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STATUS OF GEOTHERMAL DEVELOPMENT IN KENYA JUNE 1998

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ABSTRACT

Kenya has vast geothermal resources and 576 MW of electrical power are expected to be developed from Olkaria and other prospects over the next 20 years, through private and public investments. The Kenya Electricity Generating Company Ltd. (KenGen) is the Government Agency responsible for power generation in the country. It has been operating the Olkaria East geothermal station since the first of the three 15MW units was commissioned in June 1981. By the end of 1997, a total of 4547 GWh had been generated by the three units. Although the output declined to 31 MW by 1995, six makeup wells have since been connected and two more will be connected by 1999 in order to keep the plant operating at its rated capacity. Except for minor maintenance and regular overhaul shutdowns, the station has run trouble free. The initial reservoir decline of about 7% has now reduced to 3% per annum. This has partly been attributed to the success in both hot and cold re-injection.

1. KENYA'S POWER DEMAND AND SUPPLY

The power demand and peak load requirements have grown by an average of 6.1% per year for the last 20 years. This has been slightly higher than the GDP growth of about 4.2% over the same period. However, for the last six years, the load growth has been about 4.2% per year mainly because of slow growth in the economy and also due to generation capacity shortfall.

The current load forecast indicates continued growth of about 5.1% but this could increase to 6.0% when the full benefits from economic reforms are realised. This means that the power requirement will triple and the total financial requirement is estimated to be over US $3351.5 million. The implications are that the expansion will impose extreme financial strain on the country unless private power producers invest in the sector.

2. ELECTRIC POWER SYSTEM

The current electric power system in Kenya (Table 1) is made up of about 846 MW of installed capacity with effective generation of about 806 MW. Of this effective capacity, 584 MW are hydroelectric, 177 MW thermal and 45 MW geothermal. The thermal generations include 87.5 MW from two independent power producers (IPP) commissioned in 1997. Figure 1 shows Kenya's existing power system.

TABLE 1: Existing, installed and effective capacity

Power station	Installed capacity (MW)	Effective capacity (MW)
Hydro		
Masinga	40	40
Kamburu	91.5	84
Gitaru	145	145
Kindaruma	40	40
Kiambere	144	144
Turkwel	106	106
Tana	14.4	12.4
Wanji	7.4	7.4
Small Hydros	6.2	5.4
Total Hydro	594.5	584.2
Thermal		
Kipevu Steam	75.5	50
Gas turbines		
Kipevu	30	30
Nairobi South	13.5	10
IPPS		
IberAfrica,Nairobi Diesel	44.5	44.5
Westmont, Mombasa Gas Turbine	43	43
Geothermal		
Olkaria	45	45
Total system	**846**	**806.7**

3. GENERATION OPTIONS

Kenya has limited hydroelectric resources that are estimated to be about 1400 MW and capable of generating about 600GWh per year on average. This potential is found in 5 major river systems namely Tana basin 40%, Lake Victoria basin 30%, and about 10% each from the Ewaso Ng'iro North, Ewaso Ngiro South, and Athi basins. In the next 20 years, additional 313 MWs are expected to be generated from hydro at Sondu Miriu (60 MW), Gitaru Unit No. 1 (73 MW) and Ewaso Ng'iro (180 MW).

A large potential of the geothermal energy resource is manifested in the Rift Valley region of Kenya in more than 20 prospective areas. The Olkaria area alone is estimated to have reserve of over 220 MW, equivalent to over 1600 GWh per year at 80% load factor. An additional 576 MW are planned to be generated from geothermal resources in the next 20 years.

The balance of the system requirements after hydro and geothermal generation will be provided by diesel power plants. In the next 5 years, 272 MW capacity of generating plants will be constructed through public sector financing (Kipevu I, Olkaria II, Gitaru and Sondu Miriu) and 249 MW through IPPs (Kipevu II, Olkaria III, Lanet and Eldoret).

