is located inside the same park (GIBB, 2010). In addition, the Olkaria IV power plant, currently under construction, is located on KenGen's land about 15km from the Olkaria I power station. This land is an important dispersal area for wildlife from Hell's Gate National Park. Further, KenGen utilizes water from the nearby Lake Naivasha, which is a wetland of international importance according to the Ramsar Convention on Wetlands.

KenGen is implementing plans to increase geothermal power production within the Greater Olkaria Geothermal Area (GOGA) by optimizing the current potential of the Olkaria Domes and Olkaria East area. These plans will lead to the establishment of new power plants to be named Olkaria IV and Olkaria I Units 4 and 5 Power Stations, with a total generation capacity of 280 MW (KenGen, 2010).

To facilitate the implementation plans, KenGen commissioned GIBB Africa Limited, a firm of experts registered with the National Environment Management Authority (NEMA), to undertake an Environmental and Social Impact Assessment Study of the proposed Olkaria IV and the Olkaria I Units 4 and 5 Power Stations.

Subsequently, Environmental Management Plans (EMP) were developed that stipulate the measures to be undertaken to mitigate against the anticipated adverse environmental effects associated with the proposed establishment of the additional power stations (Olkaria I Units 4 and 5 and Olkaria IV).

An environmental management plan details all areas of project activities, impacts, mitigation measures, time schedules, costs, responsibilities and commitments proposed to minimize environmental impacts of activities, including monitoring and environmental audits during implementation and decommissioning phases of a project (NEMA,2003).

1.2 Objectives of the Environmental Management Plans

Establishment of the new 280 MW power stations to increase power supply to the national grid will result in additional environmental impacts that require mitigation in order to enhance conservation efforts of the ecologically significant area, specifically the Hell's Gate National Park,, the Olkaria Domes field, and Lake Naivasha.

The specific objectives of KenGen's Environmental Management Plans are:

- Identification of anticipated impacts arising from the expansion of geothermal development;
- Recommendation of appropriate mitigation measures; and
- Establishment of mechanisms to monitor the implementation and efficacy of the proposed mitigation measures.

2. PROJECT LOCATION

The proposed projects are located in the Hell's Gate National Park and on KenGen's land within Olkaria Domes field (Figures 1 and 2 below).

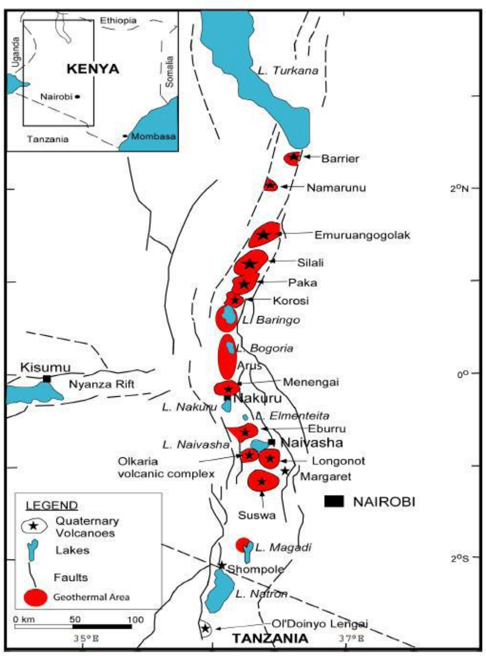

Figure 16: Map showing location of Greater Olkaria and Eburru Geothermal Area in Kenya's Great Rift Valley.

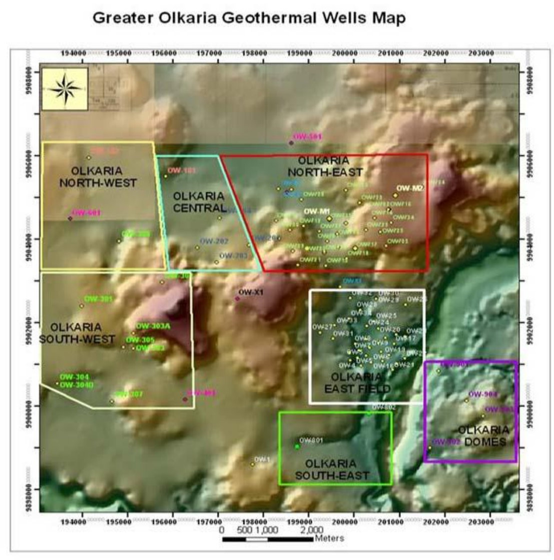

Figure 2: KenGen's geothermal licence area showing the existing and proposed power stations.

