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GEOTHERMAL TRAINING PROGRAMME
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PRELIMINARY ENVIRONMENTAL IMPACT ASSESSMENT FOR THE DEVELOPMENT OF KATWE AND KIBIRO GEOTHERMAL PROSPECTS, UGANDA

MSc thesis
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by

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INTRODUCTION

The Geothermal Training Programme of the United Nations University (UNU) has operated in Iceland since 1979 with six month annual courses for professionals from developing countries. The aim is to assist developing countries with significant geothermal potential to build up groups of specialists that cover most aspects of geothermal exploration and development. During 1979-2004, 318 scientists and engineers from 39 countries have completed the six month courses. They have come from Asia (44%), Africa (26%), Central America (14%), and Central and Eastern Europe (16%). There is a steady flow of requests from all over the world for the six month training and we can only meet a portion of the requests. Most of the trainees are awarded UNU Fellowships financed by the UNU and the Government of Iceland.

Candidates for the six month specialized training must have at least a BSc degree and a minimum of one year practical experience in geothermal work in their home countries prior to the training. Many of our trainees have already completed their MSc or PhD degrees when they come to Iceland, but several excellent students who have only BSc degrees have made requests to come again to Iceland for a higher academic degree. In 1999, it was decided to start admitting UNU Fellows to continue their studies and study for MSc degrees in geothermal science or engineering in co-operation with the University of Iceland. An agreement to this effect was signed with the University of Iceland. The six month studies at the UNU Geothermal Training Programme form a part of the graduate programme.

It is a pleasure to introduce the eighth UNU Fellow to complete the MSc studies at the University of Iceland under the co-operation agreement. Mr. Godfrey Bahati, BSc in Chemistry, of the Department of Geological Survey and Mines, Minstry of Energy and Mineral Development in Uganda, completed the six month specialized training at the UNU Geothermal Training Programme in October 1993. His research report was entitled "Geochemical studies on waters from the Katwe-Kikorongo, Buranga and Kibiro geothermal areas, Uganda". After eleven years of geothermal research work in Uganda, he came back to Iceland for MSc studies at the Faculty of Science of the University of Iceland in January 2004. In July 2005, he defended his MSc thesis presented here, entitled "Preliminary Environmental Impact Assessment for the development of the Katwe and Kibiro geothermal prospects, Uganda". His studies in Iceland were financed by a fellowship from the Government of Iceland through the Icelandic International Development Agency (ICEIDA) and the UNU Geothermal Training Programme. We congratulate him on his achievements and wish him all the best for the future. We thank the Faculty of Science of the University of Iceland for the co-operation, and his supervisors for the dedication.

Finally, I would like to mention that the graphs and diagrams in Godfrey's MSc thesis had to be printed in black and white. However, a colour version in a pdf format is available for downloading on our website at page *www.os.is/unugtp/yearbook/2005.*

With warmest wishes from Iceland,

Ingvar B. Fridleifsson, director
United Nations University
Geothermal Training Programme

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First and foremost I would like to express my sincere gratitude to the Icelandic International Development Agency and the United Nations University for sponsoring this study. I would like to thank the staff of the United Nations University Geothermal Training Programme (UNUGTP) lead by Dr. Ingvar Birgir Friðleifsson, director, for their support and guidance during the study. Special thanks to Mr. Lúdvík S. Georgsson and Ms. Gudrún Bjarnadóttir for their outstanding assistance during my stay in Iceland. I also appreciate the good working relationship with the staff of Orkustofnun and the Icelandic GeoSurvey.

I am indebted to the teachers at the University of Iceland for sharing a great learning experience and a high level of presentation. I wish to express my appreciation to Dr. Geir Oddsson and Dr. Gudrún Pétursdóttir, the directors of the Institutes of Environment and Fisheries research respectively at the University of Iceland, for their guidance in research and presentation of scientific information.

I would like to thank the organizations that have supported the Uganda geothermal exploration programme since its inception in 1993; the UNDP, OPEC, IAEA, WB, ADB and the Governments of Uganda and Iceland, for keeping the programme alive and progressing. My employer, the Ministry of Energy and Mineral Development of Uganda, is highly acknowledged for granting me a study leave to attend this course.

ABSTRACT

Geothermal investigations have been carried out in both Katwe and Kibiro geothermal prospects in Uganda. Subsurface temperatures, geological structures and flow characteristics of the surface and ground waters in the geothermal systems have been delineated using various analytical methods. Conceptual geothermal models based on results of geochemical, geological, hydrological and geophysical studies have been constructed and are currently being upgraded. The models will then be used as a basis for siting deep geothermal exploration wells. It is, therefore, foreseen that the pre-feasibility study is coming to an end in the two prospects. This will pave the way for a feasibility study that will end with the installation of the first geothermal power plants in the country.

The objective of the study was to analyse the current status of the environment in Katwe and Kibiro geothermal prospects and to identify and predict the changes in the environment if the development of geothermal resources is to take place in the two areas. There is a need to incorporate the potential and likely impacts on the environment in the design of the feasibility study as early as possible.

The preliminary environmental impact assessment for the development of Katwe and Kibiro geothermal prospects was carried out in line with Uganda's laws on the environment. The proposed feasibility study was described and its potential environmental impacts of drilling and operation on the environment affected identified. The likely environmental impacts and their significance were analysed and mitigation measures proposed. The results indicate that the Katwe prospect is subjected to more adverse environmental impacts than the Kibiro prospect and its development has a potential for indirect and cumulative impacts as well as impact interactions. The adverse environmental impacts of drilling were found to be temporary and mitigable to the level of insignificance in both Katwe and Kibiro. Preliminary assessment of adverse impacts of operation on the environment has resulted in identifying five critical areas that should be subjected to detailed investigation. These are impacts on biodiversity; water quality and hydrology; air quality; utilities; and public health and safety. Other impacts i.e. on geology; land use; visual and aesthetic quality; population, housing and employment; transportation and traffic; public services; energy; and cultural situation, are not considered to be of critical importance since they have a high mitigation potential. They should, however, be taken further during the detailed environmental impact assessment with specialist input where necessary.

In conclusion the environmental impacts of developing the two areas Katwe and Kibiro are predictable and mitigable with appropriate technology and the cooperation of all stakeholders. It is therefore recommended that these impacts be incorporated into the design plans of the feasibility study for the two areas. A detailed environmental impact assessment is recommended as a first step of the feasibility study to provide a better understanding of the potential impacts and mitigation measures that will be continuously upgraded during the study.

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1. INTRODUCTION

1.1 Background

Pre-feasibility studies on the Uganda geothermal systems have been in progress since 1993. The studies have focused on surface exploration of three major geothermal areas: Katwe-Kikorongo (Katwe), Buranga and Kibiro, all located in the Albertine graben that forms a part of the western branch of the East African Rift System (Figure 1). Two of the areas, Katwe and Kibiro, are in an advanced stage of surface exploration and their pre-feasibility study phase is coming to an end. The two areas are now being considered for feasibility studies, which, if they give positive results will pave the way for the establishment of the first pilot geothermal power plants in the country.

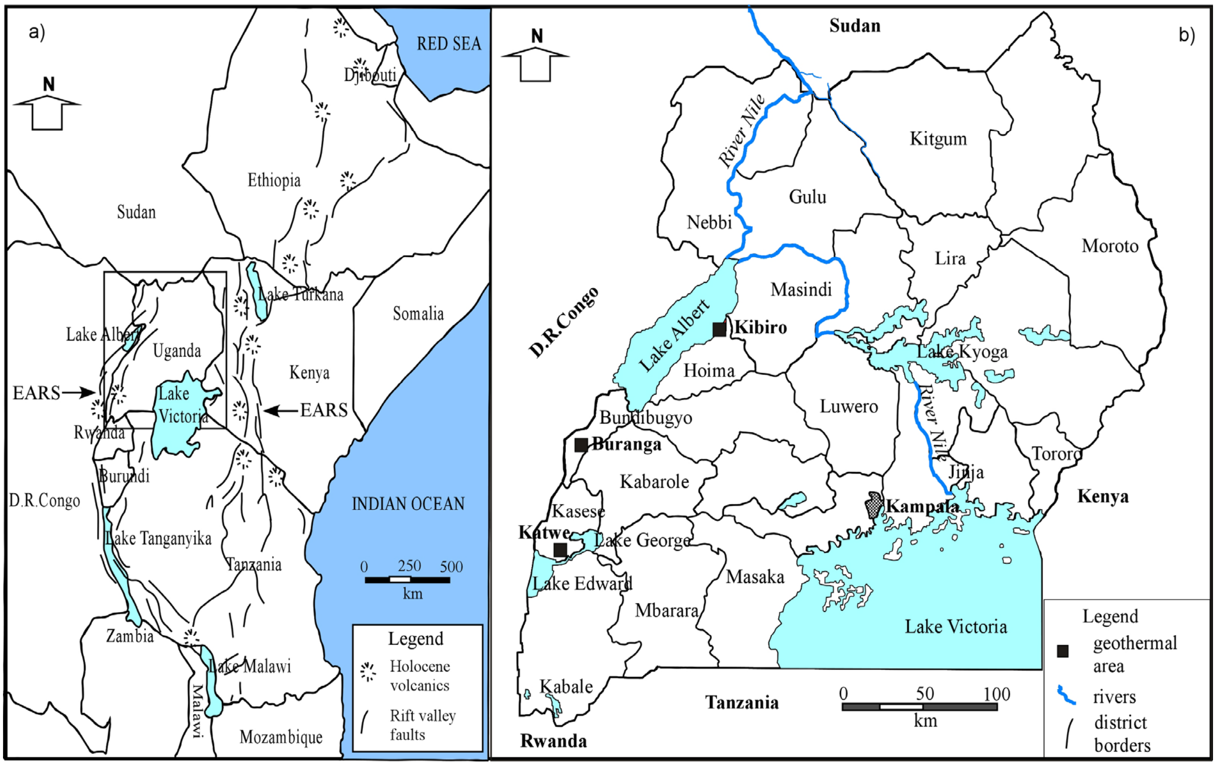


FIGURE 1: a) East African Rift System (EARS),
b) Locations of Katwe and Kibiro geothermal prospects

The current pre-feasibility study results show good potential for harnessing the geothermal resources of Katwe and Kibiro. The pre-feasibility study was focused on geology, geochemistry, hydrology and geophysics with the aim of elucidating subsurface temperatures and the existence of a geothermal system. The current results indicate that the geothermal activity in the two areas is related to the volcanic and tectonic activities of the rift, which has a higher heat flow than the surrounding Precambrian crust. Subsurface temperatures of approximately 140-200˚C and above 200˚C for Katwe and Kibiro respectively have been predicted by geothermometry and mixing models. The temperatures are suitable for electricity production and direct use in industry and agriculture. Results of the preliminary geophysical surveys indicate the existence of geothermal anomalies in the two areas. The current studies are focused on the geophysical surveys with the aim of delineating the spatial extent of the anomalies and their infrastructure. These studies once completed will mark the end of the pre-feasibility phase in Katwe and Kibiro.

The development of geothermal resources in the two areas will change/modify the current status of the environment. This development, therefore, brings natural and socio-economic environmental impacts, which must be taken into consideration. The Katwe geothermal prospect is located within a protected area, the Queen Elizabeth National Park (QENP), and the accompanying environmental impacts of its development may not be compatible with the conservation of biodiversity. The area is also associated with an important cultural archaeological site where salt has been produced from the geothermal brines for many generations, and fishing, pastoral and agricultural communities. Unlike Katwe, the Kibiro geothermal prospect is located on privately owned land but also associated with a local salt industry that has been in production for the last 900 years (Connah, et al., 1990), and fishing, pastoral and agricultural communities.

This calls for the identification and assessment of potential environmental impacts at this time when plans for development are being considered. There is a need to incorporate environmental issues into the planning and/or design of the upcoming projects and adjustments to be undertaken early enough to ensure minimal impact on the environment.

The study was, therefore, designed to identify and assess the potential environmental impacts that may accrue from the development of the two areas. The study was conceived after a wide range of consultations with stakeholders who are not familiar with potential and likely environmental impacts of geothermal development in the two areas. Geothermal is a new source of energy in Uganda and this is the first time such a study is carried out there.

1.2 Objectives of the study

The overall objective of the study was to analyse the current status of the environment in Katwe and Kibiro geothermal prospects and to identify and predict the changes in the environment if the development for geothermal resources is to take place in the two areas. The breakdown of the objectives is as follows:

- To compare geothermal energy with other alternative sources of energy at local, regional and national level.
- To review and analyse the results from the pre-feasibility study (geological, geochemical, hydrological and geophysical surveys) to assist in locating and delineating the boundaries of the feasibility study area.
- To collect baseline data on the environment affected.
- To identify potential environmental impacts.
- To predict and identify likely environmental impacts.
- To propose mitigation measures for the impacts.
- To assess the magnitude and significance of the impacts with and without mitigation.
- To scope for terms of reference for a detailed Environmental Impact Assessment of the significant environmental impacts.

1.3 Study areas

The areas under study are Katwe and Kibiro. They are both located in the Albertine graben that runs along the border of Uganda with the Democratic Republic of Congo (DRC) (Figure 1). The Albertine graben is part of the western branch of the East African Rift System (EARS) in Uganda, commonly known as the Western Rift Valley.

1.3.1 Katwe geothermal prospect

The Katwe geothermal prospect is located in Lake Katwe subcounty, Busongora county, Kasese district (Figure 2). The prospect is a part of the Katwe-Kikorongo Volcanic field (KKVF) which occupies approximately the whole area within the boundaries of Lake Katwe subcounty. The KKVF forms the northern terminal of the QENP. The total area of the QENP is 1,979 km^2 of which approximately 200 km^2 form the KKVF. The Park has one of the highest biodiversity ratings of any game reserve in the world. Almost 100 mammal species and a remarkable 606 bird species make QENP a superb safari territory, with elephants, a profusion of hippopotami, the elusive giant forest hog and the handsome Uganda Kob all regularly sighted around the tourist village on the Mweya peninsula. The QENP also boasts a marvellous waterfront setting, comprising Lakes Edward and George and the Kazinga Channel, in the shadow of the Rwenzori Mountains.

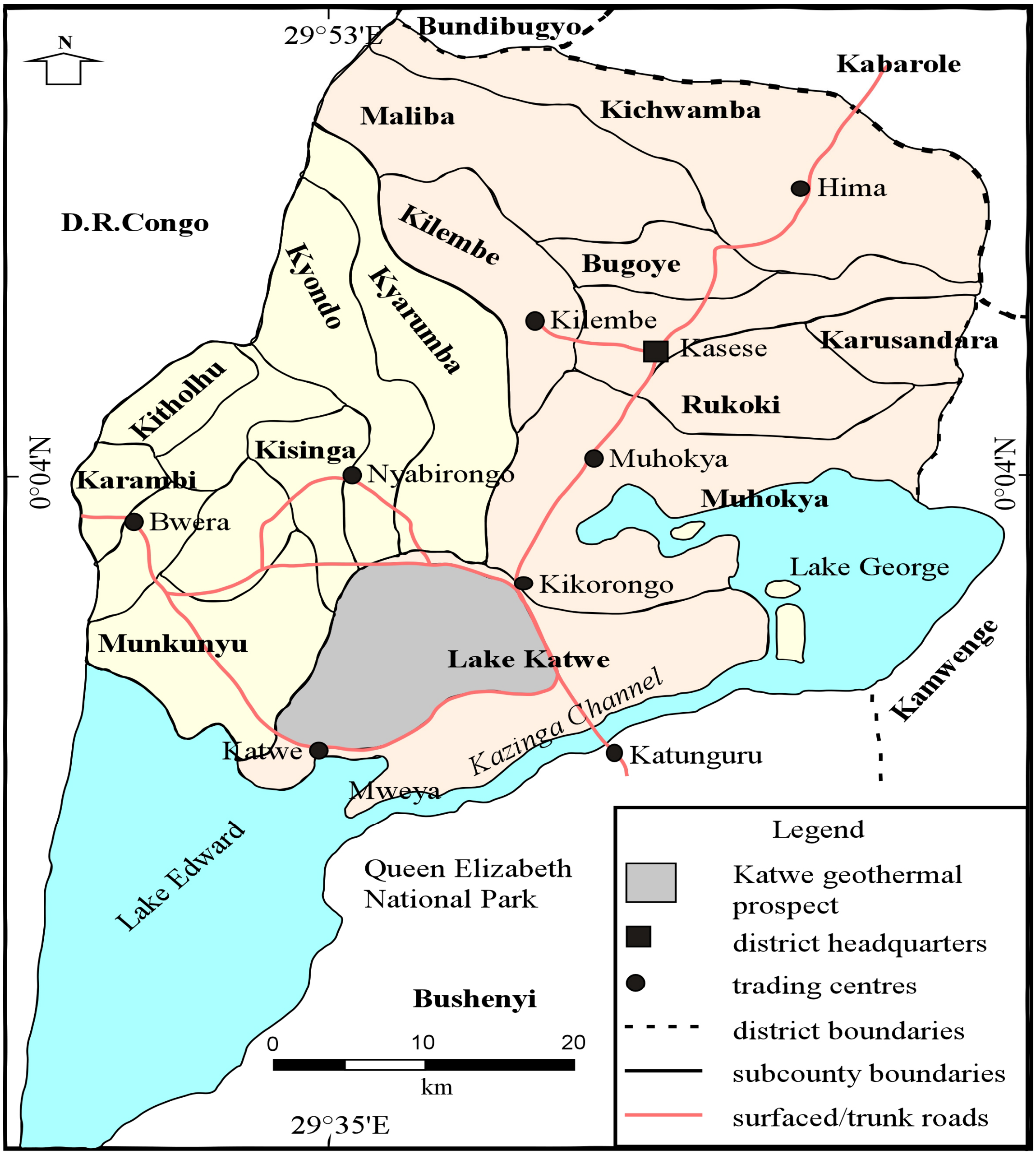


FIGURE 2: Kasese district; administrative units and the Katwe geothermal prospect

Kasese district is located along the Equator in the western region of Uganda. It lies between latitudes 0˚12´S and 0˚26´N; and longitudes 29˚42´E and 30˚18´E. The district is bordered to the north by the district of Bundibugyo, Kabarole to the northeast, Kamwenge to the east, Bushenyi to the south and the DRC to the west. The approximate total area of the district is 3,185 km^2 covered by wetlands, water and a savannah type of vegetation. Its mountainous terrain is in the north with flat plains in the south. Kasese is a multi-ethnic district with many people of different ethnic background forming a total population of approximately 530,000 people (Population census, 2002). The main languages and ethnic groups that dominate the area are the Lukonjo and Rutooro of the Bakonjo and Batooro people respectively. But there are also other groups in the district who include the Banyankole, Basongora and Bakiga. There is also common usage of English, Swahili and Luganda. Kasese district was formed in 1974 under the Provincial Administration of Rwenzori district that was curved out of Tooro. Prior to this, it was part of the Tooro kingdom that comprised the present districts of Bundibugyo, Kabarole, Kyenjojo, Kamwenge and Kasese.

The administrative structure of the district comprises two counties namely Busongora and Bukonjo which are further subdivided into 19 subcounties. Busongora county lies in the eastern part of the district with 9 subcounties namely Bugoye, Karusandara, Kilembe, Kichwamba, Kyabarungira, Lake Katwe, Maliba, Muhokya and Rukooki. Bukonjo county lies in the western part of the district with 10 subcounties namely Bwera, Ihandiro, Karambi, Kisinga, Kitholhu, Kyarumba, Kyondo, Mahango, Munkunyu and Nyakiyumbu. In addition there are two townships namely Kasese, the district administrative headquarters, and Katwe – Kabatooro (Katwe) both located in Busongora county (Figure 2).

1.3.2 Kibiro geothermal prospect

The Kibiro geothermal prospect is located in Kigorobya subcounty, Bugahya county, Hoima district (Figure 3). The prospect gets its name from a small settlement on a narrow stony plain of about three-quarters of a kilometre in width, between the lake shore and the foot of an approximately 350 m high escarpment that forms the eastern side of the Western Rift valley in Uganda. The Kibiro geothermal prospect covers almost the entire Kigorobya subcounty and is divided into two different environments by the eastern escarpment of the Rift valley. To the west lie the villages of Kibiro and Kachuru on the

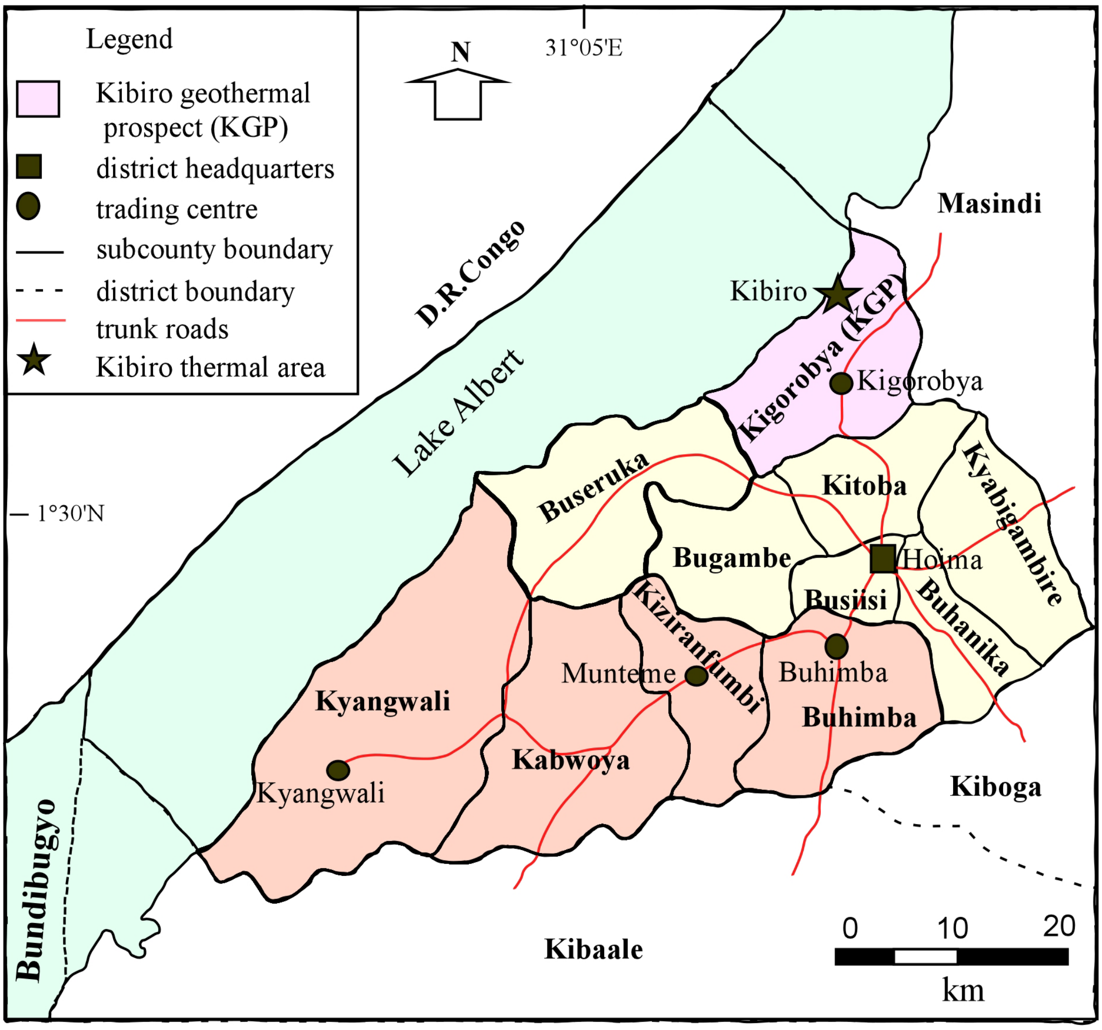


FIGURE 3: Hoima district; administrative units and the Kibiro geothermal prospect

shores of Lake Albert at a general elevation of 600 m a.s.l. Kachuru is located approximately 500 m southwest of Kibiro. East of the escarpment the ground rises gently from 950 m.a.s.l on top of the escarpment toward Kigorobya and Hoima to an average of 1,100 m a.s.l.

Hoima became a district in 1974. It was curved out of the former large region of Bunyoro Kingdom which also included the present Masindi, Kibaale and parts of Kiboga and Luwero districts. Hoima district is located in the mid-western part of Uganda. It borders the districts of Bundibugyo and Kibaale to the south, Kiboga to the east, Masindi to the north and northeast and the DRC to the west and northwest. The district lies approximately between latitudes 1°00'N and 2°00'N; and longitudes 30°30'E and 31°45'E. It covers a total area of 5,933 km^2 of which 2,269 km^2 are occupied by water bodies (mostly Lake Albert) and accounts for about 38% of the total area. Forests constitute a relatively smaller portion of about 712 km^2 which is 12% of the total area. It has a population of 349,204 people (Population and housing census, 2002). The area can be referred to as being ethnically rich with nearly every tribe in Uganda represented. The Banyoro and Bagungu form the dominant tribes and account for about 77%, followed by the Alur and Jonam (about 7%), Bakiga (about 4%), Lugbara and Aringa (about 3%) and others (about 9%).

The administrative structure of the district comprises two counties namely Bugahya and Buhaguzi which are further subdivided into 11 subcounties. Buhaguzi county lies in the southern part of the district, stretching from southeast to southwest with 5 subcounties namely Bugambe, Buhimba, Kiziranfumbi, Kabwoya and Kyangwali. Bugahya county lies in the north and runs from northwest to northeast with 6 subcounties namely Buseruka, Kigorobya, Kitoba, Busiisi, Buhanika and Kyabigambire. In addition there are two townships namely Hoima, the district administrative headquarters, and Kigorobya both located in Bugahya county (Figure 3).

1.4 Literature review

1.4.1 Previous studies on Uganda's geothermal systems

The oldest literature on the Uganda geothermal systems dates way back to the late 19th Century when Stanley described the salt works at Lake Katwe crater, and measured the temperature of the lake and one of the hot springs in the crater to be 29.1°C and 32.5°C respectively (Stanley, 1890). Similar measurements on hot springs were carried out by the Geological Survey of Uganda from 1921 to 1935, when the results were first published (Wayland, 1935).

In 1972 chemical analysis of the Katwe hot springs waters was carried out with support from the United Nations. The results indicated a reservoir temperature of 190°C and the field was recommended for economic exploitation (McNitt, 1972). In 1973, as a result of the oil crisis, an attempt was made to initiate a geothermal project with the United Nations support, but this did not materialise. In 1982, geothermal resources were estimated at about 450 MWe in the Ugandan Rift System and the three areas Katwe, Buranga and Kibiro identified as promising areas for geothermal exploration (McNitt, 1982). In 1987, a UNDP mission visited Uganda to assess the status of the geothermal exploration programme. The mission recommended a geothermal project for Uganda (Stefansson, 1987).

In 1993-1994, geological and geochemical investigation was carried out under project, Geothermal Energy Exploration I (UGA/92/002) (Armannsson, 1994; Gislason, 1994). The project was funded by the Government of Uganda (GoU), United Nations Development Programme (UNDP), Organization of Petroleum Exporting Countries (OPEC), and Government of Iceland. The results indicated that both Katwe and Kibiro are potential geothermal targets that warrant further studies. Subsurface temperatures of 140-200°C and above 200°C were inferred by geothermometry for Katwe and Kibiro respectively.

Hydrological studies by the GoU with support from the International Atomic Energy Agency (IAEA) were also carried out between 1999 and 2003 on both Katwe and Kibiro prospects with the aim of delineating flow characteristics of geothermal, surface and ground waters in the two areas. The results are in agreement with those of project UGA/92/002 on subsurface temperatures and also suggest a possible source of the geothermal waters to be from high grounds in the Rwenzori Mountains and Mukhihani-Waisembe Ridge for Katwe and Kibiro respectively.

The GoU with support from the African Development Bank (ADB) and the Government of Iceland carried out a preliminary geophysical survey and an additional geological survey in Katwe and Kibiro in 2003 and 2004 respectively. The aim of the surveys was to delineate the spatial extent of the thermal anomalies and upgrade the existing geothermal models of the two areas with geophysical information to pre-feasibility status. The results of the geophysical surveys indicated the existence of geothermal systems in the two areas, supported by low resistivity and high gravity anomalies. In both areas, the areal extent of the low resistivity proved larger than anticipated, an indication that the anomaly is somewhat larger and extends beyond the area surveyed. The funds were not sufficient to complete the pre-feasibility study in both areas. The GoU with support from the World Bank (WB) and the Government of Iceland are currently carrying out further geophysical surveys to delineate the boundaries of the anomaly and locate sites for drilling the first exploration wells. This will pave way for the feasibility study of the two areas.

1.4.2 The geothermal environment

The definition of the word "environment" as used in Environmental Impact Assessments (EIAs) includes not only the physical environment (land, water, air and soils) but also the biological environment (fauna and flora), the cultural environment, social environment, historical environment, economic environment etc. For example, the European Commission, the governing body of the European Community (EC), has defined the environment as 'the combination of elements whose complex inter-relationships make up the settings, the surroundings and the conditions of life of the individual and of society, as they are or as they are felt'.

The major components of the geothermal environment are the beautiful natural and thermal features, which vary in colour and form. Their environmental importance is enhanced because they are rare on a worldwide basis, and often fragile. The major types of natural features are: geysers – hot springs which periodically erupt a jet of hot water and steam; fumaroles – vents from which steam is emitted at high velocity; hot springs – vents from which hot water flows; silica sinters – terraces formed of opaline silica precipitated from waters of geysers and hot springs; and mud pools – hot pools in which adjacent rock or soil has been dissolved to form a viscous mud, usually sulphurous and often multi-coloured.

The second component is the cultural significance attached to the thermal areas and features. The thermal areas are often associated with myths and legends in native people's cultures. For example, the native Maori people have a legend that the thermal areas of New Zealand were formed when fire gods, summoned from far away and travelling underground, surfaced looking for the person who called them. In other areas thermal features are associated with spiritual ceremonies, e.g. in Beppu (Japan) people hold a *Hot Spring Festival* every year.

Thirdly, bathing in hot pools or spas is common in most countries where geothermal waters are available. The geothermal water is often claimed to have special medicinal properties, i.e. for treatment of rheumatism, arthritis and skin diseases. It is also used for washing and cooking. Examples are Kitagata, Ihimbo, Karungu and Rwagimba in west and southwest Uganda.

And lastly, thermal areas and features have economic uses such as being tourist destinations because of their rarity and beauty. They are also used as a source of heat for agricultural and industrial purposes; e.g. fruit and crop drying, heating greenhouses, and fish farming. Small communities often develop around places of such activities.

1.4.3 Geothermal development and the environment

Geothermal energy is known to be an environmentally friendly energy source compared to fossil fuels such as coal, oil and natural gas. The terminology "environmentally friendly" is used in comparison with other sources and should not mean that geothermal energy is completely friendly to the environment. Geothermal energy has significant impacts on the environment and the degree of friendliness of an impact on the environment depends on the point of view of the local residents of the impacted community (Popovski, 2003).

Taking into account that people usually do not have a clear understanding of what types of impacts are to be expected with the introduction of this new energy source, there is usually no resistance during the initial phases of development, i.e. exploration, investigation and project design phases. However, individual and collective attitudes toward geothermal development usually change with time as the project reaches the drilling stage and work for plant construction begins. Indeed, undesirable effects may result from these activities: on ecosystems (air, land, flora, fauna, and superficial and underground water); human health (from water pollution, noise and gas emission); and economy (detrimental impact on some production activities, tourism and damages to crops and private properties) (Cataldi, 2001).

Moreover, reaction often grows against landscape modifications and alteration of natural features of cultural or religious interest, caused by civil and industrial work; and changes in the use of public areas resulting from project activities. For all the above reasons, opposition by residents in the project area often increases as the project proceeds, especially in areas with resources suitable for geothermal-electricity generation. Thus, the number of people who label geothermal energy with terms such as costly, polluting, and dangerous to people's health also increases. Furthermore, in areas with different options, opposition to geothermal development can be used as reinforcement by parties interested in fostering the use of energy sources other than geothermal.

1.4.4 Research and experience of environmental impacts of geothermal energy

Geothermal is a source of energy that is vital in many countries of the world that are naturally endowed with the resource including neighbouring Kenya, Iceland, USA, Philippines, Indonesia, Italy, New Zealand and other countries. Over the years it has been proved to be technically feasible and simultaneously more attention is being directed towards the environmental effects of geothermal development and utilization. The following are examples of the research that has been carried out in different countries; the problems encountered, and abatement measures suggested.

In geothermal projects most land effects occur during construction and drilling which involve construction of access roads, drill pads, power plants, switch yards and transmission lines. This can lead to substantial loss of land. For example a drill pad can use a land equivalent of 200 – 2,500 m^2. Construction of access roads to drilling sites and drill pads has led to the destruction of forests and vegetation particularly in tropical areas with high rainfall (Indonesia, Philippines). This has sometimes resulted in erosion and with large amounts of silt being carried by streams and rivers draining the development areas. The silt may be deposited on the river bed causing the bed of the river to be raised and flood the adjacent land. Loss of land and vegetation has been minimised by gradient or directional drilling whereby many wells are drilled from the same pad (e.g. Tongonan, Philippines). This reduces the number of drill pads and the area for access roads and pads.

Another effect is ground subsidence that is caused by geothermal fluid withdrawal from a reservoir at a rate greater than the natural inflow. This net outflow causes rock formations at the site to become compact, particularly clays and sediments, leading to ground subsidence. The largest recorded subsidence in a geothermal field was at Wairakei in New Zealand where the ground subsided for 18 m during 30 years of geothermal fluid extraction. Monitoring has shown that a maximum subsidence rate of 45 cm/year occurred in a small region, outside the production area, with a subsidence of at least 2 cm/year occurring all over the production field (Hunt and Brown, 1996). Subsidence in other fields has been observed and measured at 1.7 m in Larderello, Italy, between 1923 and 1986 (Dini and Rossi, 1990); 10 cm in the Geysers, USA, between 1974 and 1977 (Allis, 1982); and up to 15 cm between 1982 and 1987 in Svartsengi geothermal field, Iceland (Bjornsson and Steingrimsson, 1992). Fluid re-injection has been recommended to sustain fluid pressure in the reservoir, but its effectiveness depends on where the fluid is re-injected and the permeability conditions in the field and care must be taken to avoid cooling in the reservoir.

Historical evidence shows that natural thermal features have been affected during the development and initial production stages of most high temperature geothermal systems. At Wairakei (New Zealand), nearly all thermal features in the Waiora and Geyser valleys have disappeared. At Larderello (Italy) where the original natural activity consisted of numerous steam and gas jets, activity has now largely ceased, and at the Geysers (USA) there has been a decrease in the flow from hot springs since utilization started. Scientific evidence shows that the decline in thermal features is associated with decline in reservoir pressure. As the pressure declines, so does the amount of geothermal fluids reaching the surface and hence the thermal features decline in size and vigour and may disappear if the pressure declines further. Reinjection of spent fluids into the reservoir has been recommended as a possible solution to maintaining reservoir pressures.

Geothermal fluid discharge may have an impact on local and regional surface waters such as rivers, lakes and estuaries. The water phase in wet fields sometimes contains toxic ingredients such as boron, arsenic, ammonia and mercury, which, if discharged into courses, could contaminate downstream waters used for farming, fisheries or human water supplies. High concentrations of heavy metals are associated with high-temperature brines at Salton Sea in California and on the islands of Milos and Nisyros in Greece. High boron and arsenic concentrations are found in many geothermal systems associated with andesitic volcanism. Examples include Mt. Apo in the Philippines and Ahuachapan in El Salvador. Boron rich waters occur in geothermal waters which have reacted with marine sediments, e.g. at Ngawha in New Zealand. Waters of geothermal systems hosted by basaltic rock are low in boron, arsenic and heavy metals but relatively high in both hydrogen sulphide and aluminium. Such waters have been encountered in the Krafla high temperature geothermal field, N-Iceland (Arnorsson, 2004). Reinjection of the spent fluids deep into the reservoir has been recommended and has produced good results.

In Olkaria, Kenya where a 45 MWe power plant is in operation having been commissioned in 1985, extensive environmental studies have been carried out. Prediction of potential environmental effects of geothermal wastewater has been made in various studies (Simiyu, 1995; Simiyu and Tole, 2000). For example Simiyu and Tole (2000) indicated that soils in contact with geothermal fluids concentrate elements by factors of between 13 and 6,000 in comparison to metal concentrations in overlying water columns. A similar study of the evaluation of trace element levels and their ecotoxicological relevance in geothermal wastewater of Olkaria East Field, Kenya has been carried out (Wetang'ula, 2004). The outcome of these studies has been to recommend reinjection of spent fluids and monitoring programmes as means of controlling environmental impacts that accrue from improper disposal of geothermal wastewater. Other results from Kenya show that geothermal developments can coexist with farmland, forests, animals and wildlife. For example, the Olkaria I project which is producing 45 MWe is located in Hell's Gate National Park. Land use in the park includes livestock grazing, growing of foodstuffs and flowers, and conservation of wildlife. After extensive environmental impact analysis, a second geothermal plant, Olkaria II, was approved for installation in the National Park in 1994 and commissioned in 2003, and an additional power station, Olkaria IV, is expected to be commissioned in 2008 (Wahogo, 2003).

1.5 The energy mix for Uganda

Uganda has an area of approximately 241,000 km^2 and a population of about 25 million people with an annual growth rate of 2.5% (Population census, 2002). The grid electricity access rate is very low:

9% for the whole country and about 3% for the rural areas. Demand for power is growing at 3-4 MWe a month.

Uganda is richly endowed with a variety of renewable energy resources which include plentiful woody and non-woody biomass, solar, wind, geothermal and hydrological resources. Presently, with the exception of biomass, only a meagre fraction of the country's renewable energy potential is utilised. It is estimated that other renewable sources of energy, excluding large hydropower, contribute less than 2% of Uganda's total energy consumption.

1.5.1 Geothermal

The geothermal resources of Uganda were estimated to be about 450 MWe (McNitt, 1982) and since then no new estimates have been put forward. Geothermal energy is considered a potential energy source in the energy mix of Uganda for the following reasons:

- Potential hydropower sites are more or less concentrated in one area (along the River Nile) resulting in long transmission distances to distant areas and therefore high energy losses; G
- Geothermal areas on the other hand are located in the Western Rift Valley, west Uganda, which is far from the potential hydropower sites and therefore geothermal energy has potential to strengthen the grid in western Uganda;
- The long-term effects of cascaded hydropower development along the River Nile are not known;
- Uncertainty of continued availability of hydropower arising from climatic fluctuations and therefore a need to diversify energy sources;
- Environmental degradation as a result of extensive harvests of existing natural forests for biomass and land for subsistence agriculture;
- Location of geothermal fields in isolated rural areas far from the national grid like Buranga in Bundibugyo district;
- Geothermal can also provide direct heat for use in industry and agriculture and a possibility of recovering minerals from the geothermal spent brines; and
- It is an environmentally benign energy source.

1.5.2 Alternatives

I. Hydropower
The hydroelectric power potential of Uganda is high and estimated at over 2,000 MWe, mainly along the River Nile. Current utilization is about 317 MWe, of which 300 MWe is on the River Nile. Kilembe Mines Ltd., Kasese Cobalt Company Ltd., and others generate a total of 17 MWe.

The country is currently experiencing power shortages with demand exceeding supply by 110 MWe due to climatic fluctuations that have caused the production to drop from 300 MWe to 220 MWe from the two hydropower dams, Nalubale (formerly Owen Falls) and Kiira, all located at Jinja. In the meantime construction of the planned Bujagali hydropower dam, rated at 250 MWe, by the Independent Power Producers (IPPs) has been commissioned. Bujagali dam is expected to be completed by the year 2010 but even then the country will still have a power deficit considering the current high rate of economic and industrial growth. The present uncertainty regarding the future of hydropower projects has caused the government to diversify energy sources and promote other alternatives.

II. Thermal power
This is a new energy source which has been introduced to offset the shortfall in hydropower output from the two dams at Jinja. The Government has licensed IPPs to produce 50 MWe of thermal power as an emergency to offset the shortfall. This project will use a number of generators running on diesel as a source of fuel and is expected to consume 162,000 litres per day. Such a project has serious

environmental impacts and therefore a need to develop alternatives that are environmental benign as soon as possible.

III. Biomass

Biomass (firewood, charcoal and crop residues) plays a very significant role in Uganda's energy supply. It constitutes over 90% of the total energy consumption in the country. It provides almost all the energy used to meet the basic needs of cooking and water heating in rural and most urban households, institutions and commercial buildings. Biomass is the main source of energy for rural industries. Trading in biomass energy, especially charcoal contributes to the economy in terms of rural incomes, tax revenue and employment. It saves foreign exchange, employs approximately 20,000 people and generates 36 billion Uganda Shillings (US$ 20m) per year in rural incomes. Fuel-wood requirements have contributed to the degradation of forests as wood reserves are depleted at a rapid rate in many regions. The depletion of forests poses a great challenge to environmental protection since the forests act as sinks for greenhouse gases especially carbon dioxide.

Biomass (bagasse from sugar processing industry) is also used to produce electricity and steam (cogeneration). Kakira sugar works in Jinja is constructing a 20 MWe cogeneration power plant and a Power Purchase Agreement (PPA) is already in force to supply 6 MWe to the national grid by 2006. Most of the traditional energy technologies (wood and charcoal stoves and charcoal production kilns) currently used in Uganda are inefficient. Several initiatives to conserve biomass resources have been undertaken by the GoU and the private sector, including NGOs. They include the promotion of improved stoves, as well as afforestation. However, the impact of these efforts is still limited.

IV. Solar energy

Uganda is endowed with plenty of sunshine giving solar radiation of about 4-5 kWh/m^2/day. This level of insolation is quite favourable for all solar technology applications. Solar energy applications in Uganda include solar photovoltaic (PV), water heating, cooling and crop drying. PV systems are generally required for applications where modest power needs exist mainly in areas that are not served by the grid. They provide power for lighting, telecommunications, vaccine and blood refrigeration, and for radio and television in such areas. This technology has also proven to be very successful in providing energy services to extremely inaccessible areas such as islands and mountainous areas to which the national grid cannot be expected to extend its services in the foreseeable future. The disadvantage of this kind of energy is that the output is limited, very expensive and cannot support grid systems.

V. Wind energy

The average wind speed in Uganda is about 3 metres per second. In relatively flat areas especially around Lake Victoria and NE-Uganda as well as tops of hilly areas, the speed may go as high as 6 meters per second and above. This wind regime is good enough to support wind technology applications in the country. However, these wind speeds have been recorded at low heights for the purpose of predicting weather. No measurements have been made at appropriate heights (over 10 m) for wind turbine design. A programme to that effect is to be implemented with assistance from the ADB and private sector initiatives.

VI. Small hydropower plants

The country has numerous small hydropower sites which could be developed to supply isolated areas or feed into the national grid. They include Nyagak (5 MWe), Bugoye (7.5 MWe), Nengo Bridge (12 MWe) and Buseruka (10 MWe), Muzizi (3-10 MWe) and Ishasha (10 MWe). The feasibility study for the construction of Nyagak power plant has been completed. The power plant will boost electricity supply in the West Nile region.

1.5.3 Geothermal energy versus other options

Geothermal energy has several advantages in electricity generation over other sources of energy. The most prominent are: (i) proven viable technology; (ii) reasonable capital and operating costs; (iii) well defined lead times and costs of construction; (vi) flexibility to match expansion requirements, i.e. additions can be made in modular increments; (v) the utilization of an indigenous resource, i.e. unlike fossil fuels it does not need transportation; (vi) controllable and predictable environmental impacts; (vii) diversification of supply in power generation conducive to an improved generation mix; (viii) unlike hydropower, it does not displace large numbers of people as most of the land close to surface installations can continue to be used for subsistence, commercial agriculture and conservation of natural resources; and (ix) independence of fluctuations in weather conditions. These advantages, if properly taken into account could influence the decision of implementing the geothermal option.

In most developing countries the alternatives for base-load generation are mainly geothermal plants; hydroelectric plants (with regulation), thermal electric plants (oil and coal fired). A comparison of the options listed above and other renewable sources i.e. the unit cost for investment, current and future cost prices are presented in Table 1.

Table 1 shows that geothermal energy is the cheapest energy source as far as investment is concerned and can only be compared with biomass energy. Its current cost is the same as that of hydropower but is predicted to decrease in future with improved technology and the general advantage of renewable energy over hydropower as far as environmental impacts are concerned. Geothermal has also the highest capacity factor of 45 – 90%.

TABLE 1: Cost of hydropower vs. other renewable sources (WEA, 2000)

Type	**Energy production in 1998**		**Install. capacity end of 1998**		**Capacity factor**	**Current energy cost**	**Pot. future energy**	**Turnkey investm. cost**
	TWh(e)	**%**	**GWe**	**%**	**%**	**US¢/kWh**	**US¢/kWh**	**US$/kWh**
Hydropower	2,600	92.0	663	91.8	20-70	2-10	2-10	1,000-3,500
Biomass	160	5.66	40	5.53	25-80	5-15	4-10	900-3,000
Geothermal	46	1.63	8	1.11	45-90	2-10	1-8	800-3,000
Wind energy	18	0.64	10	1.38	20-30	5-13	3-10	1,100-1,700
Solar energy:	0.5		0.5		8-20	25-125	5-25	5,000-10,000
-photovoltaic		0.05		0.12				
-thermal	1		0.4		20-35	12-18	4-10	3,000-4,000
Tidal power	0.6	0.02	0.3	0.04	20-30	8-15	8-15	1,700-2,500
Total	2826.1		722.2					

2. FRAMEWORK FOR ENVIRONMENTAL MANAGEMENT

The constitution of the Republic of Uganda 1995 is the legal source of the law, including environmental law, in Uganda. The provisions of the constitution relating to the environment are enshrined in Objective XXVII and Chapter 15 (Articles 245 and 237 (2)) of the constitution. Following the promulgation of the constitution in 1995, a number of Acts, Statutes and Regulations have been instituted to protect the environment. The relevant legislation to geothermal development is presented in Table 2.