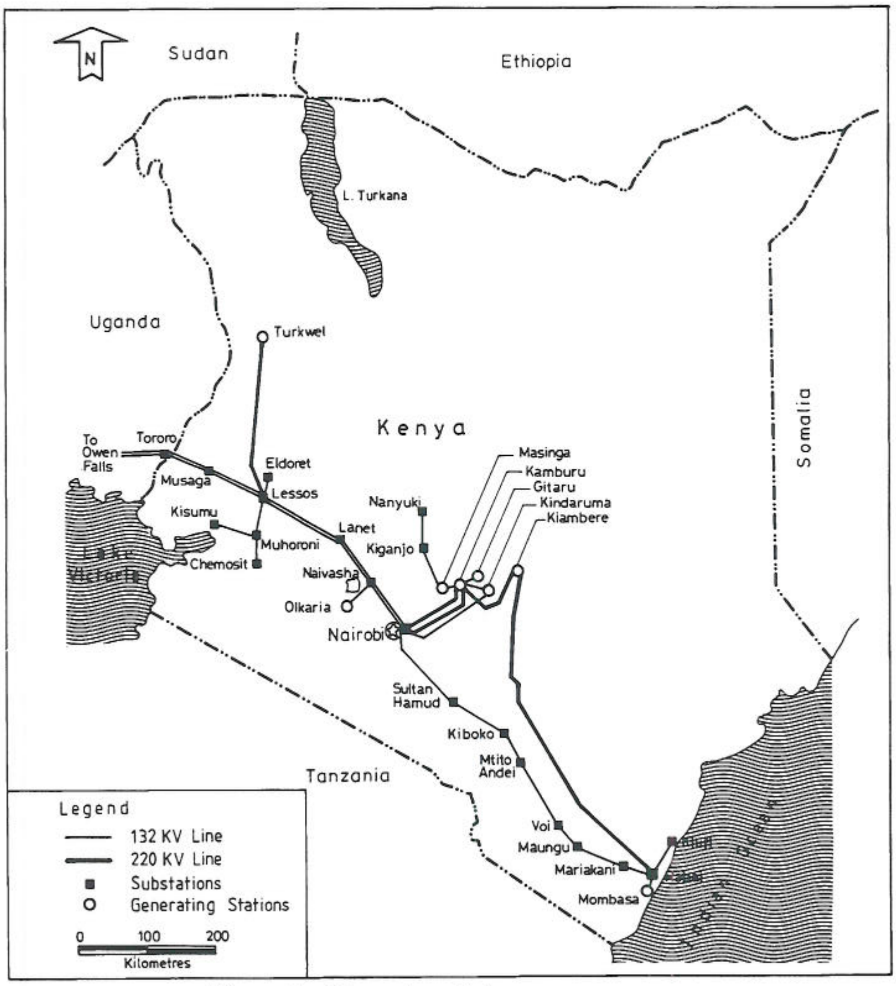

Figure 1: Kenya's existing power system

4. TAPPING POWER FROM THE EARTH'S CRUST

Most of the world's geothermal fields are located at the plate margins where plates either collide or drift apart. In Kenya, the areas of most potential are almost exclusively within the Rift Valley Province, which is part of the Great African Rift System. The geothermal fields are formed when the underground water adjacent to the hot rocks is heated sufficiently, rises through fissures and faults in the crust and accumulates in the rock matrix forming a geothermal reservoir. Figure 2 shows the location of geothermal fields in Kenya in relation to the Rift Valley.

5. HISTORY OF THE 45 MW OLKARIA GEOTHERMAL PLANT DEVELOPMENT

In the mid 60s, a resistivity survey was carried out in the Rift Valley between Lake Bogoria in the North and Olkaria in the South to determine the possibility of obtaining geothermal steam. Based on these results, drilling commenced in Olkaria in 1973. By 1976, six wells had been drilled in the area.

A feasibility study was then undertaken to evaluate Olkaria's potential for generating electricity from geothermal steam. The study established that the Olkaria geothermal field covered an area of some 80 km^2. From 1978, several geothermal wells were drilled and financing was also arranged for the construction of the power station that is now referred to as Olkaria East power station. The first 15 MW unit was commissioned in June 1981, the second unit in November 1982 and the third in March 1985, raising the total to 45 MW.

6. SEVENTEEN YEARS EXPERIENCE IN GENERATING FROM OLKARIA

6.1 Reservoir

The field covers an area of about 4 km^2 and 33 wells have been drilled there. Two of these were not productive. The reservoir is mainly composed of trachytes and basalts. Steam production zones occur chiefly in the rhyolites and underlying trachytes. The latest lava flow located south of the field is about 180-500 years old and is the youngest volcanic activity in the area. Figure 3 shows the caldera boundary in the area and major domes and lavas at Olkaria.