Hell's Gate National Park lies 0°54′57″S, 36°18′48″E, just south of Lake Naivasha and about 120km north-west of Nairobi. The park was gazetted in 1984, three years after the commissioning of Olkaria I Power Station. The Park is known for its scenery and wide variety of wildlife, including the common zebra (*Equus burchelli*), Masai giraffe (*Giraffa camelopardalis*), Thomsons gazelle (*Gazella thomsonii*), leopard (*Panthera pardus*), Klipspringer (*Oreotragus oreotragus*), African buffalo (*Syncerus caffer*), common eland (*Taurotragus oryx*), various raptors i.e. Ruppell's vulture (*Gyps rueppellii*), white backed vulture (*Gyps africanus*), among other species of wildlife. The beautiful scenery includes the Fischer's Tower and Central Tower columns and Hell's Gate Gorge. The most common vegetation types include *Hyperrhenia, Digitaria, Themeda* grasses, and *Tarchonanthus* and *Acacia* shrubs.

Lake Naivasha, on the other hand, is a Ramsar site of international ecological importance, from which the Olkaria Geothermal Project obtains it water for domestic and geothermal activities.

3. PROJECT DESCRIPTION

THE ACTIVITIES ASSOCIATED WITH THE PROPOSED PROJECT HAVE BEEN CATEGORIZED UNDER FOUR PHASES OF PROJECT IMPLEMENTATION, NAMELY, PLANNING, CONSTRUCTION (DRILLING AND POWER PLANT CONSTRUCTION), OPERATION OF THE POWER GENERATION PLANT AND DECOMMISSIONING, AS DISCUSSED BELOW:

3.1 Planning Phase Activities

The main activities considered during this phase are:

i) Well siting;
ii) Identification of access routes;
iii) Preparation of site layout drawings;
iv) Procurement of materials; and
v) Recruitment of personnel.

3.2 Construction Phase Activities

The construction phase entails the following activities:

i) Preparation of access roads using earth moving equipment;
ii) Preparation of well pads using earth moving equipment;
iii) Preparation of a temporary brine holding pond;
iv) Installation of water, power and steam supply system;
v) Drilling of production and re-injection wells; and
vi) Power plant site preparation and construction at OW 24, 28 and 908.

3.3 Operation Phase Activities

Production wells are connected to the power plant through a steam gathering system as illustrated in the Figure 3 below.

Power will be generated through a single flash steam condensing system.

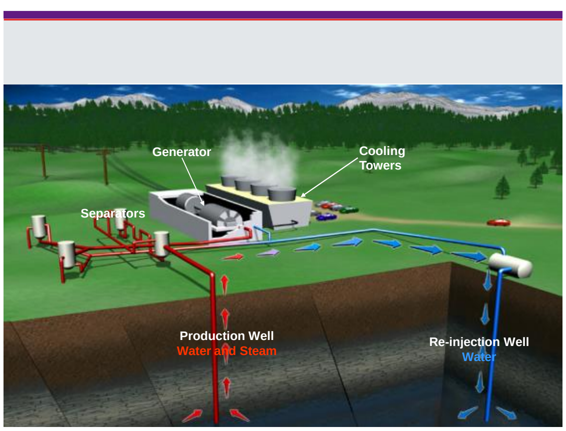

Figure 3: Schematic diagram of a geothermal system.

3.4 Decommissioning Phase Activities

Decommissioning of the drilled wells and power plants will become necessary when they stop producing steam and generating power. Once this occurs, the affected well(s) and/or power plant(s) will be decommissioned.

4. STUDY METHODOLOGY

An Environmental and Social Impact Assessment (ESIA) study that generated the respective Environmental Management Plans was conducted for the proposed Olkaria IV and the Olkaria I Units 4 and 5 Power Stations. Baseline project area data was collected through a combination of primary and secondary methodologies.