TABLE 2: Environmental legislation in geothermal development

The National Environment Statute (Statute No. 4 of 1995)
Environmental Impact Assessment Regulations, 1998
The National Environment (Standards for discharge of effluent into water or land) Regulations, 1999
The Water Statute, 1995
The Uganda Wildlife Statute (Statute No. 14 of 1996)
Mining Act, 2003
Electricity Act, 1999

2.1 The National Environment Statute (Statute No. 4 of 1995)

As a result of the National Environment Statute 1995 institutions for the protection of the environment have been established. These include the Policy Committee on the Environment; Board of Directors; National Environment Management Authority; Lead Agencies; Executive Director, Deputy Executive Director and other staff; Technical Committees; District Environment Committees; District Environment Officers; and Local Environment Committees.

The Policy Committee on the Environment is the highest policy making organ of the National Environment Management Authority (NEMA) and is composed of eleven ministers of government. The functions of the committee are to liaise with Cabinet on issues affecting the environment, formulate environmental policies and programmes and ensure that they are carried out. The Board of Directors consists of eight members appointed by the Minister for the Environment with the approval of the Policy Committee on the Environment. The Board oversees the implementation of policy and operation of NEMA, guides the Executive Director and staff, approves the annual budget and plans of NEMA and establishes and approves rules and procedures relating to the staff of NEMA. The functions of NEMA are summarized in Table 3.

TABLE 3: Functions of NEMA under the National Environment Statute (Section 7)

To co-ordinate the implementation of government policy and decisions of the Policy Committee;
To ensure the integration of environmental concerns in overall national planning through coordination with relevant ministries, departments and agencies of government;
To propose environmental policies and strategies to the Policy Committee;
To initiate legislative proposals, standards and guidelines on the environment;
To review and approve environmental impact assessments and statements;
To promote public awareness through formal, non-formal and informal education about environmental issues;
To ensure observance of proper safeguards in the planning and execution of all development projects, including those already in existence, that have or are likely to have a significant impact on the environment;
To undertake research, gather and disseminate information about the environment; mobilize, expedite and monitor resources for environmental management; and
To gather, analyze and manage environmental information.

2.2 The Uganda Wildlife Statute (Statute No. 14 of 1996)

The Katwe geothermal prospect is located in the Queen Elizabeth National Park (QENP) which is managed under the Uganda Wildlife Statute 1996 by the Uganda Wildlife Authority (UWA). The QENP has a wide range of natural resources that include a rich biodiversity, minerals and geothermal energy among others. The utilization of geothermal resources, must, therefore be compatible with the protection of biodiversity. The Environment and Wildlife Statutes allow the utilization of geothermal resources if Environmental Impact Assessment reveals positive impacts from the activity.

The Uganda Wildlife Statute 1996 lists projects, which are compulsory for environmental impact assessment (EIA). All engineering operations that include drilling, excavation and construction of roads and buildings fall under this category. Apparently geothermal development falls under this category and this calls for an EIA. The geothermal development will therefore need to involve measures to make sure that environmental impacts are critically identified, mitigated against and monitored.

2.3 Guidelines for Environmental Impact Assessment

The environmental assessment for the proposed project is conducted with stringent adherence to the National Environment Statute, 1995 (Sections 20-24) and by the Environmental Impact Assessment Regulations, 1998 *(Statutory Instrument No. 13 of 1998)*. The National Environment Statute (Statute No. 4 of 1995) identifies those activities that require an EIA due to the potential to have a detrimental impact on the environment. Every developer of a project listed under the *[Third Schedule of the National Environment Statute]* must carry out an environmental impact assessment. The proposed geothermal development is one such activity.

The NEMA (Authority) is the principal agency for the management of the environment. It coordinates monitors and supervises all activities concerning the environment. The NEMA acts through lead agencies to implement the National Environment Statute. A lead agency is any ministry, department, parastatal agency, local government system, or officer to whom the Authority delegates its functions under subsection (2) of section (7) of the statute.

2.3.1 Environmental Impact Assessment

Environmental Impact Assessment (EIA) as defined by the National Environment Statute, 1995, is "a systematic examination conducted to determine whether or not a project will have an adverse impact on the environment". An EIA is a planning tool that identifies the environmental consequences of a proposed project and assists in ensuring that the project will be environmentally acceptable and sustainable over its life cycle. However, the EIA is by no means a comprehensive environmental management plan. It is rather the first step towards it, and it is the responsibility of the proponent as well as the responsible authorities to ensure that continued environmental management takes place through appropriate planning, programmes and control.

One of the fundamental principles of an EIA is public participation. Public participation provides for a situation where the collective wisdom of the project proponent, its technical consultants, the authorities and stakeholders representing a diverse range of perspectives share the common goal of sustainability. Public participation often leads to the achievement of this goal in the best interests of everyone involved as well as fostering effective trade-offs between economic growth, social equity and ecological integrity. In this way, it is possible to maximize the benefits of the proposed project for the developer as well as for other stakeholders, to mitigate the potentially negative impacts, and to identify any potential flaws that may render the project environmentally unacceptable.

2.3.2 Environmental Impact Assessment process

The basic components of the EIA process in Uganda consist of three interconnected phases: screening, environmental impact study, and decision making. The basic components of the EIA process, including outputs and inputs, are illustrated in Figure 4. Briefly the three main phases include:

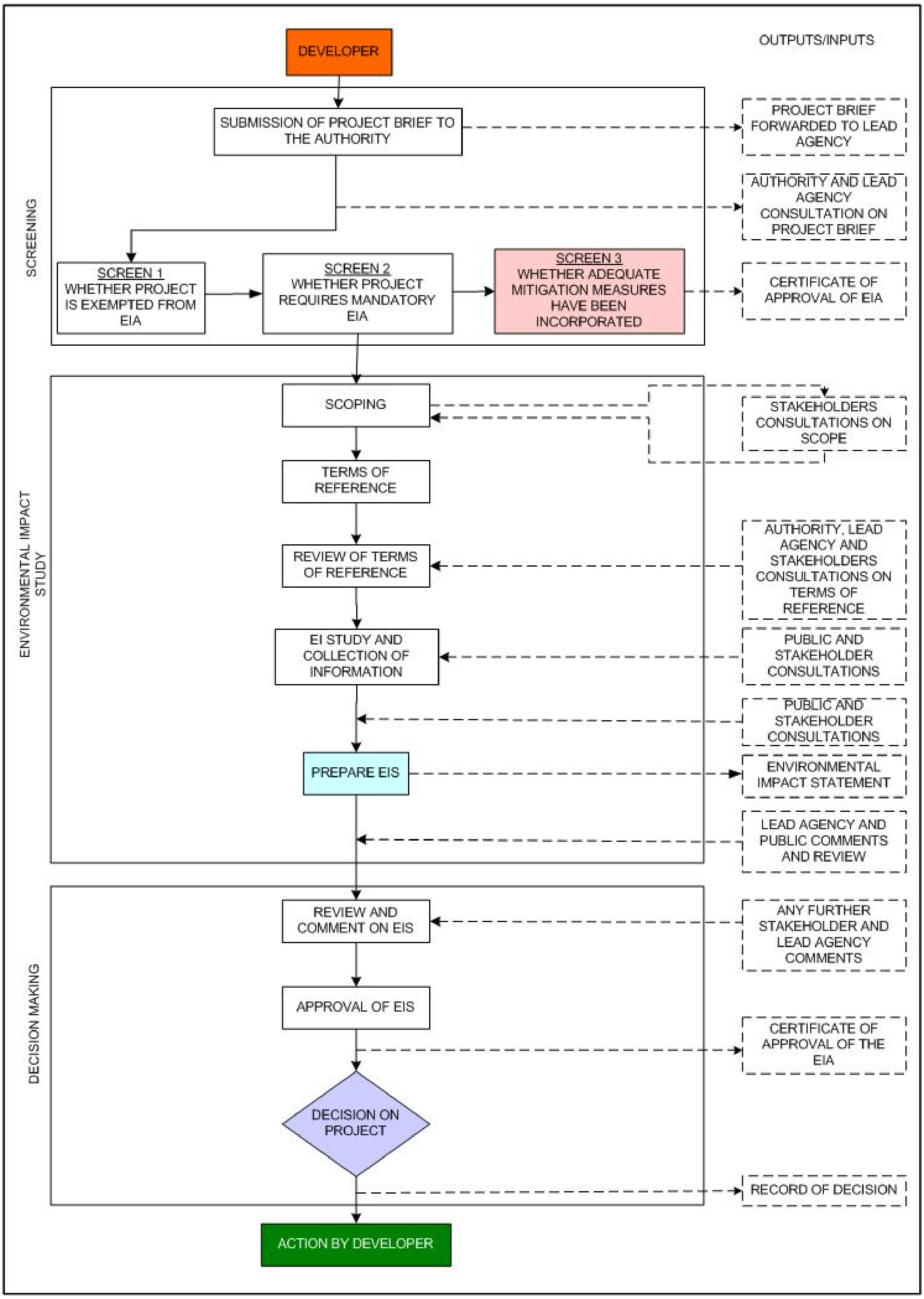


FIGURE 4: Environmental impact process flow (NEMA, 1997)

Phase I: Screening
Screening is a process to determine whether a proposed project has or does not have significant impacts. The process assists in determining whether a proposed project requires an EIA or not.

Phase II: Environmental impact study
Environmental impact study is divided into two steps namely scoping, and conducting environmental impact study and preparation of the environmental impact statement (EIS).

Scoping – A process to identify potential significant environmental impacts that are relevant to assess, and to derive terms of reference for the impact assessment.

Conducting an environmental impact study - An undertaking of specialist studies to predict and identify the likely environmental impacts of a proposed project or development taking into account inter-related consequences of the project proposal, and the socio-economic impacts. The study ends with the identification of mitigation measures (including not proceeding with the development, finding alternative designs or sites which avoid the impacts, incorporating safeguards in the design of the project, or providing compensation for adverse impacts) and an environmental impact statement (EIS).

Phase III: Decision making
Either on the basis of a finding that a project is exempt, appropriate mitigation measures have been incorporated for identification of environmental impacts, or the preparation of an EIS, a decision is made to approve or disapprove the environmental aspects of a proposed project. The Authority will issue a Certificate of Approval of the Environmental Impact Assessment.

After approval of the environmental aspects of the EIS by the Authority, the lead Agency decision makers and licensing authorities, will then take appropriate action to approve or disapprove the project based on all its merits (environmental, social, economic, political or other factors), and a Record of Decision shall be prepared.

3. CURRENT STATUS OF THE GEOTHERMAL PROJECT

The current geothermal models of Katwe and Kibiro prospects are based on the results of a 1993 - 1994 geological and geochemical investigation (Armannsson, 1994; Gislason, 1994); hydrological studies by the GoU and the IAEA of 1999 - 2003 (Bahati et al., 2005), the geophysical surveys of 2003 - 2004 (UAERAUS, 2004; Gislason et al., 2004) and the review and further analysis of the previous results (this study). The geological, geochemical and hydrological studies were carried out in three areas, Katwe, Buranga and Kibiro, all in the Western Rift Valley in Uganda. Two of the three areas, Katwe and Kibiro, were chosen for geophysical studies which are being finalised to pave way for drilling. In this chapter the current results for Katwe and Kibiro geothermal prospects are summarised.

3.1 Katwe geothermal prospect

3.1.1 Geology

The geology of the Katwe geothermal prospect is dominated by explosion craters, ejected pyroclastics, tuffs with abundant granite and gneissic rocks from the basement (Figure 5). The volcanic rocks, composed mainly of pyroclastics and utramafic xenoliths, are deposited on the extensive Pleistocene lacustrine and fluvial Kaiso beds and in some places directly on Precambrian rocks. Minor

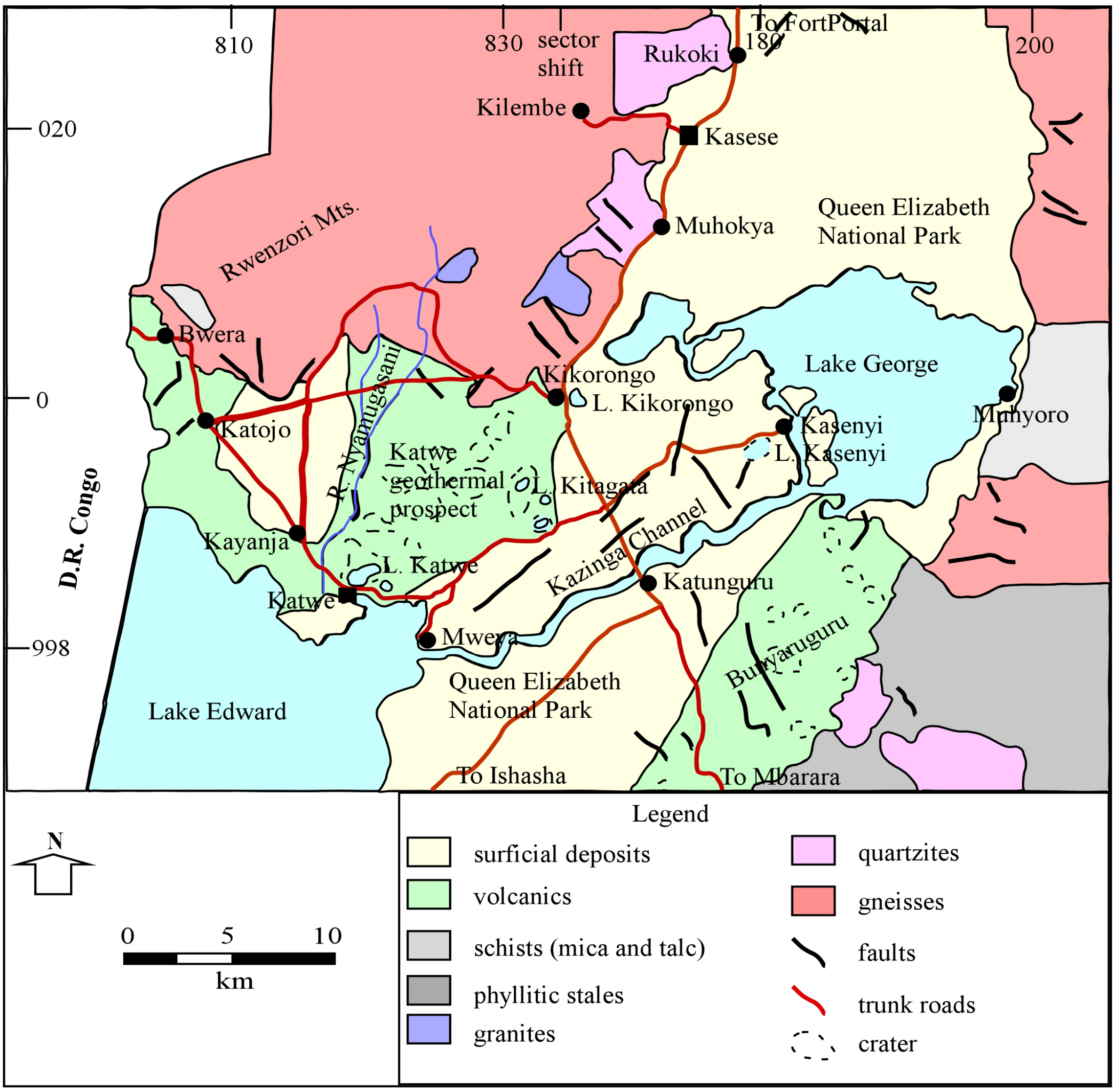


FIGURE 5: The geology of the Katwe-Kikorongo volcanic field and surroundings

occurrences of lava are found in the Lake Kitagata and Kyemengo craters. The age of the volcanic activity has been estimated as Pleistocene to Holocene (Musisi, 1991). The deposit is greyish, generally coarse-grained and calcareous. Travertine cones (Tufa), which are indicators of extinct hot spring activity, are a common feature in the Lake Katwe crater. Other travertine deposits have been found in Lake Nyamunuka, Lake Kasenyi, and Lake Kikorongo and at Kikorongo junction. The volcanic setting of this prospect gives an indication of a powerful heat source. The area of the prospect is approximately 150 km^2, all within the crater area. The prospect stretches from Lake Katwe to Lake Kikorongo and is bordered to the south by Lake Edward and the Katwe – Katunguru road, to the west by River Nyamugasani, to the north by the Kikorongo – Bwera road and to the east by the Katunguru – Kasese road. Outside the crater area the geology is characterised by surficial deposits to the east and the west, and to the north lie the Rwenzori Mountains whose geology is dominated by gneisses and in some places granites and quartzites along the Kikorongo - Kasese road. South of Lake George lies the Bunyaruguru volcano which has a number of craters and crater lakes, believed to have been formed at the same time as the Katwe-Kikorongo volcano but it has no surface geothermal manifestations. East of the Bunyaruguru volcano and Lake George from south to north are phyllitic stales, quartzites, gneisses and schists (mica and talc).

3.1.2 Geochemistry

Recent geochemical studies of the Katwe geothermal prospect started in 1993 with the Geothermal Energy Exploration Project I (UGA/92/002). In the project geochemical methods aiming at establishing the subsurface temperatures as a part of the preliminary investigations were used. However, the project was short-lived and ended in 1994. The current geochemical status of the Katwe prospect is presented in the following sections.

I. Geothermal manifestations

The discharge zones of the Katwe geothermal prospect are manifested by five hot springs located in the Lake Kitagata crater, and warm springs and travertine deposits that have built up tufas in the Lake Katwe crater, which is located 12 km southwest of Lake Kitagata (Figure 6).

Three of the hot springs in the Lake Kitagata crater are on shore and the other two are offshore at a distance of 10 - 15 m from the shore. The offshore hot springs are the most powerful, manifested by upwelling and are believed to be the source of recharge for Lake Kitagata. Lake Kitagata is at a higher altitude (944 m a.s.l.) than the surrounding craters that are all dry. Therefore, if the source of the water in this crater is controlled by the general groundwater table, the other surrounding craters would have formed lakes too. The source of the water is likely to be a deep confined aquifer and the water forced to the surface through a fault or an opening by hydrostatic pressure. The measured surface temperatures in the hot springs range from 56-70°C with the highest at 70°C measured in an offshore hot spring which is also characterized by the discharge of hydrogen sulphide of about 7-40 ppm unlike the onshore hot springs.

The highest surface temperature measured in the Lake Katwe crater is 32ºC in one of the springs at the bottom of the crater, Lusonga (Lusonga BH). Another warm spring located in the eastern part of the crater (Figure 6), discharges warm water at a temperature of 29ºC and high levels of hydrogen sulphide of about 35-40 ppm whose source is believed to be volcanic and hydrothermal. These observations together with the travertine deposits (tufas) have qualified the Lake Katwe crater like the Lake Kitagata crater as an indicator of powerful heat centres at depth. There is evidence that at one time hot fluids would flow to the surface through the tufas and this flow has ceased possibly due to reduction in hydrostatic pressure caused by the self-sealing nature of geothermal systems.

Travertine deposits have been discovered at Kikorongo junction during the reconnaissance surveys in 2003 (Kato, 2003). Other centres of travertine (calcareous tufa) deposits had been observed earlier in Lake Kasenyi, Lake Nyamunuka and Lake Kikorongo (Groves, 1930). These are indications of extinct outflow centres suggesting that the Katwe prospect could be much bigger than is currently confirmed.

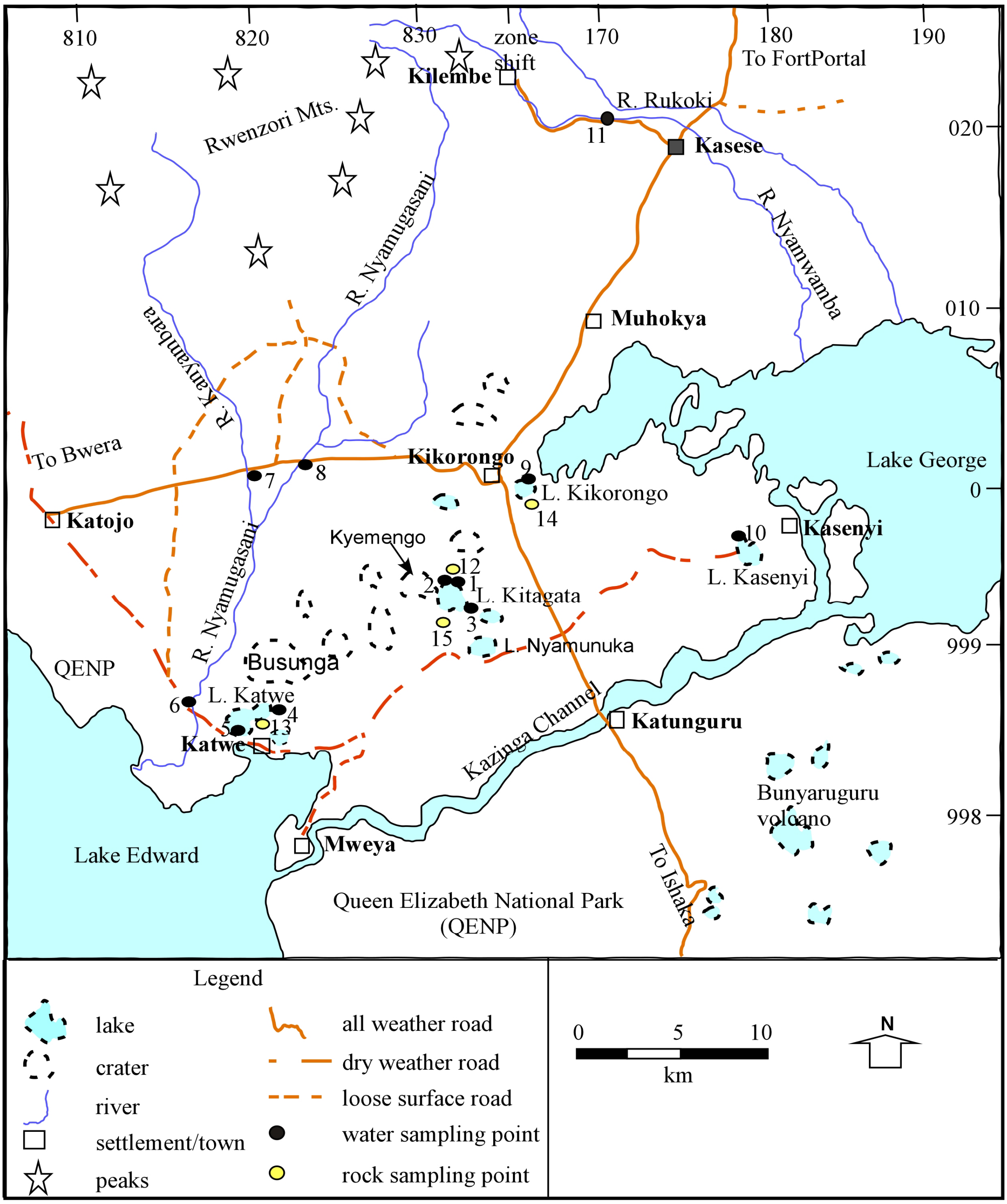


FIGURE 6: Katwe and surroundings, geothermal, surface and ground water sampling points

II. Results

The geochemistry results reveal the existence of a geothermal system in the Katwe prospect. The geothermal fluids are characterized by high carbonate contents and salinity, two of the hot springs sampled in the Lake Kitagata crater, HS-02 and HS-05 have a salinity of 19,410 and 27,770 mg/kg total dissolved solids respectively. The high carbonate affects the concentrations of Ca and Mg which are less mobile and tend to precipitate out of solution as Ca and Mg carbonates rendering the geoindicators involving the two cations unreliable. Solute geothermometers have been difficult to use in Katwe due the high salinity of the fluid. The sulphate concentrations are relatively high and all indications suggest that the geothermal system is relatively old. Relatively low B values compared to Cl and Li suggest that the fluids are more likely to originate from volcanic basement rocks rather than from the young overlying sediments. Some indications of possible mixing with groundwater were inferred from log (Q/K) diagrams (Armannsson 1994) predicting a temperature of 140 - 160°C. The NaK geothermometer (Arnórsson et al., 1983b) and quartz geothermometer (Fournier and Potter, 1982) give temperatures of 140 – 160°C and 120 - 140°C respectively for the on shore hot spring waters in the Lake Kitagata crater (Armannsson (1994). It was difficult to get a representative sample from the offshore hot springs in Lake Kitagata during the study. The samples collected at different times were variable mixtures of the geothermal water and lake water. However high levels of H_2S (7 - 40 ppm) measured in the mixed water at the different times suggest the source of the geothermal water to be volcanic and hydrothermal.

3.1.3 Hydrology

Hydrological investigations in Katwe were carried out between 1999 and 2003 under project UGA/8/003, a cooperation project between the GoU and IAEA. The main objectives of this study were to: 1) elucidate the origin of the geothermal fluids and the recharge mechanisms, 2) estimate subsurface temperature using isotope geothermometry, 3) trace the source of solutes, and 4) improve the conceptual geothermal model of the area.

I. Sampling and analysis

A number of water samples from hot springs, cold springs, rivers and lakes as well as rock samples were collected and analyzed for isotopic compositions. Isotopes analyzed for included those of hydrogen (δ^2H_{H2O}, $^3H_{H2O}$), oxygen ($\delta^{18}O_{H2O}$, $^{18}O_{SO4}$), sulphur ($\delta^{34}S_{SO4}$), and strontium ($^{87/86}Sr_{H2O}$, $^{87/86}Sr_{Rock}$). Field measurements of temperature, pH and electrical conductivity and analysis of volatiles (CO_2 and H_2S) etc., were carried out on site. Isotope analysis of water and rock samples was carried out at the IAEA's isotope hydrology laboratory in Vienna, the Institute of Hydrology (GSF) in Munich, Germany and the Institute of Geosciences and Earth Resources in Pisa, Italy. The sampling points and analytical results of isotopes are presented in Figure 6 and Table 4, respectively.

TABLE 4: Katwe geothermal area and surroundings, isotope data

ID	Sample No.	Location	Type	$\delta^{18}O$‰ SMOW	δ^2H‰ SMOW	Tritium TU	$\delta^{34}S$ (SO_4)	$\delta^{18}O$ (SO_4)	$^{87/86}Sr$ in rock or water
1	UG-02-01	L. Kitagata	GTH	-0.74	2.4	<0.3	9.6	14.1	0.7060
2	UG-02-02	L. Kitagata	GTH	-0.80	-2.1	< 0.2	9.6	13.1	0.7060
3	UG-02-03	L. Kitagata	SLA	7.76	41.8	1.6			0.7068
4	UG-02-04	L. Katwe	SPR	-2.00	-10.0	< 0.3	33.0	26.6	0.7070
5	UG-02-05	L. Katwe	SPR	-3.39	-12.3	< 0.4			0.7062
6	UG-02-06	R. Nyamugasani	SRI	-2.84	-5.2	2.2			0.7171
7	UG-02-07	R. Kanyambara	SRI	-2.54	-3.1	2.1			
8	UG-02-08	R. Nyamugasani	SRI	-3.00	-7.1	2.1			
9	UG-02-09	L. Kikorongo	SLA	6.49	40.2	1.9			
10	UG-02-10	L. Kasenyi	SPR	-3.44	-13.7	< 0.2			
11	UG-02-11	Kibenge	GTH	-4.46	-20.2	<0.5			0.7342
12	UG-02-25	L. Kitagata	Rock						0.7047
13	UG-02-26	L. Katwe	Rock						0.7049
14	UG-02-27	L. Kikorongo	Rock						0.7078
15	UG-02-33	L. Kitagata	Rock						0.8195

GTH: Geothermal spring; SPR: Cold water spring; SRI: Stream or river water; SLA: Lake water.

II. Stable isotopes of water and recharge to the Katwe geothermal system

Isotope ratios, especially $^2H/^1H$ (usually reported as δ^2H, Craig, 1961a), tend to be conservative, and are good indicators of the origin of flow, mixing and evaporation. The $^{18}O/^{16}O$ ratio or $\delta^{18}O$ is similarly useful for cold waters, but in geothermal systems exchange may take place during water/rock interaction causing an oxygen isotope shift to higher values, especially where the water/rock ratio is low, i.e. when general permeability is poor.

A general worldwide relationship between δ^2H and $\delta^{18}O$ has been established (Craig, 1961b), as the Global meteoric water line (GMWL):

$$\delta^2H = 8*\delta^{18}O + 10 \qquad \text{(i)}$$

Similarly the observed Local meteoric water line (LMWL) for precipitation at Entebbe, Uganda (GNIP, 1999) has the same slope but higher deuterium excess with the equation:

$$\delta^2H = 8*\delta^{18}O + 12.3 \qquad \text{(ii)}$$

Both lines have been drawn in Figure 7 and the stable isotope results for waters from Katwe plotted. All hot spring waters, groundwaters, and river waters plot close to the two lines. The thermal waters show isotopic compositions compatible with the LMWL, confirming the meteoric origin of the water circulating in the geothermal system. The lake waters are higher in δ^2H and $\delta^{18}O$ possibly due to evaporation. There are signs of both oxygen and deuterium shifts in the hot spring waters from the potential source water, which possibly results from mixing with lake water. The lake waters have been affected by strong evaporation resulting in increased δ^2H and $\delta^{18}O$. The Katwe hot spring water is probably a mixture of a source water similar to the most depleted local groundwaters and water from lakes in the area. The mixing model for Katwe is also presented on the same diagram (Figure 7) by a dashed trend line. This model indicates that the geothermal water is a mixture of the hot water component and a lake water component.

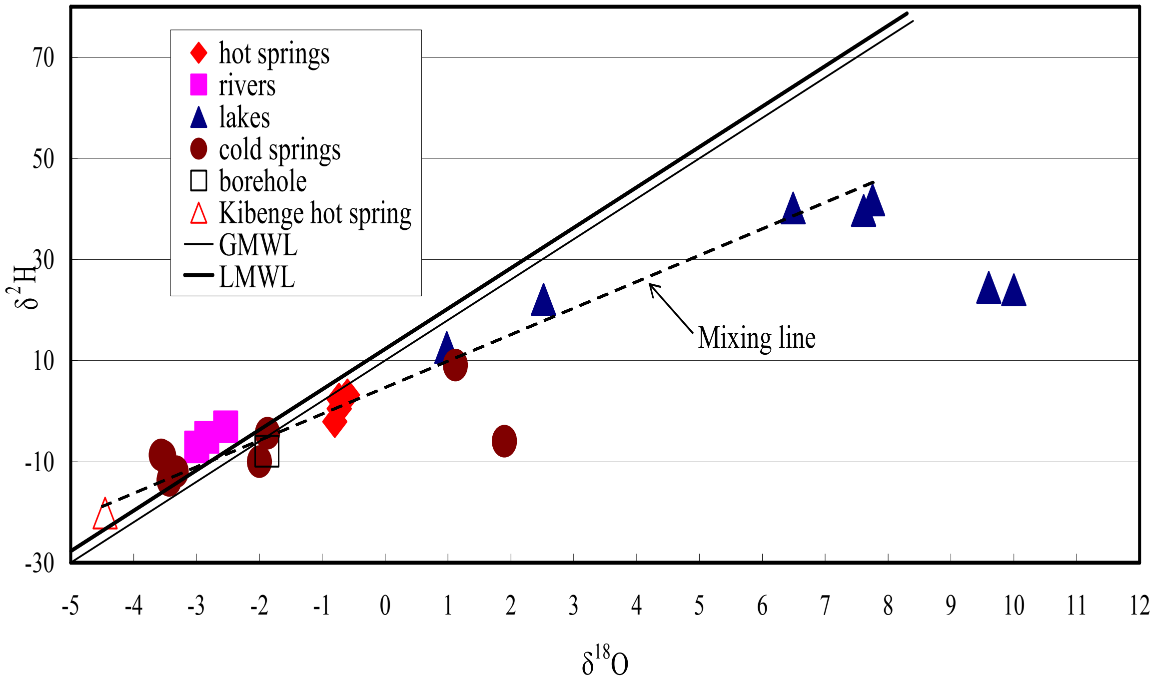


FIGURE 7: Katwe, stable isotopic composition of hot and cold water samples

The Katwe geothermal system is most likely recharged from high ground in the Rwenzori Mountains. The source of the recharge is similar to that of the Kibenge geothermal area (Figure 7), located at the foot of the Rwenzori Mountains and most likely recharged from them. The Katwe hot spring water is probably a mixture of this high-elevation component, local groundwater (cold springs), river water and water from lakes in the area. The Rwenzori Mountains are snow capped and characterized by a number of lakes, at high elevation, recharged from snowmelt. It is possible that some of these lakes are losing some of their waters through fractures (faults) which channel these waters to the geothermal reservoirs of Katwe. The evidence for this are the tectonic movements (earthquakes) that simultaneously affect Bundibugyo and Kabarole districts and indicate that the two places are connected by one or more faults possibly passing under the Rwenzori Mountains. Kabarole and Bundibugyo districts are situated east and west of the northern part of these mountains, respectively.

III. Other environmental isotopes
The results for tritium, sulphur and oxygen isotopes in sulphates, and strontium isotopes in water and rock can be interpreted as follows:

The tritium concentration in hot spring waters from the Katwe area is insignificant. This suggests that there is possibly no mixing of hot spring water with cold groundwater and that the geothermal water has a residence time of more than 50 years.

The isotope composition of sulphur and oxygen in sulphates expressed in $\delta^{34}S$ (SO_4) and $\delta^{18}O$ (SO_4) is an important characteristic in delineating the origin of water and sulphates. The results for Katwe suggest a magmatic and hydrothermal source of geothermal water.

Strontium isotopes in water and rock ($^{87/86}Sr_{H2O}$, $^{87/86}Sr_{Rock}$) indicate an interaction between the rocks sampled and the geothermal fluids. The rocks interacting with the fluids, reservoir rock types, in Katwe are most likely basalt (leucites and melilites) and ultramafic xenolith. The major source of salinity is rock dissolution, but some magmatic input is suggested (Bahati, et al., 2005).

IV. Isotope geothermometry
Solute geothermometers were difficult to use in Katwe due to the high salinity of the fluid. The sulphate concentrations are relatively high (8,000–13,000 mg/kg) and all indications suggest that the geothermal system is relatively old. Thus conditions for sulphur isotope determination and attainment of isotope equilibrium are good. A temperature of 130-140°C was obtained for the sulphate-water ($S^{18}O_4$-$H_2{}^{18}O$) isotope geothermometer (Bahati, et al., 2005) which compares reasonably well with those of the solute geothermometers (140-160°C). Some indications of possible mixing with groundwater were inferred from log (Q/K) diagrams (Armannsson, 1994), but results for tritium in geothermal water (Bahati, et al., 2005) do not show any mixing. In this case, however, it would be the geothermal component that supplied most of the sulphate. Thus a subsurface temperature of 130 - 140°C is predicted for Katwe by isotope geothermometry.

3.1.4 Geophysics

The results of the geophysical surveys indicate the existence of geothermal systems in the Katwe area suggested by the low resistivity and high gravity anomalies. The areal extent of the low resistivity has not yet been resolved due to insufficient data. The gravity data collected during the 2003 survey (UAERAUS, 2004) show a high gravity anomaly trending NE-SW along the main fault that stretches from Lake Katwe to Lake Kikorongo. Another gravity high is indicated trending in the NW-SE direction. The two seem to intersect in the region of Lake Kitagata which coincides with the low resistivity from the limited data available. Based on this information, the area around Lake Kitagata should be a reference point for further geophysical surveys. There is therefore a need to collect more geophysical data across the whole field before conclusions are made regarding siting of exploration wells. The current geophysical surveys, therefore, are designed to delineate the boundaries of the geothermal reservoir by collecting more data and to locate sites for drilling exploration wells in the Katwe geothermal prospect.

3.2 Kibiro geothermal prospect

3.2.1 Geology

The Kibiro geothermal prospect is divided into two entirely different geological environments by the escarpment, which cuts through the field from SW to NE. To the east of the escarpment the geology is dominated by an ancient crystalline basement, characterized by granites and granitic gneisses. To the west lie a thick accumulation of thick sequences of rift valley sediments of at least 5.5 km, but without any volcanic rock on the surface (Figure 8).

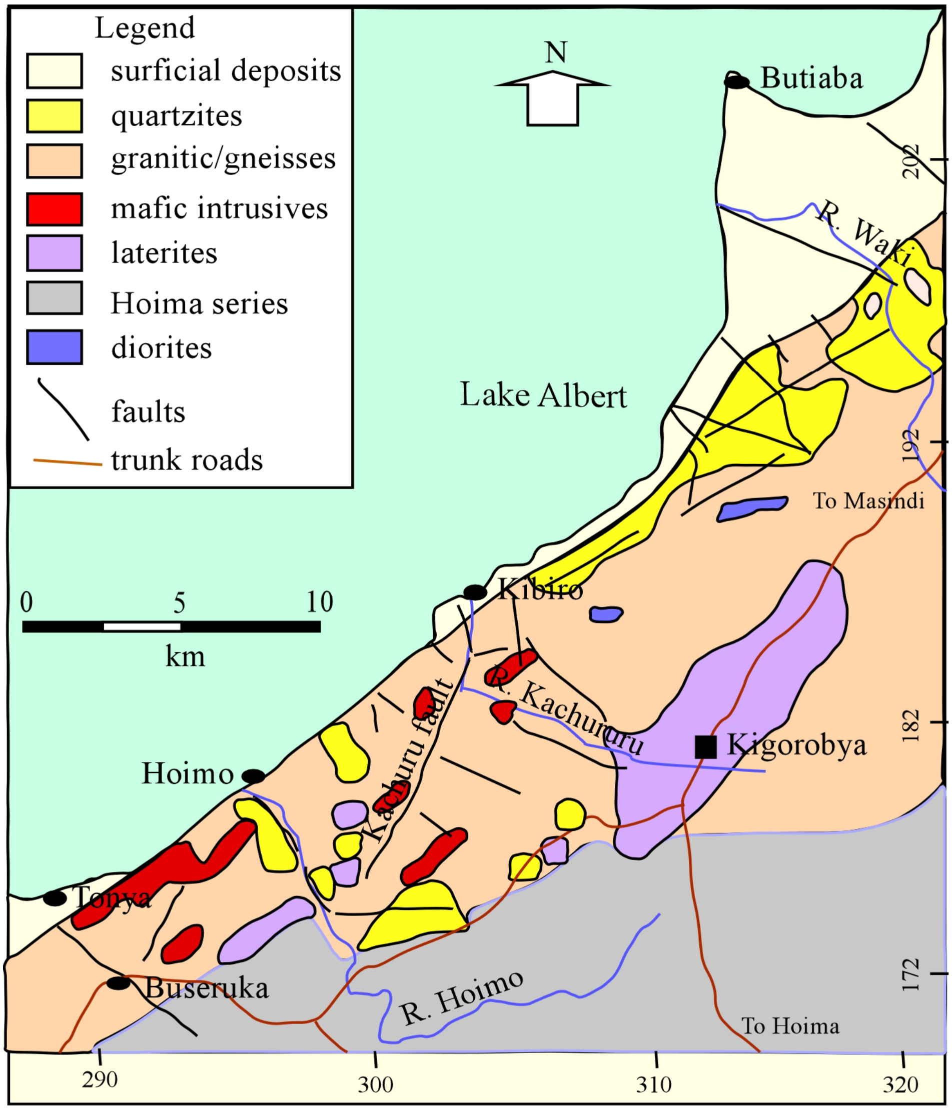


FIGURE 8: The geology of the Kibiro geothermal prospect and surroundings

Along the escarp-ment and NE of Kibiro is a stretch of quartzites, which are also found SW of Kibiro. Laterite is the main feature along the Kigorobya – Biiso – Masindi road. Also present are mafic intrusives along the Kachuru fault, Kigorobya – Kibiro road and extreme SW near Buseruka and Tonya. South of Kigorobya lie the Bunyoro (Hoima) series which are sedimentary beds (meta-sediments) mainly represented by phyllites, tillites and sandstones. Recent geological and geophysical studies show that the geothermal resource can be traced along faults in the block faulted granites to the east away from the rift. The Albertine rift is seismically active, characterized by deep-seated (27–40 km) large earthquakes. The tectonic pattern within the Kibiro geothermal area is very complex, and this complexity may well be the main contributor to the existence of a potential geothermal reservoir (Gislason et al., 2004).

3.2.2 Geochemistry

Recent geochemical studies of the Kibiro geothermal prospect started in 1993 with the Geothermal Energy Exploration Project I (UGA/92/002). Geochemical methods aiming at establishing the subsurface temperatures as a part of the preliminary investigations were used. However, the project was short-lived and ended in 1994. The current geochemical status of the Kibiro prospect is presented in the following sections.

I. Geothermal manifestations

The geothermal manifestations in the Kibiro geothermal prospect are mainly concentrated at Kibiro and Kachuru, west of the escarpment, on the shores of Lake Albert. They comprise hot springs and deposits of sulphur and travertine (Figure 9). The hot springs at Kibiro were mapped during the Geothermal Exploration I project of 1993 - 1994 (Gislason et al., 1994). In the lower slopes of the main escarpment at Kachuru approximately 500 m southwest of Kibiro hot springs, there is an outcrop of highly brecciated fault rock. There is a smell of hydrogen sulphide (H_2S) and a thin film of sulphur deposits in the cracks of the rock (Gislason et al., 2004). Also present are calcite deposits in cracks and fissures in many locations along the Kachuru fault, Kitawe fault and other locations south-southeast of Kibiro, indicating extinct hot water discharges.

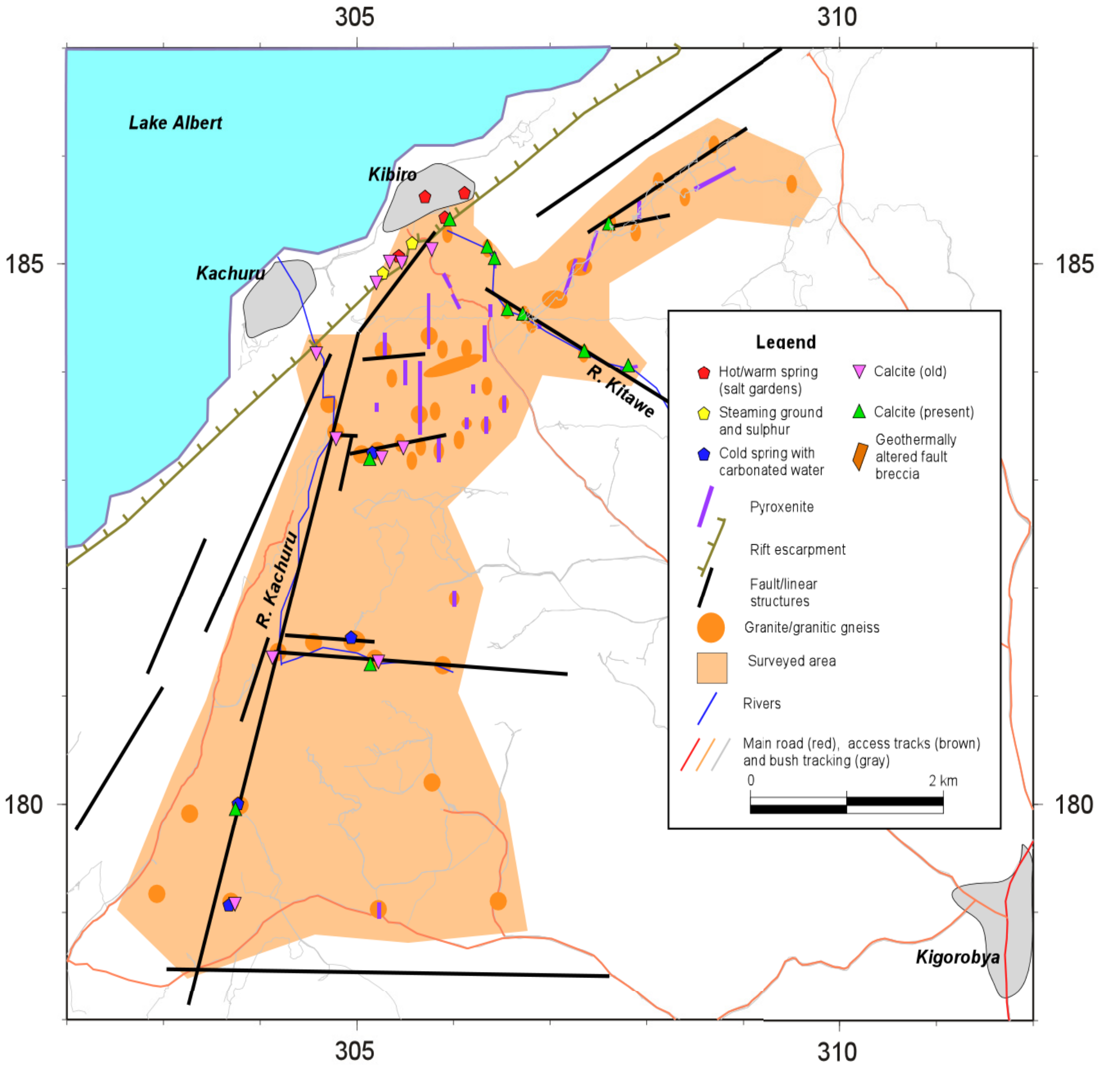


FIGURE 9: Kibiro, geothermal surface manifestations and calcite deposits

The Kibiro hot springs can be divided into three groups namely Mukabiga, Mwibanda and Muntere (Figure 10). The Mukabiga springs are apparently related to a secondary fault, oblique to the main rift fault, and most likely controlled by the intersection of the two faults. They are characterised by continuous gas bubbling from the bottom of the pool. A large amount of gas escapes from the springs, and there is a strong smell of H_2S. There is little evidence of carbonate precipitation, but white thread-like algae are common in the stream. Close to the stream the threads are coloured black indicating the presence of metal sulphides. The total flow measured from the main group, Mukabiga, was 4 l/s, and the temperature range was 57-86.4°C (Gislason et al., 1994).