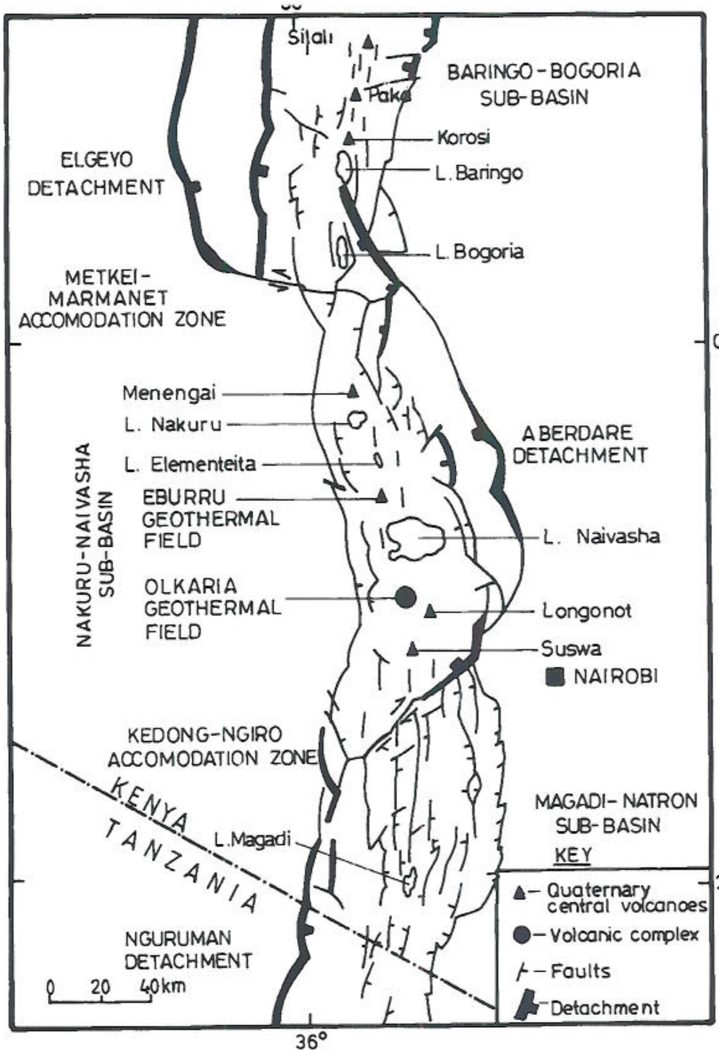

Figure 2: Location map of geothermal fields in Kenya

Figure 4 shows a schematic cross-section through the Olkaria geothermal reservoir. The field is characterised by temperatures greater than 250°C reaching up to 343°C in some wells. There are two steam-producing zones. The first one occurs between 750-900 m below the surface and is rich in steam; the second one reaches down to 1300 m and below and is water-dominated. Although the early wells were shallow, about 900-1650 m, the average wells are now 2200 m deep. The wells initially produced 75% steam and 25% water but they have continued to dry up.

Since commencement of production, total steam output from the wells has shown various regimes of decline from an initial 7% decline rate per year from 1981 to 1988 when the decline was reduced to about 4% per year and has recently reduced further, to about 3%, as a result of reinjection of fluid into the reservoir. The individual wells, however, display more varied decline rates, most wells having decline rates of 2% and 4% per year for steam and mass, respectively. The shallower wells, particularly in the central parts of the field, have higher rates of decline (8% per year). Most of these wells have attained dry conditions and produce steam only. Two of the shallow wells in this area are no longer used but will be used for re-injection purposes. Deeper wells in the centre of the field have had moderate rates of decline.

Temperature changes in the central area have shown a decline of more than 5°C from the production values in 1981. This shows that the decline in production is mainly due to fluid depletion while most of the stored heat is still in place. To the south of the field, the temperature decline is much greater than in the centre. This indicates a possible influx of cooler fluids from adjacent formations.

6.2 Quality of discharge

When production started in Olkaria East Field, the water flushed to the atmospheric pressure had a pH of 8 with comparatively low salinity (< 2000ppm). The chloride levels ranged from 200 ppm to 700 ppm, the higher concentrations being found in central well fluids. Other chemical substances with significant concentrations are silica, sodium, floride and boron. Calcium and magnesium are noticeably absent or in extremely low concentrations. This is notable because calcium carbonate and silica are among the substances that most commonly cause scaling in geothermal wells, pipes and turbines. Although silica concentrations are considerable, the steam is separated at high temperature (150°C) and silica does not precipitate unless pH is low, which is not the case at Olkaria.