The primary data collection methods included:

i) Preliminary meetings;
ii) Census and social survey of all the ‘manyattas’ (villages) in the proposed project site;
iii) Social survey through purposive random sampling of people likely to be affected by the project;
iv) Air and noise dispersion modeling;
v) Ecological assessment;
vi) Formal and informal interviews and discussions with key informants;
vii) Public meetings;
viii) Interviews with officials of key government agencies within the project area;
ix) Site walks and observations by the data collection team;
x) Data analysis; and
xi) Reporting.

Secondary data was sourced mainly from published data, i.e., scholarly reports, the World Wide Web (internet), and unpublished data from the respondents.

4.1 Preliminary Meetings

Meetings were held with the respective stakeholders to share background information and obtain views regarding the proposed projects.

4.2 Air and Noise Dispersion Modeling

The use of CALMET/CALPUFF models for air quality measurements is approved by the United States Environmental Protection Agency (US EPA).

CALMET (CALifornia METeorological model) is a computer program that prepares the meteorological data, e.g. wind speed and direction, atmospheric stability class and mixing height, required by CALPUFF (CALifornia PUFF model), a dispersion model for predicting transport and diffusion of air emissions. Dispersion modeling was used to make predictions of hydrogen sulphide (H_2S) gas emissions for 1-hr, 24-hr and 1-yr average periods (GIBB, 2010).

According to GIBB 2010, NOISE8 model was used to predict noise impacts. The model takes into account the following three (3) factors:

i) Diminution of noise with distance: sound energy spreads outwards from the source due to geometric factors and measures 6 dB each time the distance from source to receptor is doubled.
ii) Effects of artificial and natural barriers depend on frequency of the sound and the geometric arrangement of the source, barrier and receptor.
iii) Absorption of sound energy by the atmosphere: some vibration energy of sound is converted to heat in the atmosphere. Absorption of noise in the atmosphere depends on sound frequency and the temperature and humidity of the atmosphere.

To operate, the model requires data on sound power level and the tonal composition of the emitted noises.

4.3 Ecological Assessment

A comprehensive survey of biodiversity was conducted for flora and fauna using the following techniques:

i) Time constrained searches - involved hourly samplings per study site to record the numbers and abundance of the different flora, fauna and avifauna to generate data on species present at sampling time and habitat information;
ii) Sampling plots - 20m x 20m plots were established to determine the species type and diversity;
iii) Timed species count - used to assess the relative abundance of birds, counted after every 40 minutes;
iv) Mammal sampling - divided into large, medium and small mammals. Survey walks and drive transects techniques used were determined by the species, visibility of the study area and behavior of the various mammal species.

4.4 Public Consultations and Social Impact Assessment

Extensive consultations were conducted with the various stakeholders across the local, district, regional and central government levels. The aim was to create awareness and to solicit key issues of concern regarding the proposed projects. The various consultation methods used included key informant interviews, questionnaires, community meetings, advisory committees, participatory rural appraisal and public meetings.

4.5 Incorporating Public Views into the ESIA Reports

The resulting views of those affected or interested helped to identify the anticipated social and environmental impacts of the proposed project. Further, stakeholders were considered in the formulation of the respective mitigation measures and preparation of the environmental management plan.

5. REGULATORY LEGAL AND POLICY FRAMEWORK

The Olkaria IV and Olkaria I Units 4 and 5 projects are being implemented in accordance with the stipulated legal and policy framework, part of which is discussed below.

5.1 Environmental Management and Coordination Act, 1999

Implementation of the projects was preceded by ESIA studies in compliance with Section 58 of the Environmental Management and Coordination Act, 1999 (EMCA, 1999). This resulted in the issuance of environmental impact assessment licences (EIA) prior to commencement of the projects. Consequently, Olkaria I Units 4 and 5 and Olkaria IV projects were issued with EIA licences Nos. EIA/490 and EIA/491 respectively.

5.2 Environmental Impact Assessment and Audit (EIA/EA) Regulations, 2003

The ESIA studies for the projects were carried out in accordance to the EIA/EA Regulations of 2003. Some of the activities included:

- Preparation and submission of Terms of Reference (ToRs) to the National Environment Management Authority (NEMA) for approval;
- Engagement of a team of EIA/EA Experts registered with NEMA to conduct the EIA study;
- Public consultation; and
- Submission of the EIA study to NEMA alongside the prescribed fees.