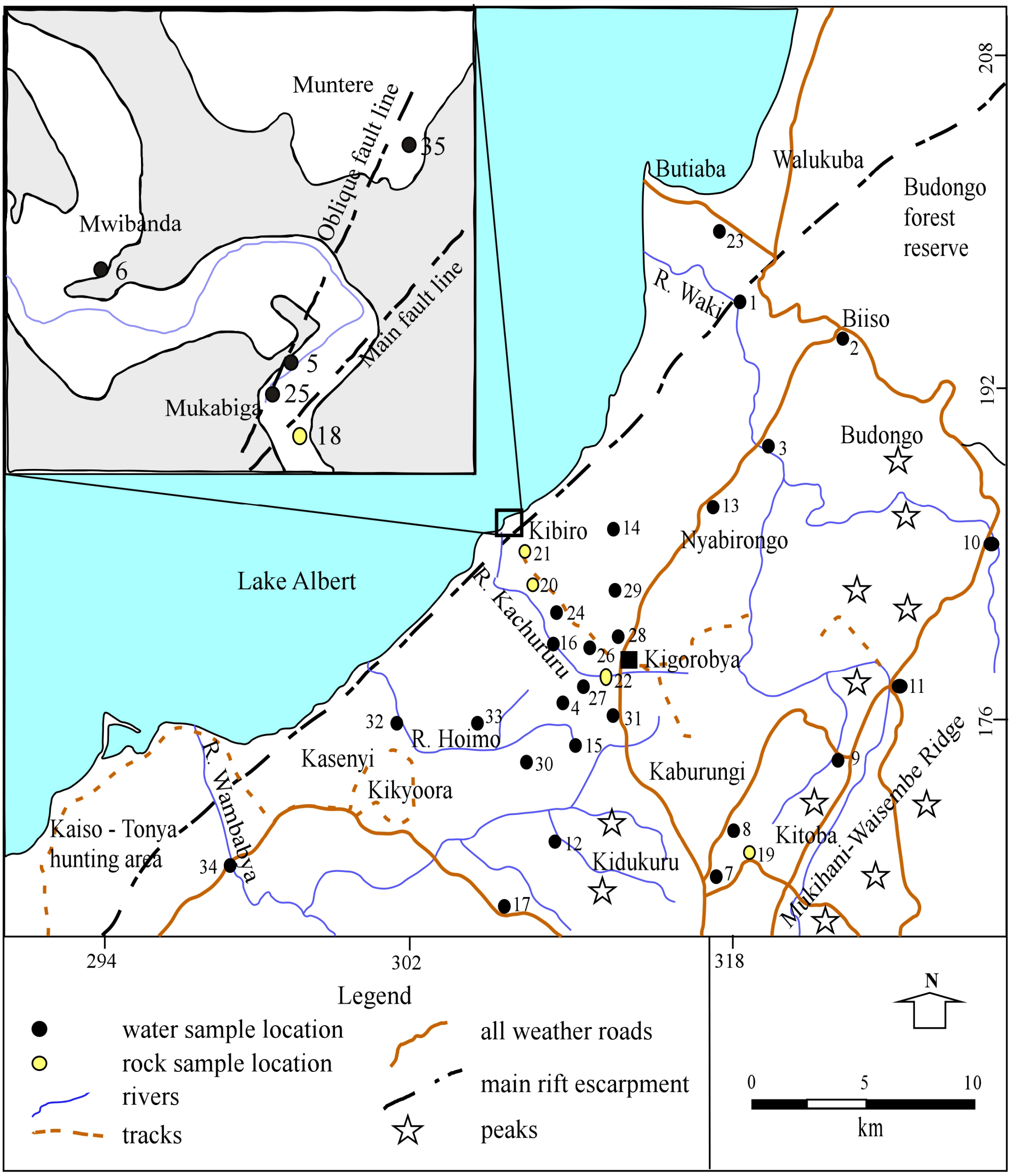


FIGURE 10: Kibiro and surrounding, geothermal, surface and ground water sampling points

A second group of hot or warm springs is found downstream, in an area of salt gardens called Mwibanda. The flow rate of 2.5 l/s is low, and the temperature range is 33-71.7°C. Some of the seepages are on a straight N-S trending lineament, in a small dugout trench. Other springs are within the nearby salt gardens. The largest salt garden is called Muntere, and is directly north of the Mukabiga area. Its eastern side may be controlled by the secondary fault. Here the ground has been lowered down to groundwater level for salt production. A number of small channels drain the area, but the water temperature is lower than in Mukabiga and Mwibanda, and there are no well defined springs. The highest recorded temperature is 39.5°C.

II. Results

The geochemistry results suggest a high temperature geothermal system in the Kibiro geothermal prospect. The fluids are characterised by a neutral pH, and salinity of up to 4,000-5,000 mg/kg total dissolved solids. Cl of the geothermal waters is high compared to the SO_4 and HCO_3 concentration and therefore they are classified as mature waters suitable for application of geoindicators. Relatively low B values compared to Cl and Li suggest that the fluids are more likely to originate from volcanic basement rocks rather than from the young overlying sediments. Armannsson (1994) found that results for different geothermometers for hot water samples from Kibiro fell into two groups, one showing a temperature of about 150°C and another 200-220°C. The geothermometers that gave the lower temperature were one component solute geothermometers, e.g. quartz, and geothermometers based on ratios of components that equilibrate fast, e.g. K-Mg. The higher temperature was obtained by geothermometers based on ratios between components that equilibrate more slowly, e.g. Na-K, and gas geothermometers. The use of mixing models (SiO_2-enthalpy, SiO_2-CO_2) and the construction of log (Q/K) diagrams supported this model. These observations suggest that the geothermal fluid is a mixture of a hot water component at 200-220°C and cold water producing a second equilibrium at 150°C. A subsurface temperature of 200-220°C is therefore inferred by geothermometry and mixing models for Kibiro. The fluids are relatively dilute and would probably cause few problems on utilization.

3.2.3 Hydrology

Like for the Katwe geothermal prospect, hydrological investigations for the Kibiro prospect were carried out between 1999 and 2003 under the same project UGA/8/003. The objectives were similar i.e., to improve the geochemical and hydrological understanding of the prospect.

I. Sampling and analysis

A number of water samples from hot springs, cold springs, dug wells, boreholes, rivers and Lake Albert as well as rocks samples were collected and analyzed for chemical and isotopic compositions. Lake Albert was sampled at a distance of 100 m offshore at Kibiro. Isotopes analyzed included hydrogen (δ^2H_{H2O}, $^3H_{H2O}$), oxygen ($\delta^{18}O_{H2O}$, $^{18}O_{SO4}$), carbon ($\delta^{13}C_{DIC}$, $^{14}C_{DIC}$), sulphur ($\delta^{34}S_{SO4}$), and strontium ($^{87/86}Sr_{H2O}$, $^{87/86}Sr_{Rock}$). Field measurements of temperature, pH, electrical conductivity, analysis of volatiles (CO_2 and H_2S) etc., were carried out on site. Chemical and isotope analyses of water and rock samples were carried out by the IAEA's isotope hydrology laboratory in Vienna, the Institute of Hydrology (GSF) in Munich, Germany and the Institute of Geosciences and Earth Resources in Pisa, Italy. The sampling points and analytical results of isotopes are presented in Figure 10 and Table 5, respectively.

II. Stable isotopes of water and recharge to the Kibiro geothermal system

The relationship between the stable isotope results from Kibiro and the GMWL and LMWL is presented in Figure 11. There is an insignificant oxygen shift in the hot spring waters compared to the LMWL. This could result from limited water-rock interaction with no change in $\delta^{18}O$ of water or rock, or from old age or a high water-rock ratio with rock $\delta^{18}O$ changed to equilibrate with water. The hot spring water from Muntere is more highly enriched in $\delta^{18}O$ and δ^2H than those from Mukabiga and Mwibanda which plot close together. This suggests that the hot spring water from Muntere could be from a different source than those from Mukabiga and Mwibanda. All the river waters are more enriched in δ^2H than the hot spring waters, an indication that they cannot be the source of recharge for the thermal waters. The lake water is highly evaporated, hence its position on the plot and most likely it is not a source of recharge for Kibiro.

TABLE 5: Kibiro geothermal area and surroundings, isotope data

ID	**Sample No.**	**Location**	**Type**	**δ^{18}O SMOW**	**δ^{2}H SMOW**	**Tritium TU**	**δ^{34}S (SO_4)**	**δ^{18}O (SO_4)**	**$^{87/86}$Sr in rock or water**
1	UG-01-01	Waki Falls	SRI	-0.74	4.6	2.49			
2	UG-01-02	Biiso	GWB	-1.93	-3.3	1.04			
3	UG-01-03	Waki Br.	SRI	-0.94	3.2	2.7			
4	UG-01-06	Bukona	GWB	-1.98	-4.2	0.13			
5	UG-01-10	Kibiro	GTH				12.7	12.4	0.7322
6	UG-01-11	Kibiro	GTH				24.2	15.5	0.7321
7	UG-01-18	Kisonde	GWB	-1.7	-1.6	1.4			0.7179
8	UG-01-19	R. Muhu	SRI	-1.75	-0.6	3			
9	UG-01-20	R. Rwempanga	SRI	-1.8	-1.2	1			0.7165
10	UG-01-21	R. Siba	SRI	-1.18	2	2.4			
11	UG-01-22	R. Kabarongo	SRI	-1.42	0.8	2.8			
12	UG-01-23	Iseisa	GWD	-1.58	-1.4	3.5			0.7140
13	UG-01-24	Kapapi	GWB	-2.14	-5.9	2.2			
14	UG-01-26	Kibanda	GWB	-2.33	-6.8	1.4			
15	UG-01-27	Bwikya	GWB	-1.8	-2.1	1.3			0.7512
16	UG-01-28	Kachururu	SRI	-0.73	5	2.3			0.7241
17	UG-01-29	Bukerenge PS	GWB	-1.52	-0.4	1.5			0.7370
18	UG-01-30	Kibiro	Rock						0.7851
19	UG-01-31	Kitoba	Rock						0.7177
20	UG-01-32	Kabiribwa	Rock						0.7115
21	UG-01-33	Kabiribwa	Rock						0.7162
22	UG-01-34	Bikira	Rock						0.7251
23	UG-93-24	Wantembo	GWB	-3.58	-15.2				
24	UG-93-26	Ndalagi	GWB	-2.08	-5.2				
25	UG-99-01	Kibiro	GTH	-2.05	-11.1	1.25			
26	UG-99-02	Nyababiri	GWD	-1.79	-2.4	1.65			
27	UG-99-03	Mahogota	GWB	-1.65	-0.95	1.88			
28	UG-99-04	Kijura	GWB	-1.58	-0.9	0.81			
29	UG-99-05	Kiganja	GWB	-1.46	-0.35	1.17			
30	UG-99-06	Bombo PS	GWB	-1.57	-0.5	0.92			
31	UG-99-07	Kisukuma	SPR	-0.47	8.15	2.66			
32	UG-99-08	Hoimo	SRI	-0.84	5.1	3.2			
33	UG-99-09	Abogora	GWB	-2.48	-8.95	1.36			
34	UG-99-10	Wambabya	SRI	-0.97	4.75	1.79			
35	UG-93-22	Kibiro	GTH	-1.01	-3.9				
	UG-01-12	Albert	SLA	5.22	37.1				
	UG-01-13	Albert	SLA	5.23	37.2				

GTH: Geothermal spring; GWD: Groundwater from dug well; GWB: Groundwater from borehole; SPR: Cold water spring; SRI: Stream or river water; and SLA: Lake water.

The groundwaters that could be the source of recharge for the Kibiro hot springs are represented by two groups of water: the first by Kapapi (13), Kibanda (14), and Ndalagi (24) located east-southeast of Kibiro and the second by Bukona (4) and Abogora (33) located south of Kibiro (Figure 10 and Figure 12). It may be borne in mind that in the UGA/92/002 geochemical report (Armannsson, 1994) it was suggested that the cold water component could be of two different origins, so that groundwater flow in the area (hot and cold) may be complicated and controlled by physical phenomena. For example, the Abogora area is connected to Kibiro by the Kachuru fault which is most likely channelling the geothermal water from this area to Kibiro. The sample from the Wantembo borehole (23) located further northeast of Kibiro, is the most depleted cold water sampled in the surrounding areas that could represent a source of recharge to Kibiro from high ground.

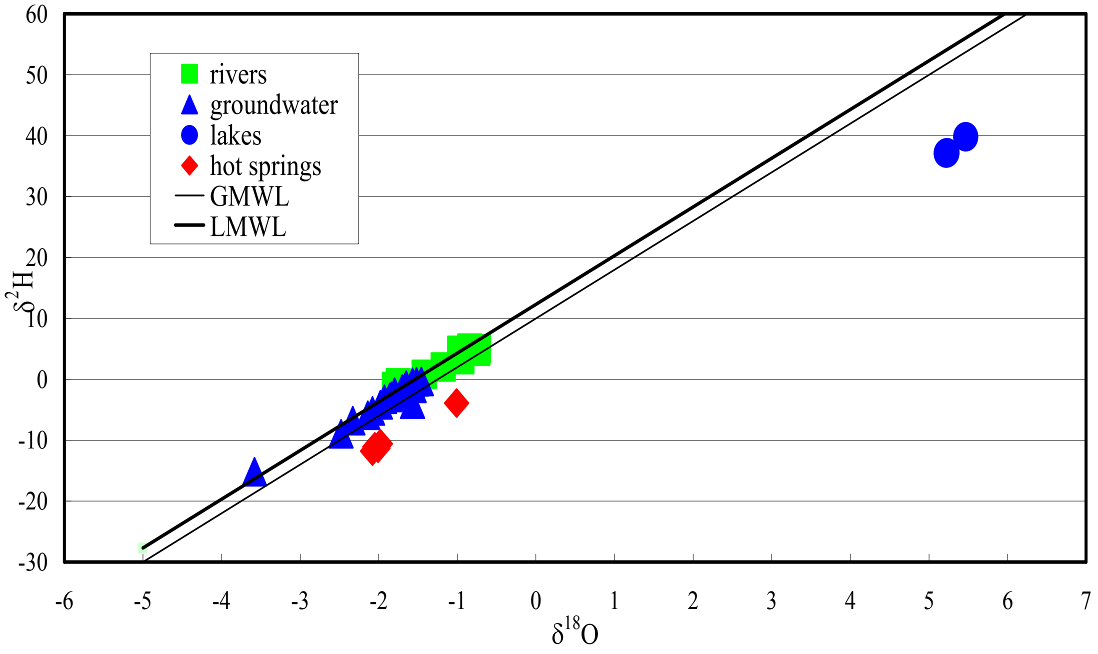


FIGURE 11: Kibiro, stable isotopic composition of hot and cold water samples

The Kibiro hot spring water is either recharged from the areas above the escarpment located south-southeast of Kibiro as discussed above or from a higher elevation than all the cold-water sampling points. This water is likely to be channelled through faults that have been identified in the area (Figure 9). The Wantembo borehole further northeast of Kibiro represents a possible source of recharge from

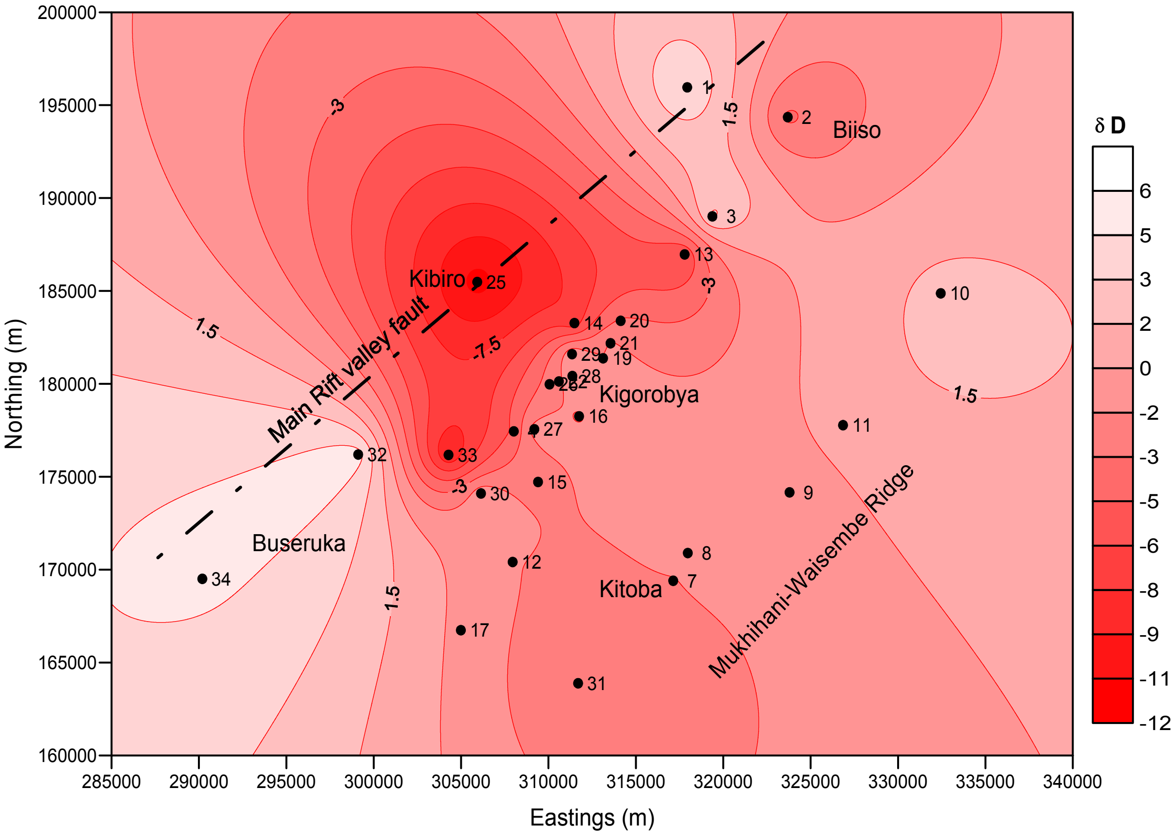


FIGURE 12: Kibiro, deuterium variation of surface and ground waters

high ground but this does not seem likely to be the source of recharge as it is at the same altitude as Kibiro. The only high ground close the Kibiro prospect is the Mukihani-Waisembe Ridge in Kitoba subcounty, located 20 km southeast of Kibiro but the mechanism by which meteoric water from this area may reach the geothermal area has not yet been established.

III. Other environmental isotopes

The tritium concentration of the Kibiro hot spring water is 1.25 TU similar to that of the groundwaters (0-3.5 TU), and indicates that the hot spring water has some cold groundwater contribution and is therefore a mixture of a hot water component and cooler water. However, it is advisable to note that the tritium background in precipitation for the area is rather low, up to a few tritium units only, and indications of mixing may not always be clear.

The isotope composition of sulphur and oxygen in sulphates expressed in $\delta^{34}S$ (SO_4) and $\delta^{18}O$ (SO_4) are important characteristics in delineating the origin of water and sulphates. The results for Kibiro suggest a sedimentary origin with a possible magmatic contribution.

Strontium isotopes in water and rock ($^{87/86}Sr_{H2O}$, $^{87/86}Sr_{Rock}$) indicate an interaction between the rocks sampled and the geothermal fluids. The rocks interacting with the fluids, reservoir rock types, in Kibiro are granitic gneisses (Bahati, et al., 2005).

IV. Isotopic geothermometry

A temperature of 130-140°C was predicted by the sulphate-water ($S^{18}O_4$-$H_2{}^{18}O$) isotope geothermometer (Bahati, et al., 2005) which compares reasonably well with those of the solute geothermometers that gave the lower temperature of 150°C. The mixing of the geothermal water with cooler water may disturb the equilibrium of the solution causing the sulphate-water geothermometer to predict too low temperatures.

3.2.4 Geophysics

The results of the geophysical surveys indicated the existence of a geothermal system in the Kibiro prospect which is supported by the low resistivity and high gravity anomaly (Gislason et al., 2004). A low resistivity anomaly trench was traced into the crystalline basement, following the fault lines of the block faulted granites, first to the SSW away from Kibiro and then following west-east fault lines toward Kigorobya Town (Figure 13).

The gravity data does not show any distinct density variations, except for the large density contrast between the sediments in the Rift valley and the granites east of the escarpment. There is, however, an indication of a higher gravity field in an area roughly coinciding with the E-W low-resistivity anomaly (Figure 14). This might indicate a deep higher density intrusive acting as a heat source for the geothermal activity producing the low-resistivity anomaly.

The cause of these low-resistivity anomalies can, at the moment, not be stated with certainty, but the most likely explanation is conductive alteration minerals in fractures in the otherwise resistive base-rock. Saline water in fractures could also be a possible candidate, but the relatively low salinity of the water discharges from hot springs at Kibiro and other cold springs in the area makes this rather unlikely.

The geophysical results indicate that the geothermal anomaly extends beyond the surveyed area and therefore additional geophysical and geological surveys are needed to delineate the spatial extent of the anomaly. These studies should be followed by a feasibility study that will begin with drilling into the target to prove the resource.

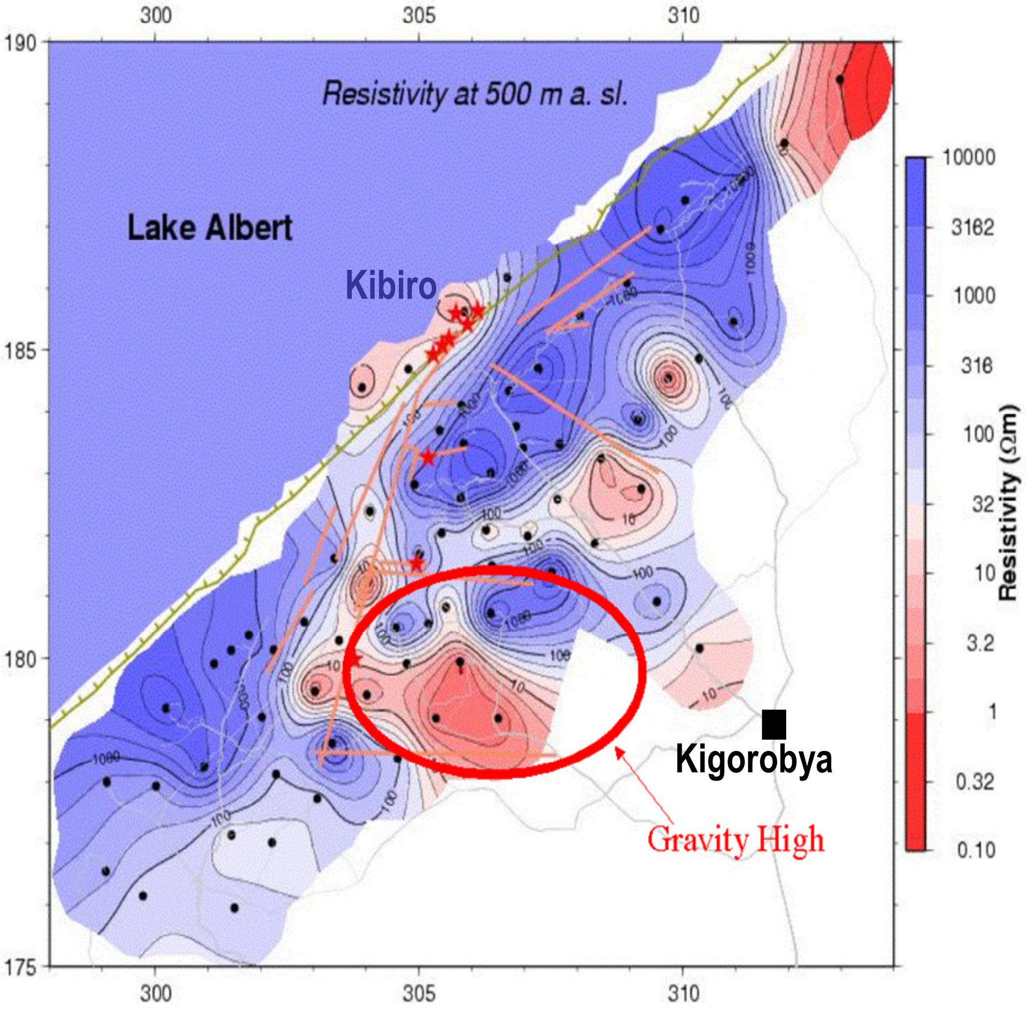


FIGURE 13: Kibiro, resistivity at 500 m a.s.l., faults and fractures (pink lines), geothermal surface manifestations (red stars) and an area of slightly higher gravity field (oval circle)

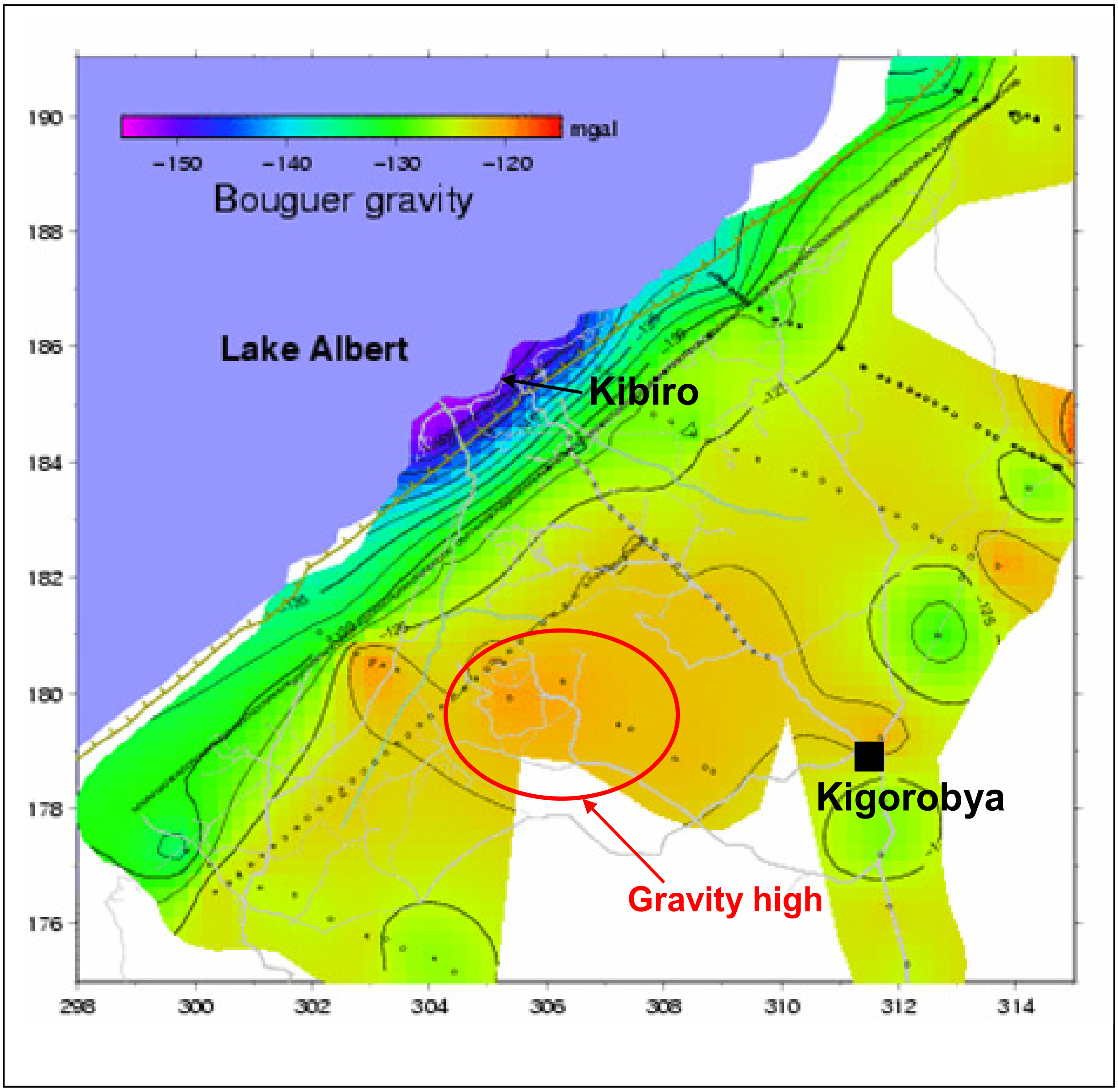


FIGURE 14: Bouguer gravity map of the Kibiro area

4. METHODOLOGY

4.1 EIA overview

An EIA is a study of the effects of a proposed action on the environment. The EIA evaluates the expected effects on human health, the natural environment and on property. The study, therefore, requires a multi-disciplinary approach. It should be carried out very early during the feasibility stage of a project. In other words a project should be assessed for its environmental feasibility.

The EIA compares various alternatives by which the project could be realized and seeks to identify the one which represents the best combination of economic and environmental costs and benefits. Alternatives include location as well as methods, process technology and construction methods.

The EIA is based on predictions and attempts to predict the changes in environmental quality which would result from the proposed operation. It attempts to place environmental effects on a common basis with economic costs and benefits and finally it is a decision making tool.

The EIA is a procedure used to examine the environmental consequences, both beneficial and adverse, of a proposed development project and to ensure that these effects are taken into account in project design. EIA should be viewed as an integral part of the project planning process.

In this study the preliminary environmental impact assessment for the development of Katwe and Kibiro geothermal prospects with stringent adherence to the National Environment Statute (Statute No. 4 of 1995) of Uganda as stated earlier in the guidelines has been carried out. EIA is mandatory for the proposed project and therefore the screening stage was omitted. According to the guidelines the Environmental Impact study (Phase II) is divided into two: the scoping and the detailed impact assessment (Figure 4). The study was centred on the scoping stage and laying a foundation for the detailed assessment in the Terms of Reference.

4.2 Project description

In order to enable the potential environmental impacts to be identified and assessed, detailed information on the proposed development should be obtained. The key characteristics of the project are important in influencing such impacts. This may include information on project phasing; the scale of the project; the location and access; the site layout; installations; emissions to land, air and water; ancillary development and environmental impacts.

The proposed project is divided into two phases i.e. drilling and operation. It will involve initial drilling of 4-5 geothermal exploration wells and then more wells to support a 30 MWe power plant in each prospect. The characteristics of the proposed project in the two areas Katwe and Kibiro are described as far as possible.

4.3 Baseline description

Particular attention was given to defining the baseline conditions of the environment affected in both Katwe and Kibiro prospects. The baseline conditions provide the context for evaluating the environmental impact of a project. The important factor is to identify data requirements early on in the assessment process and to consider how the data will be used to assess environmental impacts before the data collection process begins. Data collection should be focused on determining the current and future status of the environmental resource, historical trends, existing regulatory standards and development plans and programmes. Determining the carrying capacity or resource threshold can also assist in assessing the significance of the potential impacts.

4.4 Impact assessment

There are a number of factors which influence the approach adopted for the assessment of environmental impacts for a particular project. The method should be practical and suitable for the project given the data, time and financial resources available. It should also be able to provide a meaningful conclusion from which it would be possible to develop, where necessary, mitigation measures and monitoring. Key points to consider when choosing the method(s) include: the nature of the impact(s); the availability and quality of data; the availability of resources (time, finance and staff).

The method chosen should not be complex, but should aim at presenting the results in a way that can be easily understood by the developer, decision-maker and the public.

4.4.1 Impact identification

Numerous EIA methodologies have been developed within the last 2 to 3 decades. These methodologies can be useful in identifying anticipated impacts, determining appropriate environmental factors for inclusion in a description of the environment affected, providing information on prediction and assessment of specific impacts, allowing for systematic evaluation of alternatives and the selection of proposed action and summarising and communicating impact study results. The most-used methodologies can be categorized as interaction matrices, networks and checklists. Interaction matrices are of greatest value in impact identification and the display of comparative information on alternatives. Network methodologies provide useful information for impact identification, as well as valuable approaches for communicating information on interrelationships between environmental factors and anticipated project impacts. Others are consultations and questionnaires, spatial analysis, network and systems analysis, carrying capacity or threshold analysis, modelling and expert opinion.

In identifying potential significant environmental impacts for drilling and operation phases for the development of the Katwe and Kibiro geothermal prospects, public consultations, experience and expert knowledge of the project area/site, an interaction matrix and a checklist have been used.

I. Public consultation
Consultation is a key element in the Environmental Assessment process and can be carried out through meetings or correspondence. It is a way of obtaining data for use in the assessment. It is also useful in determining the views and concerns of those consulted regarding the project and therefore in identifying the key issues. Consultees may typically be: the relevant statutory and non-statutory authorities, experts in a particular subject matter associated with the project and its potential impacts, local businesses and the local community who may be affected by the project.

Three brainstorming workshops have been held in Uganda in the last five years to discuss the activities and impacts of exploration for energy on the environment. The first workshop was held on 16th May 2000 at Hotel Africana in Kampala, Uganda (UWA, 2000). The theme of the workshop was *"implications of mining, energy and petroleum exploration and exploitation on the conservation of natural resources in general and wildlife management in particular in the Albertine graben"*. Participants came from the Department of Geological Survey and Mines, Department of Petroleum Exploration and Production, Uganda Wildlife Authority and the National Environment Management Authority. The second workshop was held on 14th April 2003 also at Hotel Africana in Kampala. The workshop was organised by NGOs that included the National Association of Professional Environmentalists (NAPE), Joint Energy and Environment Projects (JEEP) and Uganda Wildlife Society and drew participants from civil organisations, government and geothermal experts from Uganda and other parts of the world. The aim of the workshop was to promote geothermal energy in the energy mix of Uganda and to increase public awareness of the benefits of the resource. The third workshop was held on 4th December 2003 at Imperial Botanical Beach Hotel in Entebbe. The workshop was called to update the stakeholders on the activities of the Uganda Alternative Energy Resources Assessment and Utilisation Study (UAERAUS), a study in which the first geophysical surveys on the Katwe geothermal prospect were carried out. The workshop attracted participants from the local governments in the geothermal areas, Ministry of Energy and Mineral Development (MEMD), NEMA, UWA, NGOs, and the Private Sector among others.

During the workshops, papers relevant to each workshop were presented. In all three workshops the status of geothermal exploration and development in Uganda and experience elsewhere were discussed. During the discussions emphasis was always centred on activities and environmental impacts on sensitive areas and how they could be mitigated. The need for an EIA was also emphasised for any proposed project in accordance with the National Environment Statute (Statute No. 4 of 1995). The General observations and clarifications were that:

- Environmental impact assessment is a tool for decision-making. It should not be used to justify a decision. The EIS must be part and parcel of any project right from its inception through critical decision-making to implementation.
- Demand for EIA often comes too late when the developer is almost starting operations. EIAs, however, must be built in all plans so that they are started early and any need for adjustments in planning and/or design of a project undertaken early enough to ensure minimal impact on the environment.
- Once resources have been identified and their relative quantities determined during exploration, a complete and rigorous EIA must be made to be the basis for a decision on whether production can be allowed to start (and with what limitations if any).

The positive and negative impacts of geothermal development were not understood by many participants and the MEMD was tasked to do more research in this area and to share the findings with all stakeholders as early as possible.

Other public consultations have been going on during the field activities since 1993 when the recent exploration for geothermal resources started. The consultations were mainly focused on the local communities in the prospect areas, the local governments and other stakeholders.

II. Expert opinion

Expert opinion is not a method as such but is effectively a tool for the assessment of environmental impacts of a project. During the study an exchange of views with the members of the project team on different scientific disciplines was implemented. Exchange of ideas was also extended to various experts that have participated in field activities since 1993 and also visitors to the prospects.

III. Interaction matrix

A matrix is a more complex form of a checklist. It can be used quantitatively and to evaluate impacts to some degree and can also be extended to the consideration of the cumulative impacts of multiple actions on a resource. It provides a good visual summary of impacts, can be adapted to identify and evaluate to some degree indirect and cumulative impacts, and impact interactions. Matrices can be weighted and impacts ranked to assist in evaluation but can sometimes be complex and cumbersome to use.

An interaction matrix was used for identification of potential impacts for both drilling and operation for the development of the Katwe and Kibiro geothermal prospects. It is only an adjunct to the orderly and systematic identification of possible interactions.

IV. Checklist

The checklist approach ranges from simple listings of environmental factors to complex methods involving assignment of relative importance weights to environmental factors and the scaling of environmental impact factors for each of the series of alternatives. Simple and descriptive checklists, including questionnaire checklists, are useful for identifying environmental factors and providing information on impact prediction and assessment.

A checklist was used for identification of potential impacts for both drilling and operation for the development of the Katwe and Kibiro geothermal prospects.

4.4.2 Mitigation measures

The purpose of mitigation is to look for alternative and better ways of implementing the proposed project or associated activities so that the negative impacts are eliminated or minimised, while benefits are enhanced. Impact mitigation, however, can only be possible when the full extent of the anticipated environmental problems is understood. In this regard, impact mitigation has its roots in the early stages when the significant impacts associated with the activity are identified. Impact mitigation therefore requires a full understanding of the sources of impacts.

As a result of this study mitigation measures for impacts that can be mitigated using the information available at the scoping stage were proposed. Mitigation measures for the rest of the impacts that need specialist studies under a detailed EIA will be fully described in the EIS.

4.4.3 Significance of the impacts

The determination of impact significance from predictions of the nature of impacts is a source of debate in the field of environmental assessment. Of particular concern is the use of formal quantitative methods for comparing project alternatives in order to produce a total impact score for each alternative. It has been argued that these techniques remove the responsibility for the decision from the responsible authorities (Thompson, 1988, 1990). It is necessary to distinguish between impact magnitude and impact significance. Impact magnitude is determined by prediction based on empirical measurements, while impact significance is an expression of the cost of a predicted impact to society (Thompson, 1988, 1990). The approaches to handling impact significance, as outlined below, exhibit a wide variety of techniques. They vary from the rigidly quantitative to the qualitative.

According to Thompson (1988), significance can be determined in terms of a three-stage process involving scaling, weighting and aggregation.

Scaling is the standardization of empirical data onto a common scale to allow comparisons between different types of impacts. Determining the significance of impacts may be aided by finding a common basis for comparing the magnitude of predicted impacts. A number of scaling techniques can be employed to do this, e.g. nominal scaling, ordinal or discrete scaling, interval and ratio scaling.

Weighting is the imposition of professional and/or societal values on a range of potential environmental impacts. This is a very contentious area, revolving around a number of issues, such as: (1) Whose values should be considered?; (2) How representative are they?; and (3) How should such values be elicited?

Aggregation is the combination of different types of impact values to produce composite scores, which facilitates a comparison of project alternatives. Certain methods employ various means of summation to allow a final preference ranking to be achieved. Aggregation can also be achieved by composite maps or photographic overlays. Some methods use additive summarization of plus and minus scores, which implicitly weigh all inputs equally. Others produce aggregation in the form of computer-generated clusters of highly rated impacts.

During the study, after the impacts had been identified the next step was to ascertain the magnitude of the impacts and their significance. The environmental impact should be quantified, if possible and practical to do so. An example would be the percentage of habitat lost or the increase in a particular pollutant. Where it is not possible to undertake a detailed quantitative assessment, a qualitative assessment can be carried out. In the case of a qualitative assessment, the magnitude of the impact can be ranked, e.g. high, medium or low, according to set criteria.

Other factors to take into consideration when assessing the magnitude of these impact types are: the changes that would occur in the environment if the project did not go ahead and how have past operations contributed to the current baseline conditions.

Due to lack of quantitative information/data on the impacts, the qualitative approach was used in assessing the potential impacts for the Katwe and Kibiro geothermal prospects. When describing the significance of an impact, as well as taking into account the magnitude, the following generic criteria were used:

- Extent or spatial scale of the impact, e.g. the percentage of a habitat that may be lost;
- Intensity or severity of the impact;
- Duration of the impact , i.e. will the impact be temporary or permanent;
- Mitigation potential (i.e. reversible (likely success of mitigation) or permanent);
- Acceptability; and
- Degree of certainty.

The significance of potential environmental impacts of the proposed projects was assessed both with and without mitigation.

4.5 Importance of impacts

Once the impacts had been defined and evaluated in terms of the criteria, a process of prioritisation or grouping of the impacts on environmental categories affected in the order of importance followed. The grouping was based on the results of magnitude and significance assessment. The potential environmental impacts of critical importance would then be forwarded for attention in a comprehensive EIA process.

4.6 Terms of reference for detailed EIA

The study ended by outlining the process to be used during the detailed assessment of environmental impacts of the development proposed. The process details and the specialist studies that will be required to generate detailed Terms of Reference and Scope of Work documents which will include study methodologies are presented.

5. DESCRIPTION OF THE DEVELOPMENT PROJECT PROPOSED

5.1 Overview of a geothermal system in production

Geothermal energy is the energy contained as heat in the Earth's interior. The origin of this heat is linked with the internal structure of our planet and the physical processes occurring there. Despite the fact that this heat is present in huge, practically inexhaustible quantities in the Earth's crust, not to mention the deeper parts of our planet, it is unevenly distributed, seldom concentrated, and often at depths too great to be utilised industrially.

The heat moves from the Earth's interior towards the surface where it dissipates, although this fact is generally not noticed. We are aware of its existence because the temperature of rocks increases with depth, proving that a geothermal gradient exists: this gradient averages 30°C/km of depth.

There are, however, areas of the Earth's crust which are accessible by drilling, and where the gradient is well above average. This occurs when, not far from the surface (a few kilometres) there are magma bodies undergoing cooling, still in a fluid state or in the process of solidification, and releasing heat. In other areas, where magmatic activity does not exist, the heat accumulation is due to particular geological conditions of the crust such that the geothermal gradient reaches anomalously high values. For example, the Hamar geothermal field in Iceland is one of the numerous low-temperature geothermal systems located outside the volcanic zone with the heat source believed to be the abnormally hot crust of Iceland, but faults and fractures, which are kept open by continuously ongoing tectonic activity, also play an essential role by providing the channels for the water circulating through the systems and mining the heat (Axelsson and Gunnlaugsson, 2000). Similarly Beijing City, P.R. of China, is situated on top of a large sedimentary basin where geothermal resources have been found at depth. These resources owe their existence to sufficient permeability and porosity at great depth (1-4 km) where the rocks are hot enough to heat the water to exploitable temperatures (Axelsson et al., 2005).

The extraction and utilisation of this large quantity of heat requires a carrier to transfer the heat towards accessible depths beneath the Earth's surface. Generally the heat is transferred from depth to sub-surface regions firstly by *conduction* and then by *convection*, with geothermal fluids acting as the carrier in the latter case. These fluids are essentially *rainwater* that has penetrated into the Earth's crust from the *recharge* areas, has been heated on contact with the hot rocks, and has accumulated in aquifers, occasionally at high pressures and temperatures (up to above 300°C). These aquifers (reservoirs) are the essential parts of most *geothermal fields*.

In most cases the reservoir is covered with impermeable rocks that prevent the hot fluids from easily reaching the surface and keep them under pressure. We can obtain industrial production of superheated steam or steam mixed with water, or hot water only, depending on the hydrogeological situation and the temperature of the rocks present (Figure 15).

Wells are drilled into the reservoir to extract the hot fluids, and their use depends on the temperature and pressure of the fluids: generation of electricity (the most important of the high-temperature uses), or for space heating and industrial processes (high and low-temperature uses).

Geothermal fields are generally systems with a continuous current of heat and fluid, where fluid enters the reservoir from the recharge zones and leaves through discharge areas (hot springs, wells). During utilisation fluids may be recharged to the reservoir by reinjecting through wells the waste fluids from the utilisation plants. This reinjection process may compensate for at least part of the fluid extracted by production, and will to a certain extent prolong the commercial lifetime of the field. Geothermal energy is therefore to some extent a renewable energy source, i.e. where the replacement of energy takes place on a similar time scale as the extraction. However, hot fluid production rates tend to be much larger than recharge rates. Stefansson and Axelsson (2005) underscore the terms; *renewable* to

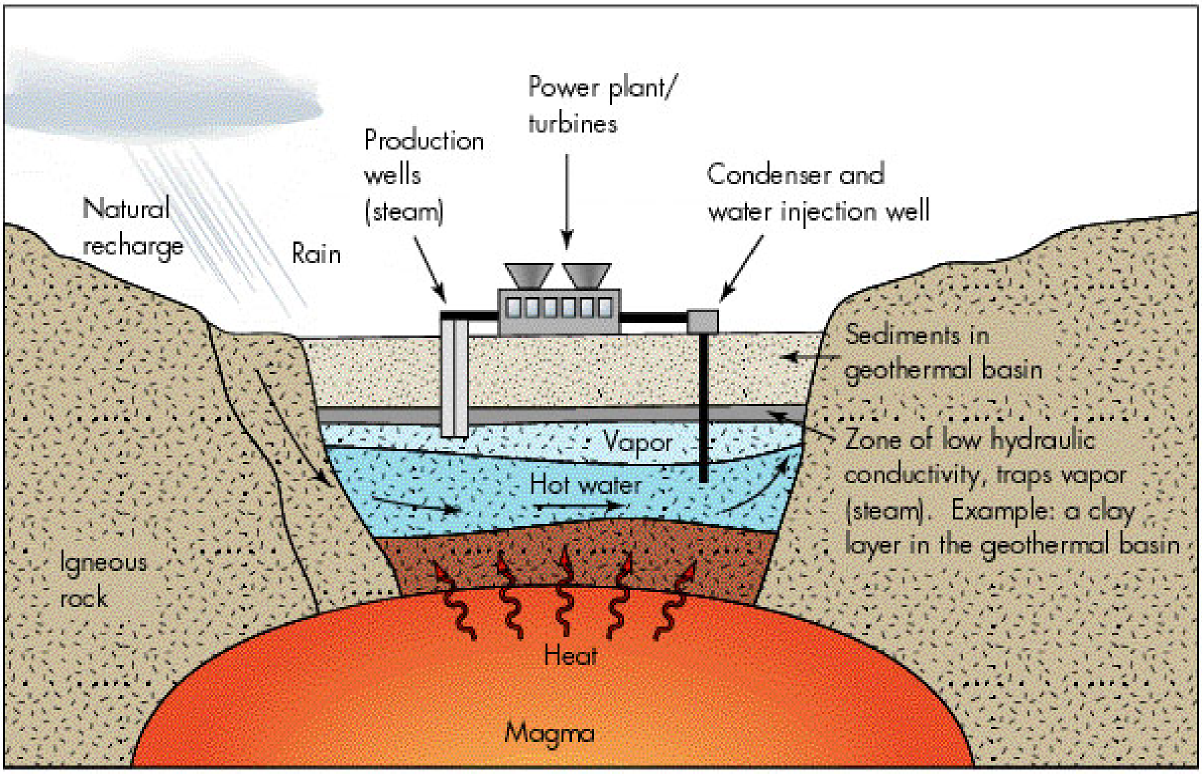


FIGURE 15: A model of a typical geothermal system in production

describe a property of the resource, namely the ability of the resource to replace what is taken out of the resource, whereas *sustainable* describes the mode of utilisation of the resource. Reinjection should be considered an integral part of any modern, sustainable, environmentally friendly geothermal utilisation. It started as a method of wastewater disposal for environmental reasons, but is now also being used to counteract pressure draw-dawn, i.e. as a man-made water recharge, and to extract more thermal energy from reservoir rock (Stefansson, 1997).