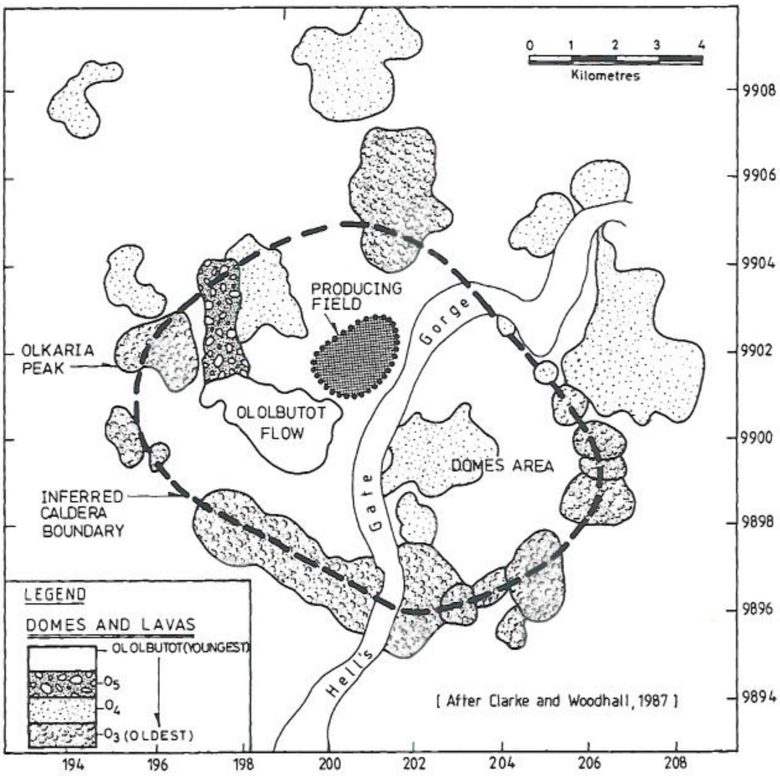

Figure 3: Caldera boundary seen in the Olkaria area with major domes and lavas

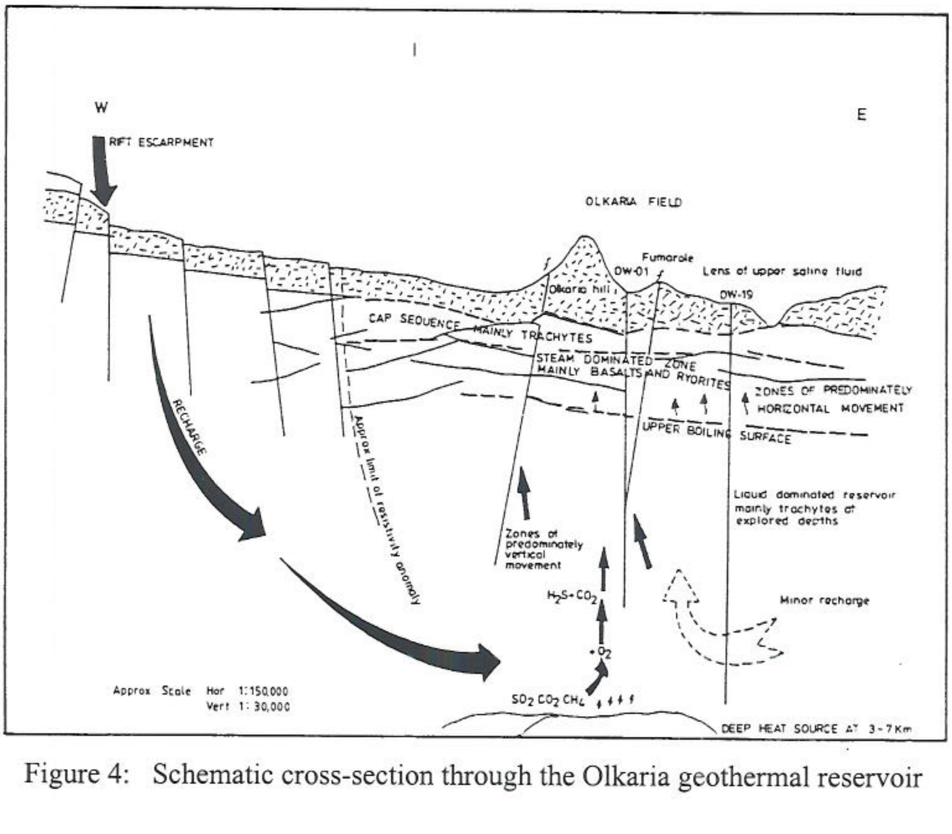

Figure 4: Schematic cross-section through the Olkaria geothermal reservoir

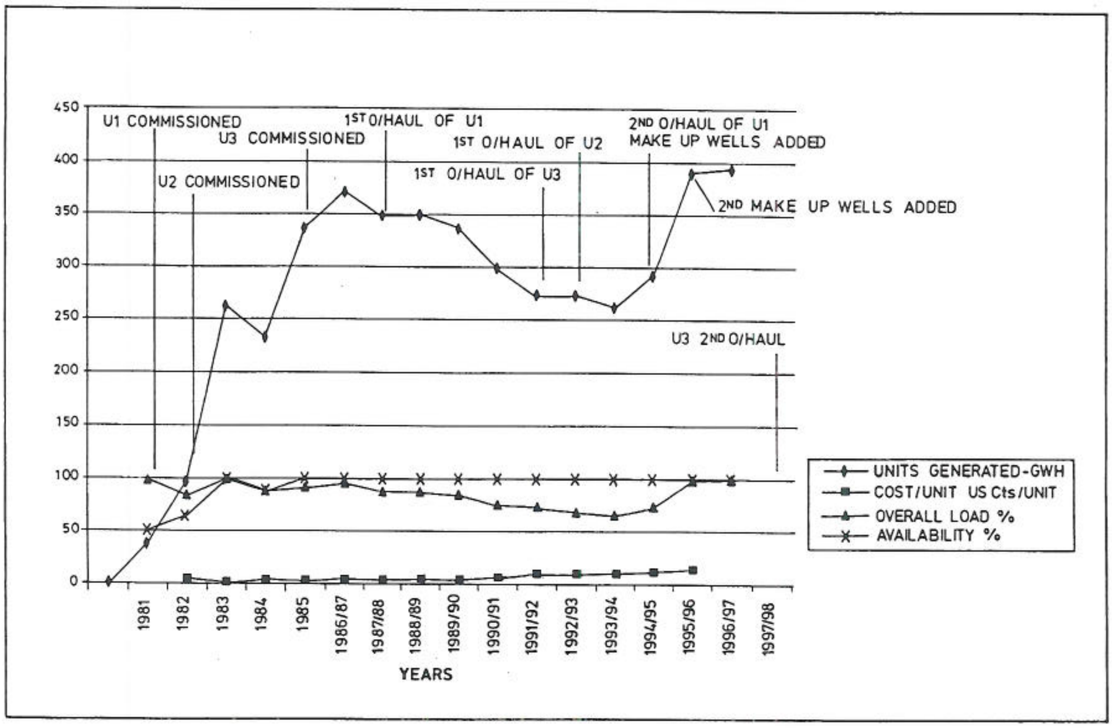

Figure 5: Generation of electricity at the Olkaria East power station in 1981-1998

The steam comprises about 99% water and 1% non-condensible gases. The main constituents of the non-condensible gases are CO_2 (80%) and H_2S (9.5%).

6.3 Power station performance

Initially, 23 wells were connected to the three turbines. However, as production continued, some wells decreased in output and had to be isolated and new ones (make-up wells) drilled to restore the generation capacity. The initial decline in steam was about 7% per annum reflecting the reservoir pressure changes. From 1986 to 1994, generation had fallen to 31 MW. Four make-up wells were connected in 1995 and 2 more in 1996 bringing the power station to its full load. Currently 25 wells of the 29 connected are producing. Two additional wells are planned to be connected by the end of 1999 to ensure full load capacity beyond the year 2000. Figure 5 shows the summary of electricity generation at the Olkaria East power station.

The average availability factor and overall load factor for the period between 1981 and 1997 were 94.0% and 86.5%, respectively. As of 30th April 1998 Unit 1 had run for 134,707 hours. Units 2 and 3 had run 121,842 hours and 107,248 hours, respectively.