5.3 Energy Act, 2006

KenGen complies with the requirements of the Act in electricity generation, which are implemented by the Electricity Regulatory Commission. These include acquisition of generation licences and related permits, and abiding by the provisions of the approved tariffs.

5.4 Geothermal Resources Act, 1982

KenGen was issued with a geothermal resources license in accordance with the requirements of the Geothermal Resources Act of 1982. The license is for the purpose of facilitating drilling, extraction and utilization of the geothermal resources.

5.5 Occupational Health and Safety Act (OSHA), 2007

In compliance with the requirements of OSHA 2007, KenGen ensures the safety of workers by providing personal protective equipment and observing the recommended occupational exposure limits with respect to air and noise pollution. Further, the Company constituted an Occupational Health and Safety Committee to oversee the implementation of the Act.

5.6 Water Act, 2002

KenGen complies with the provisions of the Water Act of 2002 in acquisition of permits from the Water Resources Management Authority (WRMA) to draw water from Lake Naivasha for its geothermal development activities. The Act also provides guidelines for the protection and conservation of riparian and catchment areas.

5.7 Wildlife (Conservation and Management) Act, Cap 376

This Act regulates conservation and management of wildlife in Kenya under the supervision of the Kenya Wildlife Service (KWS). The KWS signed a memorandum of understanding with KenGen in 2008 to ensure a harmonious co-existence in conservation of flora and fauna while developing geothermal energy resources within the park.

5.8 Ramsar Convention on Wetlands

It is an international convention mainly concerned with the conservation and management of wetlands. Lake Naivasha is the major water source that the Company relies on for its supply. Consequently, KenGen is a member of Lake Naivasha Riparian Association that adjudicates the riparian land – the marginal land that is covered and uncovered by the changing level of the water.

6. ANTICIPATED IMPACTS AND IMPLEMENTATION OF THE RESPECTIVE MITIGATION MEASURES

An impact is any change to the existing condition of the environment that is caused by human activities or external influences. Impacts may be positive (beneficial) - in which case they ought to be enhanced, or negative (adverse) - thus requiring mitigation; direct or indirect; short-term or long-term in duration; local or widespread in extent of their effect; and cumulative when they add incrementally to existing impacts. Significant impacts are defined as those which:

- Are subject to legislative control;
- Affect sensitive environmental factors and parameters;
- Relate to protected or historically or culturally important areas;
- Are of public importance and concern;
- Are determined as such by technically competent specialists;
- Trigger subsequent secondary impacts; and
- Elevate the risk of life threatening circumstances.

This section describes the anticipated adverse impacts during the construction and operation phases of the project and their respective mitigation measures. The significant environmental impacts which are associated with the development of the 280 MW geothermal project are listed below:

i) Impact on flora;
ii) Impact on fauna;
iii) Contamination of soils and vegetation;
iv) Exposure to high noise and vibration levels;
v) Impact on nearby human settlements;
vi) Exposure to hydrogen sulphide gas emissions;
vii) Water utilization and waste water for the geothermal wells;
viii) Impact of visual intrusion;
ix) Impact on tourism; and
x) Impact of power plant design and technology.

6.1 Impact on Flora

Clearing of vegetation is inevitable to allow for construction of the required infrastructure. This can lead to disturbance of the significant ecosystem that provides the habitat, feeding and breeding grounds for fauna within the park. To minimize the impact, clearing of vegetation is done selectively and strictly controlled and is limited to what is absolutely necessary. Disturbed areas are later re-vegetated with indigenous vegetation that include *Hyperrhenia, Digitaria, Themeda* grasses, *Tarchonanthus* shrubs, and *Acacia* trees. Further, directional drilling that provides for multiple wells on the same pad is being implemented to reduce the surface area of cleared vegetation. Table 1 shows the surface area of vegetation cleared for well pads as determined by the respective drilling options. Drilling multiple wells on a single pad significantly minimizes the total cleared surface area.

Table 1: Respective well pad sizes for the various drilling options

Drilling option (no. of wells per pad)	**Well pad size (m)**	**Reduced surface area of cleared vegetation (%)**
One (1)	110 x 80	-
Three (3)	180 x 80	81.8
Six (6)	300 x 110	89.6

A schematic illustration of geothermal well drilling profiles is shown in Figure 4.