The proposed geothermal development involves the drilling of 4-5 geothermal wells in the Katwe and Kibiro geothermal prospects and if results are positive to be followed by the drilling of more production wells and the construction of a 30 MWe power plant in each prospect. The Katwe and Kibiro prospects have been classified as high temperature fields by the pre-feasibility phase, i.e. their source of heat is magmatic and their subsurface temperatures of about 200°C and above are suitable for conventional power generation. The proposed project is divided into two phases, namely drilling and operation. For purposes of this study, the intermediate power plant construction phase is reflected under the operation phase as the first step towards operation.

5.2 Drilling

5.2.1 Road construction

The proposed project will involve construction of access roads to the drill sites for movement of equipment and accessories. The amount of land that is disturbed by road construction during geothermal development can be quite large; estimated at about 12 hectares for road construction alone when drilling 15 wells (Brown, 1995). It is worth noting that the general topography of the geothermal area has a large effect on these figures. The Katwe geothermal prospect is located in a volcanic environment with the volcanics rising gently to a maximum of 300-400 m above the rift valley sedimentary basin. The terrain is steep and access difficult in some parts of the crater area but most of the area is generally flat and easily accessible. Road construction is likely to take about 15 hectares of land when drilling 15 wells since the drilling is to be located in the crater area. The Kibiro geothermal prospect on the other hand is located on a plateau and road construction is not very difficult but may involve the use of privately owned land. Road construction for the proposed project is likely to take about 12 hectares of land when drilling 15 well in Kibiro.

5.2.2 Transportation

Drilling will increase traffic in the area as the rig and all its accessories are transported to the drill site. It is important to understand the traffic impacts during drilling. Before drilling starts, the area has a certain amount of traffic. The rotary drill rig is transported on set trailers pulled by a truck. Transport takes two to four days depending on the number of trucks and the distance. About 130 tons of casing, 140 tons of cement with an additional 25 tons of drilling mud and 30 tons of diesel oil and some lubrication oil will be transported to the drill site during drilling. Two to three days are needed to remove the rig after drilling is completed. Transportation will result in an increase in dust, noise, vehicular emissions and traffic. Occasional traffic delays will occur at various points in the project area.

5.2.3 Drilling activity

Initially 4-5 wells will be drilled in both Katwe and Kibiro and if results are positive additional wells will be drilled to support a 30 MWe power plant in each of the prospects. The wells will be drilled to a depth of approximately 1,500-2,000 m. Drilling will take place on a rectangular flat area, the drill pad, on the ground. This area is required to accommodate the drill rig and its accessories including drill pipes (Figure 16). One drill pad generally occupies about 0.4 hectares and this area is cleared of vegetation and compacted to form a flat and hard surface. The exposure of the area around each well site may create a major erosion hazard if the soil is not well compacted. The land required for drill pads is, therefore, 6 hectares for 15 wells in each of the prospects.

During drilling, the cuttings from the drill head are flushed out with water when water is used as a drilling fluid. Drilling with other fluids like drilling mud will need detergents to assist in the collection of cuttings. The detergent used must be capable of withstanding high temperature and in case of eruptions heavy substances like barium sulphate are usually added. Barium is essentially an inert material but can smother plants and does not support plant growth and in this respect is similar to a hard compacted surface. The returning water or fluid is channelled to sumps where it cools before being recycled or disposed off. Accidental discharge of geothermal fluids to surface drainage could occur due to blowouts during drilling, leaking pipes or wellheads, and overflow from well sumps. Of greatest concern is the protection of public drinking water supplies. Other wastes produced include petroleum products from lubricants and fuels plus cement wastes as spills. Air pollution may stem from non-condensable gas emissions and exhaust smoke from generators and compressors. In vapour-dominated reservoirs where air-only drilling is used and requires large compressors, a lot of noise may be generated.

5.2.4 Drilling fluids

Water will be required for drilling. A typical shallow well requires 1,000 m^3/day, some or all of which may be lost to the formation. A deeper well may require up to 40 l/s or 3,500 m^3 for 24 hours of drilling (Brown, 1995) for periods of up to several months. Completion testing and injection testing can use up to 10,000 m^3/day of water. If this water is discharged, care must be taken to have it disposed off into a well designed for this purpose, as the quality of the water can be affected by suspended solids and chemical content change (Brown, 1995). The wastewater from drilling can create serious gullying if discharged directly to the surface, e.g. into valleys.

Drilling mud will be used for smooth drilling of the first few hundred meters that are used for installation of the surface casing. Drilling mud also prevents loss of circulation to the groundwater

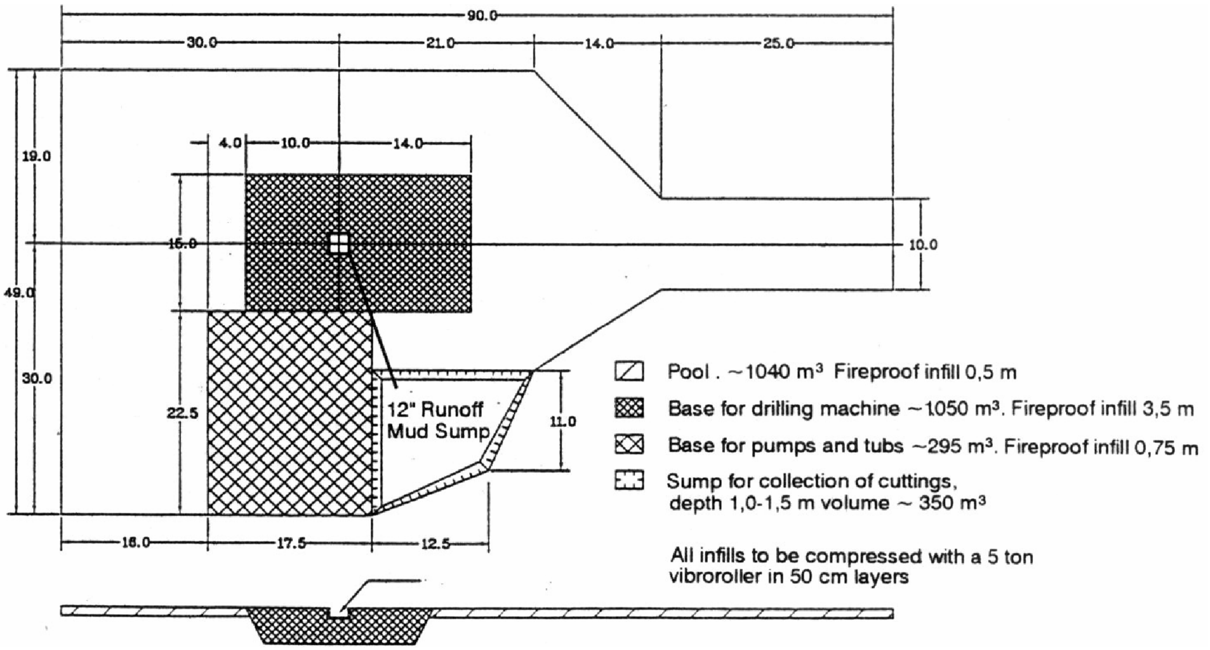


FIGURE 16: Drill pad for a high temperature well (Thorhallsson, pers. comm.)

aquifers within the groundwater table. A drilling mud like bentonite is mostly used when well clearing is inadequate or when well stability is a problem. After use drilling muds are produced as solid alkaline waste that contains many other chemicals (Table 6) (Armannsson, 1997). Drilling mud is lost to the circulation in the well or end up in the drilling sumps as solid waste disposal.

TABLE 6: Chemical composition of bentonite and perlite (% mass)

Material	**SiO_2**	**Al_2O_3**	**Fe_2O_3**	**TiO_2**	**CaO**	**MgO**	**Na_2O**	**K_2O**	**LOI$^{1)}$**	**Water solubility**	**Acid solubility**
Bentonite	64.1	20.0	3.66	0.16	1.52	2.38	2.18	0.49	6.26	-	-
Perlite	73.0	12.5	0.7	0.1	1.0	0.5	4.5	4.8	1.3	0.1	0.5

LOI$^{1)}$ = Loss on ignition

Other types of drilling fluids like aerated water or mud and foam are sometimes used for pressure balancing and will be used where the need arises. Air only drilling is used in holes with low water tables or vapour-dominated reservoirs and this requires very large compressors, which may be very noisy.

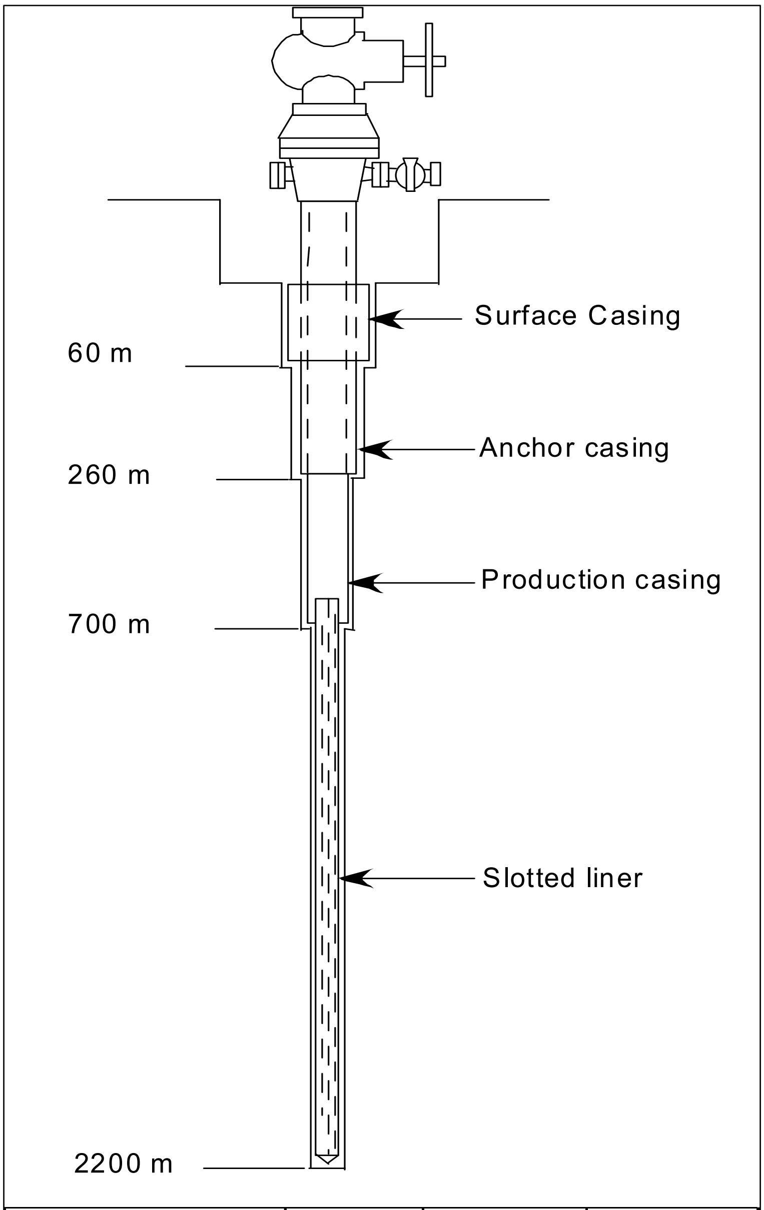
5.2.5 Casing and cementing

During drilling the use of casings and slotted liners which are fixed in the well bore at different depth as required (Figure 17) will be needed. There are three main types of casings namely the conductor casing, the surface and the slotted liner. The Conductor casing is the largest diameter casing used in a well and is required only where the surface soils are so loose that the washing and eroding action of the drilling mud would create a large cavity at the surface. It controls such erosion action. The surface casing is of a smaller diameter and serves as an anchor for well control equipment e.g. the blow-out preventers, protects fresh water zones and isolates lost circulations intervals. The amount of surface casing required, therefore depends on the depth of the fresh water table with a minimum of 60 m and a maximum of 400 m and is cemented all the way to the surface. If the fresh water table is below the surface casing, the control authority requires that the fresh water be protected by setting either intermediate or production casing and cementing with enough cement to completely fill the casing well bore annulus from the shoe to the surface (Corsi, 1995). The intermediate or anchor casing prevents breakthrough of steam up through the surface during drilling, protecting the rig and crew. The production casing closes off cold aquifers and provides a conduit for the fluid up the well. The slotted liner is not cemented and prevents the well wall from collapsing into the well during operation and is a conduit for the inflow of geothermal water into the well. The liner is perforated or slotted and the degree of perforation needed to ensure adequate flow area without undue restriction to inflow corresponds to some 3 to 6% of the surface area of the liner.

The cementing of a casing in a well is carried out for a number of reasons. Where a conductor casing is required, it must be cemented in order to prevent the drilling fluid from circulating outside the casing which may lead to surface erosion that the casing was designed to prevent. The surface casing must be cemented in order to seal off and protect freshwater formations. Cement also effectively protects the casing from corrosive environments, notably corrosive fluids that may be present in the surface formations.

5.2.6 Demobilisation

After drilling is completed, the rig will be removed and drill pads restored to their original status as far as is possible. This process is termed as demobilisation. Leaving abandoned parts, equipment and scrap on site can bring about loss of habitat. During demobilisation, a slotted liner is put in the well and the rig is transported away and flow equipment is erected i.e. pipes, additional vents, and atmospheric separators (silencers). An aerated shelter is usually fixed to protect the wellhead.



CASING	DEPTH	CASE 1	CASE 2
	(m)	(dia)	(dia)
Surface casing	60	20"	22 1/2"
Anchor casing	260	13 3/8"	18 5/8"
Production casing	700	9 5/8"	13 3/8"
Slotted liner	2200	7"	9 5/8"

FIGURE 17: Schematic diagram of a geothermal borehole (Thorhallsson, 2005)

Unplanned, careless and disorganised removal of physical facilities can cause further loss of habitat. Once the structures are removed the sites can be left to undergo a succession or be rehabilitated to achieve comparable status with the neighbouring area.

5.2.7 Warm up, flow initiation and flow

After demobilisation, the wells will be tested and closed in order to warm up and build up pressure. This is common with wells that can self-discharge. Drilling soap is normally added for compression while some wells have to be airlifted to initiate flow. The main impacts of well testing are water effluent which may contain toxic chemicals, and noise. Testing of wells has often had a deleterious effect on local vegetation with trees and other plants being scalded by escaping steam and spray. This effect is more severe during the vertical discharge of wells, which is carried out in order to clean them. The wastewater from a tested well can cause serious gullying when discharged directly to a steep area.

5.3 Operation

For the last decade, all new geothermal power generation projects have been planned in relatively small (20 - 40 MWe) phases, rather than harvesting the geothermal field in one large phase as previous plans assumed, the so-called stepwise development strategy. By building up the steam supply system and the power plant in relatively small phases, it is possible to start the power production early and then build further phases with added confidence as knowledge and experience of the geothermal system build up. Stepwise development strategy helps in estimating the financial capacity of the resource and the maximum level of sustainable use. For example this strategy, applied in Iceland, has been successful and production cost of electricity from geothermal power plants is quite favourable compared to other places in the world (Stefansson, 2002). By applying the stepwise development strategy, the production cost of electricity from geothermal power plants has turned out to be lower than the production cost from hydropower (Stefansson and Axelsson, 2005).

The Katwe and Kibiro geothermal prospects being investigated are new fields where geothermal feasibility studies are to be carried out and therefore it is appropriate to set up 30 MWe power plants to begin with.

5.3.1 Main elements of a proposed power plant

I. Simplified process diagram for the power plant
The proposed power generation facility will consist of all onsite equipment and systems required to safely and reliably generate up to 30 MWe of electricity. The equipment installed will include a number of wells, separators, a turbine and auxiliary systems, cooling tower, electrical equipment and structures for protection of equipment and operation.

The condenser-type generation process is most commonly applied to geothermal power projects, extracting energy from high temperature reservoirs with fluids in excess of 200ºC. This generation method has been used in a number of geothermal fields (e.g. in Iceland) for a long time. This model is used here to assist in identifying the potential impacts of developing a high temperature area like Katwe and Kibiro, and should not be mistaken for a proposed generation process. Figure 18 is a diagram of a conventional condenser-type power production process for a 30 MWe power plant.

II. Wells
Wells are drilled through the geothermal reservoir and produce geothermal fluids at the surface. The wells are generally 1,500 - 2,000 m deep, the top 800 – 1,000 m are cased and cemented but the production zone is completed with a slotted liner to permit flow. The wells are either drilled vertically or directionally. Directional wells increase the chances of intersecting highly productive fractures and fewer well pads are needed for directional drilling which is an environmental and economical advantage. Surface structures associated with the wells include the drill site template, wellhead equipment, wellhead shed and blow-out silencers.

III. Steam supply system
The steam supply system gathers the two-phase geothermal fluid and transports it in insulated pipes to the separation station where the steam phase is separated from the brine phase. In some cases (e.g. Krafla power plant, Iceland), the brine phase is re-flashed at a lower pressure where secondary steam is separated from the remaining brine. The steam (both high-pressure and low-pressure) is carried to the power house to drive the turbine, but the brine phase is directed to the disposal system (Figure 18).

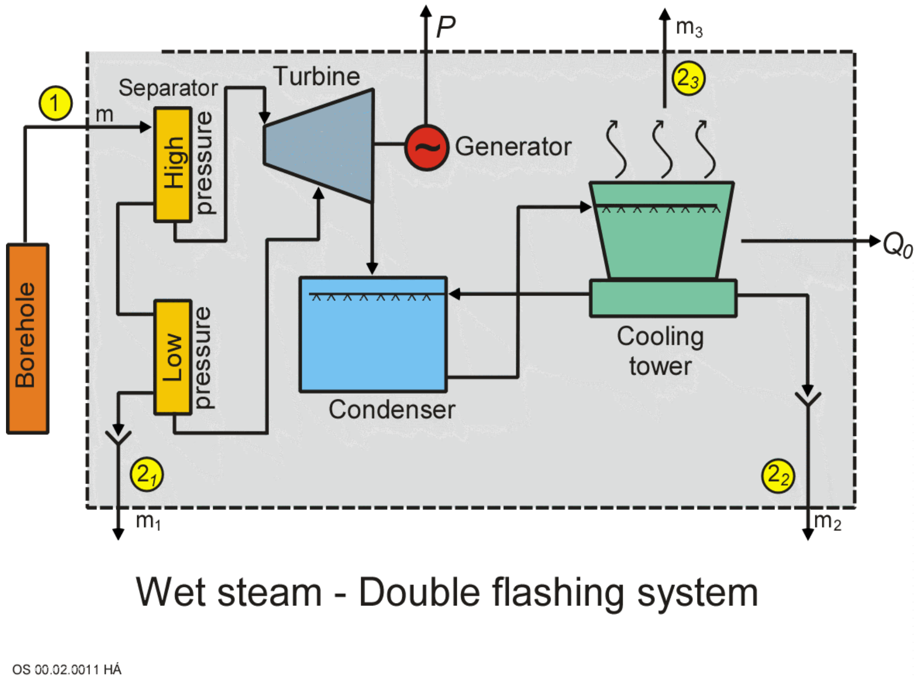


FIGURE 18: Production flow diagram for
a proposed 30 MWe power plant (Karlsson, 1982)

IV. Disposal system
A disposal system is used to dispose of both the brine from the separation station and the condensed water from the cooling towers. There are many ways of fluid disposal, namely: surface disposal to waterways or fissures and fractures; reinjection into the reservoir and shallow injection into delineated disposal zones (300 - 500 m deep).

V. Turbine and auxiliary systems
The generating system comprises a turbine, generator, intake valves, condenser, cooling system, and operating instruments. The effluent steam from the turbine is condensed in a condenser located downstream to the turbine or below it, to improve the turbine efficiency. Normally the cooling medium is condensed water that has been cooled in cooling towers but in special cases e.g. Nesjavellier power plant, Iceland, groundwater is used instead of a cooling tower (Arnorsson, 2004). The cooling towers are normally the most prominent features of the power plant. Among other auxiliary systems is the gas removal system (ejectors or pumps) that removes non-condensable gases from the condenser.

VI. Electrical equipment
The electrical equipment includes control and protection systems, a power transformer and both high and low voltage systems. The substation and the transmission lines from the substation are not considered parts of the power plant.

VII. Structures
The operation area for a power plant depends on its type and size but generally the land uptake for a geothermal power plant is approximately 20,000 m^2 at a minimum. The key elements of geothermal power plants are the power house, cooling tower, the disposal system and the switch yard. Other structures like separators, wellheads and pipelines may be located outside the operation area. Normally the powerhouses are steel buildings whereas service compartments are concrete structures.

5.3.2 Electricity generation process

The power harnessing cycle can be divided into two stages: (1) the collection and processing of steam from boreholes; and (2) the production of electricity (Figure 18). Steam mixed with water will be conveyed from boreholes through collection pipes to the separation station where the water is separated from the steam. The separation station is proposed to have two levels, high pressure and low pressure, in order to maximize the amount of steam collected. From the separation station steam will be conveyed to the turbine where steam energy is converted to mechanical energy, the turbine then drives the generator that converts mechanical energy to electrical energy. The separated fluid will be sent to the disposal system and the cooled steam from the turbine will join the cooling system composed of the condenser and the cooling tower with the excess sent to the disposal system.

5.3.3 Inputs and outputs into generation process

The proposed power plant will use the geothermal fluid from the boreholes for electricity generation and cold water for domestic/industrial use in the plant and for the operation of the cooling system i.e. the cooling tower and the condenser cycle. The inputs and outputs are summarised in Figure 19.

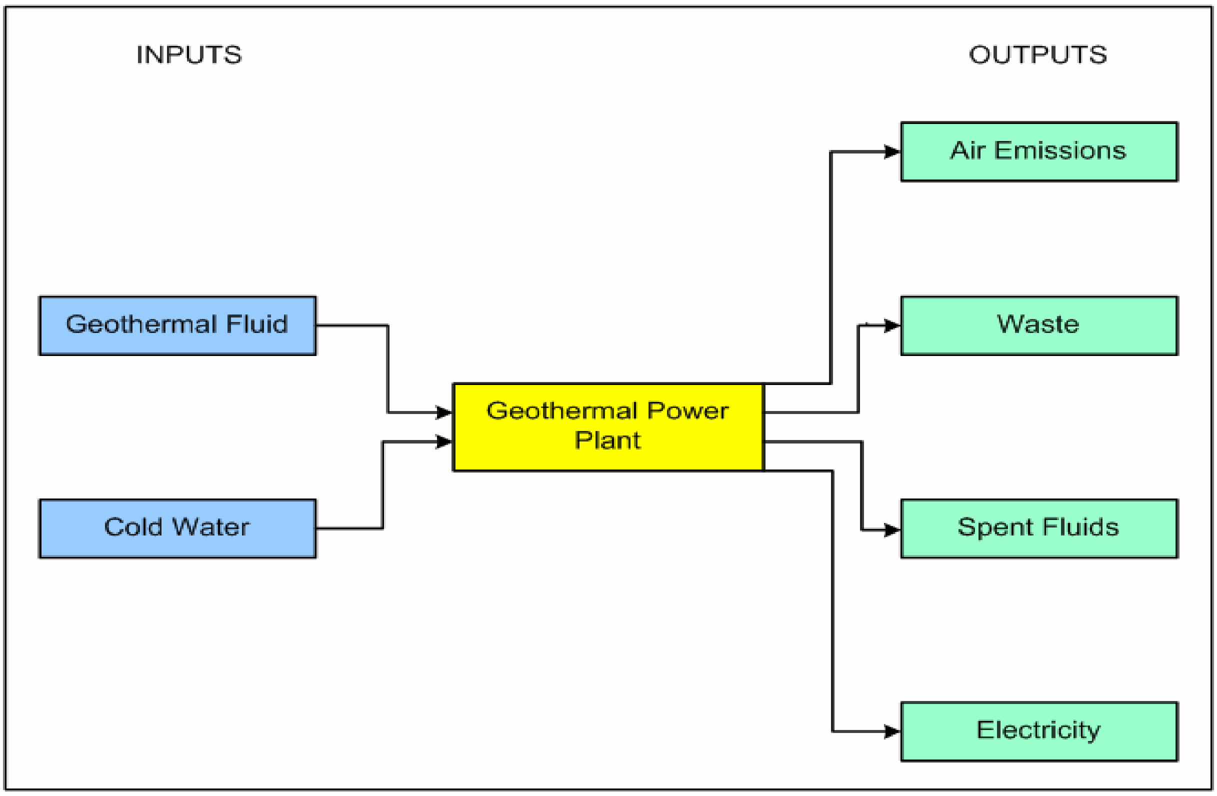


FIGURE 19: Inputs and outputs of the proposed geothermal power plant

The principal outputs from the proposed power plant will include the following:

- Gas emissions - include non-condensable gases (NCG), and fine solid particles. The gases comprise carbon dioxide (CO_2), hydrogen sulphide (H_2S), hydrogen (H_2), Nitrogen (N_2), ammonia (NH_3), hydrocarbons such as methane (CH_4) and ethane (C_2H_6), trace amounts of mercury (Hg), boron vapour, helium (He) and radon (Rn);
- Solid waste and domestic waste from the operations of the power plant;
- Spent fluids from the generation process;
- Electricity.

5.4 Proposed location

5.4.1 Katwe geothermal prospect

The location of the proposed development area cannot be ascertained at the moment since the final phase of surface geophysical exploration is still going on to narrow down on the anomaly and delineate its boundaries in an effort to locate the drilling sites. Geothermal power plants are not flexible and have to be located near the boreholes for economic reasons i.e. to avoid heat losses in transporting the fluid and to minimize infrastructure for fluid gathering. The current geothermal model suggests that the anomaly covers an area of about 150 km^2 and is a part of the KKVF (Figure 20). The area is designated as a wilderness by the UWA and forms a part of the northern terminal of the QENP.

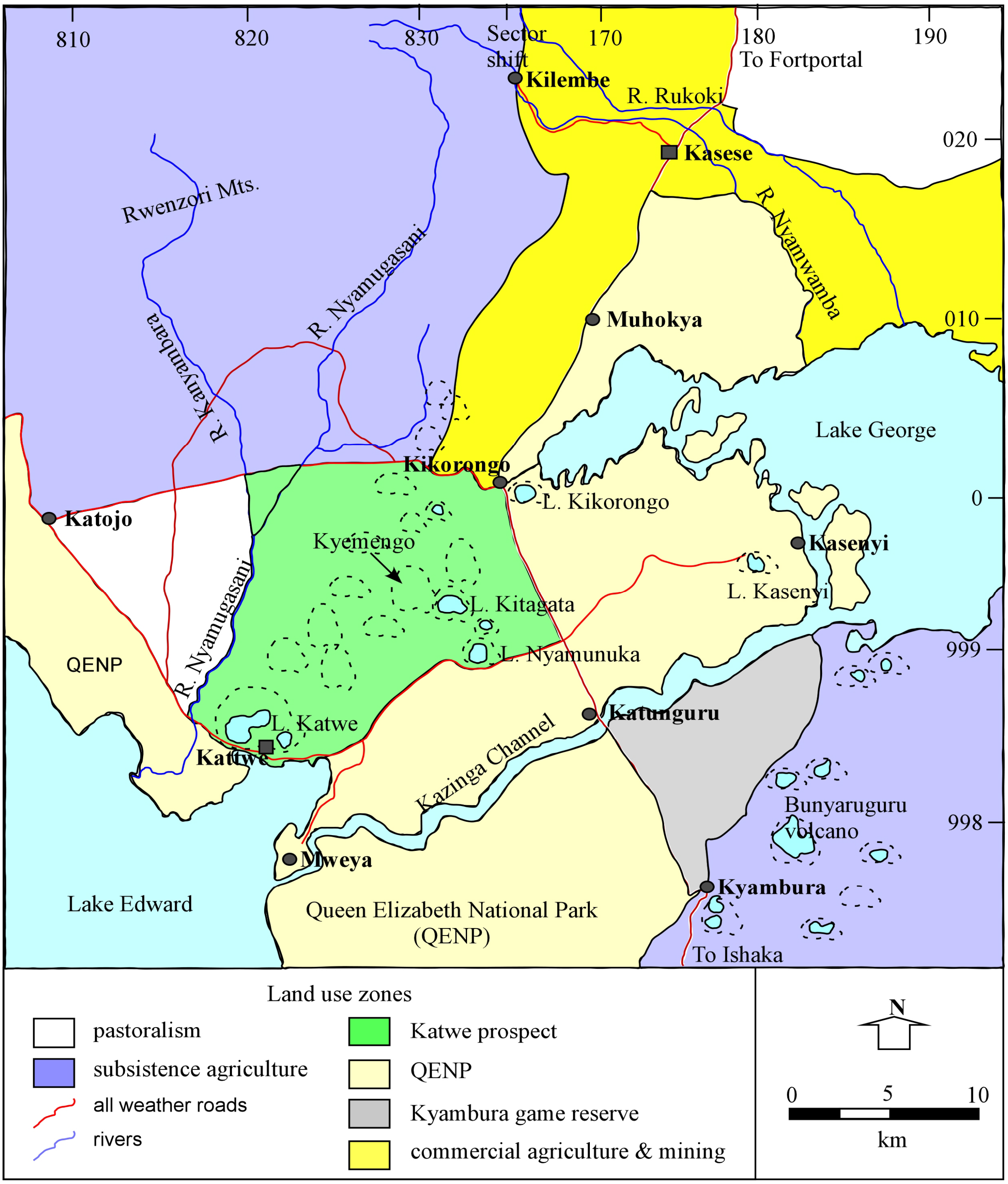


FIGURE 20: Katwe, proposed development area and surroundings, land use

It stretches from Lake Katwe to the Kikorongo junction covering the main crater area that in controlled by the NE-SW trending fault.

The current boundaries of the anomaly are the Katunguru – Katwe road to the south, Katunguru – Kasese road to the east, Kikorongo – Bwera road to the north and River Nyamugasani to the west. The only settlement within its borders is the Katwe Township.

5.4.2 Kibiro geothermal prospect

The location of the proposed development area, unlike Katwe, has been roughly delineated by the various multidisciplinary surveys and is not expected to change much after the final demarcation of the anomaly boundaries. The current geothermal model so far locates the development area approximately 3-4 km west of Kigorobya Township (Figure 21). The size of the development area is estimated to be between 30 and 50 km^2. The area is privately owned with subsistence agriculture and pastoralism as the main activities.

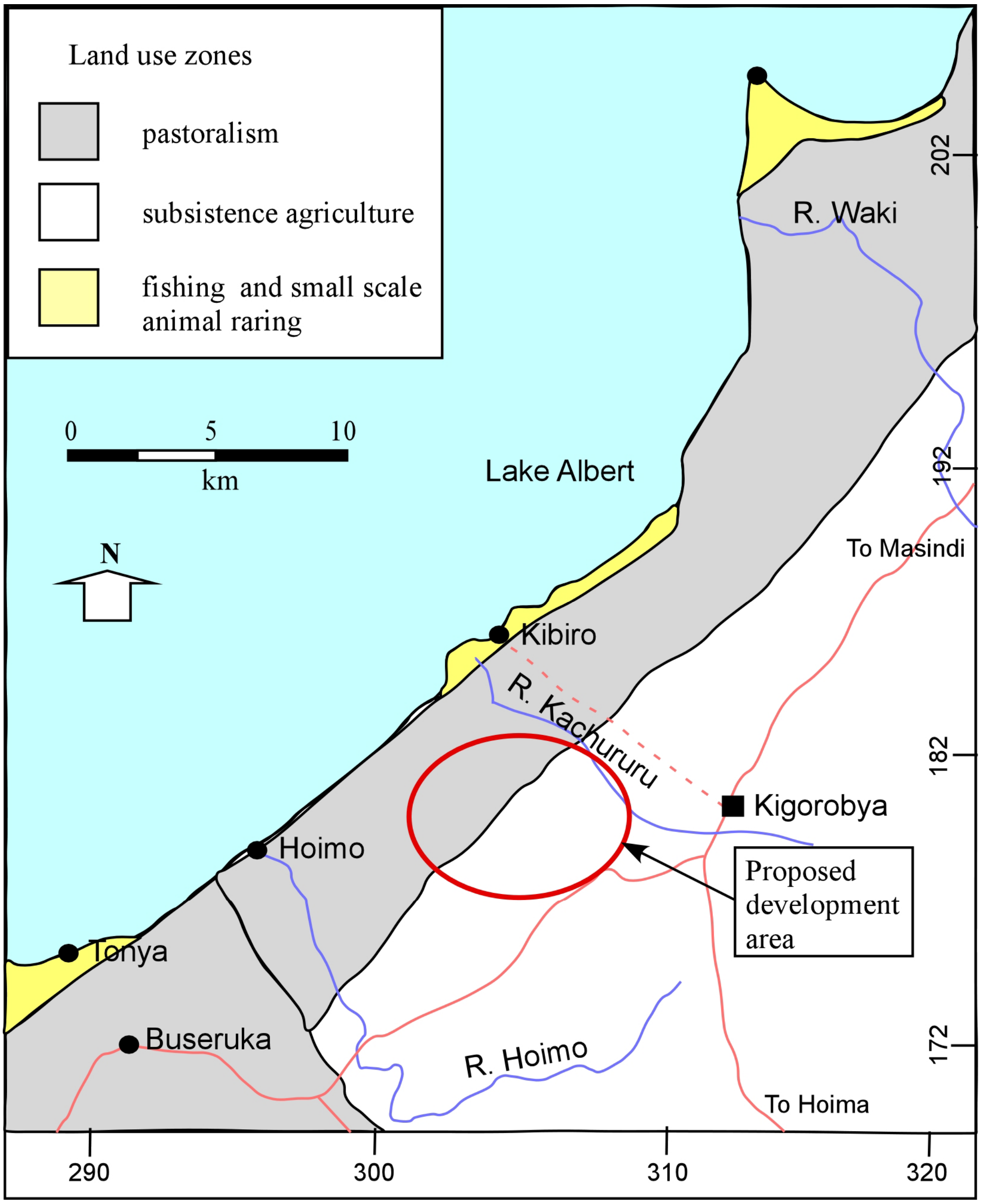


FIGURE 21: Kibiro, proposed development area and surroundings, land use

6. KATWE - DESCRIPTION OF THE ENVIRONMENT AFFECTED

The information presented in this section provides an overview of the environment affected by the proposed project. Specific components of the environment affected will be more closely examined if the detailed EIA proceeds and this will be achieved through the specialist studies that will be conducted. The environment affected by the development of the Katwe geothermal prospect is basically the environment of Kasese district although some neighbouring districts will be affected in one way or another.

6.1 Stakeholders and stakeholders' interests

The main stakeholders in the development of the Katwe geothermal prospect are the Ministry of Energy and Mineral Development (MEMD), Uganda Wildlife Authority (UWA), National Environment Management Authority (NEMA), Local Government of Kasese district, Department of Water Resources, Katwe Township, and local communities (pastoralists, fishermen, agriculturalists and salt workers) that live adjacent to the prospect, non - governmental organisations (NGOs), and development partners and international organisations.

The MEMD is responsible for exploration and development of the geothermal resources. Its interests are to develop the Katwe geothermal prospect; provide electricity for rural electrification and the national grid; provide direct heat for use in industry and agriculture; and extract minerals from the geothermal brines. The UWA is the custodian of the QENP in which the Katwe geothermal prospect is located. Their interests are in the protection of biodiversity and wildlife and to grant permits, rights and licenses for services provided to the project. NEMA is the principal agency in Uganda for the management of the environment with the express mandate to "co-ordinate, monitor and supervise all activities in the field of the environment". The geothermal prospect is administered by the local government of Kasese district. The role of the local government, therefore, is to assist in the implementation of NEMA's activities by carrying out environmental audits and monitoring; and to provide services to the development projects for example, building of access roads, bridges, and mobilizing the local community to participate in such projects. The Department of Water Resources is responsible for the development and management of the national water resources. Its interests are to protect surface and ground water systems, especially rivers and lakes, from pollution and to issue water user permits.

Other stakeholders are the salt workers whose livelihood depends on the local salt industry at Lake Katwe, the pastoralists, fishermen and agriculturalists. Their main interests are in sharing of water resources with the proposed project, jobs and markets for their produce. The NGOs are the promoters of geothermal energy and other renewable sources of energy in Uganda as alternatives to hydropower whose development is facing serious environmental problems. Such NGOs include indigenous ones like the National Association of Professional Environmentalists (NAPE), the Joint Energy and Environmental Projects (JEEP), the Uganda Wildlife Society and the International Rivers Networks (IRN). The main interests of NGOs entail sensitizing the population to renewable sources of energy that are clean and environmentally benign; educating the stakeholders and local communities about the socio-economic benefits of geothermal energy, bridging gaps between geothermal developers and other stakeholders by facilitating consultative forums and meetings.

Lastly, the development partners and international organisations that have cooperated with the Government of Uganda during exploration for geothermal resources in the Katwe geothermal prospect since 1993 are UNDP, OPEC, IAEA, ADB, WB and the Government of Iceland. These partners and organisations would like to see the Katwe geothermal prospect developed to produce electricity and direct heat for industries and agriculture. On the other hand there are organisations like the German Technical Cooperation (GTZ), the United Nations Educational Scientific and Cultural Organisation (UNESCO), the Global Environment Facility (GEF), and the International Union for Conservation of Nature and Natural Resources (IUCN), which sponsor various projects on conservation of biodiversity in the QENP. These organizations save for the GEF which would like to see a balanced situation, would not support development of geothermal resources in a protected area visualising serious environmental impacts. The GEF is one of the organizations promoting the African Rift Geothermal Development Facility (ARGEO) that was initiated in Nairobi, Kenya in 2003. The aim of the facility is to assist the East African countries to develop their geothermal resources and to promote geothermal energy as a clean source of energy for the 21st Century.

6.2 Physical characteristics

6.2.1 Climate

The climatic conditions of Kasese district vary ranging from temperate, tropical, and alpine to semi-arid plains and a bi-modal rainfall pattern which have rendered the soils fertile enough to support almost any agricultural activity. The bimodal rainfall in March - May and August - November averaging between 800 and 2,000 mm enables the people to grow crops throughout the year. The annual rainfall distribution is greatly influenced by altitude. In terms of total annual rainfall, the extreme southern to south-eastern part of the district receives slightly less than 800 mm. The savannah area spanning the QENP and Lakes Edward and George, receives 800–1,000 mm. Temperatures normally range between 23.9ºC and 30ºC in the rift valley. The Katwe geothermal prospect lies at an elevation of 900-1,300 m.a.s.l with a mean annual temperature of about 27°C. The prospect receives 800-1,000 mm of rainfall per year for it lies in the savannah belt of the QENP north of Lake Edward and the Kazinga Channel.

The Katwe geothermal prospect also lies at the foot of the Rwenzori Mountains, a massif block, which is believed to have been elevated during the Tertiary period. The mountains rise to a maximum altitude of 5,200 m a.s.l. The upper parts of the mountains are hidden in a cloud cover created periodically by moist air streams from the Atlantic and Indian oceans. The highest peaks of the Rwenzori Mountains are covered by permanent ice and snow, with a total of 37 small glaciers and ice fields covering about 67 km^2. The mean annual rainfall reaches up to 2,000 mm at an altitude of about 4,600 m a.s.l.

6.2.2 Topography and geology

The district is unique with almost all kinds of topography. It has a diversity of contrasting physical features which range from flat lowlands through undulating hills to the snow-capped Rewnzori Mountains. The Katwe geothermal prospect is located in the Katwe-Kikorongo volcanic field in the flat lowlands of the rift valley (Figure 5). The volcanics rise gently from 900 to a maximum of 1,300 m a.s.l. The terrain is steep and access difficult in some parts of the crater area but in others the land is generally flat and easily accessible. The area is characterised by a number of craters some of which have crater lakes and the rest are dry and covered with grassland and forests.

6.2.3 Soils

The types of soils found in Kasese district are organic, ferrosolic, podsolic/eutrophic, and hydromorphic. The classification of soils in Kasese district is also influenced by altitude (Table 7). The soils in the Katwe geothermal prospect and surrounding areas are predominantly eutrophic. These soils are dominated by brown sandy loams and sandy clay loams and the parent material are the rift valley sediments. They are basically developed on sands and gravel which is water-worn. North of Lake George there are large spreads of sand, gravel and clay brought down by rivers draining off Rwenzori Mountains. In general, these soils are typically deep and of high base status and calcareous as the Nyakatonzi soils. The soils occur on up-warped or older parts of the volcanic ash covered lake deposits in the Lakes George and Edward basin, and on less compacted ash which forms a higher terrace beyond Katojo to the west of the geothermal prospect.

TABLE 7: Types of soils in Kasese district

Type of soil	Elevation (m a.s.l)	Description
Organic	3,000+	Acidic with an upper layer which contains slightly more than 20% organic matter, called the Bujuku and the Kyansabo series – developed on non-volcanic mass and their pediments.
Ferrosolic	2,400–3,000	Humic soils with better agronomic qualities. Their clay content is composed of kaolin minerals, free iron oxides, amorphous gels and sometimes small amounts of 2:1 lattice clay. These soils are known as the Mulinda series - also developed on non-volcanic rock mass and their pediments.
Podsolic	1,200–2,400	Not differentiated and highly leached soils in which translocation of iron and aluminium has taken place. This transformation produces an ash-coloured bleached horizon immediately below a very acid, peaty top soil and rusty coloured B-horizon. These soils are known as Kazo Catena.
Eutrophic	900–1,200	Developed on the rift valley flat and are recent rift valley deposits. They are divided into two categories: eutrophic soils developed on volcanic ash referred to as the Kasese series, and those developed on non-volcanic material known as the Sebwe series.
Hydromorphic	-	Soils whose development and characteristics are influenced by permanent or seasonal water-logging.

Source: NEMA, 1997 (DSOER).

6.3 Ecological characteristics

6.3.1 Air quality

The state of the atmosphere within the Katwe geothermal prospect is good, it being located in the wilderness with virtually no anthropogenic interference. The Katwe Township has no industrial infrastructure to cause significant changes in the atmospheric composition but changes may occur toward Kasese Town which is a growing industrial town.

6.3.2 Water resources

Kasese district is endowed with many water sources that include lakes, rivers and streams. The Rwenzori Mountains is one of the major sources of water to the water bodies. Rivers include the Mubuku, Rwimi, Nyamwamba, Sebwe (that harbours Mubuku Irrigation Scheme), Nyamugasani and Lhubiriha (that harbours Bwera Water Scheme) at the Uganda-Congo border all from the Rwenzori Mountains. The major lakes include Lake George, Lake Edward and the Kazinga channel, while the crater lakes on top of Rwenzori Mountains provide extra water. Generally, the district is served by many safe water sources that include boreholes, protected wells and springs and piped water mostly in the urban areas. The total area occupied by water in Kasese district is 481 km^2.

I. Surface water

The Katwe geothermal prospect is characterised by a number of crater lakes with waters of high salinity which are not suitable for domestic use. The main crater lakes and their surface areas are as follows: Lake Katwe – 2.5 km^2; Lake Mahiga – 0.182 km^2; Lake Kitagata – 0.708 km^2; Lake Murumuli – 0.222 km^2; and Lake Nyamunuka – 0.931 km^2 (NEAP, 1993).

The fresh water lakes that border the geothermal prospect to the south are: Lake Edward – 2,203 km^2 of which 645 km^2 are in Uganda and the rest in the DRC; Lake George – 246 km^2 and the Kazinga channel that connects the two Lakes (NEAP, 1993). The only river in the area is River Nyamugasani with a flow rate of approximately 8.35 m^3/s (NEAP, 1993). River Nyamugasani flows into Lake Edward. The two Lakes Edward and George have many inflows and a single outflow from Lake Edward, River Semuliki, that flows northwards through the DRC and west of the Rwenzori Mountains. It emerges from the DRC on the north-western side of the Rwenzori Mountains and flows along the Uganda-DRC border before it flows through Lake Albert to join the River Nile at the northern extreme end of the lake. All the fresh water lakes and rivers still retain a good water quality in terms of industrial use, and potable/domestic use.