Machine inspection and servicing are carried out routinely every year. During this period, generator air coolers, switchgears, transformers, motors, cooling tower, etc. are serviced and turbine blades and condenser are inspected for damage. Major overhauls are carried out every 5 years. Machine No. 1 has been overhauled twice, in 1988 and 1995, after running for 56,699 hours and 107,974 hours respectively. Machine No. 2 was overhauled in 1992 after running for 74,223 hours. Machine No. 3 was overhauled in 1991, after running for 52,822 hours and again in 1997 having run for 101,705 hours. Efficiency tests are carried out on every machine after a major overhaul. Values of specific steam consumption are compared with previous measurements. In all cases and for all the machines, the values have been close to those obtained at commissioning. On the whole, the power station has performed very well without any noticeable corrosion in the turbines and pipelines.

6.4 Re-injection

When the third unit was commissioned in 1985, the total amount of separated water from the twenty-three wells in operation was about 66.7 tons/hr. This water was collected via open channels to a pond, which allowed infiltration into the formation and evaporation. When simulation of the field under production conditions was done, it was shown that substantial benefits could accrue from re-injection. It could sustain the field pressures, which were already declining, and it would be a more environmentally acceptable way of disposing of the brine. Trial experiments were carried out initially using fresh cold water with trace chemicals. This experiment was successful and the cold water is now being re-injected routinely into one of the abandoned wells in the centre of the field. Thirty tons per hour is also being re-injected hot in to another well. The effect of the re-injection has reduced the rate of pressure decline in the field to about 3% per annum. From this experience, the proposed 64MW Olkaria Northeast power station will use hot re-injection as the primary mode of disposal of the waste water near and within the field. However, cooling tower blowdown will be injected cold at the periphery of the field.

6.5 Environmental issues

The amount of non-condensible gases in Olkaria's steam is about 1% by weight. Out of the gases carbon dioxide is 80% and hydrogen sulphide is 9.5%. The brine generally has minute quantities of boron, fluoride, arsenic and lead. Of the two gases, only hydrogen sulphide has a significant impact but the amount emitted is well below the levels set by WHO.

Most of the Olkaria field is in the Hell's Gate National Park. The presence of a National Park, Lake Naivasha and flower growing farms, make environmental management and monitoring very vital in geothermal resource development at Olkaria. The Hell's Gate National Park, was gazetted on 2nd February 1984, several years after the present Olkaria East power station started operation. In view of the importance KenGen places on the conservation of the environment, and the country's need to develop this important least-cost indigenous resource, an environmental section was establihsed in 1985. This section is responsible for monitoring environmental impacts, controlling erosion, rehabilitation of sites and monitoring of emitted gases and weather changes. The waste-water produced during well testing and power station operations, is now being injected back into the ground at a depth below 600 m and, thus, cannot pollute groundwater.

An environmental impact study for the development of the proposed power station at Olkaria Northeast Field concluded that impacts of geothermal activities in the Hell's Gate National Park can and are currently being managed effectively.

7. ANTICIPATED FUTURE DEVELOPMENT

Intensive exploration has been going on in the greater Olkaria field since 1981 while development was taking place in the Olkaria East Field. Figure 6 shows the greater Olkaria geothermal area, and the various production fields. An area to the north of the existing power station called Olkaria Northeast (or Olkaria II development) was identified for further development and, to-date, 28 production wells have been drilled there, capable of producing about 78 MW of electricity. The Olkaria Northeast power station (2x32 MW) has already been designed and construction will start in late 1999. The station will be commissioned in September 2001.

Sufficient exploration has also been done in Olkaria Southwest where about 12.3 MW are available from 5 wells. An independent power producer for the development of a 64 MW power station will take up this sector. This station is planned to be commissioned in January 2002. It is referred to as Olkaria III.