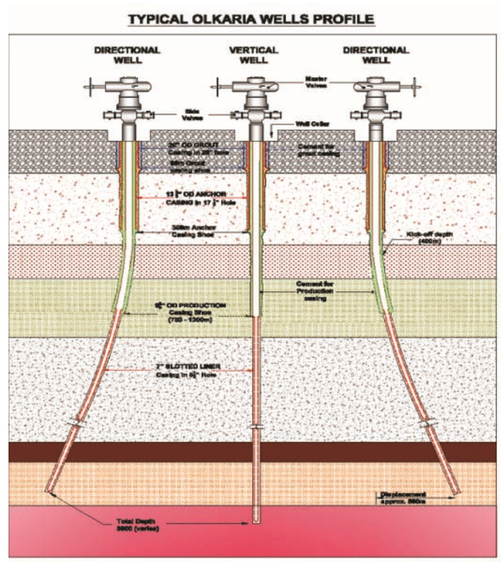

Figure 4: Schematic diagram of geothermal well drilling profiles.

Some of the pads with multiple wells include OW 44, which has three wells comprising one vertical and two directional wells as shown below:

Figure 5: Olkaria Well 44 pad with 3 wells.

6.2 Impact on Fauna

The project lies within Hell's Gate National Park and Olkaria Domes field. Both areas are environmentally significant for biodiversity conservation, the latter being an important wildlife dispersal area. The impact results from loss of habitat due to vegetation clearing and bush fires; loss of migratory corridors through installation of structures such as elevated steam pipes and power plants; use of fences to restrict animal movement; and potential drowning of animals in brine ponds. Consequently, the following mitigation measures are being implemented to reduce the stated impacts:

i) Clearing of vegetation is reduced to the absolutely necessary and rehabilitation is carried out immediately on the affected areas to restore the vegetation;

ii) A Fire Rating Board, with graduated risk levels of warning on the probability of fire occurrence at any given period, has been installed at the Olkaria Gate, the main entrance to the Park. Further, fire marshals are regularly trained on fire-fighting skills using appropriate equipment and strategies, in accordance with an emergency response plan that is implemented in case of a fire outbreak.

iii) Animal census and animal migratory route studies are conducted regularly by KenGen and KWS to determine the wildlife population as well as map their respective movement routes. The studies generate information that is used in locating and designing animal friendly steam pipes to avoid interfering with the animals' routes in search of water and a habitat for breeding, feeding and hiding. Figure 6 shows an existing giraffe passing loop at OW 713, while Figure 7 shows the proposed improvement of the current loops, which might look like traps to the animals.

Figure 6: An existing giraffe passing loop.

iv) Fences and other enclosures that reduce the grazing range and restrict the movement of wild animals have been installed to secure only critical operational areas such as power plants, offices, and temporary brine holding ponds, to avoid restricting the animals too much.

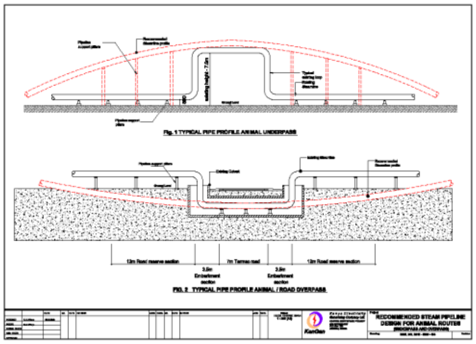

Figure 7: Proposed animal underpass and overpass loop marked in red color.

6.3 Contamination of Soils, Water and Vegetation

Substantial quantities of brine from production wells are separated from the steam that is used to drive the turbines that generate electricity in the power plants. Inappropriate disposal of the brine may cause contamination of soils, water and vegetation. The most appropriate method for disposing of brine is re-injecting it into re-injection wells. Several wells have been earmarked for re-injection, like OW 45 and OW 901. In addition, brine is held temporarily in a pond that is lined with high density polyethylene (HDPE) to prevent percolation and surface flow that can cause contamination of soils, water and vegetation. Small rocks are laid on the HDPE layer to provide a grip to small animals like lizards, snakes and rodents, against the slippery lining. Figure 8 is an illustration of a HDPE-lined and fenced brine pond at OW 710:

Figure 8: A HDPE-lined temporary brine holding pond that is also fenced to prevent drowning of stray animals.