II. Groundwater

The source of groundwater in the Katwe geothermal prospect is composed of hot springs, cold springs, protected springs and boreholes. The hot springs are only located in the Lake Kitagata crater with a temperature range of 56-70˚C. There are warm springs in Lake Katwe with temperatures between 29 and 32˚C and a number of cold springs. The salinity of the cold springs in Lake Katwe varies from nearly fresh to saline with some of them protected and used for domestic water supply. The source of the fresh water in the protected springs is not yet known but certainly it is not from Lake Edward as geophysical surveys and isotope measurements have indicated that there is no connection between Lakes Edward and Katwe. The water level of Lake Katwe (880 m.a.s.l) is about 30 m lower than that of Lake Edward (910 m.a.s.l). A protected spring in the Lake Kasenyi crater close to Lake George discharges brackish water like the boreholes that were drilled for domestic water supply in the area and could not be used. There is a local salt industry in Lake Kasenyi like in Lake Katwe.

6.4 Biological resources

6.4.1 Fauna

Queen Elizabeth National Park is one of Uganda's oldest, richest and most popular parks; it is a labyrinth of open savanna, bushlands, extensive forest, wetlands, rivers and lakes. Like many other parts of Uganda its wildlife was severely depleted during years of instability in the 1970s and early 1980s. However, with the return of peace in the late 1980s the situation has clearly reversed and a total of over 90 mammalian species within its boundaries is evidence of this. Its diverse scenery is home to a multitude of game and the wonder of searching out the many different species within the boundaries of this contrasting habitat is great fun and puts the QENP in a class of its own. Wildlife includes chimpanzee, L'Hoest monkey and Black & White Colobus monkey, a large number of predators, elephant, buffalo, rhinoceros, giant forest hog, Uganda kob and waterbuck, numerous antelopes including the elusive, semi-aquatic sitatunga, and perhaps Uganda's greatest concentration of bird-life, with over 600 species of birds recorded, as well as one of Africa's largest congregations of hippopotami, along the Kazinga Channel. Of these the ones that are common in the Katwe geothermal prospect are buffaloes, waterbucks, elephants and Uganda kobs. The populations of these animals are large during the rainy season while in the dry season they move to areas which are close to fresh water points. The hippopotami are a common feature in Lakes Edward and George and the Kazinga Channel during the day and at night they roam around the grassland and communities looking for food.

6.4.2 Flora

The information on vegetation presented here is predominantly based on a detailed overall vegetation survey carried out by Langdale-Brown et al., (1964). A lot of changes have taken place in the district due to human activities; however, there are remnants of the dominant vegetation types. In protected areas like the QENP, no significant changes are expected to have taken place.

Based on Langdale-Brown et.al. (1964) the vegetation types are categorized according to elevation. Such a classification is presented in Table 8.

TABLE 8: Types of vegetation in Kasese district

Vegetation type	Elevation (m a.s.l)
1. *Alchemilla – Helichrysum Moorland* (High altitude moorland and heath)	3,300+
2. *Ericaceae – Stoebe* (High altitude moorland and heath)	2,400 – 3,600
3. *Hagenia – Rapanea* (Moist montane forest)	2,400 – 2,700
4. *Arundinaria* (Montane bamboo forest)	2,250 – 2,700
5. *Cynometra – Celtis* (Medium altitude moist semi-deciduous forest)	660 – 1,350
6. Forest savannah mosaic at medium altitudes	900 – 1,800
7. Undifferentiated semi-deciduous thicket (Moist thicket)	900 – 1,000
8. *Acacia – Albizia – Beckeropsis – Cymbopogon* (Moist acacia savannah)	990 – 1,650
9. *Combretum – Terminalia – Albizia – Hyparrhenia* (Moist combretum savannah)	780 – 1,800
10. *Acacia – Cymbopogon/Themeda complex* (Dry acacia savannah)	725 – 1,125
11. *Themeda – Heteropogon* (Grass savannah)	900 – 1,050
12. *Acacia – Imperata* savannah	900 – 1,200
13. Cyperus papyrus	600 – 1,950
14. *Rauvolfia - croton*	High and low altitude

The Katwe geothermal prospect is inhabited by the following main types of vegetation among the listed types above: Cynometra celtis forest, Forest savanna mosaic, Moist thicket – of undifferentiated semi-deciduous thicket, Acacia-Cymbopogon/Themeda complex, Themeda-Heteropogon, Acacia Imperata Savanna, and Cyperus papyrus.

Cynometra family is closely associated with heavy elephant populations and small watering holes and mud wallows. *Pennisetum perperium*, *Imperata cylinderica*, *Hyparrhenia rufa* and *Cymbopogon afronardus,* all of the Forest/savanna Mosaic group, are common in the crater area. *Moist thicket-of undifferentiated semi-deciduous thicket* is composed of a dense growth of evergreen and deciduous shrubs and small trees with interlocking crowns which reach a height of 4-6 m with no or sparse grass cover. This zone is observed in some areas stretching from Katunguru to the shores of Lake George. *Acacia-Cymbopogon/Themeda complex* is essentially in the category of dry *Acacia* savannah. The wood cover consists overwhelmingly of species of Acacia with small thickets on anthills. This plant community is evident in Munkunyu subcounty, in areas of Nyakatonzi, west of the Katwe geothermal prospect, and also in parts of Muhokya, Kasese and Rukooki. *Themeda-Heteropogon* and *Acacia Imperata Savannah* are common in areas of Lake Katwe, on the fringes of Lake George and Muhokya. Lastly, Cyperus papyrus can attain a height of 2.3-4.5 m. It is good for thatching and rope making and dominates the swamps north of Lake George.

6.5 Potential land use options

Like most districts in Uganda, Kasese district is predominantly agricultural, relying on farming for employment and income. Agricultural production is high owing to the rich soils and reliable rainfall. But lack of proper information about markets denies farmers the opportunity to sell their produce profitably. The people keep livestock including cattle, goats, sheep and pigs. Land tenure in the district is mainly customary and freehold and there is a high potential for agricultural mechanisation. The district also has a mining potential at Kilembe and Lake Katwe, and other small-scale mines like the limestone mines in Muhokya subcounty along Katunguru – Kasese road. There are a number of industries in the district, which have greatly contributed to the availability of employment to the population.

6.5.1 Agriculture

Kasese district produces several food and cash crops and livestock products. Over 85 percent of the people in the district depend on agriculture for their livelihood. Among the food crops produced in the area are finger millet, cassava, maize, ground nuts, sorghum, potatoes and bananas. The district also practices horticulture that includes fruits like passion fruits and vegetables. Most of the agricultural products are either sold to the local markets in the region or exported to Kampala and other districts in the country like Jinja. However, the main agricultural activity is of subsistence nature although the district through the government's Program for the Modernisation of Agriculture is promoting commercial farming. The district has also introduced new crops to improve on the standards of the farmers. They include hybrid hot pepper, vanilla, okra, moringa, oleifera, apples and pears. Other crops are coffee, cotton, passion fruits, onions, tomatoes, pawpaws, cassava, sim sim, irish potatoes, sunflower and soya beans.

The district plans to increase on the number of demonstration farms and information centres at subcounty levels for the purpose of sensitising the farmers to modern farming techniques. In addition to the single irrigation scheme at Mubuku other areas are being proposed for small-scale irrigation schemes. These include Nyakatonzi, Katojo and Kiburara all in Bukonjo county and located west of the Katwe geothermal prospect. The potential for irrigation is attributed to the presence of rivers like Kinyamaseke, Kyanzi and Nyamugasani and the relatively flat terrain of the areas.

Kasese district practices livestock farming to supplement crop husbandry. The district has been encouraging farmers to cross-breed their traditional breeds with exotic dairy cows which are more productive. The district has a staff of 11 veterinary officers and 10 animal dips. Pastoralism is widely practiced mainly in the lowlands of the district stretching from Kasese town to the Uganda - DRC border and covering all the areas north, east and west of the geothermal prospect. These pastoralists are among the communities that lost their land and grazing rights when the area was gazetted into a National Park in 1952. The communities are getting organised to practice modern livestock farming. They sell milk and its products to the residents of Katwe Township, Mweya community and Kasese Town. The animals for beef are sold to Kasese, across the western region and as far as Kampala.

The districts of Kasese, Bushenyi, Kamwenge and Kabarole, which are in close proximity to the geothermal prospect, have a total population of 1,910,913 (population census, 2002). The population of Kasese alone is 532,993. Kabarole and Kamwenge are agricultural districts producing cotton, coffee and tobacco as the main cash crops. Other crops include maize, wheat, millet, sorghum, cassava, bananas and potatoes. Horticultural crops are also grown in the area and livestock keeping is also practised. Bushenyi district has many tea and banana plantations in close proximity to the geothermal prospect. Other crops grown include pineapples, coffee, maize and millet, and livestock keeping is also practiced. Kasese district is the only one in the area with an irrigation project on river Mubuku. Plans are underway to expand this project.

6.5.2 Fisheries

The fisheries sector makes a significant contribution and generates substantial income for thousands of people in Kasese district who are engaged in a variety of activities such as direct fishing, boat building, fish sales and distribution, net sales and net mending, fish processing and preservation, boat engine sales and repairs. There are five commercially important fish species namely *Oreochromis niloticus, Barbus altianalis, Protopterus aethiopicus, Bagrus docmac* and *Clarias lazera*.

Fish is harvested from Lakes Edward and George, Kazinga Channel, Kanyatete swamps, Lake Kayanja Kabaleka, River Nyamugasani and fish ponds. Lakes Edward and George and the Kazinga Channel which joins them jointly produced an estimated 2,200 tons of fish in 1994 compared to 12,000 tons in 1968. The drop in catch was attributed to the effects of over-fishing in view of the increase in the number of canoes to 904 as compared to the legal number of 397. Lakes Edward and George, which are situated in the QENP, have a gazetted number of fishing villages unlike other lakes.

The fishing villages in the Katwe area are Katwe and Kayanja on Lake Edward; Katunguru on the Kazinga Channel; and Hamukungu, Kasenyi and Kahendero on Lake George. The problem of overfishing is currently being sorted out by reducing the number of boats and enforcing the right fishing gear.

Population increase has led to an increase in the demand for fish in Kasese district. The demand exceeds the prevailing production level which has in turn intensified the fishing activity. Fish farming is being encouraged in Kasese district due to the high demand on both local and external markets. This is a new type of farming that has recently attracted attention.

6.5.3 Mining

Formerly known as the copper-mining giant because of the now defunct Kilembe Mines, Kasese district is also endowed with cobalt, limestone, salt and clay among other resources. Kilembe mine is located at the foothills of the Rwenzori Mountains approximately 8 km west of Kasese Town. Kilembe Mines Limited produced copper from 1956 to 1982. Since then it has been under care and maintenance, keeping a staff of some 300 workers. The mine established its own town and the associated infrastructure, as was the norm at that time. The mine was self-sufficient until 1993 through the use of its assets and the sale of its hydroelectric power. Revenue has greatly diminished recently and Kilembe Mines Limited can no longer cover its costs. Management has formulated some concepts to secure the future, e.g. the creation of an engineering faculty using the mine facilities and the establishment of a tourist infrastructure. However, further assessment and support are needed. Kilembe Mines Limited produces 5 MWe of electricity at Mubuku (II) hydropower station of which 2 MWe are used for its own needs and the balance is sold to the national grid.

Small scale Lime Works and Artisanal Lime Producers are located along the Kikorongo-Kasese road close to the geothermal prospect. Other small scale mining in the area is to the south of the prospect in Bushenyi, the Mashonga and Buhweju artisanal gold mines and kaolin is mined at Mutaka.

6.5.4 Katwe salt works

The Katwe Township has a population of approximately 6,000 people the majority of which depend on a local salt industry and fishing from Lakes Edward and George. Others are businessmen and civil servants. The industry has been producing salt for many centuries by evaporation of brines from the two saline crater lakes, Lake Katwe and Lake Kasenyi. Katwe is also a home to the defunct Lake Katwe Salt Factory that was commissioned in 1980 but whose production did not materialise. The factory had created many jobs and attracted many workers and contributed to the growth of the town in both infrastructure and utilities. The closure of the factory which was to produce purified salt was a blow to the community and the local government. Plans to revive the factory have not yet materialised. The Katwe salt industry is one of the major revenue sources for the local government of Kasese district.

6.5.5 Industries

Kasese district has great potential for industrial development once such industries like cobalt smelting, salt processing, metal processing and various agro-based industries become fully operational. Kasese town is an upcoming industrial town in the western region of Uganda. Its growth dates back to 1956 when the Kilembe Mines were opened and the railway line was extended to the town for transportation of copper rivets to Jinja for smelting. Following the closure of the Mine in 1982, a number of industries have been initiated including the Kasese Cobalt Company Limited (KCCL), Hima cement factory and RECO industries among others.

I. Mining-based industries
Kasese Cobalt Company Limited (KCCL) recovers cobalt from the tailings left behind by the copper mining at Kilembe. KCCL is the biggest single investment in the country and the third in Africa. The

project worth $120 million is owned by Normandy Mining with a 63% interest, through Banff Resources, of which KCCL is a subsidiary. It has been in operation since 1998. KCCL generates electrical power for its own use from Mubuku III hydropower plant rated at 10 MWe.

Hima cement factory was constructed and completed in 1970 with an installed capacity of 300,000 tonnes per annum. In 1972, the factory lost a number of its qualified staff and management following the expulsion of non-citizens from the country. Since then the factory has gone through difficult times leading to a fall in production to less than 10% in the 1980s. In April 1999, Bamburi Cement from Kenya acquired a significant stake in Hima Cement Limited. The plant currently has a capacity of 240,000 tonnes per annum. Hima has significantly improved Bamburi's market presence in Uganda, and will provide leverage into the Great Lakes region in the future.

II. Agro-based industries
A number of agro-based industries emerged in the 1980s, in addition to the old establishments such as coffee factories and a cotton ginnery. There are four coffee factories, found in Rukooki, Rwimi, Kisinga and Kasese. RECO Industries in Kasese Town is one remarkable establishment which came into being in the 1980s. The industries produce a number of products including a range of jam and honey, several tomato based sauces, fruit juice concentrates (passion fruit), dehydrated fruits and spray-dried papain (product of pawpaw fruits). Due to a ten-fold increase in the cost of electricity since 1994, the production of dried fruit using electricity powered driers became uneconomical and exports have ceased. The introduction of solar drying might enable RECO to reduce the costs of its drying operations and resume production of dried pawpaw, bananas and pineapple for export. Such industries could benefit from direct application of geothermal energy once developed.

6.6 Existing socio-economic conditions

6.6.1 Societal conditions

I. Population
The population of Kasese district is approximately 532, 993 (Population census, 2002). Lake Katwe subcounty has a population of 13,703 while that of Katwe Township is 5,690. The breakdown of the population of Kasese district by subcounty and sex is presented in Table 9 and their age-sex profile in Table 10.

The data in Table 10 indicates that the majority (50%) of the population is very young (below 14 years old). However a large number (47%) of the population is between the ages of 15-64 years. This information is significant as it indicates the percentage population that falls within the economically active age group.

II. Literacy and education
The literacy rate in the district is about 50% for people more than 10 years old. Only 0.1% has pursued university education. About 61% of the literate population comprises males. Kasese district has six tertiary institutions which offer a limited intake of potential candidates from secondary schools. They include Bwera Teacher Training College, Katwe Technical Institute and four commercial colleges. The district has 33 secondary schools of which 14 are government aided and 19 are privately owned. The number of primary schools is 274 of which 248 are government aided and 26 privately owned. Since the advent of free primary education in 2001, the enrolment in primary schools has increased from 66,536 in 1997 to 161,178 pupils in 2002. Of these 82,040 are male and 79,738 are female.

TABLE 9: Population of Kasese district by subcounty and sex (source: www.ubos.org)

County	Subcounty	Male	Female	Total
Busongora	Bugoye	15,784	16,510	32,294
	Karusandara	4,697	4,554	9,251
	Kasese T/C	26,903	26,543	53,446
	Katwe T/C	2,976	2,714	5,690
	Kilembe	10,489	10,946	21,435
	Kichamba	15,358	15,249	30,607
	Kyabarungira	18,655	19,629	38,284
	Lake Katwe	6,955	6,748	13,703
	Maliba	18,749	20,165	38,914
	Muhokya	8,341	8,344	16,685
	Rukooki	9,800	10,181	19,981
Bukonjo	Bwera	18,142	19,573	37,715
	Ihandiro	5,415	5,702	11,117
	Karambi	18,113	19,735	37,848
	Kisinga	19,275	21,512	40,787
	Kitholhu	7,149	7,339	14,488
	Kyarumba	13,683	15,054	28,737
	Kyondo	7,796	8,487	16,283
	Mahango	7,425	8,068	15,493
	Munkunyu	13,242	14,194	27,436
	Nyakiyumbu	10,773	12,026	22,799
		259,720	**273,273**	**532,993**

TABLE 10: Age-sex profile for the population of Kasese district (source: www.ubos.org)

Age (years)	Male (%)	Female (%)	Total (%)
0-4	20.7	20.5	20.6
5-14	30.3	29.5	29.9
15-64	46.5	47.8	47.1
65+	2.5	2.2	2.4
Total	100	100	100

6.6.2 Infrastructure and services

I. Communications

Kasese is linked to Kabarole and Bushenyi districts with a tarmac road network. This enables the operators in the district to transport their produce to other parts of the country. Most of the produce from Kasese gets markets in urban centres in the western and central regions of Uganda. Kasese's position along the border with the DRC encourages cross border trade. The district has murram roads linking the urban areas to the rural areas. Kasese district is also linked by air, water and the railway and is the end terminal of the Western railway line from Kampala. The telecommunication system has also improved tremendously.

Trunk roads. There are five trunk roads in Kasese district with a network covering a distance of about 162 km. All these roads traverse or are in close proximity to the Katwe geothermal prospect. This road network is summarised in Table 11. In addition the district has 36 feeder roads covering a distance of 405.6 km. The feeder roads connect the rural areas especially the mountainous areas of Rwenzori to the main trunk roads.

TABLE 11: Trunk road network

Name of road	Distance (km)	Nature of road
Katunguru-Kasese-Rwimi	68	Tarmac (Surfaced)
Kikorongo-Bwera-Mpondwe (Equator road)	38	Tarmac (Surfaced)
Katwe-Katojo	19.2	Murram
Katunguru-Katwe	20	Murram
Katunguru-Lake George	16.7	Murram

There are three main types of roads in the Katwe-Kikorongo volcanic field. The first is the Katunguru - Kasese - Rwimi highway and the Kikorongo – Bwera - Mpondwe road both of which are surfaced (tarmac). Mpondwe is the town on the Uganda - DRC border to the west of the Katwe prospect. The second type is murram that includes Katwe - Katojo, Katunguru - Katwe and Katunguru - Lake George. The third type is classified under loose surface road and includes the road from Kabatooro gate to Mweya, Katunguru gate to Mweya and one joining the Katwe – Katojo road and Kikorongo – Bwera - Mpondwe road west of River Nyamugasani. The rest are tracks for tourist and QENP patrol vehicles.

The Kikorongo – Bwera - Mpondwe and Katunguru – Kasese - Rwimi roads experience heavy traffic, such as trailers and lorries which handle fuel and other goods destined for DRC via Ishasha and Mpondwe and to FortPortal via Rwimi. Other roads like Katunguru - Lake George, Katunguru - Katwe and Katwe - Katojo have light traffic, except on market days at Katwe, once a week. Generally the area experiences considerable traffic because of its proximity to the main border post between Uganda and the DRC with most of the supplies to the eastern part of the DRC passing through it.

Rail transport. The Kampala - Kasese railway line stopped operation in the 1990s due to economic problems but plans are underway to reopen the line and extend it to Kisangani in the DRC. This will establish a connection between the ports of Mombasa on the Indian Ocean and Kisangani on River Congo and then by water to Kinshasa on the Atlantic Ocean.

Air transport. The district has two airstrips at Kanyegeya in Kasese Town and Mweya facilitating quick access to the rest of the country.

Water. Water transport is prominent on Lake George. The linkage sites include Hamukungu, Kahendero, Kasenyi and Katunguru, which also link to Mahyoro in Bushenyi. On Lake Edward, the linkage sites are at Katwe, Mweya and Kayanzi.

Telecommunications and banking. Kasese district is connected to the national telecommunications infrastructure and enjoys the services of Uganda Telecom (UTL), MTN, and Celtel. There is a number of radio stations in the district, which include Radio Messiah (97.5 FM) and Grace Radio (94.2 FM) for easy communication to the people at the grass roots. There are also rural and commercial banking facilities including credit and savings schemes and cooperative societies. Since the sale of Uganda Commercial Bank to Stanbic (U) Ltd, the Kasese branch has been upgraded to international standard.

II. Domestic water supply

Kasese district is endowed with water resources which are evenly distributed throughout the district. These sources include lakes, rivers, gravity flow schemes, protected springs and boreholes. The lakes are Lake George located in Muhokya and Lake Katwe subcounties, Lake Edward in Lake Katwe and Munkunyu subcounties. The rivers are numerous but some of the major ones are Rwimi, Mubuku, Sebwe, Rukooki (Nyamwamba), Muhokya, Nyamugasani, Kanyambara and Lhubiriha. The gravity flow schemes in the district are in Kyabarungira/Kichwamba, Muhokya, Bwera, Kasese Town, and Kagando. There were 177 boreholes in the district by 1995 of which 156 were drilled by the United Nations International Children Emergency Fund (UNICEF) as an emergency after the gravity scheme had been initiated, and are located in areas lacking reliable spring, river, or lake water sources. Table 12 shows the main water supplies.

TABLE 12: Urban water supply (piped)

Urban centre	Source of water	Maintenance/Management
Hima trading centre	Water pumped from River Mubuku	Hima cement factory
Mubuku trading centre	Pumped from River Mubuku	Prisons department
Kasese Town	Kibandama area in Kilembe subcounty	Directorate of water development (DWD)
Katwe Town	River Nyamugasani	DWD
Bwera trading centre	Streams/rivers on Rwenzori mountains	Community based with technical input from DWD
Kihara and Rukooki	Buhaura springs	Church of Uganda-Rwenzori diocese
Muhokya	Spring source	Community based with technical input from DWD
Kichwamba	Spring source	Community based with technical input from DWD
Kagando	Spring source	Kagando hospital and local community with technical input from DWD

Due to high salinity of the groundwater in the KKVF, groundwater is not used for domestic supply. The Katwe Township uses water from River Nyamugasani. The Mweya safari lodge gets its water supply from the Kazinga channel and so does the Katunguru fishing village. The areas to the west of River Nyamugasani and the foothills of the Rwenzori Mountains use water from River Nyamugasani. River Nyamugasani has two tributaries namely Kanyambara and Nyamugasani whose source is from the Rwenzori Mountains.

III. Energy supply

Kasese district is connected to the national power grid and has two additional hydro electricity power dams located at Mubuku II for Kilembe Mines producing 5 MWe and Mubuku III for KCCL producing 10 MWe. The district gets its electricity supply from a 33 kV line from Nkenda, the terminal of a 133 kV from Kampala. This line supplies electricity to Kasese Town, Hima Township, Katwe Township and Mweya Safari lodge and Katunguru Fishing Village. A line has also been extended to Bwera from the Kikorongo junction. Electricity is used for lighting and small scale industries like grinding machines, saloons, fridges and milk cooling plants. Most of the people in the settlements use charcoal stoves for cooking and firewood. Those who cannot afford electricity use kerosene lamps for lighting. Approximately 97% of the households use woodfuel and charcoal for cooking and lighting compared to 3% who use electricity and other sources like kerosene. Woody biomass has become scarce and has forced some people to encroach on game reserves and the QENP. Charcoal is imported to the district from Kabarole district and the DRC.

IV. Community health

In Kasese district there is one district hospital and 63 health units, of which 16 are government-aided while 46 are privately owned. The various health units aided by the government are categorized as Health Centre 1V which are units at county level; Health Centre III at subcounty level and Health Centre II at parish level. The health units are distributed in all subcounties across the district. Katwe subcounty in which the Katwe geothermal prospect lies has four health units at Katwe Township, Kasenyi, Katunguru and Mweya. The one at Katwe is of Health Centre IV status and has a 20 bed capacity. The main health indicators in the district are presented in Table 13.

The common diseases in the district are malaria, acute respiratory infection (ARI), intestinal worms, diarrhoea, trauma, skin diseases, genital infections including HIV-Aids, and pneumonia. The leading killer diseases in the district are malaria, ARI and diarrhoea. The district is still facing many constraints that include inadequacy of health facilities, delayed disbursement of funds from the government and understaffing.

TABLE 13: Health indicators in Kasese district

Total population	532,993
Average family size	8
Infant mortality rate (IMR)	103/1,000
Population growth rate	1.94%
Access to health units	65.6%
Latrine coverage	48%
Water coverage	48%
Doctor to person ratio	1:25,035
Nurse to person ratio	1:941

V. Housing/settlement
The settlements in the Katwe geothermal prospect are localised because of restrictions in the park and for protection from wild animals. The settlements are confined to Katwe Township, Mweya peninsula, Katunguru fishing village, and Kasenyi landing site all in the QENP. Adjacent to the QENP are the Kikorongo junction, the pastoralist community to the west of River Nyamugasani and the agricultural community at the foothills of the Rwenzori Mountains to the north of the prospect.

6.6.3 Aesthetics

I. Tourism / recreation
The QENP has many tourist attractions namely crater lakes, bird watching, game viewing, boat/launch trips, fishing, local salt industries in Lake Katwe and Lake Kasenyi and exploration and research. The park is 5-6 hours drive from Kampala on a surfaced road via Mbarara and Bushenyi. It can also be reached by air to Mweya or Kasese air field and then a one hour drive to Mweya safari lodge. At Mweya there is an upmarket lodge, a campsite and budget hostel. Another upmarket lodge fringes a crater lake in Imaramagambo Forest to the south. A low key camp is found in the Ishasha Sector. Accommodation is also available in several hotels in Kasese Town raising revenue for the local government.

The local government also receives 20% of the revenue collected by the QENP from entry permits and fees. This has been translated into provision of social services to the communities like building roads, health centres, schools and provision of utilities like electricity and water. The QENP has also instituted a fund to compensate the local communities whose property is destroyed by the wild animals.

II. Scientific research
Research has been going on in the area since the beginning of the 20th Century aimed at delineating the hydrothermal characteristics of the KKVF. This study by the Geological Survey of Uganda is the backbone of the current geothermal investigations. A similar research on the hydrocarbon potential of the Rift Valley by the Department of Petroleum Exploration and Production of Uganda, has been going on since 1985 (PEPD, 1991-2000).

Other research going on is in the field of monitoring and research which is in line with conservation of biodiversity and is open to students, institutions like Makerere University Kampala, UWA and foreigners. The goal behind the Monitoring and Research Program is the provision of relevant, accurate and timely information for planning, decision-making and evaluation in conservation of biodiversity and sustainable management of wildlife resources. The research is divided into four themes; ecology, biodiversity, socio-economics (local communities, human-wildlife interactions and cost-benefit sharing) and development (policy, tourism, user rights and trade).

6.7 Current environmental concerns

6.7.1 Land degradation

The major environmental concerns in Kasese district are related to the topography of the area. The mountainous terrain has great potential for soil erosion and land slides. There is hardly any area in the district which is not experiencing negative impacts from anthropogenic activities. Activities like overgrazing, bush fires, and deforestation have resulted in nutrient depletion and low productivity of the land.

6.7.2 Industrial pollution

I. Kilembe Copper Mines
The tailings that were dumped at the dilapidated copper roasting plant have contaminated surface water leading to pollution of water bodies like Lake George and of a portion of the QENP where vegetation has failed to grow. A similar effect is expected from excess water from the bio-leaching tanks from the KCCL project which is likely to affect the Lake George - Kazinga Channel - Lake Edward - River Semuliki and Lake Albert systems. The bio-accumulation of trace amounts of toxic metal elements and compounds has yet to be fully studied. The dumping of copper tailings along the River Rukooki (Nyamwamba) coupled with wastewater from the mine sites, has resulted in pollution of the river, making the water unfit for human consumption. The waters have been found to contain toxic levels of heavy metals like copper, iron and cobalt, and associated compounds such as sulphides and nitrates.

II. The Katwe Salt Industry
A plant set up by the Lake Katwe Salt Company and commissioned in 1980 to produce sodium chloride for human consumption failed to operate due to technical mistakes in the plant design. Plans exist to modify the plant to produce 50,000 tons of salt per year for domestic consumption and the company is to undergo divestiture. A feasibility study to appraise the project funded by the African Development Bank was completed in June 1997, and recommended the setting up of a new plant at a cost of US$ 34 million.

The Lake Katwe Salt Factory is located in Katwe Town between Lakes Edward, Katwe and Munyanyange. This industry requires further environmental studies or assessment. For example an earlier preliminary EIA for the revival of the Lake Katwe Salt Factory carried out in 1990 (NEMA, 1997) did not sufficiently address the impacts of the salt factory when it resumes production. Some of the peculiar features of the Lake Katwe area which are in danger and call for further environmental assessment include the following:

- The vegetation at Lakes Katwe and Munyanyange dominated by *Sporobolus pyramidalis, Cyperus laevigatus, Sporobolus homblei*, and *Odyssea jaegari* (a rare grass species which can only be found in the two crater lakes in the whole of Uganda).
- The birds such as the Lesser Flamingo feed and rest at Lake Munyanyange. The Greater Flamingo, Gull-billed Terns, and Avocets (known to be palearctic migrants) are rare and only found in this area.
- Lakes Katwe and Munyanyange have a very small range of phytoplankton species since the water is saline. Lake Katwe has only two and Lake Munyanyange has four genera of phytoplankton that need to be protected.
- The effect of corrosion on the infrastructure in the factory, the iron roofs and the cemented walls of houses.
- Soil decay has also been evident in the salt mining area which has affected the strength of foundations for physical (building) infrastructure.
- Salt miners are experiencing dehydration effects through their skin; as they wade through the salty water and when handling the extracted salt.

III. Hima Cement Factory

Air pollution from Hima factory is causing problems in the adjacent settlement areas. When the factory is in full operation the dust (presumably pure cement) emitted from the smoke stacks can be seen over the lower slopes of the Rwenzori Mountains for a distance of more than 15 km. The effect of the dust on the people needs to be investigated.

IV. Limestone mining and processing

This activity is gaining ground because of its good economic returns. The current method used to make lime leaves behind huge gaping holes which need to be re-filled. The degraded land becomes unsuitable for settlement or arable farming. Lime making demands large quantities of fuel-wood. Consequently there is an increase in deforestation, soil erosion and siltation of water bodies. These effects can be seen in areas of Muhokya, where the land has become more susceptible to forces of erosion. Limestone dust also pollutes the atmosphere.

6.7.3 Land scarcity

Much of Kasese district has been gazetted into National Parks, Reserves, Ibuga Prison Farm, and another portion taken up by the lakes. Less than 50% of the land is actually available to a population of over 500,000 people. This has resulted in scarcity of land, land fragmentation, and emergence of unplanned settlements in any land area that can possibly be occupied.

7. KATWE – ENVIRONMENTAL IMPACTS

Impacts of geothermal development in many regions and countries of the world have similarities and differences. While the impacts may be similar in nature, their magnitude is determined mainly by location, technology, adopted size of development and the priority of the country in question. At field level, the effects do depend on many factors including the topography, type of fluid encountered and its chemistry, type of power plant and technology employed (Webster, 1995). These factors, in turn, determine the management options that should be adopted. Sometimes priorities and interests may clash, requiring application of special mechanisms and involvement of all stakeholders to reach a solution.

In identifying potential significant environmental impacts for drilling and operation phases for the development of the Katwe geothermal prospect; public consultations, experience, expert knowledge of the project area/site, an interaction matrix and a checklist were used.

The key elements of the project are all included in the interaction matrix and checklist. Those impacts that could result if the project were implemented (direct impacts) are discussed. Only those elements of the environment, which may be impacted or might be considered as producing indirect and cumulative impacts, are included in the discussion. The interaction matrix and checklist used for identification of potential environmental impacts for both drilling and operation are presented in Appendices A and B.

Potential environmental impacts identified were categorised under 13 sections i.e., impacts on the geology of the area; land use; biodiversity; visual and aesthetic quality; water quality and hydrology; population, housing and employment; transportation and traffic; air quality; public services; utilities; energy; public health and safety; and cultural situation. The impacts are described in the following sections and subsections.

7.1 Drilling

7.1.1 Geology

The proposed development will involve construction of access roads to the drill sites for moving equipment and accessories, and clearing of land for drill pads. The terrain is steep and access difficult in some parts of the crater area and construction of roads and drill pads is likely to change the topography and geology of the area. This may lead to soil erosion of cut slopes and fill slopes if the soil is not well compacted.

7.1.2 Land use

The construction of roads and drill pads will conflict with the adopted environmental plans of the QENP and the goals of the communities through which the roads will pass. The land use for road construction will also conflict with local government general plans and community plans.

7.1.3 Biodiversity

The Katwe geothermal prospect is located in the QENP with a wide diversity of flora and fauna. Drilling will increase the rate of use of natural resources like water and will decrease the vegetation cover that would be available for the wild animals. It will decrease the habitat for wildlife and may interfere with the movements of some species. This may lead to changes in the diversity of species, or the number of any species of plants (including trees, shrubs, grass and aquatic plants) or animals (birds, land animals, reptiles, fish and insects). Clearing of bushes may lead to the introduction of new plant species in the area through succession and become a barrier to normal replenishment of existing species.

7.1.4 Visual and aesthetic quality

Drilling interferes with the local goals or guidelines related to visual quality. The visual obstruction is caused by the rig's high mast which rises several tens of metres above the surrounding environment. It may change the visual quality of the area and result in an obstruction of scenic views open to the public or destroy the visual quality of the area leading to a substantial, demonstrable negative aesthetic effect. Drilling is likely to interfere with the local guidelines or goals related to visual quality in the QENP.

7.1.5 Water quality and hydrology

The key factors surrounding the water issue are water supply, water quality, water contamination and wastewater. A considerable amount of water is required for drilling. Although most of the water is lost in the formation, excess water discharged must be disposed of into a well designed for this purpose. Improper disposal is likely to affect the quality of surface and ground waters.

The wastewater from drilling can create serious gullying if discharged directly to the surface, e.g. into valleys. It is likely to change the amount of surface water in the area and cause alteration of surface water properties including temperature, dissolved solids and turbidity. The wastewater containing drilling fluids may substantially change the chemistry of the surface and groundwaters. This may result in degraded water quality and contamination of public water supply.

7.1.6 Population, housing and employment

Drilling will create 100 temporary jobs for various activities on site and may induce substantial growth of the population and thus affect the average age of the population since the workers will not be accompanied by their families. This will increase the local population due to migrant workers and may cause a strain on the available resources and result in conflicts.

7.1.7 Transportation and traffic

Drilling will increase traffic in the area during the transportation of the rig and all its accessories to the drill site. Heavy vehicles are used to carry the rig and accessories for the 2-4 days of mobilisation and the last 2-3 days of demobilisation when a single borehole is drilled. Additionally a number of service trucks are on the roads permanently during the whole period of drilling. This will lead to an increase in dust, noise, vehicular emissions and increased traffic. Occasional traffic delays will occur at various points in the project area. The main effect will be on the wild animals in the park and people from the surrounding settlements. Special interest groups are children, elderly and disabled and sensitive locations like schools, hospitals and places of worship. Increased traffic may also alter the current patterns of circulation or movement of people and/or goods.

7.1.8 Air quality

The majority of impacts arising during the drilling phase of the proposed project will most likely affect the ambient air quality through the release of fugitive dust from the heavy traffic on the roads, site clearing etc. Emissions resulting from the operation of drilling equipment e.g. large combustion equipment, and vehicles may also impact local air quality. Other emissions will arise from the testing of wells, for example, vapours from soap used for compression to initiate the flow, and gases and steam from the discharged geothermal fluids. Testing of wells has a deleterious effect on local vegetation with trees and other plants being scalded by escaping steam or spray. Emissions are likely to hamper visibility.

7.1.9 Public services

The increased traffic during the drilling phase will inconvenience the residents by taking up parking space in Katwe Town and therefore degrading the locally acceptable park standards. This is likely to increase the risk of theft and outbreak of fires as a result of congestion and uncontrolled fuel spillages.

7.1.10 Utilities

Drilling will create all kinds of waste including waste fluid containing chemicals like barium sulphate, mud and other detergents. Barium is essentially an inert material but can smother plants and does not support plant growth and in this respect is similar to a hard compacted surface. Other types of drilling fluids like aerated water or mud and foam sometimes used for pressure balancing could have impacts on the environment e.g. foam affects vegetation around the site and causes eye irritation when it covers a large area. The activity will produce solid waste in excess of available landfill capacity and cause significant increase in the consumption of potable water. Drilling is likely to breach the local standards relating to solid waste control.

7.1.11 Energy

Drilling will require a lot of energy resources for powering the heavy combustion equipment and lighting. It will therefore significantly affect energy resources at local and regional level. The activity will cause an increase in the use of fossil fuels by encouraging activities which result in the use of substantial amounts of fuel, water and energy. It may also affect the demand upon existing sources of energy, which may conflict with the existing energy standards in the area.

7.1.12 Public health and safety

Drilling will involve hazards that the local population and those moving into the area have not been adequately warned against. It will create potential health hazards or involve the use, production, or disposal of materials which pose a hazard to people or animal or plant populations in the area. Accidental release of hazardous substances like oil, chemicals in the drilling fluids to the water cycle and toxic gas emissions, pose risks to public health and safety. The activity may create a risk that the concentration of a toxic air contaminant (TAC) may at any time exceed the air pollution control threshold.

Drilling will generate a lot of noise that will conflict with the local noise standards leading to several kinds of disturbances. Substantial noise is generated in vapour-dominated reservoirs where air-only drilling is used and requires large compressors. The substantial increase of noise levels in adjoining areas may expose people and animals to severe noise levels. Site topography and metrological conditions will influence the noise levels, which vary from 120 dBa to 45 dBa depending on the activity (Table 14). The pain threshold is 120 dBa at 1,200 to 4,000 Hz.

TABLE 14: Drilling activities and their noise levels.

Activity	**Noise level (dBa)**
Air drilling and well discharge	120
Well discharge	70-110
Well bleeding	85
Diesel engines for operating compressors	45-55

The powerful lighting to illuminate the work space at night during drilling will significantly disturb the local residents and animals (domestic and wild). Finally drilling may result in an impact upon the quality or quantity of the existing recreational opportunities especially in the QENP which is a tourist recreational area.

7.1.13 Cultural situation

The Katwe geothermal prospect is located in the QENP which is a centre of tourism and recreation. The area is also used for research on the heat, the hydrocarbon potential of the rift valley and the archaeological history of the ancient salt industry at Lake Katwe. Other kinds of research are in the fields of monitoring and conservation of biodiversity.

The drilling programme being located in an area designated as a wilderness will reduce the area available for recreation and research and therefore conflicts with the uses of the area. The activity will affect the social life of the surrounding settlements as a result of an influx of people from different backgrounds. This may give rise to social problems such as lack of housing, increased spread of diseases, and increased pressure on social services and cultural misunderstandings.

7.2 Operation

This phase is considered to have the greatest impact on the environment. Operation will involve construction of a power plant, connection of the geothermal wells to the power plant and finally operation of the plant throughout its lifetime. The main impacts are related to loss of land, mass withdrawal of the geothermal fluid from the reservoir, waste liquid/spent fluid and waste gas disposal.

7.2.1 Geology

The construction of the power plant will affect the geology and topography of the area as a part of the land will have to be levelled off at the construction site. The location of the power plant in a volcanic and faulted area and the massive withdrawal of fluids from the reservoir and reinjection may trigger micro-earthquakes. The discharge of the fluids to the surface is likely to form mineral deposits like travertine and silica which may obstruct or change the course of flow of surface waters.

7.2.2 Land use

Land will be required for production wells, pipelines, power stations, cooling towers, electrical switchyards, and power transmission lines. This will conflict with the adopted environmental plans and goals of the QENP in which the prospect lies. It will also conflict with the general plans of the local communities. The possible conversion of open space into urban or suburban scale uses as a result of new roads and influx of people into the area may also affect the general plans for the area.

7.2.3 Biodiversity

Operation is likely to affect biodiversity through the discharge of the geothermal fluids to surface waters and streams. The hot water increases temperatures in the rivers and thus decreases the oxygen available to the living organisms in the rivers and lakes downstream. The release of untreated wastewater into the waterways may result in chemical poisoning of fish, birds or animals, which reside near the water because some of the toxic substances move up in the "food chain" causing biomagnification. Massive withdrawal of fluids may raise the ground temperature which affects the land animals and plants. The River Nyamugasani which is likely to be affected in case of discharge of hot fluids into surface waters followed by Lakes Edward and George and Kazinga channel downstream is in the vicinity of the Katwe geothermal prospect.

Operation will increase the rate of use of water resources and therefore affect the rational use of the water. It may cause fish and wildlife populations to drop below self sustaining levels and may substantially diminish or reduce habitat for fish, wildlife, or plants. It may introduce into the area new species of plants or animals which are tolerant to raised temperatures, or become a barrier to the normal replenishment of existing species. It may also affect significant riparian lands, wetland, marshes or other wildlife habitats.

7.2.4 Visual and aesthetic quality

Operation involves the installation of power plants, wells, pipelines, cooling towers, switch yards and overhead cables. The complex may affect the visual and aesthetic quality of the area. It is likely to interfere with the local guidelines or goals related to visual quality. This may have substantial demonstrable negative aesthetic effect and may significantly change the visual quality of the region or eliminate visual resources.

7.2.5 Water quality and hydrology

Due to mass fluid withdrawal, groundwater is sometimes depleted through a cold downflow into the reservoir. Withdrawal of fluids leads to a reduction in pore pressure and this can lead to ground subsidence which can cause instability in dwellings, pipes, drains and well casings in the geothermal field. Surface disposal of the fluids causes contamination of fresh water due to high temperatures and toxicity of the waste fluid.

Discharge into surface waters will change the surface water quality, including but not limited to changes in temperature, dissolved oxygen and turbidity. The toxic substances include Li, B, As, H_2S, Hg and NH_3. Release of the wastewater into cooling ponds and waterways may result in groundwater contamination and cause erosion and deposition of silica. Surface discharge will also cause changes in the quantity of groundwaters, either through direct additions or withdrawals. The activity is likely to substantially degrade water quality, contaminate public water supply, degrade or deplete groundwater resources, and interfere with groundwater recharge. It may also reduce the amount of water available for public water supplies.

7.2.6 Population, housing and employment

Operation will create 100 temporary jobs during construction of the power plant and 250 permanent jobs for daily operation and maintenance of the plant, surface flow equipment and wells. The influx of the permanent job seekers and their families will induce substantial growth or concentration of the population. This is likely to alter the location, distribution, density or growth rate of the human population. It will affect the existing housing, or create a demand for additional ones. It will also conflict with the housing and population projections and policies set forth in general plans for the area.

7.2.7 Transportation and traffic

The number of vehicles into the area will be increased during operation and on a permanent basis compared to drilling. This may affect the general traffic safety in the area. Additional population and need for housing will alter the present patterns of circulation or movement of people and/or goods. The operation phase will cause an increase in traffic which is substantial in relation to the existing traffic load and may significantly impact intersection levels of services.

7.2.8 Air quality

In high temperature geothermal fields, power generation from a standard steam-cycle plant will release non-condensable gases and fine solid particles into the atmosphere. The most significant gas emission is from gas exhausters of the power station that discharge through a cooling tower. Geothermal gases are carbon dioxide (CO_2), hydrogen sulphide (H_2S), hydrogen (H_2), Nitrogen (N_2), ammonia (NH_3), hydrocarbons such as methane (CH_4) and ethane (C_2H_6), trace amounts of mercury (Hg) and boron vapour, and helium (He) and radon (Rn). The major hazardous chemical substances among possible airborne contaminants released during geothermal development are CO_2 and H_2S. These are toxic in high concentrations and may lead to loss of life at very high concentrations. Minor gases that cause concern like Hg, Rn, NH_3 and B have been found in dangerous concentrations in geothermal gas. The discharge of the gases is likely to affect plants and animals directly, and could affect the microclimate of the area by increasing fog, clouds or rain depending on the rainfall, topography and wind patterns.

Operation is likely to violate any ambient air quality standards and create objectionable odours. It may alter air movement, moisture, or temperature, or result in any changes in climate at local and/or regional level.

7.2.9 Public services

Operation will affect public services due to increased population in the area and the presence of the power plant. The increase in the number of vehicles will congest the parkland and impact on the locally accepted standard. The population increase will put strain on the existing school system, play school(s) or kindergarten(s), hospital(s), and amenities for the handicapped.

7.2.10 Utilities

Operation brings to the surface a large amount of waste fluid. The fluid is disposed off in waterways, evaporation ponds or reinjected back into the reservoir. The operation of the power plant requires a lot of potable water for the cooling tower and other apparatus inside the plant. The activity will therefore generate a considerable amount of wastewater and solid waste which has to be disposed off. It will significantly increase the consumption of potable water. This phase may breach the national and local standards relating to solid waste control and disposal of wastewater.

7.2.11 Energy

Operation will introduce a new type of energy source, geothermal energy, for electricity and direct heat and encourage activities which result in the use of substantial amounts of water and energy. This is likely to result in significant effects on other energy sources and may conflict with the existing energy standards.

7.2.12 Public health and safety

Release of untreated waste into waterways can result in chemical poisoning of fish, and also birds and animals, which reside near the water because some of the toxic substances move up the “food chain” causing biomagnification. If such a system is built in Katwe geothermal prospect the main concern will be the effect on wild animals and aquatic organisms such as fish in rivers and downstream fresh water lakes.

Operation will involve hazards that the local population and those moving into the area have not been adequately warned against. It will create potential health hazards or involve the use, production, or disposal of materials which pose a hazard to people or animal or plant populations in the area. It may create a risk that a toxic air contaminant (TAC) may at any time exceed the air pollution control threshold and result in unsafe conditions for employees, residents or surrounding neighbourhoods.

The activity may generate considerable noise that may conflict with the local noise standards leading to several kinds of disturbances. Finally operation may result in an impact upon the quality or quantity of the existing recreational opportunities especially in the QENP which is a tourist recreational area.