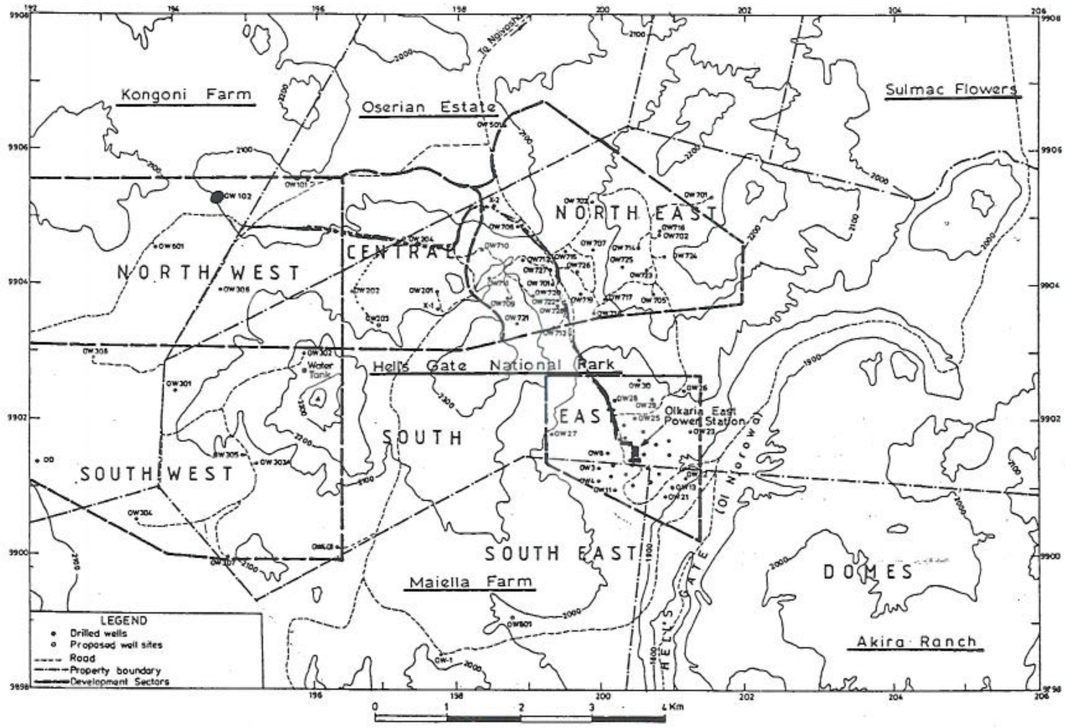

Figure 6: The greater Olkaria geothermal area, and the various production fields

Although it had been estimated that Olkaria could support substantial development, KenGen decided in 1984 to carry out detailed surface exploration work and deep drilling in Eburru, 50 km north of Olkaria, in order to compare productivity of the two areas. Drilling was carried out between 1988 and 1990 at six sites. Only the first well produced 2.4 MW of steam. Two others produce hot water. KenGen has also carried out detailed surface exploration in Suswa volcano south of Olkaria and is currently investigating Longonot volcano east of Olkaria with the intention of carrying out exploration drilling.

Several of the other geothermal prospects, many of which are located north of Olkaria, have limited amount of scientific data and will require detailed surface exploration and drilling to determine the actual size of the resources. Based on the limited data, these fields are estimated to be capable of providing over 300 MW.

According to the 1997 Least Cost Power Development Plan, geothermal power is expected to provide an additional 576 MW of electric power into the grid. About half of this amount is expected to be developed around Olkaria Field and will involve both KenGen and IPPs.

8. LOCAL CAPABILITY

Substantial investment in training local personnel has been undertaken in order to equip professionals with the requisite skills required in geothermal exploration, development and production activities (Table 2). While KenGen continues to shoulder part of this cost, a lot of support has been generously provided by institutions such as the United Nations University in Iceland, University of Auckland in New Zealand and the World Bank. In addition, professionals are encouraged to prepare technical papers for presentation in international forums so that they can benefit from the resultant discussions generated within the industry.

Table 2: Training in geothermal science and engineering

Year	UNU	UoA	Italy	Japan	Total
1980	-	-	1	-	1
1981	-	1	-	-	1
1982	3	1	-	-	4
1983	-	-	-	-	-
1984	-	-	-	-	-
1985	2	-	-	-	2
1986	2	1	-	-	3
1987	-	1	-	-	1
1988	-	2	-	-	2
1989	-	1	-	-	1
1990	2	2	-	-	4
1991	-	2	-	-	2
1992	2	1	-	-	3
1993	1	1	-	-	2
1994	-	1	-	-	1
1995	1	1	-	1	3
1996	2	1	-	-	3
1997	1	1	-	-	2
1998	2	2	-	-	4
Total	**18**	**19**	**1**	**1**	**39**
Wastage	2	5	1	0	8
Available presently	16	14	0	1	31

As a result of this aggressive training approach, there has been a major reduction in the need for expatriate personnel in the day to day management of geothermal activities. This is a marked contrast to the early stages of the Project. However, the need for specialist skills will continue to be required on an ad hoc basis depending on project needs or requirements of funding agencies.

ACKNOWLEDGEMENTS

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