6.4 Exposure to High Noise and Vibration Levels

Emission of uncontrolled noise is a danger to human health and might cause damage to the environment. During geothermal power development, noise is generated mainly from heavy equipment during drilling and construction, discharging of wells for testing, and electricity generation in the power plant. The maximum permissible noise level for residential areas near such a construction site is 60 dB during the day (6a.m. – 6p.m.) and 35 dB at night (6p.m. – 6a.m.).

Noise modeling was conducted to assess the impacts of the proposed development on noise levels. The model considered the effect of noise from a combination of the existing Olkaria I & II, the proposed Olkaria IV & I Units 4 & 5 power stations, and OW 38 that was on discharge testing at the time. Discharge testing of wells takes about three months to determine the well flow characteristics and establish the power output at different wellhead pressures. The exercise is carried out all year round to test wells that are being drilled on a continuous basis. Monitoring of noise levels is carried out on all the working days and information is circulated immediately the noise levels exceed the recommended limit. Workers and visitors to the relatively noisy areas are provided with personal protective equipment (PPEs) that comprise ear muffs and ear plugs. Further, workers operate in 12 hour shifts to prevent prolonged exposure periods to high noise levels. Informative and warning signs in the national and, in some instances, the local language are clearly displayed at the areas where it is mandatory for the PPEs to be worn. Figure 9 shows OW 909 that is discharging. It is fitted with four silencers to reduce noise levels. During discharge testing, noise levels can reach a high of 125 dB, but decline to a low of 90 dB when fitted with silencers, a 43.75% reduction.

Figure 9: Discharging OW 909 that is fitted with

silencers to minimize noise levels.

6.5 Exposure to Hydrogen Sulphide Gas Emissions

Geothermal wells and power plants emit substantial quantities of hydrogen sulphide (H_2S). Air dispersion modeling was conducted to assess the impacts of the proposed development on H_2S levels. The model considered the effect of H_2S emissions from a combination of the existing Olkaria I & II, the proposed Olkaria IV & I Units 4 & 5 power stations. Currently, the World Health Organization (WHO) 24-hour guidelines are being used to assess the impacts, since there are no ambient air quality criteria for H_2S in force in Kenya. The guidelines recommend an average exposure limit of 0.10 ppm concentrations for a period of 24 hours. Monitoring of H_2S levels is carried out on all the working days and information is circulated immediately the levels exceed the recommended limit. Informative and warning signs in the national and, where necessary, the local language are clearly displayed in areas where high emissions are recorded. The proposed power plants will be fitted with cooling towers that are similar to those at the newer Olkaria II to provide greater plume rise and achieve better dispersion than in the older Olkaria I power plant. Workers operate in 12 hour shifts to prevent prolonged exposure to the H_2S gas emissions. They are also regularly trained on the dangers of exposure to hydrogen sulphide gas.

6.6 Impact on Nearby Human Settlements

Noise modeling studies for the proposed project recommended that all settlements within the 35 dB contour should be relocated as they will be exposed to levels above the acceptable limits, as prescribed by the Environmental Management and Coordination (Noise and Excessive Vibration Pollution Control) Regulations of 2009. In addition, the air modeling study recommended that no settlements should be located within the 0.10 ppm H_2S gas contour, in accordance with the WHO, 1987 guidelines. The results of the air and noise modeling study of the cumulative impacts of the existing Olkaria I & II, the proposed Olkaria IV & I Units 4 & 5 power stations prompted KenGen to earmark the following nearby villages for resettlement:

- Cultural Centre
- Olo Nongot
- Olo Sinyat
- Olo Mayiana – the small portion of the village between the main Olo Mayiana Village and Cultural Centre

KenGen uses “Flash Steam” power plant technology, whose use of cooling towers reduces the spatial range of noise and hydrogen sulphide. Consequently, the proposed resettlement area under 0.1 ppm and 35 dB contours is much smaller than it would have been if "Dry Steam" technology were used (KenGen, 2011).

A Resettlement Action Plan (RAP) was developed to relocate the Project Affected Persons (PAPs) as a mitigation measure against the impacts of prolonged exposure to air and noise pollution. The relocated PAPs will be provided with, amongst other things, social amenities like land, water, modern residential houses, a school, churches, and a health facility. Table 2 shows the distribution of housing units to the PAPs across the four villages.