7.2.13 Cultural situation

The Katwe geothermal prospect is located in the QENP which is a centre of tourism and recreation. The area is also used for research on the heat and hydrocarbon potential of the rift valley. Other kinds of research are in the fields of monitoring and conservation of biodiversity. Operation may affect the research and recreational activities in the park especially in the area classified as a wilderness. The activity will affect the social life of the area as a result of an influx of people from different cultural backgrounds since they will stay in the area on a permanent basis. This may give rise to social problems such as, lack of housing, increased spread of disease, increased pressure on social services and cultural misunderstandings.

8. KATWE – MITIGATION MEASURES

8.1 Drilling

8.1.1 Geology

The Katwe geothermal prospect is located in the Rift Valley that is generally a flat land although the volcanics with a numerous number of craters rise gently to a height of 300 - 400 m above the sedimentary basin. The area has an average rainfall of approximately 800 – 1,000 mm/year. These conditions are favourable for road construction and other earthworks and will not cause serious topographical and geological problems like landslides and soil erosion. Re-vegetation with grass and trees on the cut slopes, fill slopes and well pads should be considered to contain any possible erosion.

8.1.2 Land use

The Katwe geothermal prospect is located in a national park and the drilling activity will definitely affect the adopted plans for the QENP and the local government. Land uptake by drilling can be minimised by directional drilling of several wells from a single pad to minimise the area/land needed for pad and road construction. In this way a large volume of the reservoir can be tapped at depth, while requiring only a small area which can be situated on stable land at the surface. It also minimises transport of drilling and construction materials and makes it possible to gather the fluids from many wells into a single pipe before it is transported to the separation plant.

8.1.3 Biodiversity

I. Flora

The vegetation is generally grassland with scattered thorny thickets within and outside the craters but becomes shorter as you move away from them. In some craters the vegetation is replaced by forests and in others by the viscous salt brines. This type of vegetation will be affected by the drilling operation but can easily be restored. The bare ground around the drill pads and along the roads will be restored after drilling and well testing through succession or revegetation.

II. Fauna

Wild animals in this part of the QENP include buffaloes, elephants, waterbucks and the Uganda kobs (a species of the antelope family). The area is sparsely populated due to lack of fresh water for the animals. All the crater lakes in the area have high salinity waters unsuitable for animal consumption. The animals that graze in this part of the park have to travel long distances in search of fresh water points. Their numbers increase in the rainy season which creates seasonal watering points that dry up at the onset of the dry season. It is therefore unlikely that drilling will affect the animal population in this part of the park especially if it is carried out during the dry season.

8.1.4 Visual and aesthetic quality

Visual quality may be diminished by loss of naturalness and the imposition of man-made structures like drill sites, drill rig, and accessories which create artificial landscape elements in the project area. The scenery needs attention, since it is located in the National Park that serves as a recreation. The obstruction will be temporary during drilling since it takes a short time and the natural beauty will be restored when the activity is completed and the rig is demobilised.

8.1.5 Water quality and hydrology

The source of water for drilling is expected to be the River Nyamugasani that forms the western boundary of the National Park. There are no possible fluctuations during the dry season because the source of the river is high up in the Rwenzori Mountains and possibly in the melting glacier. It has a significant amount of water for all types of uses i.e. domestic and watering of animals. River

Nyamugasani has a high flow of approximately 8.35 m^3/s and withdrawal of water for drilling will not cause any significant changes in the flow rate. The amount of water used as drilling fluid is enormous and although most of it is lost to the formation, the return fluid will be discharged into well designed sumps and re-circulated to keep water level in the sumps as low as possible.

8.1.6 Population, housing and employment

The increase in population due to the influx of migrant workers during the drilling phase will be temporary and once the operation is over, the population will return to its original state. Drilling will not affect the housing facilities in the Katwe area since the workers will be camping on site with all resources and facilities provided.

8.1.7 Transportation and traffic

Heavy traffic is expected during mobilization and demobilization which take 4-7 days in total when drilling a single well. The heavy traffic will cause a lot of noise and raise dust and vehicular emissions in the area. During drilling the traffic is limited to service trucks that are not expected to cause significant dust and noise in the surroundings. The Katwe geothermal prospect is located between three busy roads, namely Katunguru – Kasese, Kikorongo – Bwera and Katunguru – Katwe with a considerable amount of traffic. Increased traffic will cause traffic problems like jams in the area. However, the activity is temporary and normality is restored after the drilling is completed.

8.1.8 Air quality

The source of air pollution will be non-condensable gas emissions, exhaust smoke from generators, compressors and vehicles. The expected fugitive gases are NO_x, CO, SO_2 and hydrocarbons but their amounts could be low to cause environmental pollution. During well testing, steam and spray can have an adverse effect on the vegetation with trees and grass being scalded. There may be objectionable hydrogen sulphide odours. However, as drilling is a temporary activity, no significant long-term air quality impacts are expected. Hydrogen sulphide, sulphur dioxide and possibly mercury in atmospheric air will need to be monitored.

8.1.9 Public services

The increased traffic during the drilling phase will require the designation of additional parkland in Katwe town to remain in conformity with the locally acceptable or adopted park standards. Additional law enforcement and fire protection staff, and equipment to maintain acceptable service ratios will be required to check on possible thefts and outbreaks of fire.

8.1.10 Utilities

Proper disposal systems need to be constructed for channelling the effluent fluid before it is recycled or disposed off. The activity will need the construction of a septic tank, effluent retention sumps, communication systems, water supply and drainage, and a landfill for solid waste disposal.

8.1.11 Energy

The source of energy for drilling will be from fossil fuels which will affect the demand for energy in the area. The problem could be solved by setting up a fuel supply station in the vicinity of the activity, preferably in Katwe Town, to avoid conflict with the existing energy standards at local and regional level.

8.1.12 Public health and safety

Accidental release of hazardous substances like oil, and chemicals in the drilling fluids to the water cycle and toxic gas emissions pose public health and safety problems. Care must be taken to reduce such accidents and where they occur measures should be taken to clean up the environment. The drilling activity, being temporary, is not expected to create a risk of the concentration of the TAC exceeding the air pollution control threshold.

The effects of using powerful lamps to light the drilling site at night could be reduced by temporary screens and careful placement of lamps. The drilling operation is a temporary measure and the lights will disappear after the rig is removed from the site.

The noise generated by drilling operations can be quite high i.e. ranging from 45 - 120 dBa depending on the specific activity **(**Table 14**)**. Using cylindrical type silencers the noise can be brought down to about 85 dBa for noisy activities like air drilling, well discharge and bleeding (Brown, 1995). Thus even with good designs for noise reduction, workers are recommended to use ear protectors both during drilling and discharge tests. The noise associated with the use of heavy machinery can be reduced by using suitable mufflers on the exhausts of the earth moving equipment.

Although the Katwe prospect is located in a part of the National Park classified as a wilderness with no human habitation, some degree of noise generated by the drilling operations and well testing may have some effect on the wild animals and the surrounding communities. However, this impact is temporary and will cease when all the wells have been drilled and tested.

8.1.13 Cultural situation

Project development is usually accompanied by all sorts of social misunderstandings because of an influx of people of different cultures to a new area. It is thus vital, to avoid conflicts with the local communities, and to involve all the stakeholders in the project activities from the beginning to the end. The influx will definitely interfere with the current use of the area and the ways of life of the surrounding communities but on a temporary basis. To avoid social problems like lack of housing, spread of diseases and competition for social services, the drilling programme usually sets up a temporary arrangement with minimum infrastructure in the vicinity of the drilling site. Such infrastructure is always demobilised at the end of the drilling programme and the site restored to its original status.

8.2 Operation

Any consideration of the utilisation of any energy source must take into account the accompanying environmental impacts. The most important environmental changes brought about by geothermal utilisation are: surface disturbances, physical effects due to fluid withdrawal, noise, thermal effects and the emission of chemicals, apart from the social and economic impact that the construction of an energy plant is bound to have. For example interferences with natural phenomena, such as hot springs and fumaroles, is often a problem and may be a disadvantage as far as tourism is concerned. Reservoir engineering studies are usually carried out to determine the amount of fluid withdrawn versus recharge in order to avoid any danger of depleting the hot springs and other natural phenomena.

Experience in Krafla, Iceland and Olkaria, Kenya shows that contrary to many people’s expectations, the construction of geothermal energy plants increases the number of tourists visiting the areas, because the area is opened up. Better roads leading to the area are built, more services are available and plant managers have often been persuaded to construct utilities such as foot paths around the geothermal manifestations. Detailed discussion of impact mitigation for the proposed development in Katwe follows.

8.2.1 Geology

The construction of a power plant in the Katwe geothermal prospect may modify the topography of the area since it is most likely to be located in the crater area which will require levelling of the surface. The spent fluid will be reinjected into the reservoir and will not form mineral deposits on the surface that may obstruct or change the course of flow of surface waters.

8.2.2 Land use

The construction of pipelines, power plant, and switchyard will affect several hundreds of square meters of land. Boreholes and pipelines are probably the most characteristic signs of geothermal energy production. The construction of the power plant has to be as close to the boreholes as possible to avoid cooling of the fluid. Land uptake is usually not such a big problem in geothermal development as in hydropower development since the land will continue to be used around the installations especially the pipelines.

8.2.3 Biodiversity

The impacts on flora and fauna caused by the massive withdrawal of fluid from the reservoir and disposal of the fluid into surface waters, that would lead to changes in the ecosystem, could be avoided by reinjecting the fluid back into the reservoir. Reinjection is the only acceptable means of fluid disposal at the moment and helps maintain reservoir pressures. Reinjection also solves the problem of the thermal ground caused by leakage of the fluid in form of steam to the surface through fractures and faults. Discharge of gases from the power plant may have an effect on the flora and fauna of QENP if the concentrations of these gases exceed the limits set by regulations. Impacts of geothermal gases on the flora and fauna have not been reported in studies in Iceland and other geothermal countries including neighbouring Kenya. Consequently, such impact is not expected to occur in the Katwe geothermal prospect.

8.2.4 Visual and aesthetic quality

A geothermal power plant must be located close to the resource, so there is often little flexibility in the siting of the plant. Geothermal plants generally have a low profile, and need not have a tall stack like coal and oil fired plants. However, their visual impact and the accompanying network of pipes may still be significant, as geothermal fields are often situated in areas of outstanding natural beauty. The visual intrusion could be reduced by painting the surface installations (e.g. the pipe network and separators) and the power plant with the colour of their background. The background in the Katwe prospect is green most of the year although the grass may change colour in the dry season on a temporary basis.

8.2.5 Water quality and hydrology

During operation, impacts on the water quality of surface water or groundwater in shallow aquifers are not expected during normal production and reinjection practices. The reinjected fluid would be released to the geothermal reservoir, which is much deeper than the shallow groundwater system. However impacts could be experienced due to mixing of the geothermal fluid with water in the shallow groundwater aquifer through damaged well casings or accidental discharge. The local water quality could be affected if the well casing fails. Measures need to be taken to avoid such accidents by using robust pipes and casings to check the possible leakages that may lead to mixing of the geothermal water with cold water in the shallow groundwater table. Reinjection of the spent fluids also maintains reservoir pressure which checks subsidence and drawdown effects that are likely to lower the groundwater table and hence affect thermal features like hot springs.

8.2.6 Population, housing and employment

The influx of project workers and their families will have an effect on existing housing and create a demand for additional housing which will conflict with the policies set forth in the general plans for the area. The project management will, therefore, need to set up housing facilities for its staff preferably outside the project area to avoid conflict with the plans for the QENP. On the positive side the project may result in increased employment opportunities in the area by making use of the local skills and therefore improving the incomes of the local people.

8.2.7 Transportation and traffic

Transportation during operation will be mainly for the workers that will be operating the power plant and maintenance. This is not a big problem compared to drilling since the number of vehicles will be decreased to acceptable levels. But the building of new roads will open up the area to tourists and researchers who will be visiting the power plant and other attractions in the National Park. These movements could increase traffic on the roads to a significant level.

8.2.8 Air quality

The release of gases into the atmosphere during operation can be minimised by standard countermeasures which include the following: reinjecting all the waste fluids, designing power stations to minimize gas discharges, and employing active monitoring systems to enable the power plants to be shut down or generation reduced if the amount of gas discharged exceeds set levels. Hydrogen sulphide removal, for example, is based on the mechanism by which it is oxidised to sulphur dioxide and then to sulphuric acid. According to Sanopoulos and Karabelas (1997) the most attractive abatement methods for H_2S include: scrubbing with alkali; use of steam re-boilers; and compression and use of the reactant BIOX as a catalyst to oxidise H_2S to H_2SO_4.

8.2.9 Public services

The influx of workers and their families into the area will definitely affect public services which will have to be expanded to accommodate the increased population. The project will require additional law enforcement staff and equipment to maintain acceptable service ratios and additional fire protection staff or equipment. The project management will need to provide additional parkland to remain in conformity with the locally accepted standards. The existing school system will need to be expanded and new play school(s) or kindergarten(s) established. Additionally, there may be a need for a new hospital and amenities for the handicapped. The developer, therefore, needs to accommodate these amenities in their development plans and budgets.

8.2.10 Utilities

Operation will generate a lot of waste from the activities going on in the power plant. The project management will need to construct disposal facilities like landfills for solid waste and acquire a water supply and treatment plant for potable water to be used in the plant. Other facilities needed are: a septic tank, communication systems, and water supply and drainage lines. The national and local standards relating to solid waste control and disposal of industrial wastewater need to be studies and implemented.

8.2.11 Energy

Operation will introduce a new type of energy, geothermal energy, in the energy mix of the area that will conflict with the existing energy supplies. This will be a healthy development since most of the population is using biomass and to a small extent fossil fuels as sources of energy. The geothermal energy will also boost the existing unreliable hydropower supply from the single hydropower source on the River Nile at Jinja. Additionally, the geothermal power will be used in industry and agriculture for drying and processing purposes where it will not be in competition with other sources of energy.

8.2.12 Public health and safety

During operation care will be taken not to release waste fluid to surface waters. The fluid will be reinjected to avoid effects on biodiversity and health of humans. The TAC will be monitored not to exceed acceptable levels. Light and glare will be replaced by normal lights that will be permanent like in any other town or settlement which the environment will get used to.

Most of the noise from power plant operations results from three power plant components; the cooling tower, transformer, and turbine-generator building. Once the plant has started operation, noise mufflers will be made effective enough to keep the noise even below the 65 dBa limit (D'Alessio and Hartley, 1978). The Katwe geothermal prospect is located in a National Park and a reduced level of noise would be a good countermeasure against noise impacts on wildlife, workers and tourists. Detailed studies of the noise level would be necessary before the right noise mufflers are installed.

8.2.13 Cultural situation

The opening up of the area with roads will have a positive impact on the research and recreational activities in the QENP especially in the geothermal prospect which is classified as a wilderness. The influx of workers to the area will create employment and market for agricultural produce and other consumables which will improve the incomes of the local communities. The new people from the different cultural backgrounds will have to integrate into the new society and abide by the local government standards and legislation.

9. KATWE – ASSESSMENT OF IMPACT SIGNIFICANCE

9.1 Overview

Impact magnitude and significance should as far as possible be determined by reference to legal requirements, accepted scientific standards or social acceptability. If no legislation or scientific standards are available, the EIA practitioner can evaluate impact magnitude based on clearly described criteria. Except for exceeding of standards set by law or scientific knowledge, the description of significance is largely judgmental, subjective and variable. However, generic criteria can be used systematically to identify, predict, evaluate and determine the significance of impacts resulting from project construction, operation and decommissioning. The suite of potential environmental impacts (to both the natural and human environments) identified in the EIA should as far as possible be quantified. The process of determining impact magnitude and significance should never become mechanical. Impact magnitude is determined by empirical prediction, while impact significance should ideally involve a process of determining the acceptability of a predicted impact to society. Making the process of determining the significance of impacts more explicit, open to comment and public input would be an improvement on EIA practice.

9.2 Criteria

The following generic criteria (Munn, 1979), can be used to describe magnitude and significance of impacts in a systematic manner. The criteria are:

- Extent or spatial scale of the impact;
- Intensity or severity of the impact;
- Duration of the impact;
- Mitigation potential;
- Acceptability; and
- Degree of certainty.

Describing the impacts in terms of the above criteria provides a consistent and systematic basis for the comparison and application of judgments. Ratings should be assigned for each criterion. The significance of impacts of the proposed project should be assessed both with and without mitigation. The categories for rating of impact magnitude and significance are given in Table 15 and examples of descriptors and factors to consider for rating impacts on criteria basis in Table 16.

TABLE 15: Categories for the rating of impact magnitude and significance

Impact magnitude and significance rating	
High	Of the highest order possible within the bounds of impacts that could occur. In the case of adverse impacts, there is no possible mitigation that could offset the impact, or mitigation is difficult, expensive, time-consuming or a combination of these. For example social, cultural and economic activities of communities are disrupted to such an extent that they come to a halt.
Medium	Impact is real, but not substantial in relation to other impacts that might take effect within the bounds of those that could occur. In the case of adverse impacts, mitigation is both feasible and fairly easily possible. For example social, cultural and economic activities of communities are changed, but can be continued (albeit in a different form). Modification of the project design or alternative action may be required.
Low	Impact is of a low order and therefore likely to have little real effect. In the case of adverse impacts, mitigation is either easily achieved or little will be required, or both. For example social, cultural and economic activities of communities can continue unchanged.
No impact	Zero impact.

TABLE 16: Examples of factors to consider for rating impacts on criteria basis

Criteria	High	Medium	Low
1. Extent or spatial scale of the impact A description should be provided as to whether impacts are either limited in extent or affect a wide area or group of people. For example, impacts can either be site-specific, local, regional, national or international.	Widespread. Far beyond site boundary. Regional/national /international scale.	Beyond site boundary but within the local area.	Within site boundary.
2. Intensity or severity of the impact The study should attempt to quantify the magnitude of the impacts and outline the rationale used. When country-specific legal or scientific standards are not available, international standards can be used as a measure of the intensity of the impact.	Disturbance of pristine areas that have important conservation value. Destruction of rare or endangered species.	Disturbance of areas that have potential conservation value or are of use as resources.	Disturbance of degraded areas, which have little conservation value.
3. Duration of the impact It should be determined whether the duration of the impact will be short term (0-5 years), medium term (5-15 years), long term (more than 15 years, with the impact ceasing after the operational life of the development) or considered permanent.	**Long term:** Permanent - beyond decommissioning. Long term (more than 15 years).	**Medium term:** Reversible over time - lifespan of the project. Medium term (5-15 years)	**Short term:** Quickly reversible. Less than the project lifespan. Short term (0-5 years)
4. Mitigation potential The potential to mitigate against the negative impacts and enhance the positive impacts should be determined. For each identified impact, mitigation objectives that would result in a measurable reduction in impact should be provided. If limited information or expertise exists, estimates based on experience should be made. For each impact, practical mitigation measures that can affect the significance rating should be recommended. Management actions that could enhance the condition of the environment (i.e. potential positive impacts of the proposed project) should be identified. Quantifiable standards (performance criteria) for reviewing or tracking the effectiveness of the proposed mitigation action should be provided where appropriate.	Little or no mechanism to mitigate against negative impacts.	Potential to mitigate against negative impacts. However, the implementation of mitigation measures may still not prevent some negative effects.	Potential to mitigate against negative impacts to the level of insignificant effects.

Criteria	High	Medium	Low
5. Acceptability Criteria and standards that exist for acceptability are either emission-based or they relate to the environment affected (e.g. air quality, water quality or noise). Establishing the acceptability of a potential impact is as important as determining its significance. An impact identified as being non-significant by a specialist may be unacceptable to a particular section of the community. On the other hand, a significant impact may be acceptable if, for example, adequate compensation is given. The level of acceptability often depends on the stakeholders, particularly those directly affected by the proposed project.	**Unacceptable:** Abandon project in part or in its entirety. Redesign project to remove or avoid impact.	**Manageable:** With regulatory controls. With project proponent's commitments.	**Acceptable:** No risk to public health.
6. Degree of certainty A description should be provided of the degree of certainty of the impact actually occurring as unsure, possible, probable, or definite (impact will occur regardless of prevention measures). Where relevant, there should be some cross-reference to key indices derived from a risk analysis study.	**Probable:** Over 70% certain of a particular impact or of the likelihood of that impact occurring.	**Possible:** Only over 40% certain of a particular impact or of the likelihood of an impact occurring.	**Unsure:** Less than 40% certain of a particular impact or the likelihood of an impact occurring. No risk to public health.

9.3 Impact significance without mitigation

The rating of magnitude and significance of the impacts has been described in Section 9.2. The rating results for the Katwe geothermal prospect without impact mitigation are presented in Figure 22. The results show that operation has greater impact on the environment than drilling.

9.3.1 Extent and spatial scale of impact

The impacts of both operation and drilling are localized i.e. they are within the boundaries of the local area save for the impacts on energy which extend to regional level. The local area affected is Kasese district and parts of the neighboring districts close to the prospect (Figure 2).

9.3.2 Intensity or severity of impact

The intensity is high for impacts of operation on biodiversity; water quality and hydrology; air quality; utilities; and public health and safety, and medium rated for impacts on land use; population, housing and employment; and public services. The rest of the impacts on geology; visual and aesthetic quality; transportation and traffic; energy; and the cultural situation are rated as low. The impacts of drilling on land use; visual and aesthetic quality; water quality and hydrology; air quality; utilities; energy; and public health and safety are rated as medium while impacts on geology; biodiversity; population, housing and employment; public services and the cultural situation are rated as low. Only impacts of transportation and traffic are highly rated for the drilling phase.

KATWE PROSPECT
NOTE:
Impact Magnitude & Significance Rating
(without mitigation)
H: High
M: Medium
L: Low

A: CRITERIA	B: ENVIRONMENT AFFECTED	Geology	Land use	Biodiversity	Visual and aesthetic quality	Water quality and hydrology	Population, housing and employment	Transportation and traffic	Air quality	Public services	Utilities	Energy	Public health and safety	Cultural situation
OPERATION	Extent or spatial scale of the impact	L	L	M	M	M	M	M	M	M	M	H	M	M
	Intensity or severity of impact	L	M	H	L	H	M	L	H	M	H	L	H	L
	Duration of the impact	L	H	H	H	H	H	H	H	H	H	H	H	H
	Mitigation potential	L	L	M	L	M	L	L	M	L	M	L	M	L
	Acceptability	M	M	M	M	M	M	M	M	M	M	M	M	M
	Degree of certainty	H	H	H	H	H	M	M	M	M	H	L	H	L
DRILLING	Extent or spatial scale of the impact	L	L	M	M	M	M	M	M	M	M	H	M	M
	Intensity or severity of impact	L	M	L	M	M	L	H	M	L	M	M	M	L
	Duration of the impact	L	L	L	L	L	L	L	L	L	L	L	L	L
	Mitigation potential	L	L	L	M	M	L	M	M	L	L	L	L	L
	Acceptability	M	M	M	M	M	M	M	M	M	M	M	M	M
	Degree of certainty	H	H	M	H	M	L	H	M	L	M	M	M	L

FIGURE 22: Katwe, impact significance rating (without mitigation)

9.3.3 Duration of the impact

All the impacts of operation save for geology are highly rated i.e. they are long-term impacts that may persist for more than 15 years of the plant operation or utilization. The impacts on geology are short term i.e. occurring within the construction period of the plant. The duration of the drilling impacts on the environment is short-term and is limited to the drilling period and/or to a few years after the completion of the drilling phase in the case of some persistent impacts.

9.3.4 Mitigation potential

Most of the impacts on the environment are rated as low i.e. have high mitigation potential and can be reduced to a level of insignificance. They include impacts on geology; land use; visual and aesthetic quality; population, housing and employment; transportation and traffic; public services; energy and the cultural situation for operation, and geology; land use; biodiversity; population, housing and employment; public services; utilities; energy; public health and safety; and the cultural situation for drilling. Impacts on biodiversity; water quality and hydrology; air quality; utilities; and public health and safety for operation are rated as medium i.e. mechanisms exist to mitigate against such adverse impacts. Similarly, drilling impacts on visual and aesthetic quality; water quality and hydrology; transportation and traffic; and air quality are also medium rated.

9.3.5 Acceptability

All the impacts for both operation and drilling are rated as medium, i.e. manageable with regulatory control and project proponent’s commitment.

9.3.6 Degree of certainty

There is a higher degree of certainty that more impacts are likely to occur during operation than drilling. Impacts with a high degree of certainty for occurrence during operation i.e. 70% likelihood are impacts on geology; land use; biodiversity; visual and aesthetic quality; water quality and hydrology; utilities; and public health and safety. With medium certainty i.e. over 40% likelihood of occurring are impacts on population, housing and employment; transportation and traffic; air quality; and public services. The rest with low certainty i.e. less than 40% likelihood are impacts on energy and the cultural situation.

For drilling, impacts on geology; land use; visual and aesthetic quality; transportation and traffic have a high certainty while impacts on biodiversity; water quality and hydrology; air quality; utilities; energy; and public health and safety are rated as medium. The rest of the impacts i.e. on population, housing and employment; public services and the cultural situation are rated as low with less that 40 % probability of occurring and, therefore, not likely to pose any risk to public wellbeing.

9.4 Impact significance with mitigation

The rating results for the Katwe geothermal prospect with impact mitigation are presented in Figure 23. The results show that operation still has greater impact on the environment than drilling. Mitigation reduces most of the impacts with high rating to medium and low rating and those with medium rating to low rating. However, the presence of impacts in the medium rating category suggests that mitigation is not easily achieved and calls for additional commitment to minimize the magnitude of the impacts to acceptable levels.

9.4.1 Extent and spatial scale of the impact

The impacts of both operation and drilling are localized i.e. they are within the boundaries of the local area. Impacts of operation on geology; land use; biodiversity; visual and aesthetic quality; water quality and hydrology; air quality; public services; utilities; and public health and safety are limited to the area within the site boundaries while impacts on population, housing and employment; transportation and traffic; energy; and cultural situation may cross the site boundaries but are still within the local area. Impacts of the drilling phase on land use, and transportation and traffic may cross site boundaries but are still within the local area, while the rest of the impacts are contained within the site boundaries.

9.4.2 Intensity or severity of impact

Mitigation reduces the intensity of the impacts of operation on land use; biodiversity; water quality and hydrology; air quality; utilities; and public health and safety to medium, while impacts on geology; visual and aesthetic quality; population housing and employment; transportation and traffic; public services; energy; and cultural situation to a low rating. The intensity of all impacts of drilling is reduced to a low rating with mitigation except impacts on utilities which remain at a medium rating.

9.4.3 Duration of the impacts

Mitigation reduces the rating of impacts of operation on biodiversity; water quality and hydrology; air quality; energy; and public health and safety to medium, and impacts on geology; land use; visual and aesthetic quality; population, housing and employment; transportation and traffic; public services; utilities; and cultural situation to low. The duration of drilling impacts on the environment is short-term and is limited to the drilling period and/or to a few years after the completion of drilling for some persistent impacts.

KATWE PROSPECT
NOTE:
Impact Magnitude & Significance Rating
(with mitigation)
H: High
M: Medium
L: Low

A: CRITERIA	B: ENVIRONMENT AFFECTED	Geology	Land use	Biodiversity	Visual and aesthetic quality	Water quality and hydrology	Population, housing and employment	Transportation and traffic	Air quality	Public services	Utilities	Energy	Public health and safety	Cultural situation
OPERATION	Extent or spatial scale of the impact	L	L	L	L	L	M	M	L	L	L	M	L	M
	Intensity or severity of impact	L	M	M	L	M	L	L	M	L	M	L	M	L
	Duration of the impact	L	L	M	L	M	L	L	M	L	L	M	M	L
	Mitigation potential	L	L	M	L	M	L	L	M	L	M	L	M	L
	Acceptability	L	M	M	L	M	L	L	M	L	M	L	M	L
	Degree of certainty	L	L	M	L	M	L	L	M	L	M	L	M	L
DRILLING	Extent or spatial scale of the impact	L	M	L	L	L	L	M	L	L	L	L	L	L
	Intensity or severity of impact	L	L	L	L	L	L	L	L	L	M	L	L	L
	Duration of the impact	L	L	L	L	L	L	L	L	L	L	L	L	L
	Mitigation potential	L	L	L	L	L	L	L	L	L	L	L	L	L
	Acceptability	L	M	M	L	M	L	M	L	L	L	L	M	L
	Degree of certainty	L	L	M	L	M	L	M	L	L	M	L	M	L

FIGURE 23: Katwe, impact significance rating (with mitigation)

9.4.4 Mitigation potential

All potential drilling impacts on the environment are rated as low with mitigation i.e. have high mitigation potential and can be reduced to the level of insignificance. Implementation of mitigation measures may still not prevent some negative impacts on biodiversity; water quality and hydrology; air quality; utilities; and public health and safety during operation. Measures to minimize the impacts to acceptable levels must therefore be initiated before operation.

9.4.5 Acceptability

Mitigation reduces impacts of operation on geology; visual and aesthetic quality; population, housing and employment; transportation and traffic; public services; energy and cultural situation to acceptable levels i.e. with no risk to public wellbeing. Other impacts i.e. on land use; biodiversity; water quality and hydrology; air quality; utilities; and public health and safety can still be managed to a level that does not pose a risk to public wellbeing.

For drilling, impacts on geology; visual and aesthetic quality; population, housing and employment; air quality; public services; utilities; energy; and the cultural situation are acceptable, while the rest of the impacts i.e. on land use; biodiversity; water quality and hydrology; transportation and traffic; and public health and safety are manageable.

9.4.6 Degree of certainty

Mitigation reduces potential impacts of operation on biodiversity; water quality and hydrology; air quality; utilities; and public health and safety to a medium level of certainty i.e. between 40 and 70% likelihood of occurring. Other impacts i.e. on geology; land use; visual and aesthetic quality;

population, housing and employment; transportation and traffic; public services; energy; and the cultural situation are reduced to a level that poses no risk to public wellbeing.

For drilling impacts on biodiversity; water quality and hydrology; transportation and traffic; utilities; and public health and safety are reduced to a medium level of certainty. The rest of the impacts i.e. on geology; land use; visual and aesthetic quality; population, housing and employment; air quality; public services; energy; and cultural situation are reduced to a level that will not pose a risk to public wellbeing.

10. KIBIRO - DESCRIPTION OF THE ENVIRONMENT AFFECTED

The information presented in this section provides an overview of the environment affected by the proposed project. Specific components of the environment affected will be more closely examined if the detailed EIA proceeds and this will be achieved through the Specialist Studies that will be conducted. The environment affected by the development of the Kibiro geothermal prospect is basically the environment of Hoima district and the western parts of Masindi district that share a boundary with Hoima.

10.1 Stakeholders and stakeholders' interests

The main stakeholders in the development of the Kibiro geothermal prospect are the MEMD, NEMA, Local Government of Hoima district, Department of Water Resources, Kigorobya Township, and local communities (pastoralists, fishermen, agriculturalists and salt workers), NGOs, and development partners and international organisations.

The MEMD is responsible for exploration and development of the geothermal resources. Its interests are to develop the Kibiro geothermal prospect; provide electricity for rural electrification and the national grid; provide direct heat for use in industry and agriculture. NEMA is the principal agency in Uganda for the management of the environment with the express mandate to "co-ordinate, monitor and supervise all activities in the field of the environment". The geothermal prospect is under the administration of the local government of Hoima district. The role of the local government, therefore, is to assist in the implementation of NEMA's activities by carrying out environmental audits and monitoring; and to provide services to the development projects, for example building of access roads and bridges, and mobilizing the local community to participate in such projects. The Water Resources Department is responsible for development and management of the national water resources. Its interests are to protect surface and ground water systems especially rivers and lakes from pollution and to issue water user permits.

Other stakeholders are the salt workers whose livelihood depends on the local salt industry at Kibiro, the pastoralists, fishermen and agriculturalists. Their main interests are in sharing water resources with the proposed project, compensation for land to be used by the project, jobs and markets for their produce. The NGOs promote the integration of geothermal energy and other renewable energies into the energy mix of the country. Such NGOs include NAPE, JEEP, and IRN among others. The main interests of NGOs include sensitizing the population about renewable sources of energy that are clean and environmentally benign; educating the stakeholders and local people about the socio-economic benefits from geothermal.

Lastly, the development partners and international organisations that have cooperated with the GoU during exploration for geothermal resources in the Kibiro geothermal prospect since 1993 are UNDP, OPEC, IAEA, WB and the Government of Iceland. These partners and international organisations would like to see the Kibiro geothermal prospect developed to produce electricity and direct heat for use in industry and agriculture. The feasibility study of the Kibiro prospect is one of the projects earmarked for funding from the ARGEO facility which is funded by GEF among other organisations.

10.2 Physical characteristics

10.2.1 Climate

Hoima district generally has a pleasant climate with small variations in temperature, humidity and wind throughout the year. This is due to altitude which ranges from 620 to 1,160 m a.s.l. The lowest area is the western rift valley most of which is occupied by Lake Albert. The district receives a total rainfall of about 700-1,000 mm per annum. There are quite distinct wet and dry seasons. Rainfall is distributed fairly evenly throughout the year. The wetter months are April - May and September - October, with two dry spells occurring in June - July and December - January. Western areas bordering the rift valley are the driest and hottest. Temperatures are generally high ranging between 15 to 32˚C. Relative humidity in the district is high during the rainy seasons reaching a maximum in May and minimum in January. The rain is associated with the northern and southern movements of the Inter Tropical Convergence Zone. The district is swept by the westerly winds which produce masses of clouds and thunderstorms. The southeast monsoon winds also blow across this area.

Kibiro geothermal prospect lies in the western part of the district which is the driest. The prospect is divided into two different climatic areas with the western part in the rift valley at the lowest altitude of approximately 620 m a.s.l. This part lies in the rain shadow and is hot and dry all the year round with a few rainy days. East of the escarpment the land rises from 950 at the top of the escarpment to 1,160 m.a.s.l toward Kigorobya. The climate gradually changes with altitude inland from the escarpment. The areas near the escarpment tend to adapt conditions similar to those at Kibiro but inland the climatic conditions are generally similar to the rest of the country with both wet and dry seasons.

10.2.2 Topography and geology

The topography of Hoima district is characterized by broad, flat-topped ridges of about 1,000 - 1,100 m.a.s.l whose formation is given tentatively as upper *Cretaceous* (65 - 135 million years ago). The district can be divided into three main topographic zones; Dissected plateau, Escarpment and Rift Valley. The dissected plateau is formed from hills that are remnants of the ancient Buganda surface which experienced a slow uplift during the mid-Tertiary period and was later dissected by a rejuvenated drainage system (Wayland 1935). The escarpment stretch covers a watershed running throughout its length from Kyangwali through Buseruka to Kigorobya subcounties approximately parallel to Lake Albert (Figure 3). It has been affected by rift valley faulting with steep slopes forming along fault lines. The topography is deeply incised by streams and rivers e.g. River Wambabya, River Hoimo, River Kachururu and River Waki. The area lying in the rift valley is mainly occupied by Lake Albert. It is essentially a flat area of sand beaches and a representative of early Pleistocene or Acholi surface.

The geology of Hoima district is dominated by sedimentary beds of the Bunyoro (Hoima) series mainly represented by tillites and phyllites with subsidiary amounts of sandstones and conglomerates as basal members. These rocks are Precambrian and are part of the dissected African surface. They appear in Bugambe and parts of Kiziranfumbi, Kabwoya and Buhimba in Buhaguzi county and in Kitoba subcounty in Bugahya county (Figure 3). The Rift valley and the associated geology cover areas of Kyangwali, Buseruka and Kigorobya subcounties. The geology is characterized by quartzites, granites and schists. Their distribution follows the weathered detritus that had accumulated prior to faulting and has been removed by post rift valley geological erosion. These rocks occur along the southeastern boundary in Buhimba, Buhanika and Kyabigambire subcounties. Along the shores of Lake Albert in Buseruka subcounty is a broad tract of river and lake alluvium laid down as rift valley floor deposits. At Kaiso in the Albertine rift a fossiliferous ferruginised bed occurs in sediments marking a period of recession during interpluvial phase when Lake Albert was formed. In Uganda the oldest deposits are the Kaiso beds.

10.2.3 Soils

The soils in Hoima district are mainly yellowish-red clay loams on sedimentary beds and they occupy parts of Bugahya and Buhaguzi counties. Highly leached, reddish-brown clay loams are found in the extreme east of the district. These are of low to medium productivity. There are also dark brown, black loams (Bugangari series) found along the axis of the warp and these are mainly of low to medium productivity. The soils of recent origin which consist of quartzites are found along the escarpment. Their depth depends on the vegetation cover and land use. They are suitable for coffee and maize. Soils on highland areas developed on pediment fans are lateritized. They are red clay loams (*Kitonya catena*) derived from the Karagwe-Ankolean phyllites. They are of medium to high productivity suitable for coffee and maize production. On the other hand, greyish-black sands are base deficient, acidic and generally occupy rivers and valley floors. These alluvial soils which include the Wasa complex, the Kifu and Bukora series are of low productivity. The distribution and top soil characteristics in Hoima district (Chenery, 1960) are presented in Table 17.

In the Kibiro geothermal prospect the soil cover appears to be thin close to the escarpment and gradually becomes thicker toward Kigorobya, as the landscape changes and becomes more flat. The soil is red in colour, typical of the final stage of the weathering of granites, i.e. red lateritic soil. This type of soil is rich in aluminium and iron, but generally its clay content is low as it is composed of a mechanical mixture of fine grains of quartz with minute scales of hydrates of alumina. Although laterite soil is known to reach a thickness of tens or hundreds of meters, it is not likely to be the case in the present study area, as outcrops of granite are found on hilltops throughout the area and not far apart. It had been noted that closer to the escarpment, the soil is in some places more brownish than reddish, which may reflect the weathering product of the pyroxenites.

TABLE 17: Distribution of top soil in Hoima district

Location	Soil unit	Dominant soil type	Parent material	Productivity
Kitoba, Bugambe, Buhimba, Kabwoya	Hoima catena	Yellowish-red clay loams occasionally	Bunyoro series tillites and phyllites	Low to medium
Buhimba, Buhanika, Kyabigambire	Rukiri complex	Reddish and reddish-brown gritty clay loams	Basement complex granites, gneisses and schists	Low to medium
Kyangwali, Buseruka, Kigorobya	Bugangari series	Shallow dark-brown or black loams often very stony	Granites, gneisses, schists and amphibolites	Low to medium
Buseruka	Wasa complex	Grey sands and sandy clay loams slightly lateritized	Rift valley sediments	Low
Kiziranfumbi, Buhanika, Hoima T/C	Kitonya catena	Dark-red clay loams, occasionally lateritised	Karagwe-Ankolean phyllites	Medium to high
Along River Nkusi	papyrus catena	Peat or peaty sands and clays	Papyrus residues and river alluvium	Medium to high
Along rivers	Kifu series	Grey sands	Granitic hillwash	Low
Along rivers	Bukora series	Black sandy loams over dark-grey sands	River alluvium	Low
Kyangwali	Metu complex	Shallow skeletal loams often on steep rock slopes, no laterite	Basement complex quartzites and granites	Nil

10.3 Ecological characteristics

10.3.1 Air quality

The state of the atmosphere within Hoima district is good it being located in the countryside with no industrial developments and very low traffic movements. Hoima district has virtually no air polluting industries to speak of.

10.3.2 Water resources

I. Surface water

Hoima district has got adequate surface water resources. About 2,269 km^2 (38.3%) of the area is covered by water. The highest proportion of these open water bodies is Lake Albert which lies in the western and northern parts of the district in Kigorobya, Buseruka and Kyangwali subcounties. It is shared by Uganda and the DRC. Lake Albert is a fresh water lake and has a surface area of approximately 5,335 km^2 of which 2,913 km^2 are in Uganda and the rest in the DRC (NEAP, 1993). The depth of Lake Albert varies from 7 - 12 m increasing toward the west. Inland, there is a network of permanent swamps which traverse the district. These cover a total area of 61 km^2 which is approximately 1.03% of the total area of the district. There are a number of rivers in the district that include River Kafu which forms a boundary with Kibaale district and drains into Lake Kyoga. Others are rivers Howa, Wambabya, Hoimo, Kachururu and Waki that drain into Lake Albert. River Kachururu flows from Kigorobya north-westwards into the Kachuru fault and then northwards through the same fault into Lake Albert. The Kachuru fault is oblique to the main rift valley fault and is believed to control the Kibiro hot springs that lie at the intersection of the two faults. The only outflow from Lake Albert is the River Semuliki that joins the White Nile at the northern extreme of the lake.

II. Groundwater

Hoima district depends mainly on groundwater for domestic supply due to few rivers in the area. Groundwater in the Kibiro geothermal prospect, in particular, is obtained from boreholes scattered all over the area east of the escarpment. The boreholes closer to the escarpment south of Kibiro discharge brackish water but inland from the escarpment toward Kigorobya the water becomes dilute.

10.4 Biological resources

10.4.1 Fauna

No detailed count of the fauna has been carried out in the district but generally the wildlife fauna population is low. This is partly due to habitat loss for these animals through agricultural encroachment. The fauna is mainly concentrated in areas that have fairly heavy vegetation but are in many cases thinly populated. Monkeys, baboons, antelopes and pigs are known to exist. In other parts of the district, the fauna is confined to Lake Albert and the wetlands. Hippopotami are known to exist in the waters of Lake Albert while papyrus swamps are rich in birds both in terms of variety and numbers. The district is richly endowed with a number of bird species. This is due to the variety of physical features in the district that provide a favourable habitat to birds. Although not heavily forested, the district has some forest bird species. Many of the bird species that are found in the savannah grassland and woodlands of Uganda also exist in the district.

10.4.2 Flora

The vegetation in Hoima district varies and ranges from medium altitude moist forests through forest/savanna mosaic, savanna, swamps to post-cultivation communities. Land uses and vegetation coverage is presented in Table 18.

The Kibiro geothermal prospect is dominated by grassland, woodland and bushland. Grass savannah is derived from wooded savannah and thicket by repeated cultivation, grazing and burning. The most common plant type is the *Hyparrhenia* grass savanna dominated by *Hyparrhenia filipendula and Hyparrhenia dissoluta species.* Some of these species are associated with Acacia species while others appear to have been derived from combretaceous savannah woodland.

Inland from the escarpment where cultivation is heavily practiced, post cultivation communities cover relatively big areas with *Cymbopogon afronardus* as the common species on shallow and stony soils. The swamps are dominated by C*yperus* papyrus with the common associates *Cissampelos micronata,* *Dissotis rotundifolia, Dyopterus striata, Leersia lexandia* and *Polygonum salicifolium.* Other areas are occupied by forests and forest reserves.

TABLE 18: Hoima district, vegetation coverage (*Source: Forestry Department, 1996*)

Type	**Coverage (km^2)**
Broadleaved plantations (e.g. eucalyptus)	0.5
Conifer plantations (e.g. pines)	4.3
Tropical high forest (fully stocked)	464
Tropical high forest (degraded)	244
Woodland	9,000
Bushland	85
Grassland	715
Papyrus swamp	58

10.5 Potential land use options

10.5.1 Agriculture

Agriculture is the main economic activity and source of income in Hoima district. Eighty percent of the population depend on subsistence agriculture for their livelihood. The land under cultivation is estimated to be about 1,191 km^2. The population produces both food and cash crops. Among the food crops produced in the district are potatoes, bananas, maize, cassava, beans, soya beans, rice, millet, sorghum, cowpeas and pigeon peas, groundnuts, sim sim, and yams. The common cash crops include tobacco, cotton, tea and coffee. Hoima is one of the leading tobacco producing districts in the country. Horticultural farming is also practiced with a variety of fruits, vegetables and spices as the main products. Others include tomatoes, cabbages, onions and pineapples.

Livestock farming is also practiced, mainly with local breeds such as Zebu and Ankole cattle. But the introduction of exotic breeds is expected to increase on the productivity in dairy products. Poultry farming and bee-keeping are picking up with increasing demand for their products. Generally the district has a high potential for extensive agriculture and agro-industrialization. The district has a lot of under-utilized fertile land that can be used for establishment of large farms. Increasing population is decreasing the land available for livestock farming as more land is opened up for subsistence agriculture. The areas most affected are Kigorobya and Buseruka subcounties which are close to the rift escarpment.

The Kibiro geothermal prospect spans parts of the two districts of Hoima and Masindi although the current investigation is concentrated in Kigorobya subcounty in Bugahya county, Hoima district. The main agricultural activity west of the escarpment in the rift valley at Kibiro and the neighbouring village of Kachuru is fishing and raring of chicken, pigs, and goats, and to a small extent cattle keeping. The area is not good for crop husbandry being in the rain shadow and dry all the year round. The area east of the escarpment is grazing land occupied by pastoralists and inland from the escarpment toward Kigorobya and Hoima the land rises gently and finally becomes generally flat and fertile for agriculture. The neighbouring district, Masindi, to the northeast has high agricultural potential and grows tobacco and sugar cane as the main cash crops and has a well developed forestry industry. Kinyara sugar factory, one of three in the country, is located in Masindi district and buys most of the sugar cane from out-growers.

10.5.2 Fisheries

The district is endowed with natural water resources and this has made fishing one of the major economic activities. The main fisheries in the district are on Lake Albert which covers about 2,268 km^2 (38%) of the district. Fishing has greatly influenced the social and economic development in the subcounties of Kigorobya, Buseruka and Kyangwali which share Lake Albert. There are 22 landing sites which act as major outlets to the urban markets. The major landing sites include Waki, Runga, Bikunya, Kibiro, Hoimo, Tonya, Bugoma and Nkondo in Hoima and Butiaba in Masindi district. The number of fishermen varies from one subcounty to another.

Lake Albert has the most diverse fish fauna in Uganda including species of commercial significance (NEAP, 1993). *H. Vittatus* (Ngasya) is the most abundant species in the commercial catches. Other common species include Tilapia especially *Oreochromis niloticus* and *Tilapiazilli, Lates niloticus* (Nile Perch), *Brycinus spp.* (Ngaa), *Hydrocynus forskalli* (Ngasi) and *Bagrus spp.* (Lanya), *Barbus, Clarius mossambicus* (Male), *Labeo* and *Auchenoglaris occidentals*. Hoima district is also well endowed with a number of wetlands where some fishing is also carried out. The most prominent ones are Kafu, Wambabya, Waki, and Kabale. The major species harvested in the swamps is *Protopterus aethiopicus* (Lung fish) with a highest catch during the dry seasons when most of the swamps tend to dry up. Some fishing is also practised in Rivers Waki, Hoimo, Wambabya, Nguse and Kafu.

The kind of fish processing methods available in the district are the traditional ones which include salting, sun-drying, smoking, grilling and cooking. One of the major problems associated with traditionally processed fish is how to reduce post harvest losses. This kind of processing affects the quality if not handled properly. The salted and sun-dried fish is sold in Bundibugyo, Arua and Nebbi districts in addition to the markets in Hoima and Masindi. The problems facing the fisheries industry are mainly centred on handling and processing the fish before it is sold. These include lack of firewood for smoking and cooking the fish, storage facilities, fishing gear, poor roads, supervision and law enforcement.

10.5.3 Kibiro salt works

Kibiro has a population of approximately 3,000 people, most of them depending on a local salt industry. Extensive archaeological remains indicate both substantial occupation and salt production since 900 years ago (Connah et al., 1990). The origin of the salt is thought to be the surrounding country rocks. The six parameters required for the formation of salt in this place are the surrounding country rock, deep seated faults, thermal gradient, water, surface sediments and hot/dry weather. Meteoric water percolates to the bottom through fracture systems, joints and foliations dissolving different elements from the country rock. The dissolution process is a function of temperature and the resultant saturated hot solution rises to the surface as hot springs. The main components of this fluid are sodium, chloride, silica and potassium (Armannsson, 1994).

I. Production

The geothermal water from hot springs percolates into the sediments and is concentrated using dry soil which is spread over the salt gardens. The salt rises from the sediments to the dry soil by capillary action making the dry soil wet and impregnated with salt. The impregnated soil is then scooped and the salt recovered by dissolution and evaporation to dryness.

II. Marketing

Salt production and marketing at Kibiro is exclusively a female occupation. Early on Wednesdays and Saturdays, the market days at Kigorobya, women and girls set off up the escarpment carrying salt which they sell in the market. Kigorobya is about 10 km from Kibiro. Not only do the people of Kigorobya subcounty prefer it to imported salt but others come from Hoima, 22 kilometres away, to buy it. In Kigorobya market, a wide variety of merchandise can be found including foodstuffs, pottery, clothing, paraffin (Kerosene) and many other things, but the main interest of the Kibiro women is in foodstuffs. They buy cassava and maize flour, sweet potatoes, fresh cassava, beans, ground nuts and other foods after they have sold their salt (most of which is in fact bartered for food). Besides food, some of them bring banana wine, beer, soft drinks, soap, sugar, cigarettes and so on, which they sell in the village.

10.5.4 Other industries

Hoima district has a booming forestry industry with large forests which offer sources of both hard and soft wood for timber. Budongo forest is a big national source of both construction and building material. Budongo is in the north-eastern part of the district covering parts of Kigorobya and Kitoba subcounties and extends to Masindi district.

10.6 Existing socio-economic conditions

10.6.1 Societal conditions

I. Population

The population of Hoima district is approximately 349,204 (Population census, 2002). The population of Kigorobya subcounty is 46,771 while Kibiro village has 3,000 people. The breakdown of the population of Hoima district by subcounty and sex is presented in Table 19 and the age-sex profile in Table 20.

TABLE 19: Population of Hoima district by subcounty and sex *(Source: www.ubos.org)*

County	Subcounty	Male	Female	Total
Bugahya	Buhanika	10,441	10,207	20,648
	Buseruka	12,633	11,935	24,568
	Bisiisi	7,024	7,035	14,059
	Hoima T/C	14,827	16,803	31,630
	Kigorobya T/C	2,173	2,853	5,026
	Kigorobya	23,244	23,527	46,771
	Kitoba	16,382	16,284	32,666
	Kyabigambire	15,848	14,606	30,454
Buhaguzi	Bugambe	13,613	12,436	26,049
	Buhimba	14,690	14,352	29,042
	Kabwoya	14,306	13,171	27,477
	Kiziranfumbi	11,586	11,430	23,016
	Kyangwali	19,433	18,365	37,798
District total		**176,200**	**173,004**	**349,204**

The table shows that males outnumber females by 3,196, which is a very rare situation in Uganda. The majority of the people, estimated at 90%, are rurally based leaving only a small proportion of 10% as an urban population. This reflects the predominance of agriculture as the backbone of the district.

TABLE 20: Age-sex profile of the population of Hoima district *(Source: www.ubos.org)*

Age (years)	Male (%)	Female (%)	Total (%)
0-4	19.4	19.5	19.4
5-14	28.2	28.2	28.2
15-64	49.7	48.4	49.1
65+	2.7	3.9	3.3
Total	100.0	100.0	100.0

Table 20 shows that the ratio of very young (below 14 years old) to medium aged people (15 to 64 years) is approximately 1:1. This information is significant as it indicates the percentage population that falls within the economically active age group (15 to 64 years) which is almost half the population of the district. This implies that the resources produced by the economically active group are consumed by the young ones and the elderly (3.3%) and therefore there are no significant savings for investment.

II. Literacy and education

The literacy rate in the district is about 56% for the age group above 10 years old. About 63% of the literate population comprises males. Like in other districts of Uganda, girls tend to drop out of school on or before completion of primary education rather than boys. This is because of early marriages; demand for domestic labour; poverty and low value placed on education; and traditional attitudes towards girls which do not favour their education. Generally the reasons advanced for the high level of illiteracy include high cost of education and low incomes in households.

Hoima has got a total of 144 primary schools, 37 secondary schools and a teachers training college at Butera. The district has put much emphasis on the education of a girl child to reduce the high rates of school dropouts in the district. Hoima like other districts in the country has successfully implemented the government UPE. The district has improved primary enrolment since the introduction of UPE in 2001. Currently the total number of primary schools enrolment was 79,577 (population and housing census, 2002) and is expected to reach 110,000 by the year 2006.

10.6.2 Infrastructure and services

I. Communication

Hoima is linked to the neighbouring districts by a first class murram road network. This enables the district to transport its produce to the markets and to other parts of the country. Hoima is also linked by water to the DRC and other districts like Bundibugyo and Nebbi in West Nile through water transport on Lake Albert.

Roads. Hoima district has three types of road networks classified in accordance with the type of surface and institutions/authority responsible for their maintenance. These are trunk roads, feeder roads and community access roads. Trunk roads are maintained by the Ministry of Works, feeder roads by the local government at the district and community access roads by the communities. The districts has 213 km network of trunk roads of which 105 km is first class murram and 550 km feeder roads. The network of first class murram is presented in Table 21. There are no tarmac (surface) roads in Hoima district.

TABLE 21: Hoima district, trunk road network

Name of road	Distance (km)	Category
Hoima - Kafu	19.2	All weather
Hoima - Masindi	20.0	All weather
Hoima - Buhimba	12.0	All weather
Buhimba - River Nguse	54.4	Seasonal
Buhimba - Kabale	18.0	Seasonal
Hoima - Biiso	38.4	Seasonal
Kabwoya - Buhuka	51.0	Seasonal

Hoima district is connected to Kampala by a 70 km Kampala - Busunju surfaced road and 133 km Busunju – Kafu – Hoima which is a first class murram road which is currently being surfaced. The trunk road that traverses the Kibiro geothermal prospect is the Hoima - Biiso via Kigorobya Town. At Kigorobya a branch of a feeder road leads to Kibiro through the escarpment at Kabiribwa. Butiaba port on Lake Albert is connected to the trunk road through a branch at Biiso which is surfaced but needs repair. Both Butiaba and Biiso are located in Masindi district. The only busy roads in the district are Hoima - FortPortal via Kabwoya, Hoima - Kafu and Hoima - Masindi roads. Other trunk roads are occasionally busy on market days. But generally the district has no significant traffic, being located in the country side.

Telecommunications. Hoima district is connected to the national telecommunications infrastructure and enjoys the services of Uganda Telecom (UTL) and MTN. A number of radio stations in the district for easy communication to the people at the grass roots have also been established.

II. Domestic water supply

Water is needed for domestic use, agriculture and livestock. The water supply system in Hoima district still largely depends on natural sources many of which are considered unsafe. These sources include open water/springs, streams or lakes. Groundwater is the main source of safe water for the urban and rural population in the district. Groundwater is drawn through boreholes, springs, gravity flow schemes and shallow wells. Rainwater catchments and treatment of surface water have high per capita costs. The areas close to the rift escarpment have few natural water sources. The boreholes drilled in the areas are not very productive and people have to travel long distances in search of water. The subcounties affected are Buseruka, Kyangwali, Bugambe, Kyabigambire, Kitoba and Kigorobya.

The main source of domestic water supply in the Kibiro geothermal prospect east of the escarpment is groundwater boreholes. Other sources are protected springs and surface river water especially in the catchment areas of the main rivers Waki, Hoimo and Wambabya. In the rift valley areas, west of the escarpment, the inhabitants of Kachuru and Kibiro villages use water from River Kachururu and Lake Albert, while Butiaba gets its water supply from a gravity scheme at Waki Falls on the face of the escarpment where River Waki flows over to the rift valley.

III. Energy supply

Hoima and Masindi Towns are on a 33 kV line from Kampala that has recently been extended from Hoima to Kigorobya Township. Electricity is used for lighting and small scale industries like grinding machines, saloons, fridges and milk cooling plants. Most of the people in the settlements use charcoal stoves and firewood for cooking. Those in the townships who cannot afford electricity use kerosene lamps for lighting. Approximately 97% of the households use wood fuel and charcoal for cooking and lighting compared to 3% who use electricity and other sources like kerosene. Solar energy is used in the drying of food stuffs and by institutions which have solar panels for operating radio receivers, fridges and lighting. The use of wood fuel as the main source of energy has led to the clearing of thousands of hectares of forest. Loss of vegetation has exposed the area to soil erosion and loss of fertility.

IV. Community health

Hoima district has a total of 33 health units of which 28 are government-aided. These include 1 Hospital, 3 Health Centre IV's, 29 Health Centre III's and a number of Health Centre II's at parish level. The health units are distributed in all subcounties across the district. Kigorobya subcounty, in which the Kibiro geothermal prospect lies, has three health units at Kigorobya, Kibiro and Kitana. The one at Kigorobya is of Health Centre III status while the Kibiro and Kitana ones are of Health centre II status. The common diseases in the district are upper respiratory tract infection, malaria, diarrhoea, HIV-AIDs, eye diseases, malnutrition, skin diseases, trauma, lower respiratory tract infection, intestinal worms, dental diseases, bilharzia along the Lake Albert, and onchocerciasis. The leading killer diseases in the district are malaria, diarrhoea and acute upper respiratory tract diseases. Infant mortality rate stands at 91 per 1000 live births.

The district is still facing many constraints that include inadequacy of health facilities, delayed disbursement of funds from the government and understaffing, poor management, and lack of comprehensive health education programmes.

V. Housing/settlement

The settlements west of the escarpment are localised in landing sites and at confluences of rivers along the shores of Lake Albert. The main settlements, west of the escarpments, in Kibiro prospect are at Kachuru, Kibiro and Butiaba and other landing sites. East of the escarpment the population is scattered but increases from the escarpment toward Kigorobya and Hoima Towns. In Masindi district the areas close to the escarpment are sparsely populated and forested in some places while others are covered by sugar plantations of Kinyara sugar factory and its out-growers. The areas that are densely populated are close to Masindi Town.

10.6.3 Aesthetics

I. Tourism / recreation
Hoima district has potential for the development of a tourism industry. The potential sites include the following: the cultural/burial sites of the deceased Kings of Bunyoro - Kitara Kingdom at Mpalo, the forests, the rift valley, the escarpment, the hot springs at Kibiro and Lake Albert. The Kibiro hot springs and the salt industry attract a number of tourists. The area also gives a good view of Lake Albert from the top of the escarpment at Kabiribwa. Kibiro is not a gazetted protected area and therefore does not need an entry permit.

II. Education and scientific research
Research aimed at understanding the hot springs at Kibiro has been going on since early 20th Century like in Katwe. These studies form the backbone of the current investigations. A similar research on the hydrocarbon potential of the Rift Valley by the Geological Survey of Uganda was carried out concurrently in the 1950s. Two oil exploration wells were drilled in the Kibiro prospect, one at 1.5 km NE of Kibiro hot springs and the second one near Butiaba 25 km to the NE, revealing the existence of hydrocarbons in the rift valley sediments but the exploration was abandoned in 1956. Oil exploration resumed in the mid 1980s in the Albertine graben by the PEPD of Uganda. The current seismic surveys by the same department are concentrated on Lake Albert and in the sedimentary basin in the Butiaba area.

10.7 Comparison of the environments of Katwe and Kibiro prospects

The main similarities and differences of the environments affected by the development of the two areas are based on land ownership, communication, biodiversity, industrial development and recreation and tourism. They are briefly presented in Table 22.

TABLE 22: Katwe and Kibiro, environmental similarities and differences

Item	Katwe	Kibiro
Land	The area is located on public land, the QENP.	The area is located on privately owned farmland.
Communication	The area is well connected by road, air, water and rail transport.	The area is poorly connected, only by road and water transport.
Biodiversity	The geothermal prospect is located in the QENP and has many water bodies downstream and therefore prone to impacts on biodiversity.	The geothermal prospect has a few water bodies downstream and therefore there is little danger of impact on biodiversity.
Industrial development	The area has a considerable number of industries and commercial activities and therefore a potential for indirect and cumulative environmental impacts as well as impact interactions.	The area has no industrial infrastructure and few commercial activities and therefore little potential for indirect and cumulative environmental impacts.
Local salt industry	Prospect has a local salt industry that has survived for many generations. Salt is produced by natural evaporation of the brines from ponds. The salt is marketed nationwide and across the borders in neighbouring countries like DRC, Rwanda and Tanzania.	The prospect has a local salt industry that has survived for many generations. Salt is produced by capillary rise of salt from the sediments, the impregnated soil is dissolved and salt recovered by evaporation of the solution to dryness. The salt is marketed at regional level i.e. within Hoima and neighbouring districts.
Tourism and recreation	Well developed tourist industry and protected within the QENP. Attractions include game viewing, crater lakes, boat rides on Kazinga Channel, hiking on the Rwenzori Mountains and the salt industry at Lake Katwe.	Not well developed and not protected. Attractions include salt industry at Kibiro, Kibiro hot springs, Lake Albert, escarpment, forests, and the burial grounds of the deceased Kings of Bunyoro Kitara Kingdom at Mpalo.

11. KIBIRO - ENVIRONMENTAL IMPACTS

In identifying potential significant environmental impacts for drilling and operation phases for the development of the Kibiro geothermal prospect, public consultation, experience, expert knowledge of the project area/site, an interaction matrix and a checklist were used as for the Katwe geothermal prospect.

The key elements of the project are all included in the interaction matrix and checklist. Those impacts that could result if the project were implemented (direct impacts) are discussed. Only those elements of the environment, which may be impacted or might be considered as producing indirect and cumulative impacts, are included in the discussion. The interaction matrix and checklist used for identification of potential environmental impacts for both drilling and operation are presented in Appendices C and D.

Potential environmental impacts identified were categorised under 13 sections i.e., impacts on the geology of the area; land use; biodiversity; visual and aesthetic quality; water quality and hydrology; population, housing and employment; transportation and traffic; air quality; public services; utilities; energy; public health and safety; and cultural situation. The impacts are described in the following sections and subsections.

11.1 Drilling

11.1.1 Geology

The proposed project will involve construction of access roads to the drill site for moving equipment and accessories, and clearing of land for drill pads. The Kibiro prospect is located along the eastern escarpment of the western rift valley. A small part of it is within the rift valley sediments west of the escarpment on the shores of Lake Albert, while the rest is east of the escarpment on a plateau characterised by a number of faults. The drilling is to take place in the second part of the prospect. Construction of roads and drill pads may change the geology and topography of the area. This may lead to soil erosion of cut slopes and fill slopes if the soil is not well compacted.

11.1.2 Land use

The construction of roads and drill pads will conflict with the adopted environmental plans of the area and the goals of the communities through which the roads will pass. It will convert prime agricultural land to non-agricultural use, or impair its agricultural productivity. The land use will also conflict with local government general plans. The road construction will take up land from private farmland and therefore there will be a need to compensate the owners.

11.1.3 Biodiversity

The Kibiro geothermal prospect is located on private farmland some of which is grazing land but other parts are used for subsistence agriculture. The drilling operation will increase the rate of use of natural resources like water and will reduce the vegetation cover that would be available for grazing. It will reduce land available for agriculture, affect habitats of plant and animal species and diversity and may cause reduction in acreage of crops. Clearing of bushes may lead to the introduction of new plant species in the area and become a barrier to normal replenishment of existing species.

11.1.4 Visual and aesthetic quality

Drilling will interfere with the local goals or guidelines related to visual quality and hence create visual pollution. The visual obstruction is caused by the rig's high mast, which rises several tens of metres above the surrounding environment, and its accessories. It may change the visual quality of the area and result in an obstruction of scenic views open to the public or destroy the visual quality of the area leading to a substantial, demonstrable negative aesthetic effect.

11.1.5 Water quality and hydrology

A considerable amount of water is required for drilling, completion testing and injection testing as for the Katwe geothermal prospect. These activities are a source of wastewater which is likely to affect the quality of surface and ground waters.

The wastewater from drilling can create serious gullying if discharged directly to the surface, e.g. into valleys. It can change the amount of surface water in the area and result in alteration of surface water quality including temperature, dissolved solids and turbidity. The wastewater may be contaminated with drilling fluids which may substantially change the chemistry of the surface and ground waters. This may result in degraded water quality and contamination of public water supply.

11.1.6 Population, housing and employment

The drilling programme will create 100 temporary jobs for various activities on site and may induce substantial growth of the population and thus affect the average age of the population since the workers will not be accompanied by their families. This increase in local population due to migrant workers may cause a strain on the available resources and may result in conflicts.

11.1.7 Transportation and traffic

Drilling will increase traffic in the area during the transportation of the rig and its accessories to the drill site, Kigorobya being a town with low traffic will definitely be affected by an influx of traffic. The increased traffic will lead to an increase in dust, noise and vehicular emissions. This will have an impact on special interest groups like children, the elderly and the disabled, and sensitive locations like schools, hospitals and places of worship.

11.1.8 Air quality

The majority of impacts arising during drilling will affect the ambient air quality through the release of fugitive dust from the heavy traffic on the roads, site clearing etc. Emissions resulting from the operation of drilling equipment e.g. large combustion equipment, and vehicles may also impact local air quality. This may create objectionable odours and hamper visibility.

11.1.9 Public services

The increased traffic during the drilling phase will inconvenience the residents by taking up parking space in Kigorobya Town and therefore degrading the locally acceptable park standards. This is likely to increase the risk of theft and outbreak of fires as a result of congestion and uncontrolled fuel spillages.

11.1.10 Utilities

Drilling will create all kinds of waste including waste fluid containing chemicals like barium sulphate, mud and detergents. Other types of drilling fluids like aerated water or mud and foam sometimes used for pressure balancing can have impacts on the environment e.g. foam can affect vegetation around the site and cause eye irritation when it covers a large area. The effluent fluid is channelled to sumps where it cools before being recycled or disposed of. The activity will produce solid waste in excess of available landfill capacity and cause significant increase in the consumption of potable water. Drilling is likely to breach the local standards relating to solid waste control.

11.1.11 Energy

Drilling will require a lot of energy resources for powering the heavy combustion equipment and lighting. It will therefore significantly affect energy resources at local and regional level. The activity will cause an increase in the use of fossil fuels by encouraging activities which result in the use of substantial amounts of fuel, water and energy. It may also affect the demand upon existing sources of energy, or require a development of new sources of energy which may conflict with the existing energy standards.

11.1.12 Public health and safety

Drilling will involve hazards that the local population and those moving into the area have not been adequately warned against. It will create potential health hazards or involve the use, production, or disposal of materials which pose a hazard to people or animal or plant populations in the area. Accidental release of hazardous substances like oil, chemicals in the drilling fluids to the water cycle and toxic gas emissions pose public health and safety problems. The activity may create a risk that the concentration of a TAC may at any time exceed the air pollution control threshold.

Drilling will generate a lot of noise that will conflict with the local noise standards leading to several kinds of disturbances. Substantial noise is generated in vapour-dominated reservoirs where air-only drilling is used and requires large compressors. The substantial increase of noise levels in adjoining areas may expose people and animals to severe noise levels.

The powerful lighting to illuminate the work space at night during drilling will disturb the local residents and animals. The activity may expose people or property to water related hazards such as flooding. The main sources of erosion during the drilling phase are the accidental leakage of fluids from sumps and the surface discharge of wastewater from a well during testing.

11.1.13 Cultural situation

The Kibiro geothermal prospect is located in an area currently used for research on the heat, the hydrocarbon potential of the rift valley and the archaeological history of the ancient salt industry at Kibiro. The activity is likely to affect the social life of the area as a result of an influx of people from different areas and cultures. This may give rise to social problems such as lack of housing, increased spread of diseases, increased pressure on social services and increased cultural misunderstandings.

11.2 Operation

Operation, like in the Katwe geothermal prospect, will involve the construction of a power plant, the connection of the geothermal wells to the power plant and finally the operation of the plant through its lifetime. The main impacts are related to loss of land, mass withdrawal of the geothermal fluid from the reservoir, waste liquid and waste gas disposal.

11.2.1 Geology

The construction of the power plant is likely to affect the topography and geology of the area as part of the land will have to be levelled off on the construction site. Massive withdrawal of the fluids from the reservoir may trigger micro-earthquakes which are likely to weaken the ground and give way to landslides in case of heavy rains in the area.

11.2.2 Land use

Land will be required for production wells, pipelines, power stations, cooling towers, electrical switchyards, and power transmission lines. This will conflict with the adopted environmental plans and goals of the local government. The Kibiro prospect is located on privately owned land and operation will convert prime agricultural land to non-agricultural use, or impair its agricultural productivity. The possible conversion of open space into urban or suburban scale uses as a result of new roads and influx of people into the area may also affect the general plans for the area.

11.2.3 Biodiversity

Operation is likely to affect biodiversity through the discharge of the geothermal fluids to surface waters and streams. The hot water increases temperatures in the rivers and thus reduces the oxygen available to the living organisms in the rivers and other water bodies downstream. Massive withdrawal of fluids may raise the ground temperature through leakage of steam along faults and thus affect the land animals and plants.

Operation will increase the rate of use of water resources and therefore affect the rational use of water. It may affect water organisms and substantially diminish habitat for plants. It may introduce into the area new species of plants or animals which are tolerant to raised temperatures, or it may become a barrier to the normal replenishment of existing species. It may also affect significant riparian lands, wetland, marshes or other wildlife habitats.

11.2.4 Visual and aesthetic quality

Operation involves the installation of power plants, wells, pipelines, cooling towers, switch yards and overhead cables. The complex will affect the visual and aesthetic quality of the area. It will interfere with the local guidelines or goals related to the visual quality. This may have a substantial demonstrable negative aesthetic effect, may significantly change the visual quality of the region or eliminate visual resources.

11.2.5 Water quality and hydrology

Like in the Katwe geothermal prospect discharge of the geothermal effluent into surface waters will change the surface water quality, including but not limited to temperature, dissolved oxygen concentration and turbidity. Release of the wastewater into cooling ponds and waterways may result in groundwater contamination and cause erosion and deposition of silica.

Operation will change the amount of surface water in any water body, result in alteration of surface water quality and the direction of flow of groundwaters. It will also cause changes in the quantity of groundwaters, either through direct additions or withdrawals. The activity is likely to substantially degrade water quality, contaminate public water supply, degrade or deplete groundwater resources, and interfere with groundwater recharge. It may also decrease the amount of water available for public water supplies.

11.2.6 Population, housing and employment

Operation will create 100 temporary jobs during construction of the power plant like in Katwe and 250 permanent jobs for daily operation and maintenance of the plant, surface flow equipment and wells. The influx of these people and their families will induce a substantial growth or concentration of the population. This may alter the location, distribution, density or growth rate of the human population of the area. It will affect the existing housing, or create a demand for additional housing. It may also conflict with the housing and population projections and policies set forth in the general plans for the area.

11.2.7 Transportation and traffic

Operation will increase the number of vehicles in the area and on a permanent basis unlike drilling. This may affect the general traffic safety of the area. Additional population and need for housing will alter the present patterns of circulation or movement of people and/or goods. This phase will cause an increase in traffic which is substantial in relation to the existing traffic load and may significantly impact intersection levels of services.

11.2.8 Air quality

In high temperature geothermal fields, power generation from a standard steam-cycle plant causes non-condensable gases and fine solid particles to be released into the atmosphere. The most predominant gases are CO_2 and H_2S. The discharge of the gases affects plants and animals directly, and could also affect the microclimate of the area by increasing fog, clouds or rain depending on the rainfall, topography and wind patterns. The Kibiro geothermal prospect is classified as a high temperature area and operation is likely to violate ambient air quality standards and create objectionable odours. It may alter air movement, moisture, or temperature, or result in changes in climate at local and/or regional level.

11.2.9 Public services

Operation will affect public services due to increased population in the area and the presence of the power plant. The increase in the number of vehicles will congest the parkland and impact on the locally accepted standard. The population increase will affect the existing school system, play school(s) or kindergarten(s), hospital(s), and amenities for the handicapped.

11.2.10 Utilities

Operation brings to the surface a large amount of waste fluid. The fluid is disposed of in waterways, evaporation ponds or reinjected back into the reservoir. The operation of the power plant requires a lot of potable water for the cooling towers and other apparatus in the plant. The activity will therefore generate a considerable amount of wastewater and solid waste which has to be disposed of. It will significantly increase the consumption of potable water and may breach the national and local standards relating to solid waste control and disposal of wastewater.

11.2.11 Energy

Operation will introduce a new type of energy source, geothermal energy, for electricity and direct heat and encourage activities which result in the use of substantial amounts of water and energy. This is likely to result in significant effects on other energy sources and may conflict with the existing energy standards of the area.

11.2.12 Public health and safety

Operation is likely to cause the discharge of wastewater that contains toxic chemicals like lithium (Li), boron (B), arsenic (As), hydrogen sulphide (H_2S), mercury (Hg), and sometimes ammonia (NH_3). Release of untreated wastewater into a waterway can result in chemical poisoning of fish, birds and animals, which reside near the water because some of the toxic substances move up the “food chain” causing biomagnification. If such a system is built in Kibiro geothermal prospect the main concern will be the effect on humans who use stream and river water for domestic supply. Land animals and aquatic organisms downstream rivers, wetlands and Lake Albert will also be affected.

Operation will involve hazards that the local population and those moving into the area have not been adequately warned against. The activity may expose people or property to water related hazards such as flooding and erosion. The main sources of erosion are a result of the disposal of wastewater from the power plant to the surface. It may create a risk that a TAC may at any time exceed the air pollution control threshold and result in unsafe conditions for employees, residents or surrounding neighbourhoods. The activity may generate some considerable noise that may conflict with the local noise standards leading to several kinds of disturbances.

11.2.13 Cultural situation

The Kibiro geothermal prospect is a tourist destination because of its hot springs, and a home to an important archaeological site that has been producing salt for generations. The area is also used for research on the heat and hydrocarbon potential of the rift valley. Operation will affect the social life of the area as a result of an influx of people from different cultural backgrounds. This may give rise to social problems such as, lack of housing, increased spread of disease, increased pressure on social services and cultural misunderstandings.

12. KIBIRO - MITIGATION MEASURES

12.1 Drilling

12.1.1 Geology

Drilling will take place on the plateau east of the escarpment. The topography is favourable for road construction and other earthworks and will not cause changes in the geology that may lead to serious problems like landslides and soil erosion. Re-vegetation with grass and trees on the cut slopes, fill slopes and drill pads should be considered to contain any possible erosion.

12.1.2 Land use

The Kibiro geothermal prospect is located on private farmland and the drilling activity will definitely affect the land use and plans adopted by the local government. The farmers whose land will be used for road construction and drilling will be entitled to compensation according to the appropriate legislation. Directional drilling of several wells from a single pad should be employed to minimise the area needed for pad and road construction. This will reduce the amount of land to be used for drilling wells compared to drilling them separately from different pads.

12.1.3 Biodiversity

The vegetation in the Kibiro prospect is generally grassland with scattered thorny thickets in the areas close to the escarpment and this is the part used by the pastoralists for grazing animals. Inland toward Kigorobya the vegetation is modified by the farmers into subsistence agriculture. The types of vegetation around the drill pads can be restored easily after the drilling operation and continue to be used for grazing and crop farming.

12.1.4 Visual and aesthetic quality

Visual quality may be diminished by loss of naturalness and the imposition of man-made structures like in the Katwe geothermal prospect. The scenery needs attention, since it is located on private farmland with settlements. The obstruction will be temporary during drilling and the natural beauty will be restored when the activity is completed and the rig is demobilised.

12.1.5 Water quality and hydrology

The source of water for drilling is River Kachururu which flows from Kigorobya to the Kachuru fault/valley and then to Lake Albert. River Kachururu has a flow rate of approximately 1.5 m^3/s which is enough to supply the drilling programme without affecting other water users. The amount of water used for drilling is enormous and although most of it is lost in the formation, the return fluid will be discharged into well designed sumps and re-circulated to keep water level in the sumps as low as possible. Discharge of such fluid on the surface or into waterways must be avoided to protect the quality of surface waters in the area.

12.1.6 Population, housing and employment

The increase in population due to the influx of migrant workers during drilling will be temporary and once the drilling is over, the population will return to original state. Drilling will not affect the housing facilities since the workers will be camping on site with all the resources and facilities provided.

12.1.7 Transportation and traffic

The heavy traffic will cause disturbance in the area by generating noise, dust and vehicular emissions. Increased traffic will cause traffic problems like jams and large quantities of dust along the Hoima –

Kigorobya road and in Kigorobya Town. However, the inconvenience will be temporary and normality will be restored after drilling is completed.

12.1.8 Air quality

The source of air pollution will be non-condensable gas emissions, exhaust smoke from generators, compressors and vehicles. The expected fugitive gases are NO_x, CO, SO_2 and hydrocarbons but their amounts could be small. During well testing, steam and spray can have an adverse effect on the vegetation with trees and grass being scalded. However, drilling is a temporary activity and no significant long-term air quality impacts are expected. Hydrogen sulphide, sulphur dioxide and possibly mercury in atmospheric air will need to be monitored during well testing.

12.1.9 Public services

The increased traffic during the drilling phase will require the designation of additional parkland in Kigorobya Town to remain in conformity with the locally acceptable standards. Additional law enforcement and fire protection staff, and equipment to maintain acceptable service ratios will be required and to check on the possible theft and outbreak of fires.

12.1.10 Utilities

Proper disposal systems need to be constructed for channelling the effluent fluid before it is recycled or disposed of. The activity will need the construction of a septic tank, effluent retention sumps, communication systems, water supply and drainage, and a landfill for solid waste disposal.

12.1.11 Energy

The source of energy for drilling will be from fossil fuels and will affect the demand for energy in the area. The problem could be solved by setting up a fuel supply station in the vicinity of the activity to avoid conflict with the existing energy standards at local and regional level.

12.1.12 Public health and safety

Accidental release of hazardous substances like oil and chemicals in the drilling fluids to the water cycle, and toxic gas emissions pose public health and safety problems. Care must be taken to keep such accidents to a minimum and where they occur measures should be taken to clean up the environment. The drilling activity, being temporary, is not expected to create a risk that the concentration of a TAC will exceed the air pollution control threshold.

The effects of using powerful lamps to light the drill site at night could be reduced by temporary screens and careful placement of lamps. The noise generated by drilling operations could be reduced to acceptable standards as suggested for the Katwe prospect. The drilling operation is a temporary measure and therefore light and noise effects will disappear after the rig has been removed from the site.

12.1.13 Cultural situation

Kibiro is undergoing similar exploration as Katwe for geothermal energy and hydrocarbons and therefore attracting a number of people from different cultural backgrounds. The nature of the exploration at this stage is on a temporary basis and does not warrant permanent settlement. Therefore the social effect on the community like competition for housing and services is temporary and once the drilling operation is over the area will revert to its original status.

12.2 Operation

Like in Katwe and other geothermal areas utilising geothermal resources, the Kibiro prospect should expect the most important environmental changes brought about by geothermal utilisation i.e. surface disturbances, physical effects due to fluid withdrawal, noise, thermal effects and the emission of chemicals, apart from the social and economic impacts that the construction of a geothermal power plant is bound to have.

12.2.1 Geology

The construction of a power plant in the case of the Kibiro geothermal prospect will not change the geology and topography of the area since it will be located on a plateau east of the escarpment. The spent fluid will be reinjected back into the reservoir and will not form mineral deposits on the surface that may obstruct or change the course of flow of surface waters.

12.2.2 Land use

The construction of pipelines, power plant, and switchyard will affect several hundreds of square meters of land like in the Katwe prospect. The power plant site has to be as close to the boreholes as possible to avoid cooling of the fluid during transportation from drill holes to the plant. Land use is usually not a big problem in geothermal development compared to hydropower because land around the installations especially pipelines will continue to be used. The land use may conflict with the current plans of the local government but could be adjusted through negotiations with the developer and other stakeholders.

12.2.3 Biodiversity

The impacts on flora and fauna caused by massive withdrawal of the fluid from the reservoir and disposal of the fluid into surface waters could cause changes in the ecosystem. This could be avoided by reinjecting the fluid into the reservoir. Reinjection is the only acceptable means of fluid disposal at the moment and also helps maintain reservoir pressures. Reinjection also solves the problem of the thermal heating of ground caused by leakage of the fluid in form of steam to the surface through fractures and faults as a result of reduced pore pressure in the reservoir.

12.2.4 Visual and aesthetic quality

A geothermal power plant must be located close to the resource, so there is often little flexibility in the siting of the plant like the one in the Katwe prospect. The visual intrusion in Kibiro could be reduced by painting the surface installations (e.g. the pipeline network and separators) and the power plant with the colour of their background. The background in the Kibiro prospect is green most of the year although the grass may change colour in the dry season. However, the modified human environment may temporarily interfere with the natural background especially during the planting season when the ground is bare in areas used for subsistence agriculture.

12.2.5 Water quality and hydrology

During the operation phase, impacts on the water quality of surface water or groundwater in shallow aquifers are not expected during normal production and reinjection practices like for the Katwe prospect. The reinjected fluid would be released to the geothermal reservoir, which is much deeper than the shallow groundwater system. Once this is done the quality of groundwater will be protected. Reinjection of spent fluids also helps maintain reservoir pressure, checks subsidence and drawdown and maintains the water table. It also enhances or maintains flow of the geothermal fluid in thermal features like hot springs.

12.2.6 Population, housing and employment

The influx of project workers and their families will have an impact on the existing housing and create a demand for additional housing which will conflict with the policies set forth in the general plans for the area. As a part of the project, therefore, housing facilities for staff need to be established to avoid conflict with the plans of the local government. On the positive side the project may result in increased employment opportunities for the area by making use of the local skills and therefore improving the incomes of the local people.

12.2.7 Transportation and traffic

Transportation during operations will be mainly for the workers that will be operating and maintaining the power plant. The building of new roads will open up the area to tourists and researchers who will be visiting the power plant, Lake Albert, and the Kibiro hot springs and the salt industry. These movements could increase traffic on the roads to a significant level and therefore needs further investigation.

12.2.8 Air quality

The release of gases into the atmosphere during operation, like in the Katwe prospect, could be minimised by standard countermeasures which include the following: reinjecting all the waste fluids, designing power stations to minimize gas discharges, and employing active monitoring systems to enable the power plants to be shut down or generation reduced if the amounts of the gas discharged exceed set levels.

12.2.9 Public services

The influx of workers and their families into the area, like in Katwe, will definitely affect public services which will have to be expanded to accommodate the increased population. The project will require additional law enforcement staff and equipment to maintain acceptable service ratios and additional fire protection staff or equipment. Additional land for car parks should be set aside to remain in conformity of the locally accepted standards. The existing school system will need to be expanded and new play school(s) or kindergarten(s) established. Additionally, there may be a need for a new hospital and amenities for the handicapped.

12.2.10 Utilities

Operation will generate waste from the activities going on in the power plant. Disposal facilities like landfills for solid waste need to be constructed and a water supply and treatment plant for potable water acquired. New systems will need to be built e.g. a septic tank, communication systems, and water supply and drainage lines. The national and local standards relating to solid waste control and disposal of wastewater need to be studied and implemented.

12.2.11 Energy

During operation a new type of energy source, geothermal energy, in the energy mix of the area that will conflict with the existing energy supplies will be introduced. This will be a healthy development since most of the population is using biomass and to a small extent fossil fuels as a source of energy. The geothermal energy will not only produce electricity but also boost the existing unreliable hydropower supply from the single hydropower source on the River Nile at Jinja. Additionally the geothermal power will be used in industry and agriculture for drying and processing purposes and will in this respect compete favourably with other sources of energy.

12.2.12 Public health and safety

During operation care will be taken not to release waste fluid to surface waters which may cause possible damage to biodiversity and the health of humans. All spent fluid will be reinjected and the TAC monitored not to exceed acceptable levels. Light and glare will be replaced by normal lights which will be permanent and environmentally acceptable like in any other town or settlement. Countermeasures for noise control will be effected as in the Katwe prospect to reduce the noise levels to at least 65 dBa. The Kibiro prospect is located in inhabited farmland and therefore the need to reduce noise levels.

12.2.13 Cultural situation

The opening up of the area with roads will have a positive impact on research and recreational activities in the area especially in the rift valley west of the escarpment. The influx of workers into the area will create employment and market for agricultural produce and other consumables which will improve the incomes of the local communities. The new people from the different cultural backgrounds will have to integrate into the new society and abide by local government standards and legislation.

13. KIBIRO - ASSESSMENT OF IMPACT SIGNIFICANCE

13.1 Impact significance without mitigation

The generic criteria used to describe magnitude and significance of impacts were described in Section 9 for the Katwe geothermal prospect and the same criteria were used for Kibiro. The rating results for the Kibiro geothermal prospect without impact mitigation are presented in Figure 24. The results like those for the Katwe prospect show that operation has greater impact on the environment than drilling.

13.1.1 Extent and spatial scale of the impact

The impacts of both operation and drilling are localized i.e. they are within the boundaries of the local area save for the impacts on energy which extend to regional level. The local area affected is Hoima district and parts of Masindi district (Figure 3).

A: CRITERIA		B: ENVIRONMENT AFFECTED	Geology	Land use	Biodiversity	Visual and aesthetic quality	Water quality and hydrology	Population, housing and employment	Transportation and traffic	Air quality	Public services	Utilities	Energy	Public health and safety	Cultural situation
	OPERATION	Extent or spatial scale of the impact	L	L	M	M	M	M	M	M	M	M	H	M	M
		Intensity or severity of impact	L	L	L	L	H	M	L	H	M	H	L	H	L
		Duration of the impact	L	H	H	H	H	H	H	H	H	H	H	H	H
		Mitigation potential	L	L	M	L	M	L	L	M	L	M	L	M	L
		Acceptability	M	M	M	M	M	M	M	M	M	M	M	M	M
		Degree of certainty	M	H	H	H	H	M	M	M	M	H	L	H	L
	DRILLING	Extent or spatial scale of the impact	L	L	M	M	M	M	M	M	M	M	H	M	L
		Intensity or severity of impact	L	L	L	L	M	L	H	M	L	M	M	M	L
		Duration of the impact	L	L	L	L	L	L	L	L	L	L	L	L	L
		Mitigation potential	L	L	L	M	M	L	M	M	L	M	M	M	L
		Acceptability	M	M	M	M	M	M	M	M	M	M	M	M	M
		Degree of certainty	M	H	M	H	M	L	H	M	L	M	M	M	L

KIBIRO PROSPECT
NOTE:
Impact Magnitude & Significance Rating
(without mitigation)
H: High
M: Medium
L: Low

FIGURE 24: Kibiro, impact significance rating (without mitigation)

13.1.2 Intensity or severity of impact

The intensity is high for impacts of operation on water quality and hydrology; air quality; utilities; and public health and safety, and medium rated for impacts on population, housing and employment; and public services. The rest of the impacts on geology; land use; biodiversity; visual and aesthetic quality; transportation and traffic; energy; and cultural situation are rated as low. The impacts of drilling on water quality and hydrology; air quality; utilities; energy; and public health and safety are rated as medium while impacts on geology; land use; biodiversity; visual and aesthetic quality; population, housing and employment; public services and cultural situation are rated as low. Only impacts of transportation and traffic are highly rated for drilling.

13.1.3 Duration of the impacts

All the impacts of operation save for geology are highly rated i.e. they are long-term impacts that may persist for more than 15 years of the plant operation or utilization. The impacts on geology are short term i.e. occurring within the construction period of the plant. The duration of the drilling impacts on the environment is short and limited to the drilling period and/or to a few years after the completion of the drilling phase in the case of some persistent impacts.

13.1.4 Mitigation potential

Most of the impacts on the environment are rated as low i.e. have high mitigation potential and can be reduced to a level of insignificance. They include impacts on geology; land use; visual and aesthetic quality; population, housing and employment; transportation and traffic; public services; energy and cultural situation for operation, and geology; land use; biodiversity; population, housing and employment; public services; and cultural situation for the drilling phase. Impacts on biodiversity; water quality and hydrology; air quality; utilities; and public health and safety for operation are rated as medium i.e. mechanisms exist to mitigate against such adverse impacts. Similarly, drilling impacts on visual and aesthetic quality; water quality and hydrology; transportation and traffic; air quality; utilities; and public health and safety are also medium rated.

13.1.5 Acceptability

All the impacts for both operation and drilling are rated as medium, i.e. manageable with regulatory control and project proponent's commitment.

13.1.6 Degree of certainty

There is a higher degree of certainty that most impacts are likely to occur during operation than drilling. Impacts with a high degree of certainty for occurrence during operation i.e. 70% likelihood are impacts on land use; biodiversity; visual and aesthetic quality; water quality and hydrology; utilities; and public health and safety. With medium certainty i.e. between 40 and 70% likelihood of occurring are impacts on geology; population, housing and employment; transportation and traffic; air quality; and public services. The rest with low certainty i.e. less than 40% likelihood are impacts on energy and the cultural situation.

For drilling, impacts on land use; visual and aesthetic quality; transportation and traffic have a high certainty while impacts on geology; biodiversity; water quality and hydrology; air quality; utilities; energy; and public heath and safety are rated as medium. The rest of the impacts i.e. on population, housing and employment; public services and the cultural situation are rated as low with less that 40% probability of occurring and, therefore, not likely to pose any risk to public wellbeing.

13.2 Impact significance with mitigation

The rating results for the Kibiro geothermal prospect with impact mitigation are presented in Figure 25. The results show that the operation phase still has a greater impact on the environment than the drilling phase. Mitigation reduces most of the impacts with high rating to medium and low rating and those with medium to low rating. However the presence of impacts in the medium rating category suggests that mitigation is not easily achieved and calls for additional commitment to minimize the magnitude of the impacts to acceptable levels.

13.2.1 Extent and spatial scale of the impact

The impacts of both operation and drilling are localized i.e. they are within the boundaries of the local area. Impacts of operation on geology; land use; biodiversity; visual and aesthetic quality; water quality and hydrology; air quality; public services; utilities; and public health and safety are reduced to the area within the site boundaries while impacts on population, housing and employment; transportation and traffic; energy; and cultural situation may cross the site boundaries but are still within the local area. All the impacts of drilling save for the impacts on land use, and transportation and traffic, are contained within the site boundaries. The impacts on land use, and transportation and traffic, may cross the site boundaries but are still within the local area.

A: CRITERIA	B: ENVIRONMENT AFFECTED	Geology	Land use	Biodiversity	Visual and aesthetic quality	Water quality and hydrology	Population, housing and employment	Transportation and traffic	Air quality	Public services	Utilities	Energy	Public health and safety	Cultural situation
OPERATION	Extent or spatial scale of the impact	L	L	L	L	L	M	M	L	L	L	M	L	M
	Intensity or severity of impact	L	M	M	L	M	L	L	M	L	M	L	M	L
	Duration of the impact	L	L	M	L	M	L	L	M	L	L	M	M	L
	Mitigation potential	L	L	M	L	M	L	L	M	L	M	L	M	L
	Acceptability	L	M	M	L	M	L	L	M	L	M	L	M	L
	Degree of certainty	L	L	M	L	M	L	L	M	L	M	L	M	L
DRILLING	Extent or spatial scale of the impact	L	M	L	L	L	L	M	L	L	L	L	L	L
	Intensity or severity of impact	L	M	L	L	L	L	L	L	L	M	L	L	L
	Duration of the impact	L	L	L	L	L	L	L	L	L	L	L	L	L
	Mitigation potential	L	L	L	L	L	L	L	L	L	L	L	L	L
	Acceptability	L	M	M	L	M	L	M	L	L	L	L	M	L
	Degree of certainty	L	L	M	L	M	L	M	L	L	M	L	M	L

KIBIRO PROSPECT
NOTE:
Impact Magnitude & Significance Rating
(with mitigation)
H: High
M: Medium
L: Low

FIGURE 25: Kibiro, impact significance rating (with mitigation)

13.2.2 Intensity or severity of impact

Mitigation reduces the intensity of the impacts of operation on land use; biodiversity; water quality and hydrology; air quality; utilities; and public health and safety to medium, while impacts on geology; visual and aesthetic quality; population housing and employment; transportation and traffic; public services; energy; and the cultural situation have a low rating. The intensity of all impacts of drilling is reduced to a low rating with mitigation except impacts on land use and utilities which remain at a medium rating.