Table 2: Distribution of proposed housing units in the four villages

Affected Village	Number of Housing Units
Cultural Centre	46
Olo Nongot	46
Olo Sinyat	21
Olo Mayiana Ndogo	51
TOTAL	**164**

Source: KenGen, 2012

6.7 Water Utilization and Waste Water from the Geothermal Wells and Power Plants

The Olkaria IV and Olkaria I Units 4 & 5 will require 2,500 m^3, of fresh water for cooling towers at start up for about three years. Thereafter, only a small quantity is required for top up. Additional water is required for drilling of geothermal wells, for household use at KenGen staff housing quarters, and for supply to local communities for their domestic and livestock use. This water is abstracted from a single source, the nearby Lake Naivasha. The total amount of lake water drawn by the existing and the proposed geothermal project development on its own does not impact significantly on the lake level. Nevertheless, historical data shows that Lake Naivasha water level fluctuates significantly, and is likely to continue to do so over the expected 30-year life span of the proposed power stations (Figure 10). This can significantly scale down geothermal project development operations. The fluctuation is mainly attributed to prolonged periodic droughts as experienced in 2009 and the beginning of 2010, and subsequent over-abstraction by competing users, such as the flourishing horticulture farming and domestic water use by an ever increasing population. The mitigation measures being implemented include continued monthly monitoring of the lake level, re-using of drilling water by containing it in temporary circulation ponds, rainwater harvesting facilities installed in the newer buildings, controlled water supply at the KenGen housing staff quarters, monitoring and immediate repair of accidental pipe leakages and bursts, and use of brine for drilling.

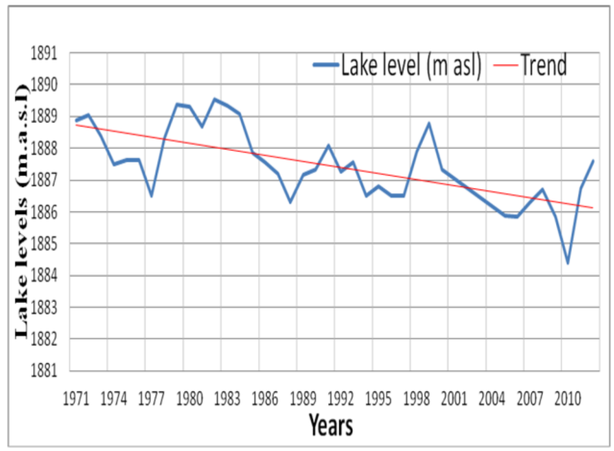

Figure 10: Average Lake Naivasha water levels monitored for about 30 years.

Brine is the main waste water from geothermal wells and power plants that, if improperly managed, can run over the surface and cause soil erosion and soil, water, and vegetation contamination. The appropriate brine disposal method is hot and cold re-injection from the wells and power plants respectively. The re-injection plays an important role of recharging the reservoir and minimizing land subsidence. Alternatively, brine is being used for drilling in order to supplement the fresh water from Lake Naivasha. A pumping station at the Olkaria I wetland supplies brine for drilling of wells that will be connected to Olkaria I Units 4 & 5.

An additional pumping station is under construction at OW 903 (see Figure 11), to supply brine for drilling wells at Domes that will supply steam to the upcoming Olkaria IV power station.

Figure 11: Excavation works for a brine pumping station at OW 903.

6.8 Impact of Visual Intrusion

Construction of the power plants and their associated infrastructure, which comprise of the traversing steam gathering pipelines, transmission lines and road network, will affect the aesthetics. The construction will be facilitated by the degradation of the surrounding environment via intrusion on the view of the natural landscape and the imposition of an image of economic and industrial nature within and in the vicinity of Hell’s Gate National Park (Figures 12 and 13).

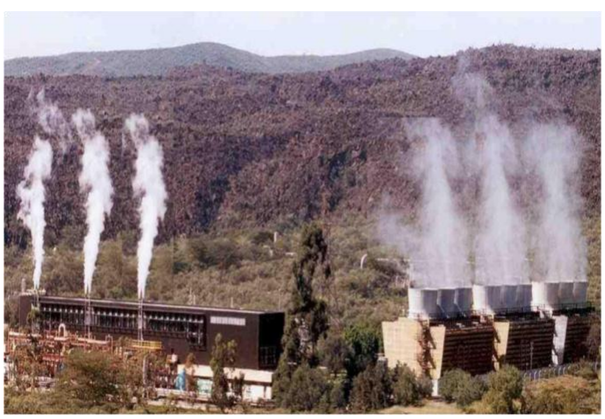

Figure 12: Olkaria I power station inside Hell’s Gate National Park.