13.2.3 Duration of the impact

Mitigation reduces the rating of impacts of operation on biodiversity; water quality and hydrology; air quality; energy; and public health and safety to medium, and impacts on geology; land use; visual and aesthetic quality; population, housing and employment; transportation and traffic; public services;

utilities; and cultural situation to low. The duration of the drilling impacts on the environment is short-term and is limited to the drilling period and/or to a few years after the completion of the drilling phase for some persistent impacts.

13.2.4 Mitigation potential

All potential drilling impacts on the environment are rated as low with mitigation i.e. have high mitigation potential and can be reduced to the level of insignificance. Implementation of mitigation measures may still not prevent some negative impacts on biodiversity; water quality and hydrology; air quality; utilities; and public health and safety for operation. The operation therefore must effect measures to minimize the impacts to acceptable levels.

13.2.5 Acceptability

Mitigation reduces impacts of operation on geology; visual and aesthetic quality; population, housing and employment; transportation and traffic; public services; energy and cultural situation to acceptable levels i.e. with no risk to public wellbeing. Other impacts i.e. on land use; biodiversity; water quality and hydrology; air quality; utilities; and public health and safety can still be managed to a level that does not pose a risk to public wellbeing.

For the drilling phase, impacts on geology; visual and aesthetic quality; population, housing and employment; air quality; public services; utilities; energy; and the cultural situation are acceptable, while the rest of the impacts i.e. on land use; biodiversity; water quality and hydrology; transportation and traffic; and public health and safety are manageable.

13.2.6 Degree of certainty

Mitigation reduces potential impacts of operation on biodiversity; water quality and hydrology; air quality; utilities; and public health and safety to a medium level of certainty i.e. between 40 and 70% likelihood of occurring. Other impacts i.e. on geology; land use; visual and aesthetic quality; population, housing and employment; transportation and traffic; public services; energy; and the cultural situation are reduced to a level that poses no risk to public wellbeing.

For drilling, impacts on biodiversity; water quality and hydrology; transportation and traffic; utilities; and public health and safety are reduced to a medium level of certainty. The rest of the impacts i.e. on geology; land use; visual and aesthetic quality; population, housing and employment; air quality; public services; energy; and the cultural situation are reduced to a level that will not pose a risk to public wellbeing.

14. IMPORTANCE OF ENVIRONMENTAL IMPACTS

The study has focused on the identification of potential impacts for drilling and operation on the environment affected. The impacts have been identified and discussed using a variety of methods, and their magnitude and significance predicted using the available information. From the various impacts that were identified, there are five critical areas that should be subjected to detailed investigation during the detailed impact assessment. These are impacts on biodiversity; water quality and hydrology; air quality; utilities; and public health and safety. The impacts on these areas or categories have been found to be persistent during operation even with mitigation and detailed studies need to be carried out to better understand the potential impacts and measures initiated to minimise their effects.

Other impacts i.e. on geology; land use; visual and aesthetic quality; population housing and employment; transportation and traffic; public services; energy; and the cultural situation, are not considered to be of critical importance since they have a high mitigation potential. However, they should be taken further during the detailed impact assessment, with specialist input being obtained where necessary.

Analysis of the potential impacts of drilling on all categories of the environment reveals that all the impacts are mitigable with the most appropriate technology. They also need to be taken further during the detailed impact assessment and the best solutions sought.

15. TERMS OF REFERENCE FOR DETAILED IMPACT ASSESSMENT

This section provides an overview of the process to be used during the assessment of environmental impacts for the development of Katwe and Kibiro geothermal prospects. The process draws on the potential impacts identified during the study and discussed in the previous sections. The terms of reference will focus on the specialist studies on the five critically important areas i.e. impacts on biodiversity; water quality and hydrology; air quality; utilities; and public health and safety. Other impacts i.e. on geology; land use; visual and aesthetic quality; population housing and employment; transportation and traffic; public services; energy; and the cultural situation will also be included in the terms of reference for a detailed study although they are classified as less important.

15.1 Specialist studies

The details of the specialist studies provided below provide a broad perspective on the issues identified. Each specialist study will be required to generate detailed Terms of Reference and Scope of Work Documents which include study methodologies. Due to the nature of the issues raised some of the specialist studies will be conducted in more detail than others.

15.1.1 Biodiversity

The biodiversity study needs to address aspects related to flora and fauna. In the study the following matters that are relevant to the proposed development should be considered:

- The general character of the existing site in terms of fauna and flora and their habitats i.e. lakes, rivers, forests and bushes;
- The natural history of the site; the importance of the area in national, regional and local terms;
- The consistence of the proposed development with any relevant statutory instruments, planning policies, heritage orders or international conventions (protecting say, wetlands, migratory birds, or threatened or endangered species);
- Present use of the area by natural history societies, researchers, tourists, and so on;
- The possible effects of the proposed development on land species (plants and animals); aquatic species (fauna and fish); on habitats; on natural resources such as lakes, forest, swamps; including the possible effects on noise;
- Primary and secondary impacts, temporary and long-term, unavoidable impacts and risks, synergism, possible irreversible changes;
- The possible mitigation of effects by technical or financial measures, by redesigning;
- The existing and likely future amenities in the neighbourhood;
- Other related developments in the area which might have a cumulative impact on biodiversity.

15.1.2 Water quality and hydrology

The water study will need to address aspects related to groundwater and surface water contamination as well as, water resource availability. In this study the following should be considered:

- Characteristics of the water resources at risk: rivers, lakes, streams, aquifers and aquifer recharge areas; topography and ecological characteristics; seasonal and annual flows; rainfall and runoff and other features;
- Use of the present water resources: domestic, commercial, and industrial, agricultural or recreational;
- Pending developments for water resources likely to affect the present and future scenarios;
- Identified sources of waste discharges from the drilling rig and power plants with and without mitigation;

- The significance of the likely emissions, specific pollutants by toxic substances, minerals, heavy metals, sludges, oil, sewage, suspended and dissolved solids;
- The likely effects on fish, wildlife, communities and vegetation;
- Provide a detailed evaluation of all effluents from the drilling rig and power plants and their impacts on the environment affected;
- Conduct a water contamination study which should include an ecological and a toxicological assessment of downstream areas from the proposed development sites;
- Incorporated into the water study should also be any potential future water requirements;
- The results of the discussion at scoping meetings with individual groups, and with authorities, on the general and specific effects of the proposed development about water quality and quantity;
- The implications for other water users.

15.1.3 Air quality

The specialist study will need to address the generation and subsequent dispersion of air pollution from the power plants. The study should entail:

- A description of the drilling process with respect to the pollutants released into the atmosphere;
- A description of the power generation process with respect to the pollutants released into the atmosphere;
- A discussion on the human health implications and environmental concerns from the pollutants released with particular focus on NO_x, CO, SO_2 and hydrocarbons from drilling; and CO_2, H_2S, H_2, N_2, NH_3, CH_4 and C_2H_6, trace amounts of Hg and B vapour, and helium (He) and radon (Rn) from operation:
- An emissions inventory during operation of the power plants, together with all data needed for dispersion modelling indicating gas ejector releases, temperatures etc.;
- A description of the meteorological characteristics of the prospects and identification of possible abnormal atmospheric conditions. This should include wind speed and direction, temperature, cloud cover, surface temperature and land use;
- A discussion of the predictions in relation to relevant Uganda Air Pollution guidelines, as well as international standards;
- All model inputs should be recorded in a specialist report;
- A description of the likely impacts of “greenhouse” gas emissions;
- A detailed discussion and identification of pollution abatement and mitigation strategies that are apparent from the study.

15.1.4 Utilities

The study should address all issues related to disposal and treatment of waste and wastewater from the drilling rig and power plants. The study should specifically consider the following elements:

- The different types of sewage disposal systems and facilities i.e. reinjection wells, sewage treatment plant, septic tank, landfills and other systems that are relevant to the development;
- The consistency of the proposed disposal mechanism with national, regional or local planning instruments, the relationship with neighbouring residential and tourist areas;
- The type of waste to be disposed of (geothermal spent fluids, industrial, domestic and etc.);
- The quantity of waste involved per day, month and year;
- The layout of the disposal systems;
- The possible impact of the disposal systems to groundwater and surface and potable water;
- Measures to improve the quality of the effluent discharged into the systems;
- Proposals for the monitoring of the systems;
- Proposals to educate users in sound environmental practices.

- The existing environment: physical site characteristics; climatological and meteorological conditions; geological and hydrological conditions; present land use of the site and surroundings; any other particular characteristics;
- Prospective future developments in the same locality which might suggest incompatibilities.

15.1.5 Public health and safety

The study should address all issues related to public health and safety. In the study the following should be considered:

- Evaluation of infrastructure requirements necessary to meet the demands of an increased labour force. These should include housing, clinics and hospitals, domestic waste management, water usage and demand and transportation;
- Consideration of potential increases in conflicts to influx of people seeking employment that are from outside the areas;
- Identification of both direct and indirect benefits which will be derived from the proposed development;
- Identification and discussion of any opportunities to maximise or reduce the positive or negative impacts through the above studies;
- The noise levels from the proposed development in relation to the ambient conditions of site and surroundings;
- The odours likely to emanate from the activity;
- The risks and hazards of the activity: expected discharge of harmful gases to the atmosphere, disposal of spent fluids from the power plants, sewage discharge, floods and etc.;
- Cumulative effects of other developments in the region or locality, for example, effects on safety of drinking water;
- Other effects likely to have a negative impact on physical or mental well-being such as split communities, ecological damage, bright night-lighting, overhead transmission lines, surface pipelines, deterioration of visual environment, local businesses in some cases and etc.;
- Mitigation measures proposed for the adverse impacts of the development and proposals for monitoring of effects on health;
- Incorporation of environmental health standards in development consent conditions; annual reporting requirements to the environmental, planning, and public health agencies.

15.2 Impact description

Based on the outcome of the various Specialist Studies, an integrated Environmental Impact Statement (EIS) will be prepared which will ensure that comprehensive and holistic reviews of the impacts associated with the proposed geothermal development have been addressed. The significance of the impacts will be based on the following criteria:

- *Nature of the impact* – This is an appraisal of the type of effect the activity would have on the environment affected. It is either classified as positive or adverse.
- *Extent* – This indicates whether the impact will be local extending only as far as the activity, will be limited to the site and its immediate surroundings, will have an impact on the region or on a national scale.
- *Intensity* – This establishes whether the impact is destructive or benign and should be indicated as low, medium or high. For example impact on the natural, cultural or social functions of a community.

  low - where the impact affects the environment in such a way that natural, cultural or social functions are not affected;

  medium – where the affected environment is altered but natural, cultural and social functions continue albeit in a modified way;

high - where natural, cultural or social functions are altered to such an extent that it will temporarily or permanently cease.

- *Duration* - This indicates the lifespan of the impact. Classified as follows: short term (e.g. 0-5 yrs); medium term (e.g. 5-15 yrs); and long term – where the impact will cease after the operational life of the activity either by natural processes or by human intervention.
- *Mitigation potential* - This indicates the scale of the potential to mitigate impacts. Classified as follows: High – if the negative impacts can be mitigated against to a level of insignificance; Medium – if the implementation of mitigation measures may still not prevent some negative effects; and Low – if little or no mechanism to mitigate against negative impact.
- *Acceptability* – The degree to which the management of impacts is acceptable to the stakeholders. Classified as follows: Unacceptable – abandon project in part or in its entirety, redesign project to remove or avoid impact; manageable – with regulatory controls or with project proponent's commitments; acceptable – no risk to public health.
- *Degree of certainty or probability* – This describes the likelihood of the impact actually occurring and is indicated as:
  improbable – where the probability of the impact is very low;
  probable – where there is a distinct possibility that the impact will take place;
  highly probable – where it is likely that the impact will take place;
  definite – where the impact will take place regardless of any prevention measures.

Impacts will be described both before and after the proposed mitigation measures have been implemented.

16. CONCLUSIONS

In conclusion this study has revealed a number of important points about the future of geothermal development in Uganda, and about Katwe and Kibiro geothermal prospects in particular. They are summarised as follows:

- Geothermal energy is environmentally friendly compared to that produced from fossil fuels, such as coal, oil and natural gas. Among other alternative sources of energy, geothermal energy is still environmentally benign compared to for example hydropower for electricity generation. Its impacts are predictable and mitigable with the most appropriate technology.
- A comparison of geothermal energy with other alternatives indicates that geothermal energy is the least cost option. It has the lowest investment cost and the lowest energy cost which is expected to decrease in future with improved technology. It has also the highest capacity factor.
- A multidisciplinary approach to surface exploration is good for locating areas for feasibility studies. Such approach has been applied successfully in the Kibiro prospect where the anomaly located by all disciplines tends to coincide or converge in the same area. The development area, therefore, coincides with low resistivity and high gravity measurements from geophysics, area of surface manifestations and faults mapped by geochemistry and geology, and the likely source of the geothermal fluids mapped by hydrology with the use of environmental isotopes.
- The potential environmental impacts for the two geothermal systems have been identified. The likely environmental impacts, their magnitude and significance were analysed and mitigation measures proposed. The results indicate that the Katwe prospect already has more impacts on the environment than the Kibiro prospect because of the industrial activities in its vicinity. Its development, therefore, has a potential for indirect and cumulative environmental impacts as well as impact interactions.
- Operation has more impact on the environment that drilling. This is because operation is a long-term process and its impacts accumulate with time while drilling is a temporary venture and has no longer-term impacts. The likely impacts of drilling on the environment affected were found to be temporary and mitigable to the level of insignificance in both Katwe and Kibiro.
- Assessment of adverse impacts of operation on the environment affected has identified five critical areas that should be subjected to detailed investigation. These are impacts on biodiversity; water quality and hydrology; air quality; utilities; and public health and safety. Implementation of mitigation measures may still not prevent some negative impacts on these areas. The operation, therefore, must effect measures to minimise the impacts to acceptable levels.
- Other likely impacts of operation on geology; land use; visual and aesthetic quality; population, housing and employment; transportation and traffic; public services; energy; and cultural, are not considered to be of critical importance since they have a high mitigation potential. However, they should also be taken further during the detailed environmental impact assessment, with specialist input being obtained where necessary.
- Continuous assessment and mitigation of environmental impacts for the development of the two areas Katwe and Kibiro should not be left to the developer alone but needs the cooperation of all stakeholders. Stakeholder consultation is a way forward at all stages of development and review of the EIS.
- EIA is a tool for decision-making and therefore it should be a continuous process. EIA should be implemented at an early stage of the planning and design. It should be an integral component in the design of projects, rather than something utilised after the design phase is completed. Preferably it should be a part of an incremental decision-making process which has a number of decision-points in the project planning procedure. In this way it helps the developer to choose the project design which emphasizes benefits and minimises harmful effects. The EIA should not end with planning process but has to continue being implemented and the EIS continuously upgraded during the project execution.

17. RECOMMENDATIONS

From the results of this study the following recommendations are made:

- A detailed EIA should be carried out as early as possible i.e. before the feasibility study as required by the Ugandan laws on the environment.
- Alternative sources of energy to geothermal were discussed in the study i.e. hydropower, thermal, biomass, solar, wind, mini and micro hydro. These alternatives need to be studied in the detailed EIA and their capacity and potential environmental impacts weighed against geothermal energy especially in the study areas.
- Katwe geothermal prospect was found to have a potential for indirect and cumulative environmental impacts as well as impact interactions when taken together with other industrial activities in the area that include Katwe salt works in Lake Katwe, Lake Katwe salt factory if revived, Muhokya kaolin works, KCCL, Kilembe mines, RECO industries, Hima cement factory and etc. The combined cumulative impacts need to be investigated in the detailed EIA for the prospect.
- Utilization of geothermal energy for electricity is always accompanied by excess heat that is dissipated to the environment mainly in the spent fluids and vapour. Such heat could be used as direct heat in agricultural processing and in industry and therefore increasing the efficiency of the generation process. The possibility of direct utilisation of geothermal and recovery of minerals from the brines needs to be investigated and their environmental impacts assessed in the detailed EIA.

NOMENCLACTURE

Acronyms

ADB	African Development Bank
ARGEO	African Rift Geothermal Facility
DRC	Democratic Republic of Congo
DWD	Directorate of Water Development
EARS	East African Rift System
EC	European Community
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
GEF	Global Environment Fund
GoU	Government of Uganda
GTZ	Germany Technical Cooperation
IAEA	International Atomic Energy Agency
IPP	Independent power producers
IRN	International Rivers Network
IUCN	International Union for Conservation of Nature and Natural Resources
JEEP	Joint energy and environment projects
KCCL	Kasese Cobalt Company Limited
KKVF	Katwe Kikorongo Volcanic Field
LML	Local meteoric line
MEMD	Ministry of Energy and Mineral Development
NAPE	National Association of Professional Environmentalists
NEAP	National Environment Action Plan
NEMA	National Environment Management Authority
NGO	Non governmental organisation
OPEC	Organisation of Petroleum Exporting Countries
PEPD	Petroleum Exploration and Production Department
PPA	Power purchase agreement
QENP	Queen Elizabeth National Park
TAC	Toxic air contaminant
UAERAUS	Uganda Alternative Energy Resources Assessment and Utilisation Study
UNDP	United Nations Development Programme
UNESCO	United Nations Education, Scientific and Cultural Organisation
UNICEF	United Nations International Children Emergency Fund
UPE	Universal primary education
UWA	Uganda Wildlife Authority
WB	World Bank
WML	World meteoric line

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APPENDIX A: Environmental interaction matrix used for assessment of drilling and operations for the Katwe geothermal prospect (based on manual, EIA, Australia, 1985)

A: CHARACTERISTICS OF THE PROPOSED DEVELOPMENT		B: CHARACTERISTICS OF THE EXISTING ENVIRONMENT	Geology	Land use	Biodiversity	Visual and aesthetic quality	Water quality and hydrology	Population, housing and employment	Transportation and traffic	Air quality	Public services	Utilities	Energy	Public health and safety	Cultural situation
	OPERATION	Land clearing		✓	✓										
		Earthworks	✓	✓	✓	✓		✓	✓	✓	✓		✓		
		Disposal systems (including landfills)		✓	✓		✓			✓		✓		✓	
		Location of building or works		✓	✓	✓				✓				✓	
		Power plant construction		✓		✓		✓	✓		✓		✓		
		Raw materials					✓		✓			✓			
		Water demand					✓					✓		✓	
		Equipment operation					✓	✓		✓	✓			✓	
		Labour requirements						✓			✓			✓	✓
		Transport requirements						✓	✓				✓	✓	
		Potential emergencies (including hazards)			✓		✓			✓				✓	
		Landscaping	✓												✓
	DRILLING	Earthworks (including road construction)	✓	✓		✓				✓	✓		✓	✓	
		Raw materials inputs							✓			✓	✓		
		Storage						✓			✓				
		Water demand			✓		✓					✓		✓	
		Waste disposal			✓		✓			✓		✓		✓	
		Demand for services							✓		✓			✓	
		Labour requirements						✓			✓				
		Traffic movements							✓	✓			✓	✓	✓
		Transport requirements						✓	✓						
		Potential emergencies (including hazards)			✓					✓				✓	
		Landscaping	✓			✓									✓

NOTE:

A: Actions which are part of the development project

B: Characteristics of the environment affected

✓ Where a characteristic of the existing environment is potentially affected by a characteristic of the proposed development. This indicates likely environmental interactions.

APPENDIX B: Checklist used for environmental assessment of drilling and operations for the Katwe geothermal prospect (based on Roberts, 1991)

Environmental impacts	Drilling			Operation		
	Yes	Maybe	No	Yes	Maybe	No
1. GEOLOGY. Will the proposed activity:						
a. Expose people, structures, or property to major geologic hazards such as earthquakes, landslides, or ground failure?			✓			✓
b. Result in unstable earth conditions or changes in geologic substructure?			✓			✓
c. Result in disruptions, displacements, compaction or over-covering of the soil?			✓			✓
d. Result in changes in topography or ground surface relief features?	✓			✓		
e. Destroy, cover, or modify any unique geologic or physical features?	✓			✓		
f. Increase wind or water erosion of soils, either on or off the site?			✓			✓
g. Result in changes in deposition or erosion or changes which may modify the channel of a river or stream or bed of any bay, inlet or lake?			✓		✓	
h. Be located within a known active fault zone, or an area characterised by surface rupture that might be related to a fault?	✓			✓		
i. Affect substrate consisting of material that is subject to liquefaction in the event of ground shaking or other secondary seismic hazards?			✓			✓
j. Possibly cause hazards, such as landslides on steep slopes, which could result in slope failure?			✓			✓
k. Be located in the vicinity of soil that is likely to collapse, as might be the case with karst topography, old mine properties or areas of subsidence caused by groundwater drawdown?			✓			✓
l. Expose soils characterised by shrink/swell potential in a way that might result in deformation of foundations or damage to structures?			✓			✓
m. Be located in a zone identified or designated as important farmland?			✓			✓
n. Affect mineral or other deposits in the area?			✓		✓	
2. LAND USE. Will the proposed activity:						
a. Conflict with adopted environmental plans and goals of communities where it is located?	✓			✓		
b. Convert prime agricultural land to non-agricultural use, or impair the agricultural productivity of prime agricultural land?			✓			✓
c. Result in the conversion of open space into urban or suburban scale uses?			✓		✓	
d. Conflict with local general plans, community plans, or zoning?	✓			✓		
3. BIODIVERSITY. Will the proposed activity:						
a. Cause a fish or wildlife population to drop below self-sustaining levels?			✓		✓	
b. Threaten to eliminate a plant or animal community?			✓			✓
c. Substantially affect, reduce the number, or restrict the range of unique, rare, or endangered species of animal or plant, or the habitat of that species?			✓		✓	
d. Substantially diminish or reduce habitat for fish, wildlife, or plants?			✓		✓	
e. Interfere substantially with the movement of any resident or			✓		✓	

Environmental impacts	Drilling			Operation		
	Yes	Maybe	No	Yes	Maybe	No
migratory fish or wildlife species?						
f. Change the diversity of species, or the number of any species of plants (including trees, shrubs, grass, crops, and aquatic plants) or animals (birds, land animals including reptiles, fish and shellfish, benthic organisms or insects)?		✓			✓	
g. Introduce new species of plants or animals into an area, or become a barrier to the normal replenishment of existing species?		✓			✓	
h. Cause reduction in acreage of any agricultural crop?			✓			✓
i. Increase the rate of use of any natural resources?	✓				✓	
j. Cause deterioration of existing fish or wildlife habitat?			✓		✓	
k. Adversely affect significant riparian lands, wetlands, marshes, or other wildlife habitats?			✓		✓	
4. VISUAL AND AESTHETIC QUALITY. Will the proposed activity:						
a. Have a substantial, demonstrable negative aesthetic effect?		✓			✓	
b. Result in the obstruction of any scenic view open to the public, or result in the creation of an aesthetically offensive site open to public view?		✓			✓	
c. Interfere with local guidelines or goals related to visual quality?		✓		✓		
d. Significantly change the existing visual quality of the region or destroy visual quality of the region or eliminate visual resources?		✓			✓	
5. WATER QUALITY AND HYDROLOGY. Will the proposed activity:						
a. Substantially degrade water quality?		✓			✓	
b. Contaminate a public water supply?		✓			✓	
c. Substantially degrade or deplete groundwater resources?		✓			✓	
d. Interfere substantially with ground water recharge?		✓			✓	
e. Cause substantial flooding, erosion, or siltation?		✓				✓
f. Result in changes in absorption rates, drainage patterns, or the rate and amount of surface runoff?			✓		✓	
g. Alter the course of flow of flood waters?			✓			✓
h. Change the amount of surface water in any water body?	✓			✓		
i. Cause discharge into surface waters, or result in any alteration of surface water quality, including but not limited to temperature, dissolved oxygen or turbidity?	✓			✓		
j. Alter the direction or rate of flow of groundwaters?			✓	✓		
k. Cause change in the quantity of groundwaters, either through direct additions or withdrawals?		✓		✓		
l. Substantially reduce the amount of water otherwise available for public water supplies?		✓			✓	
m. Expose people or property to water related hazards such as flooding?			✓			✓
n. Interfere with other proposed facilities that would be located in flood-prone areas?			✓			✓
6. POPULATION, HOUSING AND EMPLOYMENT. Will the proposed activity:						
a. Induce substantial growth or concentration of population?		✓		✓		
b. Affect the average age of the population?		✓				✓
c. Displace a large number of people?			✓			✓
d. Alter the location, distribution, density or growth rate of the human population of an area?			✓		✓	

Environmental impacts	Drilling			Operation		
	Yes	Maybe	No	Yes	Maybe	No
e. Affect existing housing, or create a demand for additional housing?			✓	✓		
f. Conflict with the housing and population projections and policies set forth in the general plan?			✓	✓		
7. TRANSPORTATION AND TRAFFIC. Will the proposed activity:						
a. Cause an increase in traffic which is substantial in relation to the existing traffic load (volume) and capacity of the street system?	✓				✓	
b. Generate substantial additional vehicular movement?	✓				✓	
c. Affect existing parking facilities, or demand for new parking?			✓			✓
d. Substantially impact existing transportation systems?			✓			✓
e. Alter present patterns of circulation or movement of people and/or goods?		✓		✓		
f. Alter waterborne, rail or air traffic?			✓			✓
g. Generate a need for harbour facilities?			✓			✓
h. Cause roads to be built that improve communication between areas?	✓			✓		
i. Move traffic away from towns or villages?		✓			✓	
j. Affect the general traffic safety?	✓			✓		
k. Significantly impact intersection levels of services which are or will be below acceptable levels?		✓			✓	
l. Provide inadequate parking and internal circulation capacity to accommodate project traffic so that neighbouring areas are adversely affected?		✓				✓
8. AIR QUALITY. Will the proposed activity:						
a. Violate any ambient air quality standards?		✓			✓	
b. Result in substantial air emissions or deterioration of ambient air quality through e.g. suspended dust?		✓			✓	
c. Create objectionable odours?		✓			✓	
d. Alter air movement, moisture, or temperature, or result in any change in climate, either locally or regionally?		✓			✓	
e. Hamper visibility?		✓				✓
9. PUBLIC SERVICES. Will the proposed activity:						
a. Require additional law enforcement staff and equipment to maintain acceptable service ratios?	✓			✓		
b. Require additional fire protection staff or equipment to maintain an acceptable level of service?	✓			✓		
c. Require expansion of the existing school system?			✓	✓		
d. Affect or require the designation of substantial additional parkland to remain in conformity with locally acceptable or adopted park standards?	✓				✓	
e. Require additional hospital(s)?			✓		✓	
f. Require building for old people?			✓			✓
g. Require the establishment of playschool(s), kindergartens(s)?			✓	✓		
h. Require additional amenities for the handicapped?			✓		✓	
i. Affect museums in the area?			✓			✓
10. UTILITIES. Will the proposed activity:						
a. Breach published national, state, or local standards relating to solid waste control?		✓			✓	
b. Require extension of a sewer trunk line with capacity to serve new development?		✓			✓	

Environmental impacts	Drilling			Operation		
	Yes	Maybe	No	Yes	Maybe	No
c. Result in a need for new systems, or substantial alterations to the following utilities: i) power or natural gas; ii)communication systems; iii) water; iv)sewer or septic tank; v)storm water drainage; and vi) solid waste disposal?	✓			✓		
d. Cause significant increase in the consumption of potable water?	✓			✓		
e. Require substantial expansion of water supply treatment and distribution capacity?			✓	✓		
f. Require substantial waste-water disposal?	✓			✓		
g. Produce solid waste in excess of available landfill capacity?	✓			✓		
11. ENERGY. Will the proposed activity:						
a. Result in significant irreversible environmental changes including uses of non-renewable resources during the initial and continued phases of the project?			✓			✓
b. Result in significant effects on local and regional energy supplies or on requirements for additional capacity?	✓			✓		
c. Result in significant effects on peak and base period demands for electricity and other forms of energy?			✓			✓
d. Conflict with existing energy standards?		✓			✓	
e. Result in significant effects on energy resources?	✓			✓		
f. Encourage activities which result in the use of substantial amounts of fuel, water and energy?	✓			✓		
g. Cause and increase in the use of fossil fuels?	✓					✓
h. Cause an increase in the use of sustainable energy sources?			✓	✓		
i. Substantially increase demand upon existing sources of energy, or require the development of new sources of energy?		✓				✓
12. PUBLIC HEALTH AND SAFETY. Will the proposed activity:						
a. Involve hazards that the indigenous population and those moving to the area have not been adequately warned against?	✓			✓		
b. Create a potential health hazard (including mental health), or involve the use, production, or disposal of materials which pose a hazard to people or animal or plant populations in the area affected?	✓			✓		
c. Create a risk of explosion or release of hazardous substances (including, but not limited to, oil, pesticides, chemicals or radiation) in the event of an accident?	✓			✓		
d. Pose a public health and safety hazard through release of toxic emissions?	✓			✓		
e. Create a risk that the concentration of a toxic air contaminant (TAC) may at any time exceed the Air Pollution Control threshold level?		✓			✓	
f. Significantly increase light and glare in the project vicinity?	✓					✓
g. Result in unsafe conditions for employees, residents, or surrounding neighbourhoods?		✓			✓	
h. Expose people or property to water related hazards such as flooding?			✓		✓	
i. Interfere with other proposed facilities that would be located in			✓			✓

Environmental impacts	**Drilling**			**Operation**		
	Yes	Maybe	No	Yes	Maybe	No
flood-prone areas?						
j. Enhance impact of the proposed facilities that would increase off-side flood hazard, erosion or sedimentation?			✓			✓
k. Increase substantially the ambient noise levels in adjoining areas?	✓				✓	
l. Expose people to severe noise levels?		✓				✓
m. Generate noise that would conflict with local noise standards?	✓				✓	
n. Involve operations that substantially increase noise levels in the area?	✓				✓	
o. Result in an impact upon the quality or quantity of existing recreational opportunities?		✓		✓		
13. CULTURAL SITUATION. Will the proposed activity:						
a. Disturb or destroy a resource which is associated with an event or person of recognised significance in the History of Uganda?			✓			✓
b. Disturb or destroy an archaeological resource which has reorganised importance in prehistory?			✓			✓
c. Disturb or destroy an archaeological resource which can provide information that is both of demonstrable public interest and useful in addressing scientifically consequential and reasonable or archaeological research questions?			✓			✓
d. Disturb or destroy archaeological or historic resource which has a special or particular quality such as oldest, best example, largest, or last surviving example of its kind?			✓			✓
e. Disturb or destroy human remains?			✓			✓
f. Disturb, alter, or destroy a site that is currently used for religious ceremonial, or other sacred purposes?			✓			✓
g. Disturb, alter, or destroy a site that is important in preserving unique ethnic cultural values?			✓		✓	
h. Disrupt or divide the physical arrangement of an established community?			✓		✓	
i. Conflict with established recreational, educational, religious or scientific uses of the area?		✓			✓	
j. Affect the social life of the inhabitants of the area?		✓			✓	
14. GENERAL. Will the proposed activity:						
a. Substantially degrade the quality of the environment?			✓			✓
b. Achieve short-term environmental goals to the disadvantage of long-term environmental goals?			✓			✓
c. Cause possible cumulative environmental effects that are individually limited but cumulatively considerable or for which the incremental effects of an individual project are considerable when viewed in connection with: Past projects; Current projects; Probable future projects?	✓			✓		
d. Cause substantial adverse effects on human beings, either directly or indirectly?		✓			✓	

APPENDIX C: Environmental interaction matrix used for assessment of drilling and operations for the Kibiro geothermal prospect (based on manual, EIA, Australia, 1985)

			B: CHARACTERISTICS OF THE EXISTING ENVIRONMENT												
			Geology	Land use	Biodiversity	Visual and aesthetic quality	Water quality and hydrology	Population, housing and employment	Transportation and traffic	Air quality	Public services	Utilities	Energy	Public health and safety	Cultural situation
A: CHARACTERISTICS OF THE PROPOSED DEVELOPMENT	OPERATION	Land clearing		✓	✓										
		Earthworks	✓	✓	✓	✓		✓	✓	✓	✓		✓		
		Disposal systems		✓	✓		✓			✓		✓		✓	
		Location of building or works		✓	✓	✓				✓				✓	
		Power plant construction		✓		✓		✓	✓		✓		✓		
		Raw materials					✓		✓			✓			
		Water demand					✓					✓		✓	
		Equipment operation					✓	✓		✓	✓			✓	
		Labour requirements						✓			✓			✓	✓
		Transport requirements						✓	✓				✓	✓	
		Potential emergencies (including hazards)			✓		✓			✓				✓	
		Landscaping	✓												✓
	DRILLING	Earthworks (including road construction)	✓	✓		✓				✓	✓		✓	✓	
		Raw materials inputs							✓			✓	✓		
		Storage						✓			✓				
		Water demand			✓		✓					✓		✓	
		Waste disposal			✓		✓			✓		✓		✓	
		Demand for services							✓		✓			✓	
		Labour requirements						✓			✓				
		Traffic movements							✓	✓			✓	✓	✓
		Transport requirements						✓	✓						
		Potential emergencies (including hazards)			✓					✓				✓	
		Landscaping	✓			✓									✓

NOTE:

A: Actions which are part of the development project

B: Characteristics of the environment affected

✓ Where a characteristic of the existing environment is potentially affected by a characteristic of the proposed development. This indicates likely environmental interactions.

APPENDIX D: Checklist used for environmental assessment of drilling and operations for the Kibiro geothermal prospect (based on Roberts, 1991)

Environmental impacts	Drilling			Operation		
	Yes	Maybe	No	Yes	Maybe	No
1. GEOLOGY. Will the proposed activity:						
a. Expose people, structures, or property to major geologic hazards such as earthquakes, landslides, or ground failure?			✓			✓
b. Result in unstable earth conditions or changes in geologic substructure?			✓			✓
c. Result in disruptions, displacements, compaction or over-covering of the soil?			✓			✓
d. Result in changes in topography or ground surface relief features?		✓		✓		
e. Destroy, cover, or modify any unique geologic or physical features?			✓			✓
f. Increase wind or water erosion of soils, either on or off the site?			✓			✓
g. Result in changes in deposition or erosion or changes which may modify the channel of a river or stream or bed of any bay, inlet or lake?			✓		✓	
h. Be located within a known active fault zone, or an area characterised by surface rupture that might be related to a fault?	✓			✓		
i. Affect substrate consisting of material that is subject to liquefaction in the event of ground shaking or other secondary seismic hazards?			✓			✓
j. Be located in the vicinity of soil that is likely to collapse, as might be the case with karst topography, old mine properties or areas of subsidence caused by groundwater drawdown?			✓			✓
k. Expose soils characterised by shrink/swell potential in a way that might result in deformation of foundations or damage to structures?			✓			✓
l. Be located in a zone identified or designated as important farmland?	✓			✓		
m. Affect mineral or other deposits in the area?			✓			✓
2. LAND USE. Will the proposed activity:						
a. Conflict with adopted environmental plans and goals of communities where it is located?	✓			✓		
b. Convert prime agricultural land to non-agricultural use, or impair the agricultural productivity of prime agricultural land?	✓			✓		
c. Result in the conversion of open space into urban or suburban scale uses?			✓		✓	
d. Conflict with local general plans, community plans, or zoning?	✓			✓		
3. BIODIVERSITY. Will the proposed activity:						
a. Cause a fish or wildlife population to drop below self-sustaining levels?			✓			✓
b. Threaten to eliminate a plant or animal community?			✓			✓
c. Substantially affect, reduce the number, or restrict the range of unique, rare, or endangered species of animal or plant, or the habitat of that species?		✓			✓	
d. Substantially diminish or reduce habitat for fish, wildlife, or plants?			✓			✓
e. Interfere substantially with the movement of any resident or migratory fish or wildlife species?			✓			✓
f. Change the diversity of species, or the number of any species of plants (including trees, shrubs, grass, crops, and aquatic plants) or animals (birds, land animals including reptiles, fish and shellfish, benthic organisms or insects)?		✓			✓	

Environmental impacts	Drilling			Operation		
	Yes	Maybe	No	Yes	Maybe	No
g. Introduce new species of plants or animals into an area, or become a barrier to the normal replenishment of existing species?		✓			✓	
h. Cause reduction in acreage of any agricultural crop?		✓			✓	
i. Increase the rate of use of any natural resources?	✓			✓		
j. Cause deterioration of existing fish or wildlife habitat?			✓			✓
k. Adversely affect significant riparian lands, wetlands, marshes, or other wildlife habitats?			✓		✓	
4. VISUAL AND AESTHETIC QUALITY. Will the proposed activity:						
a. Have a substantial, demonstrable negative aesthetic effect?		✓			✓	
b. Result in the obstruction of any scenic view open to the public, or result in the creation of an aesthetically offensive site open to public view?		✓			✓	
c. Interfere with local guidelines or goals related to visual quality?		✓		✓		
d. Significantly change the existing visual quality of the region or destroy visual quality of the region or eliminate visual resources?		✓			✓	
5. WATER QUALITY AND HYDROLOGY. Will the proposed activity:						
a. Substantially degrade water quality?		✓			✓	
b. Contaminate a public water supply?		✓			✓	
c. Substantially degrade or deplete groundwater resources?		✓			✓	
d. Interfere substantially with ground water recharge?			✓		✓	
e. Cause substantial flooding, erosion, or siltation?		✓				✓
f. Result in changes in absorption rates, drainage patterns, or the rate and amount of surface runoff?			✓		✓	
g. Alter the course of flow of flood waters?			✓			✓
h. Change the amount of surface water in any water body?	✓			✓		
i. Cause discharge into surface waters, or result in any alteration of surface water quality, including but not limited to temperature, dissolved oxygen or turbidity?	✓			✓		
j. Alter the direction or rate of flow of groundwaters?			✓	✓		
k. Cause change in the quantity of groundwaters, either through direct additions or withdrawals?		✓		✓		
l. Substantially reduce the amount of water otherwise available for public water supplies?		✓			✓	
m. Expose people or property to water related hazards such as flooding?			✓			✓
n. Interfere with other proposed facilities that would be located in flood-prone areas?			✓			✓
6. POPULATION, HOUSING AND EMPLOYMENT. Will the proposed activity:						
a. Induce substantial growth or concentration of population?		✓		✓		
b. Affect the average age of the population?		✓				✓
c. Displace a large number of people?			✓			✓
d. Alter the location, distribution, density or growth rate of the human population of an area?			✓		✓	
e. Affect existing housing, or create a demand for additional housing?			✓	✓		
f. Conflict with the housing and population projections and policies set forth in the general plan?			✓	✓		

Environmental impacts	Drilling			Operation		
	Yes	Maybe	No	Yes	Maybe	No
7. TRANSPORTATION AND TRAFFIC. Will the proposed activity:						
a. Cause an increase in traffic which is substantial in relation to the existing traffic load (volume) and capacity of the street system?	✓			✓		
b. Generate substantial additional vehicular movement?	✓			✓		
c. Affect existing parking facilities, or demand for new parking?			✓			✓
d. Substantially impact existing transportation systems?			✓			✓
e. Alter present patterns of circulation or movement of people and/or goods?		✓		✓		
f. Alter waterborne, rail or air traffic?			✓			✓
g. Generate a need for harbour facilities?			✓			✓
h. Cause roads to be built that improve communication between areas?	✓			✓		
i. Move traffic away from towns or villages?		✓			✓	
j. Affect the general traffic safety?	✓			✓		
k. Significantly impact intersection levels of services which are or will be below acceptable levels?		✓			✓	
l. Provide inadequate parking and internal circulation capacity to accommodate project traffic so that neighbouring areas are adversely affected?		✓				✓
8. AIR QUALITY. Will the proposed activity:						
a. Violate any ambient air quality standards?		✓			✓	
b. Result in substantial air emissions or deterioration of ambient air quality through e.g. suspended dust?		✓			✓	
c. Create objectionable odours?		✓			✓	
d. Alter air movement, moisture, or temperature, or result in any change in climate, either locally or regionally?		✓			✓	
e. Hamper visibility?		✓				✓
9. PUBLIC SERVICES. Will the proposed activity:						
a. Require additional law enforcement staff and equipment to maintain acceptable service ratios?	✓			✓		
b. Require additional fire protection staff or equipment to maintain an acceptable level of service?	✓			✓		
c. Require expansion of the existing school system?			✓	✓		
d. Affect or require the designation of substantial additional parkland to remain in conformity with locally acceptable or adopted park standards?	✓				✓	
e. Require additional hospital(s)?			✓		✓	
f. Require the building of old people?			✓			✓
g. Require the establishment of playschool(s), kindergartens(s)?			✓	✓		
h. Require additional amenities for the handicapped?			✓		✓	
i. Affect museums in the area?			✓			✓
10. UTILITIES. Will the proposed activity:						
a. Breach published national, state, or local standards relating to solid waste control?		✓			✓	
b. Require extension of a sewer trunk line with capacity to serve new development?		✓			✓	
c. Result in a need for new systems, or substantial alterations to the following utilities: i) power or natural gas; ii)communication systems;	✓			✓		

Environmental impacts	Drilling			Operation		
	Yes	Maybe	No	Yes	Maybe	No
iii) water; iv)sewer or septic tank; v)storm water drainage; and vi) solid waste disposal?						
d. Cause significant increase in the consumption of potable water?	✓			✓		
e. Require substantial expansion of water supply treatment and distribution capacity?			✓	✓		
f. Require substantial waste-water disposal?	✓			✓		
g. Produce solid waste in excess of available landfill capacity?	✓			✓		
11. ENERGY. Will the proposed activity:						
a. Result in significant irreversible environmental changes including uses of non-renewable resources during the initial and continued phases of the project?			✓			✓
b. Result in significant effects on local and regional energy supplies or on requirements for additional capacity?	✓			✓		
c. Result in significant effects on peak and base period demands for electricity and other forms of energy?			✓			✓
d. Conflict with existing energy standards?		✓			✓	
e. Result in significant effects on energy resources?	✓			✓		
f. Encourage activities which result in the use of substantial amounts of fuel, water and energy?	✓			✓		
g. Cause and increase in the use of fossil fuels?	✓					✓
h. Cause an increase in the use of sustainable energy sources?			✓	✓		
i. Substantially increase demand upon existing sources of energy, or require the development of new sources of energy?		✓				✓
12. PUBLIC HEALTH AND SAFETY. Will the proposed activity:						
a. Involve hazards that the indigenous population and those moving to the area have not been adequately warned against?	✓			✓		
b. Create a potential health hazard (including mental health), or involve the use, production, or disposal of materials which pose a hazard to people or animal or plant populations in the area affected?	✓			✓		
c. Create a risk of explosion or release of hazardous substances (including, but not limited to, oil, pesticides, chemicals or radiation) in the event of an accident?	✓			✓		
d. Pose a public health and safety hazard through release of toxic emissions?	✓			✓		
e. Create a risk that the concentration of a toxic air contaminant (TAC) may at any time exceed the Air Pollution Control threshold level?		✓			✓	
f. Significantly increase light and glare in the project vicinity?	✓					✓
g. Result in unsafe conditions for employees, residents, or surrounding neighbourhoods?		✓			✓	
h. Expose people or property to water related hazards such as flooding?			✓		✓	
i. Interfere with other proposed facilities that would be located in flood-prone areas?			✓			✓
j. Enhance impact of the proposed facilities that would increase off-side flood hazard, erosion or sedimentation?			✓			✓
k. Increase substantially the ambient noise levels in adjoining areas?	✓				✓	
l. Expose people to severe noise levels?		✓				✓
m. Generate noise that would conflict with local noise standards?	✓				✓	
n. Involve operations that substantially increase noise levels in area?	✓				✓	

Environmental impacts	Drilling			Operation		
	Yes	Maybe	No	Yes	Maybe	No
o. Result in an impact upon the quality or quantity of existing recreational opportunities?			✓		✓	
13. CULTURAL SITUATION. Will the proposed activity:						
a. Disturb or destroy a resource which is associated with an event or person of recognised significance in the History of Uganda?			✓			✓
b. Disturb or destroy an archaeological resource which has reorganised importance in prehistory?			✓		✓	
c. Disturb or destroy an archaeological resource which can provide information that is both of demonstrable public interest and useful in addressing scientifically consequential and reasonable or archaeological research questions?			✓		✓	
d. Disturb or destroy archaeological or historic resource which has a special or particular quality such as oldest, best example, largest, or last surviving example of its kind?			✓		✓	
e. Disturb or destroy human remains?			✓			✓
f. Disturb, alter, or destroy a site that is currently used for religious ceremonial, or other sacred purposes?			✓			✓
g. Disturb, alter, or destroy a site that is important in preserving unique ethnic cultural values?			✓		✓	
h. Disrupt or divide the physical arrangement of an established community?			✓		✓	
i. Conflict with established recreational, educational, religious or scientific uses of the area?			✓		✓	
j. Affect the social life of the inhabitants of the area?		✓			✓	
14. GENERAL. Will the proposed activity:						
a. Substantially degrade the quality of the environment?			✓			✓
b. Achieve short-term environmental goals to the disadvantage of long-term environmental goals?			✓			✓
c. Cause possible cumulative environmental effects that are individually limited but cumulatively considerable or for which the incremental effects of an individual project are considerable when viewed in connection with: Past projects; Current projects; Probable future projects?		✓			✓	
d. Cause substantial adverse effects on human beings, either directly or indirectly?		✓			✓	

15. POSITIVE IMPACTS

The proposed activity will result in the following Positive Impacts (list):

- ✓ Clean and renewable type of energy that will reduce on the use of fossil fuels that damage the environment.
- ✓ Reliable power source for rural electrification and use in small scale industries and agriculture.
- ✓ Create employment for the local population and the country.
- ✓ Possibility of extraction of chemicals and salt from the Katwe brine that could lead to the revival of the Lake Katwe Salt Factory.
- ✓ Increased number of tourists in the area attracted by the geothermal power plant (s).
- ✓ Increased revenue to the local government and the Uganda Wildlife Authority.