Figure 13: Highly visible Olkaria II power station steam gathering pipes, transmission lines, and road network within the Hell’s Gate National Park.

In an attempt to reduce the impact of visual intrusion, the steam pipes were painted in beige and green colour so as to blend with the natural environment, as shown in Figure 14 below. However, due to the increasing number of power plants and associated infrastructure and the changing climatic conditions, the beige-painted pipes are now quite conspicuous during the wet season, which is dominated by a lot of green vegetation; in contrast, the green-painted pipes are highly visible during the dry season when the prevalent vegetation and soil cover is mainly brown.

Figure 14: An existing buffalo and zebra passing loop that is painted green to blend with the environment.

To solve this problem, a new design of camouflaging the steam pipes with alternating patterns of beige and various shades of green so that the pipes are not as conspicuous during either season is currently at an advanced stage, as illustrated in Figure 15.

Figure 15: A section of a stem pipe that is camouflaged on a trial basis.

It is expected that after camouflage, the high visual intrusion impact of the steam gathering and separation network that is shown in Figure 13 will reduce significantly, as illustrated in Figure 16.

Figure 16: Camouflaged Olkaria II power station steam gathering pipes, transmission lines, and road network within the Hell's Gate National Park.

6.9 Impact on Tourism

KenGen, with the approval of KWS, is fully financing the development of a Geothermal Direct-Use and Demonstration Centre. This will go a long way in enhancing co-existence with KWS as well as tourism, amidst the growing geothermal development activities within the Hell's Gate National Park. The Centre will be located next to the Olkaria Tree Nursery and OW 708, close to the Olkaria Gate. It will consist of three blue lagoons, a sauna, a steam bath, a geothermal museum, and a conference facility (Figure 17). The main purpose of the Centre is to educate the public on the various direct uses of geothermal energy resources, including natural spas, green house heating and drying of farm products. Promoting tourism will ultimately enhance KWS's revenue base to support its conservation activities.

Figure 17: A section of the blue lagoons at the Direct Use and Demonstration Centre that is currently under construction.

6.10 Impact of Power Plant Design and Technology

KenGen adopted "Well Head" power plant technology, which involves tapping steam from wells that are undergoing tests or are awaiting connection to permanent plants, to generate electricity at an early stage on their respective pads. This is a departure from traditional geothermal power plants that require multiple wells; traversing steam gathering pipes, transmission lines and road networks that impact significantly on wildlife habitat and movement; extensive design work; long construction periods; and entail large upfront investments to cover the 4-6 years before power generation can occur. Early generation also provides power that can be used for drilling subsequent wells, thus reducing combustion of diesel that emits greenhouse gases like carbon dioxide (CO_2) and sulphur dioxide (SO_2) into the atmosphere. Figure 18 shows a well head power plant located at OW 37. It is complete with steam supply, a power generation plant, and transmission lines for power evacuation. It was commissioned in April, 2012 with a supply of 5 MW of electricity to the national grid.

Figure 18: A well head power plant at Olkaria Well 37 located within the Hell's Gate National Park.

7. CONCLUSIONS

The proposed introduction of additional power plants, Olkaria I Units 4& 5 and Olkaria IV, within and in the proximity of the Hell's Gate National Park, is expected to add 280 MW to Kenya's national power grid, which is currently strained due to demand that outstrips supply. Nevertheless, provision of this power supply should not come at the expense of conservation efforts in environmentally significant areas - like the Hell's Gate National Park and Lake Naivasha - hence the need for effective implementation of the stipulated Environmental Management Plans. The successful implementation of the mitigation measures has been enhanced by strict compliance with the applicable legal and regulatory frameworks, and adherence to the existing Memorandum of Understanding between KWS and KenGen. So far a largely consultative and participatory process has been followed and is encouraged in future, to ensure that any impacts are maintained at a low level of significance.

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